

WATER TREATMENT CERTIFICATION REVIEW COURSE



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<http://www.tlch2o.com/PDF/CEU%20State%20Approvals.pdf>

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Some States and many employers require the final exam to be proctored.

Do not solely depend on TLC's Approval list for it may be outdated.

A second certificate of completion for a second State Agency \$50 processing fee.

Most of our students prefer to do the assignment in Word and e-mail or fax the assignment back to us. We also teach this course in a conventional hands-on class. Call us and schedule a class today.

Responsibility

This course contains EPA's federal rule requirements. Please be aware that each state implements drinking water / safety regulations that may be more stringent than EPA's or OSHA's regulations. Check with your state environmental agency for more information. You are solely responsible in ensuring that you abide with your jurisdiction or agency's rules and regulations.

Technical Learning College's Scope and Function

Welcome to the Program,

Technical Learning College (TLC) offers affordable continuing education for today's working professionals who need to maintain licenses or certifications. TLC holds several different governmental agency approvals for granting of continuing education credit.

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. TLC's distance based or independent study courses are offered in a print - based distance educational format. We will beat any other training competitor's price for the same CEU material or classroom training.

Our courses are designed to be flexible and for you do finish the material on your leisure. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and instruction to obtain the assignments. All of TLC's CEU courses allow students to submit assignments using e-mail or fax, or by postal mail. (See the course description for more information.)

Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling, i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored closed-book exams depending upon your state or employer requirements.

Flexible Learning

At TLC, there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You can work at your own pace, completing assignments in time-frames that work best for you. TLC's method of flexible individualized instruction is designed to provide each student the guidance and support needed for successful course completion.

Course Structure

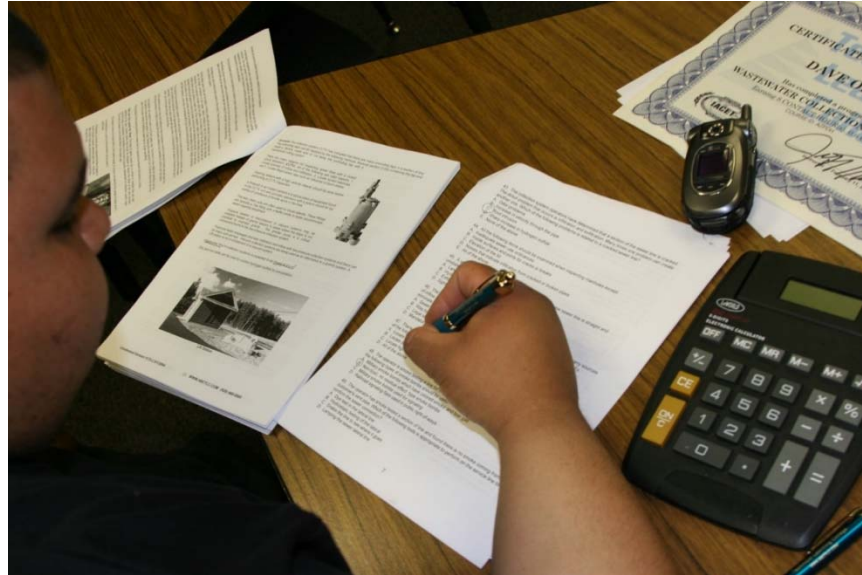
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student friendly course design allows you the most flexibility in choosing when and where you will study.

Classroom of One

TLC offers you the best of both worlds. You learn on your own terms, on your own time, but you are never on your own. Once enrolled, you will be assigned a personal Student Service Representative who works with you on an individualized basis throughout your program of study. Course specific faculty members (S.M.E.) are assigned at the beginning of each course providing the academic support you need to successfully complete each course. Please call or email us for assistance.

Satisfaction Guaranteed

We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none. This is one reason we have taught more than 20,000 students.



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail. If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of \$50.

We welcome you to complete the assignment in Word.

Once we grade it, we will mail a certificate of completion to you. Call us if you need any help.

Contact Numbers
Fax (928) 468-0675
Email Info@tlch2o.com
Telephone (866) 557-1746

Course Description

Water Treatment Certification Review CEU Training Course

Review of water treatment methods and systems, related chlorination/treatment fundamentals and operator math principles related to operator certification. This course will cover the basic requirements of the Safe Drinking Water Act and conventional water treatment principles. This study guide will present basic and complex math principles and formulas for water treatment operators to understand: area, volume, temperature conversions, flow rates, pressure, pounds and % efficiency. The objective for this class is to prepare the student to successfully pass the operator certification examination, understand treatment principles and properly calculate complex mathematical formulas for: pounds per day, volume, flow and related treatment formulas.

Proper calculation of concentration is contingent upon accurate determination of volume of water to be treated. If you are uncertain as to the volume of water to be treated, then take the time to measure the size of the tank or channel so that volume can be accurately determined. Ideally, all chemical treatments should be carried out in a special treatment or quarantine tank, but this is not always practical.

You will not need any other materials for this course. Task Analysis and Training Needs Assessments have been conducted to determine or set Needs-To-Know for this course. The following is a listing of some of those who have conducted extensive valid studies from which TLC has based this program upon: the Environmental Protection Agency (EPA), the Arizona Department of Environmental Quality (ADEQ), the Texas Commission of Environmental Quality (TCEQ) and the American Boards of Certification (ABC).

Final Examination for Credit

Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Course Procedures for Registration and Support

All of Technical Learning College's correspondence courses have complete registration and support services offered. Delivery of services will include, e-mail, web site, telephone, fax and mail support. TLC will attempt immediate and prompt service. When a student registers for a distance or correspondence course, he/she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work.

If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request. All students will be tracked by a unique number assigned to the student.

Instructions for Written Assignments

The Water Treatment Certification Review CEU training course uses a multiple choice answer key. If you should need any assistance, please email all concerns and the final test to: info@tlch2o.com. You may write your answers or type out your own answer key.

TLC would prefer that you utilize the answer key found on the TLC website under Assignments and e-mail the answer key to TLC, but it is not required. You may also fax the answer key. Please call us a couple hours later to ensure we received your information.

Feedback Mechanism (examination procedures)

Each student will receive a feedback form as part of their study packet. You will be able to find this form in the front of the assignment. You will have 90 days from start of the assignment manual to complete it in order to receive your Continuing Education Units (CEUs) or Professional Development Hours (PDHs). A score of 70% or better is necessary to pass this course.

Security and Integrity

All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage sharing of answers. Any fraud or deceit and the student will forfeit all fees and the appropriate agency will be notified.

Grading Criteria

TLC will offer the student either pass/fail or a standard letter grading assignment. If TLC is not notified, you will only receive a pass/fail notice.

Required Texts

The Water Treatment Certification Preparation CEU training course will not require any other materials. We recommend the Sacramento Manuals to successfully pass your State certification exam.

Recordkeeping and Reporting Practices

TLC will keep all student records for a minimum of seven years. It is the student's responsibility to give the completion certificate to the appropriate agencies. If necessary, we will send the required information to your State for your certificate renewals.

ADA Compliance

TLC will make reasonable accommodations for persons with documented disabilities. Students should notify TLC and their instructors of any special needs. Course content may vary from this outline to meet the needs of this particular group.

Educational Mission**The educational mission of TLC is:**

- ✓ *To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,*
- ✓ *To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification,*
- ✓ *To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,*
- ✓ *To provide a forum in which students can exchange experiences and ideas related to environmental education,*
- ✓ *To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.*

Objective: *To train water treatment operators in the safe and effective maintenance and operation of conventional water treatment procedures, sampling techniques and related daily operations in order to pass and understand operator certification requirements.*

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We recommend studying the Sacramento Manuals to successfully pass your State certification exam.

Utility Counter-Terrorism Chapter 1

Defending against and responding to Catastrophic Threats. The expertise, technology, and material needed to build the most deadly weapons known to mankind—including chemical, biological, radiological, and nuclear weapons—are spreading inexorably. If our enemies acquire these weapons, they are likely to try to use them.

The consequences of such an attack could be far more devastating than those we suffered on September 11—a chemical, biological, radiological, or nuclear terrorist attack in the United States could cause large numbers of casualties, mass psychological disruption, contamination, significant economic damage, and could overwhelm local medical capabilities.

Protecting Critical Infrastructure and Key Assets. Our society and modern way of life are dependent on networks of infrastructure—both physical networks such as our utility and transportation systems and virtual networks such as the Internet. If terrorists attack one or more pieces of our critical infrastructure, they may disrupt entire systems and cause significant damage to the Nation.

We must therefore improve protection of the individual pieces and interconnecting systems that make up our critical infrastructure. Protecting America's critical infrastructure and key assets will not only make us more secure from terrorist attack, but will also reduce our vulnerability to natural disasters, organized crime, and computer hackers.

The basic goal of the ***Utility Counter-Terrorism course*** is to make sure utility employers and employees know about potential terrorist hazards, how to recognize them and, most importantly, how to protect themselves and correct the hazards.

Reduce America's vulnerability. Homeland security involves a systematic, comprehensive, and strategic effort to reduce America's vulnerability to terrorist attack. We must recognize that as a vibrant and prosperous free society, we present an ever-evolving, ever-changing target.

Homeland security. This is a concerted national effort to prevent terrorist attacks within the United States; reduce America's vulnerability to terrorism; minimize the damage and have the ability to recover from attacks that do occur.



Minimize the damage. The United States will prepare to manage the consequences of any future terrorist attacks that may occur despite our best efforts at prevention.

Some operator certification examinations are designed to help minimize the possible incidence or damage from terrorism.

Where are the Regulations?

Terrorism, Utility Security and Emergency Plans are found in the **Federal Response Plan, Presidential Decision Directive 39, Patriot Act, Homeland Security Presidential Directive** and amendments to the **Safe Drinking Water Act**.

These Acts and Directives require that our utilities and workplaces are prepared for acts of terrorism. It's important that you have some basic understanding of the Act and the benefits and requirements necessary for a safer America.

The federal law or **Patriot Act** requires that all dangers and escapes in your workplace be fully evaluated for possible physical or health hazards. And, it mandates that all information relating to these hazards be available to other agencies in case of a disaster.

SEC. 1433.: 42 USC 300i-2 TERRORIST AND OTHER INTENTIONAL ACTS.

(a) Vulnerability Assessments.--(1) Each community water system serving a population of greater than 3,300 persons shall conduct an assessment of the vulnerability of its system to a terrorist attack or other intentional acts intended to substantially disrupt the ability of the system to provide a safe and reliable supply of drinking water. The vulnerability assessment shall include, but not be limited to, a review of pipes and constructed conveyances, physical barriers, water collection, pretreatment, treatment, storage and distribution facilities, electronic, computer or other automated systems which are utilized by the public water system, the use, storage, or handling of various chemicals, and the operation and maintenance of such system. The Administrator, not later than August 1, 2002, after consultation with appropriate departments and agencies of the Federal Government and with State and local governments, shall provide baseline information to community water systems required to conduct vulnerability assessments regarding which kinds of terrorist attacks or other intentional acts are the probable threats to--

“(A) substantially disrupt the ability of the system to provide a safe and reliable supply of drinking water; or

“(B) otherwise present significant public health concerns.

This course prepares first responders to take appropriate actions, such as secure the scene, initiate self-protective measures, and notify appropriate agencies of a potential terrorist incident. It gives learners a general understanding and ability to recognize terrorist weapons that are biological, nuclear, incendiary, chemical, or explosive.



Goals

You are one of the first to arrive on the scene of a suspected terrorist incident. As a first responder trained at the awareness level, you are among the first to witness or discover an incident involving criminal activity or terrorism and to initiate an emergency response sequence by notifying the proper authorities. In this role you need the following competencies which you can acquire through training and professional experience:

An understanding of what terrorism is and the risks associated with such an incident;

- An understanding of the potential outcomes associated with a terrorist incident;
- The ability to recognize the presence of, and identify, criminal activity or terrorism in an emergency;
- An understanding of the role of the first responder as it relates to components of an emergency response plan, including site security and the U.S. Department of Transportation's (**DOT**) North American Emergency Response Guidebook;
- The ability to realize the need for additional resources, and to make appropriate notifications to an emergency communication center; and
- The ability to self-protect, keeping responder safety as a priority.
- Understand Homeland advisory system and security methods.



USA Patriot Act

What must we protect? The USA Patriot Act defines critical infrastructure as those “**systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters.**”

Our critical infrastructures are particularly important because of the functions or services they provide to our country. Our critical infrastructures are also particularly important because they are complex systems: the effects of a terrorist attack can spread far beyond the direct target, and reverberate long after the immediate damage.

America's critical infrastructure encompasses a large number of sectors. Our agriculture, food, and water sectors, along with the public health and emergency services sectors, provide the essential goods and services Americans need to survive. Our institutions of government guarantee our national security and freedom, and administer key public functions.

Our defense industrial base provides essential capabilities to help safeguard our population from external threats. Our information and telecommunications sector enables economic productivity and growth, and is particularly important because it connects and helps control many other infrastructure sectors.

Our utilities, transportation, banking and finance, chemical industry, and postal and shipping sectors help sustain our economy and touch the lives of Americans every day.

The assets, functions, and systems within each critical infrastructure sector are not equally important. The transportation sector is vital, but not every bridge is critical to the Nation as a whole. Accordingly, the federal government will apply a consistent methodology to focus its effort on the highest priorities, and the federal budget will differentiate resources required for critical infrastructure protection from resources required for other important protection activities.

The federal government will work closely with state and local governments to develop and apply compatible approaches to ensure protection for critical assets, systems, and functions at all levels of society. For example, utilities, local schools, courthouses, and bridges are critical to the communities they serve.

Protecting America's critical infrastructure and key assets requires more than just resources. The federal government can use a broad range of measures to help enable state, local, and private sector entities to better protect the assets and infrastructures they control. For example, the government can create venues to share information on infrastructure vulnerabilities and best-practice solutions, or create a more effective means of providing specific and useful threat information to non-federal entities in a timely fashion.



A ticking time bomb, all it needs is a Terrorist to set the fuse. A possible diversion? A possible "*Sucker Punch*"?

Ever thought about the access Trash Collection or Delivery Vehicles have and the potential for Terrorist to use these trucks for a bomb or to sneak into your facility?

The Secret Service will shut down and search Routine Delivery and Sanitation Trucks within a 5 mile area when the President is in the area. They create a wall of steel to protect the President.

How about the security at your facility? Is it an elderly or unskilled person? Is there a real live person? In most cases, it is an unskilled or uneducated person who may have a criminal background. Think about the importance of a background check and reference checks.

Critical Infrastructure Sectors

- ✓ Agriculture
- ✓ Food
- ✓ Water
- ✓ Public Health
- ✓ Emergency Services
- ✓ Government
- ✓ Defense Industrial Base
- ✓ Information and Telecommunications
- ✓ Energy
- ✓ Transportation
- ✓ Banking and Finance
- ✓ Chemical Industry
- ✓ Postal and Shipping



Nuclear Plant

Major Initiatives

Unify America's infrastructure protection effort in the Department of Homeland Security. Our country requires a single accountable official to ensure we address vulnerabilities that involve more than one infrastructure sector or require action by more than one agency.

Our country also requires a single accountable official to assess threats and vulnerabilities comprehensively across all infrastructure sectors to ensure we reduce the overall risk to our country, instead of inadvertently shifting risk from one potential set of targets to another.

The Department of Homeland Security will assume responsibility for integrating and coordinating federal infrastructure protection responsibilities.

The Department of Homeland Security would consolidate and focus the activities performed by the Critical Infrastructure Assurance Office (currently part of the Department of Commerce) and the National Infrastructure Protection Center (FBI), less those portions that investigate computer crime.

The Department would augment those capabilities with the Federal Computer Incident Response Center (General Services Administration), the Computer Security Division of the National Institute of Standards and Technology (Commerce), and the National Communications System (Defense).

The Department of Homeland Security would also unify the responsibility for coordinating cyber and physical infrastructure protection efforts.

Currently, the federal government divides responsibility for cyber and physical infrastructure, and key cyber security activities are scattered in multiple departments.

While securing cyberspace poses unique challenges and issues, requiring unique tools and solutions, our physical and cyber infrastructures are interconnected.

The devices that control our physical systems, including our electrical distribution system, transportation systems, dams, and other important infrastructure, are increasingly connected to the Internet.

Thus, the consequences of an attack on our cyber infrastructure can cascade across many sectors. Moreover, the number, virulence, and maliciousness of cyber-attacks have increased dramatically in recent years.



Hoover Dam

If your water comes from surface water or impounded water, are you prepared for a water shortage or catastrophic flood from a levee or dam break?

Have you wondered why they built a bridge over the dam?

Vulnerability Statements, *Memorize these statements for your exam.*

Superfund Amendments and Reauthorization Act (SARA), Title II federal legislation requires water and wastewater systems to inform local emergency response agencies about hazardous chemicals used and stored on site. Always store your toxic and hazardous wastes in a secure area.

The USEPA Response Protocol Tool Box is a planning tool used for emergency response.

An emergency response plan for a treatment facility should be specific for the facility and be updated on an annual basis. Your critical customer list should be updated on a quarterly basis.

Completed security vulnerability assessments (VAs) and emergency response plans (ERPs) for your treatment or utility systems should be distributed to personnel with a "need to know" only. You do not need to share this information with the public.

Preparedness, Response, Recovery, and Mitigation are the four phases of emergency management that should be addressed in emergency response plans. Preparing emergency response plans for water- wastewater systems is part of the Preparedness phase of emergency management, so is stockpiling supplies, equipment and other resources to be used in the event of an emergency.

Actions taken to prevent an emergency or to lessen the harmful effects of an emergency are part of the Mitigation phase of emergency management. Initial actions taken during an emergency or disaster are part of the Response phase of emergency management. The threat management process consists of two parallel activities--threat evaluation and response decisions.

The **Incident Command System** should be utilized as a model tool for command, control and coordination of an emergency response to a public crisis. The most important part of an emergency is public notification. It is essential to assign one spokesperson to oversee this task as well as dissemination of information to the public.

Involve all of your employees in the security program in a positive manner. This is an advantage of a security awareness program.

There are three FEMA classifications of emergencies and disasters; natural, technological, and national security. The difference between an emergency and a disaster is that a disaster requires outside governmental assistance.

Protection of personnel, protection of the public, and mitigation procedures are priorities when training personnel to respond to hazardous materials released to the collection system or treatment works.

From a security perspective, deliveries of chemicals and other supplies should be performed in the presence of utilities system personnel. Always verify the credentials of all delivery drivers and check the manifest before allowing vendor or contractor personnel unescorted access to a utility's facilities.

The utility may want to adopt a policy that requires vendors to have an employee screening process. This security process may increase the cost of the services that the vendor is providing for your facility.

Detection and deterrence at your facility will improve after installing a new closed circuit TV (CCTV) around your treatment plant's perimeter fencing and additional lighting to meet the camera's lumen requirement. Remember detection and deterrence! Remove any debris that may be utilized to gain unlawful access to your facility too. Always trim bushes and other vegetation to see critical components.

Emergency back-up power generators for treatment facilities should be tested under load at least monthly.

In case your computer is damaged or suffers from a hacker attack, it is a good idea to regularly copy critical data on backup tapes or disks and store them at a secure, off-site location. Never connect your SCADA system to the Internet.

The least secure computer is a wireless computer; and the most secure system is a hard-wired system. We have seen that most cities have removed wireless systems from their networks.

Scenario:

An operator has discovered that a lock was cut from the opening of an utility system's storage tank. Until the incident is confirmed, a good business practice is to treat this type of security breach as a potential contamination threat.

Elevating the threat evaluation stage without definitive analytical data should be based on a preponderance of evidence such as a security breach, along with signs of contamination and abnormal test results. You should have an on-line monitor in a distribution system that detects an unexpected change in pH and chlorine residual.

This activity may indicate an early warning of possible contamination. If there is a contamination incident of a water supply. Water flow analysis, hydraulic modeling, areas of customer complaints, and field analysis are methods of estimating the spread.

Security Examination

Answers in rear.

1. What document assigns specific responsibilities to individuals and teams to take actions other than their normal required duties?
2. Which of the following is most useful in a water emergency?
3. At a minimum, how often should an emergency response plan be updated?
4. What is the term for a systematic process for evaluating the susceptibility of critical facilities to potential threats and identifying corrective actions that can reduce or mitigate the risk of serious consequences associated with these threats?
5. What document describes the actions that a waterworks would enact during disasters or other unexpected incidents?
6. Hazardous chemicals should be separated from other chemicals and stored in a designated area that is?
7. Often utility vehicles contain schematics, maps, and other sensitive documents. How do you protect these sensitive documents before parking the vehicle at the end of the day?
8. Placing devices to keep an individual from pumping contaminants from residential, industrial, and commercial customer sites or other access points, such as fire hydrants, into the distribution system network is known as?
9. Because the signal is transmitted directly to the receiver and not over the air, which of the following best describes hardwired surveillance systems' susceptibility to a cyber-attack?
10. A means of quickly notifying the public residing in the affected area of a "Do Not Drink" notice resulting from a health hazard in the water supply is?
11. Vegetation around the perimeter of water facilities needs to be?

12. Name an important step involved in conducting a vulnerability assessment?
13. In a plot to contaminate drinking water, microbial agents might be used because the contaminants?
14. It is important to have prepared a contact list of critical customers, like hospitals, in case you need to?
15. What is the most reliable means of confirming a water contamination incident?
16. What is one of a system's primary concerns in a contamination event?
17. How should customers and the public be notified of health hazards caused by the disruption of water treatment?
18. What is the most effective way to disseminate information to the public in the event of an emergency?
19. Adequate lighting around a distribution system's perimeter fencing may result in deterrence and?

Security Examination Answers

1. Emergency response plan
2. Sources of alternative water supplies
3. Annually
4. Vulnerability assessment
5. Emergency response plan
6. Secure with restricted access
7. Any critical information should be removed
8. Backflow prevention
9. More secure than wireless systems
10. Broadcast phone or "reverse 911" messages
11. Should be evaluated to minimize vulnerability
12. Determine against what type of assailants and threats you are trying to protect
13. Are extremely difficult to detect
14. Form a stakeholder committee
15. Analytical confirmation
16. Public notification
17. By the fastest means available
18. Designate one spokesperson for the system
19. Recovery

EPA Rules Chapter 2 *Memorize this section for your exam **

Arsenic (As) *

Arsenic is a chemical that occurs naturally in the earth's crust. When rocks, minerals, and soil erode, they release arsenic into water supplies. When people either drink this water or eat animals and plants that drink it, they are exposed to arsenic. For most people in the U.S., eating and drinking are the most common ways that people are exposed to arsenic, although it can also come from industrial sources. Studies have linked long-term exposure of arsenic in drinking water to a variety of cancers in humans.

To protect human health, an EPA standard limits the amount of arsenic in drinking water. In January 2001, the EPA revised the standard from 50 parts per billion (**ppb**), ordering that it fall to 10 ppb by 2006. After adopting 10ppb as the new standard for arsenic in drinking water, the EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits.

ICR, Know this section for exam.

The EPA has collected data required by the Information Collection Rule (ICR) * to support future regulation of microbial contaminants, disinfectants, and disinfection byproducts. The rule is intended to provide EPA with information on chemical byproducts that form when disinfectants used for microbial control react with chemicals already present in source water (disinfection byproducts (**DBPs**)); disease-causing microorganisms (pathogens), including *Cryptosporidium*; and engineering data to control these contaminants.

Disinfection Byproduct Regulations

In December 1998, the EPA established the Stage 1 Disinfectants/Disinfection Byproducts Rule that requires public water systems to use treatment measures to reduce the formation of disinfection byproducts and to meet the following specific standards:

Currently trihalomethanes are regulated at a maximum allowable annual average level of 100 parts per billion for water systems serving over 10,000 people under the Total Trihalomethane Rule finalized by the EPA in 1979.

***Disinfection byproducts** are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.

***Memorize this section for exam.**

***Trihalomethanes (THM)** are a group of four chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The trihalomethanes are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate total trihalomethanes (**TTHM**) at a maximum allowable annual average level of **80 parts per billion ***.

Haloacetic Acids (HAA5) are a group of chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water.

The regulated haloacetic acids, known as HAA5, are: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid. EPA has published the

Bromate is a chemical that is formed when ozone used to disinfect drinking water reacts with naturally occurring bromide found in source water. The EPA has established the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate bromate at annual average of **10 parts per billion** in drinking water.

This standard became effective for large **public water systems** in December 2001 and for small surface water and all ground public water systems in December 2003.

Microbial Regulations, Memorize this section for exam.

One of the key regulations developed and implemented by the United States Environmental Protection Agency (**USEPA**) to counter pathogens in drinking water is the **Surface Water Treatment Rule***. Among its provisions, the rule requires that a public water system, using surface water (or ground water under the direct influence of surface water) as its source, have sufficient treatment to reduce the source water concentration of **Giardia** and viruses by at least 99.9% and 99.99%, respectively. The Surface Water Treatment Rule specifies treatment criteria to assure that these performance requirements are met; they include turbidity limits, disinfectant residual and disinfectant contact time conditions.

Disinfection Rules Stages 1 & 2 DBPR

The following are EPA's federal rule requirements. Please be aware that each state implements drinking water regulations that may be more stringent than EPA's regulations. Check with your state environmental agency for more information.

Stage 2 DBPR

EPA finalized the Stage 2 Disinfectants and Disinfection Byproduct Rule (DBPR) to reduce potential health risks from DBPs. The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) is being finalized and implemented at the same time as the Stage 2 DBPR to ensure that drinking water is safe from both microbial pathogens and DBPs.

General Requirements

To comply with the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR), published on January 4, 2006 (71 FR 388) systems must do the following:

- **Conduct an Initial Distribution System Evaluation (IDSE)** to find locations in the distribution system that have high levels of TTHM and HAA5 and that can be used as compliance monitoring sites for the Stage 2 DBPR.

- **Use a locational running annual average (LRAA) calculation to determine compliance** with the Stage 2 DBPR maximum contaminant levels (MCLs) of:

- 0.080 mg/L for total trihalomethanes (TTHM), and

- 0.060 mg/L for five haloacetic acids (HAA5).

Note: The MCL values are the same as the Stage 1 MCLs; only the calculation method changes.

- **Monitor for Stage 2 compliance** at the required number of locations for each system's retail population

- **Identify when TTHM or HAA5 levels exceed the operational evaluation level** and, when this happens, look at source water, operational practices, and treatment to find ways to reduce TTHM and HAA5 concentrations in the distribution system. Each of these general requirements are covered in more detail in the rest of this guidance manual. The Stage 2 DBPR is an extension of the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR). Systems must also

continue to comply with the other requirements of the Stage 1 DBPR in addition to meeting the requirements of the Stage 2 DBPR. This includes compliance with the MCLs for bromate (for systems using ozone) and chlorite (for systems using chlorine dioxide), the MRDLs for chlorine or chloramine (depending on the residual disinfectant used), as well as TOC removal requirements.

Compliance Timeline

Your compliance schedule for the Stage 2 DBPR are based on whether your system is part of a *combined distribution system*:

- If your system **is** part of a combined distribution system, you must comply with the revised MCLs by the same date as required for the largest system in your combined distribution system.

Example: if your system serves 8,000 people, but you purchase water from a system that serves 250,000 people, you must comply by the dates shown in Schedule 1.

- If your system **is not** part of a combined distribution system, compliance dates are based on the population served by your system.

If you are using this guidance manual, you likely serve fewer than 10,000 people and you must comply by the dates shown in Schedule 4.

Your State (or EPA) should have sent you a letter telling you what schedule you are on. If you did not receive this letter or you have questions about your schedule, contact your State (contact information is listed in Appendix C).

Note: You are on the same schedule for Stage 2 DBPR compliance as you were on for the IDSE. The timeline on the next page shows important dates for the Stage 2 DBPR as well as periods for *Cryptosporidium* and *E. coli* required under the LT2ESWTR.

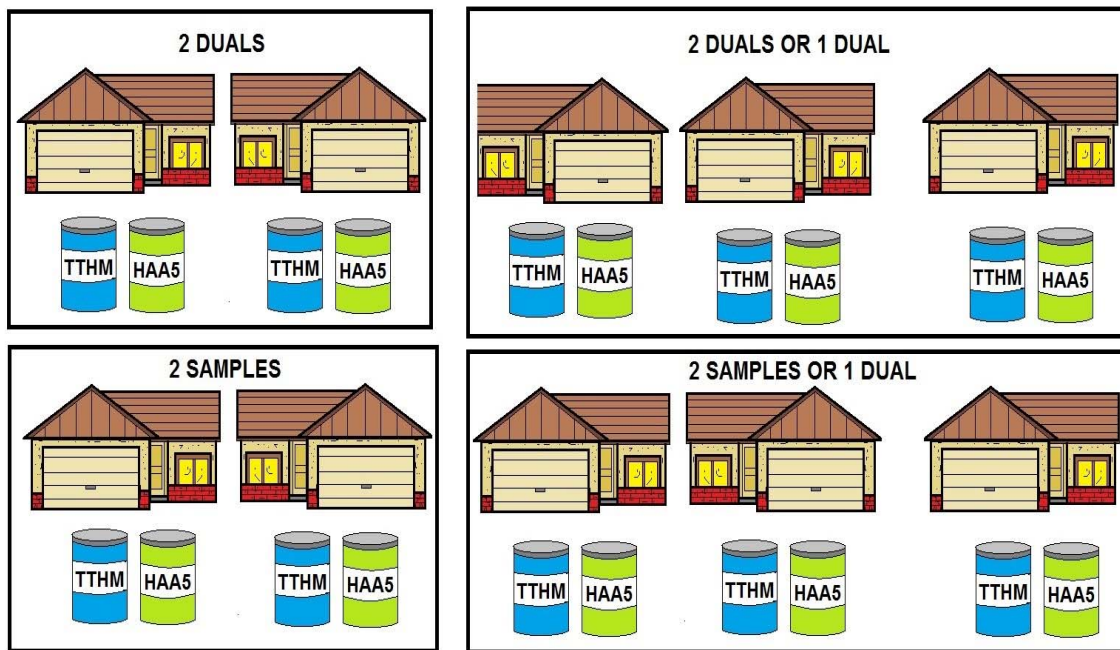
Note: The figure shows the 2-year period after systems must begin compliance as a “possible extension.” States may give you up to an additional 2 years to comply if you need time to install capital improvements.

How Does this Rule Relate to Other Federal, State, and Local Requirements?

As noted earlier, the Stage 2 DBPR is an extension of the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR). The Stage 2 DBPR and the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) were published together to address the balance between protection from microbial pathogens and the potential health effects from disinfectants and their byproducts. You are still required to continue to meet all existing federal requirements. You may call the Safe Drinking Water Hotline at (800) 426-4791 (e-mail: hotline-sdwa@epa.gov) for more information on other drinking water rules.

Where do DBPs come from?

Chlorine and other chemical disinfectants have been widely used by public water systems (along with filtration) to protect the public from microbial pathogens in drinking water. DBPs are formed when certain disinfectants react with DBP precursors (organic and inorganic materials) in source waters. In most cases, natural organic matter (NOM) is an important factor that affects the levels of DBPs that form (NOM is usually measured as TOC). The levels of DBPs in drinking water can vary significantly from one point in a distribution system to another, as many continue to form in the distribution system. DBP levels are generally higher in surface water systems because surface water usually contains higher DBP precursor levels and requires stronger disinfection.



STAGE 2 DISINFECTION BYPRODUCT RULE

Revised Total Coliform Rule (RTCR)

The following are EPA's federal rule requirements. Please be aware that each state implements drinking water regulations that may be more stringent than EPA's regulations. Check with your state environmental agency for more information.

EPA published the Revised Total Coliform Rule (RTCR) in the Federal Register (FR) on February 13, 2013 (78 FR 10269). It is the revision to the 1989 Total Coliform Rule (TCR).

Why revise the 1989 TCR?

The 1996 amendments to the Safe Drinking Water Act [Section 1412(b) (9)] require the Administrator to review and revise, as appropriate, each national primary drinking water regulation not less often than every six years. EPA published its decision to revise the TCR in July 2003 as part of its National Primary Drinking Water Regulation (NPDWR) review.

The RTCR:

- Upholds the purpose of the 1989 TCR to protect public health by ensuring the integrity of the drinking water distribution system and monitoring for the presence of microbial contamination.
- Requires public water systems (PWSs) to meet a legal limit for E. coli, as demonstrated by required monitoring.
- Specifies the frequency and timing of required microbial testing based on population served, public water system type and source water type: ground water or surface water.

When must PWSs comply with the RTCR requirements?

Unless a State determines an earlier effective date, all PWSs must comply with the RTCR requirements starting April 1, 2016. All PWSs include:

- Community Water Systems (CWSs),
- Non-Transient Non-Community Water Systems (NTNCWSs), and
- Transient Non-Community Water Systems (TNCWSs).

Minor Corrections to the Revised Total Coliform Rule (RTCR)

Minor corrections to the final RTCR became effective on April 28, 2014. No comments were received on the Direct Final Rule published on February 26, 2014 and the corrections therefore became effective without further notice. See the **Direct Final Rule** Federal Register Notice.

Revised Total Coliform Rule (RTCR) – Final Rule

On February 13, 2013, EPA published in the Federal Register the revisions to the 1989 TCR. EPA anticipates greater public health protection under the Revised Total Coliform Rule (RTCR) requirements. The RTCR:

- Requires public water systems that are vulnerable to microbial contamination to identify and fix problems; and
- Establishes criteria for systems to qualify for and stay on reduced monitoring, which could reduce water system burden and provide incentives for better system operation.

Public water systems (PWSs) and primacy agencies must comply with the revised requirements by April, 2016. Until then, PWSs and primacy agencies must continue complying with the 1989 TCR.

More on the Current Stage 2 DBP Rule

The following are EPA's federal rule requirements. Please be aware that each state implements drinking water regulations that may be more stringent than EPA's regulations. Check with your state environmental agency for more information.

The Stage 2 DBP rule is one part of the Microbial and Disinfection Byproducts Rules (MDBPs), which are a set of interrelated regulations that address risks from microbial pathogens and disinfectants/disinfection byproducts. The Stage 2 DBP rule focuses on public health protection by limiting exposure to DBPs, specifically total trihalomethanes (TTHM) and five haloacetic acids (HAA5), which can form in water through disinfectants used to control microbial pathogens. This rule will apply to all community water systems and nontransient noncommunity water systems that add a primary or residual disinfectant other than ultraviolet (UV) light or deliver water that has been disinfected by a primary or residual disinfectant other than UV.

Amendments to the SDWA in 1996 require EPA to develop rules to balance the risks between microbial pathogens and disinfection byproducts (DBPs). The Stage 1 Disinfectants and Disinfection Byproducts Rule and Interim Enhanced Surface Water Treatment Rule, promulgated in December 1998, were the first phase in a rulemaking strategy required by Congress as part of the 1996 Amendments to the Safe Drinking Water Act.

The Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR) builds upon the Stage 1 DBPR to address higher risk public water systems for protection measures beyond those required for existing regulations. The Stage 2 DBPR and the Long Term 2 Enhanced Surface Water Treatment Rule are the second phase of rules required by Congress. These rules strengthen protection against microbial contaminants, especially *Cryptosporidium*, and at the same time, reduce potential health risks of DBPs.

What is the Stage 2 DBPR?

The Stage 2 Disinfection Byproducts Rule will reduce potential cancer and reproductive and developmental health risks from disinfection byproducts (DBPs) in drinking water, which form when disinfectants are used to control microbial pathogens. Over 260 million individuals are exposed to DBPs.

This final rule strengthens public health protection for customers by tightening compliance monitoring requirements for two groups of DBPs, trihalomethanes (TTHM) and haloacetic acids (HAA5). The rule targets systems with the greatest risk and builds incrementally on existing rules. This regulation will reduce DBP exposure and related potential health risks and provide more equitable public health protection. The Stage 2 DBPR is being promulgated simultaneously with the Long Term 2 Enhanced Surface Water Treatment Rule to address concerns about risk tradeoffs between pathogens and DBPs.

What does the rule require?

Under the Stage 2 DBPR, systems will conduct an evaluation of their distribution systems, known as an Initial Distribution System Evaluation (IDSE), to identify the locations with high disinfection byproduct concentrations. These locations will then be used by the systems as the sampling sites for Stage 2 DBPR compliance monitoring. Compliance with the maximum contaminant levels for two groups of disinfection byproducts (TTHM and HAA5) will be calculated for each monitoring location in the distribution system. This approach, referred to as the locational running annual average (LRAA), differs from current requirements, which determine compliance by calculating the running annual average of samples from all monitoring locations across the system.

The Stage 2 DBPR also requires each system to determine if they have exceeded an operational evaluation level, which is identified using their compliance monitoring results. The operational evaluation level provides an early warning of possible future MCL violations, which allows the system to take proactive steps to remain in compliance.

A system that exceeds an operational evaluation level is required to review their operational practices and submit a report to their state that identifies actions that may be taken to mitigate future high DBP levels, particularly those that may jeopardize their compliance with the DBP MCLs.

Who must comply with the rule?

Entities potentially regulated by the Stage 2 DBPR are community and nontransient noncommunity water systems that produce and/or deliver water that is treated with a primary or residual disinfectant other than ultraviolet light.

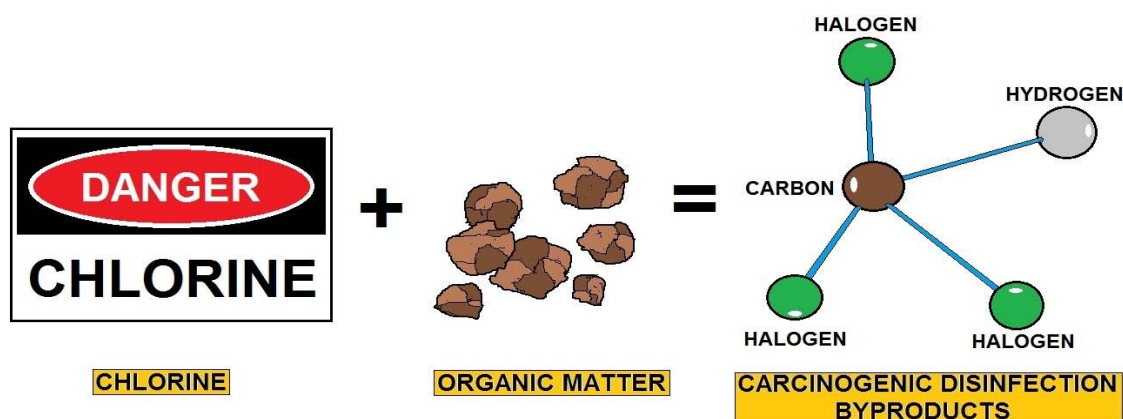
A community water system (CWS) is a public water system that serves year-round residents of a community, subdivision, or mobile home park that has at least 15 service connections or an average of at least 25 residents.

A nontransient noncommunity water system (NTNCWS) is a water system that serves at least 25 of the same people more than six months of the year, but not as primary residence, such as schools, businesses, and day care facilities.

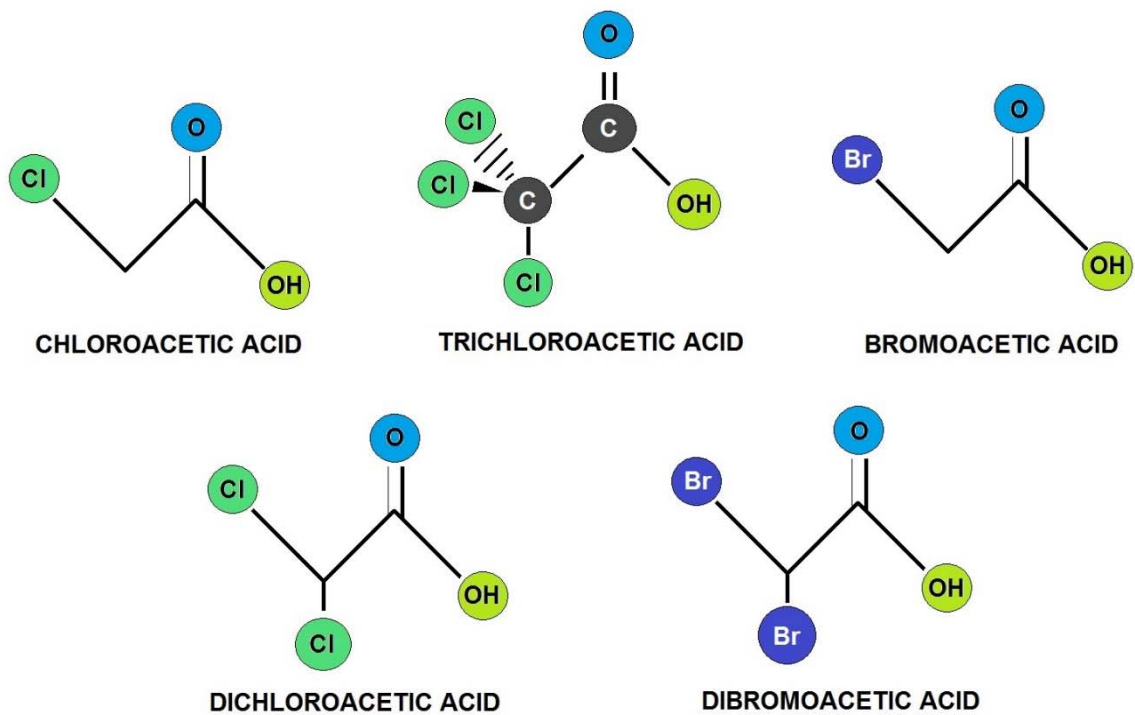
What are disinfection byproducts (DBPs)?

Disinfectants are an essential element of drinking water treatment because of the barrier they provide against waterborne disease-causing microorganisms. Disinfection byproducts (DBPs) form when disinfectants used to treat drinking water react with naturally occurring materials in the water (e.g., decomposing plant material).

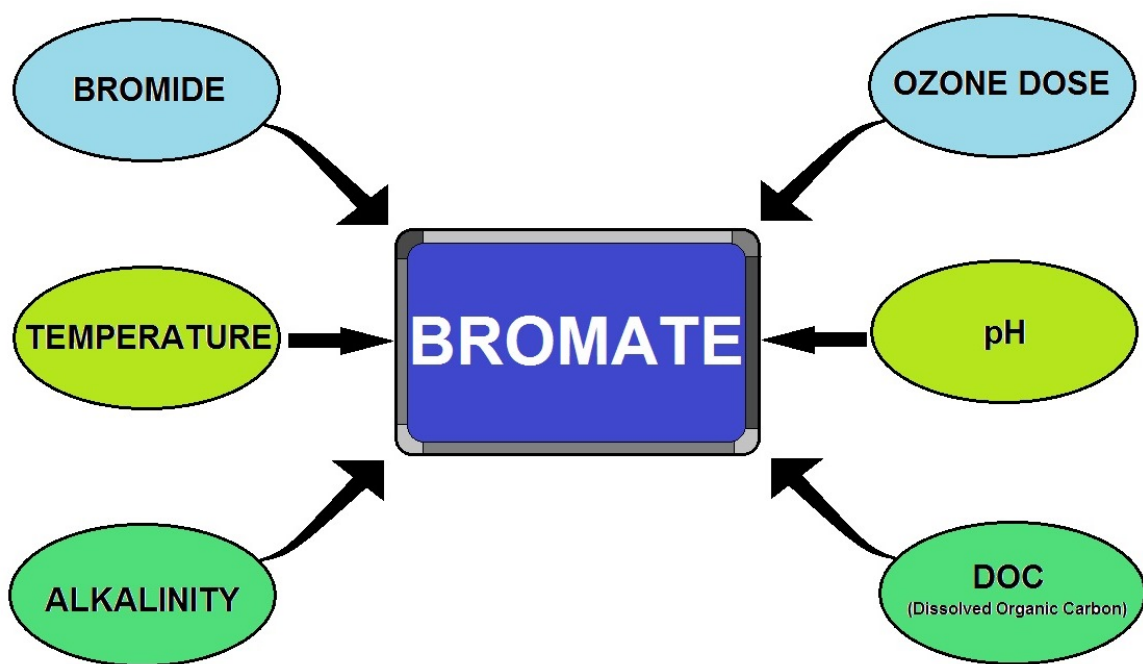
Total trihalomethanes (TTHM - chloroform, bromoform, bromodichloromethane, and dibromochloromethane) and haloacetic acids (HAA5 - monochloro-, dichloro-, trichloro-, monobromo-, dibromo-) are widely occurring classes of DBPs formed during disinfection with chlorine and chloramine. The amount of trihalomethanes and haloacetic acids in drinking water can change from day to day, depending on the season, water temperature, amount of disinfectant added, the amount of plant material in the water, and a variety of other factors.



DISINFECTION BYPRODUCT PRODUCTION DIAGRAM



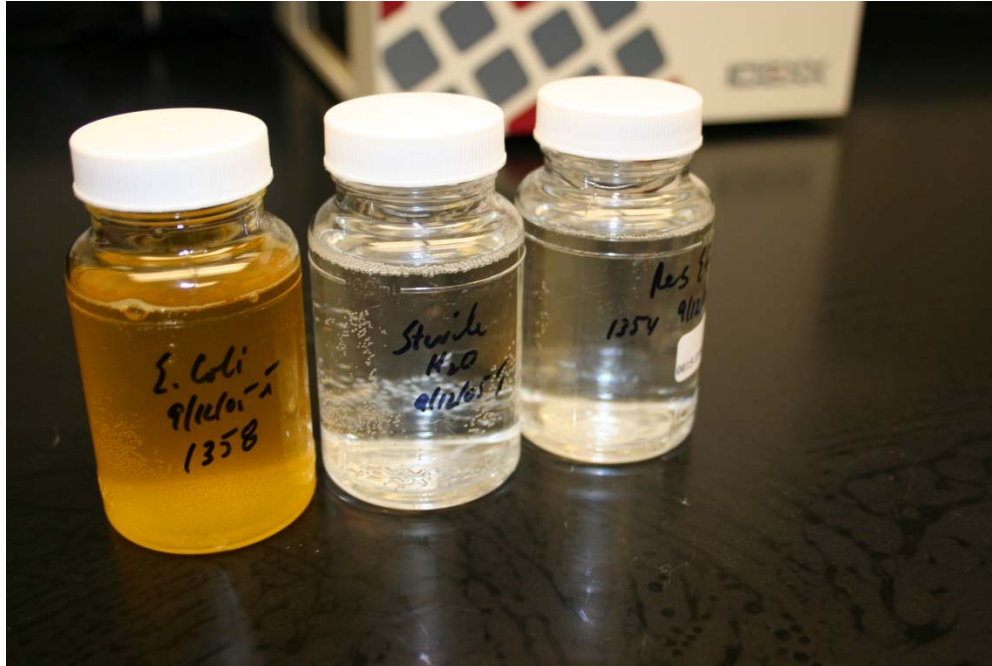
HALOACETIC ACIDS (HAA5)



BROMATE FORMATION FACTORS

Microbes

Coliform bacteria are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease.



Fecal Coliform and E coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms.

Cryptosporidium is a parasite that enters lakes and rivers through sewage and animal waste. It causes cryptosporidiosis, a mild gastrointestinal disease. However, the disease can be severe or fatal for people with severely weakened immune systems. The EPA and CDC have prepared advice for those with severely compromised immune systems who are concerned about *Cryptosporidium*.

Giardia lamblia is a parasite that enters lakes and rivers through sewage and animal waste. It causes gastrointestinal illness (e.g. diarrhea, vomiting, and cramps).

Radionuclides

Alpha emitters. Certain minerals are radioactive and may emit a form of radiation known as alpha radiation. Some people who drink water containing alpha emitters in excess of EPA standards over many years may have an increased risk of getting cancer.

Beta/photon emitters. Certain minerals are radioactive and may emit forms of radiation known as photons and beta radiation. Some people who drink water containing beta and photon emitters in excess of EPA standards over many years may have an increased risk of getting cancer.

Combined Radium 226/228. Some people who drink water containing radium 226 or 228 in excess of EPA standards over many years may have an increased risk of getting cancer.

Radon gas can dissolve and accumulate in underground water sources, such as wells, and in the air in your home. Breathing radon can cause lung cancer. Drinking water containing radon presents a risk of developing cancer. Radon in air is more dangerous than radon in water.

Inorganic Contaminants

Antimony	Cadmium	Cyanide	Nitrite
Asbestos	Chromium	Mercury	Selenium
Barium	Copper	Nitrate	Thallium
Beryllium			

***Arsenic.** Some people who drink water containing arsenic in excess of EPA standards over many years could experience skin damage or problems with their circulatory system, and may have an increased risk of getting cancer.

*** Fluoride. Memorize this section for exam.** Many communities add fluoride to their drinking water to promote dental health. Each community makes its own decision about whether or not to add fluoride. The EPA has set an enforceable drinking water standard for fluoride of 4 mg/L (some people who drink water containing fluoride in excess of this level over many years could get bone disease, including pain and tenderness of the bones). The EPA has also set a secondary fluoride standard of 2 mg/L to protect against dental fluorosis. Dental fluorosis, in its moderate or severe forms, may result in a brown staining and/or pitting of the permanent teeth. This problem occurs only in developing teeth, before they erupt from the gums. Children under nine should not drink water that has more than 2 mg/L of fluoride. Know the different types of Fluorides.

Lead typically leaches into water from plumbing in older buildings. Lead pipes and plumbing fittings have been banned since August 1998. Children and pregnant women are most susceptible to lead health risks.

Synthetic Organic Contaminants (SOCs), including pesticides & herbicides

2,4-D	Dibromochloropropane	Hexachlorobenzene
2,4,5-TP (Silvex)	Dinoseb	Hexachlorocyclopentadiene
Acrylamide	Dioxin (2,3,7,8-TCDD)	Lindane
Alachlor	Diquat	Methoxychlor
Atrazine	Endothall	Oxamyl [Vydate]
Benzoapyrene	Endrin	PCBs [Polychlorinated biphenyls]
Carbofuran	Epichlorohydrin	Pentachlorophenol
Chlordane	Ethylene dibromide	Picloram
Dalapon	Glyphosate	Simazine
Di 2-ethylhexyl adipate	Heptachlor	Toxaphene
Di 2-ethylhexyl phthalate	Heptachlor epoxide	

Volatile Organic Contaminants (VOCs)

Benzene	trans-1,2-Dichloroethylene	1,2,4-Trichlorobenzene
Carbon Tetrachloride	Dichloromethane	1,1,1,-Trichloroethane
Chlorobenzene	1,2-Dichloroethane	1,1,2-Trichloroethane
o-Dichlorobenzene	1,2-Dichloropropane	Trichloroethylene
p-Dichlorobenzene	Ethylbenzene	Toluene
1,1-Dichloroethylene	Styrene	Vinyl Chloride
cis-1,2-Dichloroethylene	Tetrachloroethylene	Xylenes

National Primary Drinking Water Regulations

Inorganic Chemicals	MCLG ¹ (mg/L) <u>4</u>	MCL ² or TT ³ (mg/L) <u>4</u>	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood glucose	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0.01 ⁵	0.010	Skin damage; circulatory system problems; increased risk of cancer	Discharge from semiconductor manufacturing; petroleum refining; wood preservatives; animal feed additives; herbicides; erosion of natural deposits
Asbestos (fiber >10 micrometers)	7 million fibers per Liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Some people who use water containing chromium well in excess of the MCL over many years could experience allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	Action Level=1.3; TT ⁶	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. Those with Wilson's Disease should consult their personal doctor if their water systems exceed the copper action level.	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth.	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	Action Level=0.015; TT ⁶	Infants and children: Delays in physical or mental development. Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits

Inorganic Mercury	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and cropland
Nitrate (measured as Nitrogen)	10	10	"Blue baby syndrome" in infants under six months - life threatening without immediate medical attention. Symptoms: Infant looks blue and has shortness of breath.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	"Blue baby syndrome" in infants under six months - life threatening without immediate medical attention. Symptoms: Infant looks blue and has shortness of breath.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and pharmaceutical companies

Organic Chemicals	MCLG ₁ (mg/L) 4	MCL ₂ or TT ₃ (mg/L) 4	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Acrylamide	zero	TT ₂	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system problems; reproductive difficulties	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood or nervous system; reproductive difficulties.	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops

Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1-1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1, 2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from pharmaceutical and chemical factories
1-2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl)adipate	0.4	0.4	General toxic effects or reproductive difficulties	Leaching from PVC plumbing systems; discharge from chemical factories
Di(2-ethylhexyl)phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Nervous system effects	Residue of banned insecticide
Epichlorohydrin	zero	TT ²	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from industrial chemical factories; added to water during treatment process
Ethylbenzene	0.7	0.7	Liver or kidney problems	Discharge from petroleum refineries
Ethylene dibromide	zero	0.00005	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens

Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased risk of cancer	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, and circulatory problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Total Trihalomethanes (TTHMs)	none ⁵	0.10	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from petroleum refineries
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

Radionuclides	MCLG ₁ (mg/L) 4	MCL ₂ or TT ₃ (mg/L) 4	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Beta particles and photon emitters	none ⁵	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits
Gross alpha particle activity	none ⁵	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits

Radium 226 and Radium 228 (combined)	none ⁵	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
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Microorganisms	MCLG ¹ (mg/L) <u>4</u>	MCL ² or TT ³ (mg/L) <u>4</u>	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
<i>Giardia lamblia</i>	zero	TT ⁴	Giardiasis, a gastroenteric disease	Human and animal fecal waste
Heterotrophic plate count	N/A	TT ⁴	HPC has no health effects, but can indicate how effective treatment is at controlling microorganisms.	n/a
<i>Legionella</i>	zero	TT ⁴	Legionnaire's Disease, commonly known as pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and <i>E. Coli</i>)	zero	5.0% ⁹	Used as an indicator that other potentially harmful bacteria may be present ¹⁰	Human and animal fecal waste
Turbidity	N/A	TT ⁴	Turbidity has no health effects but can interfere with disinfection and provide a medium for microbial growth. It may indicate the presence of microbes.	Soil runoff
Viruses (enteric)	zero	TT ⁴	Gastroenteric disease	Human and animal fecal waste

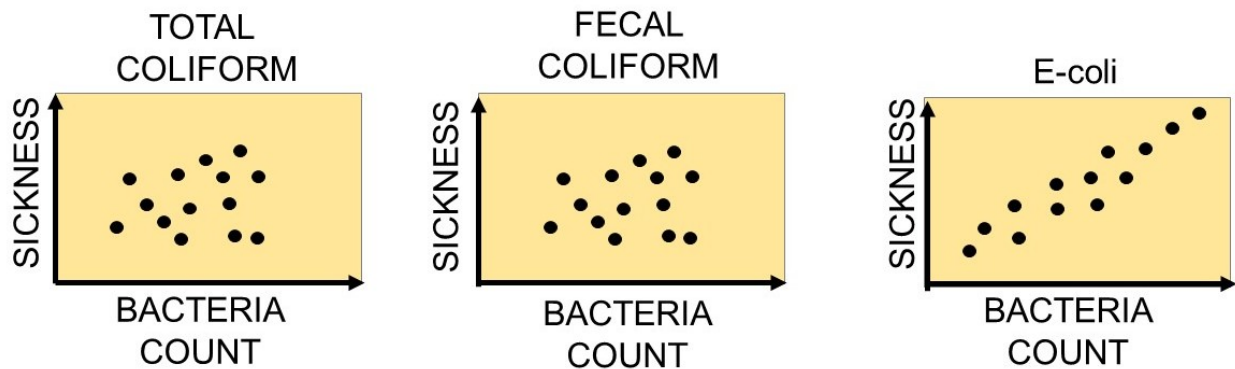
Abbreviations

BOD – biochemical oxygen demand
 DO – dissolved oxygen
 ft – feet
 gpd – gallons per day
 gpg – grains per gallon
 gpm – gallons per minute
 lbs – pounds

mg/L – milligrams per liter
 MGD – millions of gallons per day
 mL – milliliter
 MLSS – mixed liquor suspended solids
 MLVSS – mixed liquor volatile suspended solids
 TSS – Total Suspended Solids



FECAL COLIFORM BACTERIA COLONIES (Per 100 Milliliters)



BACTERIA IN DRINKING WATER DIAGRAM

*National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs) or secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L <i>Know both primary and secondary for exam</i>
Corrosivity	noncorrosive
Fluoride	2.0 mg/L <i>Know both primary and secondary for exam</i>
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

Notes

¹ Maximum Contaminant Level Goal (**MCLG**) - The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health effect of persons would occur, and which allows for an proper margin of safety. MCLGs are non-enforceable public health goals.

² Maximum Contaminant Level (**MCL**) - The maximum permissible level of a contaminant in water which is delivered to any user of a public water system. MCLs are enforceable standards. The margins of safety in MCLGs ensure that exceeding the MCL slightly does not pose significant risk to public health.

³ Treatment Technique - An enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant.

⁴ Units are in milligrams per Liter (mg/L) unless otherwise noted.

⁵ MCLGs were not established before the 1986 Amendments to the Safe Drinking Water Act. Therefore, there is no MCLG for this contaminant.

⁶ Lead and copper are regulated in a Treatment Technique which requires systems to take tap water samples at sites with lead pipes or copper pipes that have lead solder and/or are served by lead service lines. The action level, which triggers water systems into taking treatment steps if exceeded in more than 10% of tap water samples, for copper is 1.3 mg/L, and for lead is 0.015mg/L.

⁷ Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- **Acrylamide** = 0.05% dosed at 1 mg/L (or equivalent)
- **Epichlorohydrin** = 0.01% dosed at 20 mg/L (or equivalent)

⁸ The Surface Water Treatment Rule requires systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- **Giardia lamblia**: 99.9% killed/inactivated
Viruses: 99.99% killed/inactivated
- **Legionella**: No limit, but EPA believes that if **Giardia** and viruses are inactivated, **Legionella** will also be controlled.
- **Turbidity**: At no time can turbidity (**cloudiness of water**) go above 5 nephelometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month.
- **HPC**: NO more than 500 bacterial colonies per milliliter.

⁹ No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive). Every sample that has total coliforms must be analyzed for fecal coliforms. There cannot be any fecal coliforms.

¹⁰ Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms.

Safe Drinking Water Act Terms *Memorize this section for exam.**

***Community Water System (CWS).** A public water system that serves at least 15 service connections used by year-round residents of the area served by the system or regularly serves at least 25 year-round residents.

Class V Underground Injection Control (UIC) Rule. A rule under development covering wells not included in Class I, II, III or IV in which nonhazardous fluids are injected into or above underground sources of drinking water.

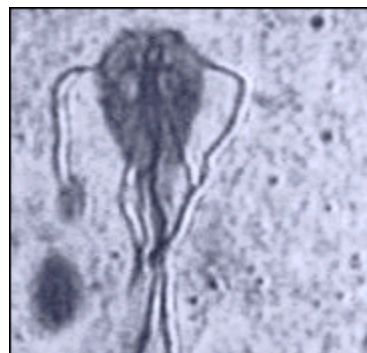
Contamination Source Inventory. The process of identifying and inventorying contaminant sources within delineated source water protection areas through recording existing data, describing sources within the source water protection area, targeting likely sources for further investigation, collecting and interpreting new information on existing or potential sources through surveys, and verifying accuracy and reliability of the information gathered.

Cryptosporidium A protozoan associated with the disease cryptosporidiosis in humans. The disease can be transmitted through ingestion of drinking water, person-to-person contact, or other exposure routes. Cryptosporidiosis may cause acute diarrhea, abdominal pain, vomiting, and fever that last 1-2 weeks in healthy adults, but may be chronic or fatal in immuno-compromised people.

Drinking Water State Revolving Fund (DWSRF). Under section 1452 of the SDWA, EPA awards capitalization grants to states to develop drinking water revolving loan funds to help finance drinking water system infrastructure improvements, source water protection, to enhance operations and management of drinking water systems, and other activities to encourage public water system compliance and protection of public health.

Exposure Contact between a person and a chemical. Exposures are calculated as the amount of chemical available for absorption by a person.

Giardia lamblia A protozoan, which can survive in water for 1 to 3 months, associated with the disease giardiasis. Ingestion of this protozoan in contaminated drinking water, exposure from person-to-person contact, and other exposure routes may cause giardiasis. The symptoms of this gastrointestinal disease may persist for weeks or months and include diarrhea, fatigue, and cramps.



Ground Water Disinfection Rule (GWDR). Under section 107 of the SDWA Amendments of 1996, the statute reads, ". . . the Administrator shall also promulgate national primary drinking water regulations requiring disinfection as a treatment technique for all public water systems, including surface water systems, and as necessary, ground water systems."

***Maximum Contaminant Level (MCL).** In the SDWA, an MCL is defined as "*the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.*" MCLs are enforceable standards.

Maximum Contaminant Level Goal (MCLG) The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health effect of persons would occur, and which allows for an adequate margin of safety. MCLGs are non-enforceable public health goals.

***Nephelometric Turbidity Units. (NTU)** A unit of measure used to describe the turbidity of water. Turbidity is the cloudiness in water.

***Nitrates** Inorganic compounds that can enter water supplies from fertilizer runoff and sanitary wastewater discharges. Nitrates in drinking water are associated with methemoglobinemia, or blue baby syndrome, which results from interferences in the blood's ability to carry oxygen.

***Non-Community Water System (NCWS).** A public water system that is not a community water system. There are two types of NCWSs: transient and non-transient.

Organics Chemical molecules that contain carbon and other elements such as hydrogen. Organic contaminants of concern to drinking water include chlorohydrocarbons, pesticides, and others.

Phase I Contaminants The Phase I Rule became effective on January 9, 1989. This rule, also called the Volatile Organic Chemical Rule, or VOC Rule, set water quality standards for 8 VOCs and required all community and Non-Transient, Non-Community water systems to monitor for, and if necessary, treat their supplies for these chemicals. The 8 VOCs regulated under this rule are: Benzene, Carbon Tetrachloride, para-dichlorobenzene, trichloroethylene, vinyl chloride, 1,1,2-trichloroethane, 1,1-dichloroethylene, and 1,2-dichloroethane.

Per capita Per person; generally used in expressions of water use, gallons per capita per day (gpcd).

Point-of-Use Water Treatment Refers to devices used in the home or office on a specific tap to provide additional drinking water treatment.

Point-of-Entry Water Treatment Refers to devices used in the home where water pipes enter to provide additional treatment of drinking water used throughout the home.

Primacy State. State that has the responsibility for ensuring a law is implemented, and has the authority to enforce the law and related regulations. State has adopted rules at least as stringent as federal regulations and has been granted primary enforcement responsibility.

Radionuclides Elements that undergo a process of natural decay. As radionuclides decay, they emit radiation in the form of alpha or beta particles and gamma photons. Radiation can cause adverse health effects, such as cancer, so limits are placed on radionuclide concentrations in drinking water.

Risk The potential for harm to people exposed to chemicals. In order for there to be risk, there must be hazard and there must be exposure.

SDWA - The Safe Drinking Water Act. The Safe Drinking Water Act was first passed in 1974 and established the basic requirements under which the nation's public water supplies were regulated. The US Environmental Protection Agency (**EPA**) is responsible for setting the national drinking water regulations while individual states are responsible for ensuring that public water systems under their jurisdiction are complying with the regulations. The SDWA was amended in 1986 and again in 1996.

Significant Potential Source of Contamination. A facility or activity that stores, uses, or produces chemicals or elements, and that has the potential to release contaminants identified in a state program (contaminants with MCLs plus any others a state considers a health threat) within a source water protection area in an amount which could contribute significantly to the concentration of the contaminants in the source waters of the public water supply.

Sole Source Aquifer (SSA) Designation. The surface area above a sole source aquifer and its recharge area.

Source Water Protection Area (SWPA). The area delineated by the state for a PWS or including numerous PWSs, whether the source is ground water or surface water or both, as part of the state SWAP approved by EPA under section 1453 of the SDWA.

Sub watershed. A topographic boundary that is the perimeter of the catchment area of a tributary of a stream.

***Surface Water Treatment Rule (SWTR).** The rule specifies maximum contaminant level goals for *Giardia lamblia*, viruses and *Legionella*, and promulgated filtration and disinfection requirements for public water systems using surface water sources, or by ground water sources under the direct influence of surface water. The regulations also specify water quality, treatment, and watershed protection criteria under which filtration may be avoided.



Legionella

Susceptibility Analysis. An analysis to determine, with a clear understanding of where the significant potential sources of contamination are located, the susceptibility of the public water systems in the source water protection area to contamination from these sources. This analysis will assist the state in determining which potential sources of contamination are "**significant**."

To the Extent Practical. States must inventory sources of contamination to the extent they have the technology and resources to complete an inventory for a Source Water Protection Area delineated as described in the guidance. All information sources may be used, particularly previous Federal and state inventories of sources.

***Transient/Non-Transient, Non-Community Water Systems (T/NT,NCWS).** Water systems that are non-community systems: transient systems serve 25 non-resident persons per day for 6 months or less per year. Transient non-community systems typically are restaurants, hotels, large stores, etc. Non-transient systems regularly serve at least 25 of the same non-resident persons per day for more than 6 months per year. These systems typically are schools, offices, churches, factories, etc.

Treatment Technique A specific treatment method required by EPA to be used to control the level of a contaminant in drinking water. In specific cases where EPA has determined it is not technically or economically feasible to establish an MCL, the EPA can instead specify a treatment technique. A treatment technique is an enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant.

Total Coliform Bacteria that are used as indicators of fecal contaminants in drinking water.

Toxicity The property of a chemical to harm people who come into contact with it.

Underground Injection Control (UIC) Program. The program is designed to prevent underground injection which endangers drinking water sources. The program applies to injection well owners and operators on Federal facilities, Native American lands, and on all U.S. land and territories.

***Watershed.** A topographic boundary area that is the perimeter of the catchment area of a stream.

Watershed Area. A topographic area that is within a line drawn connecting the highest points uphill of a drinking water intake, from which overland flow drains to the intake.

Related State Definitions

Depending on your State, these definitions will change, but generally these terms are universal and can be used on in the assignment.

The terms in this Article have the following meanings:

“Certified operator” or “operator” means an individual who holds a current certificate issued by the Department in the field of water or wastewater treatment, water distribution, or wastewater collection, and is responsible for the daily onsite operation or the remote operation from a central location of all or a part of a facility.

“Direct responsible charge” means day-to-day decision making responsibility for a facility or a major portion of a facility.

“Distribution system” means a pipeline, appurtenance, or device of a public water system that conducts water from a water source or treatment plant to consumers for domestic or potable use.

“Facility” means a water treatment plant, wastewater treatment plant, distribution system, or collection system.

“Onsite operator” means an operator who visits a facility at least daily to ensure that it is operating properly.

“Onsite representative” means a person located at a facility who monitors the daily operation at the facility and maintains contact with the remote operator regarding the facility.

“Operator” has the same meaning as certified operator, defined in this Section.

“PDH” means professional development hour.

“Professional development hour” means one hour of participation in an organized educational activity related to engineering, biological or chemical sciences, a closely related technical or scientific discipline, or operations management.

“Remote operator” means an operator who is not an onsite operator.

Various Definitions *Know these terms.*

“Action level” means a concentration of 0.015 mg/L for lead or 1.3 mg/L for copper.

“Air-gap separation” means a physical separation, between the discharge end of a supply pipe and the top rim of its receiving vessel, of at least one inch or twice the diameter of the supply pipe, whichever is greater.

“Backflow” means a reverse flow condition that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system. Backflow can be created by a difference in water pressure (backpressure), a vacuum or partial vacuum (backsiphonage), or a combination of both.

“Backflow-prevention assembly” means a mechanical device used to prevent backflow.

“BAT” means best available technology.

“Coagulation” means a treatment process that uses coagulant chemicals and mixing to destabilize and agglomerate colloidal and suspended materials into flocs.

“Community water system” means a public water system that serves 15 or more service connections used by year-round residents or that serves 25 or more year-round residents.

“Compliance cycle” means a nine-calendar-year time-frame during which a public water system is required to monitor.

“Compliance period” means a three-calendar-year time-frame within a compliance cycle.

“Conventional filtration” means a series of treatment processes, including coagulation, flocculation, sedimentation, and filtration that result in substantial particulate removal.

“Cross connection” means a physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow.

“CWS” means community water system.

“Detected” means measured in a laboratory at a concentration that is at or above the method detection limit.

“Direct filtration” means a series of treatment processes, including coagulation and filtration but excluding sedimentation, that result in substantial particulate removal.

“Disinfectant” means an oxidant, including chlorine, chlorine dioxide, chloramines, ozone, or an equivalent agent or process such as ultraviolet light, that kills or inactivates pathogenic organisms.

“Double check valve assembly” means a backflow-prevention assembly that contains two independently acting check valves with tightly closing, resilient-seated shut-off valves on each end of the assembly and properly located, resilient-seated test cocks.

“Elementary business plan” means a document containing all items, required to be submitted for evaluation, necessary for a complete review for technical, managerial, and financial capacity of a new public water system.

“Filtration” means a treatment process for removing particulate matter from water by passage through porous media.

“Financial capacity” means the ability of a public water system to acquire and manage sufficient financial resources for the system to achieve and maintain compliance with the federal Safe Drinking Water Act.

“Flocculation” means a treatment process to enhance agglomeration or collection of smaller floc particles into larger and more easily settleable particles through gentle stirring by hydraulic or mechanical means.

“GAC” means granular activated carbon.

“HPC” means heterotrophic plate count.

“Initial monitoring year” means the calendar year designated by the Department within a compliance period in which a public water system conducts initial monitoring at a sampling point.

“Large water system,” means a public water system that serves more than 50,000 persons.

“Managerial capacity” means the ability of a public water system to conduct its affairs in a manner that will meet and maintain compliance with the requirements of the federal Safe Drinking Water Act.

“Maximum contaminant level” means the maximum permissible level for a contaminant in drinking water that is delivered to any person who is served by a public water system.

“Medium water system,” means a public water system that serves more than 3,300 persons and 50,000 or fewer persons.

“Nephelometric turbidity unit” means the unit of measure for turbidity. Turbidity is a measure of light scatter or absorption caused by suspended or colloidal matter in water. Turbidity is measured as an indicator of the effectiveness of filtration treatment.

“NTNCWS” means nontransient, noncommunity water system.

“NTU” means nephelometric turbidity unit.

“Sanitary survey” means an onsite review of the water source, facilities, equipment, operation, and maintenance of a public water system to evaluate their adequacy to produce and distribute safe drinking water.

“Sedimentation” means a treatment process that holds water in a low-flow condition before filtration to remove solids by gravity or separation.

“Slow sand filtration” means a treatment process that involves the passage of raw water through a bed of sand at low velocity, generally less than 0.4 m/h, and results in substantial particulate removal by physical and biological mechanisms.

“Small water system,” means a public water system that serves 3,300 or fewer persons.

“SOC” means synthetic organic chemical.

“TNCWS” means transient, noncommunity water system.

“TOC” means total organic carbon. “Total organic carbon” means total organic carbon in mg/L measured using heat, oxygen, ultraviolet irradiation, chemical oxidants, or combinations of these oxidants that convert organic carbon to carbon dioxide, rounded to two significant figures.

“Total trihalomethanes” means the sum of the concentrations of the following trihalomethane compounds: trichloromethane (chloroform), dibromochloromethane, bromo-dichloromethane, and tribromomethane (bromoform).

“Transient, noncommunity water system” means a public water system that: Serves 15 or more service connections, but does not serve 15 or more service connections that are used by the same persons for more than six months per year; or serves an average of at least 25 persons per day for at least 60 days per year, but does not serve the same 25 persons for more than six months per year.

“Trihalomethane” means one of the families of organic compounds, named as derivatives of methane, in which three of four hydrogen atoms in methane are substituted by a halogen atom in the molecular structure.

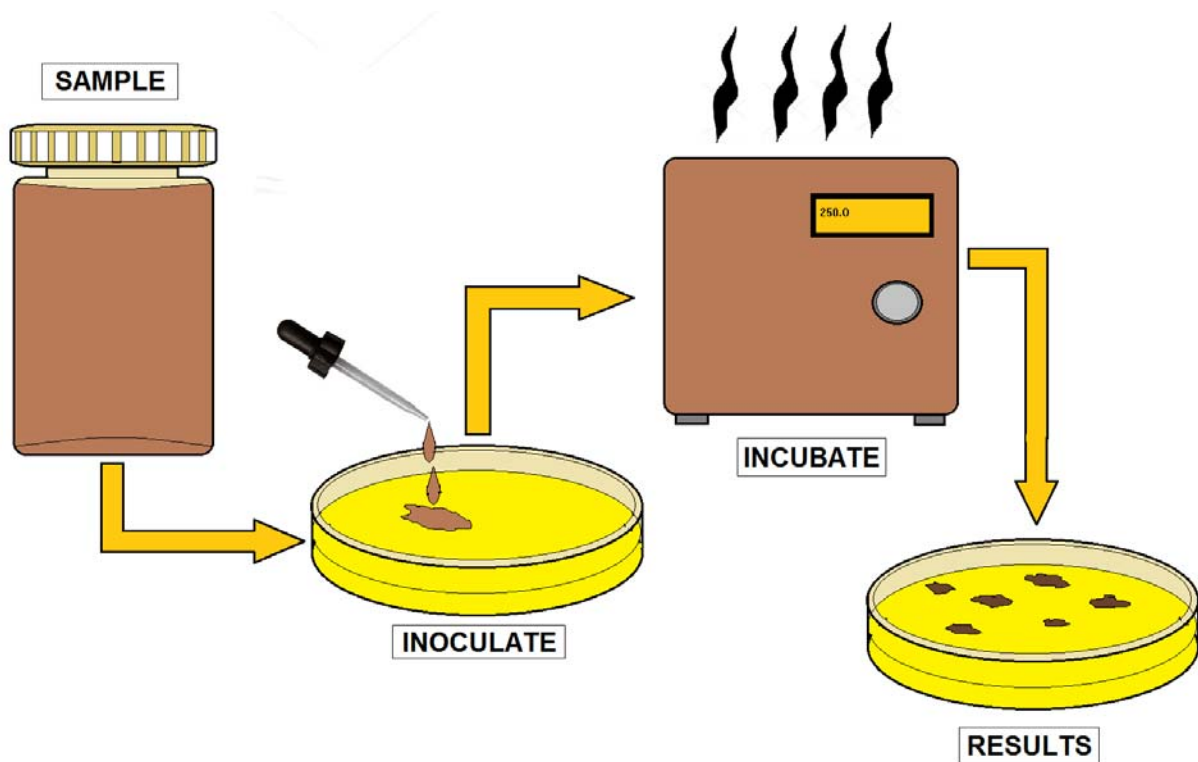
“VOC” means volatile organic chemical.

“Water treatment plant” means a process, device, or structure used to improve the physical, chemical, or biological quality of the water in a public water system.

CL₂ Gas Safety: Gas leak is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite.

CL₂ Gas will Accumulate: If a CL₂ leak occurs, the CL₂ gas will accumulate on the floor.

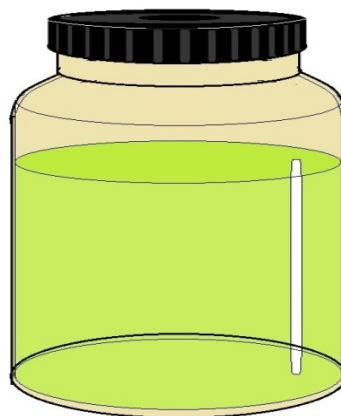
CL₂ Gaskets: Replace according to manufacturer’s recommendations should be done with the gaskets when making a new connection on a chlorine feed system.



CULTURING MICROBAL SAMPLES



COLIFORM POSITIVE
SAMPLE



COLIFORM NEGATIVE
SAMPLE

COLIFORM BACTERIA COLOR TESTING

Bacteriological Monitoring

Most waterborne disease and illnesses have been related to the microbiological quality of drinking water. The routine microbiological analysis of your water is for coliform bacteria. The coliform bacteria group is used as an indicator organism to determine the biological quality of your water.

*The presence of an indicator or pathogenic bacteria in your drinking water is an important health concern. Indicator bacteria signal possible fecal contamination and therefore, the potential presence of pathogens. They are used to monitor for pathogens because of the difficulties in determining the presence of specific disease-causing microorganisms.

Indicator bacteria are usually harmless, occur in high densities in their natural environment and are easily cultured in relatively simple bacteriological media. Indicators in common use today for routine monitoring of drinking water include total coliforms, fecal coliforms and *Escherichia coli* (*E. coli*).

Bacteria Sampling

Water samples for bacteria tests must always be collected in a sterile container. Take the sample from an inside faucet with the aerator removed. Sterilize by spraying a 5% household bleach or alcohol solution or flaming the end of the tap with a propane torch.

Run the water for five minutes to clear the water lines and bring in fresh water. Do not touch or contaminate the inside of the bottle or cap. Carefully open the sample container and hold the outside of the cap. Fill the container and replace the top.

Refrigerate the sample and transport it to the testing laboratory within six hours (in an ice chest). Many labs will not accept bacteria samples on Friday so check the lab's schedule. Mailing bacteria samples is not recommended because laboratory analysis results are not as reliable.

*Iron bacteria forms an obvious slime on the inside of pipes and fixtures. A water test is not needed for identification. Check for a reddish-brown slime inside a toilet tank or where water stands for several days.



Standard Sample Coliform Bacteria Bac-T.

***Bac-T Sample Bottle**, often referred to as a Standard Sample, 100 mls, Notice the white powder inside the bottle. That is **Sodium Thiosulfate**, a de-chlorination agent. Be careful not to wash-out this chemical while sampling. Notice the custody seal on the bottle.

***Coliform bacteria** are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can cause disease.

Laboratory Procedures

The laboratory may perform the total coliform analysis in one of four methods approved by the U.S. EPA and your local environmental or health division:

Methods

The MMO-MUG test, a product marketed as Colilert, is the most common. The sample results will be reported by the laboratories as simply coliforms present or absent. If coliforms are present, the laboratory will analyze the sample further to determine if these are fecal coliforms or E. coli and report their presence or absence.

Types of Water Samples

It is important to properly identify the type of sample you are collecting. Please indicate in the space provided on the laboratory form the type of sample.

The three (3) types of samples are:

1. **Routine:** Samples collected on a routine basis to monitor for contamination. Collection should be in accordance with an approved sampling plan.
2. **Repeat:** Samples collected following a '**coliform present**' routine sample. The number of repeat samples to be collected is based on the number of routine samples you normally collect.
3. **Special:** Samples collected for other reasons.

Examples would be a sample collected after repairs to the system and before it is placed back into operation or a sample collected at a wellhead prior to a disinfection injection point.

Routine Coliform Sampling

Noncommunity and nontransient noncommunity public water systems will sample at the same frequency as a like sized community public water system if: 1. It has more than 1,000 daily population and has ground water as a source, or 2. It serves 25 or more daily population and utilizes surface water as a source or ground water under the direct influence of surface water as its source.

Noncommunity and nontransient, noncommunity water systems with less than 1,000 daily population and groundwater as a source will sample on a quarterly basis.



Granular Activated Carbon / Powdered Activated Carbon

*Along with aeration, granular activated carbon (**GAC**) and powdered activated carbon (**PAC**) are suitable treatments for removal of organic contaminants such as VOCs, solvents, PCBs, herbicides and pesticides.

*Activated carbon is carbon that has been exposed to very high temperature, creating a vast network of pores with a very large internal surface area; one gram of activated carbon has a surface area equivalent to that of a football field. It removes contaminants through adsorption, a process in which dissolved contaminants adhere to the surface of the carbon particles.

*GAC can be used as a replacement for existing media (such as sand) in a conventional filter or it can be used in a separate contactor such as a vertical steel pressure vessel used to hold the activated carbon bed.

After a period of a few months or years, depending on the concentration of the contaminants, the surface of the pores in the GAC can no longer adsorb contaminants and the carbon must be replaced. Several operational and maintenance factors affect the performance of granular activated carbon. Contaminants in the water can occupy adsorption sites, whether or not they are targeted for removal. Also, adsorbed contaminants can be replaced by other contaminants with which GAC has a greater affinity, so their presence might interfere with removal of contaminants of concern.

A significant drop in the contaminant level in influent water can cause a GAC filter to desorb, or slough off adsorbed contaminants, because GAC is essentially an equilibrium process. As a result, raw water with frequently changing contaminant levels can result in treated water of unpredictable quality. Bacterial growth on the carbon is another potential problem. Excessive bacterial growth may cause clogging and higher bacterial counts in the treated water. The disinfection process must be carefully monitored in order to avoid this problem.

*Powdered activated carbon consists of finely ground particles and exhibits the same adsorptive properties as the granular form. PAC is normally applied to the water in a slurry and then filtered out. The addition of PAC can improve the organic removal effectiveness of conventional treatment processes and also remove tastes and odors.

*Advantages of PAC are that it can be used on a short-term or emergency basis with conventional treatment, creates no headloss, does not encourage microbial growth, and has relatively small capital costs. The main disadvantage is that some contaminants require large doses of PAC for removal. It is also somewhat ineffective in removing natural organic matter due to the competition from other contaminants for surface adsorption and the limited contact time between the water and the carbon.

Corrosion Control

Corrosion is the deterioration of a substance by chemical action. Lead, cadmium, zinc, copper and iron might be found in water when metals in water distribution systems corrode. Drinking water contaminated with certain metals (such as lead and cadmium) can harm human health. Corrosion also reduces the useful life of water distribution systems and can promote the growth of microorganisms, resulting in disagreeable tastes, odors, slimes, and further corrosion. Because it is widespread and highly toxic, lead is the corrosion product of greatest concern.

The EPA has banned the use of lead solders, fluxes, and pipes in the installation or repair of any public water system. In the past, solder used in plumbing has been 50% tin and 50% lead. Using lead-free solders, such as silver-tin and antimony-tin is a key factor in lead corrosion control. The highest level of lead in consumers' tap water will be found in water that has been standing in the pipes after periods of nonuse (overnight or longer). This is because standing water tends to leach lead or copper out of the metals in the distribution system more readily than does moving water.

Therefore, the simplest short-term or immediate measure that can be taken to reduce exposure to lead in drinking water is to let the water run for two to three minutes before each use. Also, drinking water should not be taken from the hot water tap, as hot water tends to leach lead more readily than cold. Long-term measures for addressing lead and other corrosion by-products include pH and alkalinity adjustment; corrosion inhibitors; coatings and linings; and cathodic protection, all discussed later.

Cathodic Protection

Cathodic protection protects steel from corrosion, which is the natural electrochemical process that results in the deterioration of a material because of its reaction with its environment.

Metallic structures, components, and equipment exposed to aqueous environments, soil or seawater can be subject to corrosive attack and accelerated deterioration. Therefore, it is often necessary to utilize either impressed current or sacrificial anode cathodic protection (**CP**) in combination with coatings as a means of suppressing the natural degradation phenomenon to provide a long and useful service life. However, if proper considerations are not given, problems can arise which can produce unexpected, premature failure.

Corrosion Inhibitors

Inhibitors reduce corrosion by forming protective coatings on pipes. The most common corrosion inhibitors are inorganic phosphates, sodium silicates, and mixtures of phosphates and silicates. These chemicals have proven successful in reducing corrosion in many water systems.

The phosphates used as corrosion inhibitors include polyphosphates, orthophosphates, glassy phosphates, and bimetallic phosphates. In some cases, zinc is added in conjunction with orthophosphates or polyphosphates.

*Glassy phosphates, such as sodium hexametaphosphate, effectively reduce iron corrosion at dosages of 20 to 40 mg/l.

*Glassy phosphate has an appearance of broken glass and can cut the operator. Sodium silicates have been used for over 50 years to inhibit corrosion. The effectiveness depends on the water pH and carbonate concentration.

Sodium silicates are particularly effective for systems with high water velocities, low hardness, low alkalinity and a pH of less than 8.4. Typical coating maintenance doses range from 2 to 12 mg/l.

They offer advantages in hot water systems because of their chemical stability. For this reason, they are often used in boilers of steam heating systems.



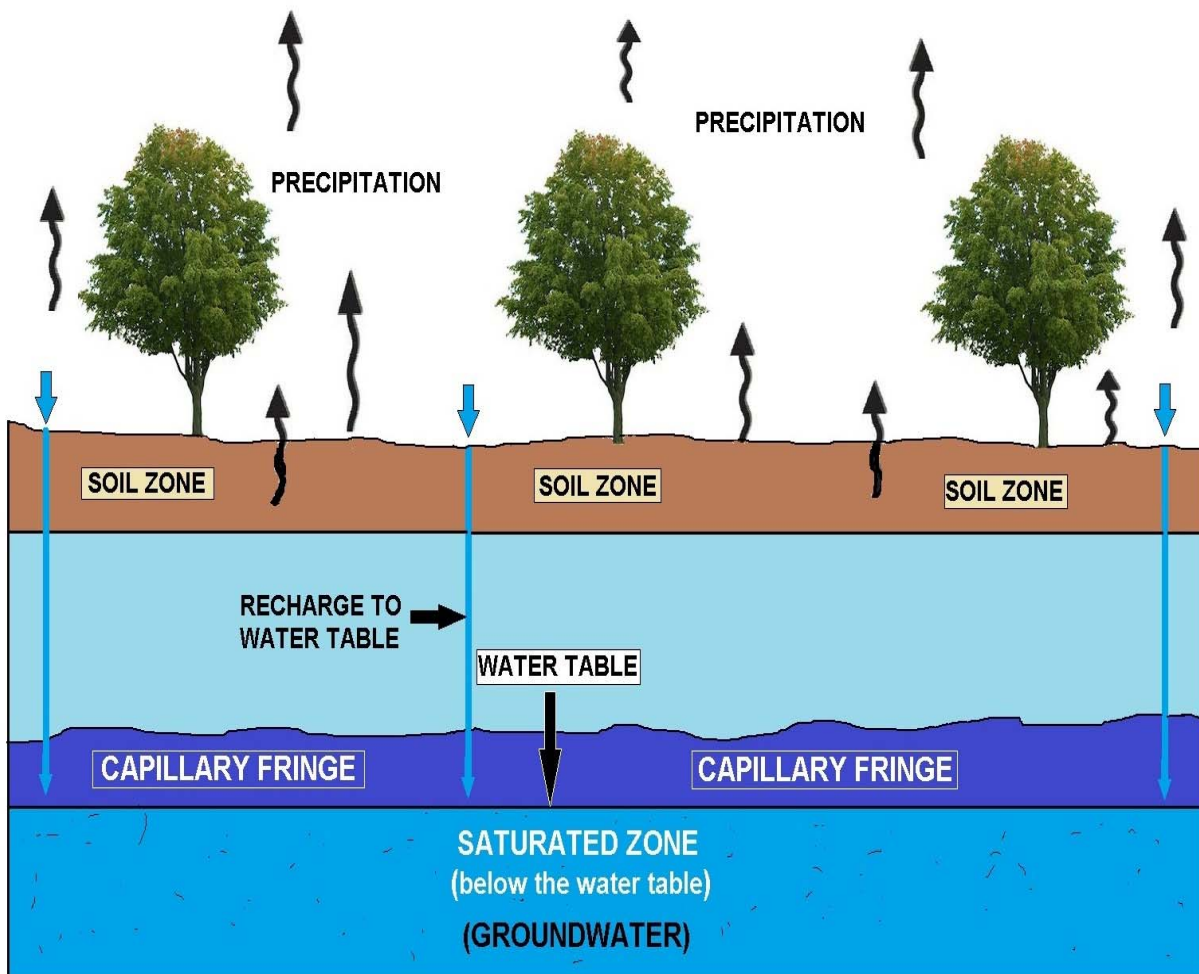
Groundwater and Well Section Chapter 3

A well can be easily contaminated if it is not properly constructed or if toxic materials are released into the well. Toxic material spilled or dumped near a well can leach into the aquifer and contaminate the groundwater drawn from that well.

Contaminated wells used for drinking water are especially dangerous. Wells can be tested to see what chemicals may be in the well and if they are present in dangerous quantities.

Groundwater is withdrawn from wells to provide water for everything from drinking water for the home and business to water to irrigate crops to industrial processing water. When water is pumped from the ground, the dynamics of groundwater flow change in response to this withdrawal.

Groundwater flows slowly through water-bearing formations (***aquifers; know for the exam**) at different rates. In some places, where groundwater has dissolved limestone to form caverns and large openings, its rate of flow can be relatively fast, but this is exceptional.



CAPILLARY FRINGE

(Material above water table that may contain water by capillary pressure in small voids)

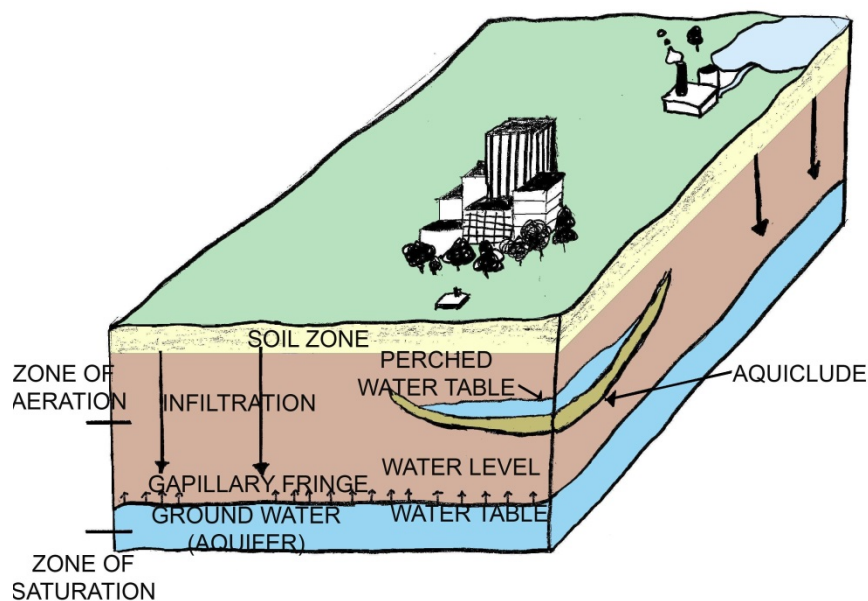
Groundwater Resource Terms

Many terms are used to describe the nature and extent of the groundwater resource. The level below which all the spaces are filled with water is called the **water table**. Above the water table lies the **unsaturated zone**. Here the spaces in the rock and soil contain both air and water. Water in this zone is called **soil moisture**. The entire region below the water table is called the **saturated zone** and water in this saturated zone is called **groundwater**.

Fractured aquifers are rocks in which the groundwater moves through cracks, joints or fractures in otherwise solid rock. Examples of fractured aquifers include granite and basalt. Limestones are often fractured aquifers, but here the cracks and fractures may be enlarged by solution, forming large channels or even caverns.

Limestone terrain where solution has been very active is termed **karst**. Porous media such as sandstone may become so highly cemented or recrystallized that all of the original space is filled. In this case, the rock is no longer a porous medium. However, if it contains cracks it can still act as a fractured aquifer.

Most of the aquifers of importance to us are unconsolidated porous media such as sand and gravel. Some very porous materials are not permeable. Clay, for instance, has many spaces between its grains, but the spaces are not large enough to permit free movement of water.



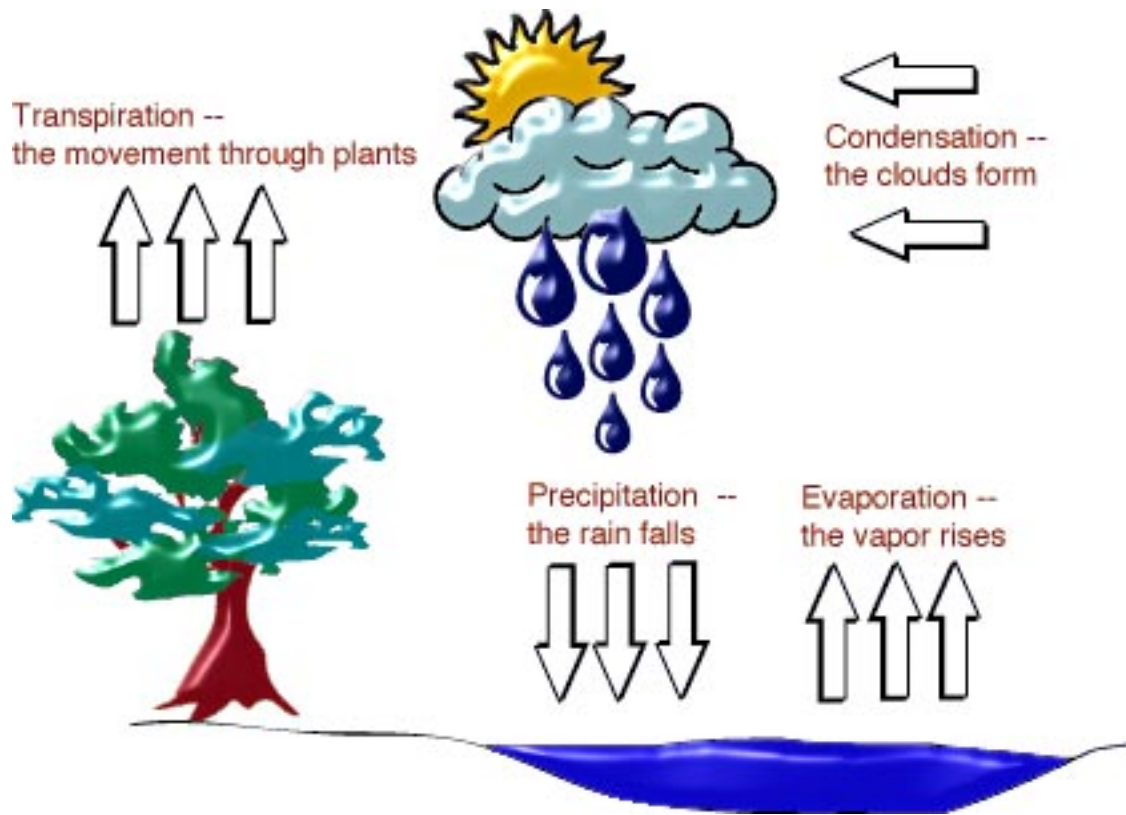
Groundwater usually flows downhill with the slope of the water table. Like surface water, groundwater flows toward, and eventually drains into streams, rivers, lakes and the oceans. Groundwater flow in the aquifers underlying surface drainage basins, however, does not always mirror the flow of water on the surface. Therefore, groundwater may move in different directions below the ground than the water flowing on the surface.

Unconfined aquifers are those that are bounded by the water table. Some aquifers, however, lie beneath layers of impermeable materials. These are called **confined aquifers**, or sometimes **artesian aquifers**.

A well in such an aquifer is called an **artesian well**. The water in these wells rises higher than the top of the aquifer because of confining pressure. If the water level rises above the ground surface a **flowing artesian well** occurs. The ***piezometric surface** is the level to which the water in an artesian aquifer will rise.

Water Sources

Before we discuss the types of treatment it is easier to first understand how the source of water arrives.



Water Cycle Terms

1. ***Precipitation:** The process by which atmospheric moisture falls onto the land or water surface as rain, snow, hail or other forms of moisture.
2. ***Infiltration:** The gradual flow or movement of water into and through the pores of the soil.
3. ***Evaporation:** The process by which the water or other liquids become a gas.
4. ***Condensation:** The collection of the evaporated water in the atmosphere.
5. ***Runoff:** Water that drains from a saturated or impermeable surface into stream channels or other surface water areas. Most lakes and rivers are formed this way.
6. ***Transpiration:** Moisture that will come from plants as a byproduct of photosynthesis.

Once the precipitation begins, water is no longer in its purest form. Water will be collected as surface supplies or circulate to form in the ground. As it becomes rain or snow it may be polluted with organisms, organic compounds, and inorganic compounds.

Because of this, we must treat the water for human consumption.

Water Rights

***Appropriative:** Acquired water rights for exclusive use.

***Prescriptive:** Rights based upon legal prescription or long use or custom.

***Riparian:** Water rights because property is adjacent to a river or surface water.

Quality of Water Know these to pass your exam *

If you classified the way water characteristics change as it passes on the surface and below the ground it would be in four categories:

***Physical** characteristics such as taste, odor, temperature, and turbidity. This is how the consumer judges how well the provider is treating the water.

***Chemical** characteristics are the elements found that are considered alkali, metals, and non-metals such as fluoride, sulfides or acids. The consumer relates it to scaling of faucets or staining.

***Biological** characteristics are the presence of living or dead organisms. This will also interact with the chemical composition of the water. The consumer will become sick or complain about hydrogen sulfide odors, the rotten egg smell.

***Radiological** characteristics are the result of water coming in contact with radioactive materials. This could be associated with atomic energy.

Surface Water

Some of the water will be immediately impounded in lakes and reservoirs, and some will collect as runoff to form streams and rivers that will then flow into the ocean. Water is known as the universal solvent because most substances that come in contact with it will dissolve. What's the difference between lakes and reservoirs? Reservoirs are lakes with man-made dams.

Surface water is usually contaminated and unsafe to drink. Depending on the region, some lakes and rivers receive discharge from sewer facilities or defective septic tanks. Runoff could produce mud, leaves, decayed vegetation, and human and animal refuse. The discharge from industry could increase volatile organic compounds. Some lakes and reservoirs may experience seasonal turnover. Changes in the dissolved oxygen, algae, temperature, suspended solids, turbidity, and carbon dioxide will change because of biological activities.

Another aspect of quality control is aquatic plants. The ecological balance in lakes and reservoirs plays a natural part in the purification of and sustaining the life of the lake. For example, algae and rooted aquatic plants are essential in the food chain of fish and birds. Algae growth is the result of photosynthesis.

Algae growth is supplied by the energy of the sun. As algae absorb this energy it converts carbon dioxide to oxygen. This creates **aerobic** conditions that supply fish with oxygen. Without sun light, the algae would consume oxygen and release carbon dioxide. The lack of dissolved oxygen in water is known as **anaerobic** conditions. Certain vegetation removes the excess nutrients that would promote the growth of algae. Too much algae will imbalance the lake and this will result in fish kill.

*Groundwater Review Statements

Runoff: Surface water sources such as a river or lake are primarily the result of which of the following natural processes?

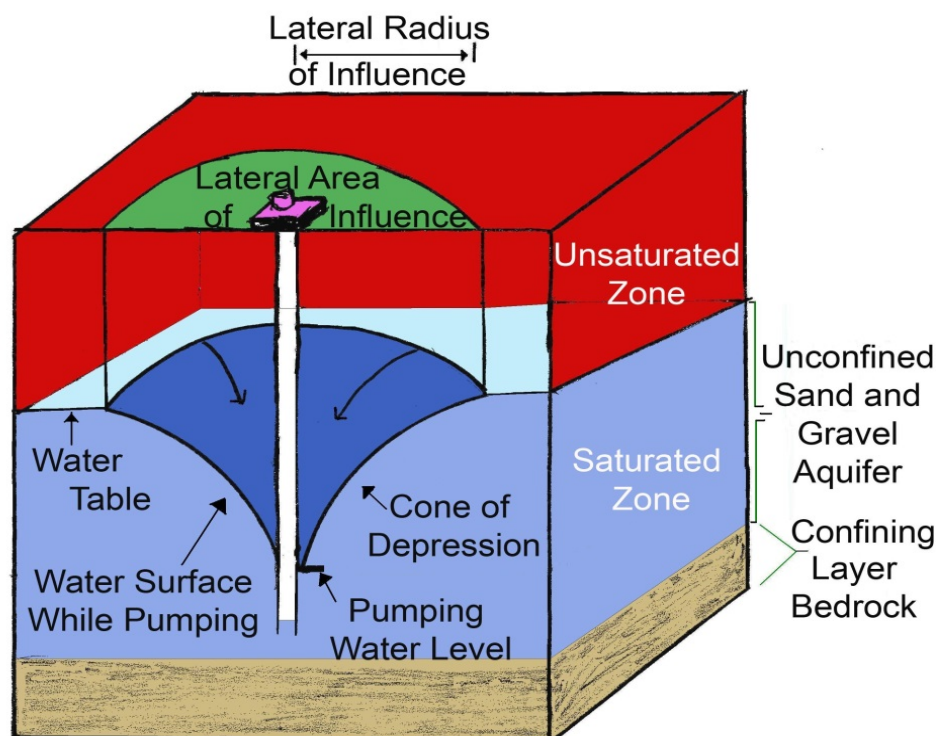
Safe yield: What is a possible consequence when the “*safe yield*” of a well is exceeded and water continues to be pumped from a well? Land subsidence around the well will occur.

Pressure Head: The measure of the pressure of water expressed in feet of height of water. 1 psi = 2.31 feet of water. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

Cone of Depression

When pumping begins, water begins to flow towards the well in contrast to the natural direction of groundwater movement. The water level in the well falls below the water table in the surrounding aquifer.

As a result, water begins to move from the aquifer into the well. As pumping continues, the water level in the well continues to increase until the rate of flow into the well equals the rate of withdrawal from pumping. The movement of water from an aquifer into a well results in the formation of a cone of depression. The cone of depression describes a three-dimensional inverted cone surrounding the well that represents the volume of water removed as a result of pumping. Drawdown is the vertical drop in the height between the water level in the well prior to pumping and the water level in the well during pumping.



When a well is installed in an unconfined aquifer, water moves from the aquifer into the well through small holes or slits in the well casing or, in some types of wells, through the open bottom of the well. The level of the water in the well is the same as the water level in the aquifer. Groundwater continues to flow through and around the well in one direction in response to gravity.

Water Use or Demand

Water system demand comes from a number of sources including residential, commercial, industrial, and public consumers, as well as some unavoidable loss and waste. If fire protection is desired, that could also represent a rather significant (although not continuous) demand upon the system. The combination of storage reservoirs and distribution lines must be capable of meeting consumers' needs for quality, quantity and pressure at all times.

The quantity of water used in any community varies from 50 to 500 gallons per person per day. A common design assumption is to use from 100 to 150 gallons per person per day for average domestic use. The maximum daily use is approximately 2 to 3 times the average daily use. Maximum daily use is usually encountered during the summer months and can vary widely depending on irrigation practices.

***Water Pressure**

For ordinary domestic use, water pressure should be between *25 and 45 psi. 35 psi is desirable. A minimum of 60 psi at a fire hydrant is usually adequate, since that allows for up to 20 psi pressure drop in fire hoses. In commercial and industrial districts, it may be common to have 75 psi or higher. 20 psi is considered the minimum required at any point in the water system, so that backflow and infiltration is prevented. Pressure is provided by the direct force of the water (such as water from a pump), or by the height of the water (such as a storage reservoir). *2.31 feet of water is equal to 1 psi, or 1 foot of water is equal to about a half a pound (.433 pounds to be exact).

Storage and Distribution

The cost of supplying water to the users of any water system includes the installation of storage and distribution facilities. Also, there are on-going maintenance costs associated with cleaning, repairing, and replacing these facilities. The distribution system must also protect water quality between the source and the customer's tap. Proper construction is important in maintaining system integrity. Care must be taken that no foreign material is introduced into the system during pipe laying operations. Pipe ends should be covered at the end of the work day or during interruptions of construction.

All pipes, joints, and fittings should be pressure tested and disinfected with a 5% chlorine solution such as household bleach before backfilling. It is also important that all materials in contact with potable water meet the requirements of the National Sanitation Foundation (**NSF**) or American Water Works Association (**AWWA**) or have equivalent third-party certification. This includes solders (must be lead-free), pipes, joining and sealing materials, and protective coatings.

Water Storage Facilities

*Water storage facilities and tanks vary in size, shape, and application. There are different types that are used in the water distribution systems, such as stand pipes, elevated tanks and reservoirs, hydropneumatic tanks and surge tanks.

Surge Tanks

What really causes water main breaks - **ENERGY** - when released in a confined space, such as a water distribution system. Shock waves are created when hydrants, valves, or pumps are opened and closed quickly, trapping the kinetic energy of moving water within the confined space of a piping system.

These shock waves can create a turbulence that travels at the speed of sound, seeking a point of release. The release the surge usually finds is an elevated tank, but the surge doesn't always find this release quickly enough. Something has to give, and oftentimes, it's your pipe fittings. Distribution operators are aware of this phenomenon! It's called **WATER HAMMER**.

Storage Reservoirs

Storage reservoirs allow the system to meet the fluctuations in demand described earlier. It is recommended that the volume of storage be equal to from one to three days of the system's average daily use. It is also recommended that storage reservoirs be located at a high enough elevation to allow the water to flow by gravity to the distribution system. This, coupled with restricted usage on the part of the consumers, should provide an uninterrupted water supply in the event of pump failure, loss of power or an acute contamination event or cross-connection.

Also, if applicable, some storage for fire protection should be provided. Reservoirs are also used as detention basins to provide the required chlorine contact time necessary to ensure the adequacy of disinfection. As such, the contact time in a reservoir is greatly improved when the reservoir is constructed with a separate inlet and outlet pipe, preferably located on opposite sides of the reservoir and at different levels. Also, baffles inside the reservoir (walls, curtains, or spirals) increase the contact time by preventing the water from leaving the reservoir too quickly *(known as "**short-circuiting**").

Steel Reservoirs

Steel reservoirs are usually welded or bolted together and are manufactured in a variety of sizes. Small steel reservoirs can be manufactured off-site and then trucked and lifted into place. Steel tanks should be inspected once a year and repainted every *5-7 years. Steel tanks should also have cathodic protection and be screened to keep birds and insects out. The maintenance program for reservoir tanks should call for annual draining for a complete inspection of the interior. Cleaning and disinfection prior to placing the reservoir or tank back in service is necessary.

Disinfection by chlorine can be accomplished by one of three methods.

1. Fill the tank or reservoir with a 25 mg/1 chlorine solution and leave it for 24 hours.
- *2. Fill the reservoir with a 50 mg/1 chlorine solution and leave it for 3 hours.
- *3. Spray or brush on a 200 mg/1 chlorine solution and allow it to remain for 3 hours.

The chlorinated water shall be disposed of in a manner that will not have an adverse effect on the environment. Check with your state environmental, health or drinking water section.

Hydropneumatic Tank Section

Hydropneumatic Tanks Out of Service for Maintenance

Effects on the Water Supply

*Whenever a tank must be taken out of service for maintenance, the operator should insure that the water pressure is maintained by other back-up tanks in the system. If this is not possible, customers should be given as much advance notice as possible, maintenance should be conducted during periods of low water demand, and the maintenance should be conducted as quickly as possible to reduce the time without water service.

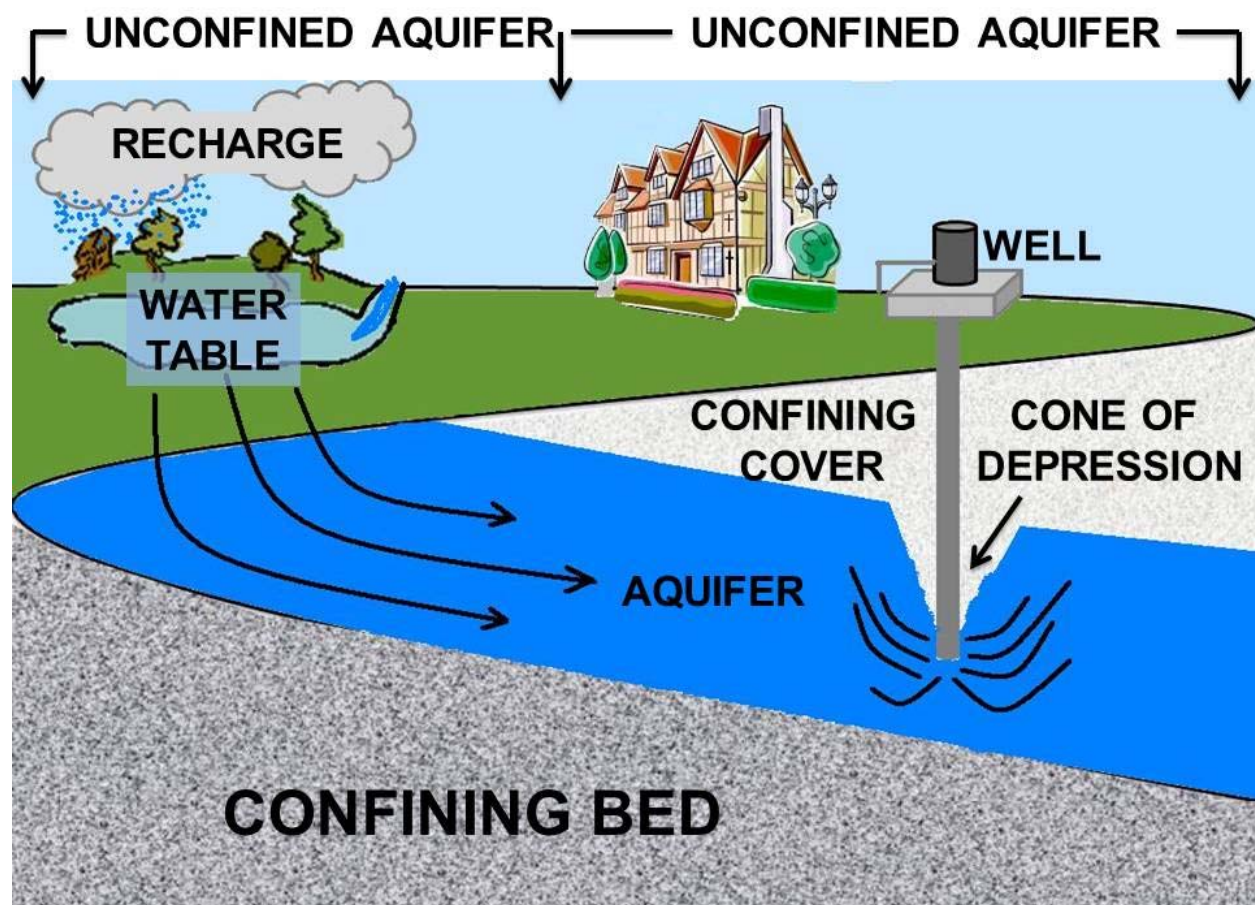
*Groundwater Statements

Runoff: Surface water sources such as a river or lake are primarily the result of which natural processes?

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Water Treatment Section Chapter 4

For thousands of years, people have treated water intended for drinking to remove particles of solid matter, reduce health risks, and improve aesthetic qualities such as appearance, odor, color, and taste. As early as 2000 B.C., medical lore of India advised, “***Impure water should be purified by being boiled over a fire, or being heated in the sun or by dipping a heated iron into it, or it may be purified by filtration through sand and coarse gravel and then allowed to cool.***”

The treatment needs of a water system are likely to differ depending on whether the system uses a groundwater or surface water source. Common surface water contaminants include turbidity, microbiological contaminants (**Giardia, viruses and bacteria**) and low levels of a large number of organic chemicals. Groundwater contaminants include naturally occurring inorganic chemicals (such as arsenic, fluoride, radium, radon and nitrate) and a number of volatile organic chemicals ***(VOCs)** that have recently been detected in localized areas.

When selecting among the different treatment options, the water supplier must consider a number of factors. These include regulatory requirements, characteristics of the raw water, configuration of the existing system, cost, operating requirements and future needs of the service area.

Preliminary Treatment

Most lakes and reservoirs are not free of logs, tree limbs, sticks, gravel, sand and rocks, weeds, leaves, and trash. If not removed, these will cause problems to the treatment plant's pumps and equipment. The best way to protect the plant is screening.

Bar screens are made of straight steel bars at the intake of the plant. Depending on the spacing of the horizontal bars will rank the size. Wire mesh screens are woven stainless steel material and the opening of the fabric is narrow. Both require manual cleaning.

Mechanical bar screens vary in size and use some type of raking mechanism that travels horizontally down the bars to scrap the debris off. The type of screening used depends on the raw water and the size of the intake.



Mechanical bar screen



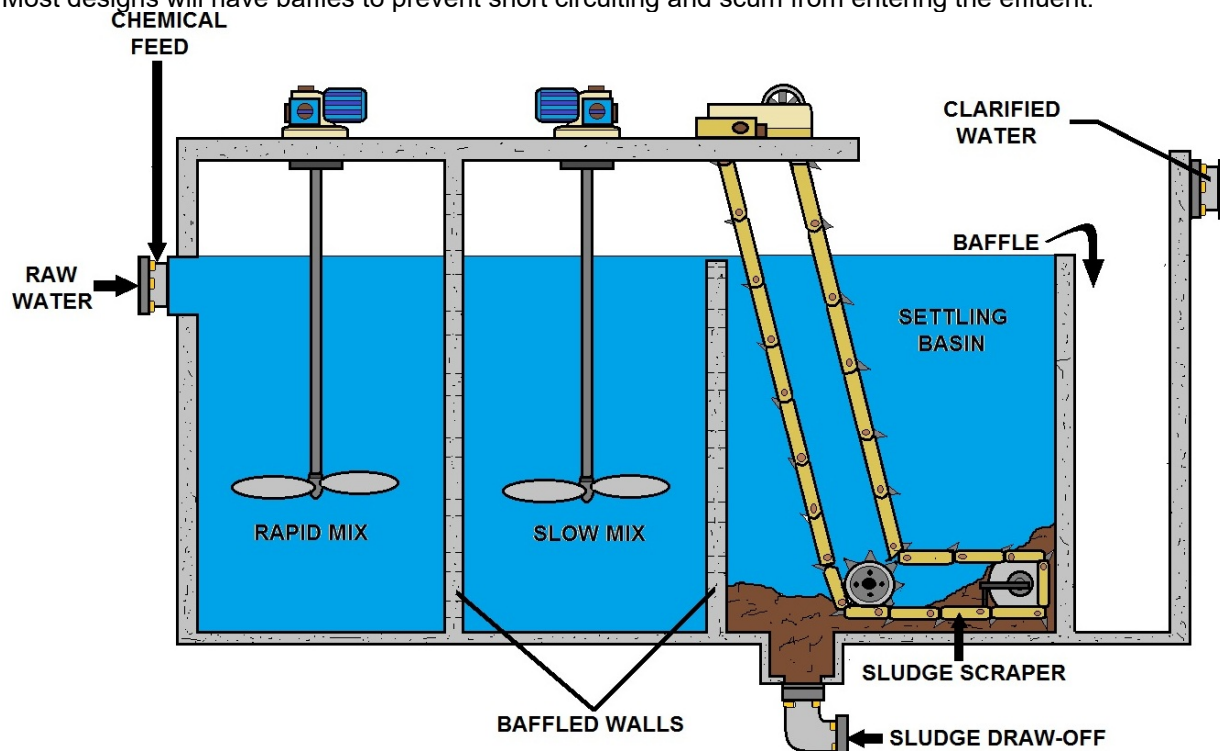
Non-automated bar screen

Pre-Sedimentation

Once the water passes the bar screens, sand and grit are still present. This will damage plant equipment and pipes, so it must be removed. This is generally done with either rectangular- or round-shaped Clarifiers. Sedimentation basins are also used after the flocculation process.



Let's first look at the components of a rectangular Clarifier. Most are designed with scrapers on the bottom to move the settled sludge to one or more hoppers at the influent end of the tank. It could have a screw conveyor or traveling bridge used to collect the sludge. The most common is a chain and flight collector. Most designs will have baffles to prevent short circuiting and scum from entering the effluent.



HORIZONTAL BASIN CLARIFIER

Flights and Chains

The most important thing to consider is the sludge and scum collection mechanism known as the “*flights and chains*”. They move the settled sludge to the hopper in the Clarifier for return and they also remove the scum from the surface of the Clarifier. The flights are usually wood or nonmetallic flights mounted on parallel chains. The motor shaft is connected through a gear reducer to a shaft which turns the drive chain. The drive chain turns the drive sprockets and the head shafts. The shafts can be located overhead or below. Some Clarifiers may not have scum removal equipment, so the configuration of the shaft may vary. As the flights travel across the bottom of the Clarifier, *wearing shoes* are used to protect the flights. The shoes are usually metal and travel across a metal track.



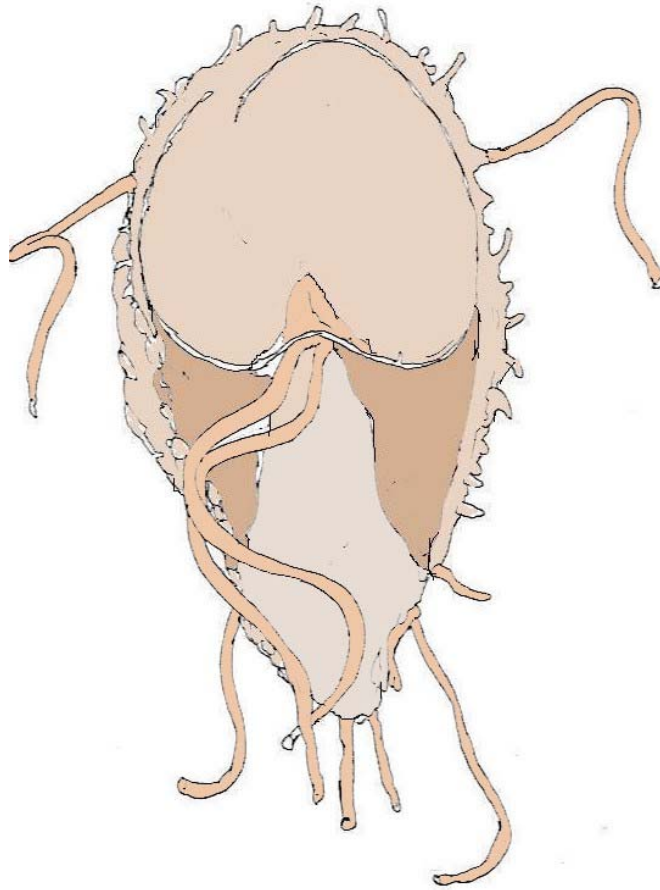
To prevent damage due to overloads, a shear pin is used. The shear pin holds the gear solidly on the shaft so that no slippage occurs. Remember that the gear moves the drive chain. If a heavy load is put on the sludge collector system then the shear pin should break. This means that the gear would simply slide around the shaft and movement of the drive chain would stop.

The most common type has a center pier or column. The major mechanic parts of the Clarifier are the drive unit, the sludge collector mechanism, and the scum removal system.



Circular clarifier and collector mechanism.

Giardia Lambia



GIARDIA LAMBLIA

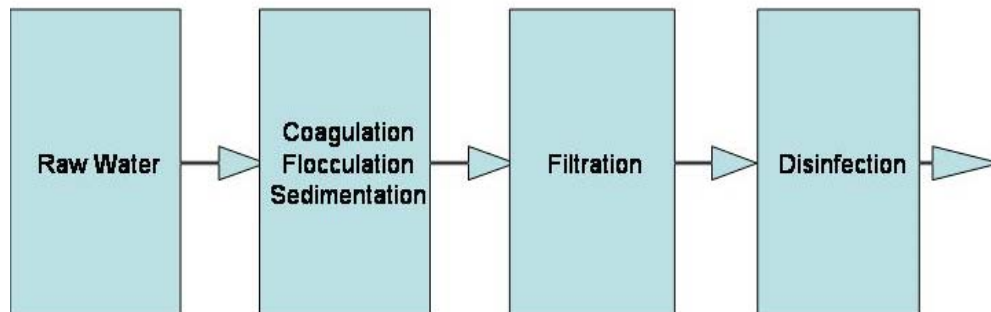
Giardia lamblia (synonymous with *Lamblia intestinalis* and *Giardia duodenalis*) is a flagellated protozoan parasite that colonizes and reproduces in the small intestine, causing giardiasis. The giardia parasite attaches to the epithelium by a ventral adhesive disc, and reproduces via binary fission. Giardiasis does not spread via the bloodstream, nor does it spread to other parts of the gastro-intestinal tract, but remains confined to the lumen of the small intestine. *Giardia* trophozoites absorb their nutrients from the lumen of the small intestine, and are anaerobes.

Giardia infection can occur through ingestion of dormant cysts in contaminated water, or by the fecal-oral route (through poor hygiene practices). The *Giardia* cyst can survive for weeks to months in cold water and therefore can be present in contaminated wells and water systems, and even clean-looking mountain streams, as well as city reservoirs, as the *Giardia* cysts are resistant to conventional water treatment methods, such as chlorination and ozonolysis.

Zoonotic transmission is also possible, and therefore *Giardia* infection is a concern for people camping in the wilderness or swimming in contaminated streams or lakes, especially the artificial lakes formed by beaver dams (hence the popular name for giardiasis, "*Beaver Fever*").

Conventional Treatment

Improving the clarity of surface water has always presented a challenge because source quality varies. Traditional treatments rely on expensive, construction-intensive processes with lengthy times.



Suspended particles carry an electrical charge which causes them to repel one another. *The conventional process uses alum (aluminum sulfate) and cationic polymer to neutralize the charge. That allows suspended particles to clump together to form more easily filtered particles.

Alum combines with alkalinity in the raw water to form a white precipitate that neutralizes suspended particles' electrical charge and forms a base for coagulating those particles. Conventional technology uses a 30 to 50 mg/L alum dosage to form a large floc that requires extensive retention time to permit settling.

Traditional filter systems use graded silica sand filter media. Since the sand grains all have about the same density, larger grains lay toward the bottom of the filter bed and finer grains lay at the top of the filter bed. As a result, filtration occurs only within the first few inches of the finer grains at the top of the bed.

A depth filter has four layers of filtration media, each of different size and density. Light, coarse material lies at the top of the filter bed. The media become progressively finer and denser in the lower layers. Larger suspended particles are removed by the upper layers while smaller particles are removed in the lower layers. Particles are trapped throughout the bed, not in just the top few inches. That allows a depth filter to run substantially longer and use less backwash water than a traditional sand filter.

As suspended particles accumulate in a filter bed, the pressure drop through the filter increases. When the pressure difference between filter inlet and outlet increases by 5 - 10 psi (34 to 68 kPa) from the beginning of the cycle, the filter should be reconditioned. Operating beyond this pressure drop increases the chance of fouling - called "mud-balling" - within the filter.

*The reconditioning cycle consists of an up flow backwash followed by a down flow rinse. *Backwash is an up flow operation, at about 14 gpm per square foot (34m/hr) of filter bed area that lasts about 10 minutes. Turbidity washes out of the filter bed as the filter media particles scour one another. The down flow rinse settles the bed before the filter returns to service. Fast rinse lasts about 5 to 10 minutes.

*Chemical pretreatment is often used to enhance filter performance, particularly when turbidity includes fine colloidal particles. Suspended particles are usually electrically charged. Feeding chemicals such as alum (aluminum sulfate), ferric chloride, or a cationic polymer neutralizes the charge, allowing the particles to Cling to one another and to the filter media.

Chemical pretreatment may increase filtered water clarity, measured in NTU, by 90% compared with filtration alone. If an operator is present to make adjustments for variations in the raw water, filtered water clarity improvements in the range of 93 to 95% are achievable.

Rapid Sand Filtration

Also known as rapid-sand filtration, this is the most prevalent form of water treatment technology in use today. This filtration process employs a combination of physical and chemical processes in order to achieve maximum effectiveness, as follows:

***Coagulation**

At the Water Treatment Plant, aluminum sulfate, commonly called alum, is added to the water in the "flash mix" to cause microscopic impurities in the water to clump together. The alum and the water are mixed rapidly by the flash mixer. The resulting larger particles will be removed by filtration.

*Coagulation is the process of joining together particles in water to help remove organic matter. When solid matter is too small to be removed by a depth filter, the fine particles must be coagulated, or "stuck together" to form larger particles which can be filtered. This is achieved through the use of coagulant chemicals.

*Coagulant chemicals are required since colloidal particles by themselves have the tendency to stay suspended in water and not settle out. This is primarily due to a negative charge on the surface of the particles. All matter has a residual surface charge to a certain degree. But since colloidal particles are so small, their charge per volume is significant. Therefore, the like charges on the particles repel each other, and they stay suspended in water.

*Coagulant chemicals such as "alum" (aluminum sulfate) work by neutralizing the negative charge, which allows the particles to come together. Other coagulants are called "cationic polymers", which can be thought of as positively charged strings that attract the particles to them, and in the process, form a larger particle. Also, new chemicals have been developed which combine the properties of alum-type coagulants and cationic polymers. Which chemical is used depends on the application, and will usually be chosen by the engineer designing the water treatment system.

*Aluminum Sulfate is the most widely used coagulant in water treatment. Coagulation is necessary to meet the current regulations for almost all potable water plants using surface water. Aluminum Sulfate is also excellent for removing nutrients such as phosphorous in wastewater treatment. Liquid Aluminum Sulfate is a 48.86% solution.

*Large microorganisms including algae and amoebic cysts are readily removed by coagulation and filtration. Bacterial removals of 99% are also achievable. More than 98% of poliovirus type 1 was removed by conventional coagulation and filtration. Several recent studies have shown that bacterial and viral agents are attached to organic and inorganic particulates. Hence, removal of these particulates by conventional coagulation and filtration is a major component of effective treatment for the removal of pathogens.

Flocculation

*The process of bringing together destabilized or coagulated particles to form larger masses which can be settled and/or filtered out of the water being treated.

*In this process, which follows the rapid mixing, the chemically treated water is sent into a basin where the suspended particles can collide, agglomerate (stick together), and form heavier particles called "floc". Gentle agitation of the water and appropriate detention times (the length of time water remains in the basin) help facilitate this process.

*The water is slowly mixed in contact chambers allowing the coagulated particles, now called "floc," to become larger and stronger. As these floc particles mix in the water, bacteria and other microorganisms are caught in the floc structure.

Pre-Sedimentation

Depending on the quality of the source water, some plants have pre-sedimentation.

- A. To allow larger particles time to settle in a reservoir or lake (sand, heavy silt) reducing solid removal loads.
- B. Provides an equalization basin which evens out fluctuations.

***Sedimentation basin zones**

- A. Inlet Zone
- B. Settling Zone
- C. Sludge Zone
- D. Outlet Zone

***Shapes for a sedimentation basin**

- A. Rectangular Basins
- B. Circular Basins
- C. Square Basins
- D. Double deck Basins

***Sedimentation**

The process of suspended solid particles settling out (going to the bottom of the vessel) in water.

Following flocculation, a sedimentation step may be used. During sedimentation, the velocity of the water is decreased so that the suspended material, including flocculated particles, can settle out by gravity. Once settled, the particles combine to form a sludge that is later removed from the bottom of the basin.

Filtration

A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.

The water flows by gravity through large filters of anthracite coal, silica sand, garnet and gravel. The floc particles are removed in these filters. The rate of filtration can be adjusted to meet water consumption needs.

Filters for suspended particle removal can also be made of graded sand, granular synthetic material, screens of various materials, and fabrics. The most widely used are rapid-sand filters in tanks. In these units, gravity holds the material in place and the flow is downwards. The filter is periodically cleaned by a reversal of flow and the discharge of back flushed water into a drain.

Cartridge filters made of fabric, paper, or plastic material are also common and are often much smaller and cheaper, as well as disposable. Filters are available in several ratings depending on the size of particles to be removed. Activated carbon filters, described earlier, will also remove turbidity, but would not be recommended for that purpose only.

With most of the larger particles settled out, the water now goes to the filtration process. At a rate of between 2 and 10 gpm per square foot, the water is filtered through an approximate 36" depth of graded sand. Anthracite coal or activated carbon may also be included in the sand to improve the filtration process, especially for the removal of organic contaminants and taste and odor problems.

The filtration process removes the following types of particles

- ❖ Silts and Clay
- ❖ Colloids
- ❖ Biological forms
- ❖ Floc

***Four Desirable Characteristics of Filter Media, Review this before the exam, at least 3 times**

- A. Good hydraulic characteristics (permeable)
- B. Does not react with substances in the water (inert and easy to clean)
- C. Hard and durable
- D. Free of impurities and insoluble in water

Evaluation of overall filtration process performance should be conducted on a routine basis, at least once per day. Poor chemical treatment can often result in either early turbidity breakthrough or rapid head loss buildup. The more uniform the media, the slower head loss buildup. *All the water treatment plants that use surface water are governed by the U.S. EPA's Surface Water Treatment Rules or **SWTR**.

Filtration Key Words, the meat of the exam.

***Accuracy:** How closely an instrument measures the true or actual value.

***Aluminum Sulfate:** The chemical name for Alum. The molecular formula of Alum is $Al_2(SO_4)_3 \cdot 14H_2O$.

***Ammonia:** Most ammonia in water is present as the ammonium ion rather than as ammonia.

***Backwashing:** Backwashing the filters more frequently can be used to increase water production if an increase in raw water turbidity and coagulation feed rate creates additional loading on the filter.

***Calcium Ion:** Divalent because it has a valence of +2.

***Calcium, Magnesium, and Iron:** The three elements that cause hardness in water.

***Capillary Fringe:** The material immediately above the water table may contain water by capillary pressure in the small void spaces.

***Carbon Dioxide Gas:** The pH will decrease and alkalinity will change as measured by the Langelier index after pumping carbon dioxide gas into water.

***Cathodic Protection:** Guards against stray current corrosion.

***Caustic:** (NaOH) also called Sodium Hydroxide, is a strong chemical used in the treatment process to neutralize acidity, increase alkalinity or raise the pH value.

***Chelation:** A chemical process used to control scale formation in which a chelating agent "captures" scale-causing ions and holds them in solution.

***Chemical Oxidation:** Used for taste and odor control because it is a strong oxidizer which eliminates many organic compounds.

***Coagulation:** Best pH range for coagulation between a pH of 5 and 7.

***Colorimetric Measurement:** A means of measuring an unknown chemical concentration in water by measuring a sample's color intensity.

***Corrosion Control:** The pH of the water is adjusted with sodium carbonate, commonly called soda ash. Soda ash is fed into the water after filtration. Corrosion control is necessary for control of lead and copper.

***Declining Rate Filters:** The flow rate will vary with head loss. Each filter operates at the same rate, but can have a variable water level. This system requires an effluent control structure (weir) to provide adequate media submergence.

***Demineralization Process:** Mineral concentration of the feed water is the most important consideration in the selection of a demineralization process. Acid feed is the most common method of scale control in a membrane demineralization treatment system.

***Depolarization:** The removal of hydrogen from a cathode.

***Detention Time:** The actual time required for a small amount of water to pass through a sedimentation basin at a given rate of flow, or the calculated time required for a small amount of liquid to pass through a tank at a given rate of flow.

***Detention Time:** The minimum detention time range recommended for flocculation is 5 – 20 minutes for direct filtration and up to 30 minutes for conventional filtration.

***Detention Time =**
$$\frac{\text{(Basin Volume, Gallons) (24 Hours/day)}}{\text{Flow, Gallons/day}}$$

***Direct Filtration Plant vs. Conventional Plant:** The only difference is that the sedimentation process or step is omitted from the Direct Filtration plant.

***Disinfection:** Chlorine is added to the water at the flash mix for pre-disinfection. The chlorine kills or inactivates harmful microorganisms. Chlorine is added again after filtration for post-disinfection.

***Dissolved Oxygen:** Can be added to zones within a lake or reservoir that would normally become anaerobic during periods of thermal stratification.

***Distillation, Reverse Osmosis and Freezing:** Processes that can be used to remove minerals from the water.

***Filter Clogging:** Inability to meet demand may occur when filters are clogging.

***Filtration Methods:** Conventional type of water treatment filtration method includes coagulation, flocculation, sedimentation, and filtration. Direct filtration method is similar to conventional, except that the sedimentation step is omitted. Slow sand filtration process does not require pretreatment, has a flow of 0.1 gallons per minute per square foot of filter surface area, and is simple to operate and maintain. Diatomaceous earth method uses a thin layer of fine siliceous material on a porous plate. This type of filtration medium is only used for water with low turbidity. Sedimentation, adsorption, and biological action are filtration processes that involves a number of interrelated removal mechanisms. Demineralization is primarily used to remove total dissolved solids from industrial wastewater, municipal water, and seawater.

***Floc Shearing:** Likely to happen to large floc particles when they reach the flocculation process.

***Flocculation Basin:** A compartmentalized basin with a reduction of speed in each compartment will give the best results.

***Flux:** The term flux describes the rate of water flow through a semipermeable membrane. The water flux decreases through a semipermeable membrane means that the mineral concentration of the water is increasing.

***Hydrofluosilicic Acid:** (H_2SiF_6) a clear, fuming corrosive liquid with a pH ranging from 1 to 1.5. Used in water treatment to fluoridate drinking water. Know the safety procedures.

***Hydrophobic:** Does not mix readily with water.

***Ion Exchange Softener:** The hardness of the source water affects the amount of water an ion exchange softener may treat before the bed requires regeneration.

***Iron and Manganese:** The presence of iron and manganese in water promote the growth of iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

***Iron Fouling:** You should look for an orange color on the resin and in backwash water.

***Jar Testing (*More information later in manual*):** Jar testing traditionally has been done on a routine basis in most water treatment plants to control the coagulant dose. Much more information, however, can be obtained with only a small modification in the conventional method of jar testing. It is the quickest and most economical way to obtain good reliable data on the many variables which affect the treatment process. These include: Determination of most effective coagulant. Determination of optimum coagulation pH for the various coagulants. Evaluation of most effective polymers. Optimum point of application of polymers in treatment train. Optimum sequence of application of coagulants, polymers, and pH adjustment chemicals. Best flocculation time.

***Langelier Index:** A measurement of corrosivity. The water is becoming corrosive in the distribution system causing rusty water if the Langelier index indicates that the pH has decreased from the equilibrium point.

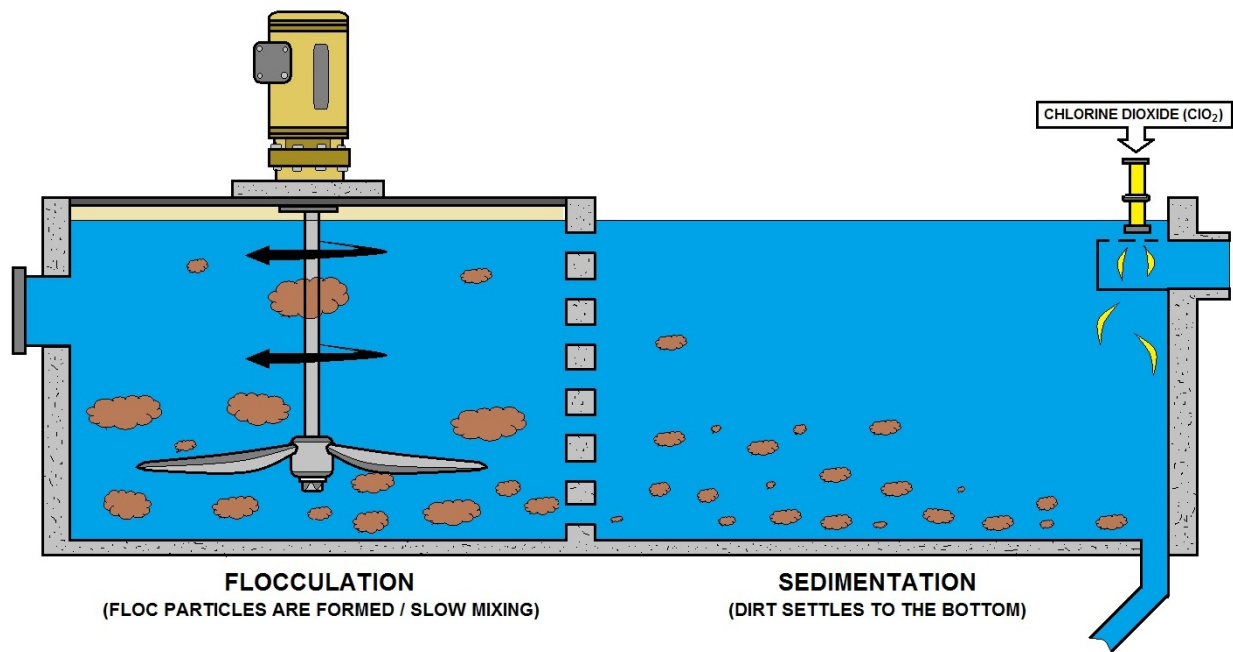
***Lime Soda Softening:** In a lime soda softening process, the pH of the water is raised to 11.0. In a lime softening process, excess lime is frequently added to remove calcium and magnesium bicarbonate. The minimum hardness which can be achieved by the lime-soda ash process is 30 to 40 mg/L as calcium carbonate. The hardness due to noncarbonate hardness is most likely to determine the choice between lime softening and ion exchange to remove hardness.

***M-Endo Broth:** The media shall be brought to the boiling point when preparing M-Endo broth to be used in the membrane filter test for total coliform.

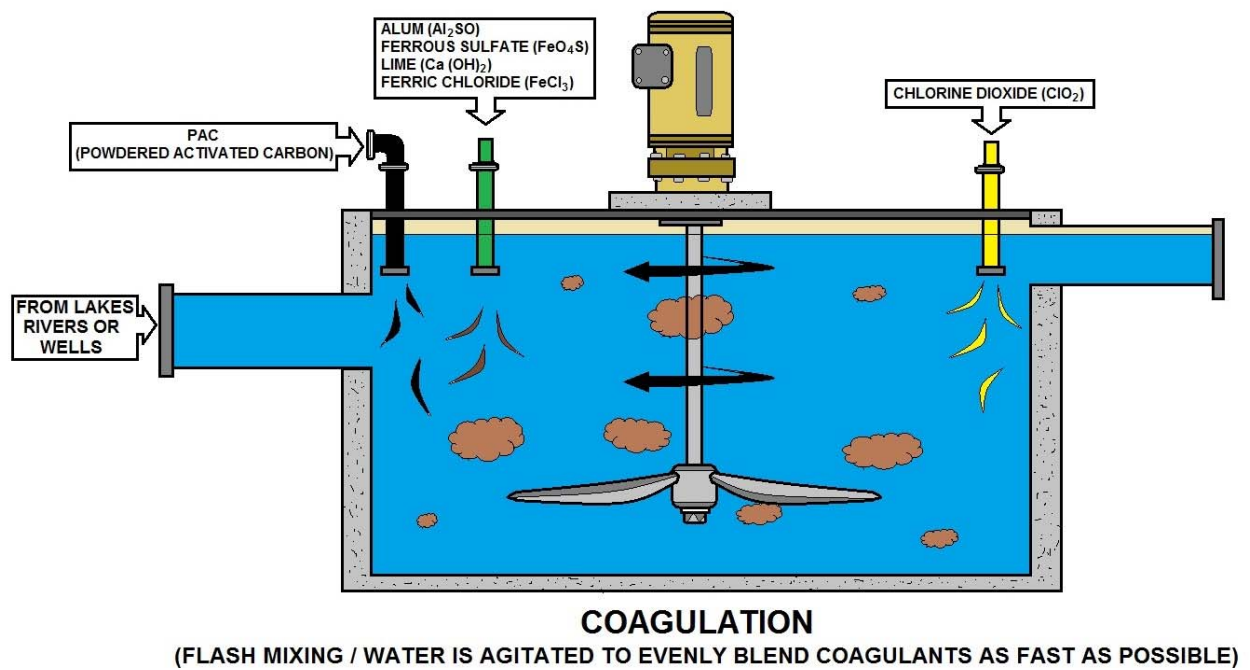
*** NH_3 :** The molecular formula of ammonia.

*** NO_3^- :** The molecular formula of the nitrate ion.

- ***Non-carbonate Hardness:** The portion of the total hardness in excess of the alkalinity.
- ***Normality:** The number of equivalent weights of solute per liter of solution.
- ***Oligotrophic:** A reservoir that is nutrient-poor and contains little plant or animal life.
- ***pH:** Expression of a basic or acid condition of a liquid. The range is from 0-14, zero being the most acid and 14 being the most alkaline. A pH of 7 is considered to be neutral. Most natural water has a pH between 6.0 and 8.5.
- ***Phenolphthalein / Total Alkalinity:** The relationship between the alkalinity constituent's bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity.
- ***Polymer:** A type of chemical when combined with other types of coagulants aid in binding small suspended particles to larger particles to help in the settling and filtering processes.
- ***Post-Chlorine:** Where the water is chlorinated to make sure to hold a residual in the distribution system. 0.2 mg/l chlorine residual.
- ***Prechlorination:** The addition of chlorine before the filtration process will help: Control algae and slime growth. Control mud ball formation. Improve coagulation. Precipitate iron.
- ***Pre-Chlorine:** Where the raw water is dosed with a large concentration of chlorine.
- ***Raw Turbidity:** The turbidity of the water coming to the treatment plant from the raw water source.
- ***Reagent:** A substance used in a chemical reaction to measure, detect, examine, or produce other substances.
- ***Sampling:** Collect the water sample at least 6 inches under the surface by plunging the container mouth down into the water and turning the mouth towards the current by dragging the container slowly horizontal. Care should be taken not to disturb the bottom of the water source or along the sides, so as not to stir up any settled solids; this would create errors.
- ***Settled Solids:** Solids that have been removed from the raw water by the coagulation and settling processes.
- ***Sulfate:** Will dissolve in water to form an anion.
- ***Taste and Odor Control:** Powdered activated carbon (**PAC**) is occasionally added for taste and odor control. PAC is added to the flash mix. Also helps remove THMs and precursors.
- ***Water Quality:** Water testing is conducted throughout the treatment process. Items like turbidity, pH, and chlorine residual are monitored and recorded continuously. Some items are tested several times per day, some once per quarter and others once per year.
- ***Zinc Orthophosphate:** A chemical used to coat the pipes in the distribution system to inhibit corrosion.



FLOCCULATION / SEDIMENTATION



Chemical Feed and Rapid Mix

Chemicals are added to the water in order to improve the subsequent treatment processes. These may include pH adjusters and coagulants. Coagulants are chemicals, such as alum, that neutralize positive or negative charges on small particles, allowing them to stick together and form larger particles that are more easily removed by sedimentation (settling) or filtration. *A variety of devices, such as baffles, static mixers, impellers, and in-line sprays can be used to mix the water and distribute the chemicals evenly.

***Short Circuiting**

Short Circuiting is a condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable, since it may result in shorter contact, reaction, or settling times in comparison with the presumed detention times.

Tube Settlers

This modification of the conventional process contains many metal “tubes” that are placed in the sedimentation basin, or clarifier. These tubes are approximately 1-inch-deep and 36 inches long, split-hexagonal shape, and installed at an angle of 60 degrees or less. These tubes provide for a very large surface area upon which particles may settle as the water flows upwards. The slope of the tubes facilitates gravity settling of the solids to the bottom of the basin, where they can be collected and removed. The large surface settling area also means that adequate clarification can be obtained with detention times of 15 minutes or less. As with conventional treatment, this sedimentation step is followed by filtration through mixed media.

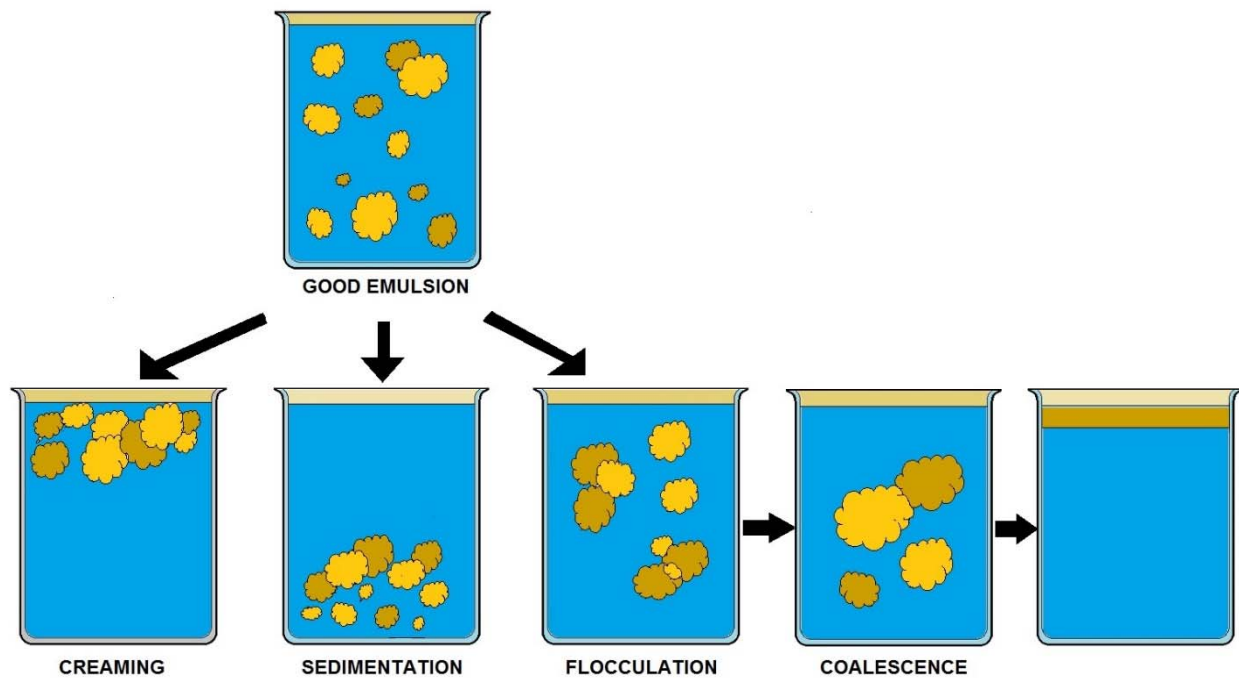
Adsorption Clarifiers

The concept of the adsorption clarifier package plant was developed in the early 1980's. This technology uses an up flow clarifier with low-density plastic bead media, usually held in place by a screen. This adsorption media is designed to enhance the sedimentation/clarification process by combining flocculation and sedimentation into one step. In this step, turbidity is reduced by adsorption of the coagulated and flocculated solids onto the adsorption media and onto the solids already adsorbed onto the media.

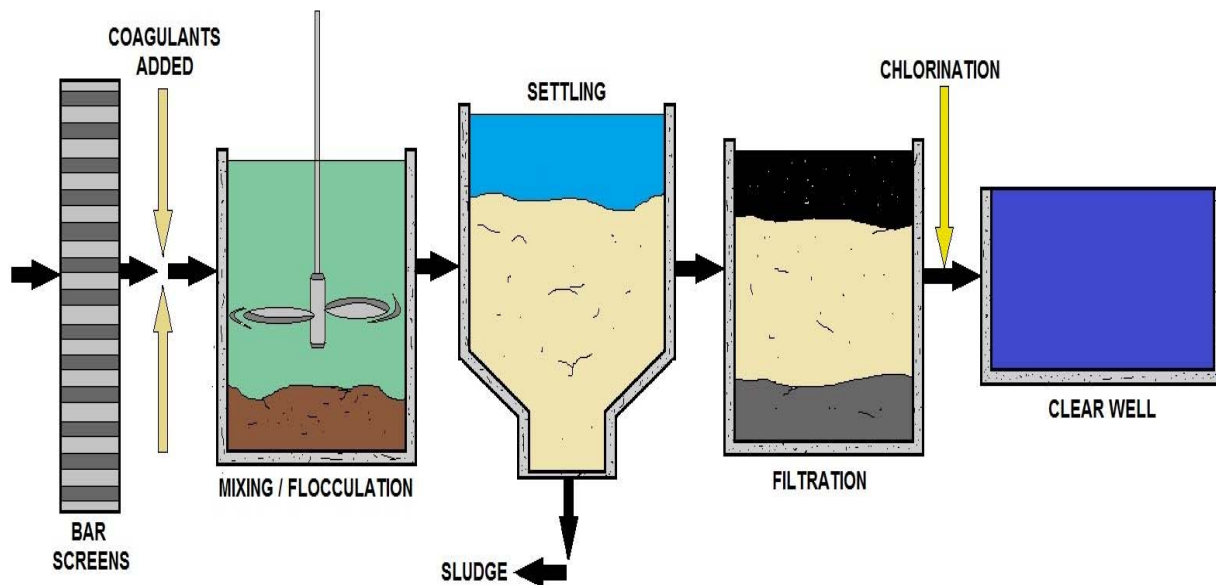
Air scouring cleans adsorption clarifiers followed by water flushing. Cleaning of this type of clarifier is initiated more often than filter backwashing because the clarifier removes more solids. As with the tube-settler type of package plant, the sedimentation/clarification process is followed by mixed-media filtration and disinfection to complete the water treatment.

***Clearwell**

The final step in the conventional filtration process, the clearwell provides temporary storage for the treated water. The two main purposes for this storage are to have filtered water available for backwashing the filter, and to provide detention time (or contact time) for the chlorine (or other disinfectant) to kill any microorganisms that may remain in the water.



MECHANISMS OF EMULSION INSTABILITY



BASIC WATER TREATMENT

Water Treatment Chemicals *Know all of this section*

***Chemicals Used for Coagulation**

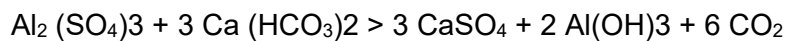
The chemical most generally used in coagulation is aluminum sulfate, $\text{Al}_2 (\text{SO}_4)_3 \cdot 18 \text{H}_2\text{O}$, which is also called filter alum or simply alum. Iron salts more or less frequently used include ferrous sulfate, $\text{Fe SO}_4 \cdot 7 \text{H}_2\text{O}$; ferric chloride, Fe Cl_3 ; ferric sulfate, $\text{Fe}_2 (\text{SO}_4)_3$, and chlorinated copperas, $\text{Fe}_2 (\text{SO}_4)_3 \cdot \text{Fe Cl}_3$. Lime in the form of calcium hydroxide, Ca (OH)_2 , is necessary in conjunction with ferrous sulfate and sometimes is used alone; it also may be needed in waters deficient in alkalinity to react with aluminum sulfate.

*These chemicals are used most effectively and economically when the acidity or alkalinity of the water is held within relatively narrow limits. In order to obtain and maintain the desired reaction, it may be necessary to use also acids or alkalis such as sodium carbonate, $\text{Na}_2 \text{CO}_3$, which is generally called soda ash; lime, CaO ; or sulfuric acid, H_2SO_4 .

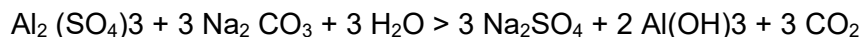
***Use of Aluminum Sulfate**

Aluminum Sulfate is obtainable either as liquid alum or in the form of lumps, which must be put into a solution prior to being fed into the water. Owing to the considerable water content of liquid alum, long-distance hauling is uneconomical, and it is available only within a relatively short radius of manufacturing plants. Its use, however, simplifies feeding problems and reduces labor required to prepare the solutions for the feeders.

*When aluminum sulfate is added to water that contains calcium bicarbonate, the following reaction takes place:



When the water contains sodium carbonate, the reaction is:



The aluminum hydroxide, which is insoluble and colloidal forms the floc. The resulting floc will indicate whether the correct amount of coagulant is being used. Large, feathery flakes generally indicate that the amount of coagulant was too great. Normally, floc particles the size of a pin head are desirable.

Theoretical Requirements

The amount of aluminum sulfate required for coagulation depends on the turbidity and color of the water that is treated. Temperatures below about 35°F or above 70°F may increase the coagulant demand slightly, because of a slower reaction or from re-absorption of the floc.

Experimental work in the laboratory will give an indication of the approximate dosage that is required, but actual results in plant operation may show that some adjustments in this quantity are necessary. For relatively clear water, a minimum dose of 0.3 gpg may be used, whereas highly turbid water may require as much as 5 gpg. The average dosage is about 1 gpg.

In order to obtain a complete reaction with aluminum sulfate, the water must contain from 6 to 10 mg/l of alkalinity of each grain per gallon of coagulant. Theoretically, 1 gpg of aluminum sulfate reduces the alkalinity of the water by 7.7 mg/l, but the reduction varies with different waters. In addition, there should be an excess of alkalinity ranging from 10 to 50 mg/l.

If this reserve alkalinity is not present, the reaction may be incomplete and some of the aluminum sulfate may pass through the filter in solution as residual alum.

Best results are usually obtained with aluminum sulfate when the pH value is between 6.5 and 8.5 but coagulation will also take place when the pH value is 5.5.

If the water to be treated with aluminum sulfate is deficient in alkalinity, the necessary adjustment can be made by adding lime or soda ash. Theoretically, 1 gpg of aluminum sulfate combines with 8.3 mg/l of 90 percent soda ash or with 5.96 mg/l of 95 percent hydrated lime. Thus, either 0.5 grain of soda ash or 0.35 grain of lime is required for each grain of aluminum sulfate used for coagulation. Also, 1 mg/l of soda ash is practically equivalent to 1 mg/l of alkalinity.

When the water is colored and aluminum sulfate is used as the coagulant, it may be necessary to produce first a color floc, which is a compound formed by the aluminum of the coagulant and the organic material causing color.

With most colored waters, this floc is best formed when the pH value is considerably below 6.5. Therefore, it is sometimes advantageous to lower the pH value of the water by adding sulfuric acid before the aluminum sulfate is applied.

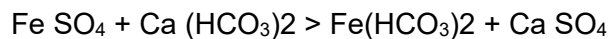
If soda ash or lime is also to be added in order to give the water the necessary alkalinity to permit complete coagulation of the aluminum sulfate or to eliminate corrosiveness, the color floc should be removed by filtration before the acidity is neutralized.

***Use of Ferrous Sulfate**

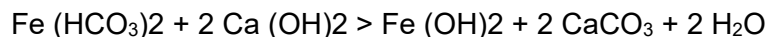
Ferrous sulfate, which is also called copperas (not to be confused with copper sulfate), is used extensively as a coagulant with lime in waters that are not colored. This substance is generally cheaper than aluminum sulfate.

In the case of waters that are highly colored, however, the addition of ferrous sulfate and lime will not give satisfactory results. Because of the high alkalinity that would be produced by this treatment, compounds that tend to set the color would be formed before a suitable floc for removing the color could be produced. In general, ferrous sulfate is most valuable in large treatment plants, where constant laboratory supervision is possible. Ferrous sulfate and lime may be applied either dry or in solution in the same manner as aluminum sulfate.

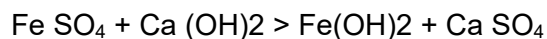
The lime may be introduced either before or after the copperas. Where the ferrous sulfate is added first to water containing calcium bicarbonate, the immediate reaction is that indicated below:



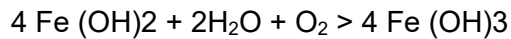
Then, when the lime is added, the reaction that takes place is the following:



If the lime is added first, the reaction that occurs when the ferrous sulfate is applied is indicated below:



In either case, ferrous hydroxide is formed. This hydroxide is oxidized by the dissolved oxygen in the water, as shown below:

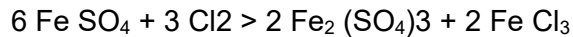


The ferric oxide forms the floc.

In general, the dosages of ferrous sulfate will be about the same as, or slightly higher than, the amount of aluminum sulfate that would be required. For each grain of ferrous sulfate per gallon of water, it is necessary to have about 0.5 mg/l of dissolved oxygen and at least 0.4 gpg of lime. The required amount of lime increases with the turbidity and for very turbid water the amounts of lime and ferrous sulfate may be equal.

Use of Chlorinated Copperas

When chlorine is added to a solution of ferrous sulfate, the two react chemically to form ferric sulfate and ferric chloride. The reaction may be as follows:

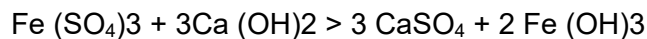


Theoretically, 1 lb of chlorine is required to react with 8 lb of ferrous sulfate, but it has been found in actual practice that 1 lb of chlorine will react with about 7.3 lb of ferrous sulfate. The combination of ferric sulfate and ferric chloride is known as chlorinated copperas. Each of these ferric compounds is a good coagulant, and their combination often is quite effective.

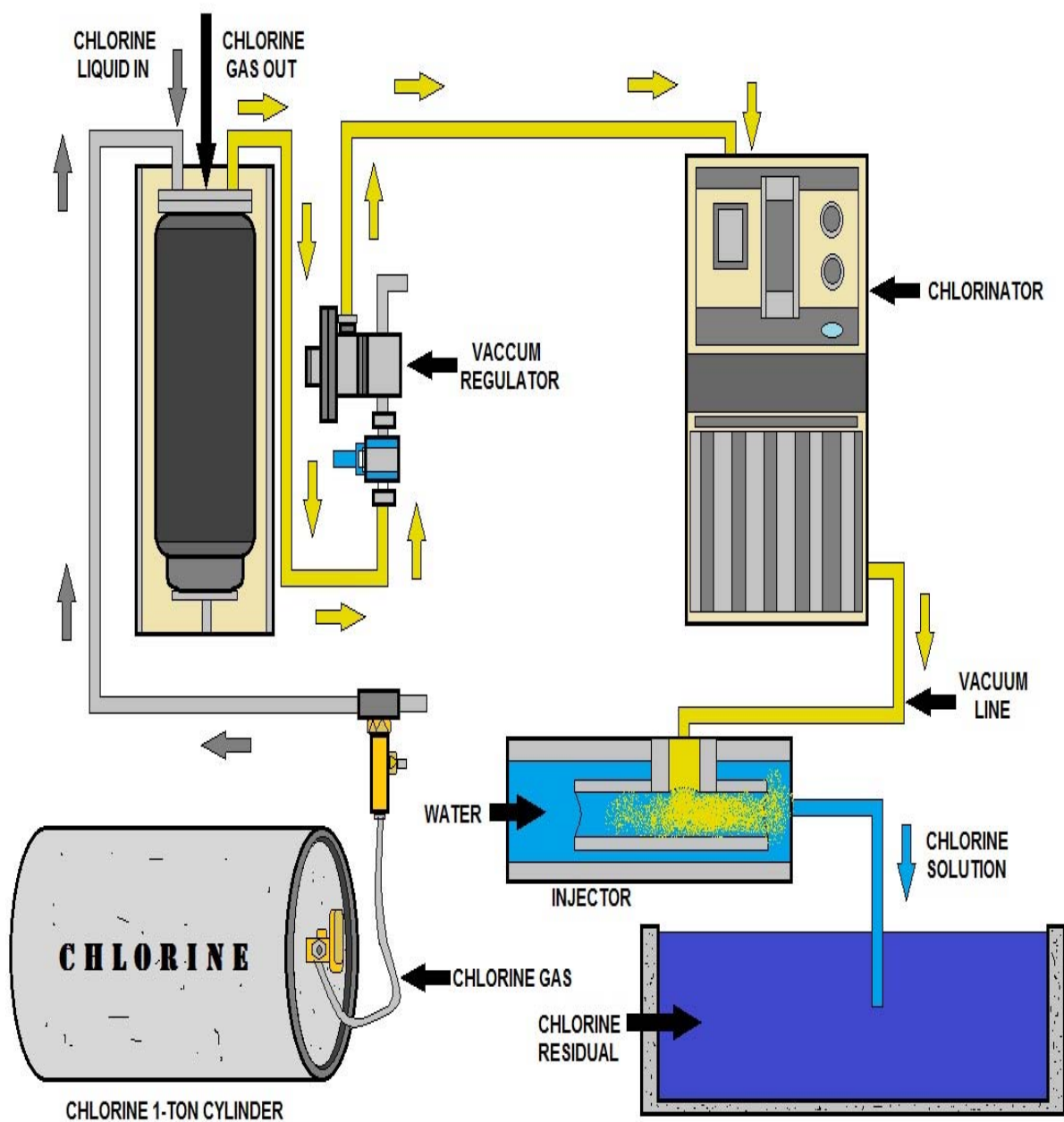
Chlorinated copperas is a valuable coagulant for removing color, especially where the water has a low pH value. First, chlorinated copperas is applied in sufficient quantities to give a good flow. When the mixing is about half completed, an alkaline coagulant, which may be aluminum sulfate and lime or chlorinated copperas and lime, is added.

Use of Ferric Sulfate

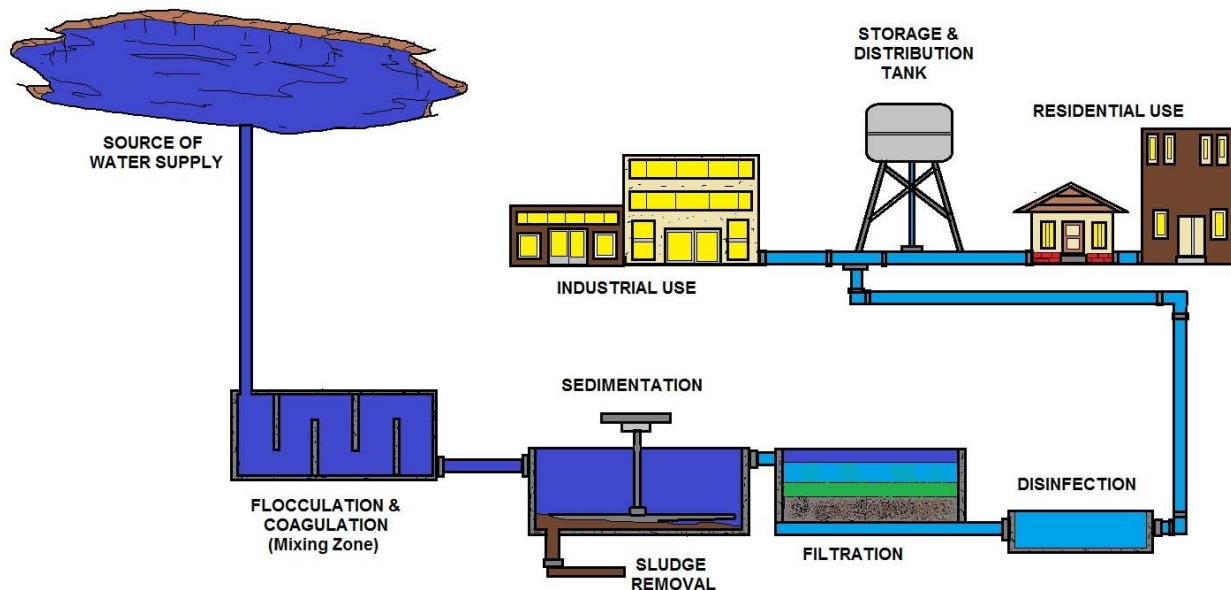
Prepared in free-flowing granular forms, ferric sulfate is applied with relative ease, and it produces a good floc over a rather wide range of pH values. It has a particular advantage where manganese is present in sufficient amounts to require removal. When ferric sulfate is used with lime, the following reaction occurs:



The ferric hydroxide forms the desired floc, just as with all other iron compounds.



Conventional Water Treatment



DRINKING WATER TREATMENT

Conventional treatment consists of the following unit processes: coagulation, flocculation, clarification, and filtration, and is typically followed by disinfection at full-scale. The above drawing describes conventional treatment. Conventional treatment is often preceded by pre-sedimentation, may be accompanied by powdered activated carbon (PAC) addition, utilize granular activated carbon (GAC) as a filter media, and in some cases be followed by GAC adsorption.

Conventional treatment is often preceded by pre-oxidation, or oxidation takes place concurrently. Oxidants common to conventional treatment are chlorine, chloramine, chlorine dioxide or permanganate. Occasionally membrane processes, either membrane filtration or ultrafiltration, accompany conventional treatment.

In coagulation, a positively charged coagulant (usually an aluminum or iron salt) is added to raw water and mixed in the rapid mix chamber. The coagulant alters or destabilizes negatively charged particulate, dissolved, and colloidal contaminants. Coagulant aid polymers and/or acid may also be added to enhance the coagulation process.

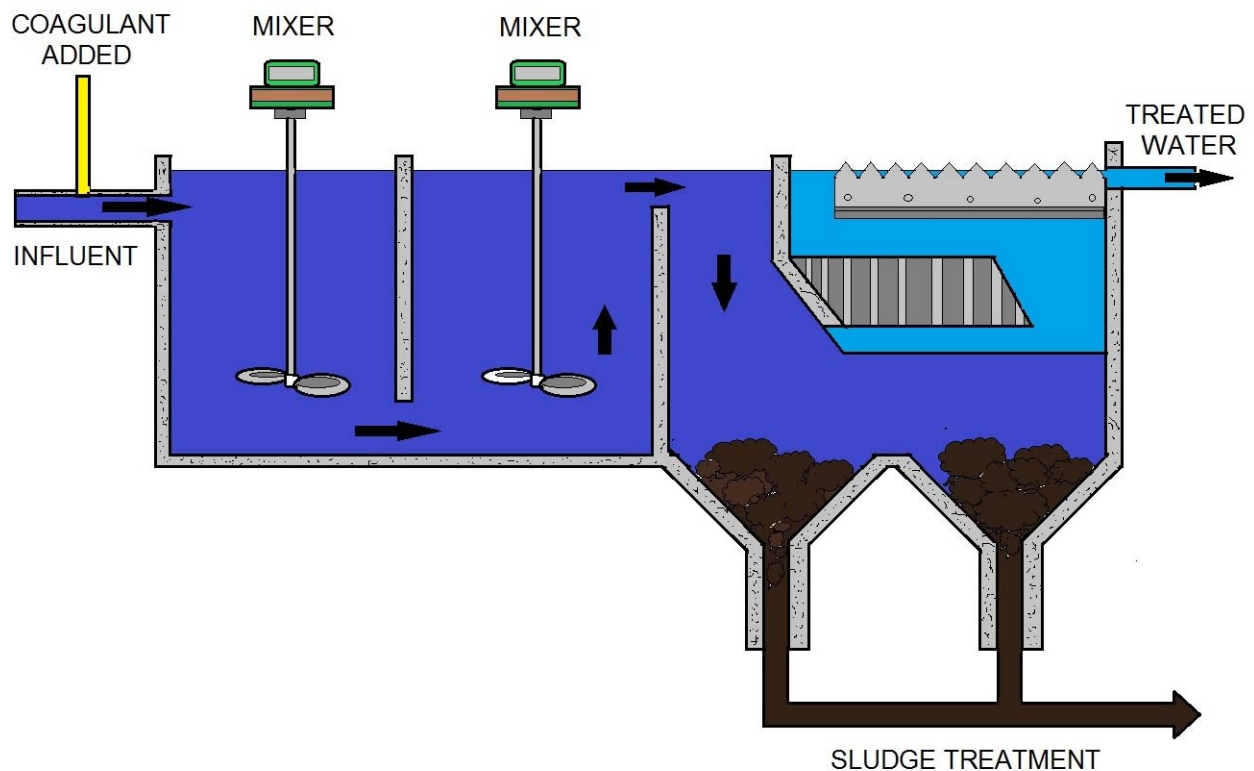
Turbidity and total organic carbon (TOC) are measures of particulates and dissolved organics impacting coagulation.

During flocculation, gentle mixing accelerates the rate of particle collision, and the destabilized particles are further aggregated and enmeshed into larger precipitates. Flocculation is affected by several parameters, including the mixing speed, mixing intensity (G), and mixing time. The product of the mixing intensity and mixing time (Gt) is frequently used to describe the flocculation process.

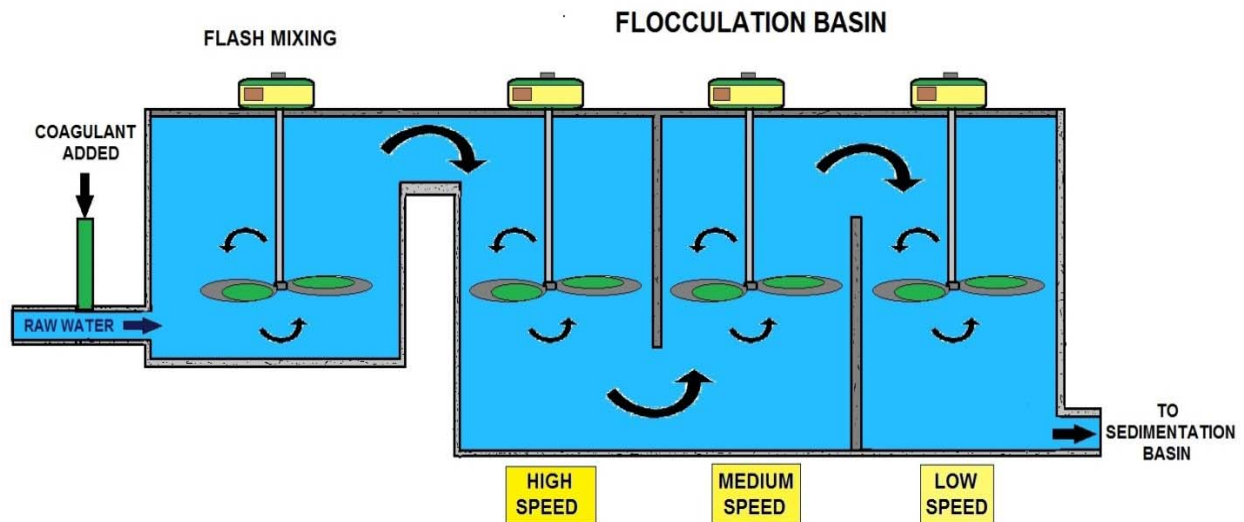
Destabilization Mechanisms

There are two primary destabilization mechanisms in drinking water treatment: charge neutralization and sweep flocculation. The mechanism is dependent upon the coagulant dose. Most drinking water treatment plants operate using sweep flocculation, which requires a higher coagulant dose, rather than charge neutralization. In charge neutralization, the positively charged metal coagulant is attracted to the negatively charged colloids via electrostatic interaction.

Flocs start to form during the neutralization step as particle collisions occur. Adding excess coagulant beyond charge-neutralization results in the formation of metal coagulant precipitates. These metal hydroxide compounds (e.g., $\text{Al}(\text{OH})_3$ or $\text{Fe}(\text{OH})_3$) are heavy, sticky and larger in particle size. Sweep flocculation occurs when colloidal contaminants are entrained or swept down by the precipitates as they settle in the suspension.



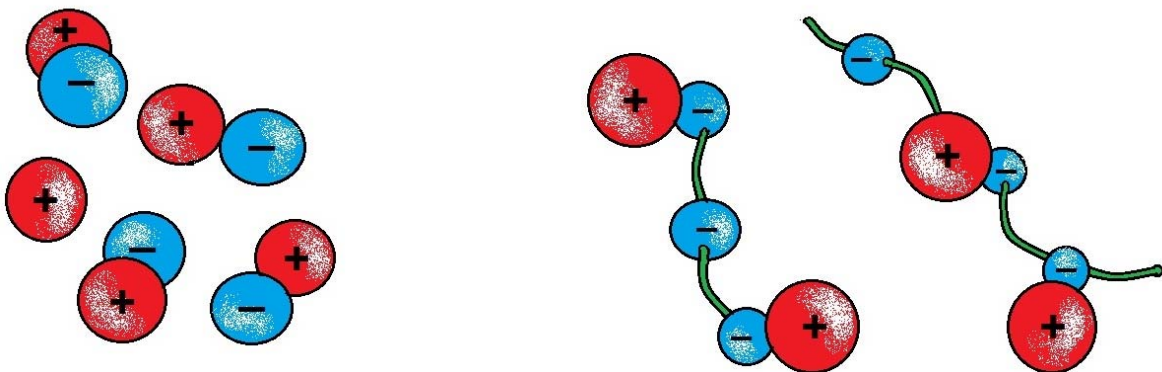
FLOCCULATION BASIN



FLASH FLOCCULATION

Coagulation

The optimal pH range for coagulation is 6 to 7 when using alum and 5.5 to 6.5 when using iron. For high alkalinity water, excessive amounts of coagulant may be needed to lower the pH to the optimal pH range. In these cases, it may be beneficial to use acid in addition to the coagulant to reduce the amount of coagulant needed and effectively lower chemical costs. Enhanced coagulation is now widely practiced for removing disinfection byproduct (DBP) precursors, and it also removes inorganics, particulates, and color causing compounds. Removing these contaminants using coagulation depends on the amount of coagulant added. It is important to determine the optimal dose for coagulation; insufficient doses will not effectively destabilize the particles and adding excessive doses can cause detrimental effects such as re-stabilization, excessive sludge production, or corrosion.



COAGULATION vs. FLOCCULATION

Coagulation invariably requires addition of a chemical with a strong positive charge, such as aluminum sulfate (alum), to neutralize the negative electrostatic charges that allow particles to remain suspended in the raw water. Coagulation involves turbulent mixing of the coagulant chemical with the raw water.

Flocculation involves gentle mixing of the coagulated water to allow the small particles to come together to form larger particles. Flocculation may occur naturally to some extent following coagulation, or may be encouraged by the addition of a chemical, such as a flocculant polymer. Coagulation and flocculation are necessary steps in conventional water treatment processes and occur in successive steps intended to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc. If step one is incomplete, the following step will be unsuccessful.

Coagulation and flocculation are necessary steps in conventional water treatment processes and occur in successive steps intended to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc. If step one is incomplete, the following step will be unsuccessful.

The first step destabilizes the particle's charges. Coagulants with charges opposite those of the suspended solids are added to the water to neutralize the negative charges on dispersed non-settleable solids such as clay and color-producing organic substances.

Once the charge is neutralized, the small suspended particles are capable of sticking together. The slightly larger particles formed through this process and called microflocs, are not visible to the naked eye. The water surrounding the newly formed microflocs should be clear. If it is not, all the particles' charges have not been neutralized, and coagulation has not been carried to completion. More coagulant may need to be added.

A high-energy, rapid-mix to properly disperse the coagulant and promote particle collisions is needed to achieve good coagulation. Over-mixing does not affect coagulation, but insufficient mixing will leave this step incomplete. Contact time in the rapid-mix chamber is typically 1 to 3 minutes.

Dissolved and Suspended Particles

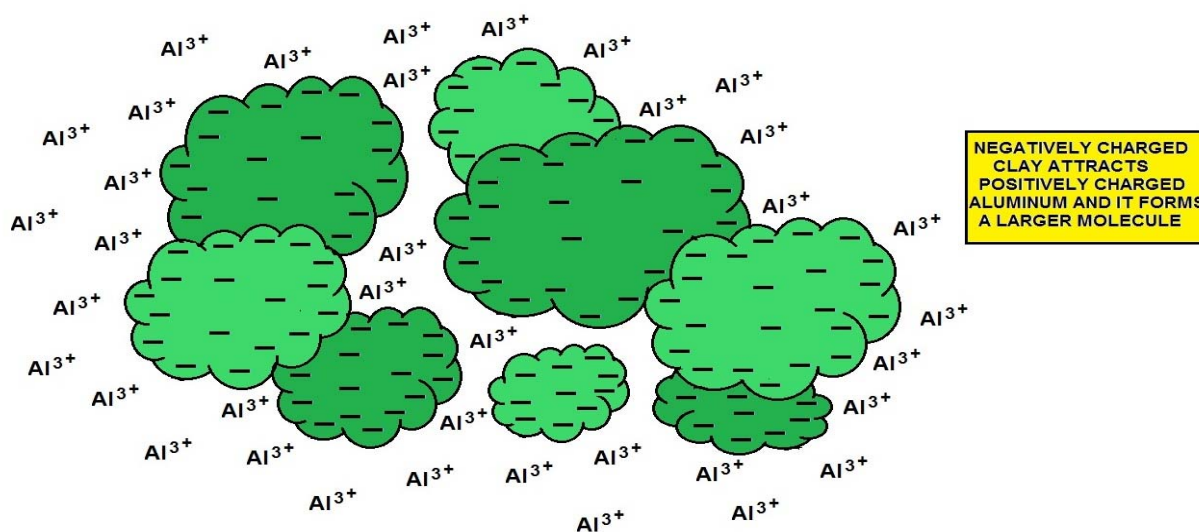
All waters, especially surface waters, contain both dissolved and suspended particles. Coagulation and flocculation processes are used to separate the suspended solids portion from the water.

The suspended particles vary considerably in source, composition charge, particle size, shape, and density. Correct application of coagulation and flocculation processes and selection of the coagulants depend upon understanding the interaction between these factors. The small particles are stabilized (kept in suspension) by the action of physical forces on the particles themselves.

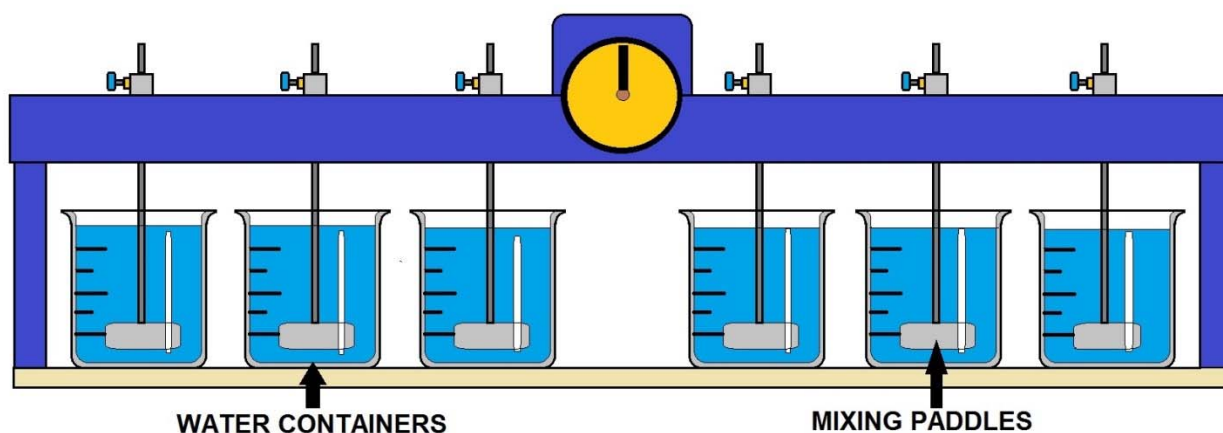
One of the forces playing a dominant role in stabilization results from the surface charge present on the particles. Most solids suspended in water possess a negative charge and, since they have the same type of surface charge, repel each other when they come close together. Therefore, they will remain in suspension rather than clump together and settle out of the water.

Water Quality Parameters

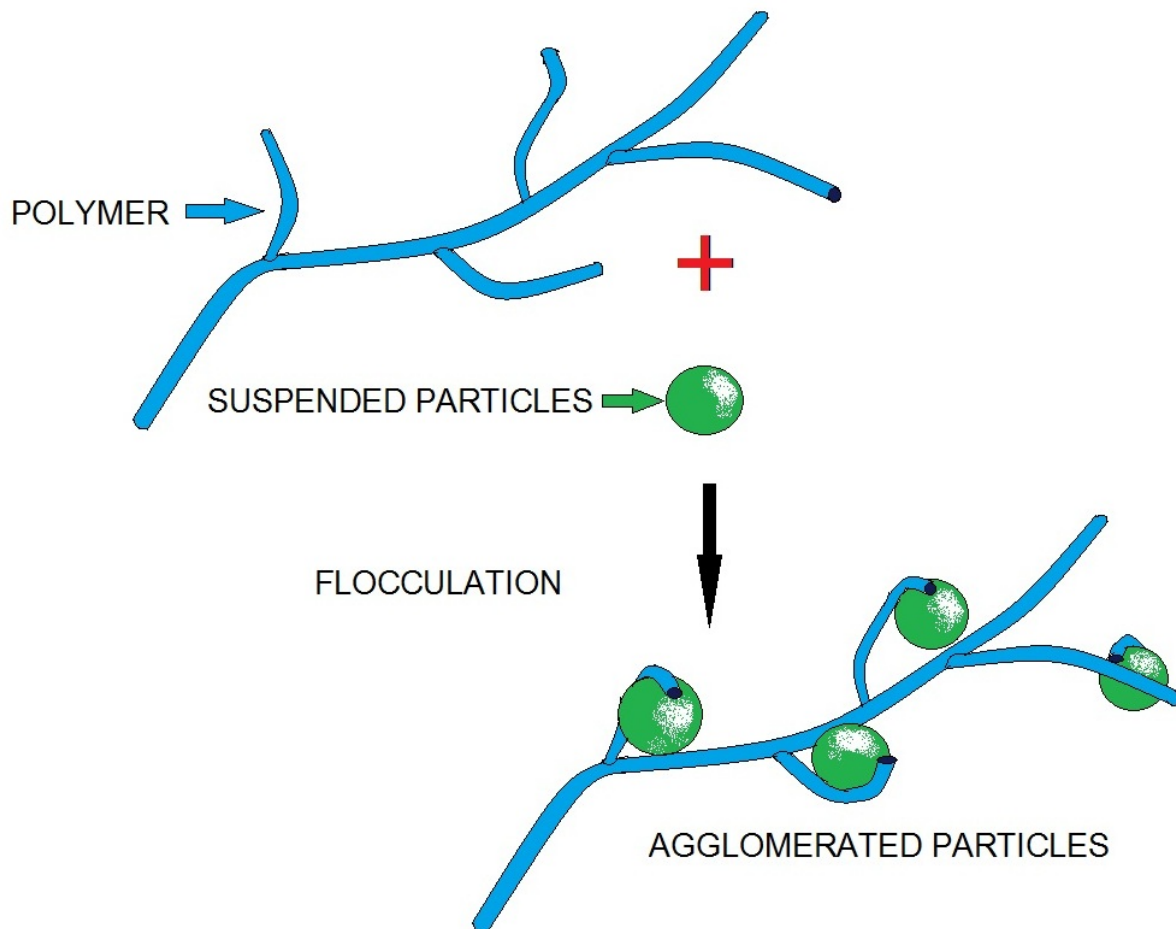
Water quality parameters such as pH, temperature, and alkalinity may dictate effectiveness of the coagulation-filtration process. The pH during coagulation has a profound influence on the effectiveness during the destabilization process. The pH controls both the speciation of the coagulant as well as its solubility, and it also affects the speciation of the contaminants. For high alkalinity water, an excessive amount of coagulant may be required to lower the pH to the optimal pH ranges (alum pH 6 to 7, iron 5.5 to 6.5). Temperature also impacts the coagulation process because it affects the viscosity of the water. Thus lower temperature waters can decrease the hydrolysis and precipitation kinetics. For some treatment objectives, other parameters like iron, manganese or sulfate impact coagulation.



FLOCCULATION



FLOCCULATION / COAGULATION JAR TEST UNIT



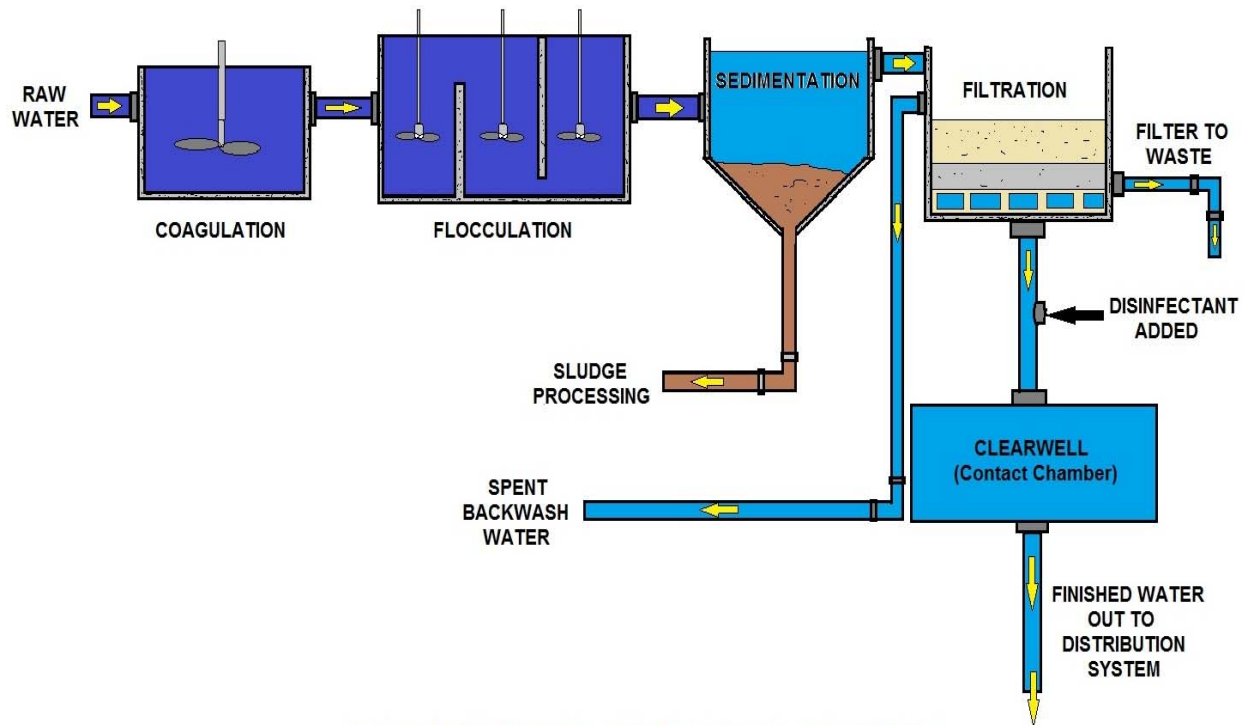
FLOCCULATION

Polyaluminium Chloride (PACl)

Some of the alternative coagulants such as polyaluminium chloride (PACl) can be advantageous over the traditional coagulants in low temperature conditions as these coagulants are already hydrolyzed, and therefore temperature tends to have less effect on the coagulation process.

Following flocculation, agglomerated particles enter the clarification unit where they are removed by sedimentation by gravity or are floated and skimmed from the surface of the clarification unit. In the sedimentation processes, the majority of the solids are removed by gravitational settling; particles that do not settle and are still suspended are removed during the filtration process.

Sedimentation is generally accomplished in rectangular or circular basins and is often enhanced by the addition of inclined plates or tubes which increase effectiveness of the process by effectively increasing the surface area of the sedimentation basin.



CONVENTIONAL WATER TREATMENT

Dissolved Air Flotation (DAF)

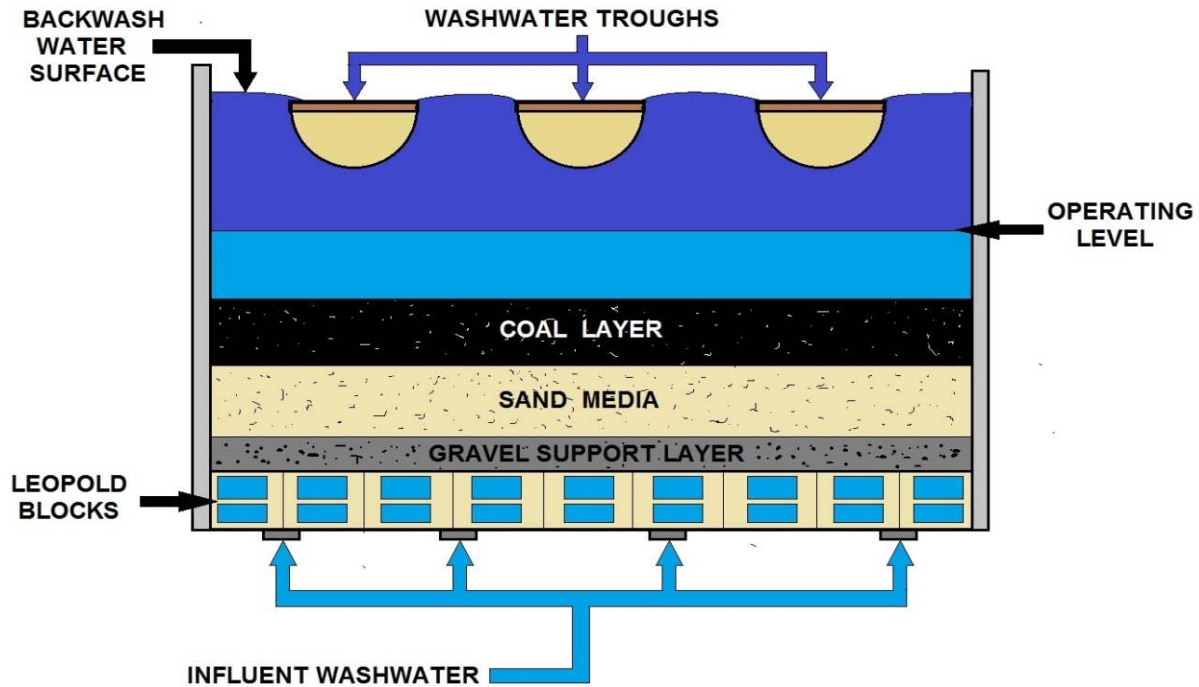
Dissolved air flotation (DAF) is another clarification process in which air is diffused as fine bubbles and suspended particles are floated to the surface and removed by skimming.

Generally, DAF is most effective for small, fine, low-density particles like algae and may not be effective in all instances. Like conventional sedimentation, solids not removed by DAF are removed during filtration.

Clarification Process

Two parameters frequently used to describe the clarification process are the overflow rate and the detention time. The overflow rate is the process loading rate and is usually expressed in gpm/sf or gpd/sf. Overflow rates for conventional sedimentation generally range from 0.3 to 1 gpm/sf (500 to 1500 gpd/sf).

Overflow rates for other processes can vary significantly. There are proprietary sand-ballasted clarification systems that have been demonstrated to operate effectively at overflow rates as high as 20 gpm/sf. Typical detention times range from 1 to 2 hours, although many states require up to 4 hours for full-scale surface water treatment.

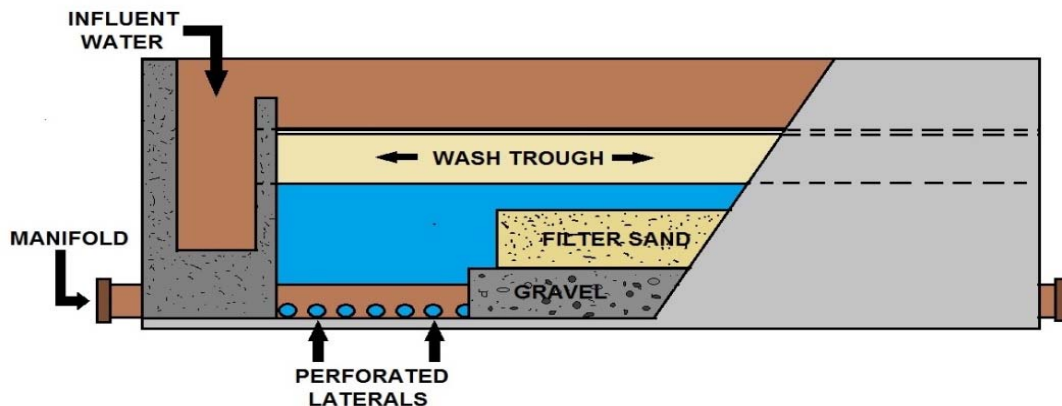


DUAL MEDIA FILTER

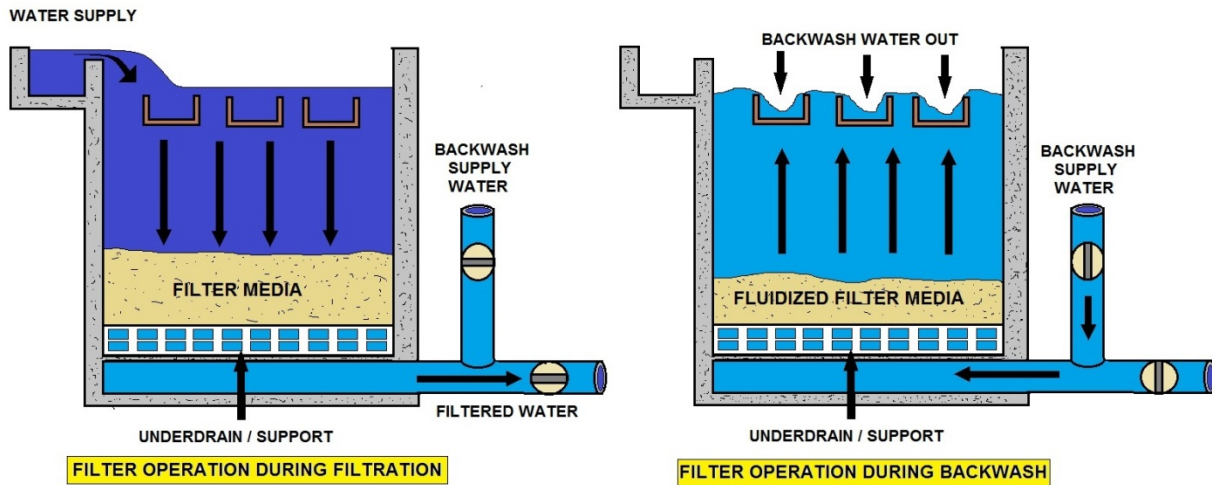
Dual-Media Filter

The most commonly used filter type in the conventional treatment process is a dual-media filter comprised of anthracite and sand; however, mono-media (sand), multi-media (garnet, anthracite, and sand), and other media configurations, including the use of granular activated carbon, are also used in drinking water treatment.

During filtration, the majority of suspended particles are removed in the top portion of the filter media. Filters are backwashed to dislodge and remove particles trapped within the filter bed, to reduce head loss (pressure build up), and to keep the filter media clean.



RAPID SAND FILTER



RAPID SAND FILTER

Filter Loading Rate

The filter loading rate is a measure of the filter production per unit area and is typically expressed in gpm/sf. Typical filter loading rates range from 2 to 4 gpm/sf; however, higher filter loading rates, 4 to 6 gpm/sf, are becoming more common at full-scale. This can be a critical parameter because it determines the water velocity through the filter bed and can impact the depth to which particles pass through the media.

The filter run time describes the length of time between filter backwashes during which a filter is in production mode. The filter run time is not only an indicator of the effectiveness of prior treatment (i.e., the ability of the coagulation and clarification steps to remove suspended solids), but also plays a role in the effectiveness of the filter itself.

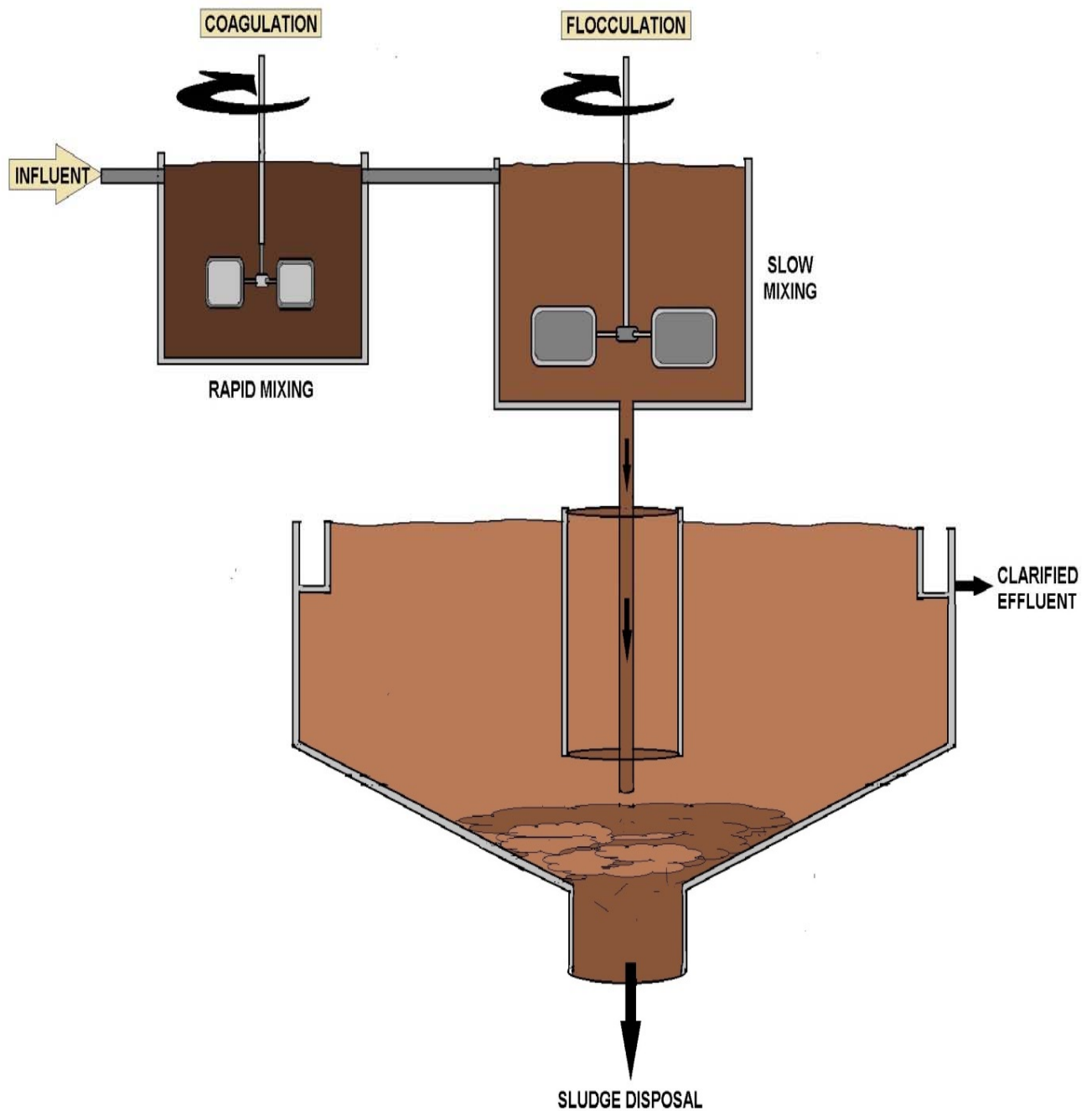
Filter Performance

Filter performance, particularly with regard to particulate contaminants, is often poorest immediately following a backwash. As the filter run time increases and the concentration of solids in the media increases, the filtration process often performs better with regard to particulate contaminant removal.

Spent Backwash

Residuals generated by the conventional treatment process include coagulation solids (sludge) and spent backwash. Spent backwash is often returned to the treatment process as a means to minimize water loss. Sludge may also be recycled to minimize coagulant and coagulant aid doses and improve process performance.

Process solids (i.e., coagulation sludge and filtered solids) will contain elevated concentrations of contaminants removed during the treatment process. Depending on the source water concentration of a particular contaminant and any disposal limitations, it may be necessary evaluate the disposal of process solids with respect to state and local hazardous waste regulations.



BASIC COAGULATION / FLOCCULATION PROCESS

Chemical Aids to Coagulation

*Lime

The principal use of lime in coagulation is to provide artificial alkalinity in waters that are treated with aluminum sulfate or ferrous sulfate. Lime may be used as a coagulant without additional chemicals for waters having a high content of magnesium compounds. A large proportion of the magnesium is thus changed to a bulky flocculent mass. However, when waters containing magnesium are coagulated with lime, they have a high alkalinity.

*Lime may be purchased in the form of either quicklime, CaO , or hydrated lime, Ca(OH)_2 . Quicklime contains from 75 to 99 percent of pure calcium oxide, but it must be slaked with water before it is used. Hydrated lime, on the other hand, is slaked lime that is ready for use, and it contains between 80 and 99 percent of calcium hydroxide. Quicklime is cheaper than hydrated lime, and therefore it is used almost entirely in large plants. However, hydrated lime is usually preferred for small plants, because the saving in the cost of chemical by using quicklime is not enough to compensate for the costs of the labor and equipment that are required for slaking the quicklime.



The effective strength of the quicklime, or the percentage of pure CaO that it contains, must be known in order to compute the required dosage. The computations may be based on the fact that 75.7 lb of pure CaO is equivalent to 100 lb of pure Ca(OH)_2 . Also, 1 gpg of pure Ca(OH)_2 will combine with 10.16 mg/l of free carbon dioxide, CO_2 . These proportions are based on the ratio of the molecular weights of the chemicals and may be computed in the following manner:

The molecular weight of CaO is $40.08 + 16.00 = 56.08$, and the molecular weight of Ca(OH)_2 is $40.08 + 32 + 2.02 = 74.10$. Therefore, 74.10 lb of Ca(OH)_2 is equivalent to 56.08 lb of CaO , or the number of pounds of pure CaO that would be equivalent to 100 lb of pure Ca(OH)_2 is $(56.08/74.10) \times 100 = 75.7$. The molecular weight of CO_2 is $12.01 + 32 = 44.01$, and that of Ca(OH)_2 has just been determined, is 74.10.

Therefore, 1 part of Ca(OH)_2 will combine with $44.01 / 74.10 = 0.594$ part of CO_2 . Since 17.1 mg/l is equivalent to 1 gpg, then 1 gpg of hydrated lime will combine with $17.1 \times 0.594 = 10.16$ mg/l of CO_2 .

*Soda Ash

Soda ash, which is essentially sodium carbonate, Na_2CO_3 , is used to provide artificial alkalinity in water that is to be treated with aluminum sulfate, and it also reduces permanent hardness. It is very soluble in and easily applied to water. The commercial product should contain 98 percent of sodium carbonate. If an excess of soda ash is used, the excess will combine with carbon dioxide to reduce the corrosiveness of the water.

Therefore, exact dosages are not essential for good treatment. For this reason, soda ash is particularly useful in small plants that lack precise control facilities, even though its cost is considerably greater than that of lime. It is useful to know that 1 gpg of soda ash will combine with 7.2 mg/l of carbon dioxide.

Other Chemical Used in Coagulation

Sulfuric Acid, H_2SO_4 , is used infrequently to acidify waters prior to treatment. Sodium Hydroxide, NaOH , which is also known as caustic soda, is an effective alkali. Also, when used to produce alkalinity, it does not increase the hardness of the water. Sodium silicates, consisting of sodium oxide, Na_2O , and silica, SiO_2 , in various proportions, are used in conjunction with aluminum sulfate to produce large floc particles. In the so-called high-rate upward-flow clarifiers, such large particles are especially desirable after being compacted and agglomerated by slow agitation.

Determining Coagulant Dosages

Jar Tests for Aluminum Sulfate

After a treatment plant has been in operation for some time, the records of chemical dosages employed for various turbidities and conditions of the water form an excellent guide to the required doses of coagulant. Records of chemical dosages should, therefore, be made daily and should be plotted on charts in order to facilitate their use. For new plants or for unusual conditions in old plants the required dosages may be determined approximately by theoretical computations as indicated in the preceding explanations. However, the computed dosages should be checked by means of laboratory tests.

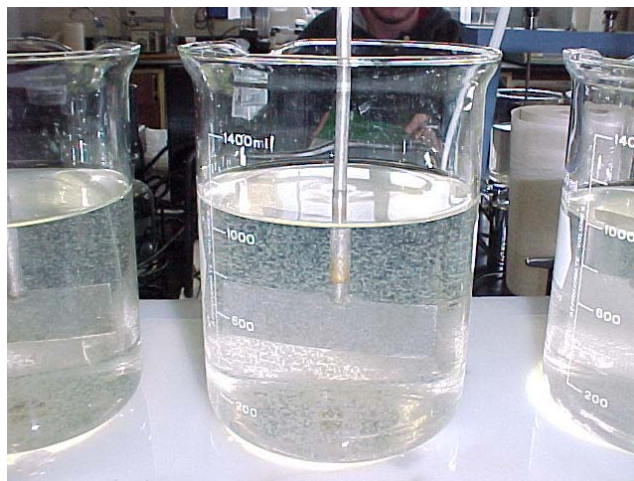
The hydrogen ion determination and other relatively simple tests will usually provide sufficient information for the control of coagulants in the operation of the plant. The laboratory test commonly used for determining the approximate dosage of a particular chemical required in a plant is called the jar test. It may be used for any of the various coagulants mentioned, but it is here described only for aluminum sulfate, which is the most common coagulant. The water that is to be tested is placed in jars or breakers that have a capacity of 500 to 1000 ml.

Various amounts of chemicals are put into the jars, and the ingredients are stirred rapidly to cause the formation of the floc. The floc is then allowed to settle in each jar, and the jar in which the least amount of chemical produced a good, settleable floc is chosen as the one with the most economical dosage.

Jar Test for Turbid Alkaline Waters

If the water contains sufficient natural alkalinity to permit the use of aluminum sulfate without the addition of lime or soda ash, the jar test may be made in the following manner:

Six jars, each containing the same amount of the sample of water, are placed in a stirring machine. A different amount of coagulant is added to each jar, the water is stirred for about 15 min, and then the liquid is allowed to stand so that the floc may form.



The smallest dosage of aluminum sulfate that produces a good floc is the desired dosage for that particular water.

Tests for Turbid Water of Low Alkalinity

When a comparatively large dosage of aluminum sulfate alone fails to produce a good floc in water and it is known that the water is of low alkalinity, the necessary procedure is as follows: A test is first made to determine the alkalinity of the water, and enough soda ash or lime is then added to provide the alkalinity required for a satisfactory reaction with aluminum sulfate.

*Equipment for Feeding Chemicals

In order to feed chemicals to the water regularly and accurately, some type of feeding equipment must be used. This is of two general types, dry feed and solution feed. Which will be the preferable for any specific plant depends on a number of factors: First, the character of the chemical; for instance, activated carbon and lime cannot be fed in solution form. The amount to be fed is also important; a dosage of $\frac{1}{2}$ mg/l for 360,000 gpd requires only 1 oz. of chemical per hour and, for accuracy, this must be fed as a weak solution by a liquid feeder.

A third factor considers the facilities available at the plant; if the plant is large, personnel will be available to make up solutions of the proper strength and have them available when needed. Size of the plant may also influence both the type of chemical used and the method of feed. In a large plant, which uses a great deal of coagulant, the chemical should be purchased in its cheapest form and the plant should be equipped to prepare and handle the chemical in that form. On the other hand, if only a small amount of coagulant is used, the chemical will be purchased in the form that can be applied most conveniently and economically. Another important factor in feeders is accuracy. Equipment should be capable of feeding the chemical within close limits, both for effectiveness of treatment and for economy.

***Dry**

Feeding

Equipment

In most dry feeders, the chemical is measured either by volume or by weight. For using volumetric feeders, the chemical must be reasonably uniform in particle size, because material ranging from lumps down to dust cannot be fed accurately by volume. With gravimetric feeders, particle size is of less importance.

Even when dry-feed machines are used, the chemical is dissolved or suspended in water before application.

Solution Feeding

In using solution feeders, solutions or suspensions of definite strength are so prepared that, when specific amount of solutions are applied, the quantity of chemical is easily determined. A constant-level tank with an adjustable orifice is used for applying large amounts of solution.

A float controls the level on the orifice, permitting accurate control of the dosage. Pumps are also used, a measured amount of solution of known strength being drawn at each stroke of the piston or plunger. For the most part, this type of feeder is applicable only to smaller installations.

Another method of application is to utilize devices in connection with meters measuring the flow of the water to be treated.

These must be of material that is not affected by the relatively strong concentration of chemical that is used. Tanks are generally of concrete to resist corrosion, though metal tanks protected with epoxy are also used. The dissolving boxes should be equipped with pipe manifolds for applying the water to the chemical after it has been weighed and placed in the tanks.

Most of the coagulating chemicals, such as aluminum sulfate and ferrous sulfate, are prepared in solutions having a strength of about 5 percent; therefore, the solution tanks should be sized to meet plant operating conditions and the amount of chemicals used daily.

Storage of Chemicals

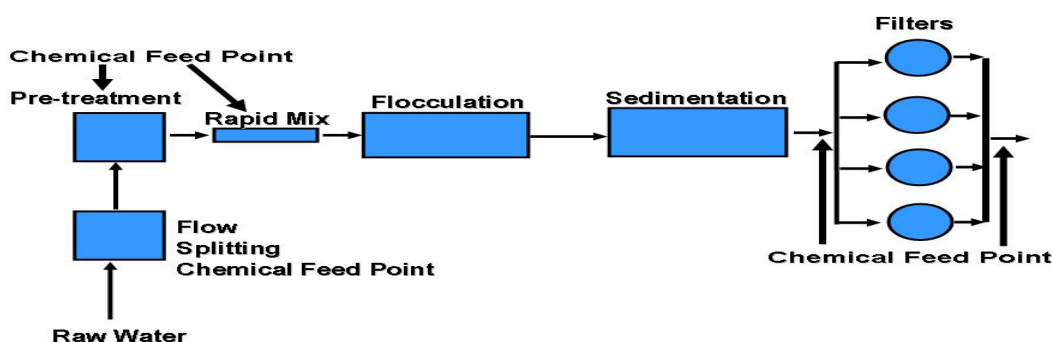
Provisions for storage and handling of chemicals vary greatly with the size of the plant. A plant treating 1 mgd of water and using 1 gpg of aluminum sulfate as a coagulant will require only 142 lb per day, and a 5-ton truckload will last for 2 months. Storage of 5 to 10 tons in bags may be provided, and handling the chemical will require very little daily labor.

On the other hand, a plant using 3 tons of aluminum sulfate daily must provide storage for 25 or more tons, since the shipment may be in bulk in carload lots or by heavy trucks. In the design of the plant, provision must be made for storage and for easy and economical handling of the chemical to the solution tanks or to the hoppers of the dry-feed machines.

Often, handling from storage bins will be by screw or belt conveyors. Weighing equipment should always be provided, both to check the weight of the chemical as it is delivered and to ensure that proper amounts are used in feeding.

The Filtration Process

Removal of suspended solids by filtration plays an important role in the natural treatment of groundwater as it percolates through the soil. It is also a major part of most water treatment. Groundwater that has been softened or treated through iron and manganese removal will require filtration to remove floc created by coagulation or oxidation processes. Since surface water sources are subject to run-off and do not undergo natural filtration, it must be filtered to remove particles and impurities.



The filter used in the filtration process can be compared to a sieve or microstrainer that traps suspended material between the grains of filter media. However, since most suspended particles can easily pass through the spaces between the grains of the filter media, straining is the least important process in filtration.

The photograph on the right illustrates debris removed during the backwash process. The particles are trapped on top of the filter media and trapped within the media.



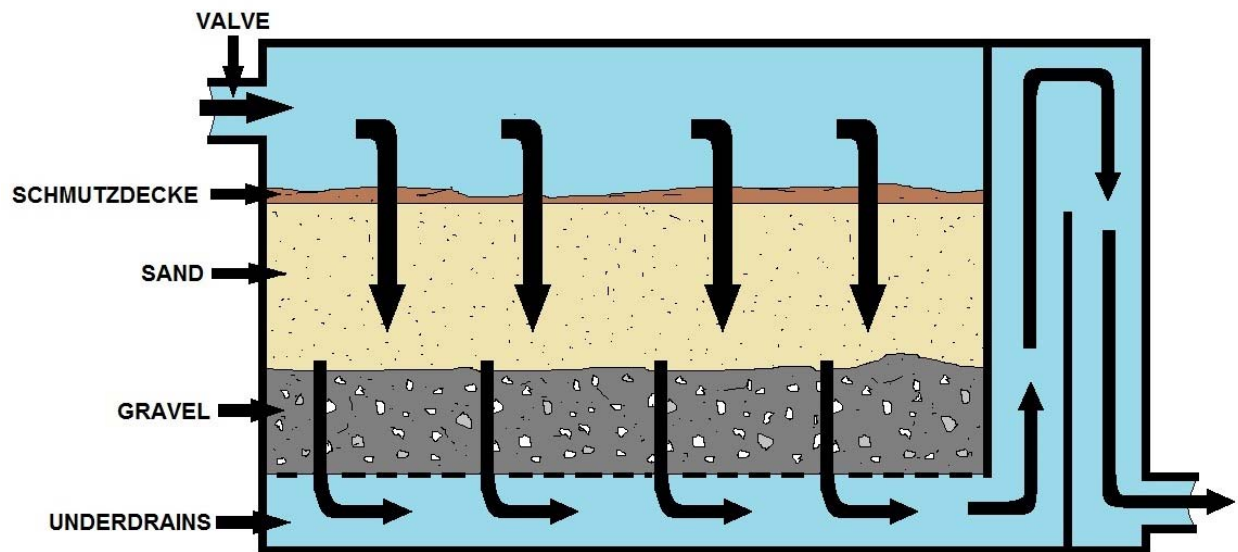
Filtration primarily depends on a combination of complex physical and chemical mechanisms, the most important being adsorption. Adsorption is the process of particles sticking onto the surface of the individual filter grains or onto the previously deposited materials. The forces that attract and hold the particles to the grains are the same as those that work in coagulation and flocculation. In fact, some coagulation and flocculation may occur in the filter bed, especially if coagulation and flocculation of the water before filtration was not properly controlled. Incomplete coagulation can cause serious problems in filter operation.

The photograph on the right shows small glass beads laid on top of a sieve.



Types of Filters

Several types of filters are used for water treatment. The earliest ones developed were the slow sand filters. They typically have filter rates of around 0.05 gpm/ft² of surface area. This type of filter requires large filter areas. The top several inches of the sand has to be removed regularly, usually by hand due to the mass of growing material ("***schmutzdecke***") that collects in the filter. The sand removed is usually washed and returned to the filter. These filters are still in use in some small plants, especially in the western United States as well as in many developing countries. They may also be used as a final step in wastewater treatment.



SLOW SAND FILTER

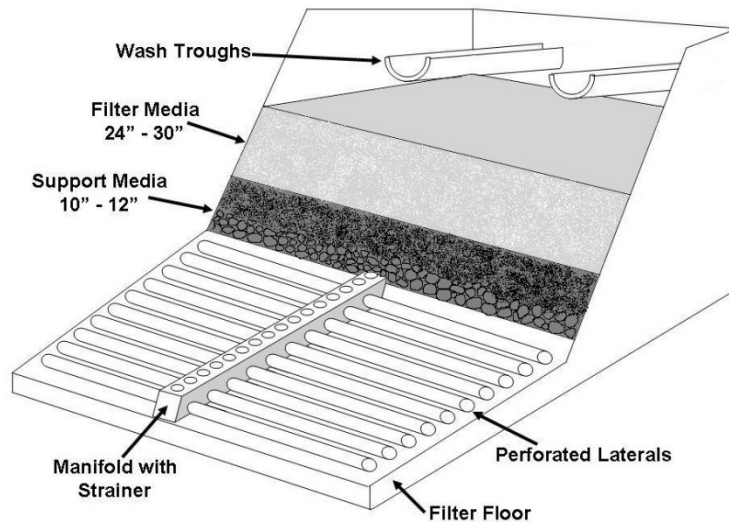
Most filters are classified by filtration rate, type of filter media, or type of operation into:

- A. Gravity Filters
 - 1. Rapid Sand Filters
 - 2. High Rate Filters
 - Dual media
 - Multi-media
- B. Pressure Filters
 - Sand or Multi-media

Rapid Sand Filters

Rapid sand filters can accommodate filter rates 40 times those of slow sand filters. The major parts of a rapid sand filter are:

- ◆ Filter tank or filter box
- ◆ Filter sand or mixed-media
- ◆ Gravel support bed
- ◆ Underdrain system
- ◆ Wash water troughs
- ◆ Filter bed agitators



The filter tank is generally constructed of concrete and is most often rectangular. Filters in large plants are usually constructed next to each other in a row, allowing the piping from the sedimentation basins to feed the filters from a central pipe gallery. Some smaller plants are designed with the filters forming a square of four filters with a central pipe gallery feeding the filters from a center well.

Filter Sand

The filter sand used in rapid sand filters is manufactured specifically for the purpose of water filtration. Most rapid sand filters contain 24-30 inches of sand, but some newer filters are deeper. The sand used is generally 0.4 to 0.6 mm in diameter. This is larger than the sand used in slow rate filtration. The coarser sand in the rapid filters has larger voids that do not fill as easily.

The gravel installed under the sand layer(s) in the filter prevents the filter sand from being lost during the operation. The under-gravel also distributes the backwash water evenly across the total filter. This under-gravel supports the filter sand and is usually graded in three to five layers, each generally 6-18 inches in thickness, depending on the type of underdrain used.

Underdrain

The filter underdrain can be one of many types, such as:

- ◆ Pipe laterals
- ◆ False floor
- ◆ Leopold system
- ◆ Porous plates or strainer nozzles
- ◆ Pipe laterals

A pipe lateral system uses a control manifold with several perforated laterals on each side. Piping materials include cast iron, asbestos cement, and PVC. The perforations are usually placed on the underside of the laterals to prevent them from plugging with sand. This also allows the backwash to be directed against the floor, which helps keep the gravel and sand beds from being directly disturbed by the high velocity water jets.

False floor

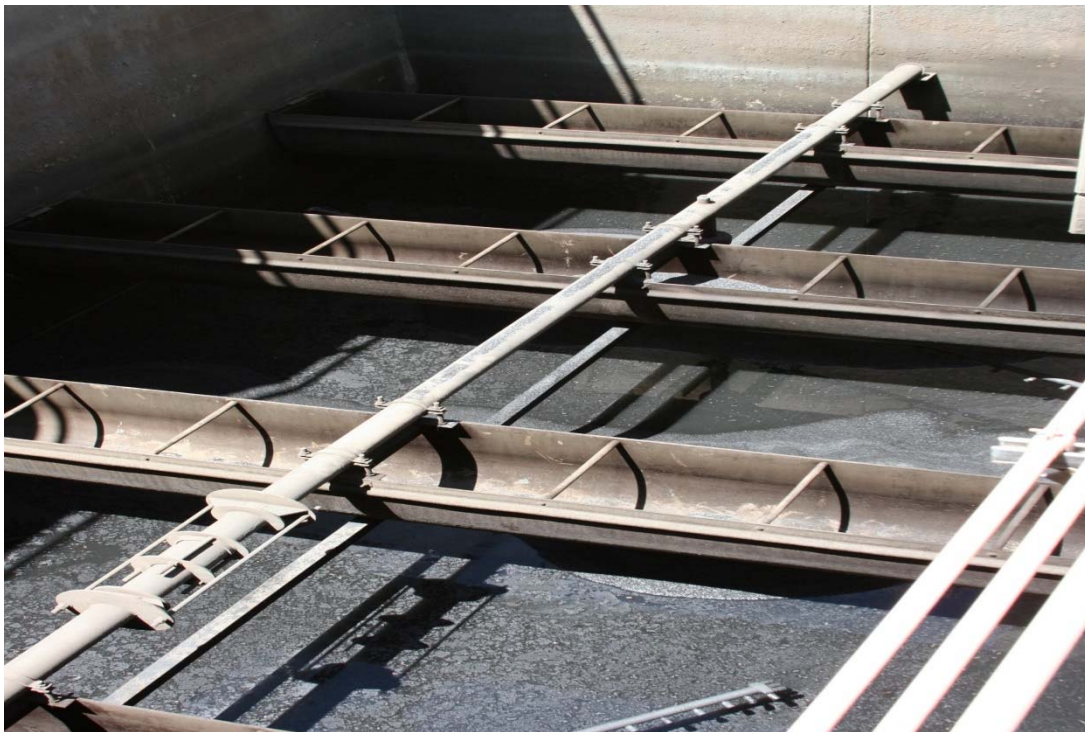
The false floor design of a filter underdrain is used together with a porous plate design or with screens that retain the sand when there is no undergravel layer. This type of underdrain allows the plenum or open space under the floor to act as the collection area for the filtered water and for the distribution of the filter backwash water.

Leopold system

The Leopold system consists of a series of clay or plastic blocks that form the channels to remove the filtered water from the filter and distribute the backwash water. This type of underdrain is generally used with an undergravel layer, although some new designs allow for sand retention without gravel.

Washwater Troughs

Washwater troughs placed above the filter media collect the backwash water and carry it to the drain system. Proper placement of these troughs is very important to ensure that the filter media is not carried into the troughs during the backwash and removed from the filter. The wash troughs must be installed at the same elevation so that they remove the backwash evenly from the filter and so that an even head is maintained across the entire filter. These backwash troughs are constructed from concrete, plastic, fiberglass, or other corrosion-resistant materials.



The photograph above shows exposed filter troughs.

Surface Wash



The photograph above shows a drained filter with the agitator and nozzles exposed. During operation these will spin spraying water during the water backwash.

During the operation of a filter, the upper six-to-ten inches of the filter media remove most of the suspended material from the water. It is important that this layer be thoroughly cleaned during the backwash cycle. Normal backwashing does not, in most cases, clean this layer completely; therefore, some method of agitation is needed to break up the top layers of the filter and to help the backwash water remove any material caught there.



The surface wash system consists of a series of pipes installed in the filter that introduce high velocity water or air jet action into the upper layer of the filter. This jet action will generally be supplied by rotating arms that are activated during the backwashing of the filter.

A newer design of surface wash uses compressed air to mix the upper layer and loosen the particles from the sand so that the backwash water can remove the particles more easily. This air wash generally is turned on before the backwash cycle.

If both are used at the same time, some sand may be washed away. The compressed air rate can be two-to-five cubic feet per minute per square foot (cfm/ft²) of filter surface, depending on the design of the filter.

High Rate Filters

High rate filters, which operate at a rate three-to-four times that of rapid sand filters, use a combination of different filter media, not just sand. The combinations vary with the application, but generally they are sand and anthracite coal. Multi-media or mixed-media filters use three or four different materials, generally sand, anthracite coal, and garnet.



In this photograph you can see the water lines on the wall of the filter. The deeper the water the more head pressure exerted on the filter media.

In rapid sand filters, finer sand grains are at the top of the sand layer with larger grains farther down into the filter. As a result, the filter removes more suspended material in the first few inches of the filter. In the high rate filter, the media size decreases. The top layers consist of a coarse material with the finer material farther down, allowing the suspended material to penetrate deeper into the filter.

The material in a filter bed forms layers in the filter, depending on their weight and specific gravities. In the coarse layer at the top, the larger suspended particles are removed first, followed by the finer materials. This allows for longer filter runs at higher rates than is possible with rapid sand filters.

The type of filter media used in a high rate filter depends on many factors, including the raw-water quality, raw-water variations, and the chemical treatment used. Pilot studies help the operator evaluate which material, or combination of materials, will give the best result.

Pressure Filters

Pressure filters fall into two categories: pressure sand and diatomite filters.

Pressure Sand Filters

This type of filter is used extensively in iron and manganese removal plants.

A pressure sand filter is contained under pressure in a steel tank, which may be vertical or horizontal, depending on the space available. As with gravity filters, the media is usually sand or a combination of media. Filtration rates are similar to gravity filters.

These filters are commonly used for iron and manganese removal from groundwater, which is first aerated to oxidize the iron or manganese present, then pumped through the filter to remove the suspended material.



Filter Media



Because the water is under pressure, air binding will not occur in the filter. However, pressure filters have a major disadvantage in that the backwash cannot be observed; in addition, cracking of the filter bed can occur quite easily, allowing the iron and manganese particles to go straight through the filter.

When using pressure filters for iron and manganese removal, the operator must regularly measure the iron and manganese concentration of the filter effluent and backwash the filter before breakthrough occurs. Because of these limitations, pressure filters must not be used to treat surface water.

Diatomaceous Earth Filter

This type of filter is commonly used for the treatment of swimming pools. The process was developed by the military during World War II to remove microorganisms that cause amoebic dysentery from water used in the field.



Two basic types of filtration processes are currently used in the United States. Conventional filtration, the traditional design for many years, provides effective treatment for just about any range of raw-water turbidity. Its success is due partially to the sedimentation that precedes filtration and follows the coagulation and flocculation steps. Sedimentation, if operated properly, should remove most of the suspended material.



Direct filtration plants have a lower capital cost. However, the process cannot handle large variations in raw water turbidity.



Filtration Operation

Filtration operation is divided into three steps: filtering, backwashing, and filtering to waste.

Filter Control of the filter operation requires the following equipment:

- ◆ Rate of flow controller
- ◆ Loss of head indicator
- ◆ On-line turbidimeter

Rate of Flow Controllers

Flow rates through filters are controlled by one of two different methods:

Declining rate

This method of control is used where the head loss through the plant is quite large. It allows the filter head to increase until the filter becomes plugged with particles and the head loss is too great to continue operation of the filter. The rate through the filter is much greater in the beginning of a filter run than at the end when the filter is dirty. This method tends to be the most commonly installed in new filter plants.

The photograph on the right shows operators walking through the filter gallery of a plant that uses declining rate filters. This is also showing pipelines to and from the filter boxes.



Constant rate

This type of control monitors the level of water on the top of the filter and attempts to control this level from the start of the operation to the end. This is accomplished by the controller operating a valve on the effluent of the filter. The valve will be nearly closed at the start of the filter run and fully open at the end. This design is used when the head or pressure on the filter is limited.



The photograph above shows the overflow in case the filter level gets too high.

Both controllers consist of a venturi tube or some other type of metering device as well as a valve to control the flow from the filter. In most cases, the valve is controlled by an automatic control device, often an air-actuated type valve that is controlled by the flow tube controller.

Loss of head indicator

As filtration proceeds, an increasing amount of pressure, called head loss across the filter, is required to force the water through the filter. The head loss should be continuously measured to help determine when the filter should be backwashed.

Usually the difference in the head is measured by a piezometer connected to the filter above the media and the effluent line.

In-line turbidimeter

Turbidity in water is caused by small suspended particles that scatter or reflect light so that the water appears to be cloudy.

Turbidity of the filtered water may shelter bacteria, preventing chlorine from reaching it during the final disinfection process. The turbidity of the filtered water is one of the factors that determine the length of a filter run. At some point, the suspended material will start to break through the filter media and increase the turbidity of the filter effluent. At this time, the filter should be backwashed.

Continuous turbidity monitors provide information about when the filter is approaching this point so that the operators can start the backwash before the turbidity is too great. Turbidity measurements will also indicate whether the coagulation and other treatment processes are operating properly.



More on Filtration Process

Water from the source or, more commonly, from pre-treatment processes, is applied to the top of the filter; it then flows downward. The water level above the filter bed is usually kept at two-to-six feet. When the filtration is started after being backwashed, there will be little head loss. In filters with a control valve installed on the filter effluent pipe, the filter flow is restricted during this time. The control valve also has the important function of preventing filter surges, which could disturb the media and force floc through the filter.

The rate of flow on a filter depends on the type of filter. A rapid sand filter will have a flow of two-to-three gpm/square foot of filter area. The high rate filter may have four-to-six gpm/square foot applied to the surface. A constant rate flow valve is almost fully closed when a filter is clean so that the desired water level on top of the filter is maintained. As the filter becomes dirty with suspended material, the valve opens gradually until the increase in the water level above the filter indicates that the filter needs backwashing.



The photograph above is a filter from a direct filtration plant; notice the size of the floc?

In filters with variable declining rate flow control, the filters are allowed to take on as much water as they can handle. As the filters become dirty, both the headloss and the depth of the water on the surface increase until the filters need backwashing.

This method is generally preferred because it requires less operator attention. With this method, a filter accepts as much flow as it can handle. As the filter becomes dirty, the flow through the filter becomes less and, if the plant has more than one filter, additional flow redistributes across the other filters. A flow restrictor is placed in the filter effluent pipe to prevent a filter inflow that is too great for the filter.

Regardless of the method of control, the filter eventually fills with suspended material. At some time, usually after 15 to 30 hours, it will need to be backwashed to clean the media.

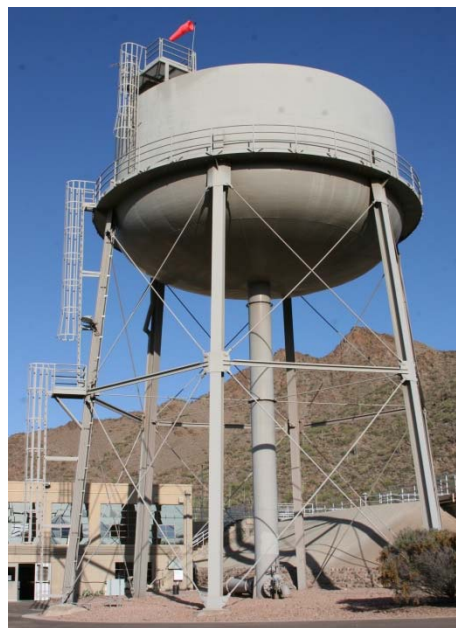
Back Washing

Proper backwashing is a very important step in the operation of a filter. If the filter is not backwashed completely, it will eventually develop additional operational problems. If a filter is to operate efficiently, it must be cleaned before the next filter run. Treated water from storage is used for the backwash cycle. This treated water is generally taken from elevated storage tanks or pumped in from the clear well.

During filtration, the filter media becomes coated with the floc, which plugs the voids between the filter grains, making the filter difficult to clean. The media must be expanded to clean the filter during the backwash. This expansion causes the filter grains to violently rub against each other, dislodging the floc from the media.

The filter backwash rate has to be great enough to expand and agitate the filter media and suspend the flocs in the water for removal. However, if the filter backwash rate is too high, media will be washed from the filter into the troughs and out of the filter. A normal backwash rate is between 12 to 15 gpm per square foot of filter surface area.

In most cases the filter backwash rate will not break up the mass on the top of the filter. The design engineer will recommend the installation of a surface wash of some type, the most common being a set of rotary arms that are suspended above the media during filtration. During filter backwash, the media expands upwards and around the washing arms. A newer method of surface wash involves using air scour before the water wash. This is a very efficient method, but requires the installation of a large air blower to produce the air. The normal design for the air wash will be two-to-five cubic feet of air per square foot of filter area.



Both photographs are important components of the backwash equipment.

The filter should be backwashed when the following conditions have been met:

- ◆ The head loss is so high that the filter no longer produces water at the desired rate; and/or
- ◆ Floc starts to break through the filter and the turbidity in the filter effluent increases; and/or
- ◆ A filter run reaches a given hour of operation.
- ◆ If a filter is taken out of service for some reason, it must always be backwashed prior to be putting on line.

The decision to backwash the filter should not be based on only one of the above conditions. If a filter is not backwashed until the headloss exceeds a certain number of feet, the turbidity may break through and cause the filter to exceed the standard of 0.5 NTU of turbidity.

Similarly, depending on filter effluent- turbidity alone can cause high head loss and decreased filter flow rate, which can cause the pressure in the filter to drop below atmospheric pressure and cause the filter to air bind and stop filtering.

If the water applied to a filter is very good quality, the filter runs can be very long. Some filters can operate longer than one week before needing to be backwashed.

However, this is not recommended as long filter runs can cause the filter media to pack down so that it is difficult to expand the bed during the backwash.

Backwashing Process

The normal method for backwashing a filter involves draining the water level above the filter to a point six inches above the filter media.

The surface wash is then turned on and allowed to operate for several minutes to break up the crust on the filter.

After that, the backwash valve is opened, allowing backwash water to start flowing into the filter and start carrying suspended material away from the filter. For a filter with an air wash instead of a water-surface wash, the filter backwash water and the air wash should not be used together. This would be possible only if some means of controlling the media carryover is installed.





This is a filter control panel.

The time elapsed from when the filter wash is started until full flow is applied to the filter should be greater than one minute. After a few minutes, the filter backwash valve should be fully opened to allow full expansion of the filter media. Generally, this expansion will be from 20 to 40 percent over the normal filter bed volume.

The expansion needed will depend on how much agitation is needed to suspend the filter media to remove to suspended material trapped in the filter. With a multi-media filter, the rate must be high enough to scrub the interface between the coal and the sand, where the highest amount of suspended solids will be removed from the media. The filter will be washed for 10 to 15 minutes, depending on the amount of solids that must be removed.

The best way to determine how long the filter should be washed is to measure the turbidity of the backwash water leaving the filter. In most cases, a filter is washed too long. This could be costly. Too much backwash water is used, and it must be treated after use. Backwash valves must be opened slowly. Opening the valves too rapidly can cause serious damage to the filter underdrain, filter gravel, and filter media.

Disposal of Filter Backwash Water

Water from the filter backwash cannot be returned directly to the environment. Normally the water is discharged into a backwash tank and allowed to settle. The supernatant, or cleared liquid, is then pumped back to the head of the treatment plant at a rate not exceeding ten percent of the raw water flow entering the plant. The settled material is pumped to a sewer or is treated in the solids-handling process of the plant. This conserves most of the backwash water and eliminates the need to obtain a pollution discharge permit for the disposal of the filter backwash water.



Since backwash is a very high flow operation, the surges that are created from the backwash coming from the filter must not be allowed to enter the head of the plant. Therefore, the spent backwash water must be stored in storage tanks and returned slowly to the treatment process.

Filter to Waste

When filtration is started after backwash, filtered water should be wasted until the turbidity in the effluent meets standards. Depending on the type of filter, this may last from two to 20 minutes. This wasting is needed as some suspended material remains in the filter media following the backwash. The media needs to become somewhat sticky again to start to capture the suspended material.

Also, the filtration rate is higher in a clean filter, causing more material to be swept from the filter during the start-up. Filtration should always be started slowly after a backwash to prevent breakthrough of suspended material.



Filter Aids

Sometimes, when water passes through a filter, the floc is torn apart into smaller particles that will penetrate deeply into the filter media, causing premature turbidity breakthrough.

This will require more frequent filter backwashing of the filter and use of large volumes of backwash water to be able to remove the floc that has penetrated deeply into the filter bed.

A filter aid is a material that adds strength to the floc and prevents its breakup. Generally, a polymer is used as a filter aid because it creates strong bonds with the floc. Polymers are water-soluble, organic compounds that can be purchased in either wet or dry form.





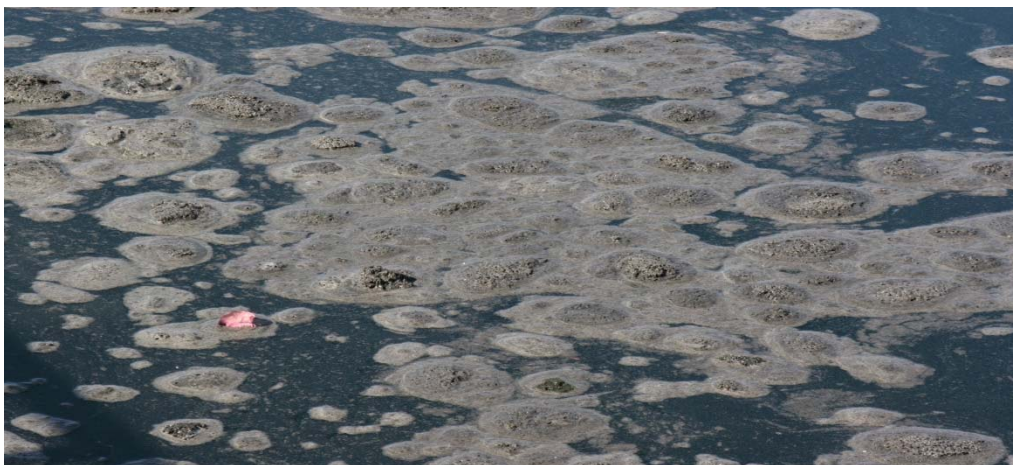
The photograph on the right is dry polymer and on the left is liquid.

Polymers have very high molecular weight and cause the floc to coagulate and flocculate quickly. Polymers can have positive or negative charges, depending on the type needed to cause attraction to the specific floc filtered.

When used as a filter aid, the polymer strengthens the bonds and prevents the shearing forces in the filter from breaking the floc apart. For best results, the polymer should be added just ahead of the filter. A normal dose of polymer for filter aiding will be less than 0.1 ppm, but the exact dose will be decided by the result of a jar test and by experimentation in the treatment plant. Too much polymer will cause the bonds to become too strong, which may then cause the filter to plug, especially the top few inches of the filter media.

Filter Operating Problems

There are three major types of filter problems. They can be caused by chemical treatment before the filter, control of filter flow rate, and backwashing of filters.



The above photograph shows clumps formed by powder activated carbon.

Chemical Treatment before the Filter

The coagulation and flocculation stages of the water treatment must be monitored continuously. Adjustments in the amount of coagulant added must be made frequently to prevent the filter from becoming overloaded with suspended material. This overload may cause the filter to prematurely reach its maximum headloss.

If there is early turbidity breakthrough in the filter effluent, more coagulant may have to be added to the coagulation process. There may be a need for better mixing during the coagulation or the addition of more filter aid.

Filter aid being fed at the weirs of sedimentation.

If there is a rapid increase in filter head loss, too much coagulant may be clogging the filter. Less coagulant or less filter aid should be used. The operator needs to learn to recognize these problems and choose the proper corrections.



In the photograph above, overfeeding flocculants to meet federal regulations caused iron to precipitates on the filter walls.

Control of Filter Flow Rate

When a filter is subjected to rapid changes in flow rate, the turbidity of the effluent may be affected; the dirtier the filter media, the greater the effect.

When a plant flow changes, the filter flow also has to change to produce the water needed. If an increase is necessary, the flow should, if possible, be increased gradually over a ten-minute period to reduce the impact on the filter. Addition of filter aids may also reduce the impact on the filter effluent.

When backwashing a filter and therefore temporarily taking it out of service, the remaining filter(s) must pick up the additional flow. This can cause an abrupt change in flow that will cause turbidity breakthrough. This problem can be avoided by keeping one filter in reserve to accept this additional flow. If the plant has a backwash storage basin, this will also prevent surges to the filters.

Filter	Value	Unit	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future	
Available	1	1												
Available	2	2												
Available	3	3												
Available	4	4												
Available	5	5												
Available	6	6												
Available	7	7												
Available	8	8												
Available	9	9	Filter No.9	DCS	Add									
Available	10	10	Filter No.10	DCS	Add									
Available	11	11	Filter No.11	DCS	Add									
Available	12	12	Filter No.12	DCS	Add	Enabled	0.08	0.25	29.5	60.0	5.27	1.00	3.07	6.00
Available	13	13	Filter No.13	DCS	Add	Enabled	0.09	0.30	9.6	72.0	7.36	1.00	3.98	6.00
Available	14	14	Filter No.14	DCS	Add	Enabled	0.08	0.25	47.7	60.0	7.30	1.00	6.57	7.00
Available	15	15	Filter No.15	DCS	Add	Enabled	0.08	0.25	39.5	60.0	7.18	1.00	6.78	6.00
Available	16	16	Filter No.16	DCS	Add	Enabled	0.08	0.25	14.2	60.0	8.60	1.00	5.83	6.00
			Filter No.17	DCS	Add	Enabled								
			Filter No.18	DCS	Add	Enabled								
			Filter No.19	DCS	Add	Enabled								
			Filter No.20	DCS	Add	Enabled	0.07	0.25	58.2	60.0	7.64	1.00	5.38	6.00
			Filter No.21	DCS	Add	Enabled	0.10	0.30	5.2	60.0	7.42	1.00	3.90	6.00
			Filter No.22	DCS	Add	Enabled								
			Filter No.23	DCS	Add	Enabled	0.08	0.25	15.1	60.0	8.31	1.00	4.87	6.00
			Filter No.24	DCS	Add	Enabled								

PLANT 2

EXIT

Many plants are not operated continuously, and the start-up at the beginning of the day will cause a surge to the filter(s). The filters should be backwashed before putting them back into operation or operated to waste until the effluent meets the standards.

Backwashing of Filters

Backwashing of the filters is the single most important operation in the maintenance of the filters. If the filter is not backwashed effectively, problems may occur that may be impossible to correct without totally replacing the filter media. These problems could be caused by improper backwashing procedures:

- Mud balls are formed by the filter media cementing together with the floc that the filter is supposed to remove. If the filter is backwashed effectively, the mud balls are broken apart and removed. As the balls gain weight, they will settle to the bottom of the filter and occupy valuable filter volume. This will cause the flow to increase in the areas of the filter that have not been plugged. Additional problems, such as filter cracking and separation of the media from the filter walls may also be the result of mud-ball formation.

- ◆ Filter bed shrinkage or compaction can result from ineffective backwashing. Media grains in a clean filter rest directly against each other with very little compaction. Filter media in a dirty filter are surrounded by a soft layer which causes it to compact. This causes filter bed cracking and separation of the filter media from the walls of the filter. When the filter is cracked, it is obvious that the filter will short circuit. The flow will seek the crack and go straight through, resulting in excessive turbidity in the effluent.



A photograph of a backwash basin that has media caked on the bottom.

- ◆ Separation of the gravel is caused by the backwash valve opening too quickly; as a result, the supporting gravel is forced to the top of the filter. This could also be caused by the filter underdrain being plugged, causing uneven distribution of the backwash water. When this happens, a boil occurs from the increased velocity in the filter. The filter media will start washing into the filter underdrain system and be removed from the filter. If displacement has occurred, the filter media must be removed from the filter and the filter rebuilt by the placement of each grade of media in its proper place.
- ◆ Air binding of the filter is not common as long as the filter is washed regularly. Air binding is the result of pressure in the filter becoming negative during operation. This causes the air dissolved in the water to come out of the solution and become trapped in the filter, resulting in resistance and short filter runs. This negative head generally occurs in a filter that has less than five feet of head above the unexpanded filter bed. If a filter head of five feet is not possible, filter backwash should be started at a lower head loss than normal.

The photograph on the right shows a filter support bed under construction.

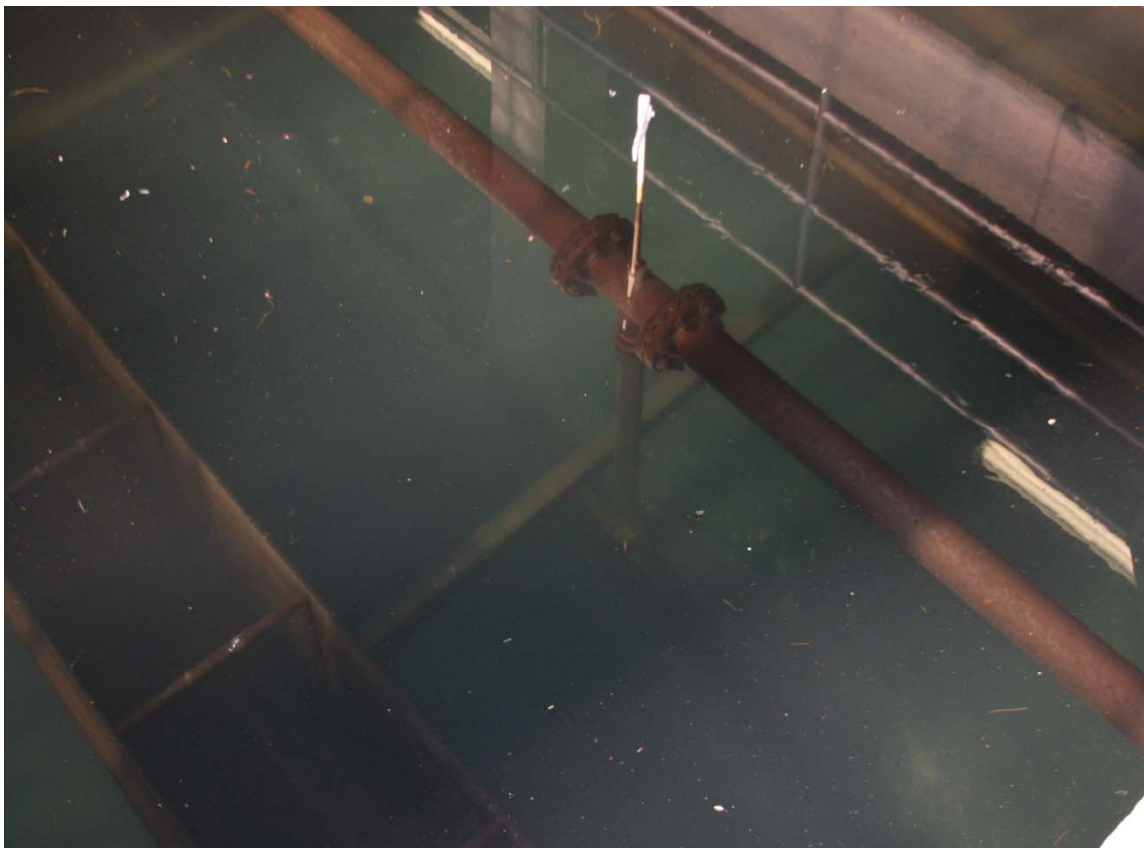


Air binding can also be caused by the water being cold and super-saturated with air. This air bubbles out as the water warms up. It is not possible for the operator to control this situation. If it happens, the filter must be backwashed more frequently to correct the filter air binding.

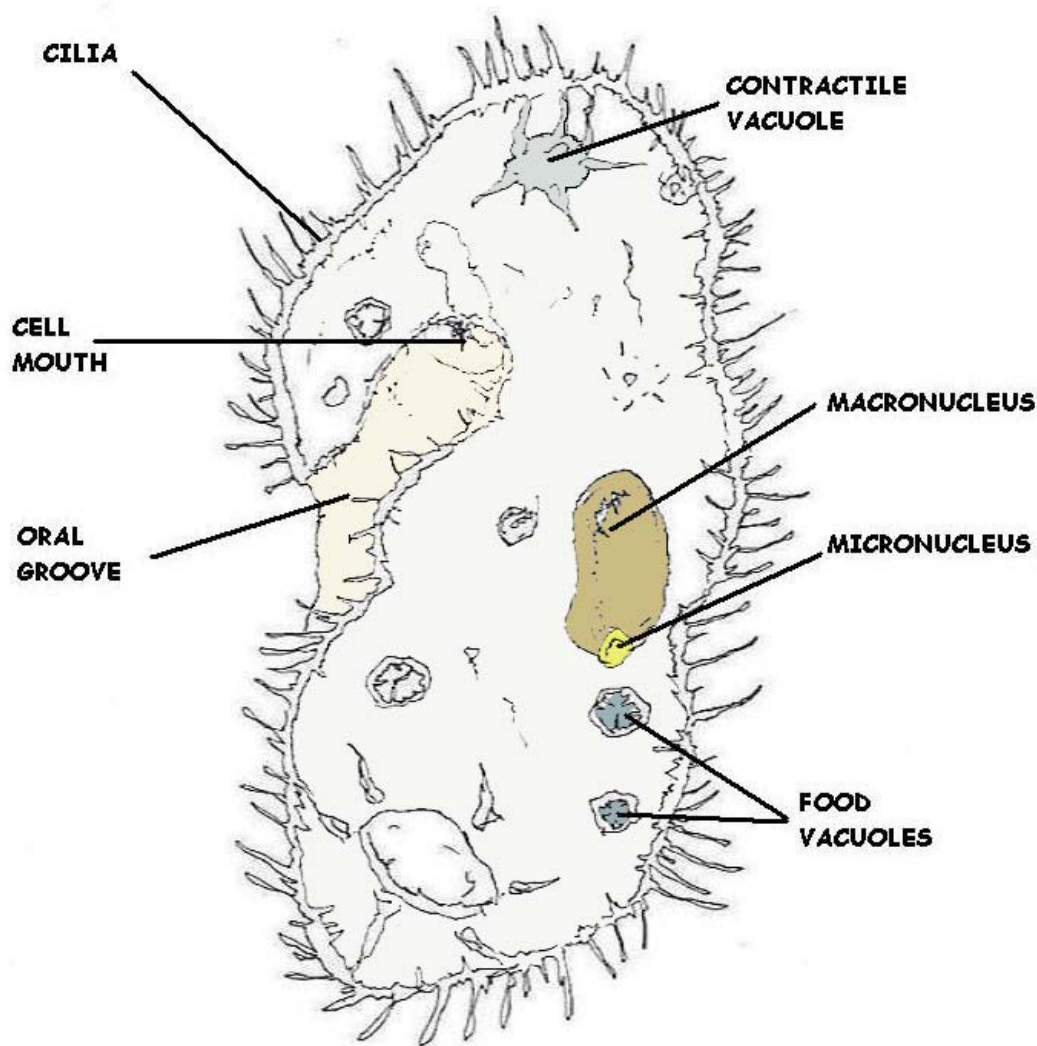
- ◆ Media loss is normal in any filter. Some are lost each time the filter is backwashed, especially if the filter surface wash is used. If a large amount of media is being lost, the method of washing should be inspected and corrected. The bed should not have to be expanded more than 20 percent during the backwash cycle. It may help to turn off the surface wash approximately two minutes before the end of the backwash. If this does not correct the problem, the filter troughs may have to be raised to prevent the excessive media loss.

Filter On-Line

After a well-operated filter backwash, the filter should be level and smooth with no cracks or mud balls at the surface. A good bed will appear to move laterally during the backwash and there will be no boils at the surface. The filter should clear up evenly cleaning. If some areas are not clean, there could be an under-drain problem.



Mudballs can be seen on the top layer of the media bed or during the backwash water cycle. Typically, these mudballs will not flow over into the filter troughs.



PARAMECIUM

Paramecia

Paramecia are a group of unicellular ciliate protozoa formerly known as slipper animalcules from their slipper shape. They are commonly studied as a representative of the ciliate group. Simple cilia cover the body which allows the cell to move with a synchronous motion (like a caterpillar). There is also a deep oral groove containing inconspicuous compound oral cilia (as found in other peniculids) that is used to draw food inside.

They generally feed upon bacteria and other small cells. Osmoregulation is carried out by a pair of contractile vacuoles, which actively expel water absorbed by osmosis from their surroundings. Paramecia are widespread in freshwater environments, and are especially common in scums. Paramecia are attracted by acidic conditions. Certain single-celled eukaryotes, such as Paramecium, are examples for exceptions to the universality of the genetic code (translation systems where a few codons differ from the standard ones).

Waterborne Pathogen Section

Bacteria, viruses, and protozoan that cause disease are known as pathogens. Most pathogens are generally associated with diseases that cause intestinal illness and affect people in a relatively short amount of time, generally a few days to two weeks. They can cause illness through exposure to small quantities of contaminated water or food or from direct contact with infected people or animals.

How Diseases are Transmitted

Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral or feces-to-mouth route. Pathogens may get into water and spread when infected humans or animals pass the bacteria, viruses, and protozoa in their stool. For another person to become infected, he or she must take that pathogen in through the mouth. Waterborne pathogens are different from other types of pathogens such as the viruses that cause influenza (the flu) or the bacteria that cause tuberculosis. Influenza virus and tuberculosis bacteria are spread by secretions that are coughed or sneezed into the air by an infected person.

Human or animal wastes in watersheds, failing septic systems, failing sewage treatment plants or cross-connections of water lines with sewage lines provide the potential for contaminating water with pathogens. The water may not appear to be contaminated because the feces has been broken up, dispersed, and diluted into microscopic particles. These particles, containing pathogens, may remain in the water and be passed to humans or animals unless adequately treated. Only proper treatment will ensure eliminating the spread of disease. In addition to water, other methods exist for spreading pathogens by the fecal-oral route. The foodborne route is one of the more common methods. A frequent source is a food handler who does not wash his hands after a bowel movement and then handles food with “*unclean*” hands. The individual who eats feces-contaminated food may become infected and ill. It is interesting to note the majority of foodborne diseases occur in the home, not restaurants.

Day care centers are another common source for spreading pathogens by the fecal-oral route. Here, infected children in diapers may get feces on their fingers, then put their fingers in a friend’s mouth or handle toys that other children put into their mouths. The general public and some of the medical community usually refer to diarrhea symptoms as “stomach flu.” Technically, influenza is an upper respiratory illness and rarely has diarrhea associated with it; therefore, stomach flu is a misleading description for foodborne or waterborne illnesses, yet is accepted by the general public. So the next time you get the stomach flu, you may want to think twice about what you’ve digested within the past few days.

Chain of Transmission

Water is contaminated with feces. This contamination may be of human or animal origin. The feces must contain pathogens (disease-causing bacteria, viruses or protozoa). If the human or animal source is not infected with a pathogen, no disease will result. The pathogens must survive in the water. This depends on the temperature of the water and the length of time the pathogens are in the water.

Some pathogens will survive for only a short time in water, others, such as *Giardia* or *Cryptosporidium*, may survive for months. The pathogens in the water must enter the water system’s intake and in numbers sufficient to infect people. The water is either not treated or inadequately treated for the pathogens present. A susceptible person must drink the water that contains the pathogen. Illness (disease) will occur. This chain lists the events that must occur for the transmission of disease via drinking water. By breaking the chain at any point, the transmission of disease will be prevented.



Bacterial Diseases

Campylobacteriosis is the most common diarrhea illness caused by bacteria. Symptoms include abdominal pain, malaise, fever, nausea and vomiting; they usually begin three to five days after exposure. The illness is frequently over within two to five days and usually lasts no more than 10 days. Campylobacteriosis outbreaks have most often been associated with food, especially chicken and unpasteurized milk, as well as unchlorinated water.

These organisms are also an important cause of “travelers’ diarrhea.” Medical treatment generally is not prescribed for campylobacteriosis because recovery is usually rapid.

*Cholera, Legionellosis, Salmonellosis, Shigellosis, and Yersiniosis are other bacterial diseases that can be transmitted through water. All bacteria in water are readily killed or inactivated with chlorine or other disinfectants.

Viral-Caused Diseases

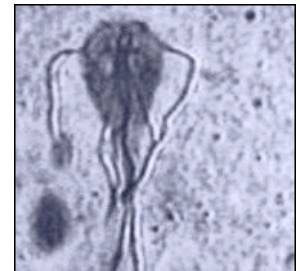
Hepatitis A is an example of a common viral disease that may be transmitted through water. The onset is usually abrupt with fever, malaise, loss of appetite, nausea and abdominal discomfort, followed within a few days by jaundice. The disease varies in severity from a mild illness lasting one to two weeks, to a severely disabling disease lasting several months (rare).

The incubation period is 15-50 days and averages 28-30 days. Hepatitis A outbreaks have been related to fecally contaminated water; food contaminated by infected food handlers, including sandwiches and salads that are not cooked or are handled after cooking, and raw or undercooked mollusks harvested from contaminated waters. Aseptic meningitis, polio and viral gastroenteritis (Norwalk agent) are other viral diseases that can be transmitted through water. Most viruses in drinking water can be inactivated by chlorine or other disinfectants.

Protozoan Caused Diseases

Protozoan pathogens are larger than bacteria and viruses, but still microscopic. They invade and inhabit the gastrointestinal tract. Some parasites enter the environment in a dormant form, with a protective cell wall called a “cyst.” The cyst can survive in the environment for long periods of time and be extremely resistant to conventional disinfectants such as chlorine. Effective filtration treatment is therefore critical to removing these organisms from water sources.

Giardiasis is a commonly reported protozoan-caused disease. It has also been referred to as “backpacker’s disease” and “beaver fever” because of the many cases reported among hikers and others who consume untreated surface water. Symptoms include chronic diarrhea, abdominal cramps, bloating, frequent loose and pale greasy stools, fatigue and weight loss. The incubation period is 5-25 days or longer, with an average of 7-10 days.



Many infections are asymptomatic (no symptoms). Giardiasis occurs worldwide. Waterborne outbreaks in the United States occur most often in communities receiving their drinking water from streams or rivers without adequate disinfection or a filtration system. The organism, *Giardia lamblia*, has been responsible for more community-wide outbreaks of disease in the U.S. than any other pathogen. Drugs are available for treatment but are not 100% effective.

Cryptosporidiosis is an example of a protozoan disease that is common worldwide, but was only recently recognized as causing human disease. The major symptom in humans is diarrhea, which may be profuse and watery. The diarrhea is associated with cramping abdominal pain. General malaise, fever, anorexia, nausea, and vomiting occur less often. Symptoms usually come and go, and end in fewer than 30 days in most cases. The incubation period is 1-12 days, with an average of about seven days. *Cryptosporidium* organisms have been identified in human fecal specimens from more than 50 countries on six continents.



The mode of transmission is fecal-oral, either by person-to-person or animal-to-person. There is no specific treatment for *Cryptosporidium* infections. All of these diseases, with the exception of hepatitis A, have one symptom in common: diarrhea.

They also have the same mode of transmission, fecal-oral, whether through person-to-person or animal-to-person contact, and the same routes of transmission, being either foodborne or waterborne. Although most pathogens cause mild, self-limiting disease, on occasion, they can cause serious, even life threatening illness. Particularly vulnerable are persons with weak immune systems, such as those with HIV infections or cancer.

By understanding the nature of waterborne diseases, the importance of properly constructed, operated and maintained public water systems becomes obvious. While water treatment cannot achieve sterile water (no microorganisms), the goal of treatment must clearly be to produce drinking water that is as pathogen-free as possible at all times. For those who operate water systems with inadequate source protection or treatment facilities, the potential risk of a waterborne disease outbreak is real. For those operating systems that currently provide adequate source protection and treatment, operating and maintaining the system at a high level on a continuing basis is critical to prevent disease.

Waterborne Diseases

Name	Causative organism	Source of organism	Disease
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Viral gastroenteritis	Rotavirus (mostly in young children)	Human feces;	Diarrhea or vomiting
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Norwalk-like viruses	Human feces; also, shellfish; lives in polluted waters;		Diarrhea and vomiting
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Salmonellosis	Salmonella (bacterium)	Animal or human feces.	Diarrhea or vomiting
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Gastroenteritis	Escherichia coli-- E. coli O1 57:H7 (bacterium); Other <i>E. coli</i> organisms;	Human feces;	symptoms vary with type caused
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Typhoid	Salmonella typhi (bacterium)	Human feces, urine;	Inflamed intestine, enlarged spleen, high temperature— sometimes fatal.
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Shigellosis	Shigella (bacterium)	Human feces.	Diarrhea
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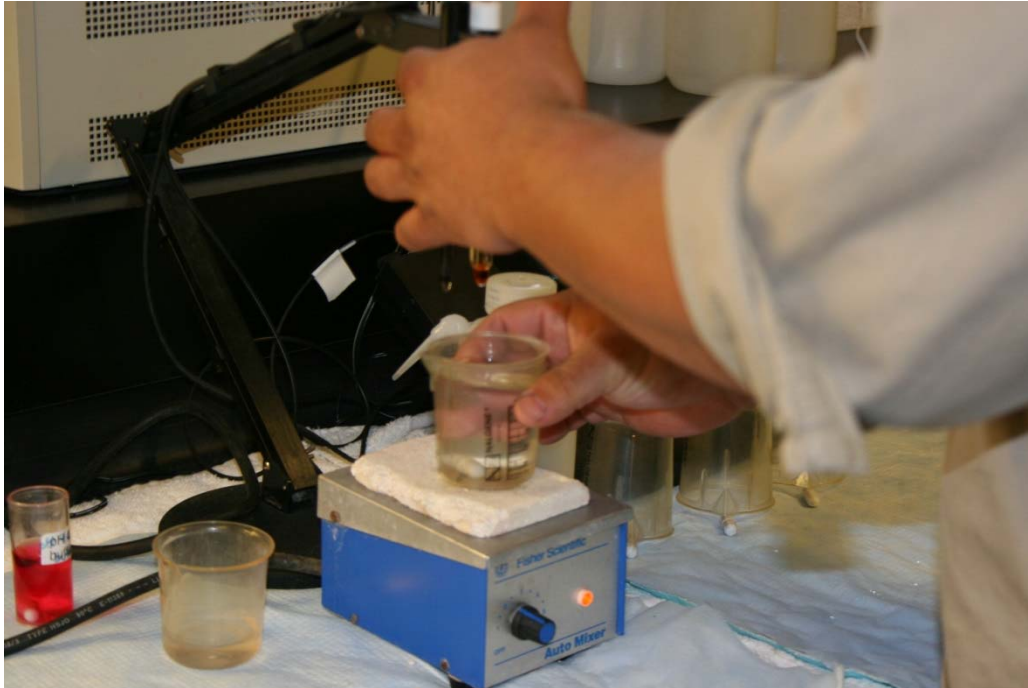
Cholera	Vibrio choleras (bacterium)	Human feces; also, shellfish; lives in many coastal waters;	Vomiting, severe diarrhea, rapid dehydration, mineral loss —high mortality.
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Hepatitis A	virus	Human feces; shellfish grown in polluted waters;	Yellowed skin, enlarged liver, fever, vomiting, weight loss, abdominal pain — low mortality, lasts up to four months.
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Amebiasis	Entamoeba histolytica (protozoan)	Human feces;	Mild diarrhea, dysentery, extra intestinal infection
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Giardiasis	Giardia lamblia (protozoan)	Animal or human feces.	Diarrhea, cramps, nausea, and general weakness — lasts one week to months.
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Cryptosporidiosis	Cryptosporidium parvum	Animal or human feces.	Diarrhea, stomach pain — lasts (protozoan) days to weeks.
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The above photograph is a pH test and the bottom is a lab tech performing a Presence/Absence test on a Bac-T sample.



Jar Testing

Jar testing, to determine the proper coagulant dosage, continues to be one of the most effective tools available to surface water plant operators. Finished water quality, cost of production, length of filter runs and overall filter life all depend on the proper application of chemicals to the raw water entering the treatment plant.

Before You Start

The jar test, as with any coagulant test, will only provide accurate results when properly performed.

Because the jar test is intended to simulate conditions in your plant, developing the proper procedure is very important. Take time to observe what happens to the raw water in your plant after the chemicals have been added, then simulate this during the jar test. THE RPM OF THE STIRRER AND THE MINUTES TO COMPLETE THE TEST DEPEND ON CONDITIONS IN YOUR PLANT. If, for instance, your plant does not have a static or flash mixer, starting the test at high rpm would provide misleading results. This rule applies to flocculator speed, length of settling time and floc development. Again, operate the jar test to simulate conditions in YOUR plant.

1. Scope

1.1 This practice covers a general procedure for the evaluation of a treatment to reduce dissolved, suspended, colloidal, and non-settleable matter from water by chemical coagulation-flocculation, followed by gravity settling. The procedure may be used to evaluate color, turbidity, and hardness reduction.

1.2 The practice provides a systematic evaluation of the variables normally encountered in the coagulation-flocculation process.

1.3 This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Terms

***Flocculation** - Agglomeration of particles into groups thereby increasing the effective diameter.

***Coagulation** - A chemical technique directed toward destabilization of colloidal particles.

***Turbidity** - A measure of the presence of suspended solid material or the cloudiness of water.



Turbidity

Particles less than or about 1 to 10 μm in diameter (primarily colloidal particles) will not settle out by gravitational forces, therefore making them very difficult to remove. These particles are the primary contributors to the turbidity of the raw water causing it to be "**Cloudy**". The most important factor(s) contributing to the stability of colloidal particles is not their mass, but their surface properties.

This idea can be better understood by relating the colloidal particles large surface area to their small volume (**S/V**) ratio resulting from their very small size. In order to remove these small particles we must either filter the water or somehow incorporate gravitational forces such that these particles will *settle* out. In order to have gravity affect these particles, we must somehow make them larger, somehow have them come together (agglomerate); in other words somehow make them "**stick**" together, thereby increasing their size and mass.

The two primary forces that control whether or not colloidal particles will agglomerate are:

Repulsive force

$$\zeta = \frac{4 \pi q d}{D}$$

*An electrostatic force called the “**Zeta Potential**” -

Where:

ζ = Zeta Potential

q = charge per unit area of the particle

d = thickness of the layer surrounding the shear surface through which the charge is effective

D = dielectric constant of the liquid

Attractive force

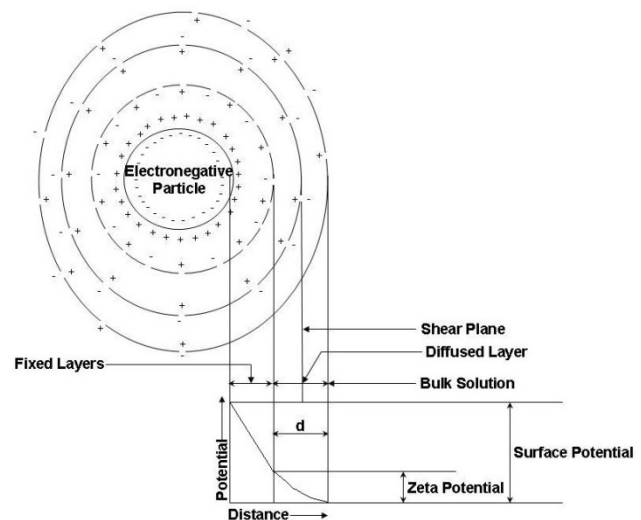
Van der Waals forces are weak forces based on a polar characteristic induced by neighboring molecules. When two or more nonpolar molecules, such as He, Ar, H₂, are in close proximity, the nucleus of each atom will weakly attract electrons in the counter atom resulting, at least momentarily, in an asymmetrical arrangement of the nucleus. This force, van der Waals force, is inversely proportional to the sixth power of the distance (1/d⁶) between the particles.

As can clearly be seen from this relationship, decay of this force occurs exponentially with distance.

*Ways to Measure Turbidity

- 1.) **Jackson Candle Test**
- 2.) **Secchi Disk** - a black and white disk divided like a pie in 4 quadrants about 6" in diameter.
- 3.) **Turbidimeter** - Light is passed through a sample. A sensitive photomultiplier tube at a 90° angle from the incident light beam detects the light scattered by the particles in the sample. The photomultiplier tube converts the light energy into an electrical signal, which is amplified and displayed on the instrument.

a.) *Units* - Nephelometric Turbidity Unit (**NTU**) or Formazin Turbidity Unit (**FTU**).



How to Treat Turbidity

Supercharge the water supply - By supercharging the water supply momentarily with a positive charge, we can upset the charge effect of the particle enough to reduce the Zeta potential (repulsive force) thereby allowing van der Waals forces (attractive forces) to take over.

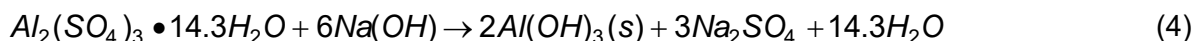
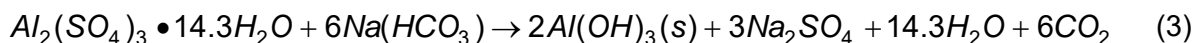
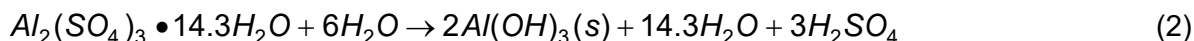
By introducing aluminum (Al^{3+}) into the water in the form of Alum ($\text{Al}_2(\text{SO}_4)_3 \cdot n\text{H}_2\text{O}$) we can accomplish the supercharging of the water. This is the *coagulation* part of the coagulation/flocculation process; flocculation follows coagulation. During the *flocculation* process the particles join together to form flocs; the larger the flocs, the faster they will settle within a clarifier. Other chemical coagulants used are Ferric Chloride and Ferrous Sulfate. Alum works best in the pH range of natural waters, 5.0 - 7.5. Ferric Chloride works best at lower pH values, down to pH 4.5. Ferrous Sulfate works well through a range of pH values, 4.5 to 9.5.

During the coagulation process, charged hydroxy-metallic complexes are formed momentarily (i.e. $\text{Al}(\text{OH})^{2+}$, $\text{Al}(\text{OH})^{1+}$ etc.). These complexes are charged highly positive, and therefore upset the stable negative charge of the target particles, thereby momentarily displacing the water layer surrounding the charged particle. This upset decreases the distance “d”, in turn decreasing the Zeta potential. The particles are then able to get close enough together for van der Waals forces to take over and the particles begin to flocculate. The chemical reaction continues until the aluminum ions (Al^{+3}) reach their final form, $\text{Al}(\text{OH})_3$ (s), and settle out (note – the flocculated particles settle out separately from the precipitated $\text{Al}(\text{OH})_3$ (s)).

If too much alum is added, then the opposite effect occurs--the particles form sub complexes with the Al^{+3} and gain a positive charge about them, and the particles re-stabilize.

The final key to obtaining good flocs is the added energy put into the system by way of rotating paddles in the flocculator tanks. By “pushing” (adding energy) the particles together we can aid in the flocculation process, forming larger flocs. It is important to understand that too much energy, i.e. rotating the paddles too fast, would cause the particles to shear (breakup), thereby reducing the size of the particles and increasing the settling time in the clarifier.

Key Equations



Apparatus

- 1) Jar Test Apparatus
- 2) 6 1500 mL Beakers
- 3) pH meter
- 4) Pipettes
- 5) Conductivity Meter
- 6) Turbidimeter

Procedure

- 1) Make up a 10-g/L solution of alum.
- 2) Make up a 0.1 N solution of NaOH (buffer). ($\text{Na}^{+1} = 23 \text{ mg/mmol}$, $\text{O}^{-2} = 16 \text{ mg/mmol}$, $\text{H}^{+} = 1 \text{ mg/mmol}$)
- 3) Fill each of the six 1500 mL beakers with one-liter of river water.
- 4) Measure the temperature and conductivity.
- 5) Measure the initial pH
- 6) Add alum and NaOH solutions in equal portions as specified by instructor.
- 7) Mixing protocol:
 - a. rapid mix - 1 minute (100 rpm)
 - b. slow mix - 15 minutes (20 rpm)
 - c. off, settling - 30 minutes

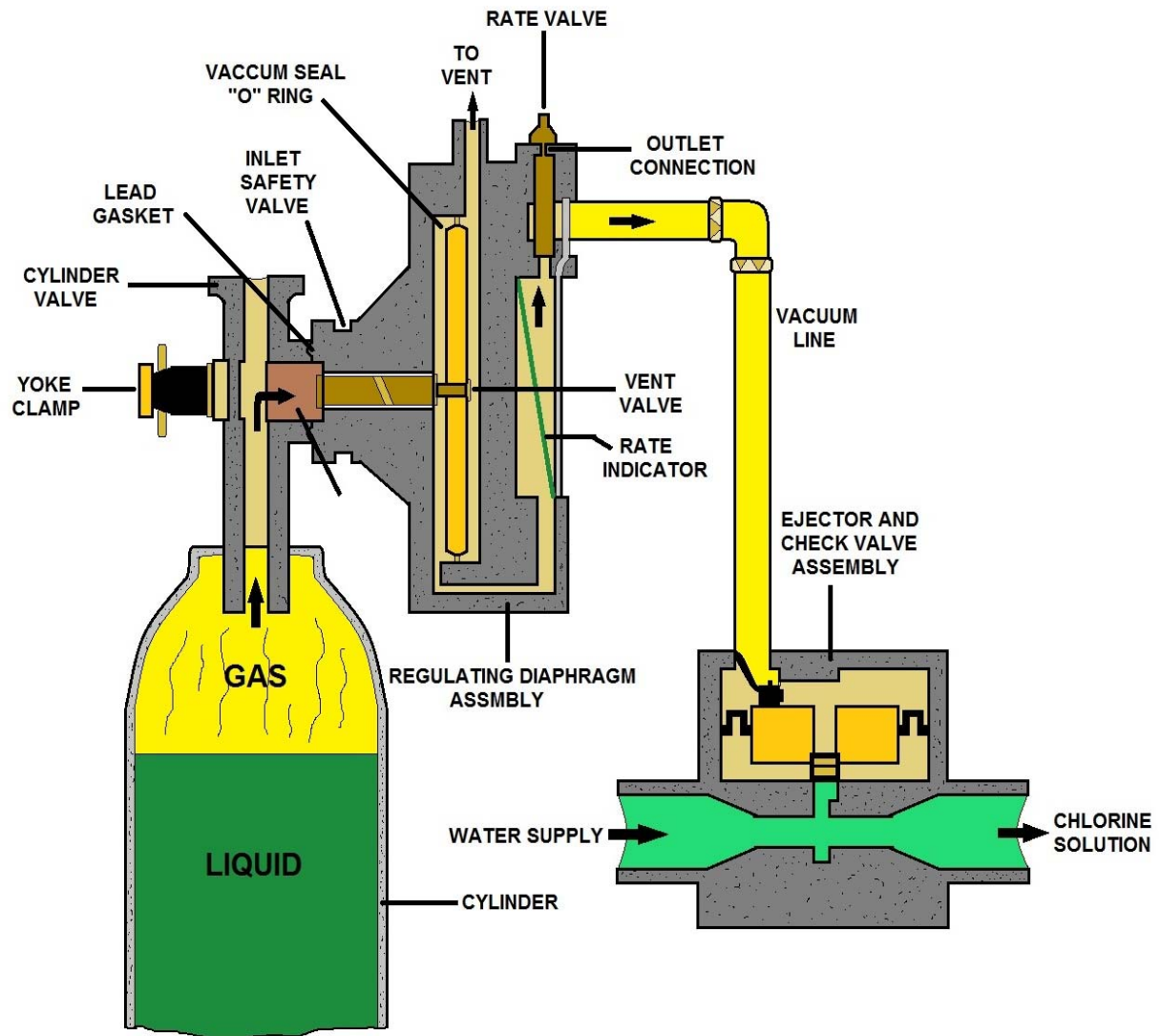
-

Initial Turbidity = ? NTU
- 0.1 N

Buffer

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Chlorine Section Chapter 5



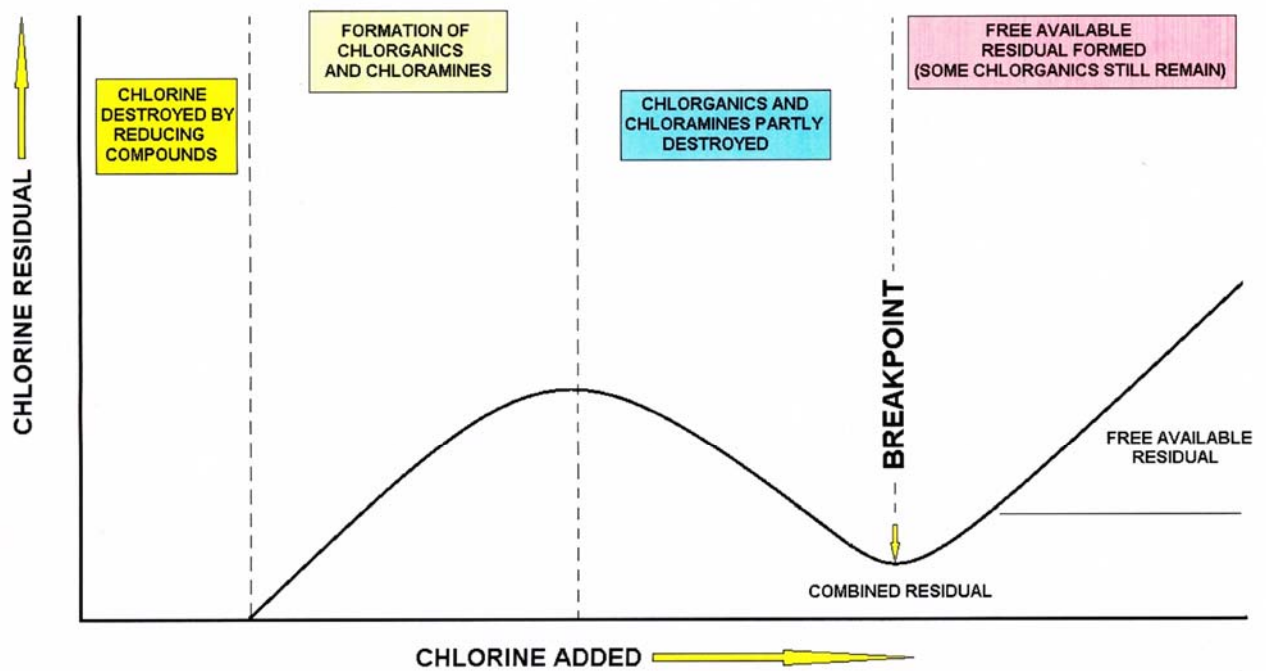
150 Lb. SINGLE CYLINDER CHLORINATOR

Chlorine Exposure Limits

This information is necessary to pass your certification exam.

*** OSHA PEL 1 PPM - IDLH 10 PPM and Fatal Exposure Limit 1,000 PPM**

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m^3)) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level. *** IDLH 10 PPM**



$$\text{CHLORINE IN USE} + \text{FREE CHLORINE} = \text{TOTAL CHLORINE}$$

Modern Water Treatment Disinfectants

Many water suppliers add a disinfectant to drinking water to kill germs such as giardia and e coli. Especially after heavy rainstorms or water main breaks, your water system may add more disinfectant to guarantee that these germs are killed.

***Chlorine.** Some people who use drinking water containing chlorine well in excess of EPA's standard could experience irritating effects to their eyes and nose. Some people who drink water containing chlorine well in excess of EPA's standard could experience stomach discomfort.

***Chloramine.** Some people who use drinking water containing chloramines well in excess of EPA's standard could experience irritating effects to their eyes and nose. Some people who drink water containing chloramines well in excess of EPA's standard could experience stomach discomfort or anemia.

***Chlorine Dioxide.** Some infants and young children who drink water containing chlorine dioxide in excess of EPA's standard could experience nervous system effects. Similar effects may occur in fetuses of pregnant women who drink water containing chlorine dioxide in excess of EPA's standard. Some people may experience anemia.

Chlorine

Today, most of our drinking water supplies are free of the micro-organisms — viruses, bacteria, and protozoa — that cause serious and life-threatening diseases, such as cholera and typhoid fever. This is largely due to the introduction of water treatment, particularly chlorination, at the turn of the century.

Living cells react with chlorine and reduce its concentration while they die. Their organic matter and other substances that are present convert to chlorinated derivatives, some of which are effective killing agents.

*Chlorine present as Cl , HOCl , and OCl^- is called *free available chlorine*, and that which is bound but still effective is *combined chlorine*. A particularly important group of compounds with combined chlorine is the chloramines formed by reactions with ammonia.

*One especially important feature of disinfection using chlorine is the ease of overdosing to create a "residual" concentration. There is a constant danger that safe water leaving the treatment plant may become contaminated later. There may be breaks in water mains, loss of pressure that permits an inward leak, or plumbing errors. This residual concentration of chlorine provides some degree of protection right to the water faucet. With free available chlorine, a typical residual is from 0.1 to 0.5 ppm. Because chlorinated organic compounds are less effective, a typical residual is 2 ppm for combined chlorine.

*There will be no chlorine residual unless there is an excess over the amount that reacts with the organic matter present. However, reaction kinetics complicates interpretation of chlorination data. The correct excess is obtained in a method called "Break Point Chlorination".

*Chlorine by-products

Chlorination by-products are the chemicals formed when the chlorine used to kill disease-causing micro-organisms reacts with naturally occurring organic matter (e.g., decay products of vegetation) in the water. *The most common chlorination by-products found in U.S. drinking water supplies are the trihalomethanes (**THMs**).

***The principal trihalomethanes are:**

Chloroform, bromodichloromethane, chlorodibromomethane, and bromoform. Other less common chlorination by-products include the haloacetic acids and haloacetonitriles. The amount of THMs formed in drinking water can be influenced by a number of factors, including the season and the source of the water.

For example, THM concentrations are generally lower in winter than in summer, because concentrations of natural organic matter are lower and *less chlorine is required to disinfect at colder temperatures but longer contact times. THM levels are also low when wells or large lakes are used as the drinking water source, because organic matter concentrations are generally low in these sources.

The opposite — high organic matter concentrations and high THM levels — is true when rivers or other surface waters are used as the source of the drinking water.

Health Effects

Laboratory animals exposed to very high levels of THMs have shown increased incidences of cancer. Also, several studies of cancer incidence in human populations have reported associations between long-term exposure to high levels of chlorination by-products and an increased risk of certain types of cancer.

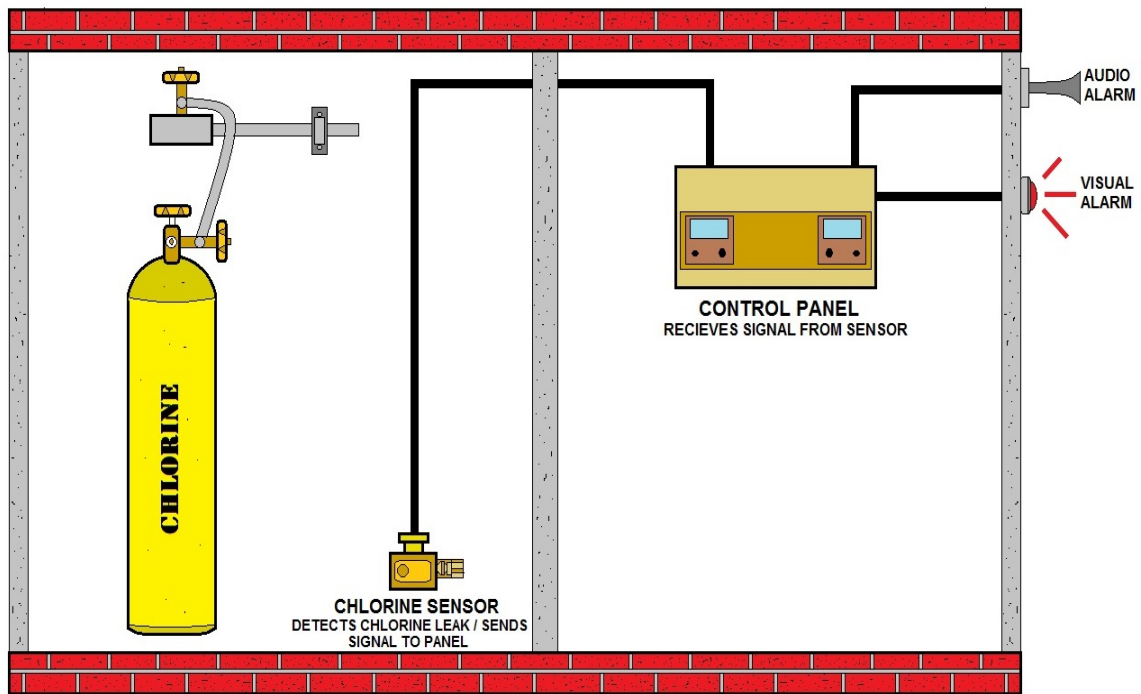
For instance, a recent study conducted in the Great Lakes basin reported an increased risk of bladder and possibly colon cancer in people who drank chlorinated surface water for 35 years or more.

Possible relationships between exposure to high levels of THMs and adverse reproductive effects in humans have also been examined recently. In a California study, pregnant women who consumed large amounts of tap water containing elevated levels of THMs were found to have an increased risk of spontaneous abortion.

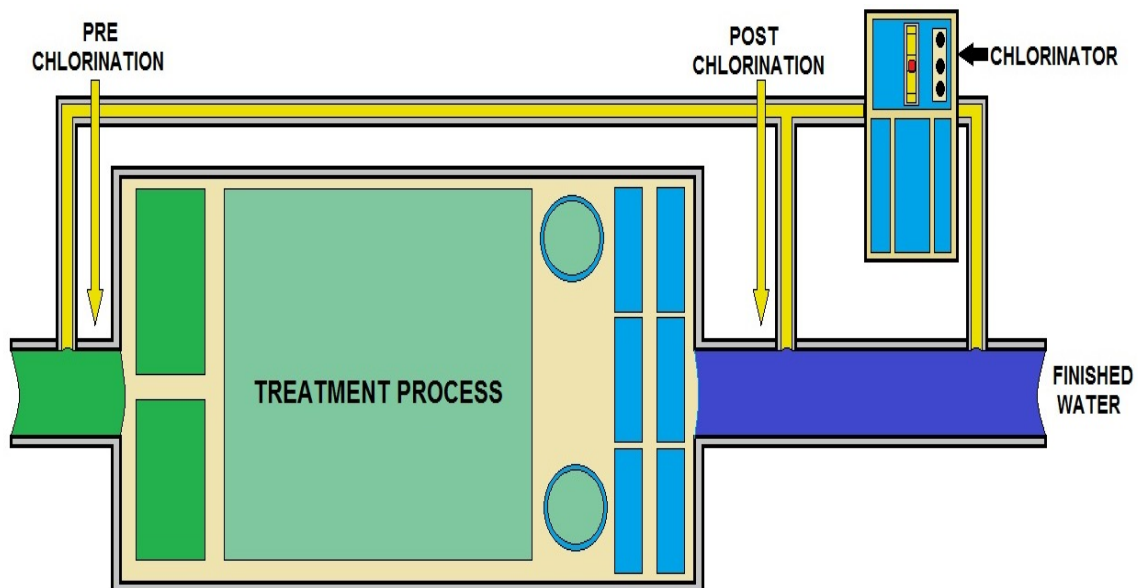
The available studies on health effects do not provide conclusive proof of a relationship between exposure to THMs and cancer or reproductive effects, but indicate the need for further research to confirm their results and to assess the potential health effects of chlorination by-products other than THMs.



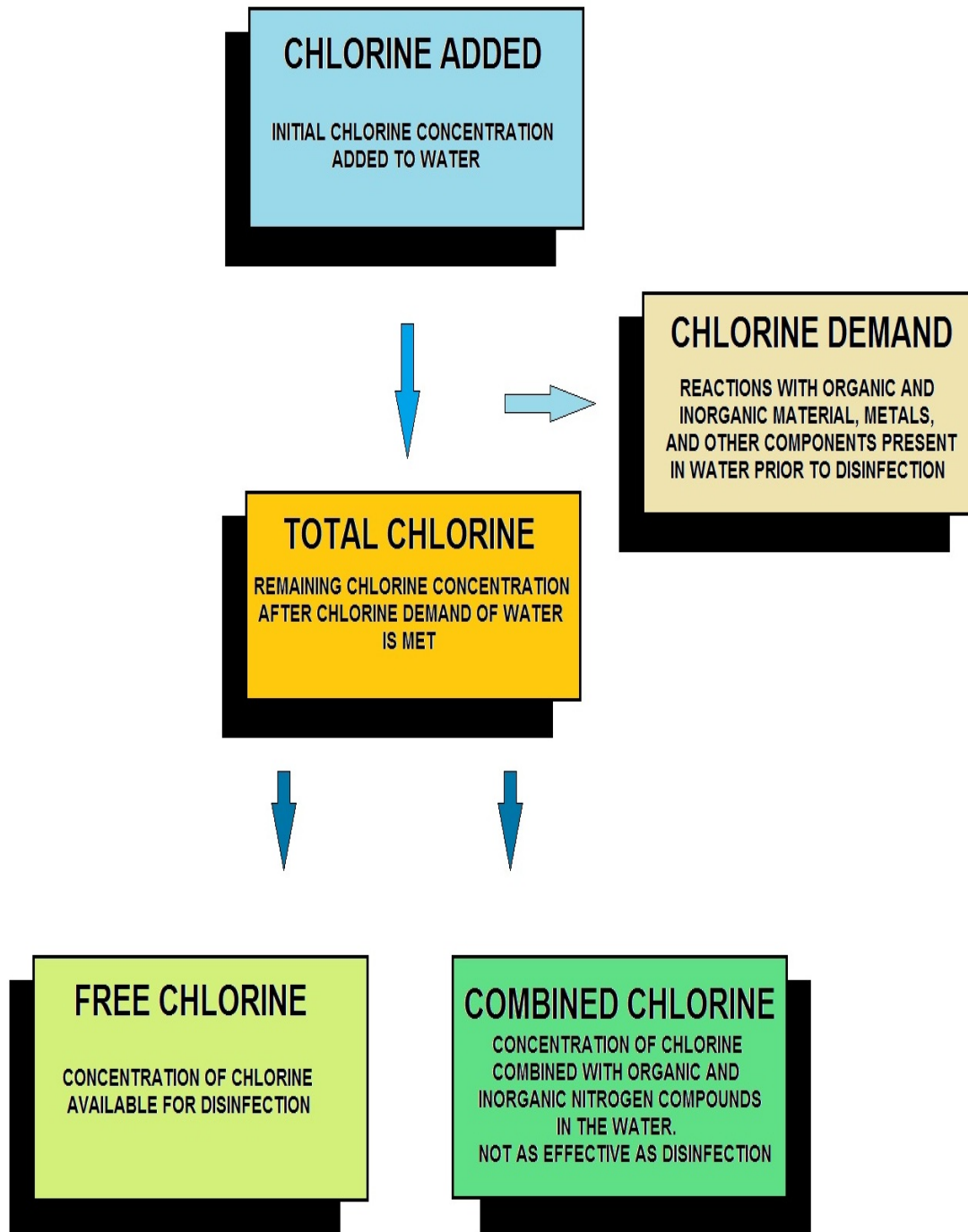
*Chlorine storage room, notice the vents at the bottom and top. The bottom vent will allow the gas to ventilate because Cl_2 gas is heavier than air.



CHLORINE STORAGE ROOM



CHLORINE FLOW IN A TREATMENT PLANT



CHLORINE DISINFECTION

Chlorine Gas

Chlorine gas is likely the most widely used oxidizing microbiocide. It has traditionally been the biocide of choice in many cooling water treatment systems. It is a strong oxidizer that is relatively easy to feed and is quite inexpensive. Upon introduction into the water stream, chlorine hydrolyzes into hypochlorous acid (HOCl) and hydrochloric acid (HCl).

This hydrolyzation provides the active toxicant, HOCl, which is pH-dependent. In alkaline cooling systems, it readily dissociates to form the hypochlorite ion (OCl⁻). This dissociation phenomenon is important to remember when working with systems that will operate at a higher pH. In alkaline conditions, OCl⁻ becomes the predominant species and lacks the biocidal efficacy of the non-dissociated form. Considerably more HOCl is present at a pH of 7.0 than at pH 8.5.

It is also widely known that chlorine is non-selective, making it very sensitive to contamination from either cooling water makeup or from in-plant process leaks. Ammonia, organic acids and organic compounds, sulfides, iron and manganese all easily react with HOCl. The amount of chlorine needed to react with these contamination species is referred to as chlorine demand and it must be satisfied before active HOCl is available to provide a free chlorine residual.

The combination of high chlorine demand in process-contaminated systems and the dissociation process in alkaline systems creates the need for greater chlorine feed to obtain the same microbial efficacy. This results in a higher concentration of HCl in the cooling system. Since HCl removes alkalinity, pH depression and system corrosion could occur. In low pH water the passive metal oxide layers protecting the metal may resolubilize, exposing the surface to corrosion. At free mineral acidity (pH <4.3), many passivating inhibitors become ineffective, and corrosion will proceed rapidly. Increased chloride may also have a negative impact on system corrosion. The chloride ion (Cl⁻) can damage or penetrate the passive oxide layer, leading to localized damage of the metal surface.

High chlorine concentrations have also been shown to directly attack traditional organic-based corrosion inhibitors. When these inhibitors are "deactivated," the metal surface would then be susceptible to corrosion.

Process Safety Management (PSM) guidelines dictated by the U.S. Occupational Safety and Health Administration (OSHA), discharge problems related to chlorinated organic compounds such as trihalomethane (THM), dezincification of admiralty brass and delignification of cooling tower wood are other significant concerns associated with the use of chlorine.

Pathophysiology

Chlorine is a greenish-yellow, noncombustible gas at room temperature and atmospheric pressure. The intermediate water solubility of chlorine accounts for its effect on the upper airway and the lower respiratory tract.

Exposure to chlorine gas may be prolonged because its moderate water solubility may not cause upper airway symptoms for several minutes. In addition, the density of the gas is greater than that of air, causing it to remain near ground level and increasing exposure time.

The odor threshold for chlorine is approximately 0.3-0.5 parts per million (ppm); however, distinguishing toxic air levels from permissible air levels may be difficult until irritative symptoms are present.



Mechanism of Activity

The mechanisms of the above biological activity are poorly understood and the predominant anatomic site of injury may vary, depending on the chemical species produced. Cellular injury is believed to result from the oxidation of functional groups in cell components, from reactions with tissue water to form hypochlorous and hydrochloric acid, and from the generation of free oxygen radicals.

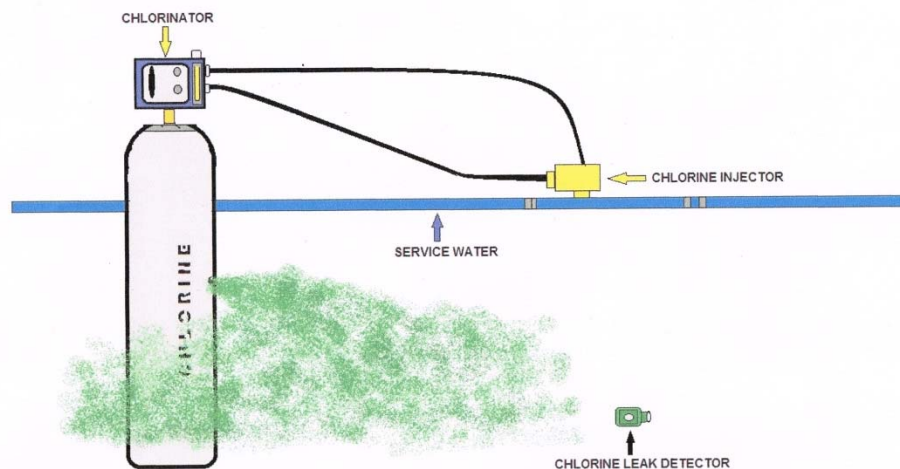
Although the idea that chlorine causes direct tissue damage by generating free oxygen radicals was once accepted, this idea is now controversial. The cylinders on the right contain chlorine gas.

The gas comes out of the cylinder through a gas regulator. The cylinders are on a scale that operators use to measure the amount used each day. The chains are used to prevent the tanks from falling over. Chlorine gas is stored in vented rooms that have panic bar equipped doors. Operators have the equipment necessary to reduce the impact of a gas leak, but rely on trained emergency response teams to contain leaks.

Solubility Effects

Hydrochloric acid is highly soluble in water. The predominant targets of the acid are the epithelia of the ocular conjunctivae and upper respiratory mucus membranes.

Hypochlorous acid is also highly water soluble with an injury pattern similar to hydrochloric acid. Hypochlorous acid may account for the toxicity of elemental chlorine and hydrochloric acid to the human body.



150 lb. CHLORINE CYLINDER LEAKING FROM SIDEWALL

Early Response to Chlorine Gas

Chlorine gas, when mixed with ammonia, reacts to form chloramine gas. In the presence of water, chloramines decompose to ammonia and hypochlorous acid or hydrochloric acid. The early response to chlorine exposure depends on the (1) concentration of chlorine gas, (2) duration of exposure, (3) water content of the tissues exposed, and (4) individual susceptibility.

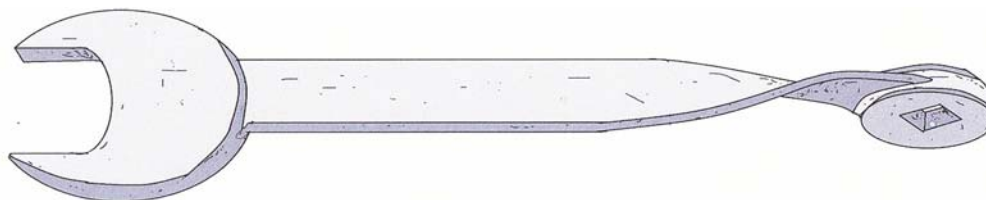
Immediate Effects

The immediate effects of chlorine gas toxicity include acute inflammation of the conjunctivae, nose, pharynx, larynx, trachea, and bronchi. Irritation of the airway mucosa leads to local edema secondary to active arterial and capillary hyperemia. Plasma exudation results in filling the alveoli with edema fluid, resulting in pulmonary congestion.

Pathological Findings

Pathologic findings are nonspecific. They include severe pulmonary edema, pneumonia, hyaline membrane formation, multiple pulmonary thromboses, and ulcerative tracheobronchitis.

The hallmark of pulmonary injury associated with chlorine toxicity is pulmonary edema, manifested as hypoxia. Noncardiogenic pulmonary edema is thought to occur when there is a loss of pulmonary capillary integrity.



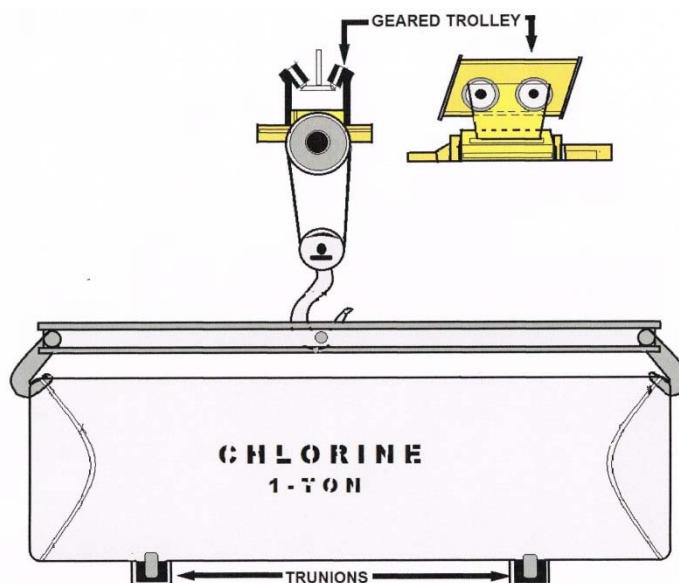
TWISTED CHLORINE WRENCH

Chlorine is a highly reactive gas. It is a naturally occurring element. Chlorine is produced in very large amounts (23 billion pounds in 1992) by eighteen companies in the United States. US demand for chlorine is expected to increase slightly over the next several years and then decline. The expected decline in US demand is due to environmental concerns for chlorinated organic chemicals. The largest users of chlorine are companies that make ethylene dichloride and other chlorinated solvents, polyvinyl chloride (PVC) resins, chlorofluorocarbons, and propylene oxide. Paper companies use chlorine to bleach paper. Water and wastewater treatment plants use chlorine to reduce water levels of microorganisms that can spread disease to humans.

Exposure to chlorine can occur in the workplace or in the environment following releases to air, water, or land. People who use laundry bleach and swimming pool chemicals containing chlorine products are usually not exposed to chlorine itself. Chlorine is generally found only in industrial settings. Chlorine enters the body breathed in with contaminated air or when consumed with contaminated food or water. It does not remain in the body due to its reactivity.

Chlorine gas is greenish yellow in color and very toxic. It is heavier than air and will therefore sink to the ground if released from its container. It is the toxic effect of chlorine gas that makes it a good disinfectant, but it is toxic to more than just waterborne pathogens; it is also toxic to humans. It is a respiratory irritant and it can also irritate skin and mucus membranes.

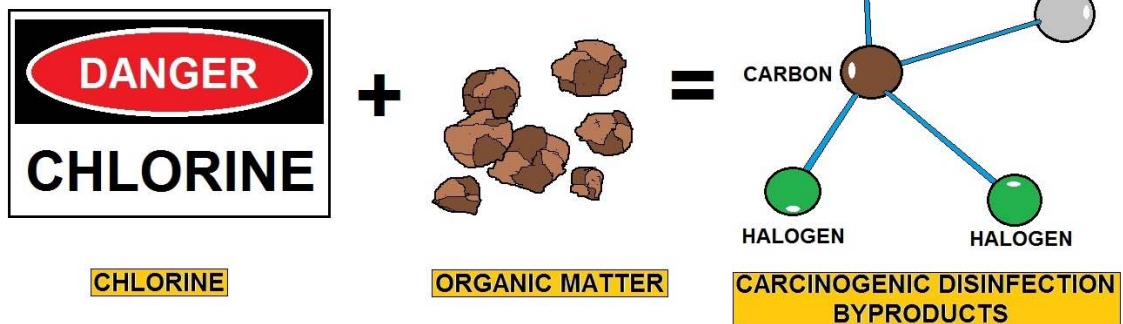
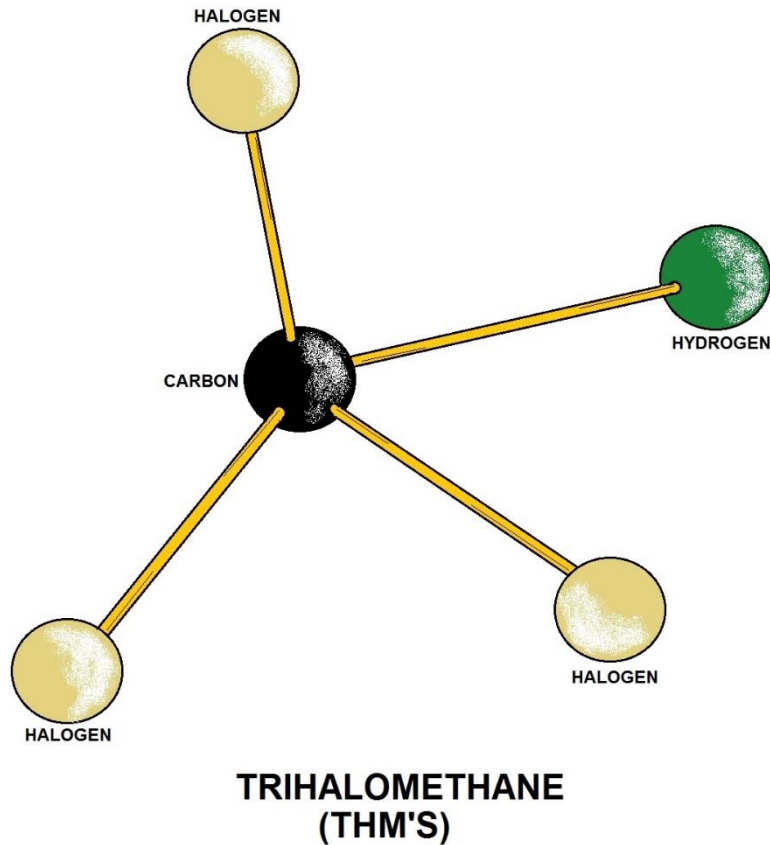
Exposure to high volumes of chlorine gas fumes can cause serious health problems, including death. However, it is important to realize that chlorine gas, once entering the water, changes into hypochlorous acid and hypochlorite ions, and therefore its human toxic properties are not found in the drinking water we consume.



**CHLORINE 1 - TON CONTAINER
AND OVERHEAD CRANE**

Chlorine gas is sold as a compressed liquid, which is amber in color. Chlorine, as a liquid, is heavier (more dense) than water. If the chlorine liquid is released from its container it will quickly return back to its gas state. Chlorine gas is the least expensive form of chlorine to use.

The typical amount of chlorine gas required for water treatment is 1-16 mg/L of water. Different amounts of chlorine gas are used depending on the quality of water that needs to be treated. If the water quality is poor, a higher concentration of chlorine gas will be required to disinfect the water if the contact time cannot be increased. We will cover this subject in greater detail.



DISINFECTION BYPRODUCT PRODUCTION DIAGRAM

Chlorine is...

- Chlorine is an element used in industry and found in some household products.
- Chlorine is sometimes in the form of a poisonous gas. Chlorine gas can be pressurized and cooled to change it into a liquid so that it can be shipped and stored. When liquid chlorine is released, it quickly turns into a gas that stays close to the ground and spreads rapidly.
- Chlorine gas can be recognized by its pungent, irritating odor, which is like the odor of bleach. The strong smell may provide adequate warning to people that they are exposed.
- Chlorine gas appears to be yellow-green in color.
- Chlorine itself is not flammable, but it can react explosively or form explosive compounds with other chemicals such as turpentine and ammonia.

Where Chlorine is Found and How it is Used

- Chlorine is one of the most commonly manufactured chemicals in the United States. Its most important use is as a bleach in the manufacture of paper and cloth, but it is also used to make pesticides (insect killers), rubber, and solvents.
- Chlorine is used in drinking water and swimming pool water to kill harmful bacteria. It is also used as part of the sanitation process for industrial waste and sewage.
- Household chlorine bleach can release chlorine gas if it is mixed with certain other cleaning agents.
- Chlorine was used during World War I as a choking (pulmonary) agent.

How People can be Exposed to Chlorine

- People's risk for exposure depends on how close they are to the place where the chlorine was released.
- If chlorine gas is released into the air, people may be exposed through skin contact or eye contact. They also may be exposed by breathing air that contains chlorine.
- If chlorine liquid is released into water, people may be exposed by touching or drinking water that contains chlorine.
- If chlorine liquid comes into contact with food, people may be exposed by eating the contaminated food.
- Chlorine gas is heavier than air, so it would settle in low-lying areas.

How Chlorine Works

- The extent of poisoning caused by chlorine depends on the amount of chlorine a person is exposed to, how the person was exposed, and the length of time of the exposure.
- When chlorine gas comes into contact with moist tissues such as the eyes, throat, and lungs, an acid is produced that can damage these tissues.

Immediate Signs and Symptoms of Chlorine Exposure

- During or immediately after exposure to dangerous concentrations of chlorine, the following signs and symptoms may develop:
 - Blurred vision
 - Burning pain, redness, and blisters on the skin if exposed to gas. Skin injuries similar to frostbite can occur if it is exposed to liquid chlorine
 - Burning sensation in the nose, throat, and eyes
 - Coughing
 - Chest tightness
 - Difficulty breathing or shortness of breath. These may appear immediately if high concentrations of chlorine gas are inhaled, or they may be delayed if low concentrations of chlorine gas are inhaled.
 - Fluid in the lungs (pulmonary edema) that may be delayed for a few hours

- Nausea and vomiting
 - Watery eyes
 - Wheezing
- Showing these signs or symptoms does not necessarily mean that a person has been exposed to chlorine.

What the Long-Term Health Effects are

- Long-term complications may occur after breathing in high concentrations of chlorine. Complications are more likely to be seen in people who develop severe health problems such as fluid in the lungs (pulmonary edema) following the initial exposure.

How People can Protect Themselves, and What they Should do if they are Exposed to Chlorine

- Leave the area where the chlorine was released and get to fresh air. Quickly moving to an area where fresh air is available is highly effective in reducing exposure to chlorine.
 - If the chlorine release was outdoors, move away from the area where the chlorine was released. Go to the highest ground possible, because chlorine is heavier than air and will sink to low-lying areas.
 - If the chlorine release was indoors, get out of the building.
- If you think you may have been exposed, remove your clothing, rapidly wash your entire body with soap and water, and get medical care as quickly as possible.
- *Removing and disposing of clothing:*
 - Quickly take off clothing that has liquid chlorine on it. Any clothing that has to be pulled over the head should be cut off the body instead of pulled over the head. If possible, seal the clothing in a plastic bag. Then seal the first plastic bag in a second plastic bag. Removing and sealing the clothing in this way will help protect you and other people from any chemicals that might be on your clothes.
 - If you placed your clothes in plastic bags, inform either the local or state health department or emergency personnel upon their arrival. Do not handle the plastic bags.
 - If you are helping other people remove their clothing, try to avoid touching any contaminated areas, and remove the clothing as quickly as possible.
- *Washing the body:*
 - As quickly as possible, wash your entire body with large amounts of soap and water. Washing with soap and water will help protect people from any chemicals on their bodies.
 - If your eyes are burning or your vision is blurred, rinse your eyes with plain water for 10 to 15 minutes. If you wear contacts, remove them before rinsing your eyes, and place them in the bags with the contaminated clothing. Do not put the contacts back in your eyes. You should dispose of them even if you do not wear disposable contacts. If you wear eyeglasses, wash them with soap and water. You can put the eyeglasses back on after you wash them.
- If you have swallowed (ingested) chlorine, do not induce vomiting or drink fluids.
- Seek medical attention right away. Consider dialing 911 and explaining what has happened.

How Chlorine Exposure is Treated

No antidote exists for chlorine exposure. Treatment consists of removing the chlorine from the body as soon as possible and providing supportive medical care such as inhaled breathing treatments for wheezing in a hospital setting.

Chlorine's Appearance and Odor

Chlorine is a greenish-yellow gas with a characteristic pungent odor. It condenses to an amber liquid at approximately -34 degrees C (-29.2 degrees F) or at high pressures. Odor thresholds ranging from 0.08 to part per million (ppm) parts of air have been reported. Prolonged exposures may result in olfactory fatigue.

Reactivity

1. **Conditions Contributing to Instability:** Cylinders of chlorine may burst when exposed to elevated temperatures. Chlorine in solution forms a corrosive material.

2. **Incompatibilities:** Flammable gases and vapors form explosive mixtures with chlorine. Contact between chlorine and many combustible substances (such as gasoline and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydrogen, ammonia, and sulfur), reducing agents, and finely divided metals may cause fires and explosions. Contact between chlorine and arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane, oxomonsilane, potassium, propylene, and silicon should be avoided. Chlorine reacts with hydrogen sulfide and water to form hydrochloric acid, and it reacts with carbon monoxide and sulfur dioxide to form phosgene and sulfuryl chloride. Chlorine is also incompatible with moisture, steam, and water.



3. **Hazardous Decomposition Products:** None reported.

4. **Special Precautions:** Chlorine will attack some forms of plastics, rubber, and coatings.

Flammability

Chlorine is a non-combustible gas.

The National Fire Protection Association has assigned a flammability rating of 0 (no fire hazard) to chlorine; however, most combustible materials will burn in chlorine.

1. **Flash point:** Not applicable.

2. **Auto-ignition temperature:** Not applicable.

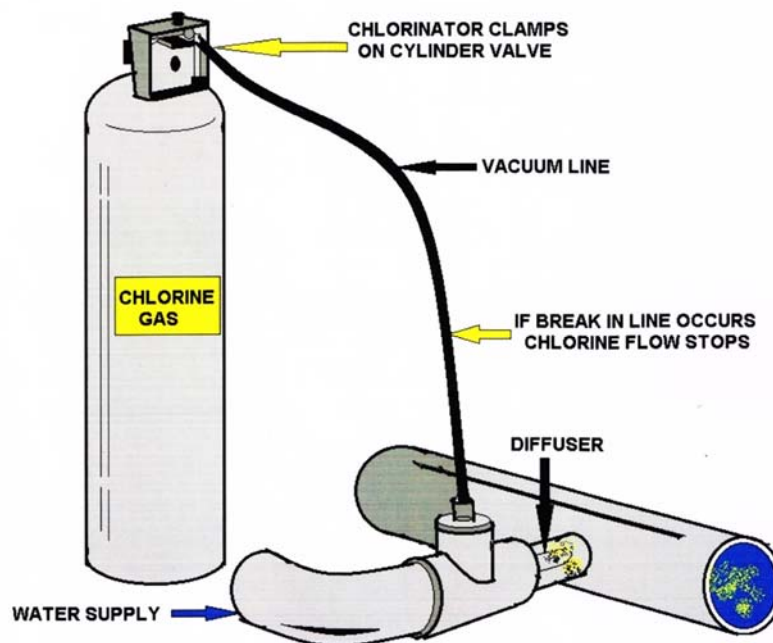
3. **Flammable limits in air:** Not applicable.

4. **Extinguishant:** For small fires use water only; do not use dry chemical or carbon dioxide. Contain and let large fires involving chlorine burn. If fire must be fought, use water spray or fog.

Fires involving chlorine should be fought upwind from the maximum distance possible.

Keep unnecessary people away; isolate the hazard area and deny entry. For a massive fire in a cargo area, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from the area and let the fire burn. Emergency personnel should stay out of low areas and ventilate closed spaces before entering.

Containers of chlorine may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool fire exposed containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Firefighters should wear a full set of protective clothing and self-contained breathing apparatus when fighting fires involving chlorine.



Disinfection Essentials

Selecting the right disinfection weapon requires understanding the factors governing the particular site and the water or wastewater to be treated. In general, the selection of an appropriate disinfection system should be evaluated against the following six criteria:

1. **Safety.** How does the disinfectant work and what types of precautions are needed to transport, store, use, and operate the disinfectant system and associated chemicals? If a system will require significant safety protection—such as use of breathing apparatus and protective clothing—as well as high levels of operator training, it may be advisable to explore other, less intensive systems. In addition, while the disinfectant may be relatively safe to use, consideration also has to be made for the effects of both intentional and unintentional releases to the environment.
2. **Effectiveness.** How effective is the disinfectant against the pathogens present in the water or wastewater? Since the intent is to reduce the levels of pathogens to acceptable standards, understanding how effective the proposed disinfectant system is in achieving those target levels, as well as the system's ability to reliably achieve the result, will be important to selecting the right system.
3. **Cost.** What are the costs associated with the disinfection system, both in terms of capital outlay and ongoing operations and maintenance? Operating costs can vary in terms of the time it takes to service the disinfectant system regularly, and the costs of supplies and components.
4. **Complexity of use.** How does the system operate and does it take specialized training to keep the system within tolerances? Since the outflow from the treatment facility may be subject to various standards and regulations, if the system is too complex it may require additional staff time to ensure that it operates within the desired parameters.
5. **Environmental/Adverse Effects.** What are some of the potential downsides to the operation of the system as it relates to the distribution system or watershed in which the treated effluent is discharged? While some systems may provide a net-positive environmental benefit through increased oxygenation of the receiving waters, other systems may need to have additional treatment of the disinfected effluent in order to render it benign when released.
6. **Flow and Water Characteristics.** Can the system handle fluctuations within the flow or with changing characteristics of the water or wastewater being processed? If a system has a narrow tolerance for the amount of water or wastewater flow, this could impact the effectiveness of the overall system. In addition, if the system cannot adjust for off-site concerns such as dry or wet weather flow rates of the receiving water body, this may also affect the system's appropriateness for your application.

With those criteria in mind, there are primarily four basic disinfection systems currently available—chlorination, ozone gas, ultraviolet radiation, and chemical treatment other than chlorine.

A variety of factors come into play in deciding which type of disinfectant system is right for your operation. The decision to install a system could be the result of local concerns and potential to mitigate health risks, as well as improved community relations. In any event, the operator of an onsite water or wastewater treatment plant needs to consider some of the safeguards that need to be in place as well.

"Typical safeguards include operator training and instrumentation monitoring that will perform a shutdown function if something goes above a certain level," says Schilling. "If they detect [for example] an ozone leak, you can do an interconnect and do a plant shutdown. UV has safeguards where you have monitors that tell you what your dosage is, and if you're over or under your dosage it will perform some kind of warning of whatever you want to do."

State and Local Regulations

State and local regulations vary considerably in their requirements to disinfect wastewater, so the decision of what type of system to use can be affected by the chemical and physical composition of the wastewater stream, the environment to which it will be discharged, and the concerns of the local health department. "It's all over the place," says Bach. "The chemical itself is a pesticide and is regulated by the US EPA.

The states will specify what sort of *E. coli* or *coliform* counts you're going to have on discharge, and the regulations vary all over the map in the states. You've got a lot of things like that throughout the country and it goes down to ultimately the views of local health departments and reflect the local topography, their local population density, and also their experience of whether or not people have gotten sick."

Alternative Disinfectants *More information in the Alternative Section*

Unknown Factors Associated with Alternatives

Scientific investigation of risk associated with alternative disinfectants and alternative disinfection by-products is limited. A decision by water facilities to switch from chlorination could be risky because scientists know so little about DBPs from processes other than chlorination.

Drinking Water Disinfectants At a Glance

Disinfectants	Residual Maintenance	State of Information on By-Product Chemistry	Color Removal	Removal of Common Odors
Chlorine	Good	Adequate	Good	Good
Chloramines	Good	Limited	Unacceptable	Poor
Chlorine dioxide	Unacceptable*	Adequate	Good	Good
Ozone	Unacceptable	Limited	Excellent	Excellent
Ultraviolet radiation	Unacceptable	Nil	N/A	N/A

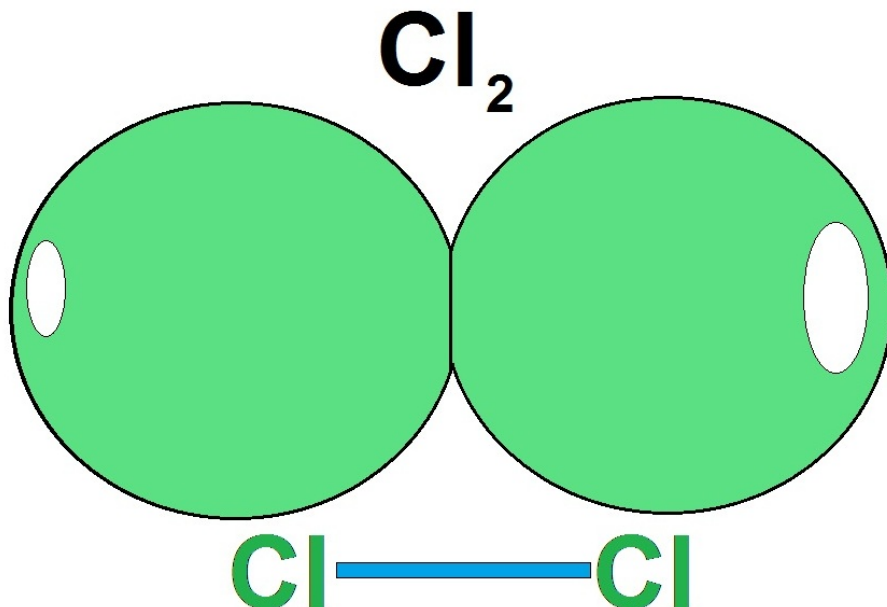
*In Europe, 50% of water distribution systems use chlorine dioxide as the residual disinfectant

Source: Trussell, R., Control Strategy 1; Alternative Oxidants and Disinfectants, 1991



Chlorine Basics

Chlorine is one of 90 natural elements, the basic building blocks of our planet. To be useful, an element must be relatively abundant or have extremely desirable properties. Chlorine has both characteristics. As a result -- over the course of many decades of careful research and development -- scientists have learned to use chlorine and the products of chlorine chemistry to make drinking water safe, destroy life-threatening germs, produce life-saving drugs and medical equipment, shield police and fire fighters in the line of duty, and ensure a plentiful food supply.



CHLORINE

In 1774, in his small experimental laboratory, Swedish pharmacist Carl Wilhem Scheele released a few drops of hydrochloric acid onto a piece of manganese dioxide. Within seconds, a greenish-yellow gas arose. Although he had no idea at the time, he had just discovered chlorine.

The fact that the greenish-yellow gas was actually an element was only recognized several decades later by English chemist Sir Humphrey Davy. Until that time, people were convinced that the gas was a compound of oxygen. Davy gave the element its name on the basis of the Greek word *khloros*, for greenish-yellow. In 1810 he suggested the name "*chloric gas*" or "*chlorine*."

One of the most effective and economical germ-killers, chlorine also destroys and deactivates a wide range of dangerous germs in homes, hospitals, swimming pools, hotels, restaurants, and other public places. Chlorine's powerful disinfectant qualities come from its ability to bond with and destroy the outer surfaces of bacteria and viruses. First used as a germicide to prevent the spread of "child bed fever" in the maternity wards of Vienna General Hospital in Austria in 1846, chlorine has been one of society's most potent weapons against a wide array of life-threatening infections, viruses, and bacteria for 150 years.

When the first men to set foot on the moon returned to earth (Apollo 11 mission: 24.7.69) a hypochlorite solution was chosen as one of the disinfectants for destroying any possible moon germs.

What Happens to Chlorine When it Enters the Environment?

- When released to air, chlorine will react with water to form hypochlorous acid and hydrochloric acid, which are removed from the atmosphere by rainfall.
- Chlorine is slightly soluble in water. It reacts with water to form hypochlorous acid and hydrochloric acid. The hypochlorous acid breaks down rapidly. The hydrochloric acid also breaks down; its breakdown products will lower the pH of the water (makes it more acidic).
- Since chlorine is a gas it is rarely found in soil. If released to soil, chlorine will react with moisture forming hypochlorous acid and hydrochloric acid. These compounds can react with other substances found in soil.
- Chlorine does not accumulate in the food chain.

Disinfectant Qualities

Restaurants and meat and poultry processing plants rely on chlorine bleach and other chlorine-based products to kill harmful levels of bacteria such as *Salmonella* and *E. coli* on food preparation surfaces and during food processing. Chlorine is so important in poultry processing that the US Department of Agriculture requires an almost constant chlorine rinse for much of the cutting equipment. In fact, no proven economical alternative to chlorine disinfection exists for use in meat and poultry processing facilities.

Properties

Because it is highly reactive, chlorine is usually found in nature bound with other elements like sodium, potassium, and magnesium. When chlorine is isolated as a free element, chlorine is a greenish yellow gas, which is 2.5 times heavier than air. It turns to a liquid state at -34°C (-29°F), and it becomes a yellowish crystalline solid at -103°C (-153°F). Chemists began experimenting with chlorine and chlorine compounds in the 18th century. They learned that chlorine has an extraordinary ability to extend a chemical bridge between various elements and compounds that would not otherwise react with each other. Chlorine has been especially useful in studying and synthesizing organic compounds -- compounds that have at least one atom of the element carbon in their molecular structure. All living organisms, including humans, are composed of organic compounds.

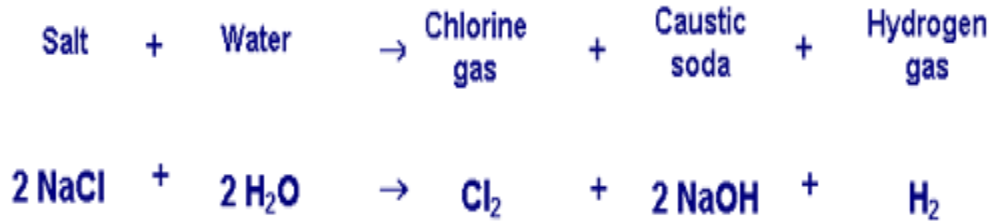
Chlorine is one of the most abundant chemical elements on Earth. It is ubiquitous in soils, minerals, plants and animals. Seawater is a huge reservoir of dissolved chlorine weathered from the continents and transported to the oceans by Earth's rivers.

Chlorine is also one of the most useful chemical elements. Each chemical element has its own set of unique properties and chlorine is known as a very reactive element--so reactive, in fact, that it is usually found combined with other elements in the form of compounds. More than 3,500 naturally occurring chlorinated organic (associated with living organisms) compounds alone have been identified.

Chlorine's chemical properties have been harnessed innovatively for good use. For example, this element plays a huge role in public health. Chlorine-based disinfectants are capable of removing a wide variety of disease-causing germs from drinking water and wastewater as well as from hospital and food production surfaces. Additionally, chlorine plays an important role in the manufacture of thousands of products we depend upon every day, including such diverse items as cars, computers, pharmaceuticals and military flak jackets. As the ninth largest chemical produced in the U.S. by volume, chlorine is truly a "workhorse chemical."

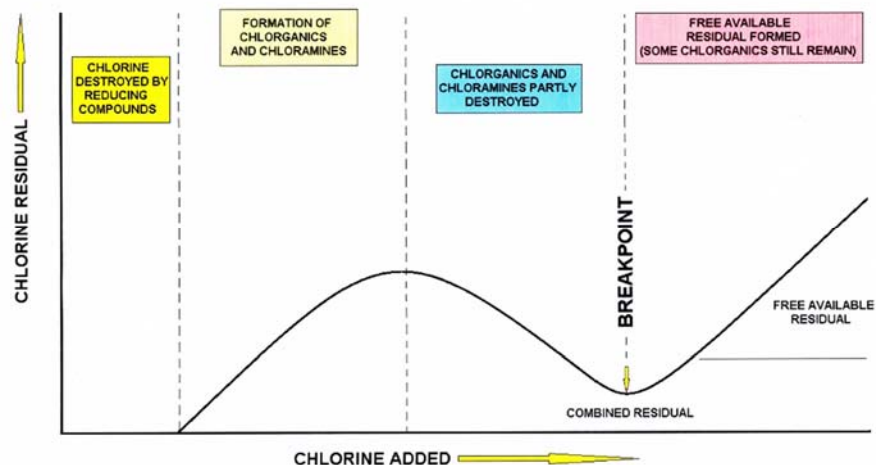
Released From the Salt of the Earth

Chlorine is produced industrially from the compound sodium chloride, one of the many salts found in geologic deposits formed from the slow evaporation of ancient seawater. When electricity is applied to a brine solution of sodium chloride, chlorine gas (Cl₂), caustic soda (NaOH) and hydrogen gas (H₂) are generated according to the following reaction:



Co-Products

As the reaction demonstrates, chlorine gas cannot be produced without producing caustic soda, so chlorine and caustic soda are known as "co-products," and their economics are inextricably linked. Caustic soda, also called "alkali," is used to produce a wide range of organic and inorganic chemicals and soaps. In addition, the pulp and paper, alumina and textiles industries use caustic soda in their manufacturing processes. Thus, the "chlor-alkali" industry obtains two very useful chemicals by applying electrical energy to sea salt.



Related Terms and Definitions

Chlorine Gas Feed Room

A chlorine gas feed room, for the purposes of this document, is a room that contains the chlorinator(s) and active cylinder(s) used to apply chlorine gas at a water or wastewater facility.

Chlorine Gas Storage Room

A chlorine gas storage room, for the purposes of this document, is a room other than a chlorine gas feed room, in which full, partial, or empty chlorine gas cylinders or ton containers are stored at a water or wastewater facility.

Gas Chlorinator

A gas chlorinator is a device used to meter and control the application rate of chlorine gas into a liquid. There is the danger of the gas escaping at a water or wastewater treatment facility. The gas chlorinator should be isolated from a water or wastewater treatment plant.

Chlorine Cabinet

A chlorine cabinet is a pre-assembled or factory built unit that contains the equipment used to apply chlorine gas at a water or wastewater treatment facility. It is isolated from a water or wastewater treatment plant.

Chlorine Exposure Limits

* OSHA PEL

The current **OSHA** permissible exposure limit (**PEL**) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m^3)) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level [29 CFR 1910.1000, Table Z-1].

* NIOSH REL

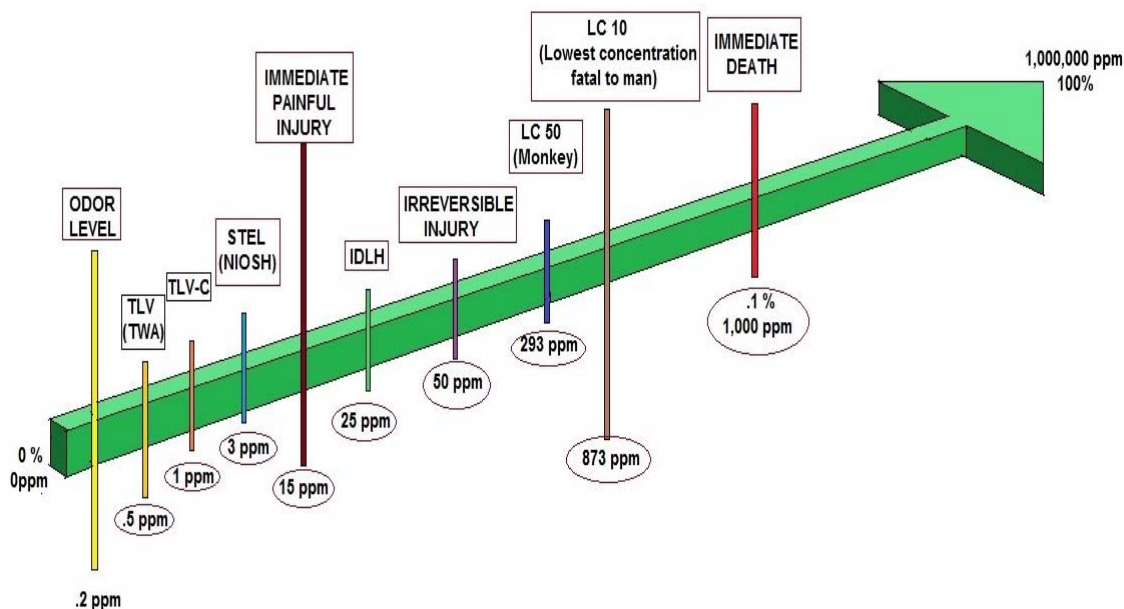
The National Institute for Occupational Safety and Health (**NIOSH**) has established a recommended exposure limit (**REL**) for chlorine of 0.5 ppm (mg/m^3) as a TWA for up to a 10-hour workday and a 40-hour workweek and a short-term exposure limit (**STEL**) of 1 ppm (3 mg/m^3) [NIOSH 1992].

* ACGIH TLV

The American Conference of Governmental Industrial Hygienists (**ACGIH**) has assigned chlorine a threshold limit value (**TLV**) of 0.5 ppm (1.5 mg/m^3) as a TWA for a normal 8-hour workday and a 40-hour workweek and a **STEL** of 1 ppm (2.9 mg/m^3) for periods not to exceed 15 minutes. Exposures at the STEL concentration should not be repeated more than four times a day and should be separated by intervals of at least 60 minutes [ACGIH 1994, p. 15].

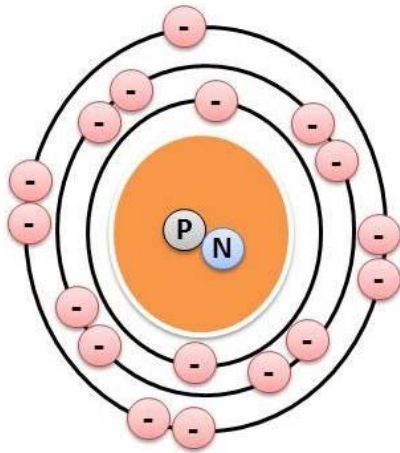
* Rationale for Limits

The NIOSH limits are based on the risk of severe eye, mucous membrane and skin irritation [NIOSH 1992]. The ACGIH limits are based on the risk of eye and mucous membrane irritation [ACGIH 1991, p. 254].



CHLORINE POISON LINES

Chlorine's Atomic Structure



 ELECTRONS = 17

 PROTONS = 17

 NEUTRONS = 18

 NUCLEUS

Isotopes

Isotope	Half Life
Cl-35	Stable
Cl-36	301000.0 years

Cl-37	Stable
Cl-38	37.2 minutes

Chlorine's Effectiveness

The effectiveness of chlorination depends on the chlorine demand of the water, the concentration of the chlorine solution added, the time that chlorine is in contact with the organism, and water quality. These effects can be summarized in the following manner:

- As the concentration of the chlorine increases, the required contact time to disinfect decreases.
- Chlorination is more effective as water temperature increases.
- Chlorination is less effective as the water's pH increases (becomes more alkaline).
- Chlorination is less effective in cloudy (turbid) water.
- When chlorine is added to the water supply, part of it combines with other chemicals in water (like iron, manganese, hydrogen sulfide, and ammonia) and is not available for disinfection. The amount of chlorine that reacts with the other chemicals plus the amount required to achieve disinfection is the **chlorine demand** of the water.

The safest way to be sure that the amount of chlorine added is sufficient is to add a little more than is required. This will result in a free chlorine residual that can be measured easily. This chlorine residual must be maintained for several minutes depending on chlorine level and water quality. Table 4 lists the free chlorine residual level needed for different contact times, water temperatures and pH levels.

Kits are available for measuring the chlorine residual by looking for a color change after the test chemical is added. The test is simple and easy for a homeowner to perform. If chlorination is required for the water supply, the chlorine residual should be tested regularly to make sure the system is working properly. The kit should specify that it measures the free chlorine residual and not the total chlorine. Once chlorine has combined with other chemicals it is not effective as a disinfectant.

If a test kit does not distinguish between free chlorine and chlorine combined with other chemicals, the test may result in an overestimation of the chlorine residual.

Chlorine will kill bacteria in water, but it takes some time (Table 4) . The time needed depends on the concentration of chlorine. Two methods of chlorination are used to disinfect water: **simple chlorination** and **super chlorination**.

Table 4. Necessary chlorine residual to disinfect water for various contact times, water temperatures and pH			
Water Temp. 50 degrees F			
Contact time (minutes)	Necessary chlorine residual (mg/l)		
	pH 7	pH 7.5	pH 8
40	0.2	0.3	0.4
30	0.3	0.4	0.5
20	0.4	0.6	0.8
10	0.8	1.2	1.6
5	1.6	2.4	3.2
2	4.0	6.0	8.0
1	8.0	12.0	16.0
Water Temp. 32 - 40 degrees F			
Contact time (minutes)	Necessary chlorine residual (mg/l)		
	pH 7	pH 7.5	pH 8
40	0.3	0.5	0.6
30	0.4	0.6	0.8
20	0.6	0.9	1.2
10	1.2	1.8	2.4
5	2.4	3.6	4.8
2	6.0	9.0	12.0
1	12.0	18.0	24.0

Example: What is the necessary chlorine residual for well water with pH 7.5?

The well water is 38 degrees F when it enters the house. The pump delivers 7 gallons per minute and after the chlorine is added it is held in a 100 gallon holding tank.

1. Contact time (from Table 5) - gallons per minute for 50 gallon tank = 5 minutes
2. Multiply by 2 for a 100 gallon tank = 10 minutes.
3. Necessary chlorine residual (from Table 4)- for water at 38 degrees F and pH 7.5 = **1.8 mg/l**.

Simple chlorination involves maintaining a low level of free residual chlorine at a concentration between 0.30 to .5 mg/l for at least 30 minutes. The residual is measured at the faucet most distant from the where chlorine is added to the water supply. To ensure the proper contact time of at least 30 minutes, a holding tank can be installed (Table 5). Pressure tanks, while often thought to be sufficient, are usually too small to always provide 30 minutes of contact time.

Table 5. Available contact time from a 50-gallon holding tank	
Water flow rate (gallons per minute)	Holding time (minutes)
5	7
7	5
10	3.5

Another way to maintain necessary contact time is to run the chlorinated water through a coil of pipe (Table 6).

Table 6. Available contact time from 1000 feet of 1-1/4 inch pipe	
Water flow rate (gallons per minute)	Holding time (minutes)
5	9.2
7	6.6
10	4.6

When the water cannot be held for at least 30 minutes before it is used, super chlorination is an alternative. For **super chlorination**, a chlorine solution is added to the water to produce a chlorine residual of between 3.0 and 5.0 mg/l, which is about ten times stronger than for simple chlorination.

The necessary contact time for this concentration is reduced to less than five minutes (Table 4). The water will have a very strong chlorine smell. If this is not desirable, the chlorine can be removed just before it is used with a carbon filter (Note: may not be currently allowed under your Department of Health for private water supplies).

Oxidation Chemistry

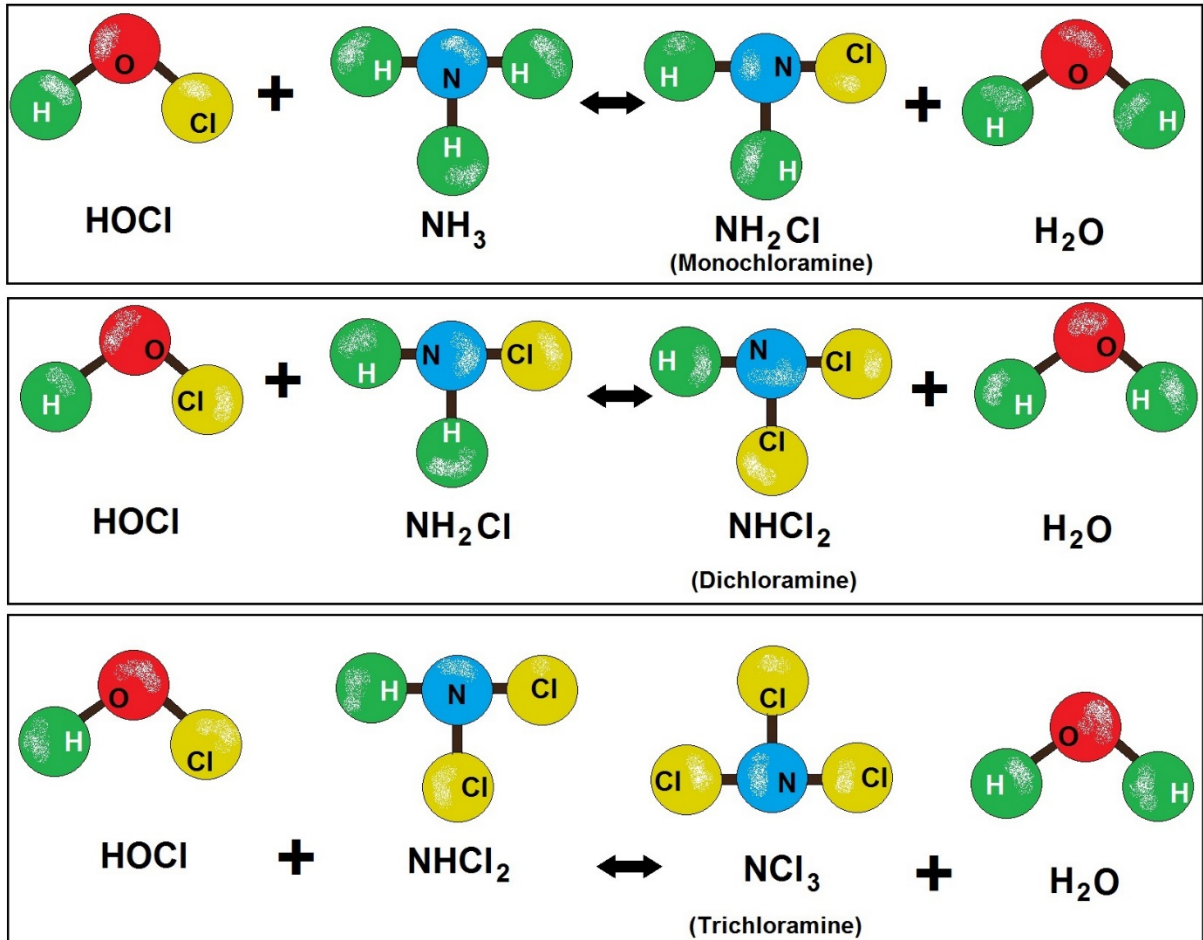
Oxidation chemistry has long been an accepted and effective part of many water treatment programs. Oxidizing chemicals used in today's water treatment programs include: chlorine, chlorine dioxide, bromine, bromine/chlorine releasing compounds, ozone and hydrogen peroxide.

Oxidizing microbiocides are often found at the forefront of many cooling water treatment programs. In large volume or once-through cooling systems they are usually the primary biocide and often are the most cost-effective programs available to a plant.

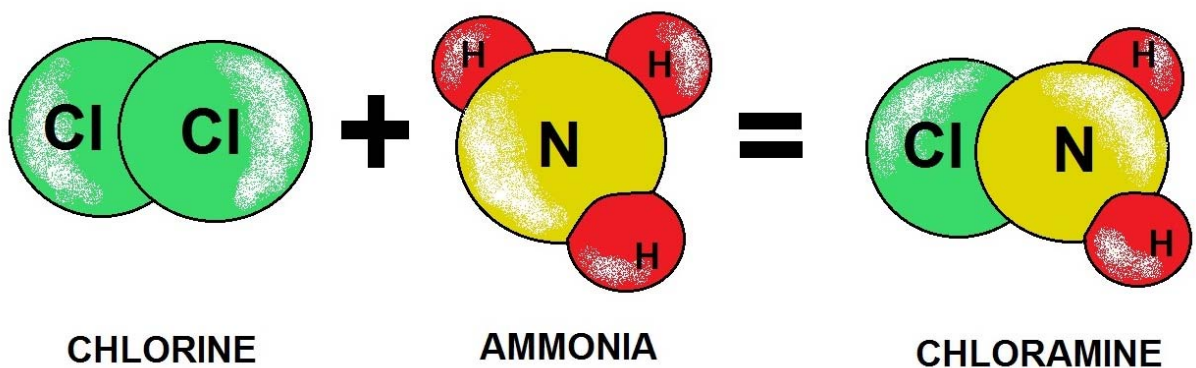
When selecting these economical and versatile chemicals, several factors should be considered before a technically sound program is implemented. Environmental and regulatory impact, system pH, process contamination, and equipment capital and maintenance expense all play a role in the decision-making process.

The primary killing mechanism these types of microbiocides use is oxidizing protein groups within a microorganism. Proteins are the basic components of essential cellular enzymes that are necessary for life-sustaining cellular processes such as respiration. The destruction of these proteins deprives the cell of its ability to carry out fundamental life functions and quickly kills it.

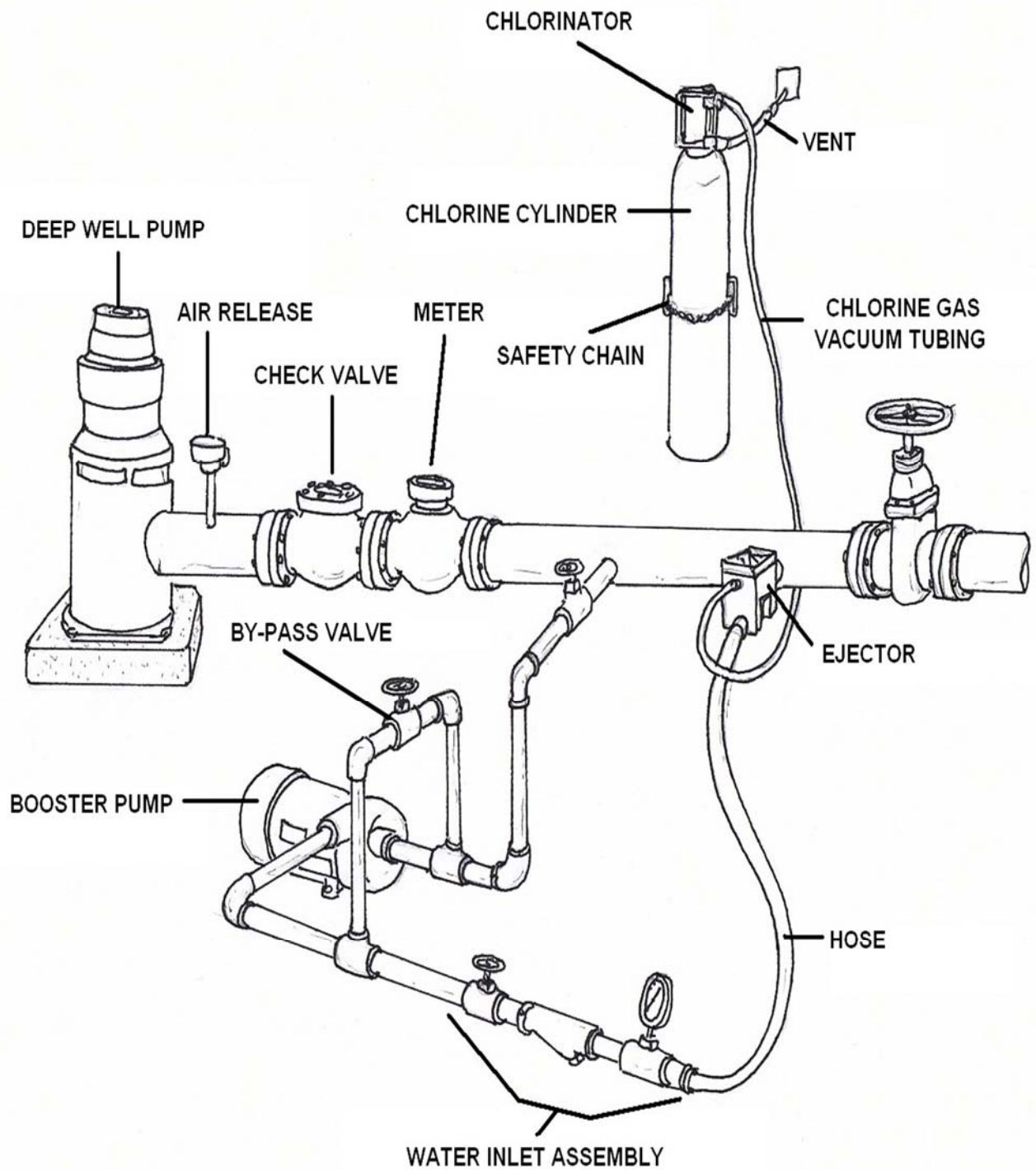
One oxidant is chlorine dioxide, which appears to provide an additional killing mechanism. Chlorine dioxide is able to diffuse readily through hydrophobic lipid layers of an organism, allowing it to react with cellular amino acids, which directly inhibits protein synthesis. Since amino acids are the basic building blocks of all cellular proteins, destruction of these molecules has a devastating effect on the microorganism.



EXAMPLE OF INTERACTION BETWEEN CHLORINE AND VARIOUS FORMS OF NITROGEN
(Which form Monochloramines, Dichloramines and Trichloramines)

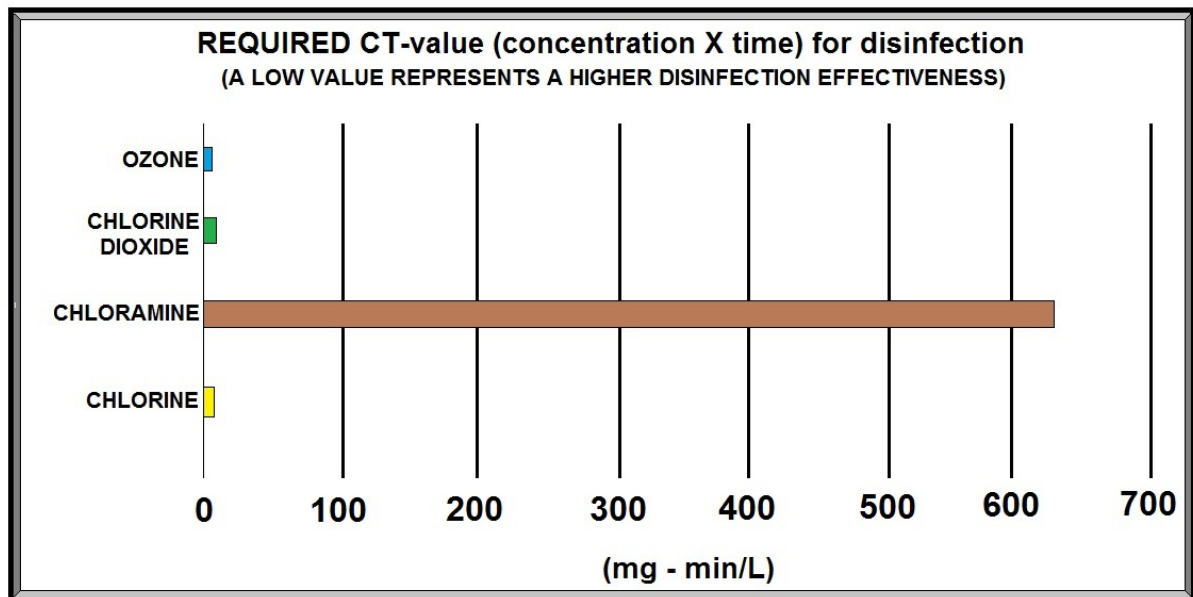


EXAMPLE OF INORGANIC COMPOUND CREATED BY ADDING AMMONIA TO CHLORINE TO
CREATE CHLORAMINE, WHICH IS USED AS A COST-EFFECTIVE DISINFECTANT



EXPOSURE LEVELS (ppm)	EFFECTS OF CHLORINE ON HUMANS
0.2 - 0.4 ppm	ODOR THRESHOLD (VARIES BY INDIVIDUAL)
Less than 0.5 ppm	NO KNOWN ACUTE OR CHRONIC EFFECT
0.5 ppm	ACGIH 8-HOUR TIME WEIGHTED AVERAGE
1.0 ppm	OSHA CEILING LEVEL (PEL) TLV-STEL ERP - 1
1.0 - 10 ppm	IRRITATION OF THE EYES AND MUCOUS MEMBRANES OF THE UPPER RESPIRATORY TRACT. SEVERITY OF SYMPTOMS DEPENDS ON THE CONCENTRATIONS AND LENGTHS OF EXPOSURE
3 ppm	ERP-2 (EMERGENCY RESPONSE PLANNING GUIDELINES AS VALUES DEVELOPED BY AIHA) IS THE MAXIMUM AIRBORNE CONCENTRATION BELOW WHICH IT IS BELIEVED THAT NEARLY ALL INDIVIDUALS COULD BE EXPOSED FOR UP TO 1-HOUR WITHOUT EXPERIENCING OR DEVELOPING IRREVERSABLE OR OTHER SERIOUS HEALTH EFFECTS THAT COULD IMPAIR AN INDIVIDUAL'S ABILITY TO TAKE PROTECTIVE ACTION.
10 ppm	NIOSH IDLH (IMMEDIATELY DANGEROUS TO LIFE AND HEALTH)
20 ppm	ERP-3 IS THE MAXIMUM AIRBORNE CONCENTRATION BELOW WHICH IT IS BELIEVED THAT NEARLY ALL INDIVIDUALS COULD BE EXPOSED FOR UP TO 1-HOUR WITHOUT EXPERIENCING OR DEVELOPING LIFE-THREATENING HEALTH EFFECTS.

EFFECTS OF CHLORINE EXPOSURE IN PARTS PER MILLION



CONTACT VALUES FOR VARIOUS TYPES OF DISINFECTANTS USED IN WATER TREATMENT

	CHLORINE AS A DISINFECTANT	ULTRAVIOLET GERMICIDAL IRRADIATION (UV) AS A DISINFECTANT
DISINFECTION BYPRODUCTS (DBPs)	X	No
CHEMICAL RESIDUE	X	No
NON-CORROSIVE	X	No
COMMUNITY SAFETY RISKS	X	No
EFFECTIVE AGAINST CRYPTOSPORIDIUM AND GIARDIA	X	Yes
WELL-SUITED FOR CHANGING REGULATIONS	X	Yes

CHLORINE vs. UV FOR DISINFECTION

DISINFECTION OF WATER	
DISINFECTANT	WHAT DISINFECTANT IS USED FOR
OZONE (O ₃)	USED IN DESTROYING BACTERIA, ODORS AND VIRUSES (Scrambles DNA in Viruses to prevent reproduction)
CHLORINE (Cl ₂)	USED TO KILL DISEASE-CAUSING PATHOGENS SUCH AS BACTERIA, VIRUSES AND PROTOZOANS
POTASSIUM PERMANGANATE (KMnO ₄)	USED TO REMOVE IRON AND HYDROGEN SULFIDE, AND ALSO USED IN TREATMENT PLANTS TO CONTROL ZEBRA MUSSEL FORMATIONS
COPPER SULFATE (CuSO ₄)	USED CONTROL PLANT AND ALGAE GROWTH
CALCIUM HYPOCHLORITE (Ca(ClO) ₂)	DESTROYS DISEASE-CAUSING ORGANISMS INCLUDING BACTERIA, YEAST, FUNGUS, SPORES AND VIRUSES
CALCIUM HYDROXIDE (Lime) (CaO)	USED FOR pH CONTROL IN WATER TREATMENT TO PREVENT CORROSION OF PIPING

TYPES OF DISINFECTION FOR WATER TREATMENT

		MICROBIOLOGICAL SAFETY	CHEMICAL SAFETY	CUSTOMER AESTHETICS	EASE OF MONITORING	ABILITY TO TREAT DIFFICULT WATER	COST OF OPERATING	CAPITAL COSTS	STATE OF COMMERCIAL DEVELOPMENT	SCALE-UP	WASTE PRODUCTION AND ENERGY USE	RELIABILITY
GROUNDWATER	CHLORINE	—	—	—	+	+	+	+	+	+	+	—
	UF ONLY	—	+	+	—	+	●	●	—	—	●	—
	UV ONLY	+	+	+	●	+	+	●	+	+	●	●
	Alternate + Residual (1)	+	●	●	+	+	●	—	+	+	+	+
SURFACE WATER	CHLORINE ONLY	—	—	—	+	—	+	+	+	+	+	+
	Conventional pre-treat + CHLORINE	+	—	—	+	—	●	●	+	+	●	—
	UF ONLY	—	—	●	—	—	●	●	—	—	●	—
	Conventional pre-treat + UF	●	+	+	—	+	—	—	—	—	—	—
	Conventional pre-treat + OZONE + UF	—	●	—	—	+	—	—	—	—	—	—
	MF + UV	●	+	—	●	—	+	●	—	—	●	+
	Conventional pre-treat + UV	●	+	+	●	—	+	●	+	+	●	●
	Conventional pre-treat + OZONE + UV	+	●	+	+	+	—	—	+	+	●	+
	Alternative + Residual (2)	+	●	●	+	+	—	—	+	+	+	+

Conventional pre-treat = Coagulation / Sedimentation
 UF - Ultrafiltration MF - Microfiltration
 + = Better than average
 — = Worse than average
 ● = Average

(1) UF + Chlorine residual or Conv + UV + Chlorine residual
 (2) Conv pre-treat + UF + Chlorine residual or MF + UV + Chlorine residual or Conv pre-treat + UV + Residual

ASSESSMENT TO DETERMINE EFFECTIVE DISINFECTION METHODS

Chlorination Equipment Requirement Section

For all water treatment facilities, chlorine gas under pressure shall not be permitted outside the chlorine room. A chlorine room is where chlorine gas cylinders and/or ton containers are stored. Vacuum regulators shall also be located inside the chlorine room. The chlorinator, which is the mechanical gas proportioning equipment, may or may not be located inside the chlorine room.

For new and upgraded facilities, from the chlorine room, chlorine gas vacuum lines should be run as close to the point of solution application as possible. Injectors should be located to minimize the length of pressurized chlorine solution lines. A gas pressure relief system shall be included in the gas vacuum line between the vacuum regulator(s) and the chlorinator(s) to ensure that pressurized chlorine gas does not enter the gas vacuum lines leaving the chlorine room.

The gas pressure relief system shall vent pressurized gas to the atmosphere at a location that is not hazardous to plant personnel; vent line should be run in such a manner that moisture collecting traps are avoided. The vacuum regulating valve(s) shall have positive shutdown in the event of a break in the downstream vacuum lines.

As an alternative to chlorine gas, it is permissible to use hypochlorite with positive displacement pumping. Anti-siphon valves shall be incorporated in the pump heads or in the discharge piping.

Capacity

The chlorinator shall have the capacity to dose enough chlorine to overcome the demand and maintain the required concentration of the "free" or "combined" chlorine.



Methods of Control

A chlorine feed system shall be automatic proportional controlled, automatic residual controlled, or compound loop controlled. In the automatic proportional controlled system, the equipment adjusts the chlorine feed rate automatically in accordance with the flow changes to provide a constant pre-established dosage for all rates of flow. In the automatic residual controlled system, the chlorine feeder is used in conjunction with a chlorine residual analyzer which controls the feed rate of the chlorine feeders to maintain a particular residual in the treated water.

In the compound loop control system, the feed rate of the chlorinator is controlled by a flow proportional signal and a residual analyzer signal to maintain particular chlorine residual in the water.

Manual chlorine feed systems may be installed for groundwater systems with constant flow rates.

Standby Provision

As a safeguard against malfunction and/or shut-down, standby chlorination equipment having the capacity to replace the largest unit shall be provided. For uninterrupted chlorination, gas chlorinators shall be equipped with an automatic changeover system. In addition, spare parts shall be available for all chlorinators.

Weigh Scales

Scales for weighing cylinders shall be provided at all plants using chlorine gas to permit an accurate reading of total daily weight of chlorine used. At large plants, scales of the recording and indicating type are recommended. As a minimum, a platform scale shall be provided. Scales shall be of corrosion-resistant material.

Securing Cylinders

All chlorine cylinders shall be securely positioned to safeguard against movement. Tag the cylinder "empty" and store upright and chained.

Ton containers may not be stacked.

Chlorine Leak Detection

Automatic chlorine leak detection and related alarm equipment shall be installed at all water treatment plants using chlorine gas. Leak detection shall be provided for the chlorine rooms. Chlorine leak detection equipment should be connected to a remote audible and visual alarm system and checked on a regular basis to verify proper operation.

Leak detection equipment shall not automatically activate the chlorine room ventilation system in such a manner as to discharge chlorine gas. During an emergency, if the chlorine room is unoccupied, the chlorine gas leakage shall be contained within the chlorine room itself in order to facilitate a proper method of clean-up.

Consideration should also be given to the provision of caustic soda solution reaction tanks for absorbing the contents of leaking one-ton cylinders where such cylinders are in use.

Chlorine leak detection equipment may not be required for very small chlorine rooms with an exterior door (e.g., floor area less than 3m²).

You can use a spray solution of ammonia or a rag soaked with ammonia to detect a small Cl₂ leak. If there is a leak, the ammonia will create a white colored smoke, Ammonium chloride.



Safety Equipment

The facility shall be provided with personnel safety equipment including the following: Respiratory equipment; safety shower, eyewash, gloves, eye protection; protective clothing; cylinder and/or ton repair kits.

Respiratory equipment shall be provided which has been approved under the Occupational Health and Safety Act, General Safety Regulation - Selection of Respiratory Protective Equipment. Equipment shall be in close proximity to the access door(s) of the chlorine room.

Chlorine Room Design Requirements

Where gas chlorination is practiced, the gas cylinders and/or the ton containers up to the vacuum regulators shall be housed in a gas-tight, well illuminated, corrosion resistant and mechanically ventilated enclosure. The chlorinator may or may not be located inside the chlorine room. The chlorine room shall be located at the ground floor level.

Ventilation

Gas chlorine rooms shall have entirely separate exhaust ventilation systems capable of delivering one (1) complete air change per minute during periods of chlorine room occupancy only. The air outlet from the room shall be 150 mm above the floor and the point of discharge located to preclude contamination of air inlets to buildings or areas used by people. The vents to the outside shall have insect screens.

Air inlets should be louvered near the ceiling, the air being of such temperature as to not adversely affect the chlorination equipment. Separate switches for fans and lights shall be outside the room at all entrance or viewing points, and a clear wire-reinforced glass window shall be installed in such a manner as to allow the operator to inspect from the outside of the room.

Heating

Chlorine rooms shall have separate heating systems, if a forced air system is used to heat the building. The hot water heating system for the building will negate the need for a separate heating system for the chlorine room. The heat should be controlled at approximately 15°C.

Cylinders or containers shall be protected to ensure that the chlorine maintains its gaseous state when entering the chlorinator.

Access

All access to the chlorine room shall only be from the exterior of the building. Visual inspection of the chlorination equipment from inside may be provided by the installation of glass window(s) in the walls of the chlorine room. Windows should be at least 0.20 m² in area, and be made of clear wire reinforced glass.

There should also be a '*panic bar*' on the inside of the chlorine room door for emergency exit.

Storage of Chlorine Cylinders

If necessary, a separate storage room may be provided to simply store the chlorine gas cylinders, with no connection to the line. The chlorine cylinder storage room shall have access either to the chlorine room or from the plant exterior, and arranged to prevent the uncontrolled release of spilled gas.

The chlorine gas storage room shall have provision for ventilation at thirty air changes per hour. Viewing glass windows and a panic button on the inside of the door should also be provided.

In very large facilities, entry into the chlorine rooms may be through a vestibule from outside.

Scrubbers

For facilities located within residential or densely populated areas, consideration shall be given to provide scrubbers for the chlorine room.

Chlorine Demand

Chlorine combines with a wide variety of materials. These side reactions complicate the use of chlorine for disinfecting purposes. Their demand for chlorine must be satisfied before chlorine becomes available to accomplish disinfection. The amount of chlorine required to react on various water impurities before a residual is obtained. Also, it means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.

Chlorine Questions and Answer Review

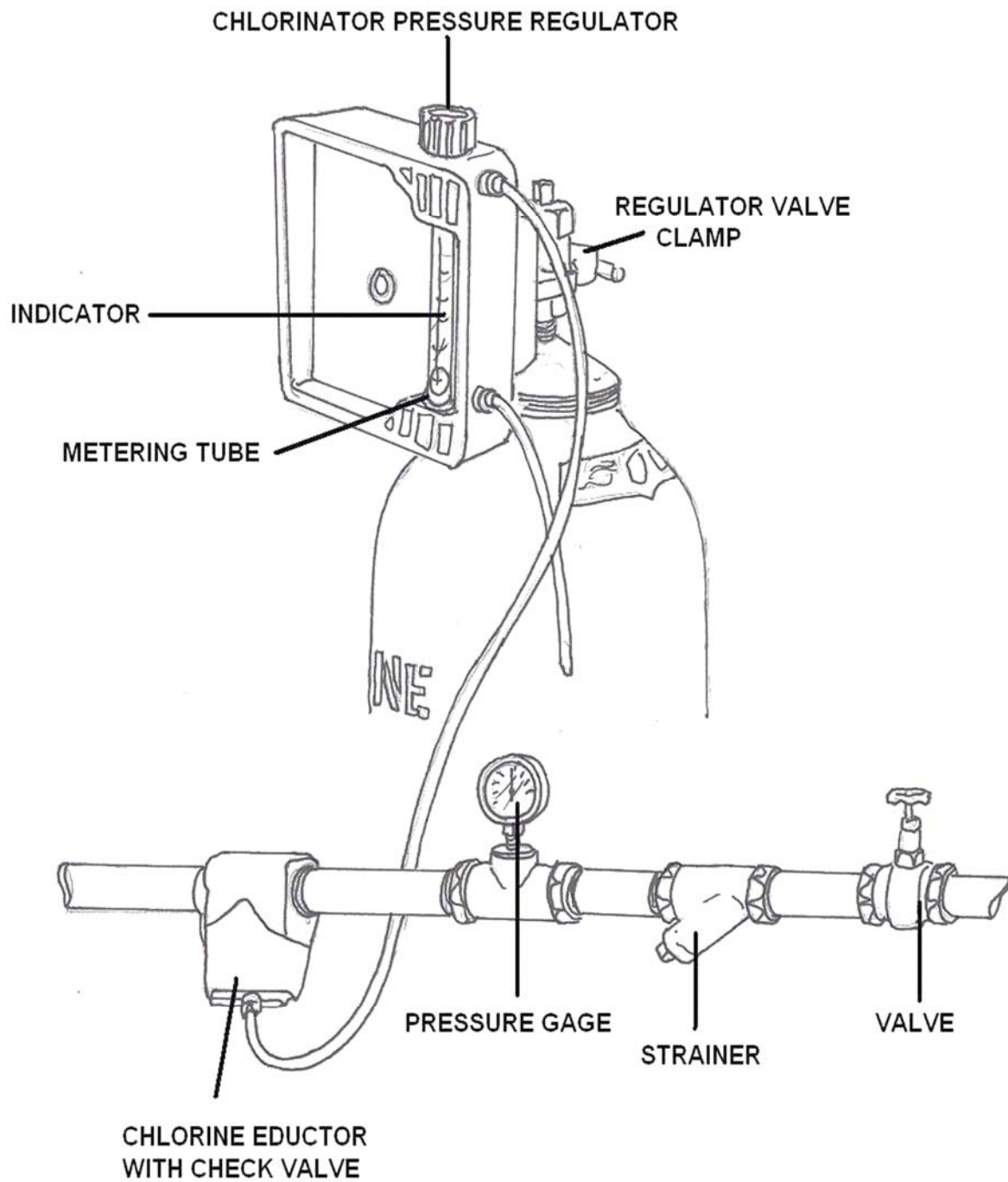
Downstream from the point of post chlorination, what should the concentration of a free chlorine residual be in a clear well or distribution reservoir? 0.5 mg/L.

True or False. Even brief exposure to 1,000 ppm of Cl₂ can be fatal. True

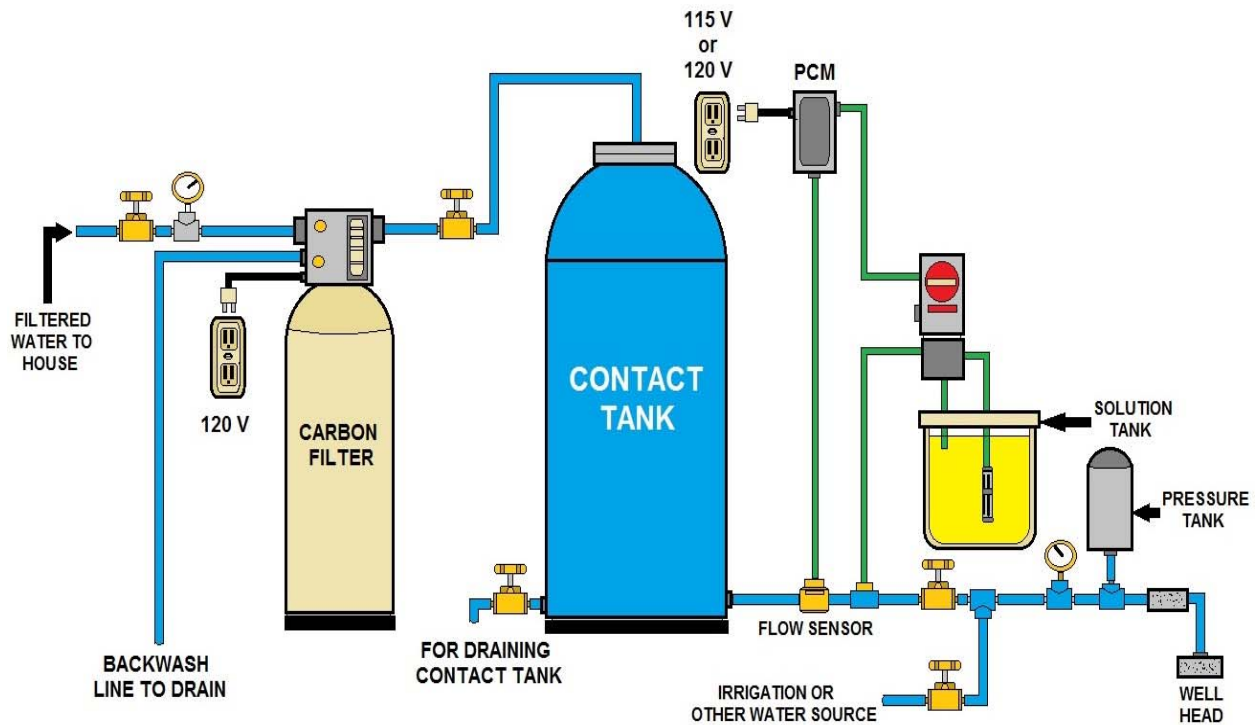
How does one determine the ambient temperature in a chlorine room? Use a regular thermometer because ambient temperature is simply the air temperature of the room.

How is the effectiveness of disinfection determined? From the results of coliform testing.

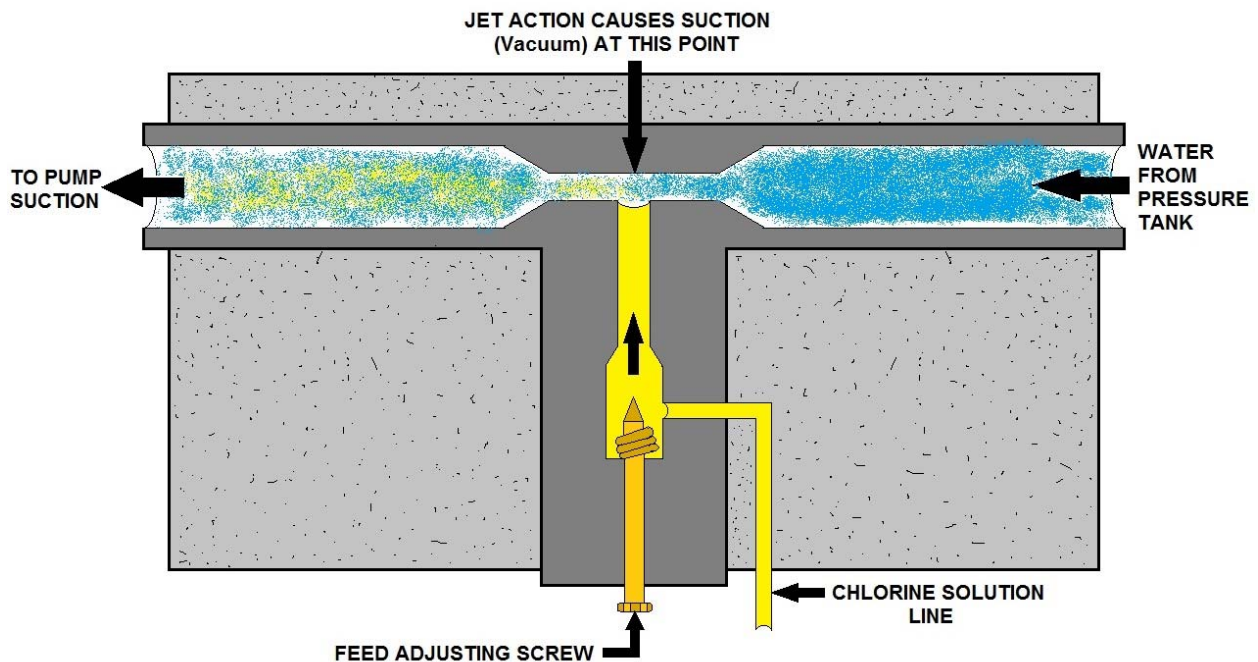
How often should chlorine storage ventilation equipment be checked? Daily.

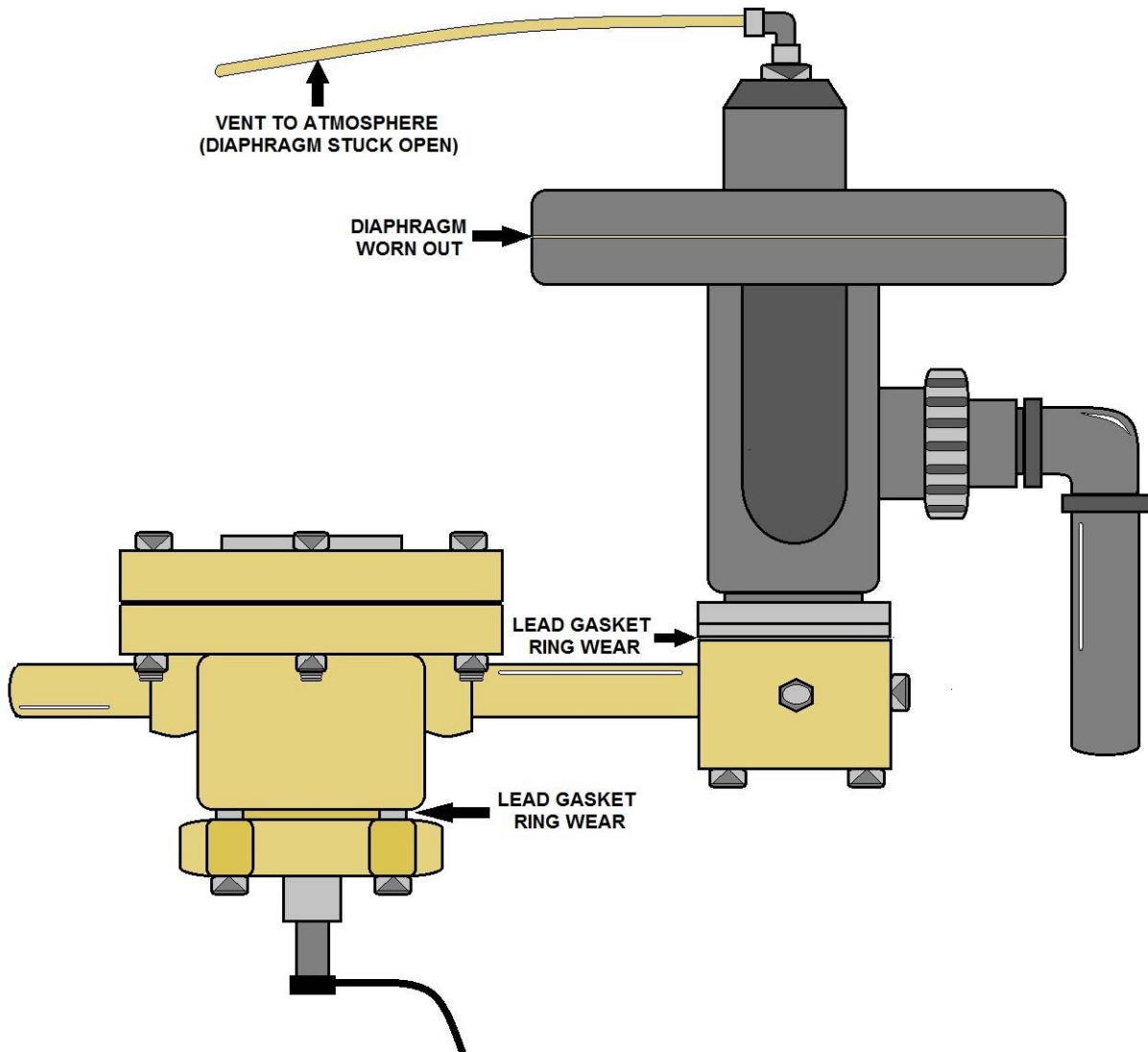


BASIC CHLORINATOR INSTALLATION SYSTEM



CHLORINATING WELL WATER





CHLORINE VACUUM REGULATOR
(SOURCES OF LEAK IN SYSTEM)

Chlorine Health Hazard Section

Signs and Symptoms of Exposure

1. Acute exposure: Acute exposure to low levels of chlorine results in eye, nose, and throat irritation, sneezing, excessive salivation, general excitement, and restlessness. Higher concentrations causes difficulty in breathing, violent coughing, nausea, vomiting, cyanosis, dizziness, headache, choking, laryngeal edema, acute tracheobronchitis, chemical pneumonia. Contact with the liquid can result in frostbite burns of the skin and eyes.

2. Chronic exposure: Chronic exposure to low levels of chlorine gas can result in a dermatitis known as chloracne, tooth enamel corrosion, coughing, severe chest pain, sore throat, hemoptysis and increased susceptibility to tuberculosis.

Inhalation

Immediately remove the exposed person upwind from the contaminated area and contact the poison control center. Inhalation can cause coughing, sneezing, shortness of breath, sensation of tightness in the chest, as well as severe restlessness or anxiety, nausea, and vomiting. The nose and throat may become irritated; a stinging and burning sensation may be experienced. Immediate fatalities can occur as a result of suffocation.

Delayed fatalities can occur as a result of pulmonary edema (fluid in the lungs). For this reason, rest and immediate attention after inhalation is important. Persons with known cardiovascular or lung problems should not risk chlorine exposure. If breathing has stopped, give artificial respiration; if breathing is difficult, give oxygen if equipment and trained personnel are available. If exposed person is breathing, place in a comfortable position and keep person warm and at rest until medical assistance becomes available.

Eye/Skin Contact

Liquid and concentrated gas could produce severe burns and injury on contact.

Eye

Pour a gentle stream of warm water through the affected eye for at least 15 minutes. Contact the poison control center, emergency room or physician right away as further treatment will be necessary.

Skin

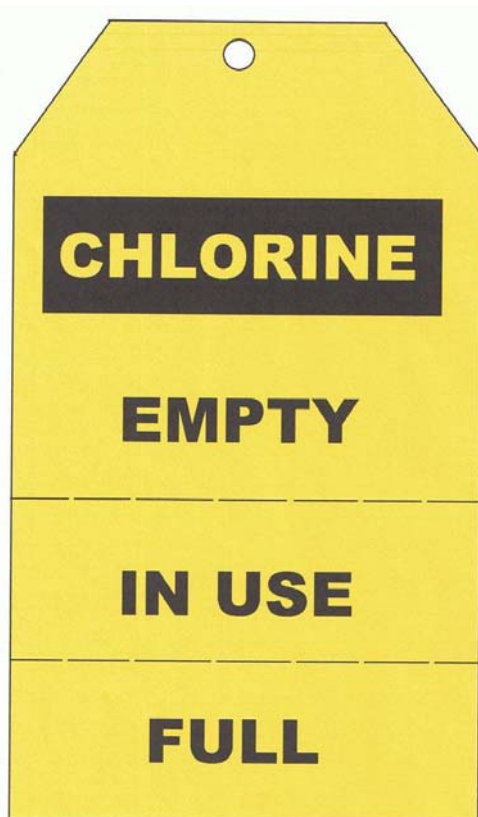
Run a gentle stream of water over the affected area for 15 minutes. A mild soap may be used if available. Contact the poison control center, emergency room or physician right away as further treatment will be necessary.

Chronic

Repeated exposures can result in a loss of ability to detect the odor of chlorine. Long term exposures may cause damage to teeth and inflammation or ulceration of the nasal passages.

Ingestion

Not applicable for gas. Liquid could produce severe burns and injury on contact.



Pre-hospital Management

* Rescue personnel are at low risk of secondary contamination from victims who have been exposed only to gases released from hypochlorite solutions. However, clothing or skin soaked with industrial-strength bleach or similar solutions may be corrosive to rescuers and may release harmful gases.

* Ingestion of hypochlorite solutions may cause pain in the mouth or throat, dysphagia, stridor, drooling, odynophagia, and vomiting. Hypochlorite irritates the skin and can cause burning pain, inflammation, and blisters. Acute exposure to gases released from hypochlorite solutions can cause coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may also occur.

* There is no specific antidote for hypochlorite poisoning. Treatment is supportive.

Hot Zone

Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection

Hypochlorite is irritating to the skin and eyes and in some cases may release toxic gases.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response to situations that involve exposure to potentially unsafe levels of chlorine gas.

Skin Protection: Chemical-protective clothing should be worn due to the risk of skin irritation and burns from direct contact with solid hypochlorite or concentrated solutions.

ABC Reminders

Quickly establish a patient airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal

If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone

Victims exposed only to chlorine gas released by hypochlorite who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection

If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders

Quickly establish a patient airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination

Rapid decontamination is critical. Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings. Flush exposed skin and hair with copious amounts of plain tepid water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed or irritated eyes with saline, Ringer's lactate, or D5W for at least 20 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the support zone.

In Cases of Ingestion, Do Not Induce Emesis or Offer Activated Charcoal.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk; if the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Dilutants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation. Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone

As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone

Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders

Quickly establish a patient airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available.

Additional Decontamination

Continue irrigating exposed skin and eyes, as appropriate. In cases of ingestion, do not induce emesis or offer activated charcoal.

Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk; if the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Dilutants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation.

Advanced Treatment

In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. Avoid blind nasotracheal intubation or use of an esophageal obturator: only use direct visualization to intubate. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so. Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25-0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or who have cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or those not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

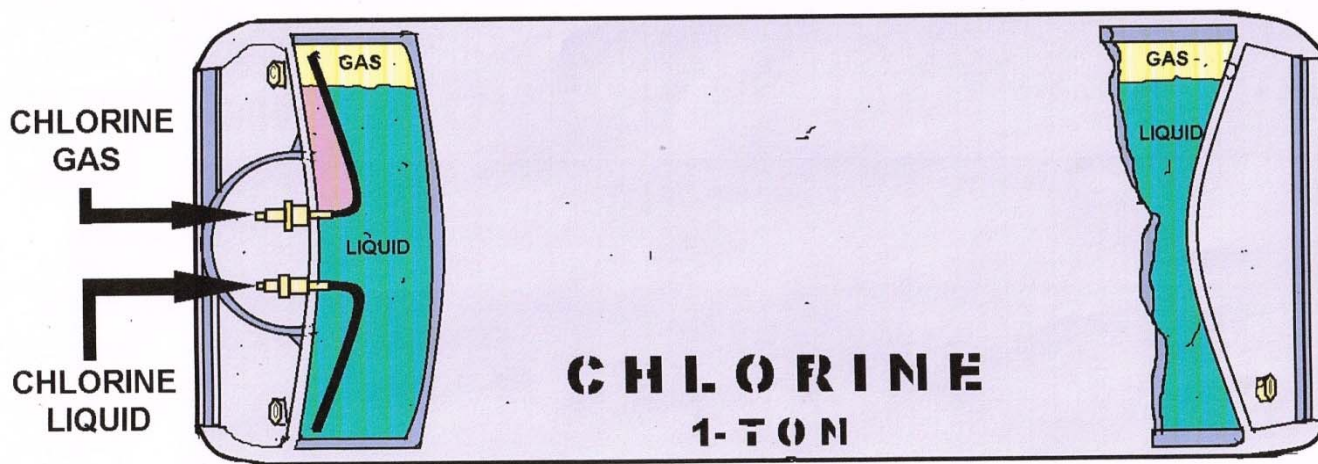
Patients who have ingested hypochlorite, or who show evidence of significant exposure to hypochlorite or chlorine (e.g., severe or persistent cough, dyspnea or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur.

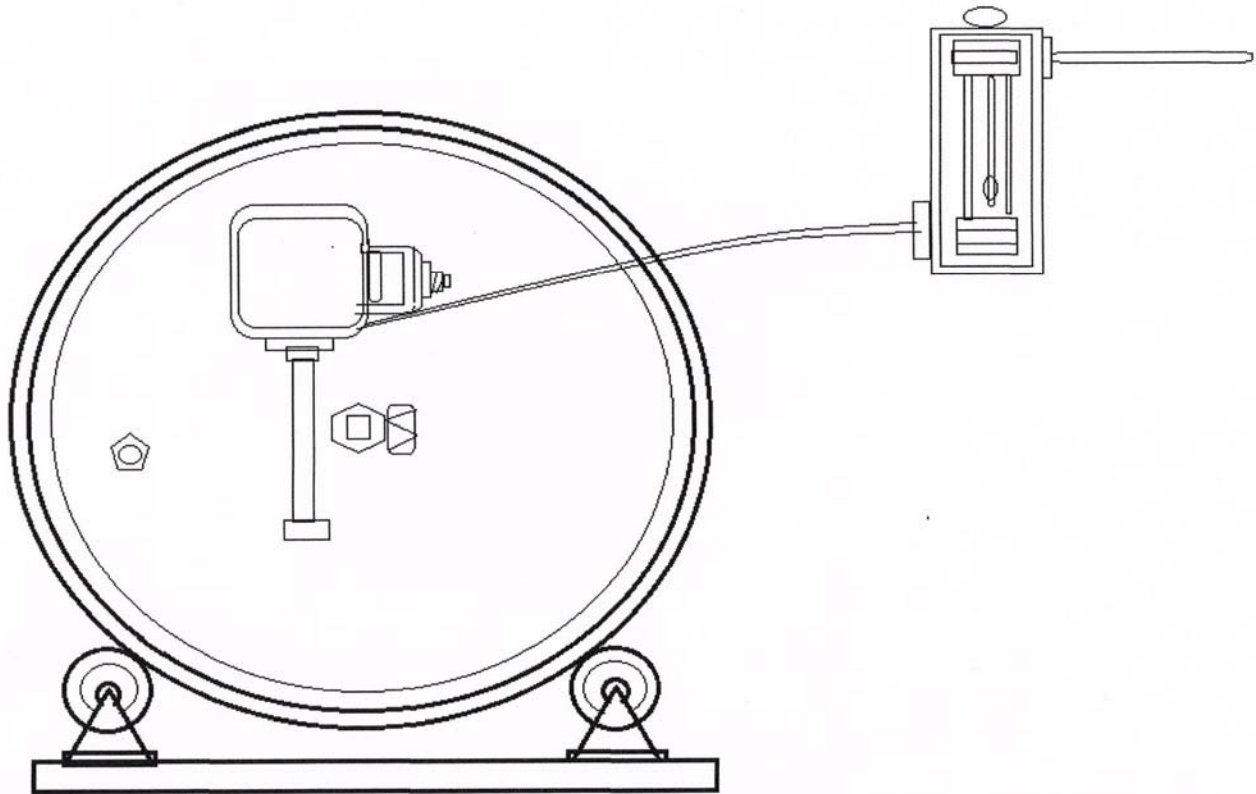
Routes of Exposure

Exposure to chlorine can occur through inhalation, ingestion, and eye or skin contact [Genium 1992].

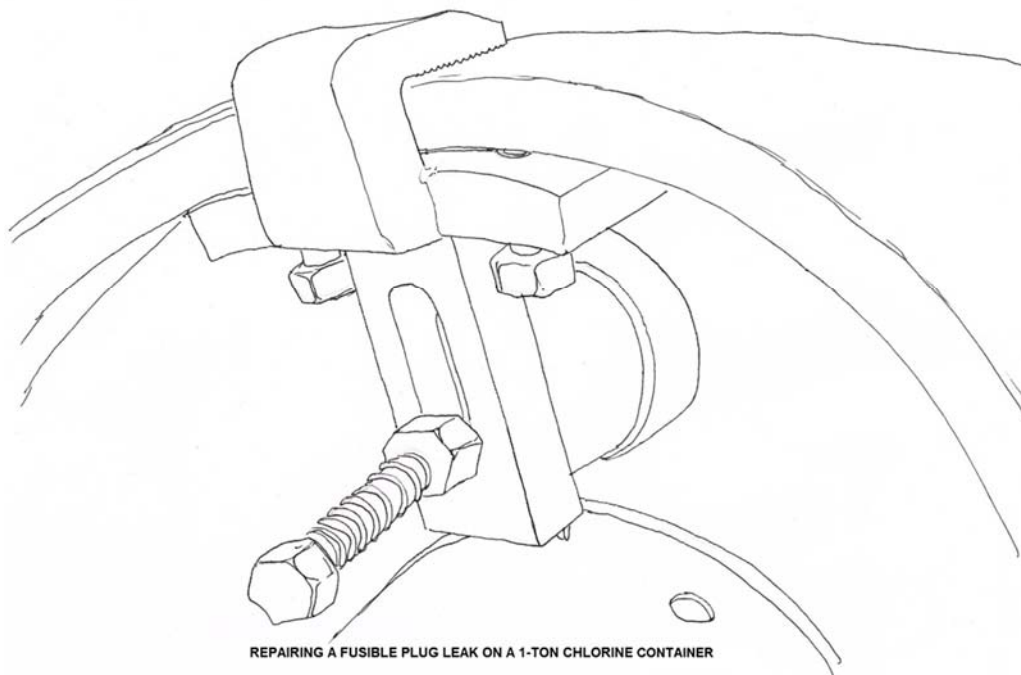
Emergency Medical Procedures: [NIOSH to Supply]

- Rescue: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the Safety Data Sheet (formerly MSDS) required by OSHA's Hazard Communication Standard [29 CFR 1910.1200]).
- All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and methods of protecting themselves during rescue operations.





CHLORINE 1 - TON CONTAINER



REPAIRING A FUSIBLE PLUG LEAK ON A 1-TON CHLORINE CONTAINER



Chlorine Storage

Chlorine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's Hazard Communication Standard [29 CFR 1910.1200].

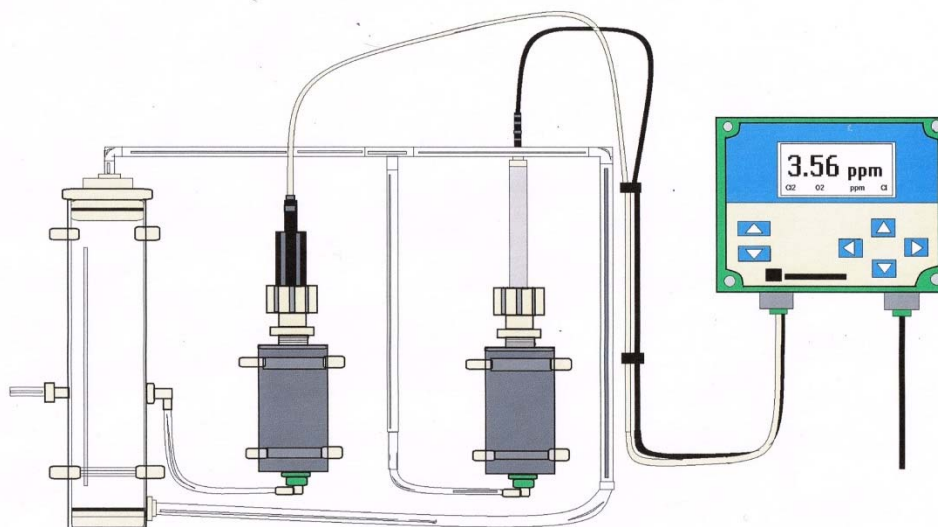
Containers of chlorine should be protected from exposure to weather, extreme temperatures changes, and physical damage, and they should be stored separately from flammable gases and vapors, combustible substances (such as gasoline and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydrogen, ammonia, and sulfur), reducing agents, finely divided metals, arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane, oxomono silane, potassium, propylene, silicon, hydrogen sulfide and water, carbon monoxide and sulfur dioxide, moisture, steam, and water.

Workers handling and operating chlorine containers, cylinders, and tank wagons should receive special training in standard safety procedures for handling compressed corrosive gases. All pipes and containment used for chlorine service should be regularly inspected and tested. Empty containers of chlorine should have secured protective covers on their valves and should be handled appropriately.

Spills and Leaks

In the event of a spill or leak involving chlorine, persons not wearing protective equipment and fully-encapsulating, vapor-protective clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak:

1. Notify safety personnel.
2. Remove all sources of heat and ignition.
3. Keep all combustibles (wood, paper, oil, etc.) away from the leak.
4. Ventilate potentially explosive atmospheres.
5. Evacuate the spill area at least 50 feet in all directions.
6. Find and stop the leak if this can be done without risk; if not, move the leaking container to an isolated area until gas has dispersed. The cylinder may be allowed to empty through a reducing agent such as sodium bisulfide and sodium bicarbonate.
7. Use water spray to reduce vapors; do not put water directly on the leak or spill area.



CHLORINE ANALYZER

Chemical Spill Procedure Example

TOXIC CHEMICAL RELEASE: CHLORINE GAS, AMMONIA, AND LIQUID CHLORINE OR OTHER SUBSTANCE POSING IMMEDIATE HEALTH

DANGER: Evacuate the area. Close all fire doors. Contact the fire department or appropriate emergency response crew immediately. If the substance is liquid and a drain is in the area of the spill, contact the sewer department.

If it is safe for you to clean up the spill:

READ SAFETY DATA SHEET (FORMERLY MSDS) (SDS) FOR SPILLED CHEMICAL.

Read the section STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED.

Read the **WASTE DISPOSAL METHOD** listed.

LOCATE CHEMICAL SPILLS KIT:

Apply gloves and protective eyewear.

Use chemical pads located in the kit to soak up the spill.

Place contaminated pads and gloves in the disposal bag and seal.

IF THE CHEMICAL IS A HAZARDOUS CHEMICAL WASTE, write the name of the chemical on the chemical label, attach the label to the disposal bag and notify a licensed Hazardous Waste Hauler for pick up. All other chemicals can be placed in regular trash.

Follow the methods listed on the SDS for cleaning the contaminated area.

Replace items used from the Chemical Spill Kit.



**READ THE SAFETY DATA
SHEET**



**WEAR PROPER
PPE**



HANDLING CHEMICALS

Evacuation and Emergency Procedures

Leak Procedures

Minor Leak

Note: A minor leak is a small leak which can be discharged to the environment without danger or when the source of the leak can be readily controlled.

If you determine from outside the chlorine feed room that there is a minor leak, do the following:

1. Notify your supervisor.
2. Have your safety partner don SCBA and be watching you from outside the chlorine room.
3. Equip yourself with a SCBA.
4. Enter chlorine gas room.

Once Inside

5. Turn chlorine cylinder(s) OFF, leave water on.
6. Adjust feed rate to maximum to purge system.
7. Vacate room and remove air pack. Wait for 15 minutes, until chlorine pressure drops to zero or vacuum goes to maximum.
8. Do the Pre-Entry Check, put SCBA back on.
9. Crack open cylinder(s) and shut off right away.
10. Use ammonium hydroxide solution to find the leak.
11. Mark the leak.
12. Purge the system of gas as indicated on page 18, Section C (3), with the water still on.
13. Repair gently, using correct tools.
14. Start-up and re-check for leaks.
15. If no more leaks, place system back into service.

NOTE: If unable to repair the source of the leak, call it a Major Leak, and follow the appropriate emergency steps.

16. Clean up:

- remove air pack and recharge;
- air or launder clothes; and
- take a shower.

17. Document the event completely. Report the events which may have serious health or safety implications to the State or Federal Occupational Safety and Health Administration and/or Environmental Protection Agency (for Possible Air Violations and Toxic Releases). Also contact the local Fire Department and your Risk Management personnel.

Major Leak

If you determine from outside the chlorine gas feed or storage room that there is a major leak, you could have a real problem not only for your fellow workers but also for nearby residents and for the plant equipment! Workers can protect themselves with SCBA. Residents may have to be evacuated.

We recommend the following steps, if you discover a Major Leak at your facility.

1. Protect yourself at all times during the emergency, and make sure you will not be overcome by the leaking gas. Stay out of the chlorine gas room. Keep the SCBA ready. Chlorine gas escaping through the ventilation outlet may be collecting outside the chlorine gas room, so be careful outside as well.

2. Isolate the area.

3. Notify your supervisor.

4. Implement the Emergency Response Contingency Plan that has been established for your facility, in consultation with the Safety/Health Committee and/or Risk Management Department.

NOTE: The following steps should be customized as necessary.

5. Notify your Chlorop/Supplier, fire department, police, Spill Report Center, according to your facility's policy.

6. Follow directions given by Chlorop/Supplier.

7. Document the events. Take photographs. Measure the Chlorine in the air.

8. Notify the State or Occupational Safety and Health Administration and/or Environmental Protection Agency (for Possible Air Violations and Toxic Releases). Also contact the local Fire Department and your Risk Management personnel.



Using DPD Method for Chlorine Residuals

N, N – diethyl-p-phenylenediamine



Small portable chlorine measuring kit. The redder the mixture the “hotter” or stronger the chlorine in solution.

Measuring Chlorine Residual * *Know and memorize.*

*Chlorine residual is the amount of chlorine remaining in water that can be used for disinfection. A convenient, simple and inexpensive way to measure chlorine residual is to use a small portable kit with pre-measured packets of chemicals that are added to water. (Make sure you buy a test kit using the **DPD method**, and not the outdated orthotolodine method.)

Chlorine test kits are very useful in adjusting the chlorine dose you apply. You can measure what chlorine levels are being found in your system (especially at the far ends).

*Free chlorine residuals need to be checked and recorded daily. These results should be kept on file for a health or regulatory agency inspection during a regular field visit.

*The most accurate method for determining chlorine residuals is to use the laboratory amperometric titration method.

****Chlorinator Parts***

- A. Ejector
- B. Check Valve Assembly
- C. Rate Valve
- D. Diaphragm Assembly
- E. Interconnection Manifold
- F. Rotometer Tube and Float
- G. Pressure Gauge
- H. Gas Supply



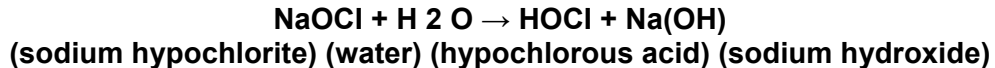
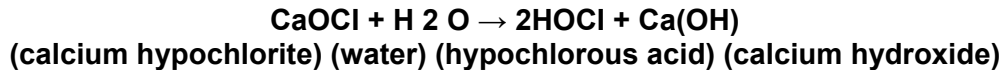
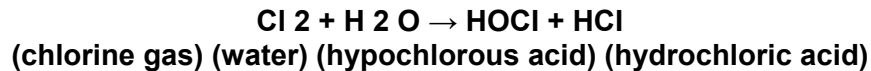
***Chlorine measurement devices or Rotameters**



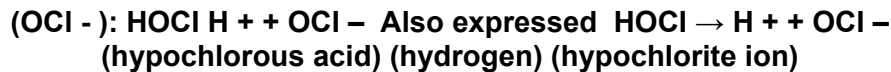
***Safety Information:** There is a fusible plug on every chlorine tank. This metal plug will melt at 158° to 165° F. This is to prevent a build-up of excessive pressure and the possibility of cylinder rupture due to fire or high temperatures. * Know and memorize.

Chemistry of Chlorination

Chlorine can be added as sodium hypochlorite, calcium hypochlorite or chlorine gas. When any of these is added to water, chemical reactions occur as these equations show:



All three forms of chlorine produce hypochlorous acid (HOCl) when added to water. Hypochlorous acid is a weak acid but a strong disinfecting agent. The amount of hypochlorous acid depends on the pH and temperature of the water. Under normal water conditions, hypochlorous acid will also chemically react and break down into a hypochlorite ion.



The hypochlorite ion is a much weaker disinfecting agent than hypochlorous acid, about 100 times less effective.

Let's now look at how pH and temperature affect the ratio of hypochlorous acid to hypochlorite ions. As the temperature is decreased, the ratio of hypochlorous acid increases. Temperature plays a small part in the acid ratio. Although the ratio of hypochlorous acid is greater at lower temperatures, pathogenic organisms are actually harder to kill. All other things being equal, higher water temperatures and a lower pH are more conducive to chlorine disinfection.

Types of Residual

If water were pure, the measured amount of chlorine in the water should be the same as the amount added. But water is not 100% pure. There are always other substances (interfering agents) such as iron, manganese, turbidity, etc., which will combine chemically with the chlorine.

This is called the **chlorine demand**. Naturally, once chlorine molecules are combined with these interfering agents, they are not capable of disinfection. It is free chlorine that is much more effective as a disinfecting agent.

So let's look now at how free, total and combined chlorine are related. When a chlorine residual test is taken, either a total or a free chlorine residual can be read.

Total residual is all chlorine that is available for disinfection.

Total chlorine residual = free + combined chlorine residual.

Free chlorine residual is a much stronger disinfecting agent. Therefore, most water regulating agencies will require that your daily chlorine residual readings be of free chlorine residual.

Break-point chlorination is where the chlorine demand has been satisfied, any additional chlorine will be considered **free chlorine**.

Residual Concentration/Contact Time (CT) Requirements

Disinfection to eliminate fecal and coliform bacteria may not be sufficient to adequately reduce pathogens such as Giardia or viruses to desired levels. Use of the "**CT**" disinfection concept is recommended to demonstrate satisfactory treatment, since monitoring for very low levels of pathogens in treated water is analytically very difficult.

The CT concept, as developed by the United States Environmental Protection Agency (Federal Register, 40 CFR, Parts 141 and 142, June 29, 1989), uses the combination of disinfectant residual concentration (mg/L) and the effective disinfection contact time (in minutes) to measure effective pathogen reduction. The residual is measured at the end of the process, and the contact time used is the T10 of the process unit (time for 10% of the water to pass).

$$\text{CT} = \text{Concentration (mg/L)} \times \text{Time (minutes)}$$

The effective reduction in pathogens can be calculated by reference to standard tables of required CTs.



500 pound chlorine gas container and 150 pound gas cylinders. The 1/2 ton is on a scale. Cylinders stand upright and containers on their sides.

Chlorine Exposure Information

This information is necessary to pass your certification exam.

* OSHA PEL 1 PPM - IDLH 10 PPM and Fatal Exposure Limit 1,000 PPM

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m³)) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level. * IDLH 10 PPM

Physical and chemical properties of chlorine: A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber-colored liquid, a noncombustible gas, and a strong oxidizer. Solid chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air. Atomic number of chlorine is 17. Cl is the elemental symbol and Cl₂ is the chemical formula. *Know it.*

Monochloramine, dichloramine, and trichloramine are also known as Combined Available Chlorine. Cl₂ + NH₄.

HOCl and OCl⁻: The **OCL**- is the hypochlorite ion and the both of these two species are known as free available chlorine. These are the two main chemical species formed by chlorine in water and they known by collectively as hypochlorous acid and the hypochlorite ion. When chlorine gas is added to water, it rapidly hydrolyzes. The chemical equations best describes this reaction is **Cl₂ + H₂O --> H⁺ + Cl⁻ + HOCl**. Hypochlorous acid is the most germicidal of the chlorine compounds with the possible exception of chlorine dioxide. * **Know and memorize.**

Yoke-type connectors should be used on a chlorine cylinder's valve, assuming that the threads on the valve may be worn.

The connection from a chlorine cylinder to a chlorinator should be replaced by using a new, approved gasket on the connector. Always follow your manufacturer's instructions.

On a 1 ton container, the chlorine pressure reducing valve should be located downstream of the evaporator when using an evaporator. This is the liquid chlorine supply line and it is going to be made into chlorine gas.

In water treatment, chlorine is added to the effluent before the contact chamber (before the clear well) for complete mixing. One reason for not adding it directly to the chamber is that the chamber has very little mixing due to low velocities.

Here are several safety precautions when using chlorine gas: in addition to protective clothing and goggles, chlorine gas should be used only in a well-ventilated area so that any leaking gas cannot concentrate. Emergency procedures in the case of a large uncontrolled chlorine leak are to: notify local emergency response team, warn and evacuate people in adjacent areas, and be sure that no one enters the leak area without adequate self-contained breathing equipment.

Here are several symptoms of chlorine exposure: burning of eyes, nose, and mouth, coughing, sneezing, choking, nausea and vomiting, headaches and dizziness, fatal pulmonary edema, pneumonia and skin blisters. A little Cl₂ will corrode the teeth and then progress to throat cancer.

Approved method for storing a 150 - 200 pound chlorine cylinder: Secure each cylinder in an upright position, attach the protective bonnet over the valve and firmly secure each cylinder. Never store near heat. Always store the empty in an upright, secure position with proper signage.

Disinfectant Review Statements

Disinfectant residual: The CT values for disinfection are used to determine the disinfection efficiency based upon time and what other parameter?

Bacteria, Virus, and Intestinal parasites: What types of organisms may transmit waterborne diseases?

Disinfection By-Products (DBPs): The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer.

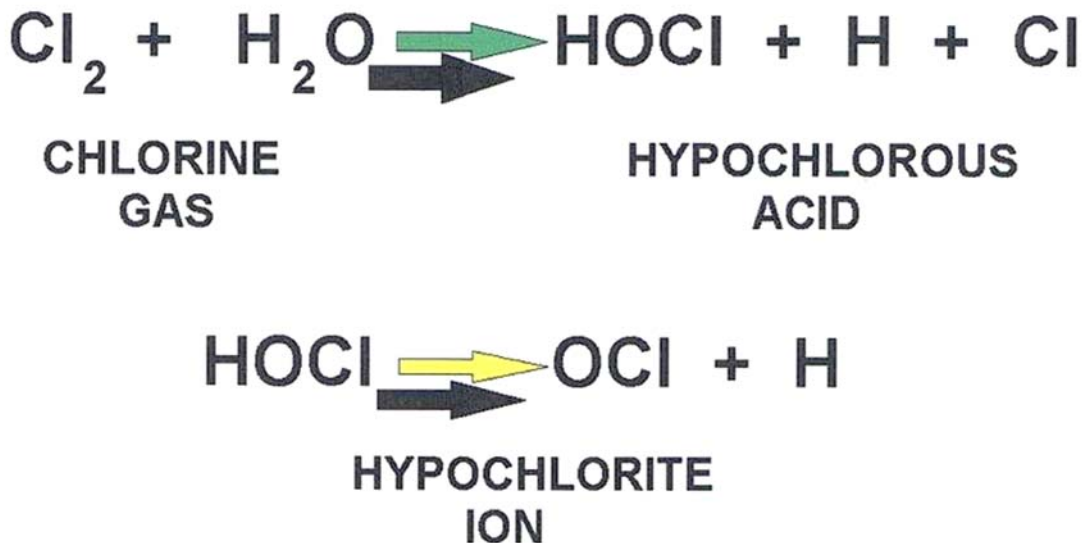
How is the effectiveness of disinfection determined? *From the results of coliform testing.*

The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites.

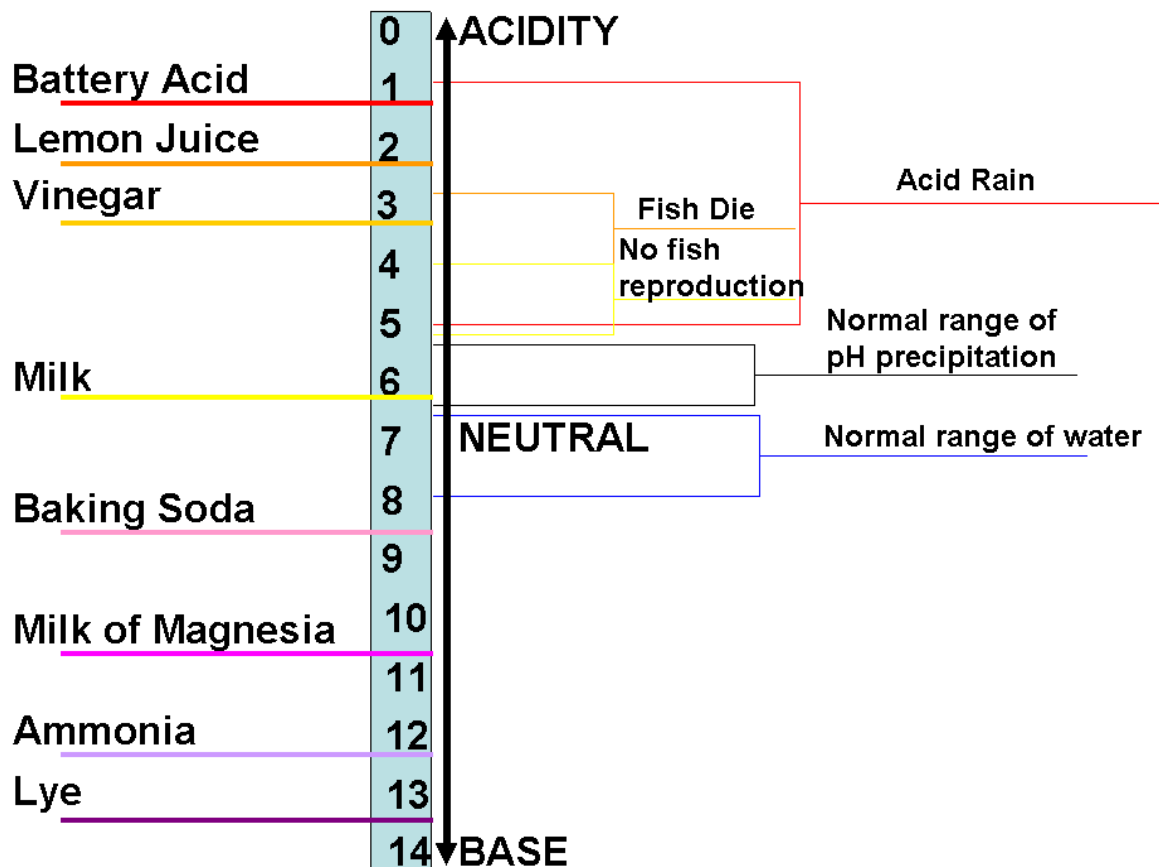
What types of source water are required by law to treat water using filtration and disinfection? Groundwater under the direct influence of surface water and surface water sources.

E. Coli, *Escherichia coli*: is a bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

pH is on a scale from 0-14. 7 is considered neutral and acid is on the 0 to 7 side and the base is 7-14. pH is known as the Power of Hydroxyl Ion activity.



pH Scale



***pH:** A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity.

***pH = (Power of Hydroxyl Ion Activity).**

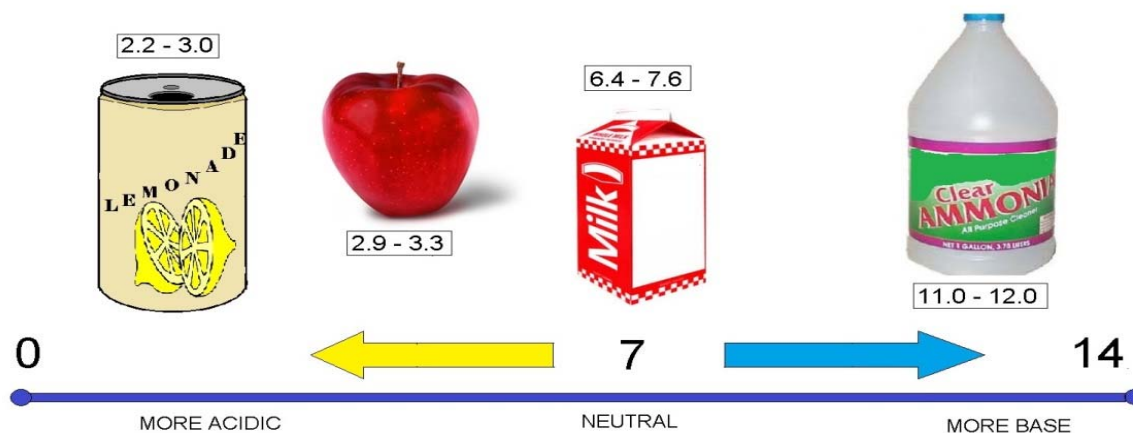
*The acidity of a water sample is measured on a pH scale. This scale ranges from **0** (maximum acidity) to **14** (maximum alkalinity). The middle of the scale, **7**, represents the neutral point. The acidity increases from neutral toward **0**.

*Because the scale is logarithmic, a difference of one pH unit represents a tenfold change. For example, the acidity of a sample with a pH of **5** is ten times greater than that of a sample with a pH of **6**. A difference of 2 units, from **6** to **4**, would mean that the acidity is one hundred times greater, and so on.

Normal rain has a pH of **5.6** – slightly acidic because of the carbon dioxide picked up in the earth's atmosphere by the rain.

CONCENTRATION OF HYDROGEN IONS COMPARED TO DISTILLED H ₂ O	1/10,000,000	14	LIQUID DRAIN CLEANER CAUSTIC SODA	EXAMPLES OF SOLUTIONS AND THEIR RESPECTIVE pH
	1/1,000,000	13	BLEACHES OVEN CLEANERS	
	1/100,000	12	SOAPY WATER	
	1/10,000	11	HOUSEHOLD AMMONIA (11.9)	
	1/1,000	10	MILK OF MAGNESIUM (10.5)	
	1/100	9	TOOTHPASTE (9.9)	
	1/10	8	BAKING SODA (8.4) / SEA WATER EGGS	
	0	7	"PURE" WATER (7)	
	10	6	URINE (6) / MILK (6.6)	
	100	5	ACID RAIN (5.6) BLACK COFFEE (5)	
	1000	4	TOMATO JUICE (4.1)	
	10,000	3	GRAPEFRUIT & ORANGE JUICE SOFT DRINK	
	100,000	2	LEMON JUICE (2.3) VINEGAR (2.9)	
	1,000,000	1	HYDROCHLORIC ACID SECRETED FROM STOMACH LINING (1)	
	10,000,000	0	BATTERY ACID	

pH Scale



pH SCALE

Chlorine Supplement *Know this section. Answers at rear.*

1. How should the connection from a chlorine cylinder to a chlorinator be replaced?
2. How many turns should a chlorine gas cylinder be initially opened?
3. If the temperature of a full chlorine cylinder is increased by 50°F or 30°C, what is the most likely result?
4. What is meant by the specific gravity of a liquid?
5. Which metals are the only metals that are totally inert to moist chlorine gas?
6. What will be discharged when opening the top valve on a one-ton chlorine cylinder?
7. What are the approved methods for storing a chlorine cylinder?
8. What are normal conditions for a gas chlorination start-up?
9. Name safety precautions when using chlorine gas.
10. What compounds are formed in water when chlorine gas is introduced?
11. Why should roller bearings not be used to rotate a one-ton chlorine cylinder?
12. What are the physical and chemical properties of chlorine?
13. What are the necessary emergency procedures in the case of a large uncontrolled chlorine leak?
14. Name several symptoms of chlorine exposure.
15. 5 lbs. of a 70% concentration sodium hypochlorite solution is added to a tank containing 650 gallons of water. What is the chlorine dosage?

16. As soon as Cl₂ gas enters the throat area, a victim will sense a sudden stricture - nature's way of signaling to prevent passage of the gas to the lungs. At this point, the victim must attempt to do two things. Name them.
17. Positive pressure SCBAs and full face piece SARs can be used in oxygen deficient atmospheres containing less than what percentage of oxygen in the atmosphere?
18. Death is possible from asphyxia, shock, reflex spasm in the larynx, or massive pulmonary edema. Populations at special risk from chlorine exposure are individuals with pulmonary disease, breathing problems, bronchitis, or chronic lung conditions.
A. TRUE
B. FALSE
19. Chlorine gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining of the respiratory tract when the tissue is exposed to chlorine. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of chlorine gas in air, causing acute discomfort that warns of the presence of the toxicant.
A. TRUE
B. FALSE
20. Even brief exposure to 1,000 ppm of Cl₂ can be fatal.
A. TRUE
B. FALSE
21. What are the two main chemical species formed by chlorine in water and what name are they known by collectively?
22. When chlorine gas is added to water, it rapidly hydrolyzes according to the reaction:
23. Which chemical reaction equation represents the dissociation of hypochlorous acid?
24. This species of chlorine is the most germicidal of ALL chlorine compounds with the possible exception of chlorine dioxide.

Chlorine Answers

1. Use a new, approved gasket on the connector
2. 1/4 turn to unseat the valve, then open one complete turn
3. The cylinder may rupture
4. The ratio of the density of the liquid to the density of water at 4 degrees C
5. Gold, Platinum, and Tantalum
6. Gas chlorine
7. Secure each cylinder in an upright position. Attach the protective bonnet over the valve. Firmly secure each cylinder.
8. Open chlorine metering orifice slightly. Inspect vacuum lines. Start injector water supply
9. In addition to protective clothing and goggles, chlorine gas should be used only in a well-ventilated area so that any leaking gas cannot concentrate.
10. Chlorine gas forms a mixture of hydrochloric and hypochlorous acids
11. Because it is too easy to roll
12. A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber colored liquid, a noncombustible gas, and a strong oxidizer. Chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air.
13. Notify local emergency response team. Warn and evacuate people in adjacent areas. Be sure that no one enters the leak area without adequate self-contained breathing equipment.
14. Burning of eyes, nose, and mouth; lacrimation and rhinorrhea; Coughing, sneezing, choking, nausea and vomiting; headaches and dizziness; Fatal pulmonary edema; pneumonia; conjunctivitis; keratitis; pharyngitis; burning chest pain; dyspnea; hemoptysis; hypoxemia; dermatitis; and skin blisters.
15. 646 mg/L
16. Get out of the area of the leak, proceeding upwind, and 2) take only very short breaths through the mouth
17. 0.195 or also written 19.5%
18. True
19. True
20. True
21. HOCl and OCl⁻; free available chlorine
22. $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{Cl}^- + \text{HOCl}$
23. $\text{HOCl} \rightleftharpoons \text{H}^+ + \text{OCl}^-$
24. Hypochlorous acid

Backflow and Cross-Connection Control Chapter 6



A Certified Backflow Tester examining a Double Check Detector check fire line assembly. Notice the water meter which will detect any water usage that may be used in the fire line. All backflow assemblies need to be tested annually and the assemblies need to be 12 inches above the ground or in some cases like the PVB, 12 inches above the highest downstream outlet.

Backflow Statements *Memorize these statements.*

Backflow condition: A continuous positive pressure in a distribution system is essential for preventing what event?

Backflow or cross-connection failure: What might be the source of an organic substance causing taste and odor problems in a water distribution system?

Backflow Prevention: To stop or prevent the occurrence of the unnatural act of reversing the normal direction of the flow of a liquid, gas, or solid substance back into the public potable (drinking) water supply. See Cross-connection control.

Backflow: Minimum water pressure must be maintained to ensure adequate customer service during peak flow periods. However minimum positive pressure must be maintained in mains to protect against backflow or backsiphonage from cross-connections.

Backflow: Name the most common **CAUSE** for public water supply contamination. Backflow, or cross-connection.

Backflow: To reverse the natural and normal directional flow of a liquid, gas, or solid substance back into the public potable (drinking) water supply. This is normally an undesirable effect.

Backflow: What does a backsiphonage condition usually cause? Reduced pressure or negative pressure on the service or supply side.

Backflow: What does a double check valve backflow assembly provide effective protection from? Both backpressure and backsiphonage of pollution only.

Backflow: What is equipment that utilizes water for cooling, lubrication, washing or as a solvent always susceptible to? A cross-connection.

Backflow: What is the definition of '**backflow**'? A reverse flow condition that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system.

Backflow: What is the difference between a reduced pressure principle backflow device and a double check backflow device? The RP has a relief valve.

Backflow: What is the maximum time period between having a backflow device tested by a certified backflow tester? 1 year.

Backflow: What must an operator ensure when installing a pressure vacuum breaker backflow device? It must be at least 12 inches about the highest downstream outlet.

Backflow Principles

Atmospheric Pressure

The atmosphere is the entire mass of air that surrounds the earth. While it extends upward for about 500 miles, the section of primary interest is the portion that rests on the earth's surface and extends upward for about 7 1/2 miles. This layer is called the troposphere.

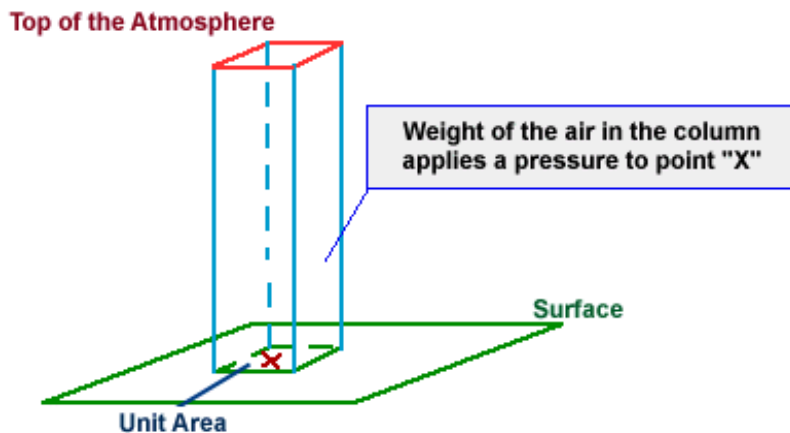
If a column of air 1-inch square extending all the way to the "**top**" of the atmosphere could be weighed, this column of air would weigh approximately 14.7 pounds at sea level. Thus, atmospheric pressure at sea level is approximately 14.7 psi.

As one ascends, the atmospheric pressure decreases by approximately 1.0 psi for every 2,343 feet. However, below sea level, in excavations and depressions, atmospheric pressure increases. Pressures under water differ from those under air only because the weight of the water must be added to the pressure of the air.

Atmospheric pressure can be measured by any of several methods. The common laboratory method uses the mercury column barometer. The height of the mercury column serves as an indicator of atmospheric pressure. At sea level and at a temperature of 0° Celsius (C), the height of the mercury column is approximately 30 inches, or 76 centimeters. This represents a pressure of approximately 14.7 psi. The 30-inch column is used as a reference standard.

Another device used to measure atmospheric pressure is the aneroid barometer. The aneroid barometer uses the change in shape of an evacuated metal cell to measure variations in atmospheric pressure. The thin metal of the aneroid cell moves in or out with the variation of pressure on its external surface. This movement is transmitted through a system of levers to a pointer, which indicates the pressure.

The atmospheric pressure does not vary uniformly with altitude. Its changes are more rapid. Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air above that surface. In the diagram below, the pressure at point "X" increases as the weight of the air above it increases. The same can be said about decreasing pressure, where the pressure at point "X" decreases if the weight of the air above it also decreases.



Pressure may be referred to using an absolute scale, pounds per square inch absolute (psia), or gauge scale, (psiag). Absolute pressure and gauge pressure are related. Absolute pressure is equal to gauge pressure plus the atmospheric pressure. At sea level, the atmospheric pressure is 14.7 psai.

Absolute pressure is the total pressure. Gauge pressure is simply the pressure read on the gauge. If there is no pressure on the gauge other than atmospheric, the gauge will read zero. Then the absolute pressure would be equal to 14.7 psi, which is the atmospheric pressure.

Vacuum

The term *vacuum* indicates that the absolute pressure is less than the atmospheric pressure and that the gauge pressure is negative. A complete or total vacuum would mean a pressure of 0 psia or -14.7 psig. Since it is impossible to produce a total vacuum, the term vacuum, as used in this document, will mean all degrees of partial vacuum. In a partial vacuum, the pressure would range from slightly less than 14.7 psia (0 psig) to slightly greater than 0 psia (-14.7 psig). Backsiphonage results from atmospheric pressure exerted on a liquid forcing it toward a supply system that is under a vacuum.

Water Pressure

*The weight of a cubic foot of water is 62.4 pounds per square foot. The base can be sub-divided into 144-square inches with each subdivision being subjected to a pressure of 0.433 psig.

Suppose you placed another cubic foot of water on top of the first cubic foot. The pressure on the top surface of the first cube which was originally atmospheric, or 0 psig, would now be 0.4333 psig as a result of the additional cubic foot of water. The pressure of the base of the first cubic foot would be increased by the same amount of 0.866 psig or two times the original pressure.

Hydraulics

The word *hydraulics* is based on the Greek word for water, and originally covered the study of the physical behavior of water at rest and in motion. Use has broadened its meaning to include the behavior of all liquids, although it is primarily concerned with the motion of liquids. Hydraulics includes the manner in which liquids act in tanks and pipes, deals with their properties, and explores ways to take advantage of these properties.

Hydraulics is a branch of engineering concerned mainly with moving liquids. The term is applied commonly to the study of the mechanical properties of water, other liquids, and even gases when the effects of compressibility are small. Hydraulics can be divided into two areas, hydrostatics and hydrokinetics. Hydrostatics, the consideration of liquids at rest, involves problems of buoyancy and flotation, pressure on dams and submerged devices, and hydraulic presses.

Hydrodynamics

The relative incompressibility of liquids is one of its basic principles. Hydrodynamics, the study of liquids in motion, is concerned with such matters as friction and turbulence generated in pipes by flowing liquids, the flow of water over weirs and through nozzles, and the use of hydraulic pressure in machinery.

Development of Hydraulics

Although the modern development of hydraulics is comparatively recent, the ancients were familiar with many hydraulic principles and their applications. The Egyptians and the ancient people of Persia, India, and China conveyed water along channels for irrigation and domestic purposes, using dams and sluice gates to control the flow. The ancient Cretans had an elaborate plumbing system. Archimedes studied the laws of floating and submerged bodies. The Romans constructed aqueducts to carry water to their cities.

Liquids are almost incompressible. For example, if a pressure of 100 pounds per square inch (**psi**) is applied to a given volume of water that is at atmospheric pressure, the volume will decrease by only 0.03 percent. It would take a force of approximately 32 tons to reduce its volume by 10 percent; however, when this force is removed, the water immediately returns to its original volume. Other liquids behave in about the same manner as water.

Another characteristic of a liquid is the tendency to keep its free surface level. If the surface is not level, liquids will flow in the direction which will tend to *make* the surface level.

Liquids at Rest

In studying fluids at rest, we are concerned with the transmission of force and the factors which affect the forces in liquids. Additionally, pressure in and on liquids and factors affecting pressure are of great importance.

Pressure and Force

Pressure is the force that pushes water through pipes. Water pressure determines the flow of water from the tap. If pressure is not sufficient then the flow can reduce to a trickle and it will take a long time to fill a kettle or a cistern. The terms *force* and *pressure* are used extensively in the study of fluid power. It is essential that we distinguish between the terms. Force means a total push or pull. It is the push or pull exerted against the total area of a particular surface and is expressed in pounds or grams.

Pressure means the amount of push or pull (force) applied to each unit area of the surface and is expressed in pounds per square inch (lb/in²) or grams per square centimeter (gm/cm²). Pressure may be exerted in one direction, in several directions, or in all directions.

Computing Force, Pressure, and Area

A formula is used in computing force, pressure, and area in fluid power systems. In this formula, P refers to pressure, F indicates force, and A represents area. Force equals pressure times area. Thus, the formula is written.



Pascal's Law

The foundation of modern hydraulics was established when Pascal discovered that pressure in a fluid acts equally in all directions. This pressure acts at right angles to the containing surfaces. If some type of pressure gauge, with an exposed face, is placed beneath the surface of a liquid at a specific depth and pointed in different directions, the pressure will read the same. Thus, we can say that pressure in a liquid is independent of direction.

Pressure due to the weight of a liquid, at any level, depends on the depth of the fluid from the surface. If the exposed face of the pressure gauges are moved closer to the surface of the liquid, the indicated pressure will be less. When the depth is doubled, the indicated pressure is doubled. Thus the pressure in a liquid is directly proportional to the depth. Consider a container with vertical sides that is 1-foot-long and 1 foot wide.

Let it be filled with water 1-foot-deep, providing 1 cubic foot of water. *1 cubic foot of water weighs 62.4 pounds. Using this information and equation, $P = F/A$, we can calculate the pressure on the bottom of the container. Since there are 144 square inches in 1 square foot, this can be stated as follows: the weight of a column of water 1 foot high, having a cross-sectional area of 1 square inch, is 0.433 pound. If the depth of the column is tripled, the weight of the column will be 3 x 0.433, or 1.299 pounds, and the pressure at the bottom will be 1.299 lb/in² (psi), since pressure equals the force divided by the area.

Thus, the pressure at any depth in a liquid is equal to the weight of the column of liquid at that depth divided by the cross-sectional area of the column at that depth. The volume of a liquid that produces the pressure is referred to as the fluid head of the liquid. The pressure of a liquid due to its fluid head is also dependent on the density of the liquid.

Gravity

Gravity is one of the four forces of nature. The strength of the gravitational force between two objects depends on their masses. The more massive the objects are, the stronger the gravitational attraction. When you pour water out of a container, the earth's gravity pulls the water towards the ground. The same thing happens when you put two buckets of water, with a tube between them, at two different heights. You must work to start the flow of water from one bucket to the other, but then gravity takes over and the process will continue on its own.

Gravity, applied forces, and atmospheric pressure are static factors that apply equally to fluids at rest or in motion, while inertia and friction are dynamic factors that apply only to fluids in motion. The mathematical sum of gravity, applied force, and atmospheric pressure is the static pressure obtained at any one point in a fluid at any given time.

Static Pressure

Static pressure exists in addition to any dynamic factors that may also be present at the same time.

Pascal's law states that a pressure set up in a fluid acts equally in all directions and at right angles to the containing surfaces. This covers the situation only for fluids at rest or practically at rest. It is true only for the factors making up static head. Obviously, when velocity becomes a factor it must have a direction, and as previously explained, the force related to the velocity must also have a direction, so that Pascal's law alone does not apply to the dynamic factors of fluid power. The dynamic factors of inertia and friction are related to the static factors.

Velocity head and friction head are obtained at the expense of static head. However, a portion of the velocity head can always be reconverted to static head. Force, which can be produced by pressure or head when dealing with fluids, is necessary to start a body moving if it is at rest, and is present in some form when the motion of the body is arrested. Therefore, whenever a fluid is given velocity, some part of its original static head is used to impart this velocity, which then exists as velocity head.

Volume and Velocity of Flow

The volume of a liquid passing a point in a given time is known as its *volume of flow* or flow rate. The volume of flow is usually expressed in gallons per minute (gpm) and is associated with relative pressures of the liquid, such as 5 gpm at 40 psi. The *velocity of flow* or velocity of the fluid is defined as the average speed at which the fluid moves past a given point. It is usually expressed in feet per second (fps) or feet per minute (fpm). Velocity of flow is an important consideration in sizing the hydraulic lines.

Volume and velocity of flow are often considered together. With other conditions unaltered—that is, with volume of input unchanged—the velocity of flow increases as the cross section or size of the pipe decreases, and the velocity of flow decreases as the cross section increases. For example, the velocity of flow is slow at wide parts of a stream and rapid at narrow parts, yet the volume of water passing each part of the stream is the same.

Bernoulli's Principle

Bernoulli's principle thus says that a rise (fall) in pressure in a flowing fluid must always be accompanied by a decrease (increase) in the speed, and conversely, an increase (decrease) in the speed of the fluid results in a decrease (increase) in the pressure. This is at the heart of a number of everyday phenomena. As a very trivial example, Bernoulli's principle is responsible for the fact that a shower curtain gets ``sucked inwards" when the water is first turned on. What happens is that the increased water/air velocity inside the curtain (relative to the still air on the other side) causes a pressure drop.

The pressure difference between the outside and inside causes a net force on the shower curtain which sucks it inward. A more useful example is provided by the functioning of a perfume bottle: squeezing the bulb over the fluid creates a low pressure area due to the higher speed of the air, which subsequently draws the fluid up.

Bernoulli's Principle also tells us why windows tend to explode, rather than implode in hurricanes. The very high speed of the air just outside the window causes the pressure just outside to be much less than the pressure inside, where the air is still.

The difference in force pushes the windows outward, and hence explode. If you know that a hurricane is coming, it is therefore better to open as many windows as possible, to equalize the pressure inside and out. Another example of Bernoulli's principle at work is in the lift of aircraft wings and the motion of "curve balls" in baseball. In both cases the design is such as to create a speed differential of the flowing air past the object on the top and the bottom - for aircraft wings this comes from the movement of the flaps, and for the baseball it is the presence of ridges. Such a speed differential leads to a pressure difference between the top and bottom of the object, resulting in a net force being exerted, either upwards or downwards.

Cross-Connection Terms

Cross-connection

A cross-connection is any temporary or permanent connection between a public water system or consumer's potable (i.e., drinking) water system and any source or system containing nonpotable water or other substances. An example is the piping between a public water system or consumer's potable water system and an auxiliary water system, cooling system, or irrigation system.

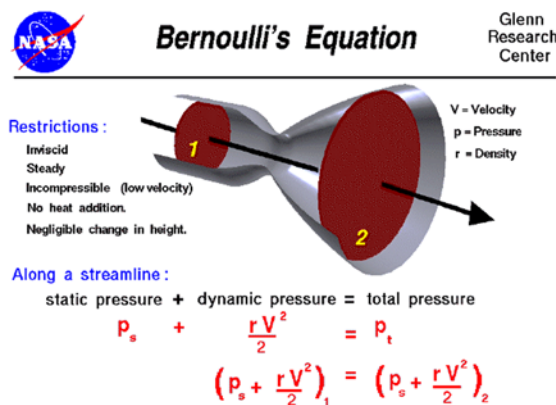
Contaminant: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

Contamination: To make something bad. To pollute or infect something. To reduce the quality of the potable (drinking) water and create an actual hazard to the water supply by poisoning or through spread of diseases.

***Corrosion:** The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers. Corrosion starts on the inside of the pipe working outwards. Caused by electrochemical reactions caused by dissimilar metals.

***Cross-connection failure:** What might be the source of an organic substance causing taste and odor problems in a water distribution system?

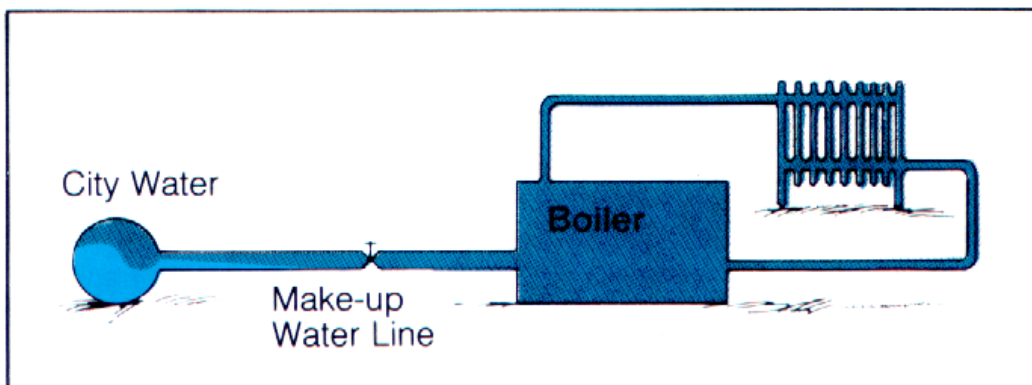
Cross-Contamination: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical substance.



Backflow Memorize this section

*Backflow is the undesirable reversal of flow of nonpotable water or other substances through a cross-connection and into the piping of a public water system or consumer's potable water system. There are two types of backflow--**backpressure** and **backsiphonage**.

Backsiphonage

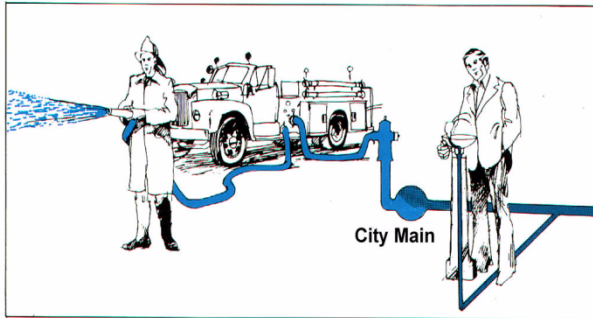


Backpressure

Backsiphonage *Memorize this statement.*

Backsiphonage is backflow caused by a negative pressure (i.e., a vacuum or partial vacuum) in a public water system or consumer's potable water system. The effect is similar to drinking water through a straw.

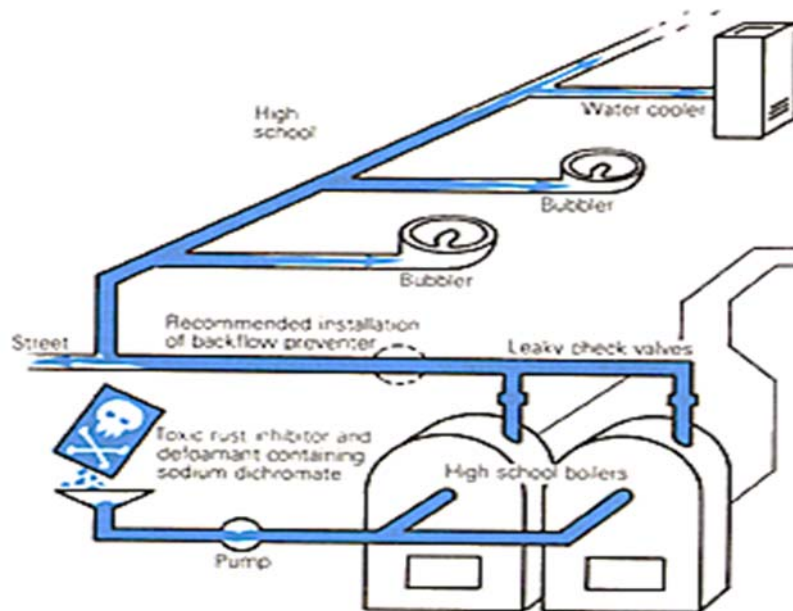
Backsiphonage can occur when there is a stoppage of water supply due to nearby firefighting, a break in a water main, etc.



Backpressure *Memorize this statement.*

Backpressure is backflow caused by a downstream pressure that is greater than the upstream or supply pressure in a public water system or consumer's potable water system. Backpressure (i.e., downstream pressure that is greater than the potable water supply pressure) can result from an increase in downstream pressure, a reduction in the potable water supply pressure, or a combination of both. Increases in downstream pressure can be created by pumps, temperature increases in boilers, elevation, etc.

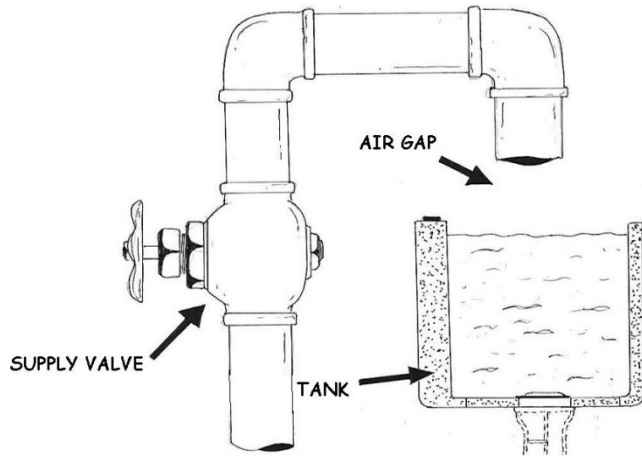
Reductions in potable water supply pressure occur whenever the amount of water being used exceeds the amount of water being supplied, such as during water line flushing, firefighting, or breaks in water mains.



Types of Backflow Prevention Methods and Assemblies

***Approved Air Gap Separation (AG)**

An approved air gap is a physical separation between the free flowing discharge end of a potable water supply pipeline, and the overflow rim of an open or non-pressure receiving vessel. These separations must be vertically orientated a distance of at least twice the inside diameter of the inlet pipe, but never less than one inch. An obstruction around or near an air gap may restrict the flow of air into the outlet pipe and nullify the effectiveness of the air gap to prevent backsiphonage. When the air flow is restricted, such as the case of an air gap located near a wall, the air gap separation must be increased. Also, within a building where the air pressure is artificially increased above atmospheric, such as a sports stadium with a flexible roof kept in place by air blowers, the air gap separation must be increased.

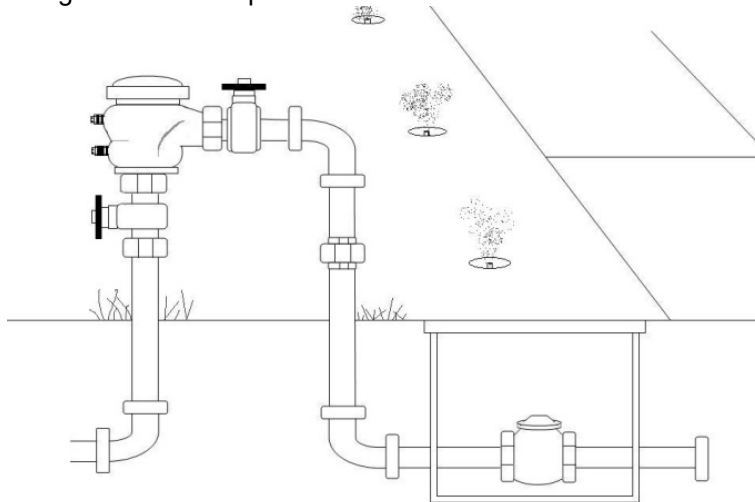


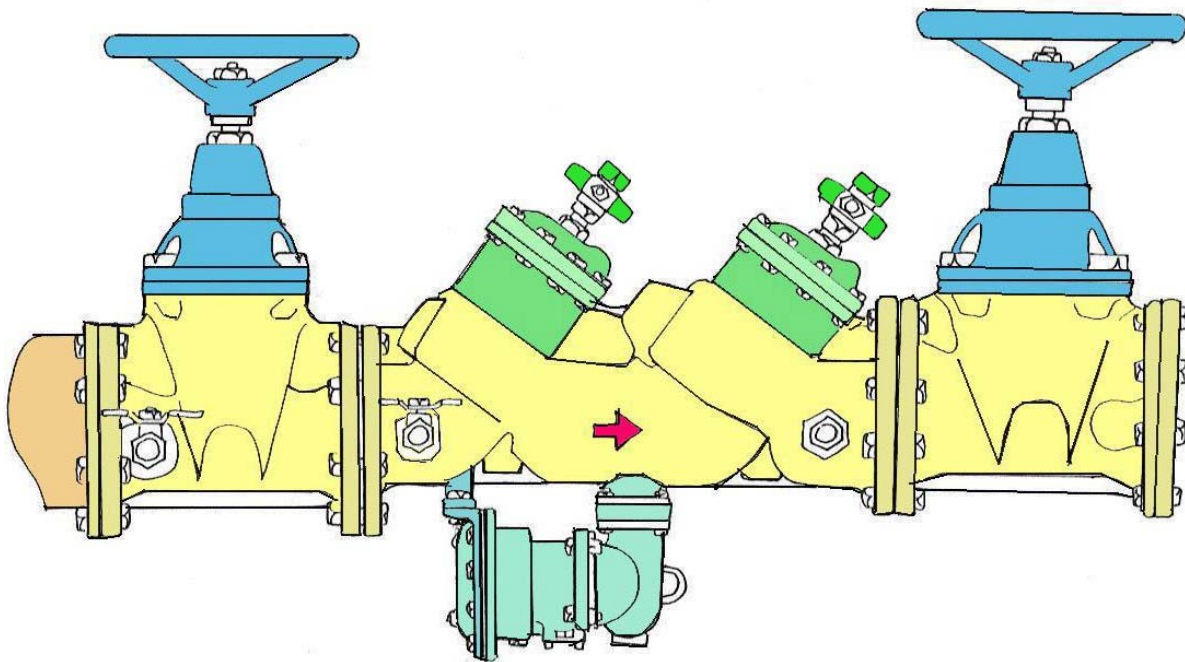
***Air Gap or Vacuum Breaker:** What should a potable water line be equipped with when connected to a chemical feeder for fluoride?

***Air Gap Separation:** A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet.

Pressure Vacuum Breaker Assembly (PVB)

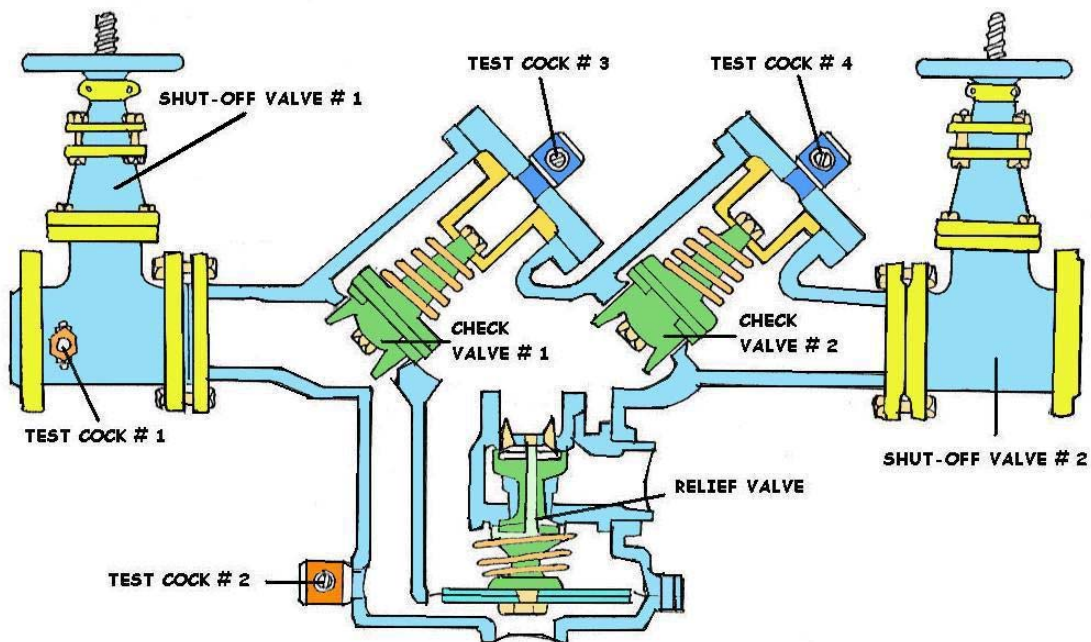
The Pressure Vacuum Breaker Assembly consists of a spring loaded check valve, an independently operating air inlet valve, two resilient seated shutoff valves, and two properly located resilient seated test cocks. It shall be installed as a unit as shipped by the manufacturer. The air inlet valve is internally loaded to the open position, normally by means of a spring, allowing installation of the assembly on the pressure side of a shutoff valve. *A PVB must be 12 inches above the highest downstream outlet and only stops backsiphonage and not backpressure.





REDUCED PRESSURE BACKFLOW ASSEMBLY

REDUCED-PRESSURE BACKFLOW ASSEMBLY



General Backflow Information

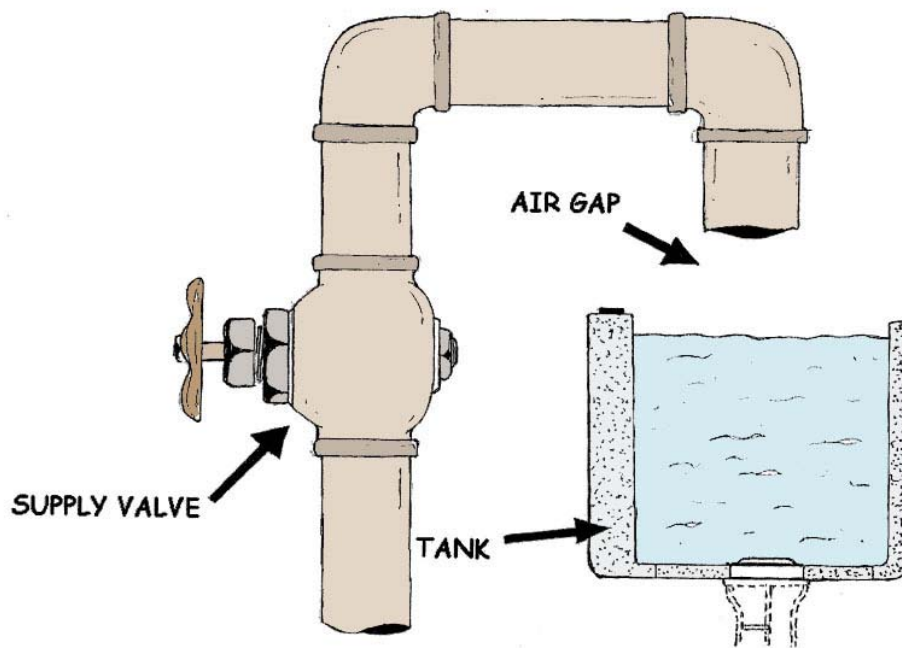
Memorize these statements.

Backflow: The reversal of the normal flow of water caused by either Backpressure or Back-siphonage. Reverse flow condition.

Backsiphonage: Negative pressure or zero pressure on the supply side. The flow of water or other liquids, mixtures, or other substances into the distribution pipes of a potable water supply system from any source or sources other than its intended source caused by the sudden reduction of pressure in the potable water supply system.

Backpressure: Higher pressure on the service side than on the supply side. A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.

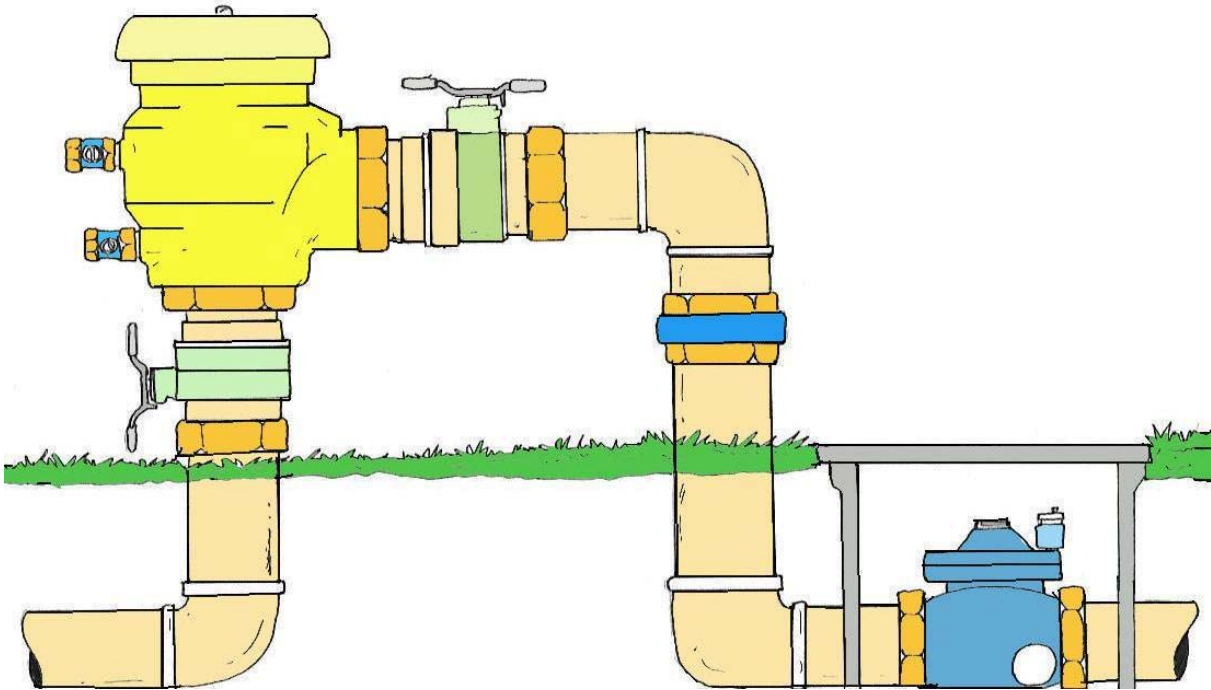
Cross-Connection: A connection between drinking (potable) water and an unapproved water supply.



Air Gap: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet. Minimum 1 inch or twice the diameter whatever is greater.

Biggest Threat: Pesticide tanks are the greatest concerns to our water distribution systems.

PRESSURE VACUUM BREAKER ASSEMBLY



Memorize these statements.

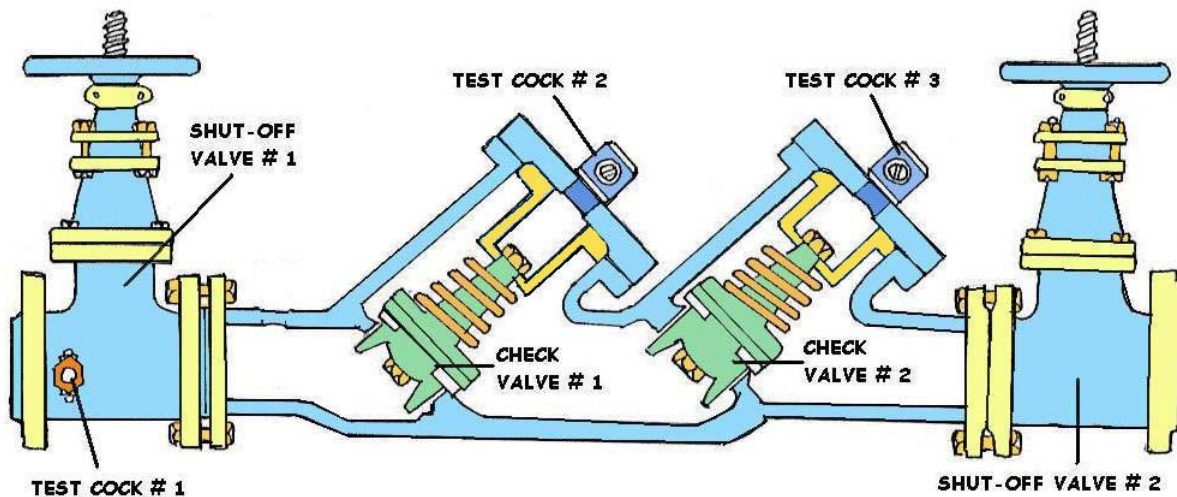
Often referred to as a vacuum breaker.

Primary found on Irrigation systems.

Stops backsiphonage of health related concerns, but not backpressure concerns.

Must be installed 12 inches above the highest downstream outlet. Must be inspected once a year by a certified general tester.

Also review the backflow statements in the glossary.



DOUBLE-CHECK BACKFLOW ASSEMBLY

Memorize these statements.

Double check valve assembly.

Stops backsiphonage and backpressure of pollution concerns only.

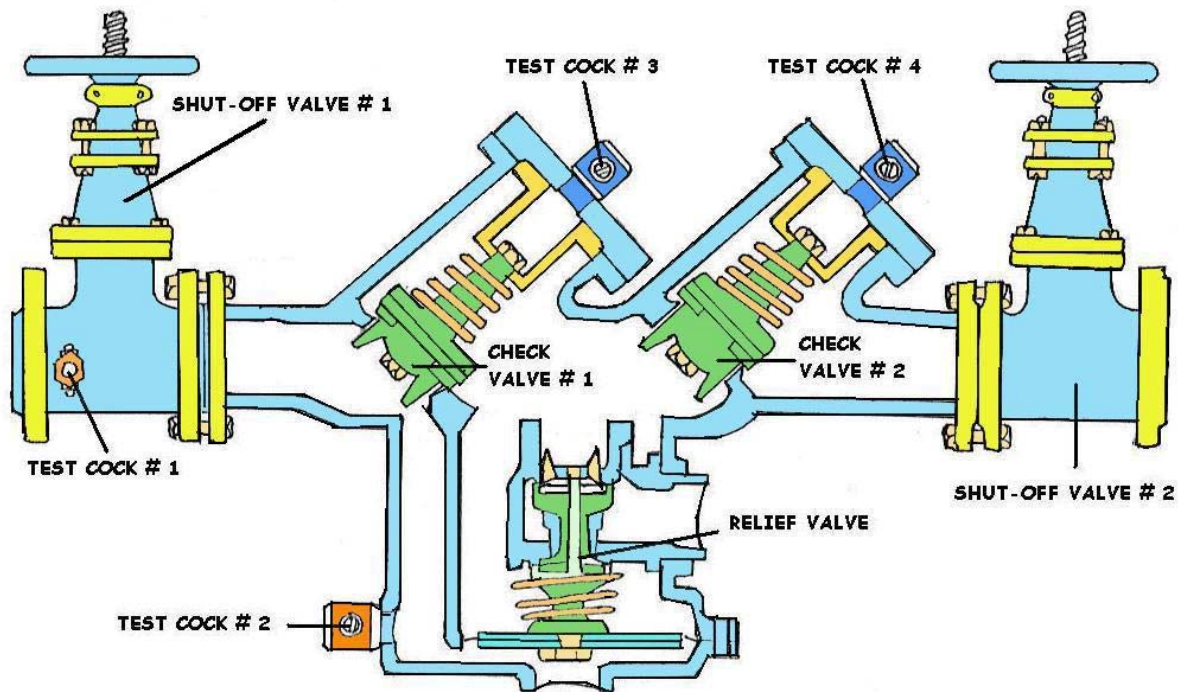
O.S. and Y: Outside screw and yoke valves are commonly found on this assembly.

Needs to be installed 12 inches above the ground and tested once a year by a certified general tester.

Note that this assembly does not have the hydraulic relief valve as with the RP.

Also review the backflow statements in the glossary.

REDUCED-PRESSURE BACKFLOW ASSEMBLY



Memorize these statements.

The RP or Reduced Pressure Principle Backflow Assembly stops backsiphonage and backpressure of health related concerns.

Needs to be tested or inspected once a year by a certified general backflow tester.

Needs to be installed 12 inches above the ground. If backflow occurs and gets past the number 2 check, a pressure differential is created and the hydraulic relief valve will open, allowing the material to dump or open to the atmosphere.

Backflow assemblies need to be installed as close as possible to the water meter, downstream. Not measured in feet but as close as possible.

Also review the backflow statements in the glossary. Please read the entire glossary and Chlorine, Pumps and Safety statements before your exam.

Double Check Valve Assembly (DC)

The Double Check Valve Assembly consists of two internally loaded check valves, either spring loaded or internally weighted, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit as shipped by the manufacturer. *The double check valve assembly is designed to prevent backflow caused by backpressure and backsiphonage from low health or pollutional hazards. *The DC is different from the RP in that it does not have a relief valve. *A DC should only be used on pollutional related concerns not health or contamination concerns.

Reduced Pressure Backflow Assembly (RP)

The reduced pressure principle backflow assembly consists of two independently acting spring loaded check valves separated by a spring loaded differential pressure relief valve, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit shipped by the manufacturer.

During normal operation, the pressure between the two check valves, referred to as the zone of reduced pressure, is maintained at a lower pressure than the supply pressure. If either check valve leaks, the differential pressure relief valve maintains a differential pressure of at least two (2) psi between the supply pressure, and the zone between the two check valves, by discharging water to atmosphere.

The reduced pressure backflow assembly is designed to prevent backflow caused by backpressure and backsiphonage from low to high health hazards.

Why do backflow preventers have to be tested periodically?

Mechanical backflow preventers have internal seals, springs, and moving parts that are subject to fouling, wear, or fatigue. Also, mechanical backflow preventers and air gaps can be bypassed. Therefore, all backflow preventers have to be tested periodically to ensure that they are functioning properly. A visual check of air gaps is sufficient, but mechanical backflow preventers have to be tested with properly calibrated gauge equipment.

Backflow prevention devices must be tested annually to ensure that they work properly. It is usually the responsibility of the property owner to have this test done and to make sure that a copy of the test report is sent to the Public Works Department or Water Purveyor.

If a device is not tested annually, Public Works or the Water Purveyor will notify the property owner asking them to comply. If the property owner does not voluntarily test their device, the water provider may be forced to turn off water service to that property.

State law requires the Water provider to discontinue water service until testing is complete.

*All backflow assemblies and air gaps need to be checked annually by a certified backflow assembly tester.



Top photograph-two gate valves blew out-you can see the kickers or thrust blocks in the background. Bottom photograph-a tapping machine and a new gate valve. These tapping machines are very, very expensive.



Slam, Surge and Water Hammer

When a valve is closed instantaneously there is a corresponding instantaneous pressure rise causing a water hammer. * Know and memorize.

Water hammer (or, more generally, fluid hammer) is a pressure surge or wave caused by the kinetic energy of a fluid in motion when it is forced to stop or change direction suddenly. It depends on the fluid compressibility where there are sudden changes in pressure. For example, if a valve is closed suddenly at an end of a pipeline system a water hammer wave propagates in the pipe. Moving water in a pipe has kinetic energy proportional to the mass of the water in a given volume times the square of the velocity of the water.

The Effects of Water Hammer and Pulsations

Quick closing valves, positive displacement pumps, and vertical pipe runs can create damaging pressure spikes, leading to blown diaphragms, seals and gaskets, and also destroyed meters and gauges.

Liquid for all practical purposes is not compressible--any energy that is applied to it is instantly transmitted. This energy becomes dynamic in nature when a force such as a quick closing valve or a pump applies velocity to the fluid.

Surge (Water Hammer)

Surge, or water hammer, as it is commonly known, is the result of a sudden change in liquid velocity. Water hammer usually occurs when a transfer system is quickly started, stopped or is forced to make a rapid change in direction. Any of these events can lead to catastrophic system component failure. Without question, the primary cause of water hammer in process applications is the quick closing valve, whether manual or automatic. A valve closing in 1.5 seconds (or less, depending upon valve size and system conditions) causes an abrupt stoppage of flow. The pressure spike (acoustic wave) created at rapid valve closure can be high as five (5) times the system working pressure.

For this reason, most pipe-sizing charts recommend keeping the flow velocity at or below 5 ft/s (1.5 m/s). If the pipe is suddenly closed at the outlet (downstream), the mass of water before the closure is still moving forward with some velocity, building up a high pressure and shock waves. In domestic plumbing, this is experienced as a loud bang resembling a hammering noise.

Water hammer can cause pipelines to break or even explode if the pressure is high enough. Air traps or stand pipes (open at the top) are sometimes added as dampers to water systems to provide a cushion to absorb the force of moving water in order to prevent damage to the system. (At some hydroelectric generating stations what appears to be a water tower is actually one of these devices.) The water hammer principle can be used to create a simple water pump called a hydraulic ram.

On the other hand, when a valve in a pipe is closed, the water downstream of the valve will attempt to continue flowing, creating a vacuum that may cause the pipe to collapse or implode. This problem can be particularly acute if the pipe is on a downhill slope. To prevent this, air and vacuum relief valves, or air vents, are installed just downstream of the valve to allow air to enter the line and prevent this vacuum from occurring.

Unrestricted, this pressure spike or wave will rapidly accelerate to the speed of sound in liquid, which can exceed 4000 ft/sec. It is possible to estimate the pressure increase by the following formula.

Water Hammer Formula: $P = (0.070) (V) (L) / t + P_1$

Where P = Increase in pressure
P₁ = Inlet Pressure
V = Flow velocity in ft/sec
t = Time in sec.(Valve closing time)
L = Upstream Pipe Length in feet

Here's an example of pressure hammer when closing an EASMT solenoid valve, with a 50 ft long upstream pipe connection:

L = 50 ft
V = 5.0 ft / sec(recommended velocity for PVC piping design)
t = 40 ms(solenoid valve closing time is approx. 40-50 ms)
P₁ = 50 psi inlet pressure

therefore, $P = 0.07 \times 5 \times 50 / 0.040 + P_1$
or $P = 437.5 \text{ psi} + P_1$

Total Pressure = $437.5 + 50 = 487.5 \text{ psi}$

Pulsation

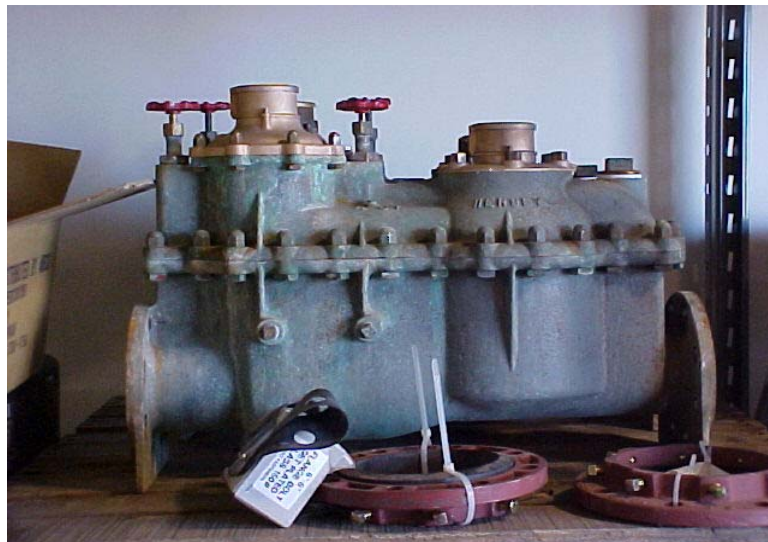
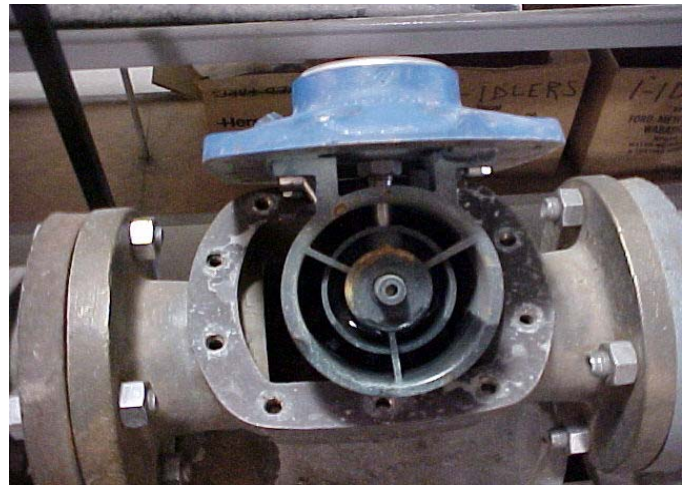
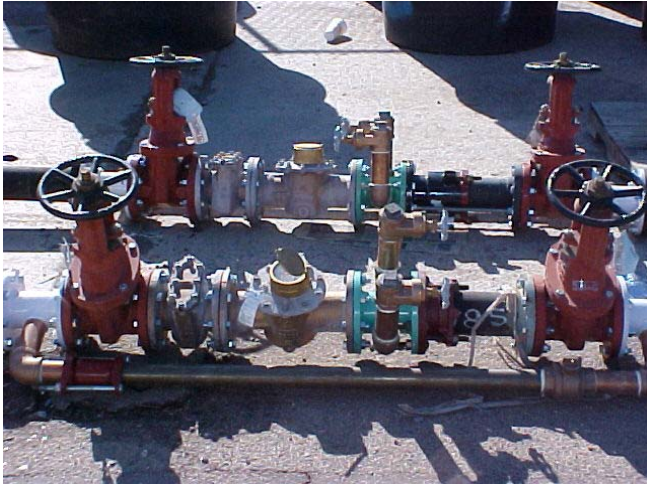
Pulsation generally occurs when a liquid's motive force is generated by reciprocating or peristaltic positive displacement pumps. It is most commonly caused by the acceleration and deceleration of the pumped fluid. This uncontrolled energy appears as pressure spikes. Vibration is the visible example of pulsation and is the culprit that usually leads the way to component failure.

Unlike centrifugal pumps(which produce normally non-damaging high-frequency but low-amplitude pulses), the amplitude is the problem because it's the pressure spike. The peak, instantaneous pressure required to accelerate the liquid in the pipe line can be greater than ten (10) times the steady state flow pressure produced by a centrifugal pump. Damage to seals, gauges, diaphragms, valves and joints in piping result from the pressure spikes created by the pulsating flow.

Remedy

We suggest that you install a pulsation dampener or surge tank. Dampeners provide the most cost efficient and effective choice to prevent the damaging effects of pulsation. A surge suppressor is in design essentially the same as pulsation dampener. The difference primarily lies in sizing and pressurizing. The most current pulsation dampener design is the hydro-pneumatic dampener, consisting of a pressure vessel containing a compressed gas, generally air or Nitrogen separated from the process liquid by a bladder or diaphragm.

Water Meters record the flow of water in a part of the distribution system. Bypass, Compound, Turbine or Propeller meters.



Troubleshooting Table for Distribution System

Problem

1. Dirty water complaints
2. Red water complaints
3. No or low water pressure
4. Excessive water **usage**.

Possible Causes

- 1A. Localized accumulations of debris, solids/**particulates** in distribution mains.
- 1B. Cross connection between water system and another system carrying non-potable water.
- 2A. Iron content of water from source is high. Iron precipitates in mains and accumulates.
- 2B. Cast iron, ductile iron, or steel mains are corroding, causing “rust” in the water.
- 3A. Source of supply, storage or pumping station interrupted.
- 3B. System cannot supply **demands**.
- 3C. Service line, meter, or connections shutoff, or clogged with debris.
- 3D. Broken or leaking distribution pipes.
- 3E. Valve in system closed or broken.
- 4A. More connections have been added to the system.
- 4B. Excessive leakage (>15% of production) is occurring, meters are not installed or not registering properly.
- 4C. Illegal connections have been made.

Possible Solutions

- 1A. Collect and **preserve** samples for **analysis** if needed. Isolate affected part of main and flush.
- 1B. Collect and preserve samples for analysis if needed. Conduct survey of system for cross connections. Contact State Drinking Water Agency.
- 2A. Collect and test water samples from water source and location of complaints for iron. If high at both sites, contact regulatory agency, TA provider, consulting engineer or water conditioning company for assistance with iron removal treatment.
- 2B. Collect and analyze samples for iron and corrosion parameters. Contact State Drinking Water Agency, TA provider, consulting engineer or water conditioning company for assistance with corrosion control treatment.
- 3A. Check source, storage and pumping stations. Correct or repair as needed.
- 3B. Check to see if demands are unusually high. If so, try to reduce demand. Contact State Drinking Water Agency, TA provider or consulting engineer.
- 3C. Investigate and open or unclog service.
- 3D. Locate and repair break or leak.
- 3E. Check and open closed isolation and pressure-reducing valves. Repair or contact contractor if valves are broken.
- 4A. Compare increase in usage over time with new connections added over same period. If correlation evident take action to curtail demand or increase **capacity** if needed. Contact State Drinking Water Agency, TA provider or consulting engineer.
- 4B. Conduct a water audit to determine the cause. If leakage, contact regulatory agency, and consulting engineer or leak detection contractor.
- 4C. Conduct survey to identify connections.

Types of Pipes Used in the Distribution Field

Several types of pipe are used in water distribution systems, but only the most common types used by operators will be discussed. These piping materials include copper, plastic, galvanized steel, and cast iron. Some of the main characteristics of pipes made from these materials are presented below.

Plastic Pipe (PVC)

Plastic pipe has seen extensive use in current construction. Available in different lengths and sizes, it is lighter than steel or copper and requires no special tools to install. Plastic pipe has several advantages over metal pipe. It is flexible, it has superior resistance to rupture from freezing, it has complete resistance to corrosion and in addition, it can be installed above ground or below ground.

One of the most versatile plastic and polyvinyl resin pipes is the polyvinyl chloride (PVC). PVC pipes are made of tough, strong thermoplastic material that has an excellent combination of physical and chemical properties. Its chemical resistance and design strength make it an excellent material for application in various mechanical systems.

Sometimes polyvinyl chloride is further chlorinated to obtain a stiffer design, a higher level of impact resistance, and a greater resistance to extremes of temperature. A CPVC pipe (a chlorinated blend of PVC) can be used not only in cold-water systems, but also in hot-water systems with temperatures up to 210°F. Economy and ease of installation make plastic pipe popular for use in either water distribution and supply systems or sewer drainage systems.



**Various types and sizes of coupons or tap cut-outs. You will want to date and collect these cut-outs to determine the condition of the pipe or measure the corrosion.*

Plastic Pipe (PVC)

This is currently the most common type of pipe used in distribution systems. It is available in diameters of 1/2" and larger, and in lengths of 10', 20', and 40'. A main advantage is its light weight, allowing for easy installation. A disadvantage is its inability to withstand shock loads. Since it is non-metallic, a tracer wire must be installed with the PVC water main so that it can be located after burial.

The National Sanitation Foundation (NSF) currently lists most brands of PVC pipe as being acceptable for potable water use. This information should be stamped on the outside of the pipe, along with working pressure and temperature, diameter and pipe manufacturer.

*PVC pipe will have the highest C Factor of all the above pipes. The higher the C factor the smoother the pipe.

Cast Iron (CIP)

This is another type of piping material that has been in use for a long time. It is found in diameters from 3" to 48". Advantages of this material are its long life, durability, and ability to withstand working pressures up to 350 psi. Disadvantages include the fact that it is heavy, difficult to install, and does not withstand shock loading. Although it is not currently the material of choice, there is still a lot of it in the ground.



Ductile Iron Pipe (DIP)

This was developed to overcome the breakage problems associated with cast iron pipe. It can be purchased in 4" to 45" diameters and lengths of 18' to 20'. Its main advantage is that it is nearly indestructible by internal or external pressures.

It is manufactured by injecting magnesium into molten cast iron. It is sometimes protected from highly corrosive soils by wrapping the pipe in plastic sheeting prior to installation. This practice can greatly extend the life of this type of pipe.



Steel Pipe

This pipe is often used in water treatment plants and pump stations. It is available in various diameters and in 20' or 21' lengths. Its main advantage is the ability to form it into a variety of shapes. It also exhibits good yielding and shock resistance. It has a smooth interior surface and can withstand pressures up to 250 psi.

A disadvantage is that it is easily corroded by both soil and water. To reduce corrosion problems, steel pipe is usually galvanized or dipped in coal-tar enamel and wrapped with coal-tar impregnated felt. At present, however, coal-tar products are undergoing scrutiny from a health standpoint and it is recommended that the appropriate regulatory agencies be contacted prior to use of this material.

Asbestos Cement Pipe (ACP)

This pipe is manufactured from Portland cement, long fibrous asbestos, and silica. It is available in diameters from 3" to 36" and in 13' lengths. Its main advantages are its ability to withstand corrosion and its excellent hydraulic flow characteristics due to its smoothness.

A major disadvantage is that it is brittle and is easily broken during construction or by shock loading. There is some concern regarding the possible release of asbestos fibers in corrosive water and there has been much debate over the health effects of ingested asbestos.



Of greater certainty, however, is the danger posed by inhalation of asbestos fibers. Asbestos is considered a hazardous material, and precautionary measures must be taken to protect water utility workers when cutting, tapping, or otherwise handling this type of pipe.

Galvanized Pipe

Galvanized pipe is commonly used for the water distributing pipes inside a building to supply hot and cold water to the fixtures. This type of pipe is manufactured in 21-ft lengths. *It is **GALVANIZED** (coated with zinc) both inside and outside at the factory to resist corrosion. Pipe sizes are based on nominal INSIDE diameters. Inside diameters vary with the thickness of the pipe. Outside diameters remain constant so that pipe can be threaded for standard fittings.

Copper

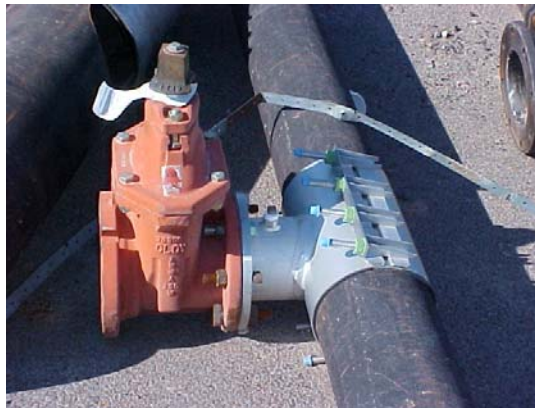
Copper is one of the most widely used materials for tubing. This is because it does not rust and is highly resistant to any accumulation of scale particles in the pipe. This tubing is available in three different types:

K, L, and M.

K has the thickest walls, and M, the thinnest walls, with L's thickness in between the other two. The thin walls of copper tubing are soldered to copper fittings. Soldering allows all the tubing and fittings to be set in place before the joints are finished. Generally, faster installation will be the result. Type K copper tubing is available in either rigid (hard temper) or flexible (soft temper) and is primarily used for underground service in the water distribution systems.

Joints and Fittings

Fittings vary according to the type of piping material used. The major types commonly used in water service include elbows, tees, unions, couplings, caps, plugs, nipples, reducers, and adapters. Besides bell-and-spigot joints, cast-iron water pipes and fittings are made with either flanged, mechanical, or screwed joints. The screwed joints are used only on small-diameter pipe.



Tapping Sleeve

*A Gate Valve (shown above) is used to isolate sections of water mains. Not to be used to throttle or regulate the flow.

*A Globe valve should be used to regulate the flow.

Be sure to chlorinate or disinfect all distribution parts such as valves and piping!

Caps

A pipe cap is a fitting with a female (inside) thread. It is used like a plug, except that the pipe cap screws on the male thread of a pipe or nipple.

Couplings

The three common types of couplings are straight coupling, reducer, and eccentric reducer. The **STRAIGHT COUPLING** is for joining two lengths of pipe in a straight run that do not require additional fittings. A run is that portion of a pipe or fitting continuing in a straight line in the direction of flow.

A **REDUCER** is used to join two pipes of different sizes. The **ECCENTRIC REDUCER** (also called a **BELL REDUCER**) has two female (inside) threads of different sizes with centers so designed that when they are joined, the two pieces of pipe will not be in line with each other, but they can be installed to provide optimum drainage of the line.

Elbows (OR ELLS) 90° AND 45°

These fittings (fig. 8-5, close to middle of figure) are used to change the direction of the pipe either 90 or 45 degrees. **REGULAR** elbows have female threads at both outlets. **STREET** elbows change the direction of a pipe in a close space where it would be impossible or impractical to use an elbow and nipple.



Nipples

A nipple is a short length of pipe (12 in. or less) with a male thread on each end. It is used for extension from a fitting. At times, you may use the **DIELECTRIC** or **INSULATING TYPE** of fittings. These fittings connect underground tanks or hot-water tanks. They are also used with pipes of dissimilar metals. These help slow down corrosion that starts inside the pipe and works to the outside of the pipe. Do not heat or solder dielectric fittings; you may melt the plastic coating on them.

*Zinc is a coating on the outside and inside of pipes to slow corrosion. This process is called "**Galvanization**".

Tees

A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. A common type of pipe tee is the **STRAIGHT** tee, which has a straight-through portion and a 90-degree takeoff on one side.

All three openings of the straight tee are of the same size. Another common type is the **REDUCING** tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the other.

Unions

There are two types of pipe unions. The **GROUND JOINT UNION** consists of three pieces, and the **FLANGE UNION** is made in two parts. Both types are used for joining two pipes together and are designed so that they can be disconnected easily. When joined, the two pieces of pipe will not be in line with each other, but they can be installed to provide optimum drainage of the line.



Dielectric Union

Distribution and Storage Summary *Study and memorize these statements.*

Storage Tanks

Safe entry into a confined space requires that all entrants wear a harness and safety line. If an operator is working inside a storage tank and suddenly faints or has a serious problem, there should be two people outside standing by to remove the injured operator.

Climbing safety devices are commonly used on fixed ladders.

During an inspection of your water storage facility, you should inspect the Cathodic protection system including checking the anode's condition and the connections.

Three types of water usage that determines the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage.

Equalization storage is the volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protects the interior about 3-5 years.

Standpipes (Storage tanks) should not be located in at a low point in the system, a bottom of a hill.

The concentration of polyphosphates that is used for corrosion control in storage tanks is typically 5 mg/L or less.

External corrosion of steel water storage facilities can be reduced with zinc or aluminum coatings.

All storage facilities should be regularly sampled to determine the quality of water that enters and leaves the facility. One tool or piece of measuring equipment is the Jackson turbidimeter, which is a method to measure cloudiness in water.

The effects of water freezing in storage tanks can be minimized by alternating water levels in the tank. There are 3 types of ice found: sheet, anchor and frazil.

The venting of air is not a major concern when checking water levels in a storage tank.

If an overflow occurs on a storage tank, the operator should first check the altitude-control valve.

Altitude-Control Valve is designed to, 1. Prevent overflows from the storage tank or reservoir, or 2. Maintain a constant water level as long as water pressure in the distribution system is adequate.

The following are common pressure sensing devices: Helical Sensor, Bourdon Tube, and Bellows Sensor.

The most frequent problem that affects a liquid pressure-sensing device is air accumulation at the sensor.

A diaphragm element being used as a level sensor would be used in conjunction with a pressure sensor.

The Strain Gauge is a common measuring device used for a variety of changes such as head. As the pressure in the system changes, the diaphragm expands which changes the length of the wire attached. This change of length of the wire changes the Resistance of the wire, which is then converted to head.

Float mechanisms, diaphragm elements, bubbler tubes, and direct electronic sensors are common types of level sensors.

Distribution system water quality can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. The common customer complaint of Milky Water is sometimes solved by the installation of these air relief valves.

When the superintendent is inspecting the plans for a new ground water storage tank, the superintendent should pay attention to the outlet and inlet and be sure that they are on opposite sides of the tank.

Surge tanks are used to control Water Hammer.

A limitation of hydropneumatic tanks is that they do not provide much storage to meet peak demands during power outages and you have very limited time to do repairs on equipment.

The maximum momentary load placed on a water treatment plant, pumping station or distribution system is the Peak Demand.

General & Safety Information *Memorize*

One of the roles of a distribution system supervisor is to inform the operators of SOPs concerning public relations. This can be accomplished by regular informational staff meetings.

Sprains and strains are the most frequent type of accident(s) encountered by water distribution personnel.

Right to Know Laws state that the employer has the responsibility to provide the employees with information about health hazards and chemical handling.

Uniforms and proper credentials aid meter readers and operators that work close to private property because they help readily identify personnel.

The Building Inspector is responsible for the enforcement of building regulations.

For a dead-end line of over 2,000 feet, the design criteria would dictate a minimum pipe diameter of 8 inches.

Backflow

Any equipment that utilizes water for cooling, lubrication, washing or as a solvent is always susceptible to Cross-connections.

When installing a vacuum breaker backflow device, the operator must make sure that it is 12 inches above the highest discharge outlet. A double check will stop backsiphonage and backpressure of low contamination threats.

The relief valve will open and drain if a pressure differential occurs between the two checks; this best describes the operation of a reduced pressure principal backflow assembly device.

The water utility has the responsibility for insuring that water contamination due to cross connections does not occur.

Pesticide mixing tanks have one of the greatest potential hazards of contamination if a cross connection occurs.

The most likely consequence if a backsiphonage condition causes a cross connection and pressure is then restored to the system is that the distribution system downstream of the cross connection will be contaminated.

An operator can place a screen before a backflow prevention assembly to prevent debris from fouling the assembly.

Cross-Connection: Physical connection between potable and any other source.

Backsiphonage is backflow caused by a negative pressure (i.e., a vacuum or partial vacuum) in a public water system or consumer's potable water system. The effect is similar to drinking water through a straw.

Backpressure : Is a form of backflow caused by a downstream pressure that is greater than the upstream or supply pressure in a public water system or consumer's potable water system.

General Information *It is good to study the glossary too.*

Chlorine gas is easily detected because of the smell, but can also cause olfactory fatigue, which makes Chlorine gas deadly. Olfactory fatigue means that you lose the ability to smell the odor.

When bumping slip joint pipe, the operator should use a recommended lubricant. Bacterial growth could occur if the wrong lubricant is used.

Negative pressure in parts of the system may occur during periods of high flow or a fire when the waterline's pressure has dropped drastically.

If the desired result of cleaning large pipes is to remove slime and light scale without disturbing heavier encrustation, the best choice for cleaning would be a *Pig*.

Review the Chlorine practice exam too.

Water audits can be performed in order to account for the water in the system. A 24-hour measure of all the water entering the system should be the first step in a water audit.

When you are shutting a large valve, a bypass valve will reduce high pressure that can be present.

If the pH of water from a dead-end line begins to drop, it is most likely an indication that anaerobic conditions are present.

The Hazen-Williams formula is used to determine pipe size.

Thrust Control

Surge tanks are used to control water hammer.

Thrust blocks are commonly known as kickers, not on the test but many of you do not know what is being talked about.

You do not need to use thrust blocks (on exam) if you weld the pipe or use restraining or mechanical joints with restraining lugs.

If a thrust block of another utility is discovered in your path while excavating, you should not alter the existing thrust block in any way.

Maps

Comprehensive maps provide an overall view of the system.

The preferred scale is 500 feet per inch.

Sectional maps show various sections of the comprehensive map in more detail.

Valve and hydrant maps will show valve and hydrants and the number of turns to open the valve, model and installation date.

Plan and profile will show the depth, pipe location and location of both vertically and horizontally.

A Valve Intersection Map or Valve and Hydrant Map would most likely indicate specific information such as the number of turns necessary to open or close a valve.

Motor Statements, Memorize each statement.**Biggest Killer of Electric Motors;**

Thermal Overload, usually the number one answer.

Improper Lubrication and Voltage Imbalance will kill a motor.

You can air lock a pump, but not a motor. Cold weather is also not a negative factor in running a motor.

If the overload control on a motor has tripped and the motor has stopped running. An operator should wait for the overload to cool, then try to start the motor again. If the motor does not start, the operator should first check the fuse. Always check equipment before resetting. Always use a time delay fuse.

A Megger is an electrical device used to test the insulation resistance value on a motor or any electrical equipment.

One possible cause for a mechanical noise coming from a motor is an unbalance of the rotating mechanical parts.

One possible result of over greasing a bearing is that it will create extreme friction in the bearing chamber.

If grease comes in contact with the winding of a motor, the winding insulation may deteriorate. Always replace brushes and contacts as a set.

Motors are sized by Amperes or Amps. If a motor is rated for 10 amps the overload protection that should be used is a 10 to 11 amps fuse. 10 percent or also written as .10

Hertz is the term is used to describe the frequency of cycles in an alternating current (AC) circuit. If the motor has 60 Hertz, the maximum speed will be 3600 RPM.

Pump Statements

Cavitation can be caused by a suction line that is clogged or is above the water line.

Centrifugal pumps do not generate suction unless the impeller is submerged in water. If a pump is located above the level of water, a foot valve or check valve must be provided on the suction piping to hold the prime. One disadvantage of a centrifugal pump is that it is not self-priming.

Double suction means water enters from two sides of the impeller casing.

The main purpose of the wear rings in a centrifugal double suction pump is that the wear rings maintain a flow restriction between the impeller discharge and suction areas.

With most lubricants, the viscosity decreases as the temperature increases.

Two pumps of the same size can be operated alternately to equalize wear and distribute lubricant in bearings.

A key and a tight fit is the common method used to secure an impeller to the shaft on double-suction pump.

An Axial Flow pump is also known as a Propeller Pump.

Never run a positive displacement, reciprocating pump or piston pump with the discharge closed.

A Screw Pump always needs to have the screw submersed in liquid in order to work.

As you add stages to a pump, this only increases the pressure, never the volume.

Stuffing Box

That portion of the pump that houses the packing or mechanical seal.

Packing Gland

Very easy to work on and inexpensive, but will leak water. It will leak approximately 20-60 drops per minute.

A possible cause of a scored shaft sleeve is that the packing has broken down or the packing has been over tightened.

Mechanical Seal

A mechanical seal is the best seal to use for a pump operating under high suction head conditions.

Very expensive and difficult to replace.

Should never leak unless there is an abnormal operating condition.

Should last about 5,000 to 20,000 operating hours.

Held in place with spring tension.

Continuous leakage from a mechanical seal on a pump indicates that the mechanical seal needs to be replaced.

Sometimes mechanical seals require cooling water to the seal faces. Use filtered effluent or tap water.

Please review this section and the pump assignment before your exam. So many people fail because they do not take the time to study.

Fire Hydrant Information. Always use a non-rising stem gate valve if you need to use water through a steamer or meter. If the fire hydrant is painted, Blue-1500 GPM or more, Green - 1000-1499 GPM. Dry barrel hydrants are for areas that might freeze.

C-Factor Carrying Capacity of Pipe

The smoother the pipe the greater the C-Factor. Steel pipe has poorest C-Factor.

Remember to review the safety subjects and trenching too.

SCADA

This is a remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to withstand. If the level controller is set with too close a tolerance, frequent turning on and off of a pump could be the cause of a control system. When a pump receives a signal to start, a light will typically be illuminated on the control panel indicating that the pump is running. In order to be sure that the pump is actually pumping water, a positive flow report-back signal should be installed on the control panel.

Telemetry systems must often transmit more than one signal. You can use several types of systems including: Polling, Scanning and Multiplexing.

Valves

The four most common categories of valves encountered in the water distribution system are the slide (linear), rotary, globe, and diaphragm valves.

Rotary and Linear

Only one linear or slide valve, this is the **Gate Valve**. It is used for main line isolation. Never regulate flow with a gate valve and always store this valve in the open position.

Rotary

Globe, used for flow regulation.

Butterfly, full bore opening, operates on a spindle.

Ball, fully on or fully off.

Other Valves

Insertion, valve used to obtain a shutdown on a hot main.

PRV, pressure regulating, rubber diaphragm.

Bypass can be used to prevent a water hammer.

Corp, service line regulation.

An Insertion Valve (Hydrostop) is used in the water distribution system to isolate sections of mains to permit the making of emergency repairs to be made without interruption of service to a large number of customers, it is a valve used when you are unable to obtain a shut down. The most commonly used valve for isolation is the **Gate valve**.

Pressure Regulation Valves control water pressure and operate by restricting flows. They are used to deliver water from a high pressure to a low-pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening.

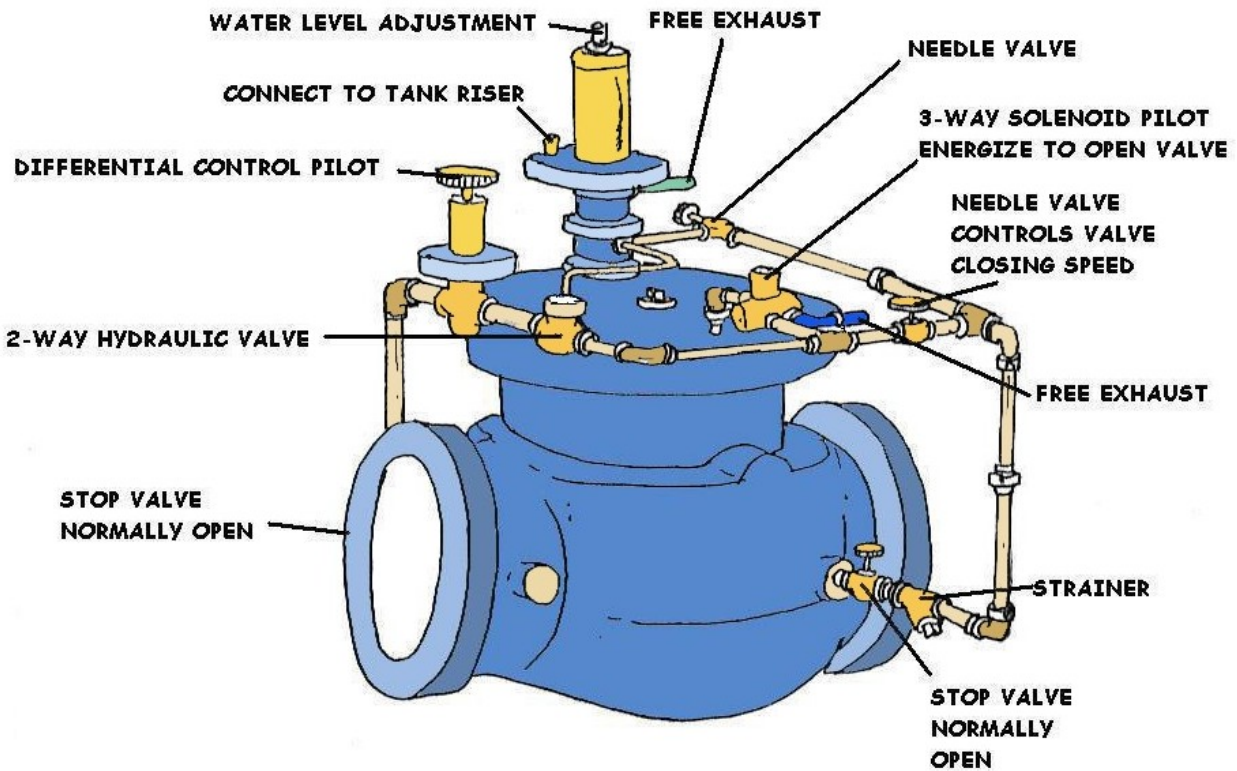
Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In other words, something is “*sucked*” into the system because the main is under a vacuum.

Meters

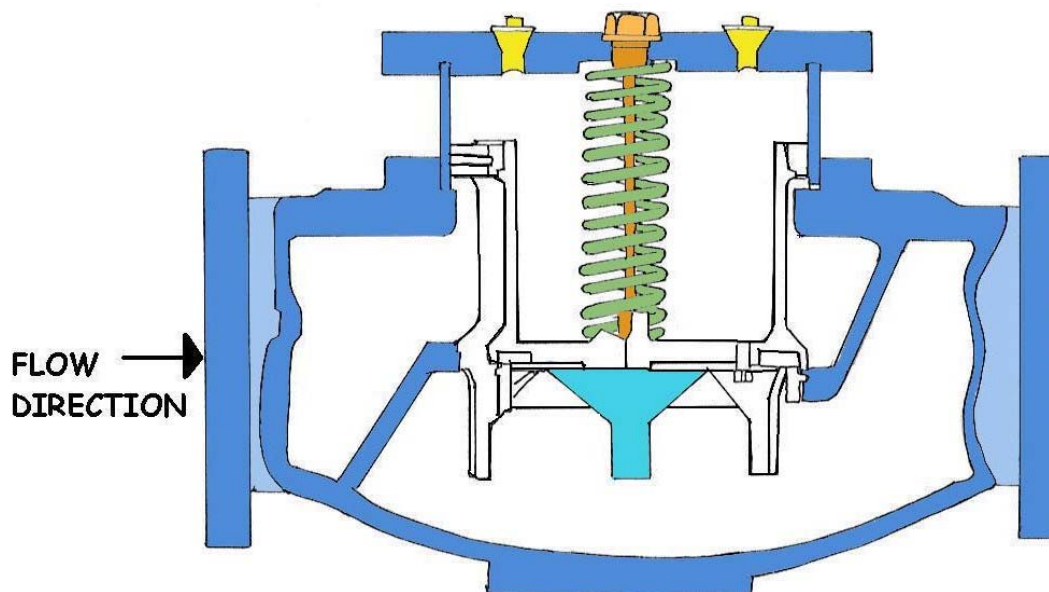
Three classifications of meters, **Velocity, Displacement and Compound**. The most common Displacement meter is the **Nutating disk**. Compound meters are advantageous for places where there are predominantly low or intermediate flows, only occasionally, high flows.

Inspection of magnetic flow meter instrumentation should include checking for corrosion or insulation deterioration.

Always replace the caps on a water meter when replacing it. The only negative effect of a meter is head loss. Displacement meters are used to measure flows in lines.

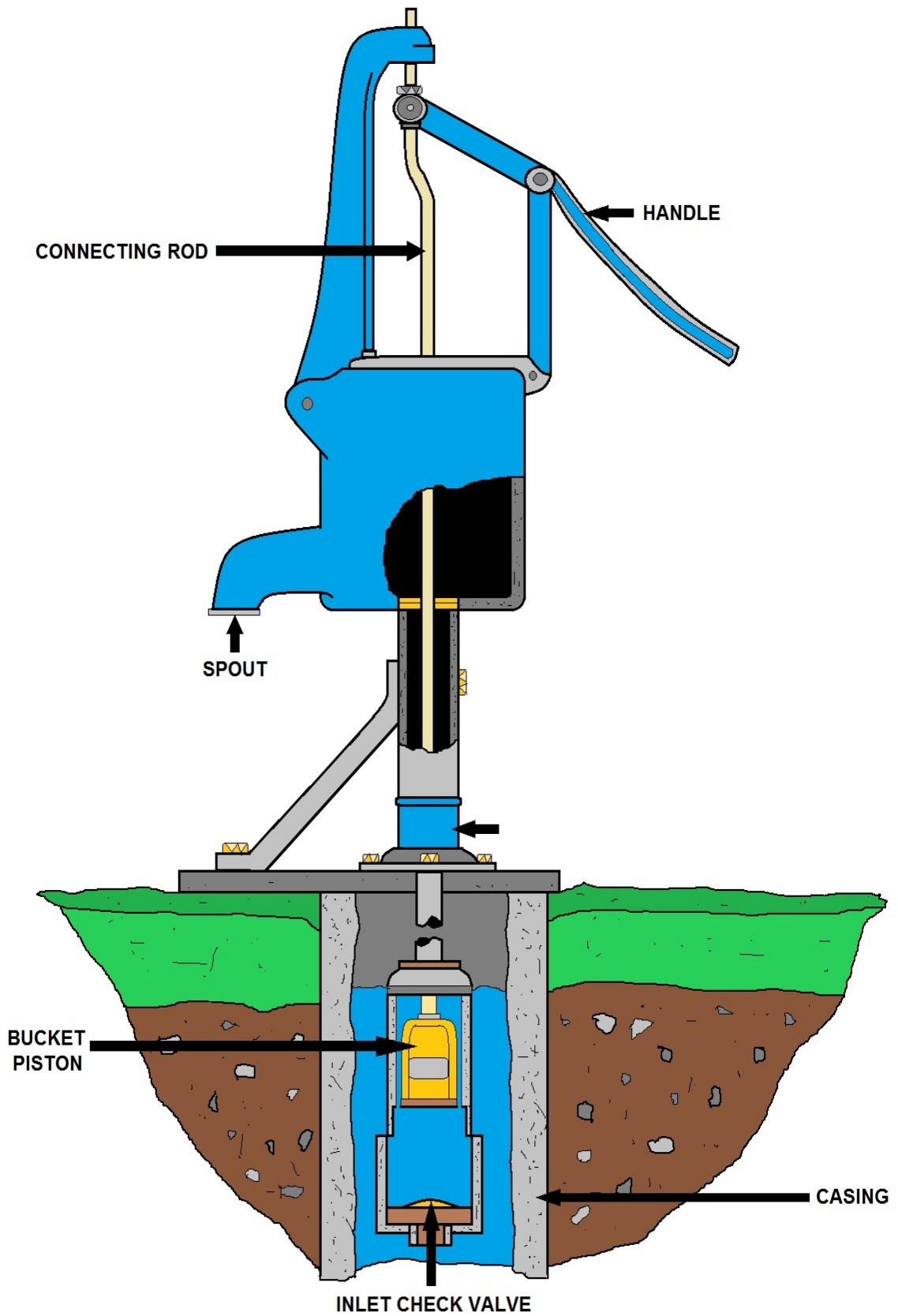


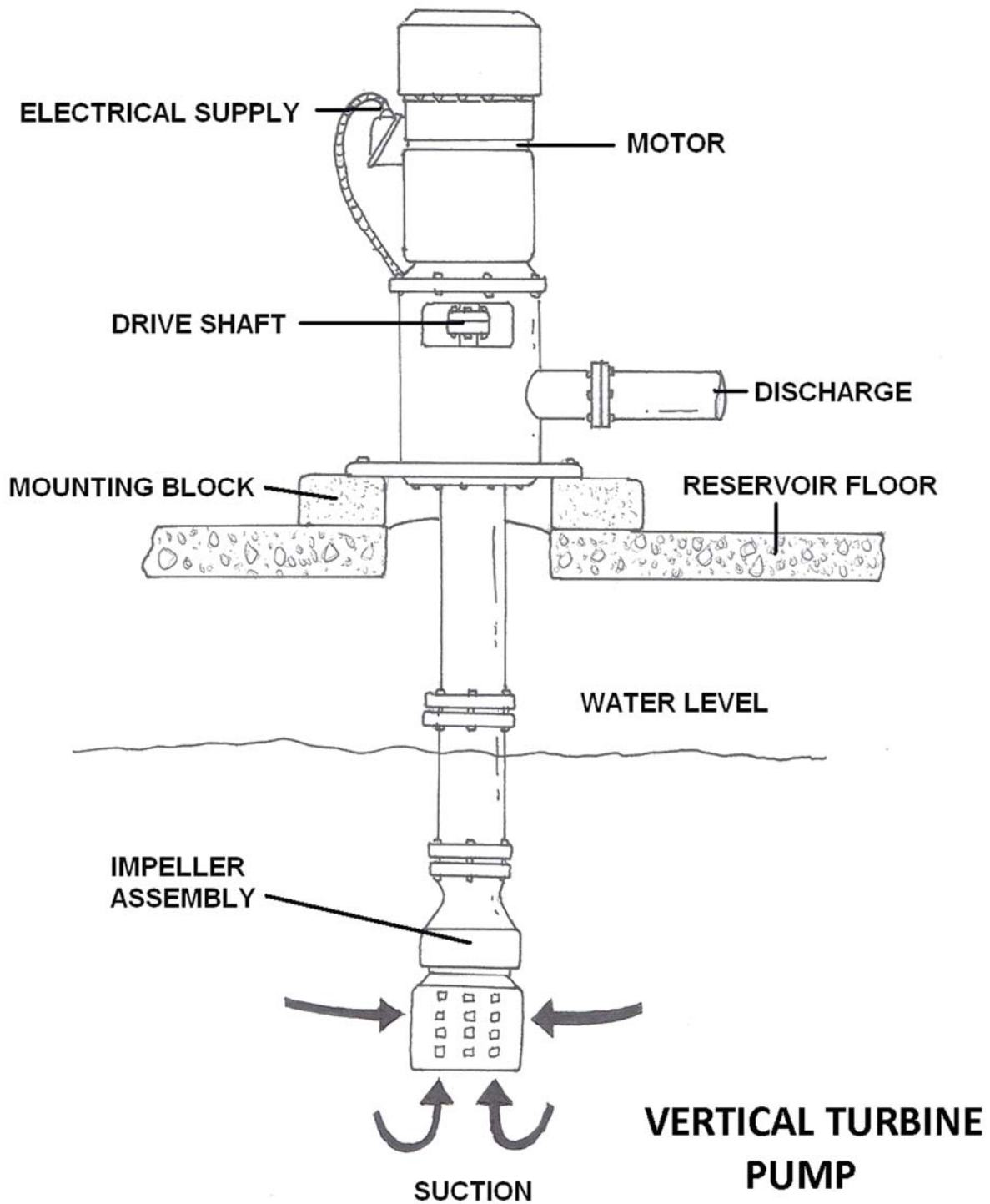
ALTITUDE CONTROL VALVE



FLANGED GLOBE STYLE PRESSURE REDUCING VALVE

Pump, and Motor Section Chapter 7





Common Hydraulic Terms

Head

The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. Pressure is equal to the height times the density of the liquid.

Head, Friction

The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type, and conditions of conductors and fittings, and the fluid characteristics.

Head, static

The height of a column or body of fluid above a given point.

Hydraulics

Engineering science pertaining to liquid pressure and flow.

Hydrokinetics

Engineering science pertaining to the energy of liquid flow and pressure.

Pascal's Law

A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

Pressure

The application of continuous force by one body upon another that it is touching; compression. Force per unit area, usually expressed in pounds per square inch (Pascal or bar).

Pressure, Absolute

The pressure above zone absolute, i.e. the sum of atmospheric and gauge pressure. In vacuum related work it is usually expressed in millimeters of mercury. (mmHg).

Pressure, Atmospheric

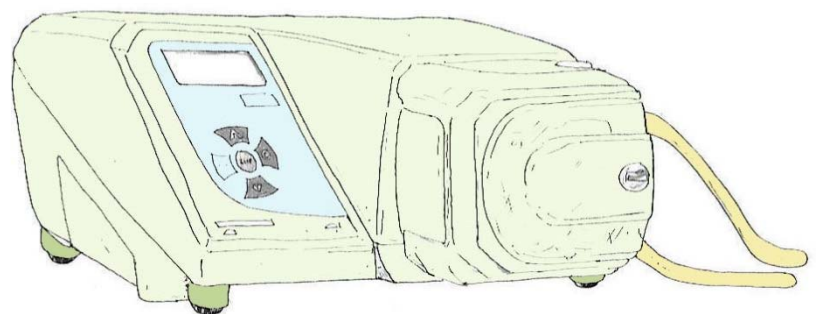
Pressure exported by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute, 1 bar = 14.5psi.)

Pressure, Gauge

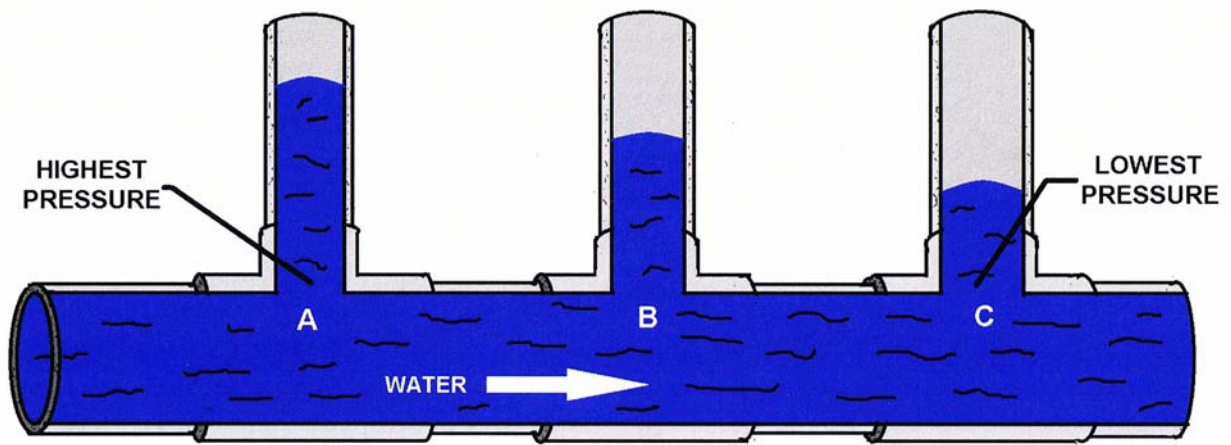
Pressure differential above or below ambient atmospheric pressure.

Pressure, Static

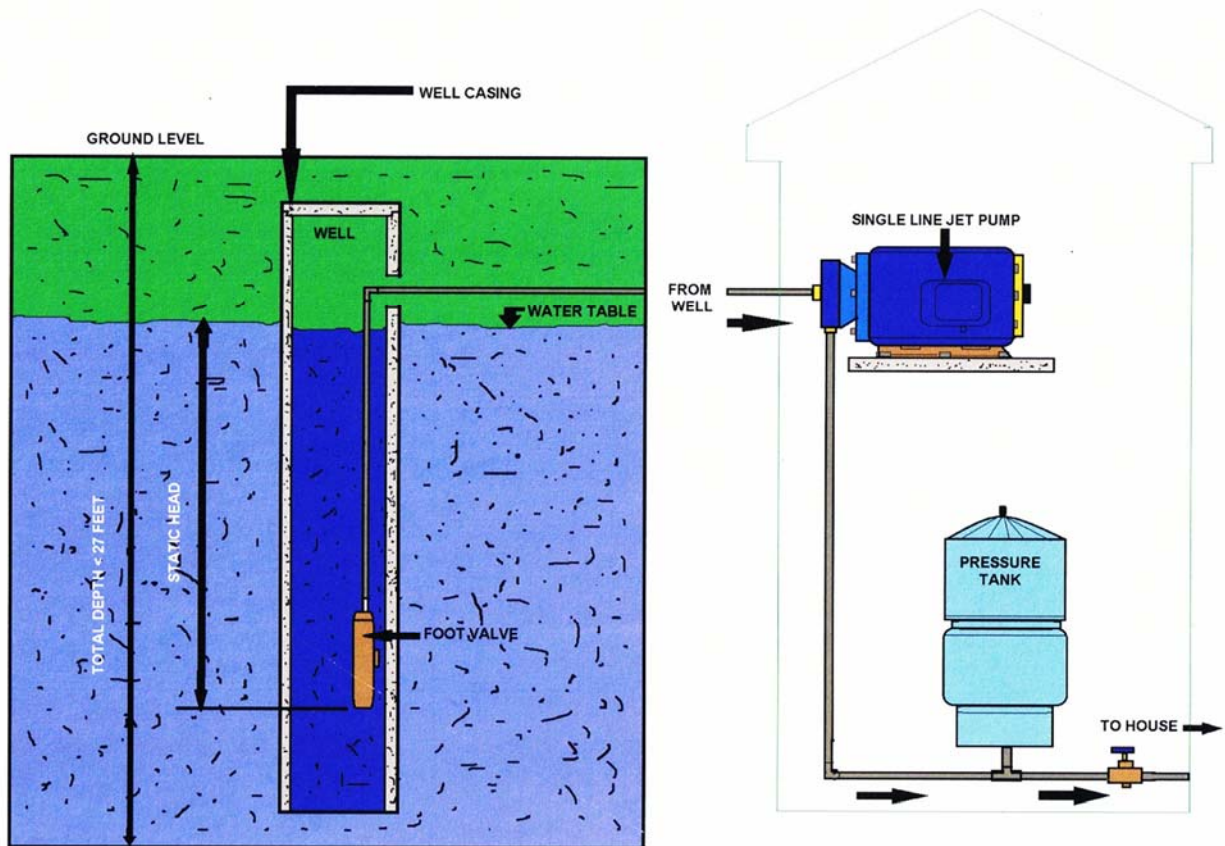
The pressure in a fluid at rest.



PERISTALTIC PUMP



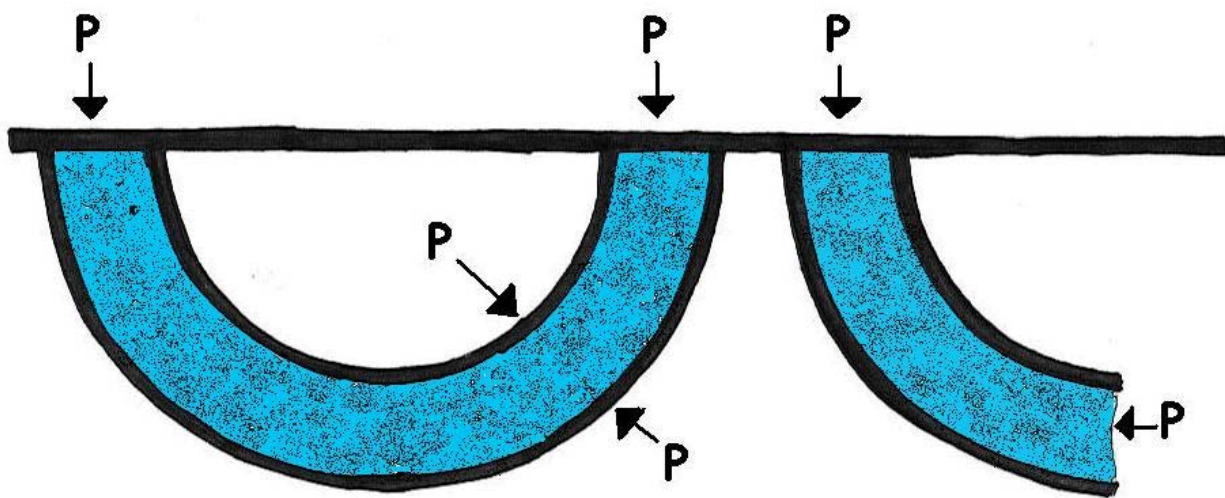
WATER FLOWS FROM HIGHEST PRESSURE ZONE TO LOW ZONE
 Pressure at A > Pressure at B > Pressure at C.



SHALLOW WELL WITH SINGLE-LINE JET PUMP
 (SUITABLE FOR SHALLOW WELLS LESS THAN 27 FEET DEEP)

Pressure

By a fluid, we have a material in mind like water or air, two very common and important fluids. Water is incompressible, while air is very compressible, but both are fluids. Water has a definite volume; air does not. Water and air have low viscosity; that is, layers of them slide very easily on one another, and they quickly assume their permanent shapes when disturbed by rapid flows. Other fluids, such as molasses, may have high viscosity and take a long time to come to equilibrium, but they are no less fluids. The coefficient of viscosity is the ratio of the shearing force to the velocity gradient. Hydrostatics deals with permanent, time-independent states of fluids, so viscosity does not appear, except as discussed in the Introduction.



EQUALITY OF PRESSURE

A fluid, therefore, is a substance that cannot exert any permanent forces tangential to a boundary. Any force that it exerts on a boundary must be normal to the boundary. Such a force is proportional to the area on which it is exerted, and is called a pressure. We can imagine any surface in a fluid as dividing the fluid into parts pressing on each other, as if it were a thin material membrane, and so think of the pressure at any point in the fluid, not just at the boundaries. In order for any small element of the fluid to be in equilibrium, the pressure must be the same in all directions (or the element would move in the direction of least pressure), and if no other forces are acting on the body of the fluid, the pressure must be the same at all neighboring points.

Therefore, in this case the pressure will be the same throughout the fluid, and the same in any direction at a point (Pascal's Principle).

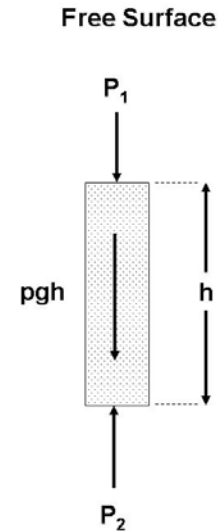
Pressure is expressed in units of force per unit area such as dyne/cm², N/cm² (pascal), pounds/in² (psi) or pounds/ft² (psf). The axiom that if a certain volume of fluid were somehow made solid, the equilibrium of forces would not be disturbed, is useful in reasoning about forces in fluids.

On earth, fluids are also subject to the force of gravity, which acts vertically downward, and has a magnitude $\gamma = \rho g$ per unit volume, where g is the acceleration of gravity, approximately 981 cm/s^2 or 32.15 ft/s^2 , ρ is the density, the mass per unit volume, expressed in g/cm^3 , kg/m^3 , or slug/ft^3 , and γ is the specific weight, measured in lb/in^3 , or lb/ft^3 (pcf). Gravitation is an example of a body force that disturbs the equality of pressure in a fluid. The presence of the gravitational body force causes the pressure to increase with depth, according to the equation $dp = \rho g dh$, in order to support the water above.

We call this relation the barometric equation, for when this equation is integrated, we find the variation of pressure with height or depth. If the fluid is incompressible, the equation can be integrated at once, and the pressure as a function of depth h is $p = \rho gh + p_0$.

The density of water is about 1 g/cm^3 , or its specific weight is 62.4 pcf . We may ask what depth of water gives the normal sea-level atmospheric pressure of 14.7 psi , or 2117 psf .

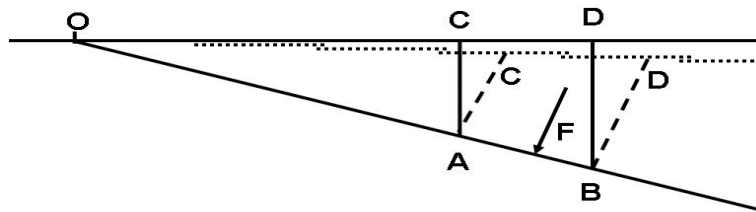
This is simply $2117 / 62.4 = 33.9 \text{ ft}$ of water. This is the maximum height to which water can be raised by a suction pump, or, more correctly, can be supported by atmospheric pressure. Professor James Thomson (brother of William Thomson, Lord Kelvin) illustrated the equality of pressure by a "curtain-ring" analogy shown in the diagram. A section of the toroid was identified, imagined to be solidified, and its equilibrium was analyzed.



Increase of Pressure with Depth

The forces exerted on the curved surfaces have no component along the normal to a plane section, so the pressures at any two points of a plane must be equal, since the fluid represented by the curtain ring was in equilibrium. The diagram illustrates the equality of pressures in orthogonal directions.

This can be extended to any direction whatever, so Pascal's Principle is established. This demonstration is similar to the usual one using a triangular prism and considering the forces on the end and lateral faces separately.



Thrust on a Plane

Pump Definitions *(Larger Glossary in the rear of this manual)*

Fluid: Any substance that can be pumped such as oil, water, refrigerant, or even air.

Gasket: Flat material that is compressed between two flanges to form a seal.

Gland follower: A bushing used to compress the packing in the stuffing box and to control leakoff.

Gland sealing line: A line that directs sealing fluid to the stuffing box.

Horizontal pumps: Pumps in which the Center line of the shaft is horizontal.

Impeller: The part of the pump that increases the speed of the fluid being handled.

Inboard: The end of the pump closest to the motor.

Inter-stage diaphragm: A barrier that separates stages of a multi-stage pump.

Key: A rectangular piece of metal that prevents the impeller from rotating on the shaft.

Keyway: The area on the shaft that accepts the key.

Kinetic energy: Energy associated with motion.

Lantern ring: A metal ring located between rings of packing that distributes gland sealing fluid.

Leak-off: Fluid that leaks from the stuffing box.

Mechanical seal: A mechanical device that seals the pump stuffing box.

Mixed flow pump: A pump that uses both axial-flow and radial-flow components in one impeller.

Multi-stage pumps: Pumps with more than one impeller.

Outboard: The end of the pump farthest from the motor.

Packing: Soft, pliable material that seals the stuffing box.

Positive displacement pumps: Pumps that move fluids by physically displacing the fluid inside the pump.

Radial bearings: Bearings that prevent shaft movement in any direction outward from the center line of the pump.

Radial flow: Flow at 90° to the center line of the shaft.

Retaining nut: A nut that keeps the parts in place.

Rotor: The rotating parts, usually including the impeller, shaft, bearing housings, and all other parts included between the bearing housing and the impeller.

Score: To cause lines, grooves or scratches.

Shaft: A cylindrical bar that transmits power from the driver to the pump impeller.

Shaft sleeve: A replaceable tubular covering on the shaft.

Shroud: The metal covering over the vanes of an impeller.

Slop drain: The drain from the area that collects leak-off from the stuffing box.

Slurry: A thick, viscous fluid, usually containing small particles.

Stages: Impellers in a multi-stage pump.

Stethoscope: A metal device that can amplify and pinpoint pump sounds.

Strainer: A device that retains solid pieces while letting liquids through.

Stuffing box: The area of the pump where the shaft penetrates the casing.

Suction: The place where fluid enters the pump.

Suction eye: The place where fluid enters the pump impeller.

Throat bushing: A bushing at the bottom of the stuffing box that prevents packing from being pushed out of the stuffing box into the suction eye of the impeller.

Thrust: Force, usually along the center line of the pump.

Thrust bearings: Bearings that prevent shaft movement back and forth in the same direction as the center line of the shaft.

Troubleshooting: Locating a problem.

Vanes: The parts of the impeller that push and increase the speed of the fluid in the pump.

Vertical pumps: Pumps in which the center line of the shaft runs vertically.

Volute: The part of the pump that changes the speed of the fluid into pressure.

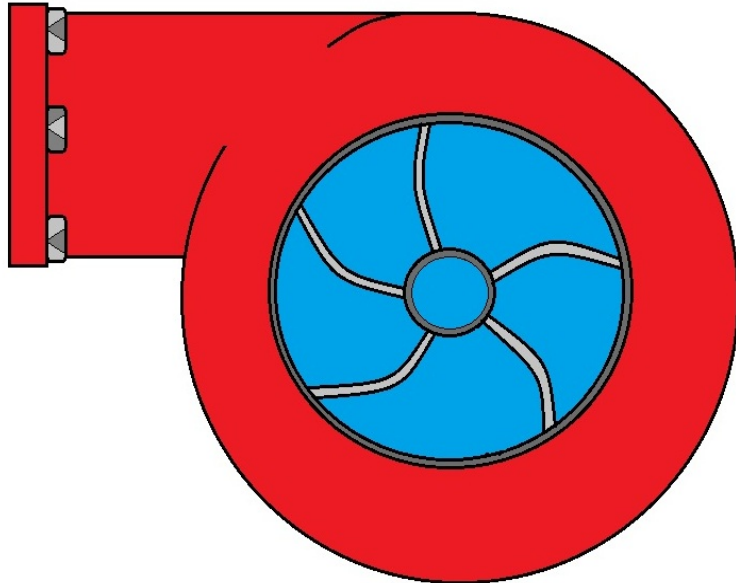
Wearing rings: Replaceable rings on the impeller or the casing that wear as the pump operates.

Understanding the Pump

Pumps are used to move or raise fluids. They are not only very useful, but are excellent examples of hydrostatics. Pumps are of two general types, hydrostatic or positive displacement pumps, and pumps depending on dynamic forces, such as centrifugal pumps. Here we will only consider positive displacement pumps, which can be understood purely by hydrostatic considerations. They have a piston (or equivalent) moving in a closely-fitting cylinder, and forces are exerted on the fluid by motion of the piston.

BASIC COMPONENTS OF A CENTRIFUGAL PUMP:

- VOLUTE, CASING, BODY
- OR DIFFUSER
- IMPELLER
- OR IMPELLERS
- DRIVER (MOTOR)



BASICS OF A CENTRIFUGAL PUMP

We have already seen an important example of this in the hydraulic lever or hydraulic press, which we have called quasi-static. The simplest pump is the syringe, filled by withdrawing the piston and emptied by pressing it back in, as its port is immersed in the fluid or removed from it.

More complicated pumps have valves allowing them to work repetitively. These are usually check valves that open to allow passage in one direction, and close automatically to prevent reverse flow. There are many kinds of valves, and they are usually the most trouble-prone and complicated part of a pump. The force pump has two check valves in the cylinder, one for supply and the other for delivery. The supply valve opens when the cylinder volume increases, the delivery valve when the cylinder volume decreases.

The lift pump has a supply valve and a valve in the piston that allows the liquid to pass around it when the volume of the cylinder is reduced. The delivery in this case is from the upper part of the cylinder, which the piston does not enter.

Diaphragm pumps are force pumps in which the oscillating diaphragm takes the place of the piston. The diaphragm may be moved mechanically, or by the pressure of the fluid on one side of the diaphragm.

Some positive displacement pumps are shown below. The force and lift pumps are typically used for water. The force pump has two valves in the cylinder, while the lift pump has one valve in the cylinder and one in the piston. The maximum lift, or "suction," is determined by the atmospheric pressure, and either cylinder must be within this height of the free surface. The force pump, however, can give an arbitrarily large pressure to the discharged fluid, as in the case of a diesel engine injector. A nozzle can be used to convert the pressure to velocity, to produce a jet, as for firefighting. Fire fighting force pumps usually have two cylinders feeding one receiver alternately. The air space in the receiver helps to make the water pressure uniform.

The three pumps below are typically used for air, but would be equally applicable to liquids. The Roots blower has no valves, their place taken by the sliding contact between the rotors and the housing.

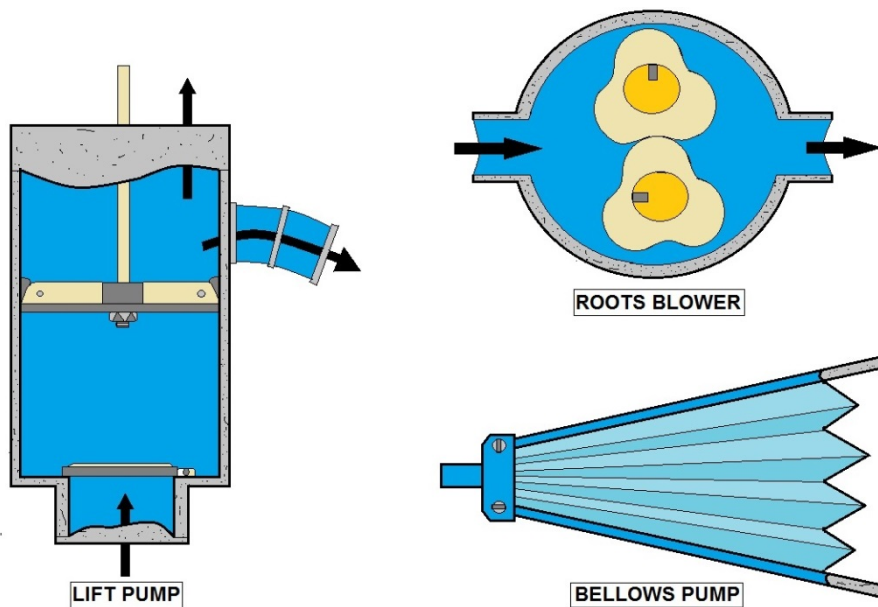
The Roots blower can either exhaust a receiver or provide air under moderate pressure, in large volumes.

The Bellows is a very old device, requiring no accurate machining. The single valve is in one or both sides of the expandable chamber.

Another valve can be placed at the nozzle if required. The valve can be a piece of soft leather held close to holes in the chamber.

The Bicycle pump uses the valve on the valve stem of the tire or inner tube to hold pressure in the tire. The piston, which is attached to the discharge tube, has a flexible seal that seals when the cylinder is moved to compress the air, but allows air to pass when the movement is reversed.

Diaphragm and vane pumps are not shown, but they act the same way by varying the volume of a chamber, and directing the flow with check valves.



TYPES OF POSITIVE DISPLACEMENT PUMPS

Types of Pumps

The family of pumps comprises a large number of types based on application and capabilities. The two major groups of pumps are dynamic and positive displacement.

Dynamic Pumps (Centrifugal Pump)

Centrifugal pumps are classified into three general categories:

Radial flow—a centrifugal pump in which the pressure is developed wholly by centrifugal force.

Mixed flow—a centrifugal pump in which the pressure is developed partly by centrifugal force and partly by the lift of the vanes of the impeller on the liquid.

Axial flow—a centrifugal pump in which the pressure is developed by the propelling or lifting action of the vanes of the impeller on the liquid.

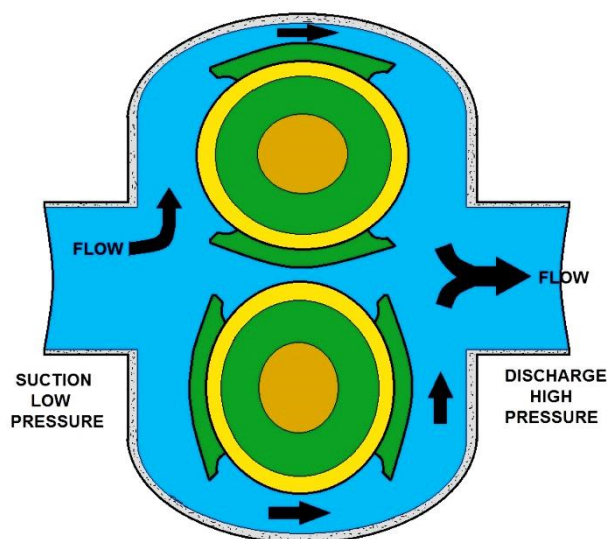
Positive Displacement Pumps

A Positive Displacement Pump has an expanding cavity on the suction side of the pump and a decreasing cavity on the discharge side. Liquid is allowed to flow into the pump as the cavity on the suction side expands and the liquid is forced out of the discharge as the cavity collapses. This principle applies to all types of Positive Displacement Pumps whether the pump is a rotary lobe, gear within a gear, piston, diaphragm, screw, progressing cavity, etc.

A Positive Displacement Pump, unlike a Centrifugal Pump, will produce the same flow at a given RPM no matter what the discharge pressure is. A Positive Displacement Pump cannot be operated against a closed valve on the discharge side of the pump, i.e. it does not have a shut-off head like a Centrifugal Pump does. If a Positive Displacement Pump is allowed to operate against a closed discharge valve it will continue to produce flow which will increase the pressure in the discharge line until either the line bursts or the pump is severely damaged or both.

Types of Positive Displacement Pumps

Single Rotor	Multiple Rotor
Vane	Gear
Piston	Lobe
Flexible Member	Circumferential Piston
Single Screw	Multiple Screw



COMMONLY FOUND POSITIVE DISPLACEMENT PUMP

There are many types of positive displacement pumps. We will look at:

- ☛ Plunger pumps
- ☛ Diaphragm pumps
- ☛ Progressing cavity pumps, and
- ☛ Screw pumps

Single Rotator

Component	Description
Vane	The vane(s) may be blades, buckets, rollers, or slippers that cooperate with a dam to draw fluid into and out of the pump chamber.
Piston	Fluid is drawn in and out of the pump chamber by a piston(s) reciprocating within a cylinder(s) and operating port valves.
Flexible Member	Pumping and sealing depends on the elasticity of a flexible member(s) that may be a tube, vane, or a liner.
Single Screw	Fluid is carried between rotor screw threads as they mesh with internal threads on the stator.

Multiple Rotator

Component	Description
Gear	Fluid is carried between gear teeth and is expelled by the meshing of the gears that cooperate to provide continuous sealing between the pump inlet and outlet.
Lobe	Fluid is carried between rotor lobes that cooperate to provide continuous sealing between the pump inlet and outlet.
Circumferential piston	Fluid is carried in spaces between piston surfaces not requiring contacts between rotor surfaces.
Multiple Screw	Fluid is carried between rotor screw threads as they mesh.

Plunger Pump

The plunger pump is a positive displacement pump that uses a plunger or piston to force liquid from the suction side to the discharge side of the pump. It is used for heavy sludge. The movement of the plunger or piston inside the pump creates pressure inside the pump, so you have to be careful that this kind of pump is never operated against any closed discharge valve. All discharge valves must be open before the pump is started, to prevent any fast build-up of pressure that could damage the pump.

Diaphragm Pumps

In this type of pump, a diaphragm provides the mechanical action used to force liquid from the suction to the discharge side of the pump. The advantage the diaphragm has over the plunger is that the diaphragm pump does not come in contact with moving metal. This can be important when pumping abrasive or corrosive materials.

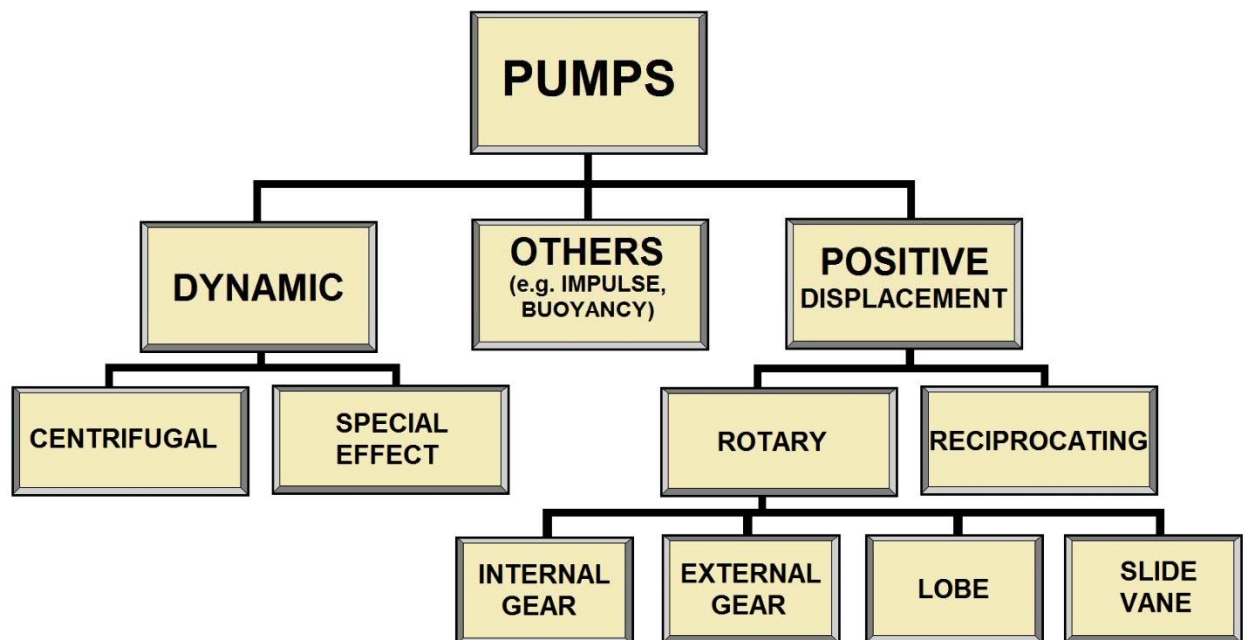
There are three main types of diaphragm pumps available:

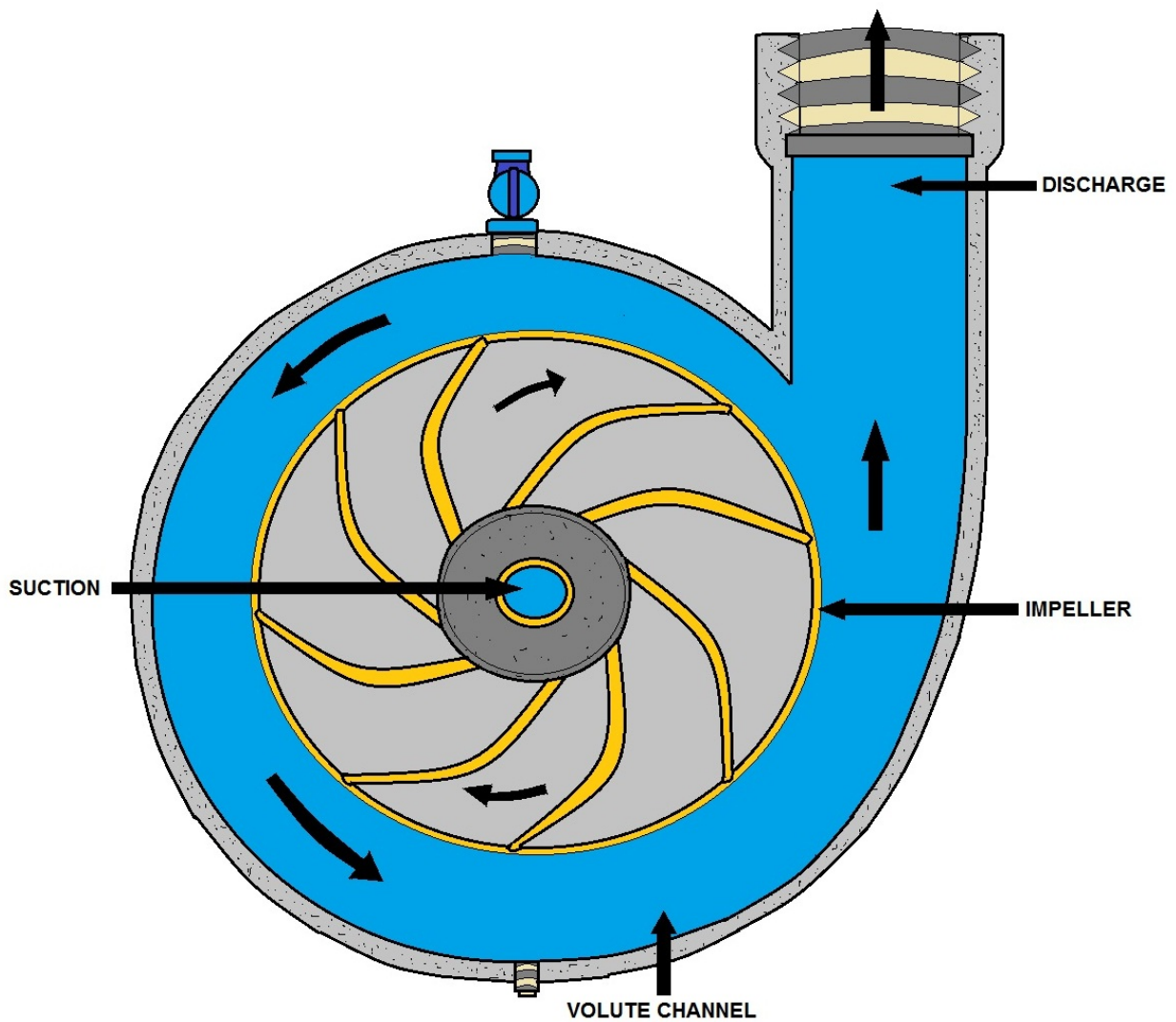
1. Diaphragm sludge pump
2. Chemical metering or proportional pump
3. Air-powered double-diaphragm pump

Pump Categories

Let's cover the essentials first. The key to the whole operation is, of course, the *pump*. And regardless of what type it is (reciprocating piston, centrifugal, turbine or jet-ejector, for either shallow or deep well applications), its purpose is to move water and generate the delivery force we call pressure. Sometimes — with centrifugal pumps in particular — pressure is not referred to in pounds per square inch but rather as the equivalent in elevation, called head. No matter; head in feet divided by 2.31 equals pressure, so it's simple enough to establish a common figure.

Pumps may be classified on the basis of the application they serve. All pumps may be divided into two major categories: (1) dynamic, in which energy is continuously added to increase the fluid velocities within the machine, and (2) displacement, in which the energy is periodically added by application of force.



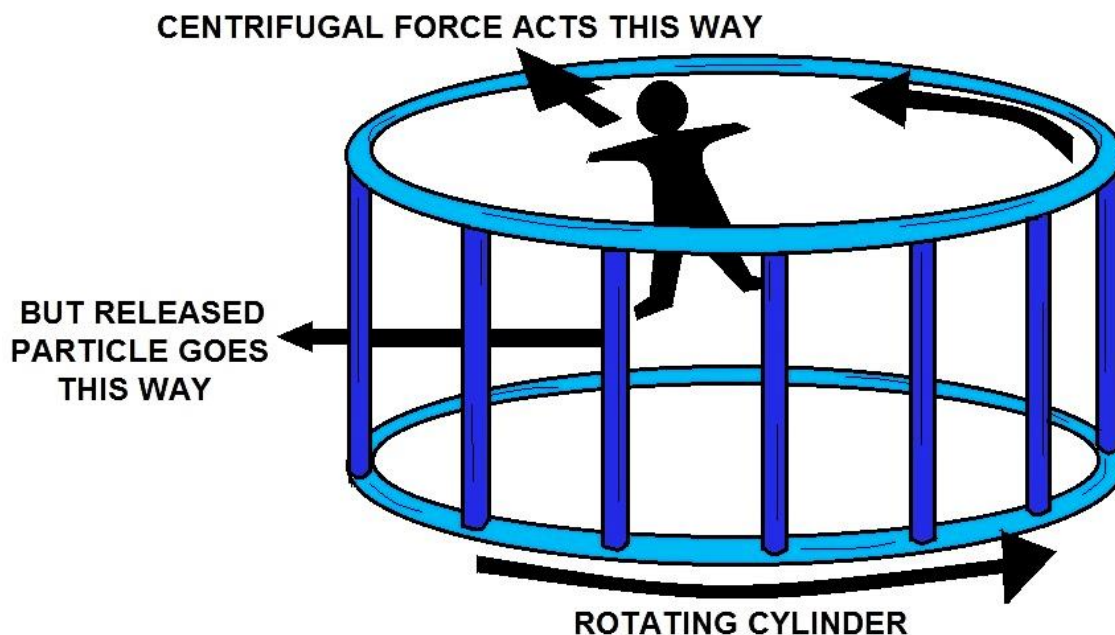


**CENTRIFUGAL PUMP
PROGRESSIVE CAVITY TYPE**

Basic Water Pump

The water pump commonly found in our systems is centrifugal pumps. These pumps work by spinning water around in a circle inside a cylindrical pump housing. The pump makes the water spin by pushing it with an impeller. The blades of this impeller project outward from an axle like the arms of a turnstile and, as the impeller spins, the water spins with it. As the water spins, the pressure near the outer edge of the pump housing becomes much higher than near the center of the impeller.

There are many ways to understand this rise in pressure, and here are two:



CENTRIFUGAL WATER EFFECTS

First, you can view the water between the impeller blades as an object traveling in a circle. Objects do not naturally travel in a circle--they need an inward force to cause them to accelerate inward as they spin. Without such an inward force, an object will travel in a straight line and will not complete the circle. In a centrifugal pump, that inward force is provided by high-pressure water near the outer edge of the pump housing. The water at the edge of the pump pushes inward on the water between the impeller blades and makes it possible for that water to travel in a circle. The water pressure at the edge of the turning impeller rises until it is able to keep water circling with the impeller blades.

You can also view the water as an incompressible fluid, one that obeys Bernoulli's equation in the appropriate contexts. As water drifts outward between the impeller blades of the pump, it must move faster and faster because its circular path is getting larger and larger. The impeller blades cause the water to move faster and faster. By the time the water has reached the outer edge of the impeller, it is moving quite fast. However, when the water leaves the impeller and arrives at the outer edge of the cylindrical pump housing, it slows down.

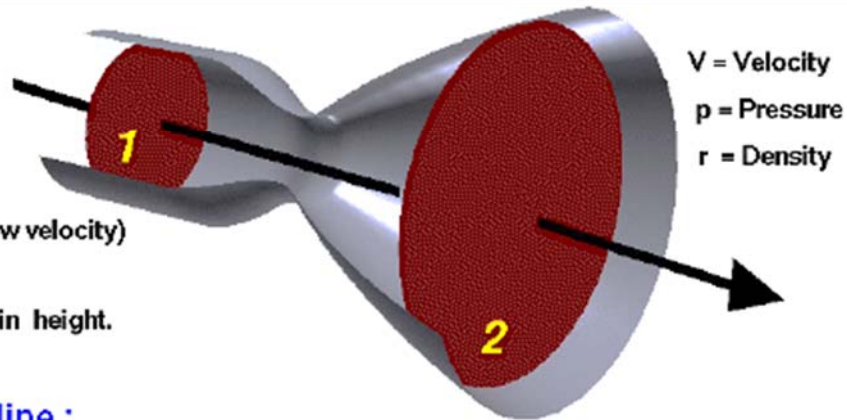


Bernoulli's Equation

Glenn
Research
Center

Restrictions :

Inviscid
Steady
Incompressible (low velocity)
No heat addition.
Negligible change in height.

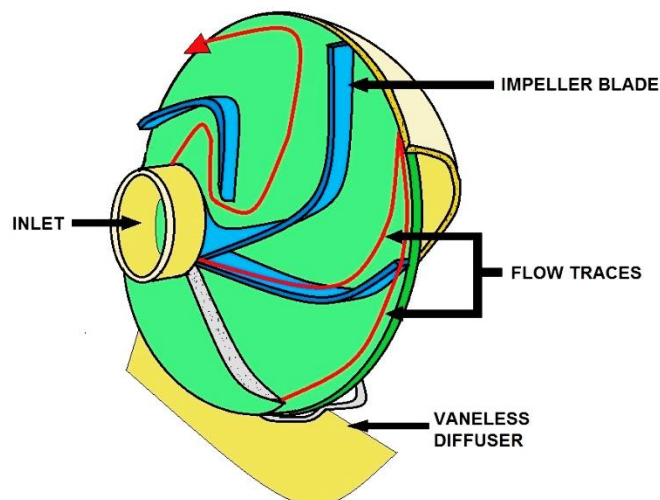


Along a streamline :

static pressure + dynamic pressure = total pressure

$$p_s + \frac{rV^2}{2} = p_t$$
$$\left(p_s + \frac{rV^2}{2}\right)_1 = \left(p_s + \frac{rV^2}{2}\right)_2$$

Here is where Bernoulli's equation figures in. As the water slows down and its kinetic energy decreases, that water's pressure potential energy increases (**to conserve energy**). Thus, the slowing is accompanied by a pressure rise. That is why the water pressure at the outer edge of the pump housing is higher than the water pressure near the center of the impeller. When water is actively flowing through the pump, arriving through a hole near the center of the impeller and leaving through a hole near the outer edge of the pump housing, the pressure rise between center and edge of the pump is not as large.



COMMON PUMP IMPELLER

Types of Water Pumps

The most common type of water pumps used for municipal and domestic water supplies are *variable displacement* pumps. A variable displacement pump will produce at different rates relative to the amount of pressure or lift the pump is working against. *Centrifugal* pumps are variable displacement pumps that are by far used the most. The water production well industry almost exclusively uses *Turbine* pumps, which are a type of centrifugal pump.

The turbine pump utilizes *impellers* enclosed in single or multiple *bowls or stages* to lift water by *centrifugal force*. The impellers may be of either a *semi-open or closed type*. Impellers are rotated by the *pump motor*, which provides the horsepower needed to overcome the pumping head. A more thorough discussion of how these and other pumps work is presented later in this section. The size and number of stages, horsepower of the motor and pumping head are the key components relating to the pump's lifting capacity.

Vertical turbine pumps are commonly used in groundwater wells. These pumps are driven by a shaft rotated by a motor on the surface. The shaft turns the impellers within the pump housing while the water moves up the column.

This type of pumping system is also called a *line-shaft turbine*. The rotating shaft in a line shaft turbine is actually housed within the column pipe that delivers the water to the surface. The size of the column, impeller, and bowls are selected based on the desired pumping rate and lift requirements.

Column pipe sections can be threaded or coupled together while the drive shaft is coupled and suspended within the column by *spider bearings*. The spider bearings provide both a seal at the column pipe joints and keep the shaft aligned within the column. The water passing through the column pipe serves as the lubricant for the bearings. Some vertical turbines are lubricated by oil rather than water. These pumps are essentially the same as water lubricated units; only the drive shaft is enclosed within an *oil tube*.

Food grade oil is supplied to the tube through a gravity feed system during operation. The oil tube is suspended within the column by *spider flanges*, while the line shaft is supported within the oil tube by *brass or redwood bearings*. A continuous supply of oil lubricates the drive shaft as it proceeds downward through the oil tube.

A small hole located at the top of the pump bow unit allows excess oil to enter the well. This results in the formation of an oil film on the water surface within oil-lubricated wells. Careful operation of oil lubricated turbines is needed to ensure that the pumping levels do not drop enough to allow oil to enter the pump. Both water and oil lubricated turbine pump units can be driven by electric or fuel powered motors. Most installations use an electric motor that is connected to the drive shaft by a keyway and nut. However, where electricity is not readily available, fuel powered engines may be connected to the drive shaft by a right angle drive gear. Also, both oil and water lubricated systems will have a strainer attached to the intake to prevent sediment from entering the pump.

When the line shaft turbine is turned off, water will flow back down the column, turning the impellers in a reverse direction. A pump and shaft can easily be broken if the motor were to turn on during this process. This is why a *time delay* or *ratchet* assembly is often installed on these motors to either prevent the motor from turning on before reverse rotation stops or simply not allow it to reverse at all.

There are three main types of diaphragm pumps:

In the first type, the diaphragm is sealed with one side in the fluid to be pumped, and the other in air or hydraulic fluid. The diaphragm is flexed, causing the volume of the pump chamber to increase and decrease. A pair of non-return check valves prevents reverse flow of the fluid.

As described above, the second type of diaphragm pump works with volumetric positive displacement, but differs in that the prime mover of the diaphragm is neither oil nor air; but is electro-mechanical, working through a crank or geared motor drive. This method flexes the diaphragm through simple mechanical action, and one side of the diaphragm is open to air. The third type of diaphragm pump has one or more unsealed diaphragms with the fluid to be pumped on both sides. The diaphragm(s) again are flexed, causing the volume to change.

When the volume of a chamber of either type of pump is increased (the diaphragm moving up), the pressure decreases, and fluid is drawn into the chamber. When the chamber pressure later increases from decreased volume (the diaphragm moving down), the fluid previously drawn in is forced out. Finally, the diaphragm moving up once again draws fluid into the chamber, completing the cycle. This action is similar to that of the cylinder in an internal combustion engine.

Cavitation

Cavitation is defined as the phenomenon of formation of vapor bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure. Cavitation is usually divided into two classes of behavior: inertial (or transient) cavitation and non-inertial cavitation. Inertial cavitation is the process where a void or bubble in a liquid rapidly collapses, producing a shock wave. Such cavitation often occurs in pumps, propellers, impellers, and in the vascular tissues of plants. Non-inertial cavitation is the process in which a bubble in a fluid is forced to oscillate in size or shape due to some form of energy input, such as an acoustic field. Such cavitation is often employed in ultrasonic cleaning baths and can also be observed in pumps, propellers etc.

Cavitation is, in many cases, an undesirable occurrence. In devices such as propellers and pumps, cavitation causes a great deal of noise, damage to components, vibrations, and a loss of efficiency. When the cavitation bubbles collapse, they force liquid energy into very small volumes, thereby creating spots of high temperature and emitting shock waves, the latter of which are a source of noise.

The noise created by cavitation is a particular problem for military submarines, as it increases the chances of being detected by passive sonar. Although the collapse of a cavity is a relatively low-energy event, highly localized collapses can erode metals, such as steel, over time. The pitting caused by the collapse of cavities produces great wear on components and can dramatically shorten a propeller's or pump's lifetime. After a surface is initially affected by cavitation, it tends to erode at an accelerating pace. The cavitation pits increase the turbulence of the fluid flow and create crevasses that act as nucleation sites for additional cavitation bubbles. The pits also increase the component's surface area and leave behind residual stresses. This makes the surface more prone to stress corrosion.

Impeller

An impeller is a rotating component of a centrifugal pump, usually made of iron, steel, aluminum or plastic, which transfers energy from the motor that drives the pump to the fluid being pumped by accelerating the fluid outwards from the center of rotation. The velocity achieved by the impeller transfers into pressure when the outward movement of the fluid is confined by the pump casing. Impellers are usually short cylinders with an open inlet (called an eye) to accept incoming fluid, vanes to push the fluid radially, and a splined center to accept a driveshaft.

Submersible Pumps

Submersible pumps are in essence very similar to turbine pumps. They both use impellers rotated by a shaft within the bowls to pump water. However, the pump portion is directly connected to the motor.

The pump shaft has a keyway in which the splined motor end shaft inserts. The motor is bolted to the pump housing. The pump's intake is located between the motor and the pump and is normally screened to prevent sediment from entering the pump and damaging the impellers.

The efficient cooling of submersible motors is very important, so these types of pumps are often installed such that flow through the well screen can occur upwards past the motor and into the intake. If the motor end is inserted below the screened interval or below all productive portions of the aquifer, it will not be cooled, resulting in premature motor failure.

Some pumps may have *pump shrouds* installed on them to force all the water to move past the motor to prevent overheating.

The shroud is a piece of pipe that attaches to the pump housing with an open end below the motor. As with turbine pumps, the size of the bowls and impellers, number of stages, and horsepower of the motor are adjusted to achieve the desired production rate within the limitations of the pumping head.



Insertion of motor spline into the pump keyway.

Cut away of a small submersible pump.

Key Pump Words

NPSH: Net positive suction head - related to how much suction lift a pump can achieve by creating a partial vacuum. Atmospheric pressure then pushes liquid into the pump. A method of calculating if the pump will work or not.

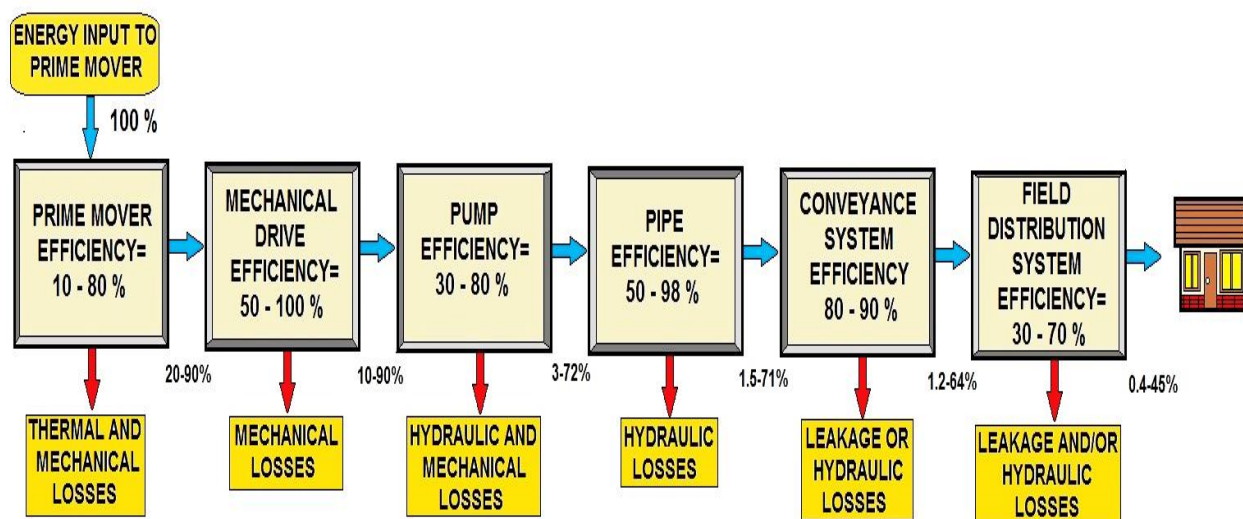
S.G.: Specific gravity. The weight of liquid in comparison to water at approx. 20 degrees C (SG = 1).

Specific Speed: A number which is the function of pump flow, head, efficiency etc. Not used in day to day pump selection, but very useful, as pumps with similar specific speed will have similar shaped curves, similar efficiency / NPSH / solids handling characteristics.

Vapor Pressure: If the vapor pressure of a liquid is greater than the surrounding air pressure, the liquid will boil.

Viscosity: A measure of a liquid's resistance to flow. i.e.: how thick it is. The viscosity determines the type of pump used, the speed it can run at, and with gear pumps, the internal clearances required.

Friction Loss: The amount of pressure / head required to 'force' liquid through pipe and fittings.



PUMPING EFFICIENCY

Understanding the Operation of a Vertical Turbine Pump

Vertical turbine pumps are available in deep well, shallow well, or canned configurations. VHS or VSS motors will be provided to fulfill environmental requirements. Submersible motors are also available. These pumps are also suitable industrial, municipal, commercial and agricultural applications.

Deep well turbine pumps are adapted for use in cased wells or where the water surface is below the practical limits of a centrifugal pump. Turbine pumps are also used with surface water systems. Since the intake for the turbine pump is continuously under water, priming is not a concern. Turbine pump efficiencies are comparable to, or greater than most centrifugal pumps. They are usually more expensive than centrifugal pumps and more difficult to inspect and repair. The turbine pump has three main parts: (1) the head assembly, (2) the shaft and column assembly and (3) the pump bowl assembly. The head is normally cast iron and designed to be installed on a foundation. It supports the column, shaft, and bowl assemblies, and provides a discharge for the water. It also will support an electric motor, a right angle gear drive or a belt drive.

Bowl Assembly

The bowl assembly is the heart of the vertical turbine pump. The impeller and diffuser type casing is designed to deliver the head and capacity that the system requires in the most efficient way. Vertical turbine pumps can be multi-staged, allowing maximum flexibility both in the initial pump selection and in the event that future system modifications require a change in the pump rating. The submerged impellers allow the pump to be started without priming. The discharge head changes the direction of flow from vertical to horizontal, and couples the pump to the system piping, in addition to supporting and aligning the driver.

Drivers

A variety of drivers may be used; however, electric motors are most common. For the purposes of this manual, all types of drivers can be grouped into two categories:

1. Hollow shaft drivers where the pump shaft extends through a tube in the center of the rotor and is connected to the driver by a clutch assembly at the top of the driver.
2. Solid shaft drivers where the rotor shaft is solid and projects below the driver mounting base. This type of driver requires an adjustable flanged coupling for connecting to the pump.

Discharge Head Assembly

The discharge head supports the driver and bowl assembly as well as supplying a discharge connection (the “NUF” type discharge connection which will be located on one of the column pipe sections below the discharge head). A shaft sealing arrangement is located in the discharge head to seal the shaft where it leaves the liquid chamber. The shaft seal will usually be either a mechanical seal assembly or stuffing box.

Column Assembly

The shaft and column assembly provides a connection between the head and pump bowls. The line shaft transfers the power from the motor to the impellers and the column carries the water to the surface. The line shaft on a turbine pump may be either water lubricated or oil lubricated.

The oil-lubricated pump has an enclosed shaft into which oil drips, lubricating the bearings. The water-lubricated pump has an open shaft. The bearings are lubricated by the pumped water. If there is a possibility of fine sand being pumped, select the oil lubricated pump because it will keep the sand out of the bearings. If the water is for domestic or livestock use, it must be free of oil and a water-lubricated pump must be used.

Line shaft bearings are commonly placed on 10-foot centers for water-lubricated pumps operating at speeds under 2,200 RPM and at 5-foot centers for pumps operating at higher speeds. Oil-lubricated bearings are commonly placed on 5-foot centers.

A pump bowl encloses the impeller. Due to its limited diameter, each impeller develops a relatively low head. In most deep well turbine installations, several bowls are stacked in series one above the other. This is called staging. A four-stage bowl assembly contains four impellers, all attached to a common shaft and will operate at four times the discharge head of a single-stage pump.

Impellers used in turbine pumps may be either semi-open or enclosed. The vanes on semi-open impellers are open on the bottom and they rotate with a close tolerance to the bottom of the pump bowl. The tolerance is critical and must be adjusted when the pump is new. During the initial break-in period the line shaft couplings will tighten, therefore, after about 100 hours of operation, the impeller adjustments should be checked. After break-in, the tolerance must be checked and adjusted every three to five years or more often if pumping sand.

Column assembly is of two basic types, either of which may be used:

1. Open lineshaft construction utilizes the fluid being pumped to lubricate the lineshaft bearings.
2. Enclosed lineshaft construction has an enclosing tube around the lineshaft and utilizes oil, grease or injected liquid (usually clean water) to lubricate the lineshaft bearings.

Column assembly will consist of:

- 1) column pipe, which connects the bowl assembly to the discharge head,
- 2) shaft, connecting the bowl shaft to the driver and,
- 3) may contain bearings, if required, for the particular unit. Column pipe may be either threaded or flanged.

Note: Some units will not require column assembly, having the bowl assembly connected directly to the discharge head instead.

Bowl Assemblies

The bowl consists of:

- 1) impellers rigidly mounted on the bowl shaft, which rotate and impart energy to the fluid,
- 2) bowls to contain the increased pressure and direct the fluid,
- 3) suction bell or case which directs the fluid into the first impeller, and
- 4) bearings located in the suction bell (or case) and in each bowl.

Both types of impellers may cause inefficient pump operation if they are not properly adjusted. Mechanical damage will result if the semi-open impellers are set too low and the vanes rub against the bottom of the bowls. The adjustment of enclosed impellers is not as critical; however, they must still be checked and adjusted.

Impeller adjustments are made by tightening or loosening a nut on the top of the head assembly. Impeller adjustments are normally made by lowering the impellers to the bottom of the bowls and adjusting them upward. The amount of upward adjustment is determined by how much the line shaft will stretch during pumping. The adjustment must be made based on the lowest possible pumping level in the well. The proper adjustment procedure is often provided by the pump manufacturer.

Basic Operation of a Vertical Turbine

Pre-start

Before starting the pump, the following checks should be made:

1. Rotate the pump shaft by hand to make sure the pump is free and the impellers are correctly positioned.
2. Is the head shaft adjusting nut properly locked into position?
3. Has the driver been properly lubricated in accordance with the instructions furnished with the driver?
4. Has the driver been checked for proper rotation? If not, the pump must be disconnected from the driver before checking. The driver must rotate COUNTER CLOCKWISE when looking down at the top of the driver.
5. Check all connections to the driver and control equipment.
6. Check that all piping connections are tight.
7. Check all anchor bolts for tightness.
8. Check all bolting and tubing connections for tightness (driver mounting bolts, flanged coupling bolts, gland plate bolts, seal piping, etc.).
9. On pumps equipped with stuffing box, make sure the gland nuts are only finger tight — DO NOT TIGHTEN packing gland before starting.
10. On pumps equipped with mechanical seals, clean fluid should be put into the seal chamber. With pumps under suction pressure this can be accomplished by bleeding all air and vapor out of the seal chamber and allowing the fluid to enter. With pumps not under suction pressure, the seal chamber should be flushed liberally with clean fluid to provide initial lubrication. Make sure the mechanical seal is properly adjusted and locked into place.

NOTE: After initial start-up, pre-lubrication of the mechanical seal will usually not be required, as enough liquid will remain in the seal chamber for subsequent start-up lubrication.

11. On pumps equipped with enclosed lineshaft, lubricating liquid must be available and should be allowed to run into the enclosing tube in sufficient quantity to thoroughly lubricate all lineshaft bearings.

Initial Start-Up

1. If the discharge line has a valve in it, it should be partially open for initial starting — Min. 10%.
2. Start lubrication liquid flow on enclosed lineshaft units.
3. Start the pump and observe the operation. If there is any difficulty, excess noise or vibration, stop the pump immediately.
4. Open the discharge valve as desired.
5. Check complete pump and driver for leaks, loose connections or improper operation.
6. If possible, the pump should be left running for approximately ½ hour on the initial start-up. This will allow the bearings, packing or seals, and other parts to “run-in” and reduce the possibility of trouble on future starts.

NOTE: If abrasives or debris are present upon startup, the pump should be allowed to run until the pumpage is clean. Stopping the pump when handling large amounts of abrasives (as sometimes present on initial starting) may lock the pump and cause more damage than if the pump is allowed to continue operation.

CAUTION: Every effort should be made to keep abrasives out of lines, sumps, etc. so that abrasives will not enter the pump.

Stuffing Box Adjustment

On the initial starting it is very important that the packing gland not be tightened too much. New packing must be “run in” properly to prevent damage to the shaft and shortening of the packing life. The stuffing box must be allowed to leak for proper operation. The proper amount of leakage can be determined by checking the temperature of the leakage; this should be cool or just lukewarm — NOT HOT. When adjusting the packing gland, bring both nuts down evenly and in small steps until the leakage is reduced as required. The nuts should only be tightened about ½ turn at a time at 20 to 30 minute intervals to allow the packing to “run in”. Under proper operation, a set of packing will last a long time. Occasionally a new ring of packing will need to be added to keep the box full. After adding two or three rings of packing, or when proper adjustment cannot be achieved, the stuffing box should be cleaned completely of all old packing and re-packed.

Lineshaft Lubrication

Open lineshaft bearings are lubricated by the pumped fluid and on close coupled units (less than 30' long), will usually not require pre or post lubrication. Enclosed lineshaft bearings are lubricated by extraneous liquid (usually oil or clean water), which is fed to the tension nut by either a gravity flow system or pressure injection system. The gravity flow system utilizing oil is the most common arrangement. The oil reservoir must be kept filled with a good quality light turbine oil (about 150 SSU at operating temperature) and adjusted to feed 10 to 12 drops per minute plus one (1) drop per 100' of setting. Injection systems are designed for each installation — injection pressure and quantity of lubricating liquid will vary. Refer to packing slip or separate instruction sheet for requirements when unit is designed for injection lubrication.

General Maintenance Section

A periodic inspection is recommended as the best means of preventing breakdown and keeping maintenance costs to a minimum. Maintenance personnel should look over the whole installation with a critical eye each time the pump is inspected — a change in noise level, amplitude or vibration, or performance can be an indication of impending trouble. Any deviation in performance or operation from what is expected can be traced to some specific cause. Determination of the cause of any misperformance or improper operation is essential to the correction of the trouble — whether the correction is done by the user, the dealer or reported back to the factory. Variances from initial performance will indicate changing system conditions or wear or impending breakdown of unit.

Deep well turbine pumps must have correct alignment between the pump and the power unit. Correct alignment is made easy by using a head assembly that matches the motor and column/pump assembly. It is very important that the well is straight and plumb. The pump column assembly must be vertically aligned so that no part touches the well casing. Spacers are usually attached to the pump column to prevent the pump assembly from touching the well casing. If the pump column does touch the well casing, vibration will wear holes in the casing. A pump column out of vertical alignment may also cause excessive bearing wear.

The head assembly must be mounted on a good foundation at least 12 inches above the ground surface. A foundation of concrete provides a permanent and trouble-free installation. The foundation must be large enough to allow the head assembly to be securely fastened. The foundation should have at least 12 inches of bearing surface on all sides of the well. In the case of a gravel-packed well, the 12-inch clearance is measured from the outside edge of the gravel packing.

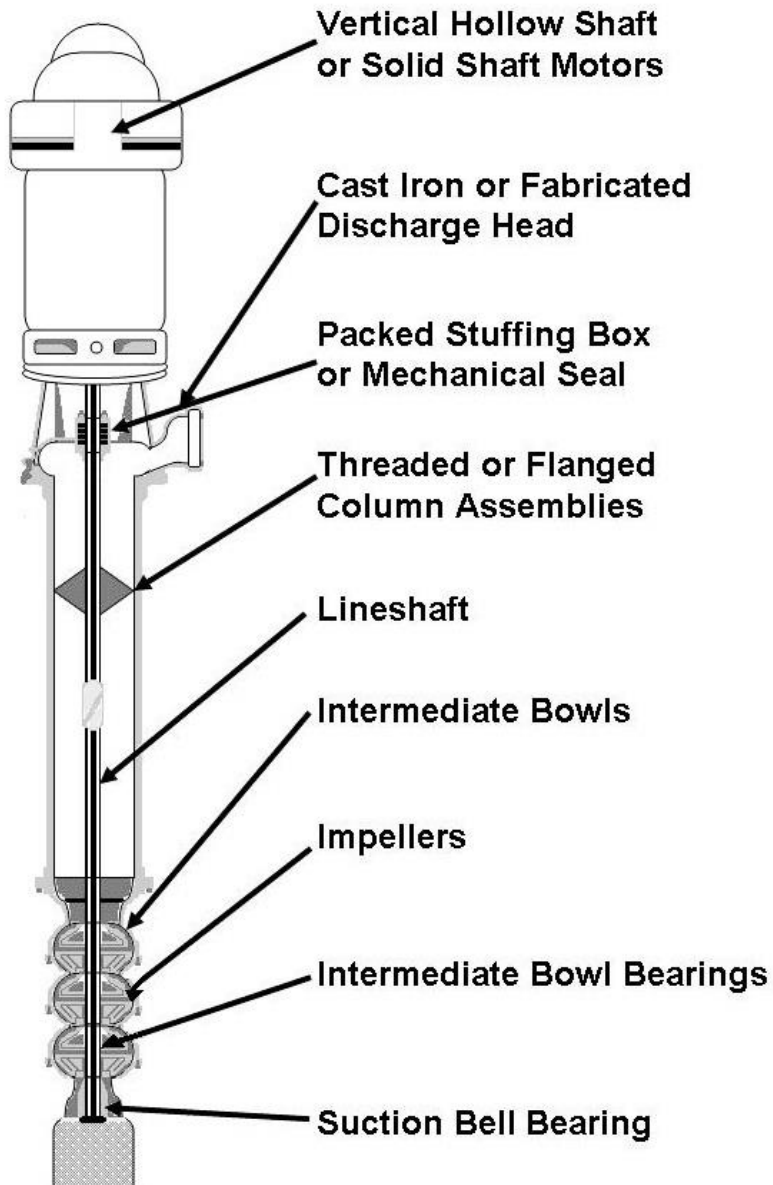
Vertical Turbine Pump



Large Diameter Submersible Pump, Motor, and Column Pipe

Larger check valve installed on submersible pump to prevent water hammer (notice motor shaft splines.)

Common Elements of Vertical Turbines



Closed Pump Impeller

Centrifugal Pump Section

By definition, a centrifugal pump is a machine. More specifically, it is a machine that imparts energy to a fluid. This energy infusion can cause a liquid to flow, rise to a higher level, or both.

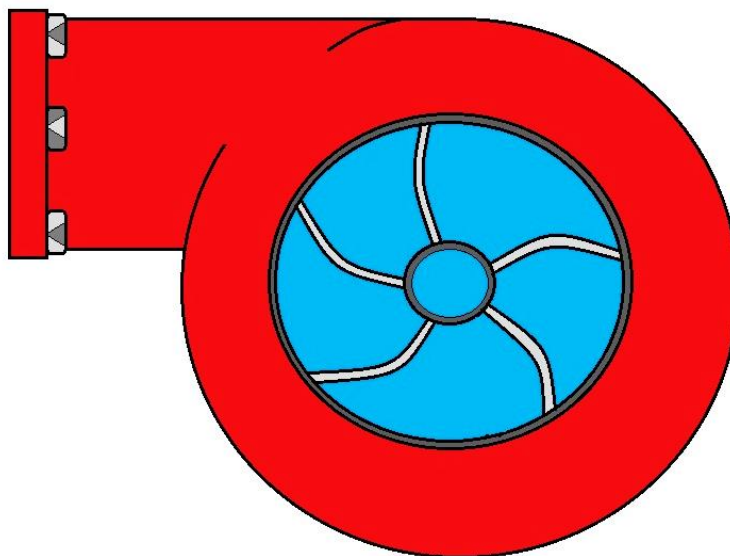
The centrifugal pump is an extremely simple machine. It is a member of a family known as rotary machines and consists of two basic parts: 1) the rotary element or impeller and 2) the stationary element or casing (volute). The figure at the bottom of the page is a cross section of a centrifugal pump and shows the two basic parts.

In operation, a centrifugal pump “slings” liquid out of the impeller via centrifugal force. One fact that must always be remembered: A pump does not create pressure, it only provides flow. Pressure is just an indication of the amount of resistance to flow.

Centrifugal pumps may be classified in several ways. For example, they may be either SINGLE STAGE or MULTI-STAGE. A single-stage pump has only one impeller. A multi-stage pump has two or more impellers housed together in one casing.

BASIC COMPONENTS OF A CENTRIFUGAL PUMP:

- VOLUTE, CASING, BODY
- OR DIFFUSER
- IMPELLER
- OR IMPELLERS
- DRIVER (MOTOR)



BASICS OF A CENTRIFUGAL PUMP

As a rule, each impeller acts separately, discharging to the suction of the next stage impeller. This arrangement is called series staging. Centrifugal pumps are also classified as HORIZONTAL or VERTICAL, depending upon the position of the pump shaft.

The impellers used on centrifugal pumps may be classified as SINGLE SUCTION or DOUBLE SUCTION. The single-suction impeller allows liquid to enter the eye from one side only. The double-suction impeller allows liquid to enter the eye from two directions.

Impellers are also classified as CLOSED or OPEN. Closed impellers have side walls that extend from the eye to the outer edge of the vane tips. Open impellers do not have these side walls. Some small pumps with single-suction impellers have only a casing wearing ring and no impeller ring. In this type of pump, the casing wearing ring is fitted into the end plate.

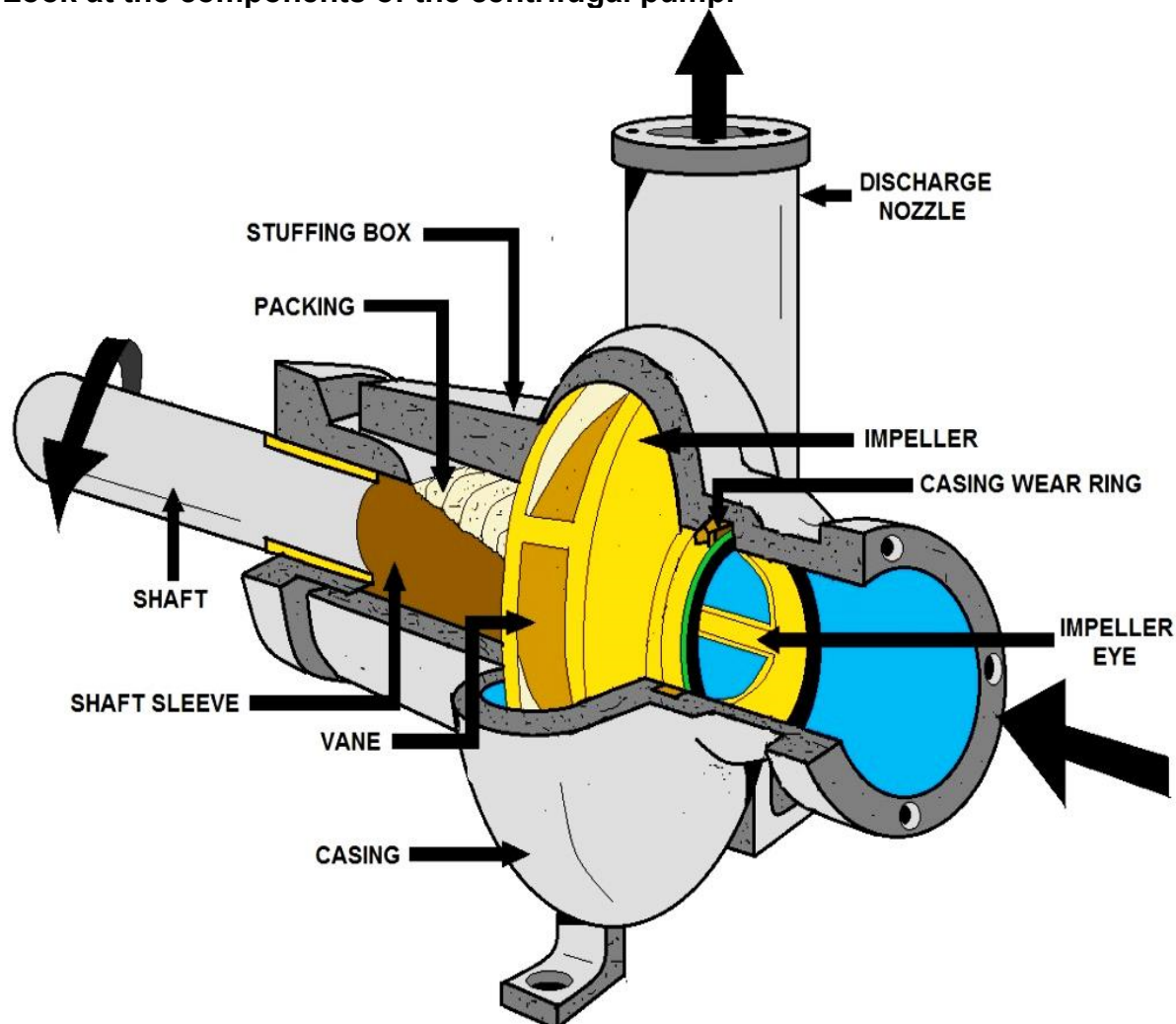
Recirculation lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor bound, in case the discharge is entirely shut off or the flow of fluid is stopped for extended periods.

Seal piping is installed to cool the shaft and the packing, to lubricate the packing, and to seal the rotating joint between the shaft and the packing against air leakage. A lantern ring spacer is inserted between the rings of the packing in the stuffing box.

Seal piping leads the liquid from the discharge side of the pump to the annular space formed by the lantern ring. The web of the ring is perforated so that the water can flow in either direction along the shaft (between the shaft and the packing).

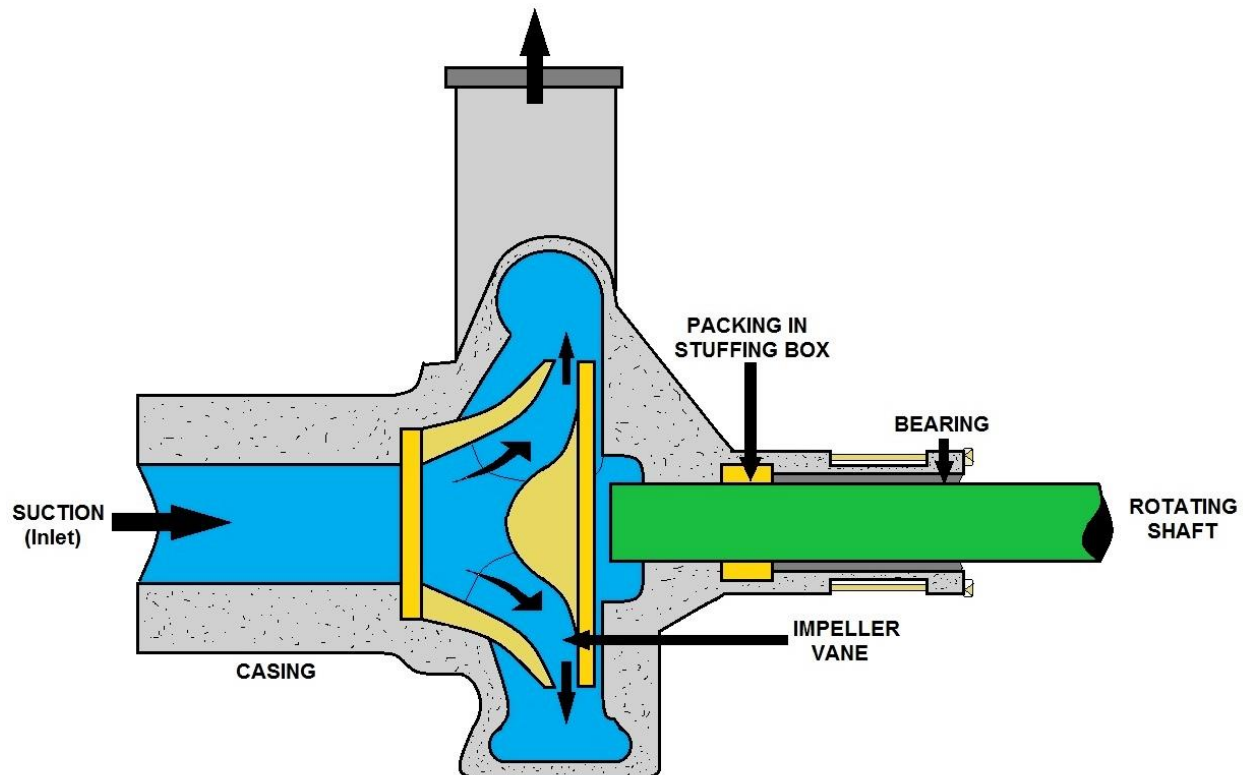
Water flinger rings are fitted on the shaft between the packing gland and the pump bearing housing. These flingers prevent water in the stuffing box from flowing along the shaft and entering the bearing housing.

Look at the components of the centrifugal pump.

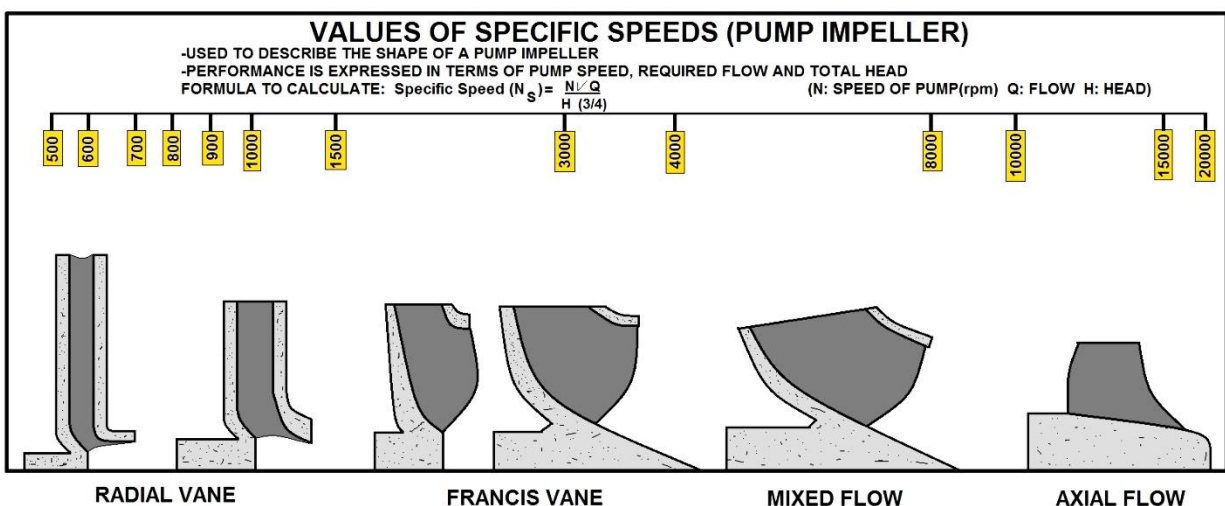


CENTRIFUGAL PUMP PARTS

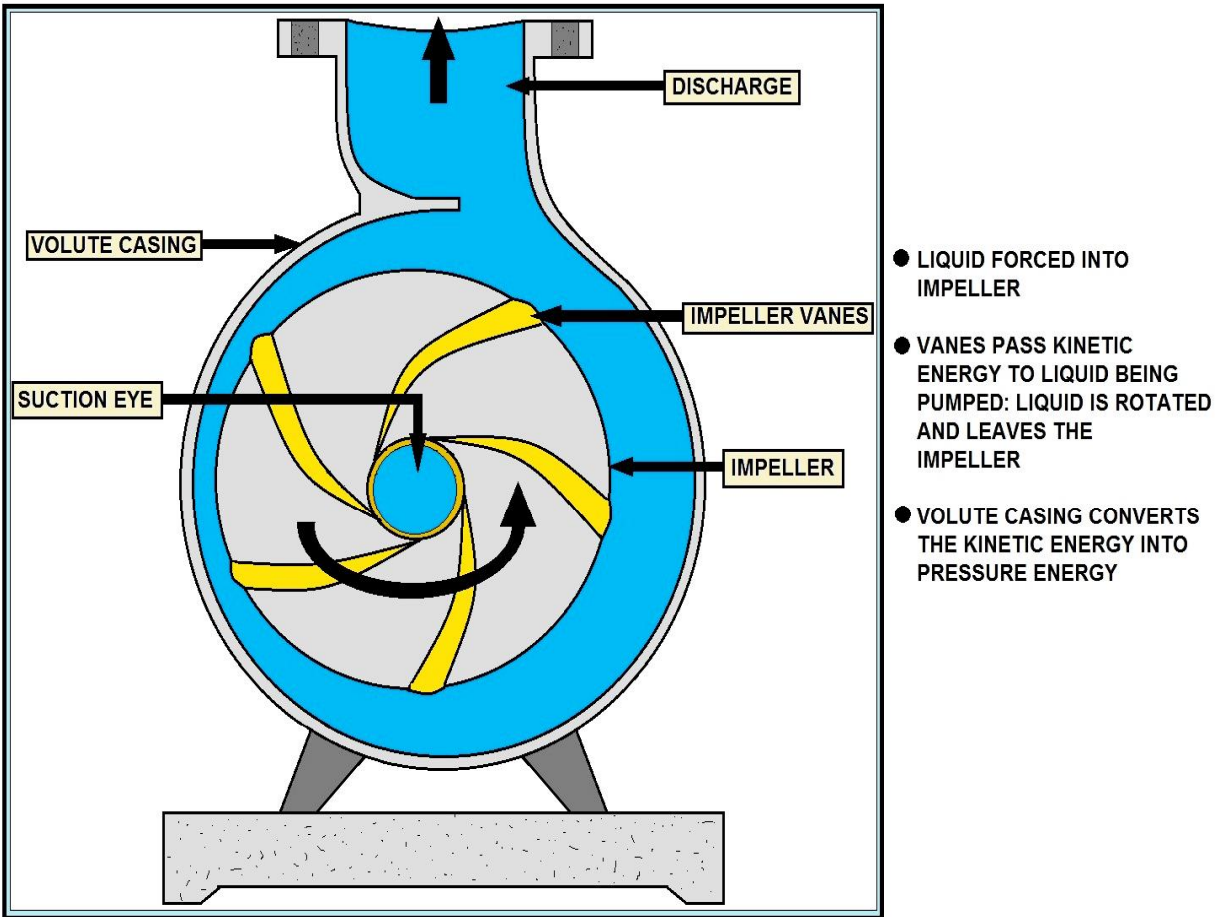
As the impeller rotates, it sucks the liquid into the center of the pump and throws it out under pressure through the outlet. The casing that houses the impeller is referred to as the volute, the impeller fits on the shaft inside. The volute has an inlet and outlet that carries the water as shown below.



CENTRIFUGAL PUMP



SPECIFIC SPEED



HOW A CENTRIFUGAL PUMP WORKS

NPSH - Net Positive Suction Head

If you accept that a pump creates a partial vacuum and atmospheric pressure forces water into the suction of the pump, then you will find NPSH a simple concept.

NPSH (a) is the Net Positive Suction Head Available, which is calculated as follows:

$$\text{NPSH (a)} = p + s - v - f$$

Where:

'p'= atmospheric pressure,

's'= static suction (If liquid is below pump, it is shown as a negative value)

'v'= liquid vapor pressure

'f'= friction loss

NPSH (a) must exceed NPSH(r) to allow pump operation without cavitation. (It is advisable to allow approximately 1 meter difference for most installations.) The other important fact to remember is that water will boil at much less than 100 deg C° if the pressure acting on it is less than its vapor pressure, i.e. water at 95 deg C is just hot water at sea level, but at 1500m above sea level it is boiling water and vapor.

The vapor pressure of water at 95 deg C is 84.53 kPa, there was enough atmospheric pressure at sea level to contain the vapor, but once the atmospheric pressure dropped at the higher elevation, the vapor was able to escape. This is why vapor pressure is always considered in NPSH calculations when temperatures exceed 30 to 40 degrees C.

NPSH(r) is the Net Positive Suction Head Required by the pump, which is read from the pump performance curve. (Think of NPSH(r) as friction loss caused by the entry to the pump suction.)

Affinity Laws

The Centrifugal Pump is a very capable and flexible machine. Because of this it is unnecessary to design a separate pump for each job. The performance of a centrifugal pump can be varied by changing the impeller diameter or its rotational speed. Either change produces approximately the same results. Reducing impeller diameter is probably the most common change and is usually the most economical. The speed can be altered by changing pulley diameters or by changing the speed of the driver. In some cases, both speed and impeller diameter are changed to obtain the desired results.

When the driven speed or impeller diameter of a centrifugal pump changes, operation of the pump changes in accordance with three fundamental laws. These laws are known as the "Laws of Affinity". They state that:

- 1) Capacity varies directly as the change in speed
- 2) Head varies as the square of the change in speed
- 3) Brake horsepower varies as the cube of the change in speed

If, for example, the pump speed were doubled:

- 1) Capacity will double
- 2) Head will increase by a factor of 4 (2 to the second power)
- 3) Brake horsepower will increase by a factor of 8 (2 to the third power)

These principles apply regardless of the direction (up or down) of the speed or change in diameter.

Consider the following example. A pump operating at 1750 RPM, delivers 210 GPM at 75' TDH, and requires 5.2 brake horsepower. What will happen if the speed is increased to 2000 RPM? First we find the speed ratio.

$$\text{Speed Ratio} = 2000/1750 = 1.14$$

From the laws of Affinity:

1) Capacity varies directly or:

$$1.14 \times 210 \text{ GPM} = 240 \text{ GPM}$$

2) Head varies as the square or:

$$1.14 \times 1.14 \times 75 = 97.5' \text{ TDH}$$

3) BHP varies as the cube or:

$$1.14 \times 1.14 \times 1.14 \times 5.2 = 7.72 \text{ BHP}$$

Theoretically the efficiency is the same for both conditions. By calculating several points a new curve can be drawn.

Whether it be a speed change or change in impeller diameter, the Laws of Affinity give results that are approximate. The discrepancy between the calculated values and the actual values obtained in test are due to hydraulic efficiency changes that result from the modification. The Laws of Affinity give reasonably close results when the changes are not more than 50% of the original speed or 15% of the original diameter.

Suction conditions are some of the most important factors affecting centrifugal pump operation. If they are ignored during the design or installation stages of an application, they will probably come back to haunt you.

Suction Lift

A pump cannot pull or "suck" a liquid up its suction pipe because liquids do not exhibit tensile strength. Therefore, they cannot transmit tension or be pulled. When a pump creates a suction, it is simply reducing local pressure by creating a partial vacuum. Atmospheric or some other external pressure acting on the surface of the liquid pushes the liquid up the suction pipe into the pump.

Atmospheric pressure at sea level is called absolute pressure (PSIA) because it is a measurement using absolute zero (a perfect vacuum) as a base. If pressure is measured using atmospheric pressure as a base it is called gauge pressure (PSIG or simply PSI).

Atmospheric pressure, as measured at sea level, is 14.7 PSIA. In feet of head it is:

$$\text{Head} = \text{PSI} \times 2.31 / \text{Specific Gravity}$$

For Water it is:

$$\text{Head} = 14.7 \times 2.31 / 1.0 = 34 \text{ Ft}$$

Thus, 34 feet is the theoretical maximum suction lift for a pump pumping cold water at sea level. No pump can attain a suction lift of 34 ft; however, well designed ones can reach 25 ft quite easily. You will note, from the equation above, that specific gravity can have a major effect on suction lift. For example, the theoretical maximum lift for brine (Specific Gravity = 1.2) at sea level is 28

ft. The realistic maximum is around 20ft. Remember to always factor in specific gravity if the liquid being pumped is anything but clear, cold (68 degrees F) water.

In addition to pump design and suction piping, there are two physical properties of the liquid being pumped that affect suction lift.

1) Maximum suction lift is dependent upon the pressure applied to the surface of the liquid at the suction source. Maximum suction lift decreases as pressure decreases.

2) 2) Maximum suction lift is dependent upon the vapor pressure of the liquid being pumped. The vapor pressure of a liquid is the pressure necessary to keep the liquid from vaporizing (boiling) at a given temperature. Vapor pressure increases as liquid temperature increases. Maximum suction lift decreases as vapor pressure rises.

It follows then, that the maximum suction lift of a centrifugal pump varies inversely with altitude. Conversely, maximum suction lift will increase as the external pressure on its source increases (for example: a closed pressure vessel).

Cavitation - Two Main Causes:

A. NPSH (r) EXCEEDS NPSH (a)

Due to low pressure the water vaporizes (boils), and higher pressure implodes into the vapor bubbles as they pass through the pump, causing reduced performance and potentially major damage.

B. Suction or discharge recirculation. The pump is designed for a certain flow range, if there is not enough or too much flow going through the pump, the resulting turbulence and vortexes can reduce performance and damage the pump.

Affinity Laws - Centrifugal Pumps

If the speed or impeller diameter of a pump changes, we can calculate the resulting performance change using:

Affinity laws

a. The flow changes proportionally to speed

i.e.: double the speed / double the flow

b. The pressure changes by the square of the difference

i.e.: double the speed / multiply the pressure by 4

c. The power changes by the cube of the difference

i.e.: double the speed / multiply the power by 8

Notes:

1. These laws apply to operating points at the same efficiency.

2. Variations in impeller diameter greater than 10% are hard to predict due to the change in relationship between the impeller and the casing. For rough calculations you can adjust a duty point or performance curve to suit a different speed. NPSH (r) is affected by speed / impeller diameter change = **DANGER!**

Pump Casing

There are many variations of centrifugal pumps. The most common type is an end suction pump. Another type of pump used is the split case. There are many variations of split case, such as; two-stage, single suction, and double suction. Most of these pumps are horizontal.

There are variations of vertical centrifugal pumps. The line shaft turbine is really a multistage centrifugal pump.

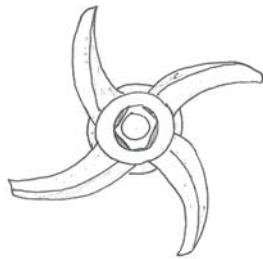
Impeller

In most centrifugal pumps, the impeller looks like a number of cupped vanes on blades mounted on a disc or shaft. Notice in the picture below how the vanes of the impeller force the water into the outlet of the pipe.

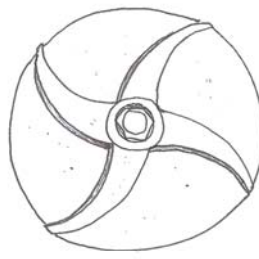
The shape of the vanes of the impeller is important. As the water is being thrown out of the pump, this means you can run centrifugal pumps with the discharged valve closed for a **SHORT** period of time. Remember the motor sends energy along the shaft, and if the water is in the volute too long it will heat up and create steam. Not good!

Impellers are designed in various ways. We will look at:

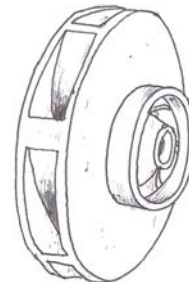
- Closed impellers
- Semi-open impellers
- Opened impellers, and
- Recessed impellers



OPEN



SEMI-OPEN



CLOSED

IMPELLER TYPES

The impellers all cause a flow from the eye of the impeller to the outside of the impeller. These impellers cause what is called radial flow, and they can be referred to as radial flow impellers.

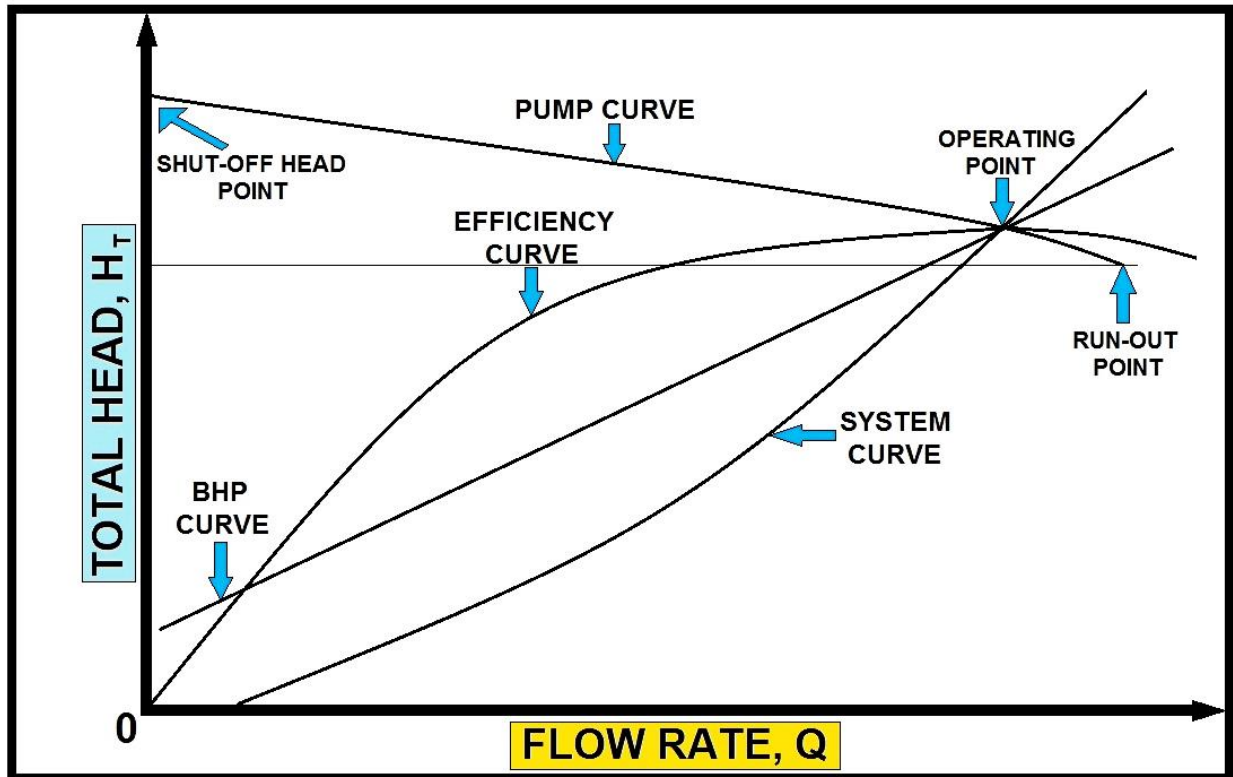
The critical distance of the impeller and how it is installed in the casing will determine if it is high volume / low pressure or the type of liquid that could be pumped.

Axial flow impellers look like a propeller and create a flow that is parallel to the shaft.

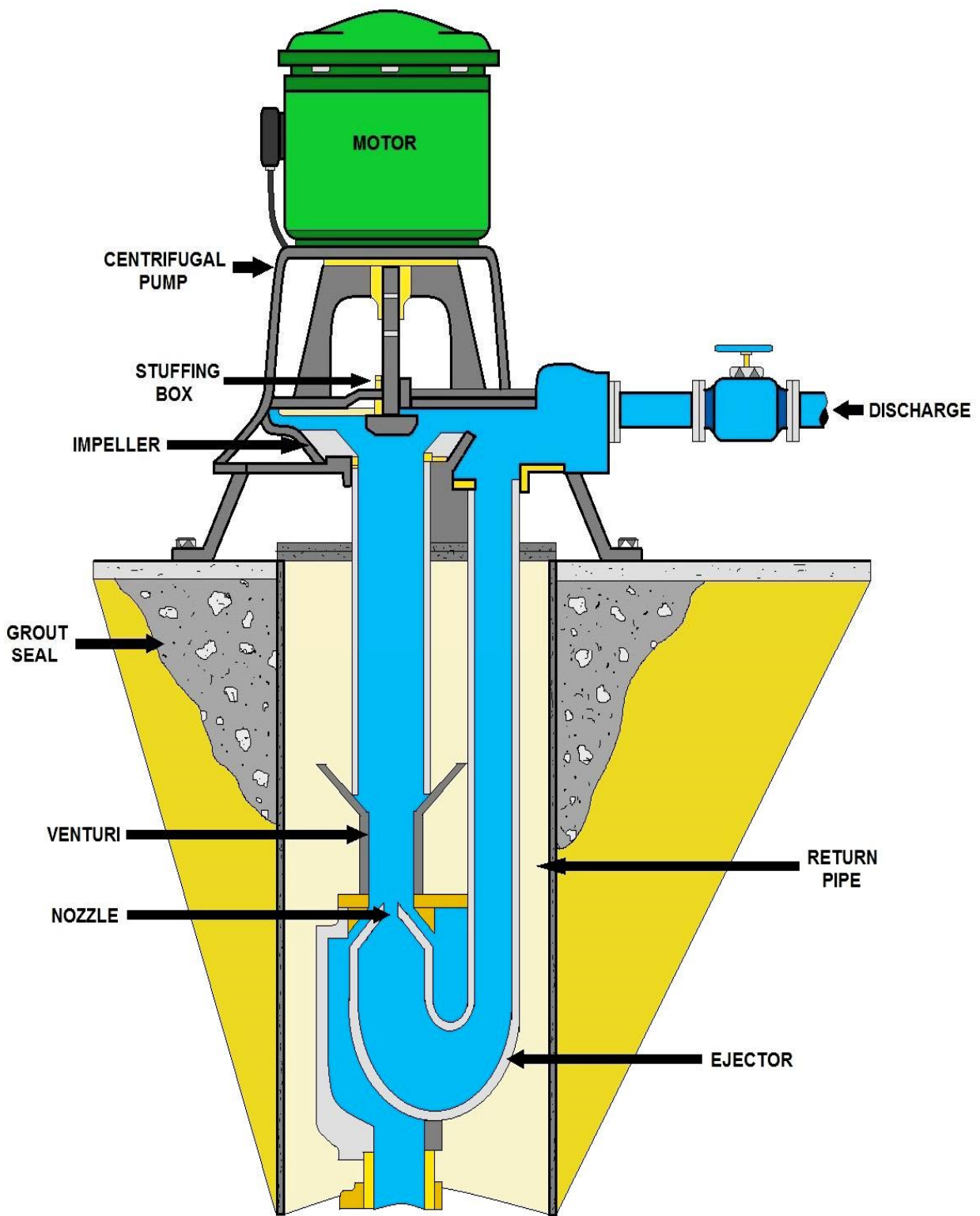
Pump Performance and Curves

Let's look at the big picture. Before you make that purchase of the pump and motor you need to know the basics such as:

- Total dynamic head, the travel distance
- Capacity, how much water you need to provide
- Efficiency, help determine the impeller size
- HP, how many squirrels you need
- RPM, how fast the squirrels run



PUMP PERFORMANCE CURVE (CENTRIFUGAL PUMP)



VERTICAL TURBINE INSTALLATION DIAGRAM

Motor and Pump Calculations

The centrifugal pump pumps the difference between the suction and the discharge heads. There are three kinds of discharge head:

- **Static head.** The height we are pumping to or the height to the discharge piping outlet that is filling the tank from the top. Note: that if you are filling the tank from the bottom, the static head will be constantly changing.
- **Pressure head.** If we are pumping to a pressurized vessel (like a boiler) we must convert the pressure units (psi. or Kg.) to head units (feet or meters).
- **System or dynamic head.** Caused by friction in the pipes, fittings, and system components. We get this number by making the calculations from published charts.

Suction head is measured the same way.

- If the liquid level is above the pump center line, that level is a positive suction head. If the pump is lifting a liquid level from below its center line, it is a negative suction head.
- If the pump is pumping liquid from a pressurized vessel, you must convert this pressure to a positive suction head. A vacuum in the tank would be converted to a negative suction head.
- Friction in the pipes, fittings, and associated hardware is a negative suction head.
- Negative suction heads are added to the pump discharge head, positive suction heads are subtracted from the pump discharge head.

Total Dynamic Head (TDH) is the total height that a fluid is to be pumped, taking into account friction losses in the pipe.

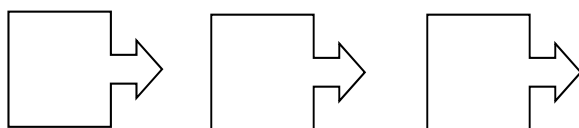
$$\text{TDH} = \text{Static Lift} + \text{Static Height} + \text{Friction Loss}$$

where:

Static Lift is the height the water will rise before arriving at the pump (also known as the 'suction head').

Static Height is the maximum height reached by the pipe after the pump (also known as the 'discharge head').

Friction Loss is the head equivalent to the energy losses due to viscous drag of fluid flowing in the pipe (both on the suction and discharge sides of the pump). It is calculated via a formula or a chart, taking into account the pipe diameter and roughness and the fluid flow rate, density, and viscosity.



Motor hp

Brake hp

Water hp

Horsepower

Work involves the operation of force over a specific distance. The rate of doing work is called power.

The rate in which a horse could work was determined to be about 550 ft-lbs/sec or 33,000 ft-lbs/min.

$$1 \text{ hp} = 33,000 \text{ ft-lbs/min}$$

Motor Horsepower (mhp)

$$1 \text{ hp} = 746 \text{ watts or } .746 \text{ Kilowatts}$$

MHP refers to the horsepower supplied in the form of electrical current. The efficiency of most motors range from 80-95%. (Manufactures will list efficiency %)

Brake Horsepower (bhp)

$$\text{Brake hp} = \frac{\text{Water hp}}{\text{Pump Efficiency}}$$

BHP refers to the horsepower supplied to the pump from the motor. As the power moves through the pump, additional horsepower is lost, resulting from slippage and friction of the shaft and other factors.

Water Horsepower

$$\text{Water hp} = \frac{(\text{flow gpm})(\text{total hd})}{3960}$$

Water horsepower refers to the actual horse power available to pump the water.

Horsepower and Specific Gravity

The specific gravity of a liquid is an indication of its density or weight compared to water. The difference in specific gravity, include it when calculating ft-lbs/min pumping requirements.

$$\frac{(\text{ft})(\text{lbs/min})(\text{sp.gr.})}{33,000 \text{ ft-lbs/min/hp}} = \text{whp}$$

MHP and Kilowatt requirements

$$1 \text{ hp} = 0.746 \text{ kW or } \frac{(\text{hp}) (746 \text{ watts/hp})}{1000 \text{ watts/kW}}$$

Well Calculations

1. Well drawdown

Drawdown ft = Pumping water level, ft - Static water level, ft

2. Well yield

Well yield, gpm = $\frac{\text{Flow, gallons}}{\text{Duration of test, min}}$

3. Specific yield

Specific yield, gpm/ft = $\frac{\text{Well yield, gpm}}{\text{Drawdown, ft}}$

4. Deep well turbine pump calculations.

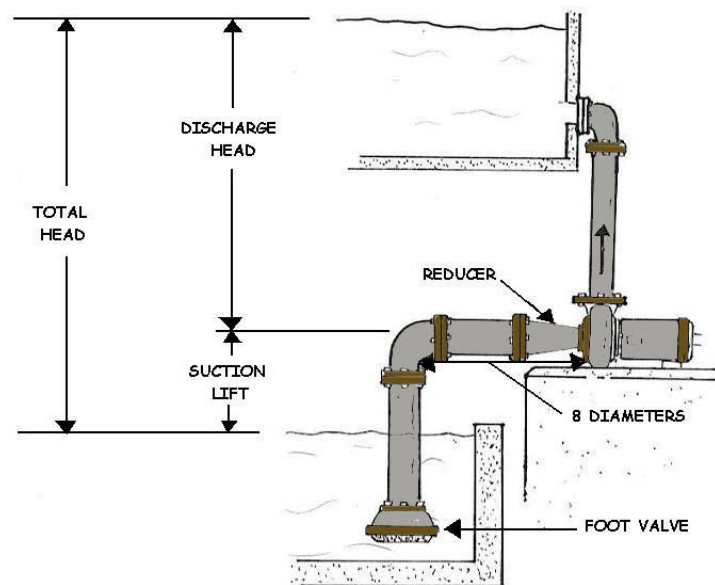
Discharge head, ft = (pressure measured) (2.31 ft/psi)

Field head, ft = pumping water + discharge head, ft

Bowl head, ft = field head + column friction

1 psi = 2.31 feet of head

1 foot of head = .433 psi



Example 1

A centrifugal pump is located at an elevation of 722 ft. This pump is used to move water from reservoir **A** to reservoir **B**. The water level in reservoir **A** is 742 ft and the water level in reservoir **B** is 927 ft. Based on these conditions answer the following questions:

- 1. If the pump is not running and pressure gauges are installed on the suction and discharge lines, what pressures would the gauges read?**

Suction side:

Discharge side:

- 2. How can you tell if this is a suction head condition?**

- 3. Calculate the following head measurements:**

SSH:

SDH:

TSH:

- 4. Convert the pressure gauge readings to feet:**

6 psi:

48 psi:

110 psi:

- 5. Calculate the following head in feet to psi:**

20 ft:

205 ft:

185 ft:

Motor Section

We will now refer to the motor, coupling, and bearings. The power source of the pump is usually an electric motor. The motor is connected by a coupling to the pump shaft. The purpose of the bearings is to hold the shaft firmly in place, yet allow it to rotate. The bearing house supports the bearings and provides a reservoir for the lubricant. An impeller is connected to the shaft. The pump assembly can be a vertical or horizontal set-up; the components for both are basically the same.

Motors

The purpose of this discussion on pump motors is to identify and describe the main types of motors, starters, enclosures, and motor controls, as well as to provide you with some basic maintenance and troubleshooting information. Although pumps could be driven by diesel or gasoline engines, pumps driven by electric motors are commonly used in our industry.

There are two general categories of electric motors:

- ✱ D-C motors, or direct current
- ✱ A-C motors, or alternating current

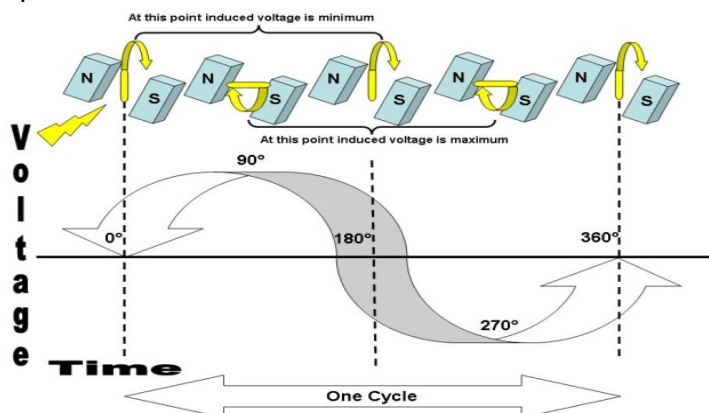
You can expect most motors at facilities to be A-C type.

D-C Motors

The important characteristic of the D-C motor is that its speed will vary with the amount of current used. There are many different kinds of D-C motors, depending on how they are wound and their speed/torque characteristics.

A-C Motors

There are a number of different types of alternating current motors, such as Synchronous, Induction, wound rotor, and squirrel cage. The synchronous type of A-C motor requires complex control equipment, since they use a combination of A-C and D-C. This also means that the synchronous type of A-C motor is used in large horsepower sizes, usually above 250 HP. The induction type motor uses only alternating current. The squirrel cage motor provides a relatively constant speed. The wound rotor type could be used as a variable speed motor.



Define the Following Terms:

Voltage:

EMF:

Power:

Current:

Resistance:

Conductor:

Phase:

Single Phase:

Three Phase:

Hertz:

Motor Starters

All electric motors, except very small ones such as chemical feed pumps, are equipped with starters, either full voltage or reduced voltage. This is because motors draw a much higher current when they are starting and gaining speed. The purpose of the reduced voltage starter is to prevent the load from coming on until the amperage is low enough.

How do you think keeping the discharge valve closed on a centrifugal pump could reduce the start-up load?

Motor Enclosures

Depending on the application, motors may need special protection. Some motors are referred to as open motors. They allow air to pass through to remove heat generated when current passes through the windings. Other motors use specific enclosures for special environments or safety protection.



Can you think of any locations within your facility that requires special enclosures?

Two Types of Totally Enclosed Motors Commonly Used are:

- ☞ **TENV**, or totally enclosed non-ventilated motor
- ☞ **TEFC**, or totally enclosed fan cooled motor

Totally enclosed motors include dust-proof, water-proof and explosion-proof motors. An explosion proof enclosure must be provided on any motor where dangerous gases might accumulate.

Motor Controls

All pump motors are provided with some method of control, typically a combination of manual and automatic. Manual pump controls can be located at the central control panel at the pump or at the suction or discharge points of the liquid being pumped.

There are a number of ways in which automatic control of a pump motor can be regulated:

- ☞ Pressure and vacuum sensors
- ☞ Preset time intervals
- ☞ Flow sensors
- ☞ Level sensors

Two typical level sensors are the float sensor and the bubble regulator. The float sensor is pear-shaped and hangs in the wet well. As the height increases, the float tilts, and the mercury in the glass tube flows toward the end of the tube that has two wires attached to it. When the mercury covers the wires, it closes the circuit.



A low pressure air supply is allowed to escape from a bubbler pipe in the wet well. The back-pressure on the air supply will vary with the liquid level over the pipe. Sensitive air pressure switches will detect this change and use this information to control pump operation.

Motor Maintenance

Motors should be kept clean, free of moisture, and lubricated properly. Dirt, dust, and grime will plug the ventilating spaces and can actually form an insulating layer over the metal surface of the motor.

What condition would occur if the ventilation becomes blocked?



Moisture

Moisture harms the insulation on the windings to the point where they may no longer provide the required insulation for the voltage applied to the motor. In addition, moisture on windings tend to absorb acid and alkali fumes, causing damage to both insulation and metals. To reduce problems caused by moisture, the most suitable motor enclosure for the existing environment will normally be used. It is recommended to run stand by motors to dry up any condensation which accumulates in the motor.

Motor Lubrication

Friction will cause wear in all moving parts, and lubrication is needed to reduce this friction. It is very important that all your manufacturer's recommended lubrication procedures are strictly followed. You have to be careful not to add too much grease or oil, as this could cause more friction and generate heat.

To grease the motor bearings, this is the usual approach:

1. Remove the protective plugs and caps from the grease inlet and relief holes.
2. Pump grease in until fresh starts coming from the relief hole.

If fresh grease does not come out of the relief hole, this could mean that the grease has been pumped into the motor windings. The motor must then be taken apart and cleaned by a qualified service representative.

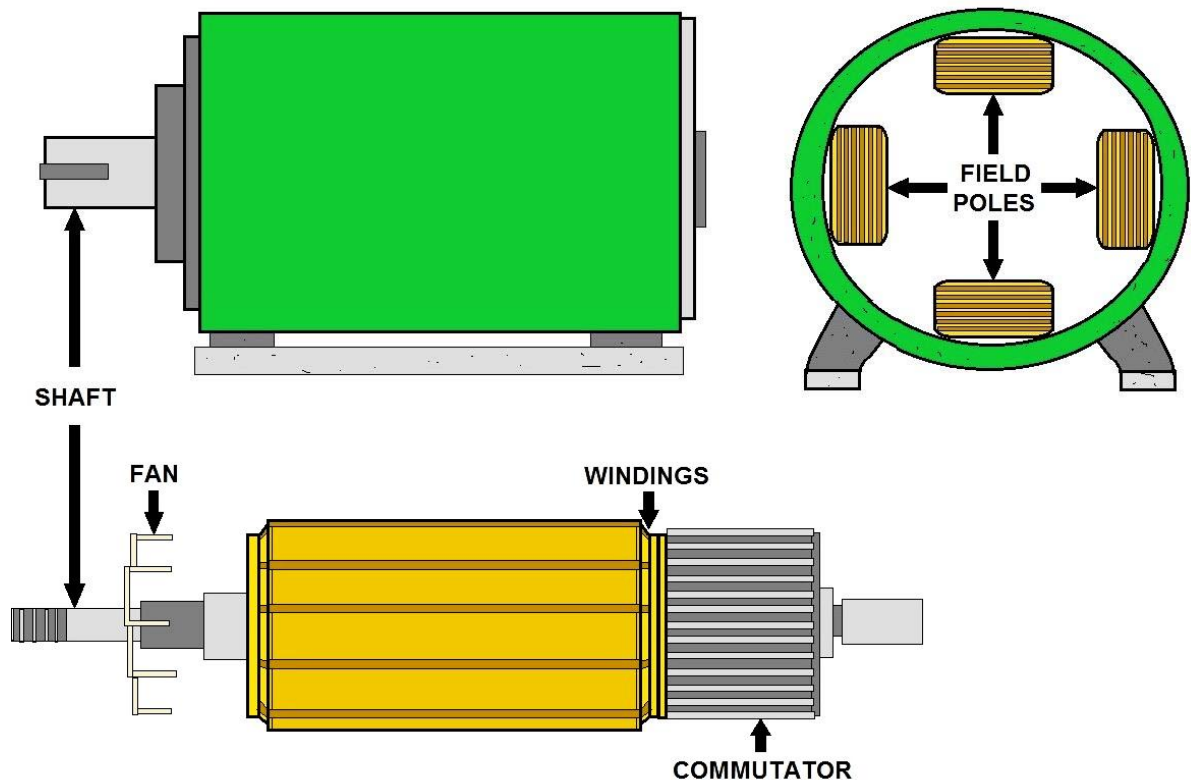
To change the oil in an oil lubricated motor, this is the usual approach:

1. Remove all plugs and let the oil drain.
2. Check for metal shearing.
3. Replace the oil drain.
4. Add new oil until it is up to the oil level plug.
5. Replace the oil level and filter plug.

Never mix oils, since the additives of different oils when combined can cause breakdown of the oil.



More Detailed Information on Motors



DC ELECTRIC MOTOR DIAGRAM

The classic division of electric motors has been that of Direct Current (DC) types vs. Alternating Current (AC) types. This is more a de facto convention, rather than a rigid distinction. For example, many classic DC motors run happily on AC power.

The ongoing trend toward electronic control further muddles the distinction, as modern drivers have moved the commutator out of the motor shell. For this new breed of motor, driver circuits are relied upon to generate sinusoidal AC drive currents, or some approximation of. The two best examples are: the brushless DC motor and the stepping motor, both being polyphase AC motors requiring external electronic control.

There is a clearer distinction between a synchronous motor and asynchronous types. In the synchronous types, the rotor rotates in synchrony with the oscillating field or current (e.g. permanent magnet motors). In contrast, an asynchronous motor is designed to slip; the most ubiquitous example being the common AC induction motor which must slip in order to generate torque.

A DC motor is designed to run on DC electric power. Two examples of pure DC designs are Michael Faraday's homopolar motor (which is uncommon), and the ball bearing motor, which is (so far) a novelty. By far the most common DC motor types are the brushed and brushless types, which use internal and external commutation respectively to create an oscillating AC current from the DC source -- so they are not purely DC machines in a strict sense.

Brushed DC motors

The classic DC motor design generates an oscillating current in a wound rotor with a split ring commutator, and either a wound or permanent magnet stator. A rotor consists of a coil wound around a rotor, which is then powered by any type of battery. Many of the limitations of the classic commutator DC motor are due to the need for brushes to press against the commutator. This creates friction. At higher speeds, brushes have increasing difficulty in maintaining contact. Brushes may bounce off the irregularities in the commutator surface, creating sparks. This limits the maximum speed of the machine.

The current density per unit area of the brushes limits the output of the motor. The imperfect electric contact also causes electrical noise. Brushes eventually wear out and require replacement, and the commutator itself is subject to wear and maintenance. The commutator assembly on a large machine is a costly element, requiring precision assembly of many parts.

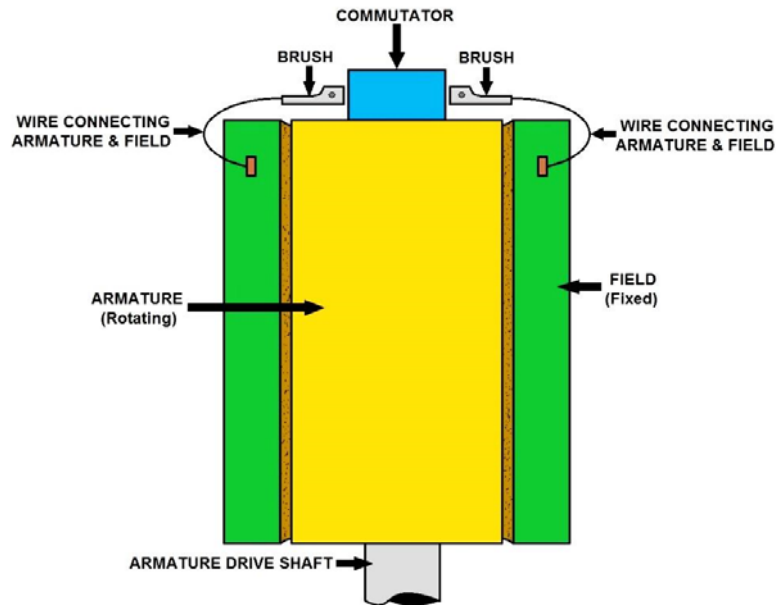


DIAGRAM SHOWING MECHANICAL CONSTRUCTION
OF A DC SERIES WOUND MOTOR

Brushless DC motors

Some of the problems of the brushed DC motor are eliminated in the brushless design. In this motor, the mechanical "rotating switch" or commutator/brush gear assembly is replaced by an external electronic switch synchronized to the rotor's position. Brushless motors are typically 85-90% efficient, whereas DC motors with brush gear are typically 75-80% efficient.

Midway between ordinary DC motors and stepper motors lies the realm of the brushless DC motor. Built in a fashion very similar to stepper motors, these often use a permanent magnet external rotor, three phases of driving coils, one or more Hall Effect sensors to sense the position of the rotor, and the associated drive electronics.

The coils are activated one phase after the other by the drive electronics, as cued by the signals from the Hall Effect sensors. In effect, they act as three-phase synchronous motors containing their own variable-frequency drive electronics. Brushless DC motors are commonly used where precise speed control is necessary, as in computer disk drives or in video cassette recorders, the spindles within CD, CD-ROM (etc.) drives, and mechanisms within office products such as fans, laser printers, and photocopiers.

They have several advantages over conventional motors:

- * Compared to AC fans using shaded-pole motors, they are very efficient, running much cooler than the equivalent AC motors. This cool operation leads to much-improved life of the fan's bearings.
- * Without a commutator to wear out, the life of a DC brushless motor can be significantly longer compared to a DC motor using brushes and a commutator. Commutation also tends to cause a great deal of electrical and RF noise; without a commutator or brushes, a brushless motor may be used in electrically sensitive devices like audio equipment or computers.
- * The same Hall Effect sensors that provide the commutation can also provide a convenient tachometer signal for closed-loop control (servo-controlled) applications. In fans, the tachometer signal can be used to derive a "fan OK" signal.
- * The motor can be easily synchronized to an internal or external clock, leading to precise speed control.
- * Brushless motors have no chance of sparking, unlike brushed motors, making them better suited to environments with volatile chemicals and fuels.
- * Brushless motors are usually used in small equipment such as computers, and are generally used to get rid of unwanted heat.
- * They are also very quiet motors, which is an advantage if being used in equipment that is affected by vibrations.

Modern DC brushless motors range in power from a fraction of a watt to many kilowatts. Larger brushless motors up to about 100 kW rating are used in electric vehicles. They also find significant use in high-performance electric model aircraft.

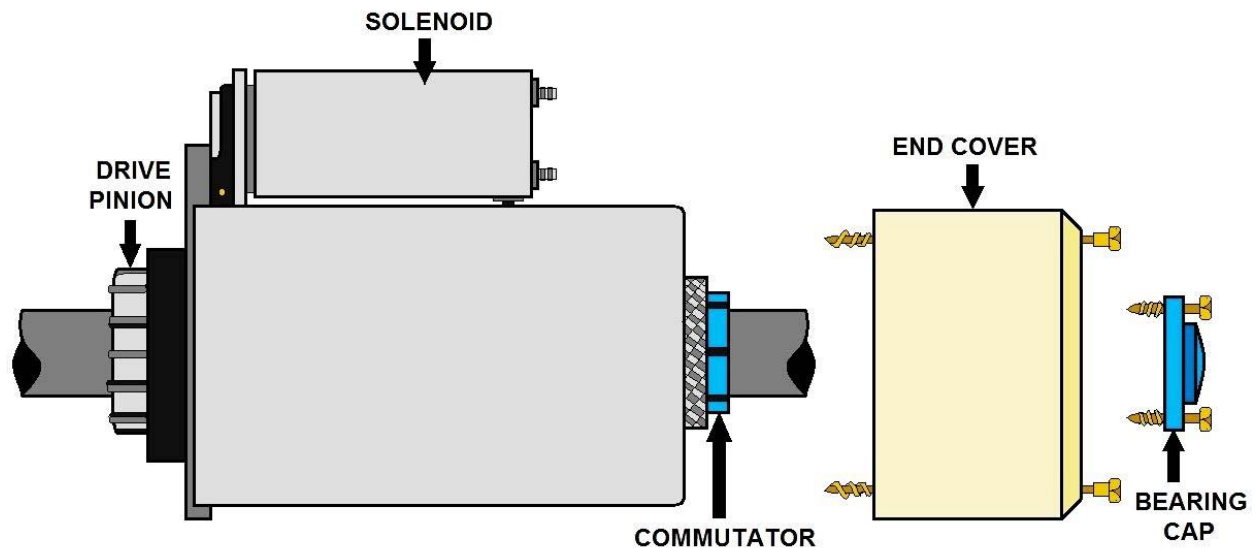
Coreless DC Motors

Nothing in the design of any of the motors described above requires that the iron (steel) portions of the rotor actually rotate; torque is exerted only on the windings of the electromagnets. Taking advantage of this fact is the coreless DC motor, a specialized form of a brush or brushless DC motor. Optimized for rapid acceleration, these motors have a rotor that is constructed without any iron core.

The rotor can take the form of a winding-filled cylinder inside the stator magnets, a basket surrounding the stator magnets, or a flat pancake (possibly formed on a printed wiring board) running between upper and lower stator magnets. The windings are typically stabilized by being impregnated with electrical epoxy potting systems. Filled epoxies that have moderate mixed viscosity and a long gel time. These systems are highlighted by low shrinkage and low exotherm.

Because the rotor is much lighter in weight (mass) than a conventional rotor formed from copper windings on steel laminations, the rotor can accelerate much more rapidly, often achieving a mechanical time constant under 1 ms. This is especially true if the windings use aluminum rather than the heavier copper. But because there is no metal mass in the rotor to act as a heat sink, even small coreless motors must often be cooled by forced air.

These motors were commonly used to drive the capstan(s) of magnetic tape drives and are still widely used in high-performance servo-controlled systems, like radio-controlled vehicles/aircraft, humanoid robotic systems, industrial automation, medical devices, etc.



STARTER MOTOR

Universal Motors

A variant of the wound field DC motor is the universal motor. The name derives from the fact that it may use AC or DC supply current, although in practice they are nearly always used with AC supplies. The principle is that in a wound field DC motor the current in both the field and the armature (and hence the resultant magnetic fields) will alternate (reverse polarity) at the same time, and hence the mechanical force generated is always in the same direction.

In practice, the motor must be specially designed to cope with the AC current (impedance must be taken into account, as must the pulsating force), and the resultant motor is generally less efficient than an equivalent pure DC motor.

Operating at normal power line frequencies, the maximum output of universal motors is limited and motors exceeding one kilowatt are rare. But universal motors also form the basis of the traditional railway traction motor in electric railways. In this application, to keep their electrical efficiency high, they were operated from very low frequency AC supplies, with 25 Hz and 16 2/3 hertz operation being common. Because they are universal motors, locomotives using this design were also commonly capable of operating from a third rail powered by DC.

The advantage of the universal motor is that AC supplies may be used on motors which have the typical characteristics of DC motors, specifically high starting torque and very compact design if high running speeds are used. The negative aspect is the maintenance and short life problems caused by the commutator. As a result, such motors are usually used in AC devices such as food mixers and power tools, which are used only intermittently.

Continuous speed control of a universal motor running on AC is very easily accomplished using a thyristor circuit, while stepped speed control can be accomplished using multiple taps on the field coil. Household blenders that advertise many speeds frequently combine a field coil with several taps and a diode that can be inserted in series with the motor (causing the motor to run on half-wave rectified AC).

Universal motors can rotate at relatively high revolutions per minute (rpm). This makes them useful for appliances such as blenders, vacuum cleaners, and hair dryers where high-speed operation is desired. Many vacuum cleaner and weed trimmer motors exceed 10,000 rpm; Dremel and other similar miniature grinders will often exceed 30,000 rpm. Motor damage may occur due to overspeed (rpm in excess of design specifications) if the unit is operated with no significant load.

On larger motors, sudden loss of load is to be avoided, and the possibility of such an occurrence is incorporated into the motor's protection and control schemes. Often, a small fan blade attached to the armature acts as an artificial load to limit the motor speed to a safe value, as well as provide cooling airflow to the armature and field windings.

With the very low cost of semiconductor rectifiers, some applications that would have previously used a universal motor now use a pure DC motor, sometimes with a permanent magnet field.

AC Motors

In 1882, Nicola Tesla identified the rotating magnetic field principle, and pioneered the use of a rotary field of force to operate machines. He exploited the principle to design a unique two-phase induction motor in 1883. In 1885, Galileo Ferraris independently researched the concept. In 1888, Ferraris published his research in a paper to the Royal Academy of Sciences in Turin.

Introduction of Tesla's motor from 1888 onwards initiated what is sometimes referred to as the Second Industrial Revolution, making possible the efficient generation and long distance distribution of electrical energy using the alternating current transmission system, also of Tesla's invention (1888). Before the invention of the rotating magnetic field, motors operated by continually passing a conductor through a stationary magnetic field (as in homopolar motors). Tesla had suggested that the commutators from a machine could be removed and the device could operate on a rotary field of force. Professor Poeschel, his teacher, stated that would be akin to building a perpetual motion machine.

Components

A typical AC motor consists of two parts:

1. An outside stationary stator having coils supplied with AC current to produce a rotating magnetic field, and;
2. An inside rotor attached to the output shaft that is given a torque by the rotating field.

Torque Motors

A torque motor is a specialized form of induction motor which is capable of operating indefinitely at stall (with the rotor blocked from turning) without damage. In this mode, the motor will apply a steady stall torque to the load (hence the name).

A common application of a torque motor would be the supply- and take-up reel motors in a tape drive. In this application, driven from a low voltage, the characteristics of these motors allow a relatively-constant light tension to be applied to the tape whether or not the capstan is feeding tape past the tape heads.

Driven from a higher voltage, (and so delivering a higher torque), the torque motors can also achieve fast-forward and rewind operation without requiring any additional mechanics such as gears or clutches. In the computer world, torque motors are used with force feedback steering wheels.

Slip Ring

The slip ring or wound rotor motor is an induction machine where the rotor comprises a set of coils that are terminated in slip rings to which external impedances can be connected. The stator is the same as is used with a standard squirrel cage motor. By changing the impedance connected to the rotor circuit, the speed/current and speed/torque curves can be altered.

The slip ring motor is used primarily to start a high inertia load or a load that requires a very high starting torque across the full speed range. By correctly selecting the resistors used in the secondary resistance or slip ring starter, the motor is able to produce maximum torque at a relatively low current from zero speed to full speed. A secondary use of the slip ring motor is to provide a means of speed control.

Because the torque curve of the motor is effectively modified by the resistance connected to the rotor circuit, the speed of the motor can be altered. Increasing the value of resistance on the rotor circuit will move the speed of maximum torque down. If the resistance connected to the rotor is increased beyond the point where the maximum torque occurs at zero speed, the torque will be further reduced. When used with a load that has a torque curve that increases with speed, the motor will operate at the speed where the torque developed by the motor is equal to the load torque. Reducing the load will cause the motor to speed up, and increasing the load will cause the motor to slow down until the load and motor torque are equal. Operated in this manner, the slip losses are dissipated in the secondary resistors and can be very significant. The speed regulation is also very poor.

Stepper Motors

Closely related in design to three-phase AC synchronous motors are stepper motors, where an internal rotor containing permanent magnets or a large iron core with salient poles is controlled by a set of external magnets that are switched electronically. A stepper motor may also be thought of as a cross between a DC electric motor and a solenoid. As each coil is energized in turn, the rotor aligns itself with the magnetic field produced by the energized field winding. Unlike a synchronous motor, in its application, the motor may not rotate continuously; instead, it "steps" from one position to the next as field windings are energized and de-energized in sequence. Depending on the sequence, the rotor may turn forwards or backwards.

Simple stepper motor drivers entirely energize or entirely de-energize the field windings, leading the rotor to "cog" to a limited number of positions; more sophisticated drivers can proportionally control the power to the field windings, allowing the rotors to position between the cog points and thereby rotate extremely smoothly. Computer controlled stepper motors are one of the most versatile forms of positioning systems, particularly when part of a digital servo-controlled system.

Stepper motors can be rotated to a specific angle with ease, and hence stepper motors are used in pre-gigabyte era computer disk drives, where the precision they offered was adequate for the correct positioning of the read/write head of a hard disk drive. As drive density increased, the precision limitations of stepper motors made them obsolete for hard drives, thus newer hard disk drives use read/write head control systems based on voice coils. Stepper motors were up-scaled to be used in electric vehicles under the term SRM (switched reluctance machine).

Coupling Section

The pump coupling serves two main purposes:

- It couples or joins the two shafts together to transfer the rotation from motor to impeller.
- It compensates for small amounts of misalignment between the pump and the motor.

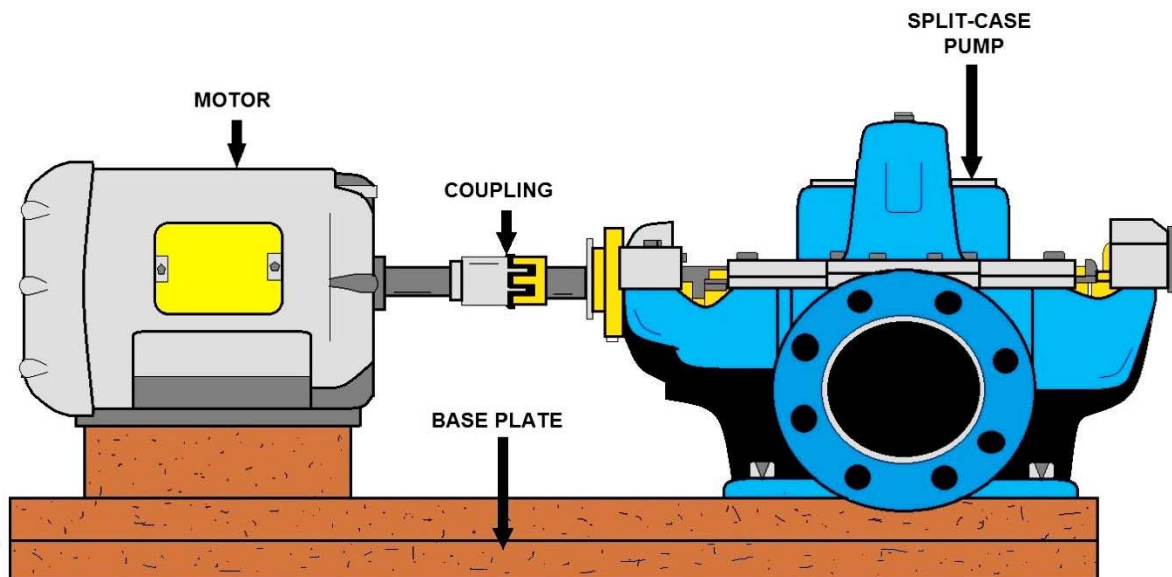
Remember that any coupling is a device in motion. If you have a 4-inch diameter coupling rotating at 1800 rpm, its outer surface is traveling about 20 mph. With that in mind, can you think of safety considerations?

There are three commonly used types of couplings: ***Rigid, Flexible and V-belts.***

Rigid Coupling

Rigid couplings are most commonly used on vertically mounted pumps. The rigid coupling is usually specially keyed or constructed for joining the coupling to the motor shaft and the pump shaft. There are two types of rigid couplings: the flanged coupling, and the split coupling.

Flexible Coupling. The flexible coupling provides the ability to compensate for small shaft misalignments. Shafts should be aligned as close as possible, regardless. The greater the misalignment, the shorter the life of the coupling. Bearing wear and life are also affected by misalignment.



CLOSED COUPLED PUMP

Alignment of Flexible and Rigid Couplings

Both flexible and rigid couplings must be carefully aligned before they are connected. Misalignment will cause excessive heat and vibration, as well as bearing wear. Usually, the noise from the coupling will warn you of shaft misalignment problems.

Three types of shaft alignment problems are shown in the pictures below:



Different couplings will require different alignment procedures. We will look at the general procedures for aligning shafts.

1. Place the coupling on each shaft.
2. Arrange the units so they appear to be aligned. (Place shims under the legs of one of the units to raise it.)
3. Check the run-out, or difference between the driver and driven unit, by rotating the shafts by hand.
4. Turn both units so that the maximum run-out is on top.

Now you can check the units for both parallel and angular alignment. Many techniques are used, such as: straight edge, needle deflection (dial indicators), calipers, tapered wedges, and laser alignment.

V-Belt Drive Couplings

V-belt drives connect the pump to the motor. A pulley is mounted on the pump and motor shaft. One or more belts are used to connect the two pulleys. Sometimes a separately mounted third pulley is used. This idler pulley is located off centerline between the two pulleys, just enough to allow tensioning of the belts by moving the idler pulley. An advantage of driving a pump with belts is that various speed ratios can be achieved between the motor and the pump.

Shaft Bearings

There are three types of bearings commonly used: ball bearings, roller bearings, and sleeve bearings. Regardless of the particular type of bearings used within a system--whether it is ball bearings, a sleeve bearing, or a roller bearing--the bearings are designed to carry the loads imposed on the shaft.

Bearings must be lubricated. Without proper lubrication, bearings will overheat and seize.

Proper lubrication means using the correct type and the correct amount of lubrication. Similar to motor bearings, shaft bearings can be lubricated either by oil or by grease.

How can we prevent the water from leaking along the shaft?

A special seal is used to prevent liquid leaking out along the shaft. There are two types of seals commonly used:

- **Packing seal**
- **Mechanical seal**

Packing Seals

Should packing have leakage?

Leakage

During pump operation, a certain amount of leakage around the shafts and casings normally takes place.

This leakage must be controlled for two reasons: (1) to prevent excessive fluid loss from the pump, and (2) to prevent air from entering the area where the pump suction pressure is below atmospheric pressure.

The amount of leakage that can occur without limiting pump efficiency determines the type of shaft sealing selected. Shaft sealing systems are found in every pump. They can vary from simple packing to complicated sealing systems.

Packing is the most common and oldest method of sealing. Leakage is checked by the compression of packing rings that causes the rings to deform and seal around the pump shaft and casing. The packing is lubricated by liquid moving through a lantern ring in the center of the packing. The sealing slows down the rate of leakage. It does not stop it completely, since a certain amount of leakage is necessary during operation. Mechanical seals are rapidly replacing conventional packing on centrifugal pumps.

Some of the reasons for the use of mechanical seals are as follows:

1. Leaking causes bearing failure by contaminating the oil with water. This is a major problem in engine-mounted water pumps.
2. Properly installed mechanical seals eliminate leakoff on idle (vertical) pumps. This design prevents the leak (water) from bypassing the water flinger and entering the lower bearings.

Leakoff causes two types of seal leakage:

- a. Water contamination of the engine lubrication oil.
- b. Loss of treated fresh water that causes scale buildup in the cooling system.

Centrifugal pumps are versatile and have many uses. This type of pump is commonly used to pump all types of water and wastewater flows, including thin sludge.



Lantern Rings

Lantern rings are used to supply clean water along the shaft. This helps to prevent grit and air from reaching the area. Another component is the slinger ring. The slinger ring is an important part of the pump because it is used to protect the bearings. Other materials can be used to prevent this burier.

Mechanical Seals

Mechanical seals are commonly used to reduce leakage around the pump shaft. There are many types of mechanical seals. The photograph below illustrates the basic components of a mechanical seal. Similar to the packing seal, clean water is fed at a pressure greater than that of the liquid being pumped. There is little or no leakage through the mechanical seal. The wearing surface must be kept extremely clean. Even fingerprints on the wearing surface can introduce enough dirt to cause problems.



What care should be taken when storing mechanical seals?



Mechanical Seals

Wear Rings

Not all pumps have wear rings. However, when they are included, they are usually replaceable. Wear rings can be located on the suction side and head side of the volute. Wear rings could be made of the same metal but of different alloys. The wear ring on the head side is usually a harder alloy.

It's called a "**WEAR RING**" and what would be the purpose?

Mechanical Seals

Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage, which causes failure of pump and motor bearings and motor windings.

Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water, and various cooling systems). They not only conserve the fluid being pumped, but also improve system operation.

The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for one of the seal faces and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced.

You should replace a mechanical seal whenever the seal is removed from the shaft for any reason, or whenever leakage causes undesirable effects on equipment or surrounding spaces. Do not touch a new seal on the sealing face because body acid and grease or dirt will cause the seal to pit prematurely and leak.

Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals must not be positioned by setscrews. Shaft sleeves are chamfered (beveled) on the outboard ends for easy mechanical seal mounting. Mechanical shaft seals serve to ensure that position liquid pressure is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.



Finger is shown pointing to a Lantern Ring. This old school method of sealing a pump is still out there. Notice the packing on both sides of the ring. The packing joints need to be staggered and the purpose of this device is to allow air to the Stuffing Box.

Pump Troubleshooting Section

Some of the operating problems you may encounter with centrifugal pumps as an Operator, together with the probable causes, are discussed in the following paragraphs.

If a centrifugal pump **DOES NOT DELIVER ANY LIQUID**, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, such as might be caused by a partially closed valve or some other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation (this may occur after motor overhaul); (7) clogged suction screen (if used); (8) ruptured suction line; or (9) loss of suction pressure.

If a centrifugal pump delivers some liquid but operates at **INSUFFICIENT CAPACITY**, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes in pumps operating at less than atmospheric pressure; (3) insufficient pump speed; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump **DOES NOT DEVELOP DESIGN DISCHARGE PRESSURE**, the trouble may be caused by (1) insufficient pump speed; (2) air or gas in the liquid being pumped; (3) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves; or (4) reversed rotation of the impeller (3-phase electric motor-driven pumps). If a pump **WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID**, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage in the stuffing boxes; (3) clogged water seal passages; (4) insufficient liquid on the suction side; or (5) excessive heat in the liquid being pumped.

If a motor-driven centrifugal pump **DRAWS TOO MUCH POWER**, the trouble will probably be indicated by overheating of the motor. The basic causes may be (1) operation of the pump to excess capacity and insufficient discharge pressure; (2) too high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration, as well as noisy operation and fluctuating discharge pressure, particularly in pumps that handle hot or volatile liquids. If the pump fails to build up pressure when the discharge valve is opened and the pump comes up to normal operating speed, proceed as follows:

1. Shut the pump discharge valve.
2. Secure the pump.
3. Open all valves in the pump suction line.
4. Prime the pump (*fill casing with the liquid being pumped*) and be sure that all air is expelled through the air cocks on the pump casing.
5. Restart the pump. If the pump is electrically driven, be sure the pump is rotating in the correct direction.
6. Open the discharge valve to “load” the pump. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller may be broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump and continue troubleshooting according to the technical manual for that unit.

Maintenance of Centrifugal Pumps

When properly installed, maintained and operated, centrifugal pumps are usually trouble-free. Some of the most common corrective maintenance actions that you may be required to perform are discussed in the following sections.

Repacking - Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When operating a centrifugal pump, be sure there is always a slight trickle of water coming out of the stuffing box or seal. How often the packing in a centrifugal pump should be renewed depends on several factors, such as the type of pump, condition of the shaft sleeve, and hours in use.



To ensure the longest possible service from pump packing, make certain the shaft or sleeve is smooth when the packing is removed from a gland. Rapid wear of the packing will be caused by roughness of the shaft sleeve (or shaft where no sleeve is installed). If the shaft is rough, it should be sent to the machine shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing. When replacing packing, be sure the packing fits uniformly around the stuffing box. If you have to flatten the packing with a hammer to make it fit, **YOU ARE NOT USING THE RIGHT SIZE**. Pack the box loosely, and set up the packing gland lightly. Allow a liberal leak-off for stuffing boxes that operate above atmospheric pressure.

Next, start the pump. Let it operate for about 30 minutes before you adjust the packing gland for the desired amount of leak-off. This gives the packing time to run-in and swell. You may then begin to adjust the packing gland. Tighten the adjusting nuts one flat at a time. Wait about 30 minutes between adjustments. Be sure to tighten the same amount on both adjusting nuts. If you pull up the packing gland unevenly (or cocked), it will cause the packing to overheat and score the shaft sleeves. Once you have the desired leak-off, check it regularly to make certain that sufficient flow is maintained.

Mechanical Seals

Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage, which causes failure of pump and motor bearings and motor windings.

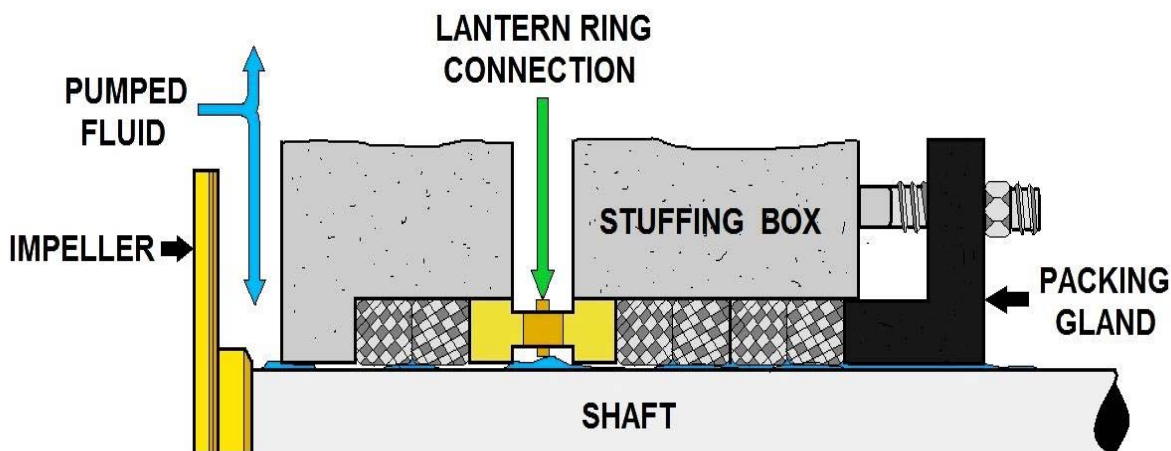
Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water, and various cooling systems). They not only conserve the fluid being pumped, but also improve system operation. The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for one of the seal faces and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced.



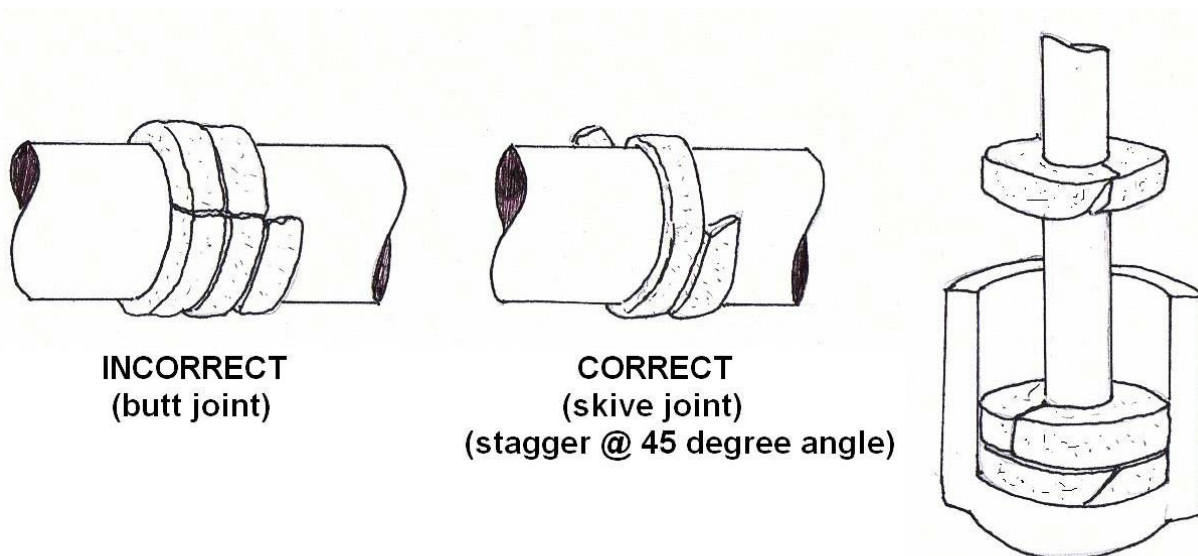
You should replace a mechanical seal whenever the seal is removed from the shaft for any reason, or whenever leakage causes undesirable effects on equipment or surrounding spaces. Do not touch a new seal on the sealing face because body acid and grease or dirt will cause the seal to pit prematurely and leak.

Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals must not be positioned by setscrews. Shaft sleeves are chamfered (beveled) on outboard ends for easy mechanical seal mounting.

Mechanical shaft seals serve to ensure that liquid pressure is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.



LANTERN RING BETWEEN PACKING FOR COOL / CLEAN FLUID BARRIER

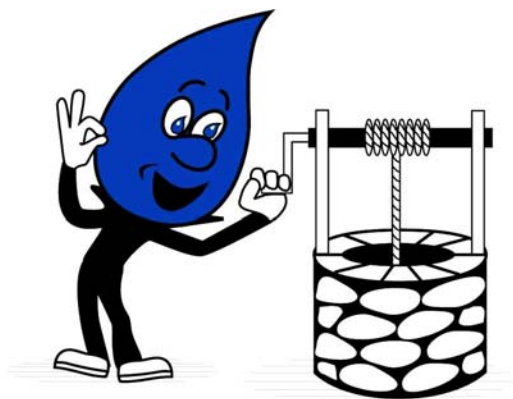


Troubleshooting Table for Well/Pump Problems

1. Well pump will not start.
2. Well pump will not shut off.
3. Well pump starts and stops too frequently (excessive cycle rate).
4. Sand sediment is present in the water.
5. Well pump operates with reduced flow.
6. Well house flooded without recent precipitation.
7. Red or black water complaints.
8. Raw water appears turbid or a light tan color following rainfall.
9. Coliform tests are positive.

Possible Causes

- 1A. Circuit breaker or overload relay tripped.
- 1B. Fuse(s) burned out.
- 1C. No power to switch box.
- 1D. Short, broken or loose wire.
- 1E. Low voltage.
- 1F. Defective motor.
- 1G. Defective pressure switch.
- 2A. Defective pressure switch.
- 2B. Cut-off pressure setting too high.
- 2C. Float switch or pressure transducer not functioning.
- 3A. Pressure switch settings too close.
- 3B. Pump foot valve leaking.
- 3C. Water-logged hydropneumatic tank.
- 4A. Problems with well screen or gravel envelope.
- 5A. Valve on discharge partially closed or line clogged.
- 5B. Well is over-pumped.
- 5C. Well screen clogged.
- 6A. Check valve not operating properly.
- 6B. Leakage occurring in discharge piping or valves.
- 7A. Water contains excessive iron (red brown) and/or manganese (black water).
- 7B. Complainant's hot water needs maintenance.
- 8A. Surface water entering or influencing well.
- 9A. Sample is invalid.
- 9B. Sanitary protection of well has been breached.



Possible Solutions

- 1A. Reset breaker or manual overload relay.
- 1B. Check for cause and correct, replace fuse(s).
- 1C. Check incoming power supply. Contact power company.
- 1D. Check for shorts and correct, tighten terminals, replace broken wires.
- 1E. Check incoming line voltage. Contact power company if low.
- 1F. Contact electrical contractor.
- 1G. Check voltage of incoming electric supply with pressure switch closed. Contact power company if voltage low. Perform maintenance on switch if voltage normal.
- 2A. Check switch for proper operation. Replace switch.
- 2B. Adjust setting.
- 2C. Check and replace components or cable as needed.

- 3A. Adjust settings.
- 3B. Check for backflow. Contact well contractor.
- 3C. Check air volume. Add air if needed. If persistent, check air compressor, relief valve, air lines and connections, and repair if needed.
- 4A. Contact well contractor.
- 5A. Open valve, unclog discharge line.
- 5B. Check static water level and compare to past readings. If significantly lower, notify well contractor.
- 5C. Contact well contractor.
- 6A. Repair or replace check valve.
- 6B. Inspect and repair/replace as necessary.
- 7A. Test for iron and manganese at well. If levels exceed 0.3 mg/L iron or 0.005mg/L manganese, contact regulatory agency, TA provider or water treatment contractor.
- 7B. Check hot water heater and flush if needed.
- 8A. Check well for openings that allow surface water to enter. Check area for sinkholes, fractures, or other physical evidence of surface water intrusion. Check water turbidity. Notify regulatory agency if >0.5 NTU. Check raw water for coliform bacteria. Notify regulatory agency immediately if positive.
- 9A. Check sampling technique, sampling container, and sampling location and tap.
- 9B. Notify regulatory agency immediately and re-sample for re-testing.



This brush is used to dislodge debris inside well casing. Just a big toilet cleaning brush.

SCADA

What is SCADA?

SCADA stands for Supervisory Control and Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs), or other commercial hardware modules. Contemporary SCADA systems exhibit predominantly open-loop control characteristics and utilize predominantly long distance communications, although some elements of closed-loop control and/or short distance communications may also be present. Systems similar to SCADA systems are routinely seen in treatment plants and distribution systems. These are often referred to as Distributed Control Systems (DCS). They have similar functions to SCADA systems, but the field data gathering or control units are usually located within a more confined area. Communications may be via a local area network (LAN), and will normally be reliable and high speed. A DCS system usually employs significant amounts of closed loop control.

What is Data Acquisition?

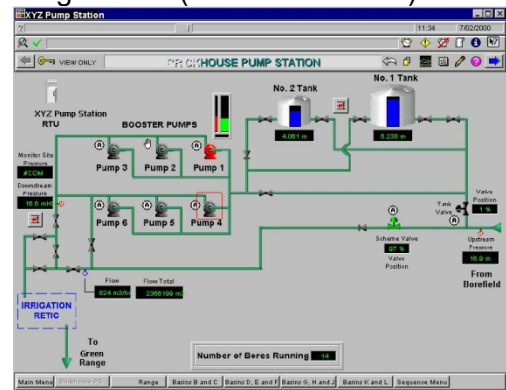
Data acquisition refers to the method used to access and control information or data from the equipment being controlled and monitored. The data accessed are then forwarded onto a telemetry system ready for transfer to the different sites. They can be analog and digital information gathered by sensors, such as flowmeter, ammeter, etc. It can also be data to control equipment such as actuators, relays, valves, motors, etc.

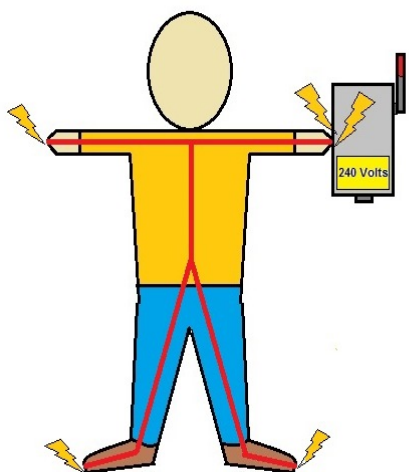
So Why or Where Would You Use SCADA?

SCADA can be used to monitor and control plant or equipment. The control may be automatic, or initiated by operator commands. The data acquisition is accomplished firstly by the RTU's (remote Terminal Units) scanning the field inputs connected to the RTU (RTU may also be called a PLC - programmable logic controller). This is usually at a fast rate. The central host will scan the RTU's (usually at a slower rate.)

The data is processed to detect alarm conditions, and if an alarm is present, it will be displayed on special alarm lists. Data can be of three main types. Analogue data (i.e. real numbers) will be trended (i.e. placed in graphs). Digital data (on/off) may have alarms attached to one state or the other. Pulse data (e.g. counting revolutions of a meter) is normally accumulated or counted.

The primary interface to the operator is a graphical display (mimic) usually via a PC Screen which shows a representation of the plant or equipment in graphical form. Live data is shown as graphical shapes (foreground) over a static background. As the data changes in the field, the foreground is updated. A valve may be shown as open or closed. Analog data can be shown either as a number, or graphically. The system may have many such displays, and the operator can select from the relevant ones at any time.





mA	Effects on the Human Body
0.5 - 3	Tingling sensations
3 - 10	Muscle contractions and some pain
10 - 40	"Let - Go" Threshold
30 - 75	Respiratory paralysis
100 - 200	Ventricular Fibrillation
200 - 500	The Heart clamps tight
1500 +	Tissue and Organs begin to burn

THE EFFECTS OF ELECTRICITY AND THE HUMAN BODY

Pump Section Summary and Review Statements

Memorize every one of these statements.

In general, any *Centrifugal* pump can be designed with a multistage configuration. Each stage requires an additional *Impeller* and casing chamber in order to develop increased pressure, which adds to the pressure developed by the preceding stage.

In all centrifugal pumps, there must be a flow restriction between the impeller discharge and suction areas that will prevent excessive circulation of water between the two parts.

When a pump operates under suction, the impeller inlet is actually operating in a vacuum. Air will enter the water stream along the shaft if the packing does not provide an effective seal. It may be impossible to tighten the packing sufficiently to prevent air from entering without causing excessive heat and wear on the packing and shaft or shaft sleeve. To solve this problem, a Lantern Ring is placed inside the Stuffing Box.

A centrifugal pump consists of an impeller fixed on a rotating shaft that is enclosed in a casing, and has an inlet and discharge connection. As the rotating impeller spins the liquid around, force builds up enough pressure to force the water through the discharge outlet.

The foot valve is a special type of check valve located at the bottom end of the suction side of a pump. This valve opens when the pump operates to allow water to enter the suction pipe, but closes when the pump shuts off to prevent water from flowing out of the suction pipe.

A pump engineer will design a system that uses multiple pumps for a parallel operation in the case of the following: To provide for a fluctuating demand, to provide an increased discharge head, to reduce the friction coefficient on a larger pump for greater efficiency.

When multiple water pumps are installed for paralleled operation, the intent of the designer is to provide for a fluctuating demand, or for if one pump is out of service.

If the pump must operate under high suction head, the suction pressure itself will compress the packing rings, regardless of the operator's care. Packing will then require frequent replacement. Most manufacturers recommend using Mechanical Seals for both high and low-suction head conditions as well.

The mechanical seal is designed so that it can be hydraulically balanced. The result is that the wearing force between the machined surfaces does not vary, regardless of the suction head. Most seals have an operating life of 5,000 to 20,000 hours.

The axial-flow pump is often referred to as a Propeller Pump.

On most kilowatt meters, the current kilowatt load is indicated by disk revolutions.

If a single-phase motor is receiving adequate power and the run windings are operable, but the motor will not start, there is a problem with the start winding. A single-phase motor will have a capacitor start motor which has a high starting torque and a high starting current.

As the wear ring inside a centrifugal pump loses tolerance between it and the impeller, the efficiency of the pump will decrease.

Multistage centrifugal pumps can discharge high-pressure water. The pressure increases with the number of stages, but what happens to the capacity/ flow of the pump? The flow will remain the same through each stage.

With remote manual control, the operator is also required to turn a switch or push a button to operate equipment. Control devices which actuate equipment by inducing a magnetic field in the device are commonly known as solenoids.

Mechanical seals consist of two machined and polished surfaces which must contact each other. This contact is maintained by spring pressure.

The speed at which the magnetic field rotates is called the motor's synchronous speed. It is expressed in revolutions per minute. For a motor that operates on an electric power system having a frequency of 60Hz, the maximum synchronous speed is 3,600 rpm, or 60 revolutions per second. In other words, because the electric current changes its flow direction 60 times a second, the rotor can rotate 60 times per second. This speed is achieved by a two-pole motor. A wound-rotor induction motor would be expected to have the lowest demand for starting current.

The purpose of a sump on a vertical turbine pump is used to maintain adequate liquid above the suction level.

Friction Loss is the term used to describe head pressure or energy lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restriction by fittings.

Continuous leakage from a mechanical seal indicates an abnormal condition.



Wearing Rings



A new 8 inch submersible pump and motor with 6 inch column pipe about to be installed in a high capacity municipal supply well.

The Well Head Assembly

An approved well cap or seal is to be installed at the *wellhead* to prevent any contamination from entering the well through the top once construction is complete. When the well is completed with pumping equipment a well vent is also required.

The well *vent pipe* should be at least $\frac{1}{2}$ inch in diameter, 8 inches above the finished grade, and be turned down, with the opening screened with a minimum 24-mesh durable screen to prevent entry of insects. Only approved well casing material meeting the requirements of the Code may be utilized.

In addition, frost protection should be provided by use of insulation or pump house. Turbine and submersible pumps are normally used. Any pressure, vent, and electric lines to and from the pump should enter the casing only through a watertight seal.

Pumps and pressure tanks may be located in basements and enclosures. However, wells should not be located within vaults or pits, except with a *variance permit*.

If the pump discharge line passes through the well casing underground, an approved *pitless adapter* should be installed. The *well manifold* should include an air relief valve, flow meter, sample port, isolation valve, and a check valve. If the well should need rehabilitation, additional construction, or repair, it must be done in compliance with the State or Local Water Well Construction Codes.

Pump Assignment. Please practice and memorize these pump related questions and answers. Answers are provided at the rear of this section.

1. Which steps should be followed to complete the preventive maintenance of a greasing procedure?
2. What should be included on the maintenance of a pneumatically operated diaphragm pump?
3. How does a mechanical seal in a stuffing box receive lubrication?
4. Name one advantage a mechanical seal has over packing in a centrifugal pump.
5. What is the purpose of a check valve installed on the discharge side of a sump pump that is being used in a dry well?
6. A centrifugal pump is making noise and the efficiency of the pump is decreasing. The pump is dismantled and the impeller has pits on all of the vanes. What is a possible cause of the pitting?
7. For which of the following reasons might cavitation occur?
8. What is required to prevent damage to the face of a mechanical seal on a pump?
9. A lift station is equipped with two centrifugal self-priming trash pumps. The bubbler system is air locking and causing the pumps to overheat and shut off. What may be causing this problem?
10. What is used to compare the actual pump efficiency to its expected efficiency?
11. Which condition might cause a positive displacement diaphragm pump to cycle improperly?
12. What is the recommended type of fuse to use in the circuit leading to the electric motor?

13. Which valve would be the best choice to replace a suction side pump valve that is continually clogging?
14. What component might be tested using an Ohmmeter?
15. What describes the proper adjustment of the packing gland in a centrifugal pump?
16. Name one disadvantage of using mechanical seals in a centrifugal pump.
17. How much overload is a heater element on a motor starter usually rated at to drop the circuit?
18. If the voltage of the circuit to be tested is unknown, what should the meter be set on?
19. What is the expected voltage when testing the incoming voltage that is 220 VAC, single phase power?
20. What is the overload protection rating on magnetic starters?
21. What determines the capacity of a progressive pump?
22. What is an essential aspect of priming a pump?
23. What should be done with the motor disconnect switch when shutting down a pump for a long period?
24. What are the two basic types of propeller pumps?
25. What is the most important task when isolating a pump from service?
26. What is the name of a popular method of automatically controlling a pump, valve, chemical feeder, and other devices?
27. What do you call the use of a transmission line with remote signaling to monitor a pumping station?

28. What is a common problem with an electrical probe that is used to measure the level of water?
29. What may be the cause of a control system that is frequently turning a pump on and off?
30. What is the advantage of a double suction pump?
31. What is the maximum number of volts that electrical equipment can be insulated with a lower limit of 1 megaohm?
32. What should be done with a motor that after several years of testing with a Megger indicates low but stable and consistent values?
33. What will employ the use of a magnetic starter?
34. What will cause the deterioration of oil in a transformer?
35. What does continuous leakage from a mechanical seal on a pump indicate?
36. What is a possible cause of a scored shaft sleeve?
37. What does each stage of a multistage centrifugal pump require in order to develop increased pressure adding to the pressure developed by each preceding stage?
38. What is a possible result of overgreasing a bearing?
39. What is another name for an axial-flow pump?
40. What is one disadvantage of a centrifugal pump?
41. What is the common method used to secure an impeller to the shaft on double-suction pump?
42. What is the main purpose of the wear rings in a centrifugal double suction pump?

- 43. What maintains contact between the two surfaces of a mechanical seal?
- 44. Which pump is one of the most frequently used as a booster pump in a water distribution system?
- 45. What happens if grease comes in contact with the windings of a motor?
- 46. What is the maximum synchronous speed of an electric motor that has a frequency of 60Hz?

Math Pump Drill

Please show your work. Math conversions in rear of Glossary.

47. During a test for well yield, the time required to fill a 600 liter tank was 45.8 sec. Based on this pumping rate, what was the well yield in cubic feet per second?

48. A pump delivers 199 GPM. If the desired chlorine dose is 2.1 mg/L, what should the chlorinator be set at in pounds of chlorine per day?

49. A pump moves a liquid at the rate of 25 gpm. How many pounds per day are pumped if the liquid weighs 74.9 lb/ft³?

50. A wet well measures 8' x 10' and measures 3' feet in depth between the high and low levels. A pump empties the wet well between the high and low level 9 times per hour, 24 hours a day. Calculate the flow in millions of gallons per day.

51. How much brake horsepower is required to meet the following conditions: 250 gpm, total head = 110 feet. The submersible pump that is being specified is a combined 64% efficient?

52. Calculate the pumping capacity (gpm) of a pump given the following information: -Wet well diameter 10 feet -Water drops 6 feet in 17.75 minutes

Answers for Pump Assignment

1. Run the motor for approximately 30 minutes before reinstalling the drain plug.
2. Periodic inspection of the packing and shaft sleeves
3. Through the seal water supply
4. Mechanical seals do not need routine adjustment
5. To prevent backflow due to back siphoning
6. Cavitation inside the pump
7. Several reasons, If modifications over time change the basic balance of the hydraulic system. If the system is not properly designed. If the wrong pump is used for a particular application.
8. Keep fresh water or filtered effluent on the face of the seal.
9. The bubbler line is plugged or restricted
10. Pump curve
11. Plugged exhaust port
12. Time-delay fuse
13. A plug valve
14. A Coil or relay
15. Tighten gland until there is a flow of 20 to 60 drops of water per minute.
16. Pump must be dismantled to repair
17. 0.1 or 10%
18. Highest range for voltage and work down
19. 110 volts.
20. A ten percent overload
21. The size of the cavity in which the rotor turns
22. Vent the excess air
23. Opened, Locked out, and Tagged.
24. Axial-flow impellers and mixed-flow impellers
25. Draining the volute of the pump
26. Relay logic
27. Telemetry links
28. The probe may be coated by calcium carbonate
29. The level controller may be set with too close a tolerance
30. A reduction in the thrust load that the bearings must carry
31. 1,000 volts
32. Nothing, but the testing should be continued
33. Large three-phase pump
34. Moisture
35. A mechanical seal needs to be replaced
36. The packing has broken down
37. An additional impeller bowl assembly
38. There is extreme friction in the bearing chamber
39. A propeller pump
40. It is not self-priming
41. A key and a tight fit
42. The wear rings maintain a flow restriction between the impeller discharge and suction areas
43. Spring pressure
44. A vertical turbine pump

- 45. The winding insulation may deteriorate
- 46. 3600 rpms
- 47. 0.46 CFS
- 48. 5
- 49. 360,360 lb/day
- 50. 0.39 MGD
- 51. 10.8 BHP
- 52. 199 gpm

Math Assignment

It is very important for you to practice the math assignment before coming to your exam review class. Get in a habit of writing the math problem and answer out to show your work. Write the formula and become very familiar with the math.

This is a simple exercise and a good practice review for you to prepare for the operator certification exam.

Long Math Answers for Pump Drill

47. During a test for well yield, the time required to fill a 600 liter tank was 45.8 sec. Based on this pumping rate, what was the well yield in cubic feet per second?

$$1. \frac{600 \cancel{\text{L}}}{1} \times \frac{1 \text{ GAL}}{3.785 \cancel{\text{L}}} = 158.5 \text{ GAL} / 45.8 \text{ SEC.}$$

$$2. \frac{158.5 \text{ GAL}}{45.8 \text{ SEC}} \times \frac{1 \text{ CU FT}}{7.48 \text{ GAL}} = .463 \text{ CFS}$$

48. A pump delivers 199 GPM. If the desired chlorine dose is 2.1 mg/L, what should the chlorinator be set at in pounds of chlorine per day?

$$1. \text{ LBS/DAY} = \text{FLOW} \times \text{DOSE} \times 8.34 \text{ LB/GAL.}$$

$$2. \frac{199 \text{ GAL}}{1 \text{ MIN}} \times \frac{1440 \text{ MIN}}{1 \text{ DAY}} = \frac{286560}{1,000,000} = .28656 \text{ MGD}$$

$$3. .28656 \text{ MGD} \times 2.1 \text{ mg/L} \times 8.34 \text{ lbs/gal} = 5.02 \text{ LBS/DAY}$$

49. A pump moves a liquid at the rate of 25 gpm. How many pounds per day are pumped if the liquid weighs 74.9 lb/ft³?

$$1. \frac{25 \text{ GAL}}{\text{MIN}} \times \frac{1 \text{ CU FT}}{7.48 \text{ GAL}} \times \frac{74.9 \text{ LBS}}{1 \text{ CU FT}} \times \frac{1440 \text{ MIN}}{1 \text{ DAY}} = 360481.28 \text{ LBS/DAY}$$

$$\frac{25 \text{ GAL}}{\text{MIN}} \times \frac{1440 \text{ MIN}}{1 \text{ DAY}} = 2. \frac{\text{GAL}}{\text{DAY}} \times \frac{1 \text{ CU FT}}{7.48 \text{ GAL}} = 3. \frac{\text{CU FT}}{\text{DAY}} \times \frac{74.9 \text{ LBS}}{1 \text{ CU FT}} = \frac{\text{LBS}}{\text{DAY}}$$

50. A wet well measures 8' x 10' and measures 3' feet in depth between the high and low levels. A pump empties the wet well between the high and low level 9 times per hour, 24 hours a day. Calculate the flow in millions of gallons per day.

$$1. V = L \times W \times H$$

$$2. 8' \times 10' \times 3' = 240 \text{ CU FT.}$$

$$3. 240 \text{ CU FT.} \times \frac{7.48 \text{ GAL}}{1 \text{ CU FT.}} = 1795.2 \text{ GAL}$$

$$4. 1795.2 \text{ GAL} \times \frac{9 \text{ TIMES}}{1 \text{ HOUR}} \times \frac{24 \text{ HOURS}}{1 \text{ DAY}} = \frac{387763.2 \text{ GAL}}{1,000,000 \text{ DAY}} = .388 \text{ MGD}$$

51. How much brake horsepower is required to meet the following conditions: 250 gpm, total head = 110 feet. The submersible pump that is being specified is a combined 64% efficient?

$$HPB = \frac{(GPM) (HEAD \text{ FT})}{(3960) (EFF)} = \frac{(250 \text{ GPM}) (110 \text{ FT})}{(3960) (.64\%)} = \frac{27500}{2534.4}$$

$$\frac{27500}{2534.4} = 10.85 \text{ BHP}$$

52. Calculate the pumping capacity (gpm) of a pump given the following information: -Wet well diameter 10 feet -Water drops 6 feet in 17.75 minutes

$$1. .785 \times \text{DIAMETER}^2 \times \text{DEPTH} = V \text{ CU FT.}$$

$$2. .785 \times 10' \times 10' \times 6' = \underline{471 \text{ CU FT.}} \times \frac{7.48 \text{ GAL}}{\text{CU FT.}} = \underline{3523.08 \text{ GAL}}$$

$$3. \frac{3523.08 \text{ GAL}}{17.75 \text{ MIN}} = \underline{198.483 \text{ GPM}}$$

Safety Section Chapter 8

Excavation & Trenching

This section outlines procedures and guidelines for the protection of employees working in and around excavations and trenches. This section requires compliance with OSHA Standards described in Subpart P (**CFR 1926.650**) for the construction industry. Safety compliance is mandatory to ensure employee protection when working in or around excavations.

The competent person(s) must be trained in accordance with the OSHA Excavation Standard, and all other programs that may apply (examples Hazard Communication, Confined Space, and Respiratory Protection), and must demonstrate a thorough understanding and knowledge of the programs and the hazards associated. All other employees working in and around the excavation must be trained in the recognition of hazards associated with trenching and excavating.

REFERENCES

- **29 CFR 1926.650, Subpart P - Excavations**
- **Excavation Equipment Manufacturer Safety Procedures**

Hazards

One of the reasons OSHA requires a competent person on-site during excavation & trenching are the numerous potential hazardous that may be encountered or created. Hazards include:

Electrocution
Gas Explosion
Entrapment
Struck by equipment
Suffocation

Hazard Controls

Before any work is performed and before any employees enter the excavation, a number of items must be checked and ensured:

- Before any excavation, underground installations must be determined. This can be accomplished by either contacting the local utility companies or the local "**one-call**" center for the area. All under-ground utility locations must be documented on the proper forms. All overhead hazards (**surface encumbrances**) that create a hazard to employees must be removed or supported to eliminate the hazard.
- If the excavation is to be over 20 feet deep, it must be designed by a registered professional engineer who is registered in the state where work will be performed.
- Adequate protective systems will be utilized to protect employees. This can be accomplished through sloping, shoring, or shielding.
- The worksite must be analyzed in order to design adequate protection systems and prevent cave-ins. There must also be an excavation safety plan developed to protect employees.
- Workers must be supplied with and wear any personal protective equipment deemed necessary to assure their protection.



- *All spoil piles will be stored a minimum of **two (2) feet from** the sides of the excavation. The spoil pile must not block the safe means of egress.
- If a trench or excavation is 4 feet or deeper, stairways, ramps, or ladders will be used as a safe means of access and egress. For trenches, the employee must not have to travel any more than 25 feet of lateral travel to reach the stairway, ramp, or ladder.
- No employee will work in an excavation where water is accumulating unless adequate measures are used to protect the employees.
- A competent person will inspect all excavations and trenches daily, prior to employee exposure or entry, and after any rainfall, soil change, or any other time needed during the shift. The competent person must take prompt measures to eliminate any and all hazards.
- Excavations and trenches 4 feet or deeper that have the potential for toxic substances or hazardous atmospheres will be tested at least daily. If the atmosphere is inadequate, protective systems will be utilized.
- If work is in or around traffic, employees must be supplied with and wear orange reflective vests. Signs and barricades must be utilized to ensure the safety of employees, vehicular traffic, and pedestrians.

Competent Person Responsibilities

The OSHA Standards require that the competent person must be capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and have authorization to take prompt corrective measures to eliminate them and, if necessary, to stop the work.

A competent person is required to:

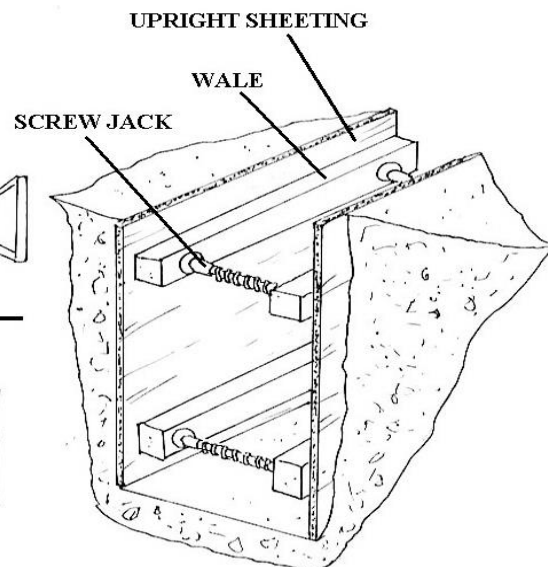
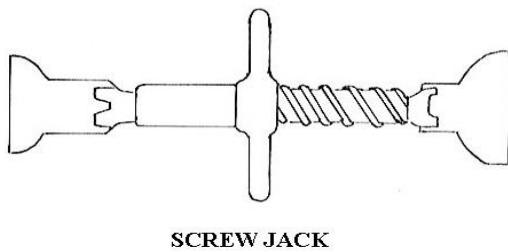
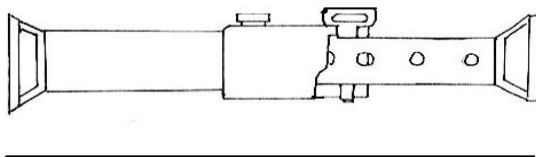
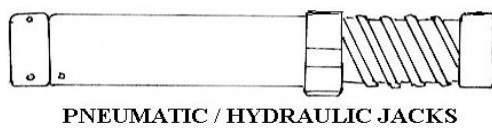
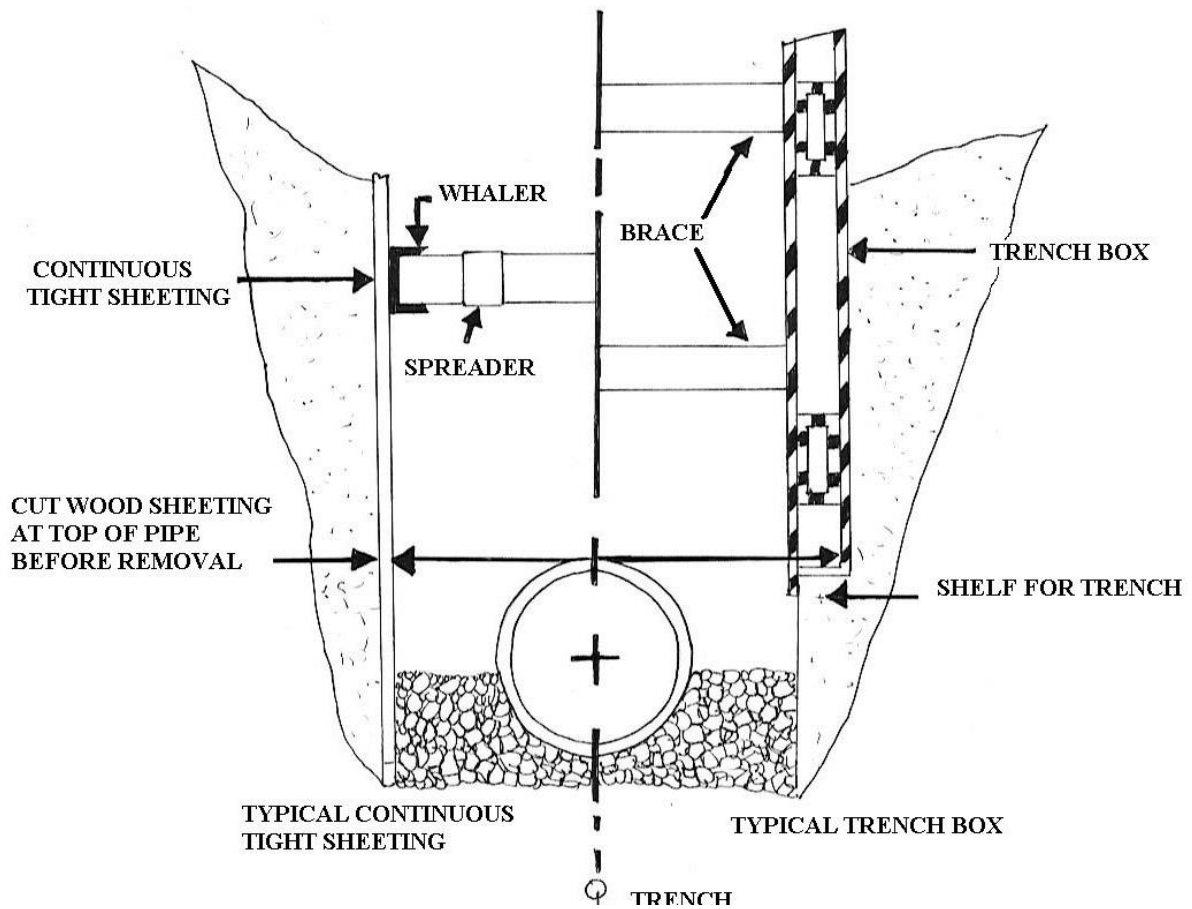
- Have a complete understanding of the applicable safety standards and any other data provided.
- Assure the proper locations of underground installations or utilities, and that the proper utility companies have been contacted.
- Conduct soil classification tests and reclassify soil after any condition changes.
- Determine adequate protective systems (sloping, shoring, or shielding systems) for employee protection.
- Conduct all air monitoring for potential hazardous atmospheres.
- Conduct daily and periodic inspections of excavations and trenches.
- Approve design of structural ramps, if used.

Excavation Safety Plan

An excavation safety plan is required in written form. This plan is to be developed to the level necessary to ensure complete compliance with the OSHA Excavation Safety Standard and state and local safety standards.

Excavation safety plan factors:

- Utilization of the local one-call system
- Determination of locations of all underground utilities
- Consideration of confined space atmosphere potential
- Proper soil protection systems and personal protective equipment and clothing
- Determination of soil composition and classification
- Determination of surface and subsurface water
- Depth of excavation and length of time it will remain open
- Proper adherence to all OSHA Standards, this excavation and trenching safety program, and any other coinciding safety programs.



Confined Spaces are

- large enough to allow entry of any body part, and
- limited or restricted entry or exit, and
- not designed for continuous employee occupancy

Permit Required Confined Spaces are confined spaces that have any of the following

- potential hazardous atmosphere
- material inside that may engulf or trap you
- internal design that could trap or asphyxiate you
- any other serious safety or health hazard**

Entry Permits are required before you enter any
"Permit Required Confined Space"

Hazards include

- Fire & Explosion
- Engulfment
- Asphyxiation
- Entrapment
- Slips & Falls
- Electric Shock
- Noise & Vibration
- Chemical Exposure
- Toxic Atmospheres
- Thermal / Chemical Burns

Engineering Controls

- ☐ Ventilation
- ☐ Locked Access
- ☐ Lighting

Administrative Controls

- ☐ Controlled Access
- ☐ Hazard Assessments
- ☐ Entry Permits & Procedures
- ☐ Signs & Lockout Tagout
- ☐ Training

Smart Safety Rules

Know what you are getting into.

Know how to get out in an emergency.

Know the hazards & how they are controlled.

Only authorized & trained personnel may enter a Confined Space or act as an attendant.

No smoking in Confined Space or near entrance or exit area.

Attendant must be present at all times.

Constant visual or voice communication must be maintained between the attendant and entrants.

No bottom or side entry will be made, or work conducted below, the level any hanging material or material which could cause engulfment.

Air and oxygen Monitoring is required before entering a Permit-Required Confined Space.

Ventilation & oxygen monitoring is required when welding is performed.

Safety Review Statements *Memorize these statements for your exam.*

What is the definition of "stable rock" regarding a trench excavation? This is natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed.

What is the maximum allowable slope and height/depth ratio for type B soils in excavations less than 20 ft (6.09 m)? The slope is 45 degrees and height/depth ratio 1:1.

What is the maximum distance between horizontal cross braces for each zone in a trench? 4 feet apart.

What does the term "relative compaction" refer to? The level of compaction obtained compared to the level possible under ideal conditions.

What is the maximum distance between ladders and how far above the excavation should ladders be in trenches 4 ft or more in depth? Spacing between ladders should be no more than 25 ft laterally to the nearest means of egress and extend a minimum of 36 in (10.98 m) above the landing.

What is this classification of material that includes granular soils such as gravel, sand and loamy sand, submerged soil, and soil from which water is freely seeping? Type C soils.

When a trench is dug for a new line or replacement of an old line, it should be dug and backfilled in such a manner to support the pipe. What is used to determine the width of the trench? Narrow as possible for safety and to increase pipe sidewall support.

When backfilling around a flexible pipe, what could happen if the load above the pipe is too great? The pipe could deflect and collapse.

When uprights are installed during the shoring activity, the operator must place them at required intervals along the trench wall. Where should the uprights be placed? At the top of the trench and within two feet of the bottom.

Why are hydraulic shores usually not used on jobs exceeding five (5) days in length? There is a possibility of the hydraulic pressure bleeding off during this length of time.

If a trench is more than five feet deep where must the spoil be placed? At least 2 feet from the trench and only on one side of the trench.

What is the minimum compaction height of backfill when laying piping in Class A or Class B bedding? 12 inches.

What could possibly happen when groundwater is removed from a construction site or trench? Subsidence of ground and/or adjacent structures.

What is the maximum depth of the cut below the bottom of a shield when used for earth excavation? Earth excavation to a depth of 2 ft (0.61 m) below the shield is permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench.

What the definition of a "trench" excavation? This is a narrow excavation (in relation to its length) made below the surface of the ground.

Which fluid is recommended for use in hydraulic shoring equipment? Hydraulic shoring fluid.

When should atmospheric monitoring in a confined space be performed? Continuously from pre-entry to exit.

Below what maximum percentage is an atmosphere considered oxygen deficient? 19.5% or sometimes written .195.

The detailed plan for emergency response to an injury or other emergency within the confined space should be described in detail in what kind of program? The water system's Confined Space Entry Program.

What does entry into a confined space require? A confined space entry permit.

What is the definition of a hazardous atmosphere? An atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful that may cause death, illness, or injury.

What type of Confined Space Entry permit is required when operations may cause a source of ignition to a material or substance or create a work induced hazard by ignition within any confined space? Two different permits, Confined space entry Permitted Entry, Hot Work permit type is required.

Which type of confined space has the characteristic of containing or has the potential to contain a hazardous atmosphere? Type 2 confined space or permit required confined space.

What is the definition of an "Energy Isolating Device"? A mechanical device that physically prevents the transmission or release of energy.

The following are all listed as forms of hazardous energy under OSHA 29 CFR 1910.147: Electrical energy in a pump station; hydraulic pressure in a pipeline, known as static **Head**; Mechanical energy in a surge-relief valve; but not magnetic energy in a motor coil.



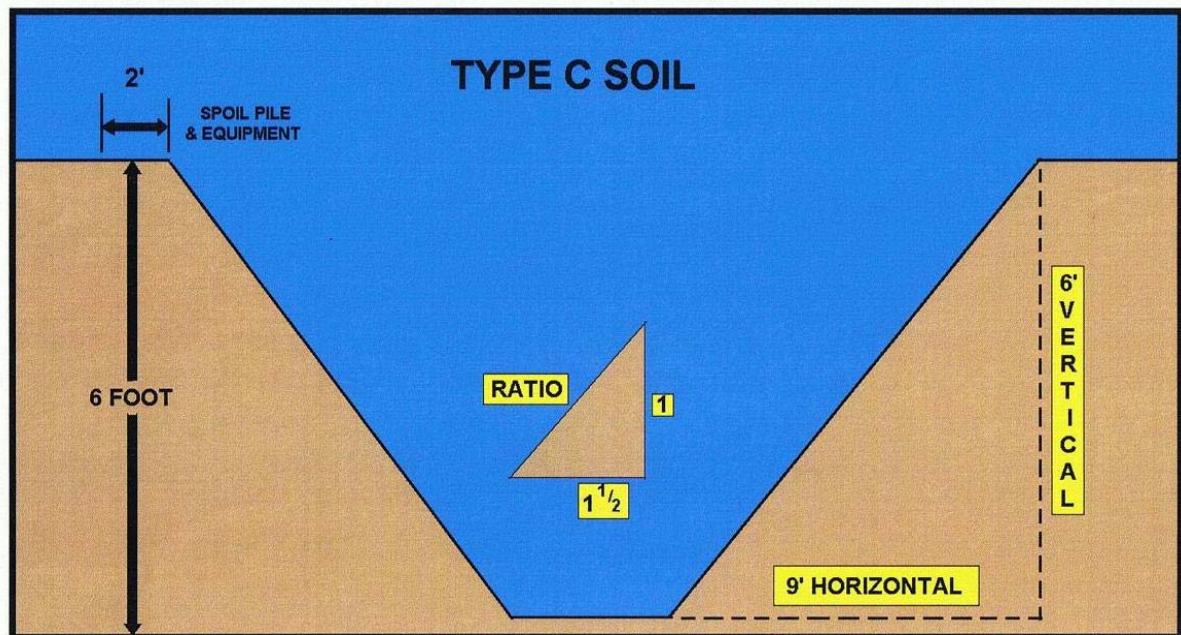
Two poor souls trying to get killed in a thirty foot deep trench without any trench protection.

Safety Review Practice *Exam Answers at rear.*

1. What is the maximum depth of the cut below the bottom of a shield when used for earth excavation?
2. What is the maximum distance between ladders and how far above the excavation should ladders be in trenches 4 ft or more in depth?
3. What is the maximum allowable slope and height/depth ratio for type B soils in excavations less than 20 ft ?
4. The detailed plan for emergency response to an injury or other emergency within the confined space should be described in detail in what kind of program?
5. What type of Confined Space Entry permit is required when operations may cause a source of ignition to a material or substance or create a work induced hazard by ignition within any confined space?
6. What critical safety advantage does hydraulic shoring have over timber shoring?
7. What is the definition of "stable rock" regarding a trench excavation?
8. What is the definition of a hazardous atmosphere?
9. What is the definition of an "Energy Isolating Device"?
10. What is the classification of material that includes granular soils such as gravel, sand and loamy sand, submerged soil, soil from which water is freely seeping?
11. What the definition of a "trench" excavation?
12. How should the presence of a confined space be identified to an employee?

Safety Review Answers

1. Earth excavation to a depth of 2 ft below the shield is permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench
2. Spacing between ladders should be no more than 25 ft laterally to the nearest means of egress and extend a minimum of 36 in above the landing.
3. The slope is 45 degrees and height/depth ratio 1:1
4. The water system's Confined Space Entry Program
5. Confined space entry Permitted Entry, Hot Work permit type is required
6. Are light enough to be installed by one worker and workers do not have to enter the trench to install or remove hydraulic shoring
7. This is natural solid mineral material that can be excavated with vertical sides and will remain intact while exposed
8. An atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful that may cause death, illness, or injury
9. A mechanical device that physically prevents the transmission or release of energy
10. Type C soils
11. This is a narrow excavation (in relation to its length) made below the surface of the ground
12. By clearly posting the appropriate signage at all entries to a confined space



First Practice Exam *Answers in rear of exam*

1. What is the general definition of an ion? An _____ with a positive or negative charge.
2. A continuous positive pressure in a distribution system is essential for preventing what event?
3. _____ water pressure must be maintained to ensure adequate customer service during peak flow periods. However, minimum positive pressure must be maintained in mains to protect against backflow or backsiphonage from cross-connections.
4. Name the most common **CAUSE** for public water supply contamination. _____ or cross-connection.
5. What does a backsiphonage condition usually cause? _____ pressure or negative pressure on the service or supply side.
6. What does a double check valve backflow assembly provide effective protection from? Both backpressure and backsiphonage of _____.
7. What is equipment that utilizes water for cooling, lubrication, washing or as a solvent always susceptible to?
8. What is the difference between a reduced pressure principle backflow device and a double check backflow device? The RP has a _____.
9. What is the maximum time period between having a backflow device tested by a certified backflow tester? _____ year.
10. What is the regulatory definition of a cross-connection in a water supply? A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the _____ through backflow.
11. What is the name of a type of valve that reduces the differential pressure across a closed disk making the main valve easier to open and close?
12. As soon as Cl₂ gas enters the throat area, a victim will sense a sudden stricture--Nature's way of signaling to prevent passage of the gas to the lungs. At this point, the victim must attempt to do two things: get out of the area of the leak, proceeding upwind, and to take only very short breaths through the mouth. Normal breathing will cause _____, which must be prevented if possible.

13. Chlorine gas causes suffocation, constriction of the chest, tightness in the throat, and edema of the _____.
14. _____ available chlorine is very effective in killing bacteria.
15. How should an operator store an empty chlorine cylinder? _____, tagged as empty.
16. If a chlorine leak occurs, where will chlorine gas accumulate? Near the _____ of the tank.
17. What effect does chlorine gas have on the sense of smell? It produces olfactory _____.
18. What is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite? The potential for a _____ leak.
19. What may occur due to chronic exposure to low concentrations of chlorine gas? Chronic exposure may cause corrosion of the _____.
20. What is the process called that changes water vapor to tiny droplets or ice crystals?
21. What is the unit of measurement for sound?
22. What happens if grease comes in contact with the winding of a motor? The winding insulation may deteriorate.
23. What is the most common type of valve used in isolating a small or medium sized section of a distribution system?
24. What is a possible result of over-greasing a bearing? There is extreme _____ in the bearing chamber causing heat and scoring of the shaft.
25. What is meant by the term "**peak demand**?" The _____ momentary load placed on a water treatment plant, pumping station or distribution system.
26. What is the range of the pH scale? between _____ -14.
27. What does a Bellows-type sensor react to a change in? _____.
28. Centrifugal pumps do not generate suction unless the impeller is submerged in water. If a pump is located above the level of water, what must be provided on the suction piping to hold the prime?

29. What causes pump cavitation? A suction line may be _____ or the pump is above the waterline. You have overpumped the well.
30. What does continuous leakage from a mechanical seal on a pump indicate? The mechanical seal needs to be _____.
31. What is a possible cause of a scored shaft sleeve? The _____ has broken down
32. What is one disadvantage of a centrifugal pump? It is not _____.
33. What is the best seal to use for a pump operating under high suction head conditions? A _____ seal.
34. What is the common method used to secure an impeller to the shaft on double-suction pump? A _____ and a tight fit.
35. What is the main purpose of the wear rings in a centrifugal double suction pump? The wear rings maintain a flow _____ between the impeller discharge and suction areas.
36. What is the purpose of the foot valve on a pump? It keeps the pump _____.
37. What is the objective of a vulnerability assessment? To determine _____ in the distribution or water system.
38. How far from the edge of a hole must you place the spoil from an excavation?
39. Before beginning an excavation, who should be contacted to assist in determining the location of all underground utilities in the work area? An "**Underground Service Alert**" center, "**One Call Center**" or _____, all three of these are the same.
40. This type of chemical classification may weaken, burn, or destroy a person's skin or eyes and can be either acidic or _____.
41. How should a supervisor warn an operator about the presence of a confined space? By clearly posting the appropriate _____ at all entries to a confined space.
42. List the correct order for placing shoring equipment in a trench. Starting at the top move to the bottom of the trench and _____ to remove it.
43. How frequently should ladders and climbing devices be inspected by a qualified individual?

44. What is the name of a map that provides detailed drawings of the distribution system's zones?
45. What maintains contact between the two surfaces of a mechanical seal?
46. What does the work "**stationing**" on a plan drawing refer to? It is a representation of a location from a starting point or reference.
47. Generally, how long will a water storage tank's interior coating (paint) protect the interior?
_____ years.
48. What is the name of the valve that is specifically designed for connecting a new water main to an existing main that is under pressure?
49. Define the term "**Water Hammer**." A _____ in a pipeline resulting from the rapid increase or decrease in water flow.
50. Water hammer exerts tremendous force on a system and can be highly _____.
51. How should a water meter that is removed from service for repair be handled? _____ the meter to retain water.
52. Name the three main classifications of water meters. Compound, Displacement, and _____.
53. Peak day demand is the greatest amount of water used for any one _____ in a calendar year.
54. What negative effect does a water meter have on a service? _____ loss may occur.
55. Name the 4 broad categories of water quality. Physical, _____, biological, radiological.
56. What are disease causing organisms such as bacteria and viruses called?
57. What does a positive bacteriological sample indicate? The _____ of bacteriological contamination.
58. What is the name of the area from which surface runoff is carried away by a single drainage system?

59. What is an advantage of a “**wet tap**” vs. a “**dry tap**”? You do not need to _____ the water line down.
60. What is the most likely type of symptom one could expect upon exposure to a very small percentage of chlorine in the air? A _____ sensation in the eyes and throat.
61. What must an operator ensure when installing a pressure vacuum breaker backflow device? It must be at least _____ inches about the highest downstream outlet.

First Practice Exam Answers

- | | |
|---------------------|---------------------|
| 1. Atom | 32. Self-Priming |
| 2. Backflow Event | 33. Mechanical |
| 3. Minimum | 34. Key |
| 4. Backflow | 35. Restriction |
| 5. Reduced | 36. Primed |
| 6. Pollution | 37. Weakness |
| 7. Cross-Connection | 38. 2 feet |
| 8. Relief Valve | 39. Bluestake |
| 9. 1 | 40. Basic |
| 10. PWS | 41. Signage |
| 11. Bypass Valve | 42. Reverse |
| 12. Coughing | 43. Once a year |
| 13. Lungs | 44. Sectional Maps |
| 14. Free | 45. Spring Pressure |
| 15. Upright | 46. Stationing |
| 16. Bottom | 47. 3-5 years |
| 17. Fatigue | 48. Tapping Valve |
| 18. Gas | 49. Pressure Surge |
| 19. Teeth | 50. Destructive |
| 20. Condensation | 51. Seal |
| 21. Decibels | 52. Velocity |
| 22. Deteriorate | 53. Day |
| 23. Gate | 54. Head |
| 24. Friction | 55. Chemical |
| 25. Maximum | 56. Pathogens |
| 26. Zero | 57. Presence |
| 27. Pressure | 58. Watershed |
| 28. Foot Valve | 59. Down |
| 29. Clogged | 60. Burning |
| 30. Replaced | 61. 12 Inches |
| 31. Packing | |

Operator Certification Practice Exam # 2

1. Because both iron and manganese react with dissolved oxygen to form **INSOLUBLE COMPOUNDS** they are not found in high concentrations in waters containing dissolved oxygen except as _____ of the oxide.
2. _____ in water can usually be detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed.
3. Perhaps the most troublesome consequence of iron and manganese in the water is they promote the growth of a group of microorganism known as:
4. Salmonella, Shigella, Bacillus, Vibri Cholera, Cholera are all examples of :
5. The importance of a detailed sanitary survey of a new water source cannot be:
6. Persons trained in public health engineering and the _____ of waterborne diseases should conduct the sanitary survey.
7. In the United States, this agency responsible for setting drinking water standards and for ensuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce.
8. When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with this term in the stratified waters.
9. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the:
10. One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for:
11. Which is correct when reviewing fluoride feeding system designs and specifications?
12. This chemical disinfectant has been used only on a very limited scale for water treatment because of its handling difficulties. This chemical causes skin burns on contact, and a residual is difficult to obtain.

13. Regardless of whether pre-chlorination is practiced or not, a free chlorine residual of at least _____mg/L should be maintained in the clear well or distribution reservoir immediately downstream from the point of postchlorination.

14. Chlorine may be delivered by _____ solution feed chlorinators. The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.

15. A reservoir has a surface area of 51,200 square feet and the desired dose of copper sulfate is six pounds per acre. How many pounds of copper sulfate will be needed?

16. A polymer feed pump delivers a flow of 200 gallons per day containing a five percent polymer solution with a specific gravity of 1.02. Estimate the polymer delivered in pounds per day.

17. Estimate the actual dose in milligrams per liter if a plant treats a raw water with a flow of 1.8 MGD. The alum feed rate is 135 pounds per day.

18. Liquid polymer is supplied to a water treatment plant as a ten percent solution. How many gallons of liquid polymer should be mixed in a tank with water to produce 200 gallons of 0.6 percent polymer solution?

19. Determine the strength of a polymer solution as a percent if 80 grams (80 gm/454 gm/lb = 0.176 lbs.) of dry polymer are mixed with four (4) gallons of water.

20. Estimate the overflow rate in gallons per minute per square foot for a rectangular sedimentation basin 20 feet wide and 40 feet long when the flow is 0.5 MGD.

21. Estimate the flow velocity in feet per minute through a rectangular sedimentation basin 20 feet wide and 8 feet deep when the flow is 350 GPM.

22. Estimate the weir loading rate in gallons per minute per foot of weir length for a 30-foot diameter circular clarifier treating a flow of 350 GPM. The weir is located on the water edge of the clarifier.

23. Color and odor problems are most likely to occur under what conditions?
24. Ineffective or inadequate filter conditions may result in:
25. A filter has been brought back into service after backwashing. You have found excessive head losses are still being recorded for the filter. What might be the cause of this situation?
26. When the “**safe yield**” of a well is exceeded and water continues to be pumped from a well, what is the possible consequence?
27. When water cannot be softened to the desired level with lime only, it contains:
28. Which component should be included in the intake structure?
29. What is an underground layer of rock or soil which permits the passage of water?
30. Water which is evaporated into the atmosphere has the following characteristics:
31. A sanitary survey would always include looking for:
32. In watersheds containing large quantities of vegetation such as chaparral, it has been noted that there is an increase in organic loading and in associated _____ immediately following periods of major runoffs.
33. Surface water supplies are more likely to experience:
34. Which diseases may be transmitted through the contamination of water supplies?
35. Many of the instrument systems used in water treatment plants are combinations of previously described systems, and are commonly referred to as Hybrid systems. Perhaps the most widely used method of automatically controlling pumps, valves, chemical feeder, and other devices is known as _____.
36. When water reaches an impermeable surface, it becomes:
37. What is the chemical symbol for **Calcium**?
38. A grab sample may be used for the following water tests:

39. When collecting a water sample from the distribution system, what should not be used as a sample location?
40. You should include what information when you collect a water sample?
41. Before determining the pH of a sample, the pH meter should be:
42. Iron and manganese are undesirable in water because:
43. Low levels of iron and manganese may be removed by the addition of:
44. Iron and manganese usually do not create problems in surface water because they form insoluble compounds in the presence of:
45. After cleaning sludge basins and before returning the tanks into service, the tanks should be:
46. Chlorine dioxide may be used as a disinfectant but it seems to react with:
47. What is the name of a device that has a transparent tube with a tapered bore that contains a ball and is often used to measure the rate of a gas or liquid especially chlorine?
48. Which factors are important in providing good disinfection with chlorine?
49. Larger plants or plants that produce large volumes of sludge may use _____ processes to reduce the volume of sludge that must be handled and ultimately disposed of. Sometimes polymers are added to sludges for conditioning prior to dewatering. Belt filter presses, centrifuges, solar lagoons, and sand drying beds are some of the processes used to dewater sludges.
50. Which chemical will dissolve in water to form an anion?
51. A volume of 600 ml is equal to how many liters?
52. A weight of 4,500 mg is equal to how many grams?

53. The equipment service card tells what should be done and when, while the service card tells?
54. What conditions must be prevented to protect public health when using a fluoridation system?
55. Which water treatment chemicals must not be overfed due to possible illnesses?
56. What safety characteristic are the most important to know about fluoride chemicals?
57. High levels of fluoride may cause staining of the teeth which is called:
58. The maximum contaminant level for fluoride in drinking water is:
59. Which processes are used to remove minerals from water using a phase change?
60. The gradual decomposition or destruction of a material (**Such as a metal or cement lining**) as it reacts with water is referred to as:
61. The removal of hydrogen from a cathode is called:
62. The mixing of the raw water and a coagulant chemical in order to be treated is referred to as:
63. Alkalinity and pH are important factors in coagulation and may be used:
64. Which flocculation basins will give the best results?
65. One of the major drawbacks to the use of ozone as a disinfectant for drinking water is:
66. The best way to compare filter runs is by using this technique.
67. Powdered activated carbon is **hydrophobic**, this means that:
68. One of the disadvantages of using **PAC** is:
69. Remote monitoring and control over long distribution systems can be best accomplished by using?
70. Which duties are the most difficult for a newly promoted supervisor?

71. Record keeping is an important part of plant operations because:

72. The D/DBP rule attempts to future reduce potential formations of harmful disinfection by-products by requiring the removal of THM precursors. A treatment technique of enhanced coagulation, enhanced softening, or use of GAC applies to conventional filtration systems. In most cases, systems must reduce _____ levels based on specific source water quality factors.

73. Identify corrosive substances that may be found in a laboratory.

74. This Rule is a set of treatment technique requirements that apply to all water systems using surface water and those using groundwater that is under the influence of surface water. This rule requires that these systems properly filter the water unless they can meet certain strict criteria. This rule also requires that all systems using surface water disinfect the water; there are no exemptions from the disinfection requirements.

75. How should you add acid to water?

76. If a motor is rated for 10 amps, what size of overload relays should be used with this motor?

77. What information is important to know when storing lubricants?

78. A reciprocating pump or piston pump should never be operated:

79. What is the advantage of a double suction pump?

80. Direct current may be used for standby lighting in a water treatment facility. The electrical current used in a **DC** (direct current) system comes from:

81. An inventory should be kept filled of parts and supplies for which there is a definite need. A definite need is an item:

82. If an overload relay on a three phase motor is constantly being tripped, the operator should:

83. What factors affect the cost of providing water to customers?

84. What substance may be used in electrical wiring to prevent the flow of electricity?

85. When the temperature decreases what happens to the chemical reaction rate?

86. The complete absence of oxygen in water can be described as:

87. Clear wells or plant storage reservoirs are usually filled:
88. Which organisms can carry water borne diseases?
89. Which activity is the best method of informing the public about your utility's efforts to provide a safe high quality water supply?
90. What reaction will happen if you were going to add lime to water?
91. A high level of suspended solids in the raw water will result in a _____ of sludge solids produced by the plant.
92. Identify physical characteristic(s) of water.
93. A recorder which measures flow is most likely to be found:

Practice Exam Number 2 Answers

1. Colloidal Suspensions
2. Iron and manganese
3. Iron Bacteria
4. Bacteria
5. Overemphasized
6. Epidemiology
7. U.S. Environmental Protection Agency
8. Reduction
9. Reservoir bottom sediments
10. Cathodic protection
11. Determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and correct.
12. Bromine
13. 10
14. Vacuum-controlled
15. 7.1 lbs.
16. 85
17. 9.0
18. 12 gallons
19. 0.52%
20. 0.43 GPM/sq. ft.
21. 0.29 ft/min
22. 3.7 GPM/ft
23. Anaerobic
24. Mud Balls in filter media
25. Clogged underdrain
26. Land subsidence around the well
27. Noncarbonate hardness
28. Cathodic protection
29. Aquifers
30. Absence of salts
31. Cross-connections
32. THM Precursors
33. Variations in turbidity
34. Giardiasis, Hepatitis, Typhoid
35. Relay Logic
36. Direct runoff
37. Ca
38. pH, Bacteria and Temperature
39. A faucet with an aerator
40. Sample location, date, and time of collection and the name of the sampler
41. Standardized with a known buffer
42. They cause stains and promote the growth of iron bacteria
43. Polyphosphates
44. Fluoride
45. Inspected, repaired if necessary, and disinfected
46. Iron and manganese
47. Rotameter
48. Good contact time and low turbidity
49. Thickening, Conditioning, and Dewatering
50. Sulfate
51. .60

52. 4.5
53. What maintenance has been done
54. Undersaturation
55. Fluoride
56. All fluoride chemicals are extremely corrosive
57. Mottling
58. 4.0 mg/L
59. Electrodialysis
60. Corrosion
61. Depolarization
62. Flash Mixing
63. To determine the best chemical coagulant to be used
64. A compartmentalized basin with a reduction of speed in each compartment
65. Ozone does not provide a residual In the distribution system
66. Unit Filter Run Volume
67. Does not mix readily with water
68. It is very abrasive and requires careful maintenance of equipment
69. Telemetry
70. Delegating instead of doing the work themselves
71. Records are needed for effective management and satisfy legal requirements
72. TOC
73. Hydrochloric acid, Sulfuric Acid, Glacial Acetic Acid, Caustic Soda
74. SWTR
75. Add the acid to water slowly
76. 10 to 11 amps
77. Lubricants are flammable
78. With a Closed discharge valve
79. An increase in the pump output capacity
80. A battery
81. That is frequently used and is vital to the operation of the plant
82. Find the cause of tripping and repair it
83. The turbidity of raw water
84. Rubber
85. The rate decreases
86. Anaerobic
87. When demand is low usually late evening and early morning
88. Viruses/Bacteria and Intestinal parasites
89. Plant tours
90. The alkalinity will increase and the pH increases
91. Increase
92. The physical characteristics of water include suspended sediments and temperature. Chemical characteristics include nutrients, toxics, and dissolved oxygen. Biological aspects include bacteria, algae, insects, and fish.
93. At a central location at the plant

Practice Exam Number 3

Answers are in the rear of this section.

1. An action plan should be....
2. An example of a technological threat that a waterworks can potentially encounter is....
3. Once a threat of contamination has been determined to be "credible," what is one of the first steps to confirm or eliminate the threat?
4. Preparing emergency response plans for water systems is the responsibility of....
5. What is the difference between an emergency and a disaster?
6. Which physical property of a substance can contribute to the severity of a biological contamination event?
7. Adequate lighting around a utility treatment plant's perimeter fencing may result in deterrence and....
8. What document assigns specific responsibilities to individuals and teams to take actions other than their normal required duties?
9. Which of the following is most useful in a water emergency?
10. At a minimum, how often should an emergency response plan be updated?
11. What document describes the actions that a waterworks would enact during disasters or other unexpected incidents?
12. Vegetation around the perimeter of water facilities....
13. Identify an important step involved in conducting a vulnerability assessment?
14. Delivery of treatment chemicals and materials can pose a security risk. Which of the following is the best way to reduce a treatment plant's vulnerability?
15. What is the main difference between a tagout system and a lockout system?
16. What is considered the most dangerous type of overexposure when using dry chemicals?

17. Name one of the most common hazards associated with the use of polymers?
18. What is the best way to treat an acid spill?
19. What type of hazard exists when working with dry alum?

Grades 1 and 2 Operators

20. What chemical may be added to remove low levels of iron and manganese?
21. What must be present in water for iron and manganese to form insoluble compounds?
22. What chemical may be added to water to reduce the corrosivity?
23. What is the gradual decomposition or destruction of a material as it chemically reacts with water referred to as?
24. The sedimentation basin in most plants are sized so that at least two basins are available. What does this allow?
25. Name a strong oxidant commonly used to control taste and odor problems?
26. Powdered activated carbon is hydrophobic. What does this mean?
27. Where is the best location for adding PAC?
28. As the pH of water increases, what happens to the alkalinity?
29. Name a reaction which takes place when lime is added to water?
30. What will increasing the aeration rate do to volatile substances in water?
31. Define sedimentation.
32. Why is powdered activated carbon frequently used for taste and odor control?
33. Which type of microorganism may develop if there are elevated levels of iron or manganese in the water?

34. Why are the elements iron and manganese undesirable in water?

35. Powdered activated carbon may be used with some success in removing which group of chemicals?

Grades 3 and 4 Review

36. What is the most common process used to remove iron and manganese from drinking water?

37. Why would you increase the dosage of chlorine dioxide in water high in iron and manganese?

38. What will effectively control iron and manganese if the concentration of both is relatively low?

39. Potassium permanganate is sometimes used for taste and odor control. What other process is this compound sometimes used for?

40. When added to a treatment process, which chemical will increase the pH the most?

41. A water treatment plant contains naturally occurring organics and is using a lime softening treatment at a pH of 10.5. What effect will the pH have on the production of THMs?

42. As the pH of water increases, what happens to the alkalinity?

43. Identify a reaction which takes place when lime is added to water?

44. What will increasing the aeration rate do to volatile substances in water?

45. Define sedimentation.

46. What is the definition of 'accuracy'?

47. The relationship between the alkalinity constituents' bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity. What do P and T represent?

48. What is a 'reagent'?

49. What is 'chelation'?

50. What is the definition of 'normality'?

51. What is the chemical name for Alum?
52. What is the molecular formula of Alum?
53. What chemical may be added to raw water to prevent the precipitation of Ca^{+2} and Mg^{+2} cations to prevent fouling?
54. Which of the four different filter media characteristics is the most desirable?
55. Which characteristics are important in the design of a flocculator?
56. How is the mixing for the rapid dispersion of chemicals and other materials throughout the water best accomplished?
57. What does the term 'Gt' represent in flocculation?
58. What is perikinesis?
59. Which design condition of a flocculation chamber prevents floc destruction in conjunction with sufficient mixing to achieve floc formation?
60. Which mechanism is predominant in the flocculation process of water treatment?
61. The rinse water used after regeneration of an ion exchange softener has a high concentration of?

Practice Exam Number 3 Section Answers

1. A short, concise summary of the emergency response plan
2. Cyber-attack on the SCADA system
3. Collection of samples for analysis
4. Facility owner
5. A disaster requires resources beyond the capability of the local government
6. Survivability in water
7. Detection
8. Emergency response plan
9. Sources of alternative water supplies
10. Annually
11. Emergency response plan
12. Should be evaluated to minimize vulnerability
13. Determine against what type of assailants and threats you are trying to protect
14. Verify the credentials of all delivery drivers
15. A tag is a warning device while a lock provides a physical restraint
16. Inhalation of chemical dust
17. Polymers are very slippery and may create an unsafe working environment
18. Liberally sprinkle baking soda on the spill or flush the spill with water
19. Irritation due to dermal contact, eye contact, or inhalation

Grades 1 and 2 Operators

20. Polyphosphates
21. Oxygen
22. Lime
23. Corrosion
24. Maintenance may be performed on one basin without requiring a complete plant shut down
25. Potassium permanganate
26. PAC does not mix readily with water
27. Where flash mixing takes place
28. It progressively shifts to carbonate and hydroxide forms
29. The pH increases, calcium and magnesium become less soluble, and the alkalinity increases.
30. Increase the removal of volatile compounds
31. The process in which solid particles settle out of the water being treated in a large Clarifier or sedimentation basin
32. PAC is non-specific and removes a broad range of compounds
33. Iron bacteria
34. They cause stains and promote the growth of iron bacteria
35. Precursors of THMs

Grades 3 and 4 Review

36. Oxidation, precipitation, filtration
37. Because it is an effective oxidizing agent
38. Feeding polyphosphate and chlorine
39. Disinfection
40. Caustic soda
41. THMs will be produced much faster under these conditions
42. It progressively shifts to carbonate and hydroxide forms
43. The pH increases, calcium and magnesium become less soluble, and the alkalinity increases.
44. Increase the removal of volatile compounds
45. The process in which solid particles settle out of the water being treated in a large Clarifier or sedimentation basin
46. How closely an instrument measures the true or actual value

- 47. Phenolphthalein / total alkalinity
- 48. A substance used in a chemical reaction to measure, detect, examine, or produce other substances
- 49. A chemical process used to control scale formation in which a chelating agent "captures" scale-causing ions and holds them in solution.
- 50. It is the number of equivalent weights of solute per liter of solution
- 51. Aluminum sulfate
- 52. $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$
- 53. Polyphosphates
- 54. Insoluble in water
- 55. Detention time and proper stirring intensity
- 56. By generating intense turbulence in the water
- 57. (Detention time) x (mixing intensity)
- 58. Aggregation resulting from random thermal motion of fluid molecules
- 59. Enhancing laminar flow
- 60. Orthokinesis
- 61. Calcium chloride and magnesium chloride

Operator Certification Practice Exam 3A *No Answers Provided*

1. What does **MCL** stand for?
2. This term means the aliquot of finished drinking water that is examined for the presence of coliform bacteria. This sample volume is 100 milliliters and is commonly referred to as:
3. This term means 1 of the family of organic compounds, named as derivatives of methane, wherein 3 of 4 hydrogen atoms in methane are substituted by a halogen atom in the molecular structure.
4. What term best represents an oxidant, including chlorine, chlorine dioxide, chloramines, ozone, or an equivalent agent or process such as ultraviolet light, that kills or inactivates pathogenic organisms?
5. Reservoirs which are nutrient-poor and contain little plant or animal life are known as:
6. What is the definition of “**backflow**”?
7. What is a compliance cycle?
8. What is a compliance period?
9. Name the three types of public water systems.
10. How many persons does a small water system serve?
11. How many persons does a medium water system serve?
12. How many persons does a large water system serve?
13. What is a **POE**?
14. What is a **VOC**?
15. Many water quality problems in domestic water supply reservoirs occur in reservoirs containing moderate or large quantities of nutrients such as phosphate, _____ compounds.

16. _____ filtration rates and increased frequency of filter backwashing are reflected in an inability to meet system water demands and increased water treatment costs.
17. A major problem associated with algal blooms is that certain species of algae tend to clog filters at water treatment plants and thereby reduce both filtration rates and the duration of filter runs. Normal filter runs will last _____ before cleaning is required.
18. When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with this term in the stratified waters.
19. When significant levels of dissolved oxygen are present, iron and manganese exist in an _____ state and normally precipitate into the reservoir bottom sediments?
20. One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for:
21. The proper pH range must be maintained because coagulants generally react with the alkalinity in water. What is the pH range for the best coagulation?
22. The information furnished by a sanitary survey is essential to evaluating the bacteriological and chemical quality data. What items are essential or considered in a sanitary survey?
23. The minimum detention time recommended for flocculation ranges from about:
24. This substance or mixture is a pure chemical substance that is used to make new products or is used in chemical tests to measure, detect, or examine other substances. Jar test _____ can be prepared at several concentrations, depending upon desired dosage.
25. Which of the following terms best represents the definition of the property of a material or soil that permits considerable movement of water through it when it is saturated.
26. Which of the following are desirable filter media characteristics?
27. The volume of a reservoir is estimated to be 581,000 cubic feet. Estimate the volume in acre-feet.

28. Determine the actual chemical feed in pounds per day from a dry chemical feeder. A bucket placed under the chemical feeder weighed 0.3 pounds empty and 2.1 pounds after 30 minutes.

29. A small chemical feed pump lowered the chemical solution in a three-foot diameter tank one foot and seven inches during an eight-hour period. Estimate the flow delivered by the pump in gallons per minute.

30. The optimum liquid alum dose from the jar tests is 12 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the plant flow is 4.7 MGD. The liquid alum delivered to the plant contains 642.3 milligrams per milliliter of liquid solution.

31. Convert a flow of 800 gallons per minute to million gallons per day.

32. Determine the chlorinator setting in pounds per 24 hours to treat a flow of 2 MGD with a chlorine dose of 3.0 mg/L.

33. A reservoir has a volume of 6.8-acre feet. What is the reservoir in million gallons?

34. To check an ion exchange unit for iron fouling the operator should make careful observations during the backwash cycle and look for:

35. Identify one physical characteristic of water.

36. How is groundwater produced?

37. What are plant nutrients which may cause an increase in the growth of algae?

38. Fluoride is added to a water supply:

39. What are the essential factors that should be considered during a **Sanitary Survey**?

40. What is the chemical symbol for chlorine?

41. A rotameter measures gallons per hour or pounds per day, and is commonly used to determine chemical feed rates for:

42. A cross-connection in a water supply is:

43. Pneumatic systems are not reliable as transmission lines over:
44. Surface water such as rivers and lakes are the result of which process?
45. What will result when calcium carbonate or limestone is added to water?
46. Before entering the chlorine room to check on a chlorine leak, the operator should:
47. What are the two forms of activated carbon which are used in water treatment?
48. Powdered Activated Carbon, or **PAC** is commonly used in water plants for what purpose?
49. What is the chemical name of **Cu** ?
50. Which piece of labware may have a glass stopcock that must be lubricated?
51. The simplest way to define an organic compound is that it:
52. A water sample may be collected from a surface water or basin by hand. To do this, the sample bottle should be plunged mouth down below the surface then tilted upward to allow _____ to escape from the bottle.
53. Excessive turbidity during disinfection will:
54. What should be used to test for chlorine leaks around valves and piping?
55. When the temperature of a chlorine cylinder is increased, the chlorine will:
56. Why do many operators chlorinate past the breakpoint?
57. If you cannot open the valve on a chlorine cylinder because it is too tight, you should:
58. If there is a chlorine leak in the chlorine tank, the chlorine gas will accumulate:
59. Which of laboratory tests should be done immediately with no holding time?
60. The best place to take a water sample from the distribution system is from:

61. A Grab Sample should be used when testing for:
62. You should never use a composite sample when testing for:
63. If an operator was to put water on a leaking chlorine cylinder, which of the following is most likely to occur?
64. If the chlorination system goes out of service or operation, what should be done?
65. Chlorine gas enters the injector, this makes the chlorine:
66. What is the purpose of the ejector on a hypochlorinator?
67. Which safety device found on chlorine cylinders?
68. Sodium Hypochlorite compounds have all of the following properties:
69. What chemical may be added to water to reduce corrosivity?
70. Corrosive water may cause:
71. When a hypochlorinator is taken out of service, the most important and very first step should be:
72. What type of fittings and gaskets should be used when making connections to chlorine containers?
73. When determining the chlorine use rate, the scales or meters should be read?
74. A major problem with air in aerobic water is when iron and manganese passes in solution. What will occur?
75. What is the purpose of a sanitary survey?
76. What condition may occur when filters are clogging ?
77. Cascade systems and spray aerators may develop what types of maintenance problems?

78. What will the combination of moisture and potassium permanganate produce?
79. What strong oxidant can be used to control taste and odor problems?
80. Which chemical removes tastes and odors by adsorption only?
81. Aeration can remove volatile substances from water. Increasing the aeration rate in such systems will:
82. A standard solution is a prepared chemical solution in which:
83. What precautions are necessary when mixing dry polymer solutions?
84. Powdered activated carbon is frequently used for taste and odor control because:
85. What are the necessary emergency procedures in case of a large uncontrolled chlorine leak?
86. The water temperature decreases from 70° F (21° C) to 40° F (4°C). To maintain good disinfection you need:
87. Chlorine reacts with phenol which can cause:
88. When making a new connection on a chlorine feed system, the gaskets should be:
89. The best pH range for coagulation is:
90. Good coagulation and flocculation processes promote the removal of natural organic compounds from the water which also aids the treatment process by:
91. Large, light floc particles which are formed in the coagulation flocculation process are more likely to:
92. _____ is undesirable and may result in shortened filter runs and loss of media during backwash.
93. The _____ detention time recommended for flocculation ranges from about _____ minutes for direct filtration systems and up to 30 minutes for conventional filtration.

94. The two factors which determine whether or not a change in filter media size should be made are:
95. If an increase in raw water turbidity and an increase in coagulation feed rate creates additional loading on the filter, which operational changes may be helpful?
96. A detailed evaluation and inspection of a new water supply source should be made to identify and protect against sources of pollution. What would you call this type of evaluation?
97. If you exceed the “**safe yield**” what may happen?
98. Organic chemicals such as pesticides may enter a surface water supply through:
99. Acid rain is the result of:
100. Under normal plant conditions the flow is 3.0 MGD and a one minute flash mixing in the jar test is adequate. If the plant flow increases to 4.0 MGD, how long of fast mix is needed in the jar test?
101. An organic chemical is causing taste and odor problems in the water distribution system. What might cause these problems?
102. A very small percentage of chlorine in the air is most likely to:
103. The chlorine storage ventilation equipment should be checked:
104. What would happen if the temperature of a full chlorine cylinder is increased by a temperature of 50°F or 30°C?
105. The effectiveness of disinfection may be determined by:
106. The chlorine gas lines connected to the evaporator have been incorrectly connected to the liquid side of the chlorine container. When this happens the most likely result will be:
107. What should be the target value for the free chlorine residual in the distribution system?
108. Which factors will influence the effectiveness of chlorination?

Operator Certification Practice Exam # 4

1. What is the monitoring frequency for inorganic chemicals that a community water system or non-community water system must sample.
a) groundwater b) surface water
2. After the initial 4 quarters of radiochemical monitoring, what is the monitoring frequency for sampling radiochemicals at a community water system?
3. Blending is an approved method to achieve compliance with maximum contaminant levels provided the Department has given written approval to a blending plan. Name the 5 elements which must be included in the blending plan.
4. Bottled water may be used on a temporary basis to avoid an unreasonable risk to health. If bottled water is used, what is the responsibility of the public water system?
5. A groundwater system may need to provide disinfection if one of three events occur. Name 1 of the 3 events.
6. Because both iron and manganese react with dissolved oxygen to form **INSOLUBLE COMPOUNDS**, they are not found in high concentrations in waters containing dissolved oxygen, except as _____ of the oxide.
7. A good definition for the term _____ are compounds that cannot be dissolved.
8. Define very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge. When most of the particles in water have a negative electrical charge, they tend to repel each other. This repulsion prevents the particles from clumping together, becoming heavier and settling out.
9. Iron and manganese in water can be easily detected by observing the color of the inside walls of the filters and the filter media. If the raw water is pre-chlorinated, there will be this color stain on the walls below the water level and the same color coating over the top portion of sand filter bed.
10. An _____ is something peculiar to particular people or locality, such as a disease which is always present in the population.
11. Although saturated solutions of sodium fluoride can be manually prepared, generally the easiest and best way is an automatic feed device. Only _____ sodium fluoride should be fed with a saturator.

12. Water can be softened before use with fluoridation equipment by the use of zeolite ion exchangers. As an alternative to the zeolite water softener, _____ may be used to prevent plugging by scale in the feed system.

13. Alkalinity is the capacity of water to neutralize acids. This capacity is caused by the water's content of carbonate, bicarbonate, hydroxide, and occasionally borate, silicate, and phosphate. Alkalinity is expressed in milligrams per liter of equivalent calcium carbonate. Alkalinity is not the same as pH because water does not have to be strongly basic to have a high alkalinity. Alkalinity is a measure of how much acid must be added to a liquid to lower the pH to:

14. Alkalinity is the capacity of water to neutralize acids. Total alkalinity is the sum of the bicarbonate, carbonate, and hydroxide. Which chemical can raise alkalinity in water?

15. Fresh water supplies, which have been the major sources of water developed in the past, usually contain less than 1,000mg/L of total dissolved solids. Secondary drinking water standards recommend 500 mg/L TDS as the limit. Waters containing slightly higher concentrations can be used without adverse effects. The selection of a demineralization process for a particular application depends on several factors including:

16. As our country's population continues to grow, so does our demand for more water resources. Traditionally, water supplies have been obtained from "**fresh water**" sources. This constantly increasing need for water has started to deplete the available fresh water supplies in some areas of the country. Faced with potential shortages, water planners must now consider new treatment technologies which until recently were not considered to be economically feasible. One type of water treatment process is freezing and distillation, this process is applied primarily to:

17. Methods of removing minerals from water can be divided into two Classes: 1). Those that use a phase change such as freezing or distillation. 2). Non-phase change methods such as reverse osmosis, electrodialysis, and ion exchange. _____ has been primarily used to remove dissolved inorganic material (**TDS**) from industrial and wastewater, municipal water and wastewater, and seawater. However, some processes will also remove suspended material, organic material, bacteria, and viruses.

18. This term is used to describe the rate of water flow through a semipermeable membrane. It is usually expressed in gallons per day, per square foot of membrane surface or in grams per second per square centimeter.

19. Even under ideal conditions, pure feedwater and no fouling of the membrane surface, there is a _____ in the water flux with time.

20. This term is used to describe a shallow, small-volume storage pond in which treatment process sludge is concentrated and stored for extended time periods.

21. Sludge has a unique characteristic about it; once it has even partially dried, it will not _____, therefore, layer after layer of wet sludge can be added over a period of time.

22. _____ power is generally found in lighting systems, small pump motors, various portable tools and throughout our homes.
23. An alternating current circuit is one in which the voltage and current periodically change direction and _____. In other words, the current goes to zero to maximum strength, back to zero and to the same strength in the opposite direction.
24. Calculate the Langelier Index for a water with a calculated pH of 8.69 and an actual pH of 8.5.
25. In the determination of a chlorine residual by the drop-dilution method, three drops of sample produced a chlorine residual of 0.2 mg/L in 10mL of distilled water. Assume 0.05 mL per drop. Calculate the actual chlorine residual in milligrams per liter.
26. Which meter is most likely to include a totalizer?
27. Electrical probes may be used to sense water levels especially in tanks, however, one of the common problems with these probes is:
28. Which method of measuring flow is not subject to mechanical failure?
29. The period of time between the moment of change in a chlorinator control system and the moment when the change is sensed by the chlorine residual indicator is called:
30. If the concentration of iron and manganese is low, 0.3 mg/L and 0.1 mg/L respectively, effective control may be achieved by:
31. Iron and manganese react with DO to form:
32. The atomic number of chlorine is:

33. Backwash recovery ponds or lagoons are used to separate the water from the solids after the filters have been backwashed. The water is usually returned or recycled to the plant headworks for treatment with the source water. These ponds also may be used to concentrate or thicken sludges from sedimentation tanks. Sludges from _____ process are usually stored in lagoons. The drainage water is removed and the sludge may be covered or hauled off to a disposal site or applied to agricultural lands to achieve the best soil pH for optimum crop yields.

34. Larger plants or plants that produce large volumes of sludge may use _____ processes to reduce the volume of sludge that must be handled and ultimately disposed of. Sometimes polymers are added to sludges for conditioning prior to dewatering. Belt filter presses, centrifuges, solar lagoons, and sand drying beds are some of the processes used to dewater sludges.

35. What actions should be taken if media is being lost during the backwash cycle on a filter?

36. Which processes can be used to remove minerals from the water?

37. A potable water line connected to a chemical feeder for feeding fluoride should be equipped with:

38. A treatment plant is using a saturator to feed a sodium fluoride solution and the dilution water contains 85 mg/L hardness. In this situation, the dilution water must be _____ prior to use in the saturator.

39. A polyelectrolyte with a positive charge commonly used in water treatment as a coagulant aid or primary coagulant is also called:

40. During the coagulation process the coagulant causes the formation of floc through:

41. Under what condition would you speed up the flocculators?

42. When performing a jar test, the floc begins to settle before mixing is complete and 85% of the floc has settled after 2 minutes. These conditions indicate:

43. Detention time is a critical factor in which treatment units?

44. One of the hazards associated with the use of polymers in water treatment plants is:

45. What are important factors in the design of a flocculator?

46. A water treatment plant is feeding both alum and a cationic polymer. The lab has set up a jar test to test both coagulants. What is the best testing sequence for the jar tests?

47. In the Galvanic Series, the base metals are listed at the top are more reactive. Which metal would be near the top of the Galvanic Series?
48. Troubleshooting electric motors: What could be the cause for a mechanical noise from a motor?
49. This term represents a computer program that combines mapping with detailed information about the physical locations of structures such as pipes, valves, and manholes within geographic areas. The system is used to help operators and maintenance personnel locate utility system features or structures and to assist with the scheduling and performance of maintenance activities.
50. A water is considered stable when it is just saturated with calcium carbonate. The Langelier Index is a measure of:
51. This type of filtration is different from all other types of filtration in its method of operation. There is usually no pretreatment of the water. Disposal of backwash wastes is still a problem.
52. Which procedures are used in the disposal of sludges and brines?
53. Which procedures are used in the dewatering of sludge?
54. Sedimentation tanks should be drained and cleaned at least _____ and more often if the sludge buildup interferes with the treatment processes. Alum or polymer sludge solids content is only 0.5 to 1 percent for continuous sludge removal and 2 to 4 percent when the sludge is allowed to accumulate and compact.
55. Centrifuges have been used to dewater municipal sludges for some time. The principle advantage of this dewatering technique is that the density of the sludge cake can be varied from a thickened liquid slurry to a dry cake. The major limitation of using centrifuges is:
56. Name the two basic types of centrifuges.
57. _____ sludge has a tendency to cause soils to harden and does not provide any beneficial value.
58. The location of the water treatment plant and the methods used to ultimately dispose of the process wastes will dictate the monitoring and reporting requirements. These reporting requirements may be established by local or state health or pollution control agencies. Monitoring and reporting volumes of sludges or brines, percent solids, and other measurements which will prove that these processes are not:

59. Monitoring of filter effluent turbidity on a continuous basis with an on-line_____ is highly recommended. This will provide you with continuous feedback on the performance of the filtration process. In most instances, it is desirable to cut off filter operation at a predetermined effluent level.

60. Identify the following type of water treatment filtration method: This technology uses a thin layer of fine siliceous material that is deposited on a porous plate to serve as the filter. Chemical pretreatment is not required.

61. The Surface Water Treatment Rule requires that water systems using surface water, or groundwater under the influence of surface water achieve a ___% reduction of Giardia Cysts.

62. What step must be done when preparing M-Endo broth to be used in the membrane filter test for total coliform?

63. How is the standardization of a solution determined in the lab?

64. Name common filter control systems used in gravity filtration installations.

65. In _____ control systems, each filter effluent control valve is connected to a flowmeter. As the filter run continues and the media begins to clog, the control valve slowly opens to maintain a constant flow of water through the filter. A master controller is required to monitor the overall plant flow and adjust the flow rate of each filter accordingly.

66. The application rate for Powdered Activated Carbon is determined by:

67. In the _____ control system, the flow to each filter influent is “**split**” or divided by a weir. With this system, equal flow is automatically distributed to each filter. The filter effluent valve position is controlled by the water level in the filter. Each filter operates within a narrow water level range.

68. In the _____ filters, flow rate varies with head loss. Each filter operates at the same time, but at a variable water surface level. This system is relatively simple, but requires an effluent control structure to provide adequate media submergence. Effluent control structures are usually desirable with the other systems described here as well.

69. The rights of an individual to use water for domestic, irrigation or other purposes varies in different states. Some water rights stem from ownership of the land bordering or overlying the source, while others are acquired by a performance of certain acts required by law. What are the three basic types of water rights?

70. Testing records indicate that a motor has been tested for several years with a Megger. The tests indicate lower values than expected, but they have remained stable and consistent. What should be done with the motor?

71. How can you reduce the starting load from a pump?

72. The following list is for general preventative maintenance service: check water seal packing glands for leakage; see that the _____ is protected with a clear water supply from an outside source; make sure that the water seal pressure is at least 5 PSI greater than maximum pump suction pressure; check packing glands for leakage during operation; and allow a slight seal leakage during pump to keep packing cool and in good condition.

73. Compressors are commonly used in the operation and maintenance of water treatment of water treatment plants. They are used to activate and control pump control systems, valve operators, and water pressure systems. Air compressors generate heat during compression which causes:

74. Fluoride produces two effects, depending on its concentration. At levels of 6 to 8 mg/L. fluoride may cause skeletal fluorosis and stiffening of the joints. For these reasons fluoride has been added to the list of primary standards. The MCL established for fluoride in drinking water is:

Operator Certification Practice Exam # 4 Answers

1. a) 1 sample at each sampling point once every 3 years, b) 1 sample annually at each surface water sampling point.
2. Once every 4 years
3. Individual test results from all sources proposed to be blended.
4. The PWS is required to provide sufficient quantities of bottled water to every person served by the PWS via door-to-door bottled water delivery
5. All three are correct.
6. Colloidal Suspensions
7. Insoluble Compounds
8. Colloidal Suspensions
9. Black
10. Endemic
11. Crystal-grade
12. Polyphosphates
13. 4.5
14. Soda Ash
15. Mineral concentrations in feedwater. Product water quality desired. Brine disposal facilities.
16. Seawater demineralization
17. Demineralization
18. Flux
19. Decline
20. Solar Drying beds or lagoons
21. Expand
22. Single phase
23. Amplitude
24. -0.19
25. 13 mg/L
26. Flow Meter
27. The probe may be coated by calcium carbonate
28. Venturi meter
29. The detection lag
30. Feeding polyphosphate and chlorine
31. Insoluble compounds

32. 17
33. Lime-soda softening
34. Thickening, Conditioning, and Dewatering
35. Adjust the backwash flow rate
36. Distillation, RO and freezing
37. An air gap or vacuum breaker
38. Soften
39. A cationic polymer
40. A physical and chemical reaction with the alkalinity in the water
41. A lower water temperature
42. Too much polymer
43. Flocculation basin
44. Polymers are very slippery and hard to remove from floors
45. Detention time and proper stirring intensity
46. In the first test, vary the polymer dose but keep the alum the same; in the next test sequence, vary the alum dose but keep the polymer dose the same.
47. Magnesium
48. Mechanical unbalance of rotating parts
49. GIS
50. Corrosivity
51. DE
52. Spreads on land, Landfills, and Sewers, not Floating Headers
53. Solar drying beds, Centrifuges, Filter Presses and Belt Presses.
54. Twice a year
55. High energy consumption
56. Scroll and basket type
57. Alum
58. Causing adverse environmental impacts
59. Turbidimeter
60. DE
61. Four log
62. The media shall be autoclaved
63. Titration
64. Split flow, Declining rate and Self-backwash
65. Rate-of-flow
66. Jar tests and threshold odor number testing
67. Split Flow
68. Declining Rate
69. Riparian, Appropriative, Prescriptive
70. No need for concern but the testing should be continued
71. Throttle down the discharge valve on the pump
72. Stuffing or Packing Box
73. Oil lubricants to break down quickly and requires frequent replacement
74. 4.0 mg/L

Memorize these for your exam.

Chemical Name	Common Name	Chemical Formula
Aluminum sulfate	Alum, liquid	$Al_2(SO_4)_3 \cdot 14(H_2O)$
Ammonia		NH_3
Ammonium		NH_4
Calcium Hypochlorite	HTH	$Ca(OCl)_2 \cdot 4H_2O$
Calcium hydroxide	Slaked Lime	$Ca(OH)_2$
Carbon	Activated Carbon	C
Carbon dioxide		CO_2
Carbonic acid		H_2CO_3
Chlorine gas		Cl_2
Chlorine Dioxide		ClO_2
Hydrofluorosilicic acid		H_2SiF_6
Hydrochloric acid	Muriatic acid	HCl
Hydrogen sulfide		H_2S
Hypochlorous acid		HOCL
Monochloramine		NH_2Cl
Potassium permanganate		$KMnO_4$ Strong Oxidizer
Sodium fluoride		NaF
Sodium fluorsilicate		Na_2SiF_6
Sodium hydroxide	Lye	NaOH
Sodium hypochlorite		NaOCl
Sodium Metaphosphate	Hexametaphosphate	Could Cut the Operator
Sodium sulfate		Na_2SO_4
Sulfuric acid		H_2SO_4

Cl ,

Cl_2

17 Atomic Number of Cl_2

10 PPM, IDLH

Cl_2 Fatal exposure limit

DPD

0.2 Mg/L

Small amount of Cl_2 exposure. Olfactory fatigue too

Halogenated Organics and THMS

Carbon

PAC

GAC

HTH storage

O₃

UV,

NH₃,

Cl₂NH₃

Too much Fluoride will?

Specific gravity

Acid to Water or Water to Acid?

pH, the power of hydroxyl ion activity measured by the reciprocal of the hydrogen ion on a logarithmic scale from 0-14.

Logarithmic: The power to which a base, such as 10, must be raised to produce a given number. If $n^x = a$, the logarithm of a , with n as the base, is x ; symbolically, $\log_n a = x$. For example, $10^3 = 1,000$; therefore, $\log_{10} 1,000 = 3$.

Precision: The extent to which a given set of measurements of the same sample agree with their mean.

Accuracy: The extent to which a given measurement agrees with the standard value for that measurement.

Groundwater Practice Exam

Groundwater exercise, answers in rear of this section.

1. Which source of water has the greatest natural protection from bacterial contamination?
 - A. Shallow well
 - B. Deep well in gravel
 - C. Surface water
 - D. Spring
 - E. None of the above

2. Which of the following should an operator investigate first when well pump and control problems occur?
 - A. Depth of supply
 - B. Piping
 - C. Electricity
 - D. Water leaks
 - E. None of the above

3. The pumping water level is best defined as the distance from the top of the well to the:
 - A. Intake screen of the pump
 - B. Location where the main flow of water enters a well
 - C. Water after the pump has been operating for a period of time
 - D. Water level from the start of a pump test to the end of the test
 - E. None of the above

4. A submersible pump would be a good choice in a well which:
 - A. Is straight and plumb
 - B. May not be straight and plumb
 - C. Brackish
 - D. Perched
 - E. None of the above

5. The cone of depression forms around:
 - A. A well during pumping
 - B. Bacteriological samples during incubation
 - C. Pump impellers cavitating
 - D. An air line
 - E. None of the above

6. A submersible pump is a:
 - A. Positive displacement pump
 - B. A double check valve assembly
 - C. A centrifugal pump
 - D. An Archimedes screw
 - E. None of the above

7. Turbine pumps are often used in large wells because they:
 - A. Use little energy
 - B. Can pump a wide range of flows
 - C. Require no lubrication
 - D. Use a submerged motor and wiring
 - E. None of the above

8. In a well, the difference between the pumping level and the static level is called:
- A. The static level
 - B. The yield
 - C. The drawdown
 - D. None of the above
9. Chlorine should be stored in a separate room from the well pump in order to:
- A. Reduce piping run length
 - B. Ensure complete disinfection
 - C. Prevent corrosion and enhance safety
 - D. Save on annual chemical costs
 - E. None of the above
10. The basic types of pumps used for pumping ground water wells are:
- A. Positive displacement and diaphragm pumps
 - B. Vertical turbine, line-shaft turbine and submersible pumps
 - C. Sewage ejector and screw pumps
 - D. Split-case, frame-mounted pumps and close-coupled vertically mounted pumps
 - E. None of the above
11. A vent fan for a chlorinator in a well house should be located:
- A. Near the pump
 - B. In the roof
 - C. Near the roof
 - D. Above the light switch
 - E. None of the above
12. Well screens serve mainly to:
- A. Aid chlorination
 - B. Prevent fine sand and soil particles from entering the pump
 - C. Exclude bacteria
 - D. Prevent artesian conditions
 - E. None of the above
13. Turbine pumps are often used in large wells because they:
- A. Use lots of energy
 - B. Can pump a wide range of flow
 - C. Require lots of lubrication
 - D. Use a submerged motor and wiring
 - E. None of the above
14. A multiple well supply system with varying quality sources would benefit by having:
- A. Cross-connections sources
 - B. Chlorination
 - C. Storage to allow blending sources
 - D. No answers apply
 - E. None of the above
15. To increase efficiency of a well you might:
- A. Place and develop a gravel pack
 - B. Reduce specific capacity
 - C. Increase motor size
 - D. Reduce iron content
 - E. None of the above

16. Iron (**Fe**) and manganese (**Mn**) are more likely to be a problem in:
- A. Ground level tanks
 - B. Surface water supplies
 - C. Ground water
 - D. The mid-west
 - E. None of the above
17. Well pits for pumps are considered hazardous because they are:
- A. Prone to cause accidents when employees climb in and out of the pit
 - B. Prone to cause condensate problems of the electrical equipment
 - C. Subject to collecting toxic gases
 - D. Subject to flooding
 - E. None of the above
18. A sanitary seal on a well is used to:
- A. Neutralize pressures
 - B. Prevent contamination
 - C. Color code the capacity
 - D. Prevent air from entering the casing
 - E. None of the above
19. You are chlorinating a well supply and the chlorine demand jumps from 0.9 mg/L to 3.0 mg/L. This is an indication that:
- A. More water is being pumped
 - B. Pollution was recently introduced
 - C. A weak chlorine solution is being fed and you need more of it.
 - D. The reagent in your test kit is out-of-date.
 - E. None of the above
20. When the static level of the ground water is 50 feet below the ground surface, the most suitable type of pump is a(n):
- A. Air lift pump
 - B. Gear pump
 - C. Horizontal centrifugal pump
 - D. Turbine pump
 - E. None of the above
21. The drawdown in a well is measured from:
- A. The motor base to the tip of the pump strainer
 - B. The static water level to the tip of the pump strainer
 - C. The static water level to the pumping water level
 - D. No answers apply
22. Which of the following well types is most protected from surface contamination?
- A. Artesian well
 - B. Infiltration gallery
 - C. Rock well
 - D. Shallow well
 - E. None of the above

23. The yield of a well could be affected by several factors, including:

- A. Depth into the aquifer
- B. Composition of the aquifer
- C. Temperature of the water
- D. All of the above
- E. None of the above

24. Ground water generally requires less treatment than surface water for:

- A. Radionuclides
- B. Industrial solvents
- C. Microorganisms
- D. Iron and manganese
- E. None of the above

25. What is a cone of depression?

- A. The drop in water level between the static water level and the pumping water level
- B. The distance between the original static water level and the level the water in a well reaches after the pumping stops
- C. A cone- or funnel-shaped well
- D. A depression in the free water surface in an aquifer as it flows toward a well during pumping
- E. None of the above

Answers

1. B, 2.C, 3.A, 4.A, 5.A, 6.C, 7.B,8.C,9.C, 10.B, 11.C, 12.B, 13.B, 14.C, 15.A, 16. C, 17.C, 18.B, 19.B, 20.D, 21.C, 22.A, 23.D, 24.C, 25.D

Water Quality Exam Review

Answers in rear of this exercise.

1. Disease causing bacteria are known as:
 - A. Coliforms
 - B. Noncoliforms
 - C. Nonpathogenic
 - D. Pathogenic
 - E. None of the above
2. Coliform bacteria are reported in organisms per:
 - A. liter
 - B. 100 milliliters
 - C. milliliter
 - D. plate
 - E. None of the above
3. The primary health risk associated with synthetic organic compounds (SOCs) is:
 - A. Acute respiratory diseases
 - B. Cancer
 - C. "Baby blue" syndrome
 - D. Reduced IQ levels in children
 - E. None of the above
4. The primary source(s) of synthetic organic compound (SOC) contamination in water supplies is (are):
 - A. Industrial solvents and agricultural pesticides
 - B. Mammalian fecal contamination of surface water
 - C. Agricultural fertilizers and natural mineral deposits
 - D. Disinfection by-products
 - E. None of the above
5. Normally, the pH of surface water and of ground water ranges from:
 - A. 9.0 to 10.5
 - B. 6.8 to 8.5
 - C. 1.5 to 4.0
 - D. No answers apply
6. One indication of corrosive water is a high concentration of:
 - A. Algae odors
 - B. Carbon dioxide
 - C. Carbonates
 - D. Total dissolved solids
 - E. None of the above
7. A cross-connection can best be described as:
 - A. A loose connection between any two water pipes.
 - B. A piping mistake, like when the pump inlet is connected to the outlet or vice- versa.
 - C. A situation which rarely happens.
 - D. A physical connection between a potable water supply and any other source of water of unknown, or unsafe quality.
 - E. None of the above

8. A chlorine taste is reported by two or more customers in a given section of town some distance from the plant. If you are required to handle all complaints and you receive this complaint, how should it be handled?
- A. Inform the plant manager that a chlorine taste problem exists and that they may need to cut down on chlorine.
 - B. Disregard, as they will get accustomed to the taste in a short time anyway.
 - C. Inform the customers that the chlorine taste is good for them.
 - D. Inform the plant manager that a chlorine taste problem exists and that they may need to add more chlorine.
 - E. None of the above
9. Which of the following best describes chlorine demand?
- A. The difference between the amount of chlorine added and turbidity
 - B. The difference between the amount of chlorine added and pH
 - C. The difference between the total chlorine residual and the free chlorine residual
 - D. The difference between the amount of chlorine added and the amount of residual chlorine after a given contact time
 - E. None of the above
10. Fusible plugs on chlorine cylinders are designed to melt at:
- A. 80° F
 - B. 102° F
 - C. 135° F
 - D. 158° F
 - E. None of the above
11. How is the water disinfected before it is delivered to the public through a water distribution system?
- A. Chlorination
 - B. Filtration
 - C. Fluoridation
 - D. Reduction
 - E. None of the above
12. What is the purpose of a check valve?
- A. To be a double check method for the meter flow of water
 - B. To act as a back-up system for air-vac valves
 - C. To prevent the reverse flow of water in a pipeline
 - D. To have an accounting system that checks all of the valves that a water system purchases
 - E. None of the above
13. What affects the flow of water in a pipeline?
- A. C factor, capillary action, and piezometric surfaces
 - B. Weir level, tees, and tuberculation
 - C. Pipe size, elbows, crosses, and tees
 - D. Elbows, C factor, and runoff
 - E. None of the above
14. A coupon test installation in a distribution system is used to:
- A. Determine the system's water quality
 - B. Determine the rate of scaling or corrosion
 - C. Calculate the daily treatment changes
 - D. Assist in calculating hydrant flows
 - E. None of the above

15. In a distribution system, which type of valve is usually used for isolation of a section?
- A. Check
 - B. Gate
 - C. Globe
 - D. Needle
 - E. None of the above
16. If the speed of a centrifugal pump is increased and the head remains the same, the gallons per minute output will:
- A. Decrease
 - B. Increase
 - C. Remain the same
 - D. Increase slightly, then decrease
 - E. None of the above
17. The most rapid damage to a centrifugal pump is from:
- A. Cavitation
 - B. Excessive head pressure
 - C. High velocity
 - D. Sand
 - E. None of the above
18. Which of the following is the most important reason to keep daily records of operational data?
- A. Maintain records for customer billing
 - B. Document the need for an increased budget
 - C. Provide insurance data
 - D. Document that safe drinking water has been delivered to customers
 - E. None of the above
19. What is the difference between a maximum contaminant level (MCL) and a secondary maximum contaminant level (SMCL)?
- A. MCLs relate to health effects, while SMCLs relate to aesthetic concerns
 - B. MCL violations automatically trigger acute violations while violations of SMCLs do not
 - C. MCL violation levels may not be superseded by the state, while SMCL violation levels may
 - D. MCLs relate to known effects of contaminants, while SMCLs relate to suspected effects of contaminants
20. A 4-log removal means _____ percent removal/inactivation:
- A. 99.9
 - B. 99.99
 - C. 99.999
 - D. 100.0
 - E. None of the above
21. What is the definition of a hazardous atmosphere?
- A. An atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful that may cause death, illness, or injury
 - B. An atmosphere that is only explosive and oxygen-deficient which may cause death to persons exposed to it
 - C. An atmosphere that contains less than 22% oxygen and otherwise harmful which may cause death, illness, or injury to persons exposed to it
 - D. An atmosphere that employees shall not be permitted to work in which contain more than 19.5% but less than 23.5% oxygen that will cause death
 - E. None of the above

22. How often should safety training be conducted to ensure a safe workplace for operators?

- A. After an accident
- B. Continuous and ongoing
- C. When employees have time
- D. Whenever needed
- E. None of the above

23. A grab sample represents:

- A. The quality of the water at the time the sample was taken
- B. Approximately 2 L of water
- C. A time-proportional sample
- D. A flow-proportional sample

24. American Water Works Association (AWWA) recommends that all storage structures be completely inspected every:

- A. 3 to 5 years
- B. Annually
- C. 4 to 8 years, depending on water quality
- D. Time the exterior requires painting
- E. None of the above

25. Reverse osmosis is a(n):

- A. Membrane process
- B. Air stripping procedure
- C. Type of chemical oxidation
- D. Backflow prevention procedure

Answers

1. D, 2.C, 3.B, 4. A, 5. B, 6. B, 7.D, 8. D, 9.C, 10. D, 11.A, 12.C, 13.C, 14.B, 15. B, 16.C, 17.A, 18. D, 19. A, 20. B, 21.A, 22.B, 23.A, 24.A, 25. A

Math Exercise Section

Volume in Cubic Feet

Cube Formula

$$V = (L) (W) (D)$$

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Depth}$$

Cylinder Formula

$$V = (.785) (D^2) (d)$$

Build it, Fill it, and Dose it.

1. Convert 10 cubic feet to gallons of water.

There is 7.48 gallons in one cubic foot.

2. A tank weighs 800 pounds, how many gallons are in the tank?

3. Convert a flow rate of 953 gallons per minute to million gallons per day.
There is 1440 minutes in a day.

4. Convert a flow rate of 610 gallons per minute to millions of gallons per day.

5. Convert a flow of 550 gallons per minute to gallons per second,

6. Now, convert this number to liters per second.

7. A tank is 6' X 15' x 7' and can hold a maximum of _____ gallons of water.
 $V = (L) (W) (D) \times 7.48 =$

8. A tank is 25' X 75' X 10'. What is the volume of water in gallons?
 $V = (L) (W) (D) \times 7.48 =$

9. In Liters?
 $V = (L) (W) (D) \times 7.48 =$ _____ $\times 3.785$

10. A tank holds 67,320 gallons of water. The length is 60' and the width is 15'. How deep is the tank?

Gallons _____ $\div 7.48 =$ _____ $60 \times 15 =$

11. The diameter of a tank is 60' and the depth is 25'. How many gallons does it hold?

Cylinder Formula
 $V = (.785) (D^2) (d)$

$.785 \times 60' \times 60' \times 25' \times 7.48 =$

Cubic Feet Information

There is no universally agreed symbol but the following are used:

cubic feet, cubic foot, cubic ft

cu ft, cu feet, cu foot

ft³, feet³, foot³

feet³, foot³, ft³

feet/-3, foot/-3, ft/-3

Water Treatment Production Math Numbering System

In water treatment, we express our production numbers in Million Gallon numbers.

Example 2,000,000 or 2 million gallons would be expressed as 2 MG or 2 MGD.

Hints. A million has six zeros; you can always divide your final number by 1,000,000 or move the decimal point to the left six places. Example 528,462 would be expressed .56 MGD.

12. The diameter of a tank is 15 Centimeters or cm and the depth is 25 cm, what is the volume in liters?

2.54cm = 1 inch, 12 inches = 1 foot

15 cm ÷ 2.54 cm ÷ 12 inches = .492 feet

.785 X .492' X .492' X _____' = _____ X 7.48 = _____ X 3.785 L =

Percentage and Fractions

Let's look again at the sequence of numbers 1000, 100, 10, 1, and continue the pattern to get new terms by dividing previous terms by 10:

.1 = 1/10

.01 = 1/100

.001 = 1/1000



So just as the digits to the left of the decimal represent 1's, 10's, 100's, and so forth, digits to the right of the decimal point represent 1/10's, 1/100's, 1/1000's, and so forth.

Let's express 5% as a decimal. $5 \div 100 = 0.05$ or you can move the decimal point to the left two places.

Changing a fraction to a decimal:

Divide the numerator by the denominator

A. 5/10 (five tenths) = five divided by ten:

$$\begin{array}{r} .5 \\ \text{-----} \\ 10 \overline{) 5.0} \\ \underline{50} \\ \text{----} \end{array}$$

So 5/10 (five tenths) = .5 (five tenths).

B. How about 1/2 (one half) or 1 divided by 2 ?

$$\begin{array}{r} .5 \\ \text{----} \\ 2 \) \ 1.0 \\ \underline{1 \ 0} \\ \text{----} \end{array}$$

So 1/2 (one half) = .5 (five tenths)

Notice that equivalent fractions convert to the same decimal representation.

8/12 is a good example. $8 \div 12 = .66666666$ or rounded off to .667

How about 6/12 or 6 inches? .5 or half a foot

Flow and Velocity

This depends on measuring the average velocity of flow and the cross-sectional area of the channel and calculating the flow from:

$$Q(\text{m}^3/\text{s}) = A(\text{m}^2) \times V(\text{m}/\text{s})$$

Or

$$Q = A \times V$$

Q CFM = Cubic Ft, Inches, Yards of time, Sec, Min, Hrs, Days

A = Area, squared Length X Width

V f/m = Inch, Ft, Yards, Per Time, Sec, Min, Ft or Speed

13. A channel is 3 feet wide and has water flowing to a depth of 2.5 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel?

$$Q = A \times V$$

$Q = 7.5 \text{ sq. ft.} \times 2 \text{ fps}$ What is Q?

$$A = 3' \times 2.5' = 7.5$$

$$V = 2 \text{ fps}$$

14. A channel is 40 inches wide and has water flowing to a depth of 1.5 ft. If the velocity of the water is 2.3 fps, what is the cfs flow in the channel? $Q = A \times V$

First we must convert 40 inches to feet.

$$40 \div 12 = 3.333 \text{ feet}$$

$$A = 3.333' \times 1.5' = 4.999 \text{ or round up to } 5$$

$$V = 2.3 \text{ fps}$$

We can round this answer up.

15. The flow through a 6 inch diameter pipe is moving at a velocity of 3 ft/sec. What is the cfs flow rate through the pipeline?

$$Q =$$

$$A = .785 \times .5' \times .5' =$$

$$V = 3 \text{ fps}$$

16. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?

$$Q = \text{_____ cfs} \times 60 \text{ sec/min} \times 7.48 = \text{_____ gpm}$$

$$A = .785 \times .667' \times .667'$$

$$V = 3.4 \text{ fps}$$

17. A 6 inch diameter pipe delivers 280 gpm. What is the velocity of flow in the pipe in ft/sec?

Take the water out of the pipe. $280 \text{ gpm} \div 7.48 \div 60 \text{ sec/min} = \underline{\hspace{2cm}}$ cfs

$Q =$

$A = .785 \times .5' \times .5' =$

$V =$

18. A new section of 12 inch diameter pipe is to be disinfected before it is placed in service. If the length is 2000 feet, how many gallons of 5% NaOCl will be need for a dosage of 200 mg/L?

Cylinder Formula

$V = (.785) (D^2) (d)$

$.785 \times 1' \times 1' \times 2000' = \underline{\hspace{2cm}}$ cuft $\times 7.48 = \underline{\hspace{2cm}} \div 1,000,000 = \underline{\hspace{2cm}}$ MG

Pounds per day formula = Flow (MGD) \times Dose (mg/L) \times 8.34 lbs/gal if 100% concentrate. If not, divide the lbs/day by the given %

$0.0117436 \text{ MG} \times 200 \text{ mg/L} \times 8.34 = \underline{\hspace{2cm}}$ lbs/day $\div .05 =$

19. A section of 6 inch diameter pipe is to be filled with water. The length of the pipe is 1320 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 3 mg/L?

$.785 \times .5' \times .5' \times 1320' \times 7.48 = \underline{\hspace{2cm}}$ Make it MGD

Pounds per day formula = Flow \times Dose \times 8.34 \times 45.4 Grams per pound

20. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 3.4 MGD with a chlorine dose of 3.35 mg/L.

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

21. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 85 GPM. Approximately how much will odor control cost annually if chlorine is \$0.17 per pound?

85 gpm X 1440 min/day = _____ gpd ÷ 1,000,000 = _____ MGD

_____ MGD X 15 mg/L X 8.34 lbs/gal X \$0.17 per pound X 365 days/year =

22. A wet well measures 8 feet by 10 feet and 3 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in millions of gallons per day (MGD).

Build it, fill it and do what it says, hint: X 9 X 24

Crazy Math Section

The metric system is known for its simplicity. All units of measurement in the metric system are based on decimals—that is, units that increase or decrease by multiples of ten. A series of Greek decimal prefixes is used to express units of ten or greater; a similar series of Latin decimal prefixes is used to express fractions. For example, *deca* equals ten, *hecto* equals one hundred, *kilo* equals one thousand, *mega* equals one million, *giga* equals one billion, and *tera* equals one trillion. For units below one, *deci* equals one-tenth, *centi* equals one-hundredth, *milli* equals one-thousandth, *micro* equals one-millionth, *nano* equals one-billionth, and *pico* equals one-trillionth.

23. How many grams equal 3,500 mg?

Just simply divide by 1,000.

Remember this “King Henry died by drinking Chocolate Milk”.

Kilo- Heca- Deca- Centi - Mili

Temperature

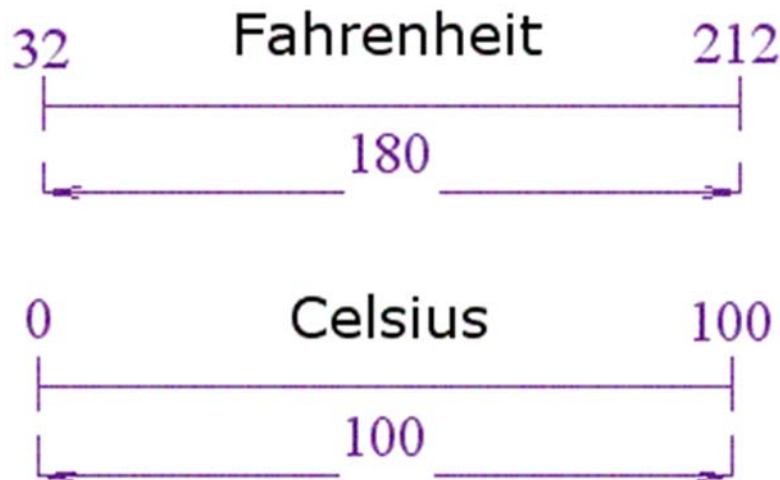
There are two main temperature scales. The **Fahrenheit Scale** (used in the US), and the **Celsius Scale** (part of the Metric System, used in most other Countries)

They both measure the same thing (temperature!), just using different numbers.

If you freeze water, it measures 0° in Celsius, but 32° in Fahrenheit

If you boil water, it measures 100° in Celsius, but 212° in Fahrenheit

The difference between freezing and boiling is 100° in Celsius, but 180° in Fahrenheit.



Conversion Method

Looking at the diagram, notice:

The scales start at a different number (32 vs. 0), so we will need to add or subtract 32

The scales rise at a different rate (180 vs. 100), so we will also need to multiply

And this is how it works out:

To convert from Celsius to Fahrenheit, first multiply by 180/100, then add 32

To convert from Fahrenheit to Celsius, first subtract 32, then multiply by 100/180

Note: 180/100 can be simplified to **9/5**, and likewise 100/180=**5/9**.

$$^{\circ}\text{F} = (^{\circ}\text{C} \times 9/5) + 32 \quad 9/5 = 1.8$$

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 5/9 \quad 5/9 = .555$$

24. Convert 20 degrees Celsius to degrees Fahrenheit.

$$20^{\circ} \times 1.8 + 32 = \text{F}$$

25. Convert 4 degrees Celsius to degrees Fahrenheit.

Water Treatment Filters

26. A 19 foot wide by 31 foot long rapid sand filter treats a flow of 2,050 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

GPM ÷ Square Feet

27. A 26 foot wide by 36 foot wide long rapid sand filter treats a flow of 2,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

Chemical Dose

28. A pond has a surface area of 51,500 square feet and the desired dose of a chemical is 6.5 lbs. per acre. How many pounds of the chemical will be needed?

43,560 Square feet in an acre

$51,500 \div 43,560 = \underline{\hspace{2cm}} \times 6.5 =$

29. A pond having a volume of 6.85 acre feet equals how many millions of gallons?

Q=AV Review

30. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the GPM flow rate through the pipe?

$Q = 1.18 \text{ CFS} \times 60 \text{ Seconds} \times 7.48 \text{ GAL/CU.FT} = 532 \text{ GPM}$

$A = .785 \times .667 \times .667 \times 1 = .349 \text{ Sq. Ft.}$

$V = 3.4 \text{ Feet per second}$

31. An 6 inch diameter pipe delivers 280 GPM. What is the velocity of flow in the pipe in Ft/Sec?

$280 \text{ GPM} \div 60 \text{ seconds in a minute} \div 7.48 \text{ gallons in a cu. ft.} = .623 \text{ CFS}$

$Q = .623$

$A = .785 \times .5 \times .5 = .196 \text{ Sq. Ft.}$

$V = 3.17 \text{ Ft/Second}$

32. Calculate the total dosage in pounds of a chemical. Assume the sewer is completely filled with the concentration. Pipe diameter: 18 inches, Pipe length: 420 feet, Dose: 120 mg/L.

Figure out the volume first.

$.785 \times 1.5' \times 1.5' \times 420' \times 7.48 = \underline{\hspace{2cm}}$ convert to MG

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

More Math Review, No answers provided, you can find the answers in the Sacramento manual.

1. A 17-inch water main is flushed at a velocity of 4.4 ft/sec. What should the reading on the flow meter be in cubic feet per second?

2. Convert a flow rate of 389 gallons per minute to millions of gallons per day.

3. A chlorine demand test from a well water sample produces a result of 1.12 mg/L. The water supplier maintains a chlorine residual of 0.24 mg/L throughout the system. What is the chlorine dose in mg/L from the chlorinator?

4. The net weight of a tank of water is 857 lbs. How many gallons does it contain?

5. A rectangular concrete channel is 4-feet wide contains 2 feet of water. The water is flowing at a velocity of 1.5 feet per second. What is the flow rate in CFS?

6. A pressure gauge on a fire hydrant reads 53 psi. What is the head on the fire hydrant in feet?

7. Estimate the chlorine demand for water in milligrams per liter if the chlorine dosage is 3.63 mg/L and the chlorine residual is 0.42 mg/L.

8. Calculate the volume of a cube with the following dimensions: L=24 inches W=15 inches H=18 inches.

9. Convert 20 °Celsius to Fahrenheit.

10. A chlorinator feeds 51.33 pounds of chlorine per day to a flow of 0.831 MGD. What is the chlorine dose in mg/L?

Learn to convert your answers into metric values.

Math Conversion Factors and Practical Exercise

1 PSI = 2.31 Feet of Water
 1 Foot of Water = .433 PSI
 1.13 Feet of Water = 1 Inch of Mercury
 454 Grams = 1 Pound
 2.54 CM = Inch
 1 Gallon of Water = 8.34 Pounds
 1 mg/L = 1 PPM
 17.1 mg/L = 1 Grain/Gallon
 1% = 10,000 mg/L
 694 Gallons per Minute = MGD
 1.55 Cubic Feet per Second = 1 MGD
 60 Seconds = 1 Minute
 1440 Minutes = 1 Day
 .746 kW = 1 Horsepower

LENGTH

12 Inches = 1 Foot
 3 Feet = 1 Yard
 5,280 Feet = 1 Mile

AREA

144 Square Inches = 1 Square Foot
 43,560 Square Feet = 1 Acre

VOLUME

1000 Milliliters = 1 Liter
 3.785 Liters = 1 Gallon
 231 Cubic Inches = 1 Gallon
 7.48 Gallons = 1 Cubic Foot of Water
 62.38 Pounds = 1 Cubic Foot of Water

Dimensions

SQUARE: Area (sq.ft) = Length X Width
 Volume (cu.ft.) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq.ft) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. ft) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

PIPE VOLUME: .785 X Diameter ² X Length = ? To obtain gallons multiply by 7.48

SPHERE: $\frac{(3.14) (\text{Diameter})^3}{(6)}$ Circumference = 3.14 X Diameter

General Conversions

Flowrate

Multiply	→	to get
to get	←	Divide
cc/min	1	mL/min
cfm (ft ³ /min)	28.31	L/min
cfm (ft ³ /min)	1.699	m ³ /hr
cfh (ft ³ /hr)	472	mL/min
cfh (ft ³ /hr)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m ³ /hr
GPM	3.785	L/min
oz/min	29.57	mL/min

POUNDS PER DAY = Flow (MG) X Concentration (mg/L) X 8.34

AKA Solids Applied Formula = Flow X Dose X 8.34

$$\text{PERCENT EFFICIENCY} = \frac{\text{In} - \text{Out}}{\text{In}} \times 100$$

$$\begin{aligned} \text{TEMPERATURE: } & ^\circ\text{F} = (^\circ\text{C} \times 9/5) + 32 & 9/5 &= 1.8 \\ & ^\circ\text{C} = (^\circ\text{F} - 32) \times 5/9 & 5/9 &= .555 \end{aligned}$$

$$\text{CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)}$$

$$\text{FLOW RATE (Q): } Q = A \times V \text{ (Quantity = Area X Velocity)}$$

$$\text{FLOW RATE (gpm): Flow Rate (gpm) = } \frac{2.83 (\text{Diameter, in})^2 (\text{Distance, in})}{\text{Height, in}}$$

$$\% \text{ SLOPE} = \frac{\text{Rise (feet)}}{\text{Run (feet)}} \times 100$$

$$\text{ACTUAL LEAKAGE} = \frac{\text{Leak Rate (GPD)}}{\text{Length (mi.) X Diameter (in)}}$$

$$\text{VELOCITY} = \frac{\text{Distance (ft)}}{\text{Time (Sec)}}$$

N = Manning's Coefficient of Roughness

R = Hydraulic Radius (ft.)

S = Slope of Sewer (ft/ft.)

$$\text{HYDRAULIC RADIUS (ft)} = \frac{\text{Cross Sectional Area of Flow (ft)}}{\text{Wetted pipe Perimeter (ft)}}$$

$$\text{WATER HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960}$$

$$\text{BRAKE HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times \text{Pump Efficiency}}$$

$$\text{MOTOR HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times \text{Pump Eff.} \times \text{Motor Eff.}}$$

$$\text{MEAN OR AVERAGE} = \frac{\text{Sum of the Values}}{\text{Number of Values}}$$

$$\text{TOTAL HEAD (ft)} = \text{Suction Lift (ft)} \times \text{Discharge Head (ft)}$$

$$\text{SURFACE LOADING RATE} = \frac{\text{Flow Rate (gpm)}}{(\text{gal/min/sq.ft}) \times \text{Surface Area (sq. ft)}}$$

$$\text{MIXTURE STRENGTH (\%)} = \frac{(\text{Volume 1, gal}) (\text{Strength 1, \%}) + (\text{Volume 2, gal}) (\text{Strength 2, \%})}{(\text{Volume 1, gal}) + (\text{Volume 2, gal})}$$

$$\text{INJURY FREQUENCY RATE} = \frac{(\text{Number of Injuries}) \times 1,000,000}{\text{Number of hours worked per year}}$$

$$\text{DETENTION TIME (hrs.)} = \frac{\text{Volume of Basin (gals)} \times 24 \text{ hrs.}}{\text{Flow (GPD)}}$$

$$\text{SLOPE} = \frac{\text{Rise (ft)}}{\text{Run (ft)}}$$

$$\text{SLOPE (\%)} = \frac{\text{Rise (ft)} \times 100}{\text{Run (ft)}}$$

POPULATION EQUIVALENT (PE):

- 1 PE = .17 Pounds of BOD per Day
- 1 PE = .20 Pounds of Solids per Day
- 1 PE = 100 Gallons per Day

$$\text{LEAKAGE (GPD/inch)} = \frac{\text{Leakage of Water per Day (GPD)}}{\text{Sewer Diameter (inch)}}$$

$$\text{CHLORINE DEMAND (mg/L)} = \text{Chlorine Dose (mg/L)} - \text{Chlorine Residual (mg/L)}$$

MANNING'S FORMULA

τQ = Allowable time for decrease in pressure from 3.5 PSI to 2.5 PSI

τq = As below

$$\tau Q = (0.022) (d_1^2 L_1) / Q \quad \tau q = \frac{[0.085] [(d_1^2 L_1)]}{q}$$

Q = 2.0 cfm air loss

θ = .0030 cfm air loss per square foot of internal pipe surface

δ = Pipe diameter (inches)

L = Pipe Length (feet)

$$V = \frac{1.486}{v} R^{2/3} S^{1/2}$$

V = Velocity (ft./sec.)

v = Pipe Roughness

R = Hydraulic Radius (ft)

S = Slope (ft/ft)

$$\text{HYDRAULIC RADIUS (ft)} = \frac{\text{Flow Area (ft. 2)}}{\text{Wetted Perimeter (ft.)}}$$

$$\text{WIDTH OF TRENCH (ft)} = \text{Base (ft)} + (2 \text{ Sides}) \times \frac{\text{Depth (ft 2)}}{\text{Slope}}$$

Water Formula/Conversion Table

$$\text{Acid Feed Rate} = \frac{(\text{Waste Flow}) (\text{Waste Normality})}{\text{Acid Normality}}$$

$$\text{Alkalinity} = \frac{(\text{mL of Titrant}) (\text{Acid Normality}) (50,000)}{\text{mL of Sample}}$$

$$\text{Amperage} = \text{Voltage} \div \text{Ohms}$$

$$\text{Area of Circle} = (0.785)(\text{Diameter}^2) \text{ OR } (\pi)(\text{Radius}^2)$$

$$\text{Area of Rectangle} = (\text{Length})(\text{Width})$$

$$\text{Area of Triangle} = \frac{(\text{Base}) (\text{Height})}{2}$$

$$\text{C Factor Slope} = \text{Energy loss, ft.} \div \text{Distance, ft.}$$

$$\text{C Factor Calculation} = \text{Flow, GPM} \div [193.75 (\text{Diameter, ft.})^{2.63} (\text{Slope})^{0.54}]$$

$$\text{Chemical Feed Pump Setting, \% Stroke} = \frac{(\text{Desired Flow}) (100\%)}{\text{Maximum Flow}}$$

$$\text{Chemical Feed Pump Setting, mL/min} = \frac{(\text{Flow, MGD}) (\text{Dose, mg/L}) (3.785\text{L/gal}) (1,000,000 \text{ gal/MG})}{(\text{Liquid, mg/mL}) (24 \text{ hr / day}) (60 \text{ min/hr})}$$

$$\text{Chlorine Demand (mg/L)} = \text{Chlorine dose (mg/L)} - \text{Chlorine residual (mg/L)}$$

$$\text{Circumference of Circle} = (3.141)(\text{Diameter})$$

$$\text{Composite Sample Single Portion} = \frac{(\text{Instantaneous Flow}) (\text{Total Sample Volume})}{(\text{Number of Portions}) (\text{Average Flow})}$$

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Digested Sludge Remaining, \%} = \frac{(\text{Raw Dry Solids}) (\text{Ash Solids}) (100\%)}{(\text{Digested Dry Solids}) (\text{Digested Ash Solids})}$$

$$\text{Discharge} = \frac{\text{Volume}}{\text{Time}}$$

$$\text{Dosage, lbs/day} = (\text{mg/L})(8.34)(\text{MGD})$$

$$\text{Dry Polymer (lbs.)} = (\text{gal. of solution})(8.34 \text{ lbs/gal})(\% \text{ polymer solution})$$

$$\text{Efficiency, \%} = \frac{(\text{In} - \text{Out}) (100\%)}{\text{In}}$$

$$\text{Feed rate, lbs/day} = \frac{(\text{Dosage, mg/L}) (\text{Capacity, MGD}) (8.34 \text{ lbs/gals})}{(\text{Available fluoride ion}) (\text{Purity})}$$

$$\text{Feed rate, gal/min (Saturator)} = \frac{(\text{Plant capacity, gal/min.}) (\text{Dosage, mg /L})}{18,000 \text{ mg/L}}$$

$$\text{Filter Backwash Rate} = \frac{\text{Flow}}{\text{Filter Area}}$$

$$\text{Filter Yield, lbs/hr/sq. ft} = \frac{(\text{Solids Loading, lbs/day}) (\text{Recovery, \% / 100\%})}{(\text{Filter operation, hr/day}) (\text{Area, ft}^2)}$$

$$\text{Flow, cu. ft./sec.} = (\text{Area, Sq. Ft.}) (\text{Velocity, ft./sec.})$$

$$\text{Gallons/Capita/Day} = \frac{\text{Gallons / day}}{\text{Population}}$$

$$\text{Hardness} = \frac{(\text{mL of Titrant}) (1,000)}{\text{mL of Sample}}$$

$$\text{Horsepower (brake)} = \frac{(\text{Flow, gpm}) (\text{Head, ft})}{(3,960) (\text{Efficiency})}$$

$$\text{Horsepower (motor)} = \frac{(\text{Flow, gpm}) (\text{Head, ft})}{(3960) (\text{Pump, Eff}) (\text{Motor, Eff})}$$

$$\text{Horsepower (water)} = \frac{(\text{Flow, gpm}) (\text{Head, ft})}{(3960)}$$

$$\text{Hydraulic Loading Rate} = \frac{\text{Flow}}{\text{Area}}$$

$$\text{Leakage (actual)} = \text{Leak rate (GPD)} \div [\text{Length (mi.)} \times \text{Diameter (in.)}]$$

$$\text{Mean} = \text{Sum of values} \div \text{total number of values}$$

$$\text{Mean Cell Residence Time (MCRT)} = \frac{\text{Suspended Solids in Aeration System, lbs}}{\text{SS Wasted, lbs / day} + \text{SS lost, lbs / day}}$$

$$\text{Organic Loading Rate} = \frac{\text{Organic Load, lbs BOD / day}}{\text{Volume}}$$

$$\text{Oxygen Uptake} = \frac{\text{Oxygen Usage}}{\text{Time}}$$

$$\text{Pounds per day} = (\text{Flow, MGD}) (\text{Dose, mg/L}) (8.34)$$

$$\text{Population Equivalent} = \frac{(\text{Flow MGD})(\text{BOD, mg/L})(8.34 \text{ lbs / gal})}{\text{Lbs BOD / day / person}}$$

$$\text{RAS Suspended Solids, mg/l} = \frac{1,000,000}{\text{SVI}}$$

$$\text{RAS Flow, MGD} = \frac{(\text{Infl. Flow, MGD})(\text{MLSS, mg/l})}{\text{RAS Susp. Sol., mg/l} - \text{MLSS, mg/l}}$$

$$\text{RAS Flow \%} = \frac{(\text{RAS Flow, MGD})(100 \%)}{\text{Infl. Flow, MGD}}$$

$$\text{Reduction in Flow, \%} = \frac{(\text{Original Flow} - \text{Reduced Flow})(100\%)}{\text{Original Flow}}$$

$$\text{Slope} = \frac{\text{Drop or Rise}}{\text{Run or Distance}}$$

$$\text{Sludge Age} = \frac{\text{Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs / day}}$$

$$\text{Sludge Index} = \frac{\% \text{ Settleable Solids}}{\% \text{ Suspended Solids}}$$

$$\text{Sludge Volume Index} = \frac{(\text{Settleable Solids, \%})(10,000)}{\text{MLSS, mg/L}}$$

$$\text{Solids, mg/L} = \frac{(\text{Dry Solids, grams})(1,000,000)}{\text{mL of Sample}}$$

$$\text{Solids Applied, lbs/day} = (\text{Flow, MGD})(\text{Concentration, mg/L})(8.34 \text{ lbs/gal})$$

$$\text{Solids Concentration} = \frac{\text{Weight}}{\text{Volume}}$$

$$\text{Solids Loading, lbs/day/sq ft} = \frac{\text{Solids Applied, lbs / day}}{\text{Surface Area, sq ft}}$$

$$\text{Surface Loading Rate} = \frac{\text{Flow}}{\text{Rate}}$$

$$\text{Total suspended solids (TSS), mg/L} = \frac{(\text{Dry weight, mg})(1,000 \text{ mL/L})}{(\text{Sample vol., mL})}$$

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}} \quad \text{O R} \quad \frac{\text{Distance}}{\text{Time}}$$

$$\text{Volatile Solids, \%} = \frac{(\text{Dry Solids} - \text{Ash Solids}) (100\%)}{\text{Dry Solids}}$$

$$\text{Volume of Cone} = (1/3)(0.785)(\text{Diameter}^2)(\text{Height})$$

$$\text{Volume of Cylinder} = (0.785)(\text{Diameter}^2)(\text{Height}) \text{ OR } (\pi)(r^2)(h)$$

$$\text{Volume of Rectangle} = (\text{Length})(\text{Width})(\text{Height})$$

$$\text{Volume of Sphere} = [(\pi)(\text{diameter}^3)] \div 6$$

$$\text{Waste Milliequivalent} = (\text{mL}) (\text{Normality})$$

$$\text{Waste Normality} = \frac{(\text{Titrant Volume}) (\text{Titrant Normality})}{\text{Sample Volume}}$$

$$\text{Weir Overflow Rate} = \frac{\text{Flow}}{\text{Weir Length}}$$

Conversion Factors

1 acre = 43,560 square feet

1 cubic foot = 7.48 gallons

1 foot = 0.305 meters

1 gallon = 3.785 liters

1 gallon = 8.34 pounds

1 grain per gallon = 17.1 mg/L

1 horsepower = 0.746 kilowatts

1 million gallons per day = 694.45 gallons per minute

1 pound = 0.454 kilograms

1 pound per square inch = 2.31 feet of water

1% = 10,000 mg/L

Degrees Celsius = (Degrees Fahrenheit - 32) (5/9)

Degrees Fahrenheit = (Degrees Celsius * 9/5) + 32

64.7 grains = 1 cubic foot

1,000 meters = 1 kilometer

1,000 grams = 1 kilogram

1,000 milliliters = 1 liter

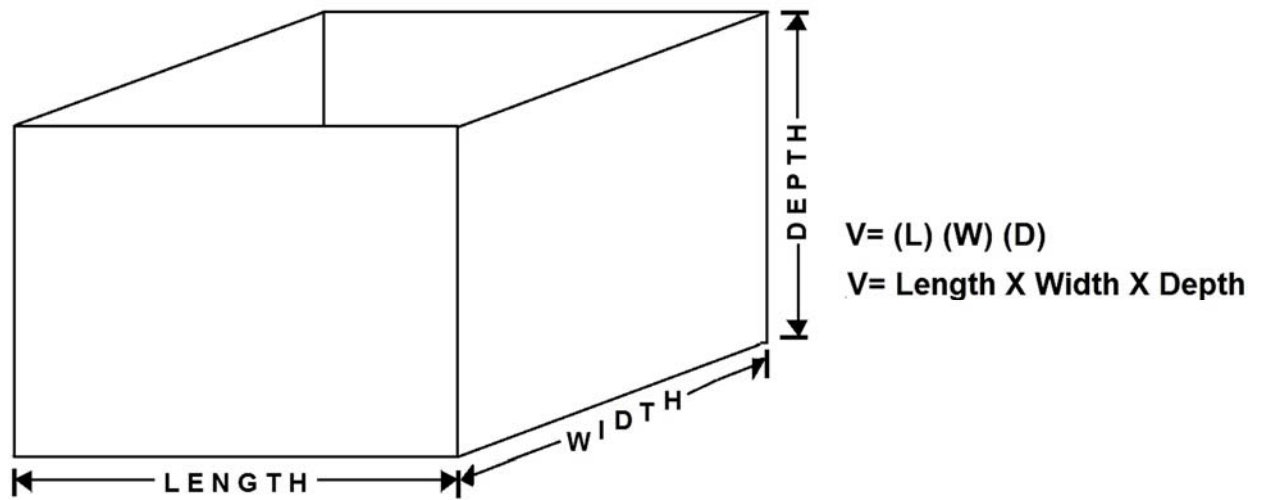
144 square inches = 1 square foot

1.55 cubic feet per second = 1 MGD

1 meter = 3.28 feet

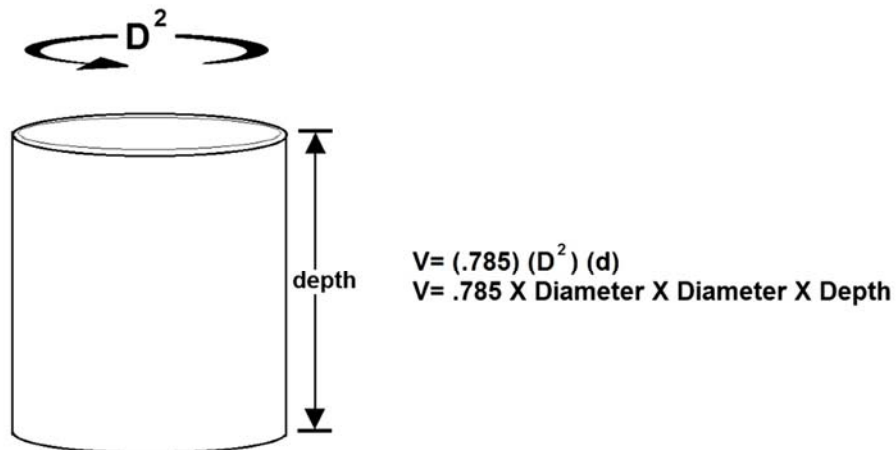
π = 3.141

Math Review Section- Practice Exam



CALCULATING THE VOLUME OF A CUBE

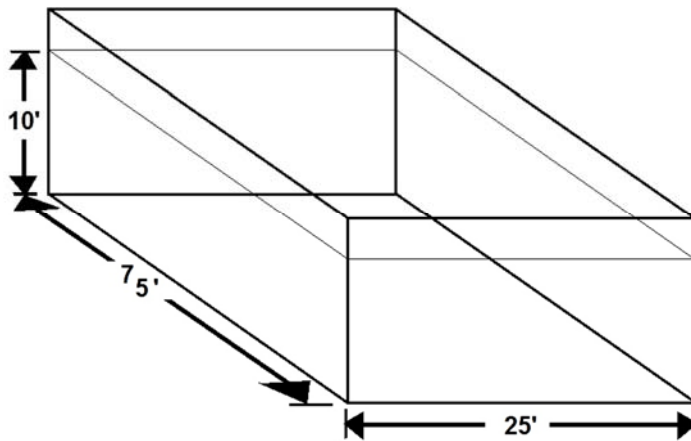
Cube Formula
 $V = (L) (W) (D)$
Volume = Length X Width X Depth



CALCULATING THE VOLUME OF A CYLINDER

Cylinder Formula
 $V = (.785) (D^2) (d)$

Build it, Fill it and Dose it.



A TANK IS 25' x 75' x 10', WHAT IS THE VOLUME OF WATER IN GALLONS

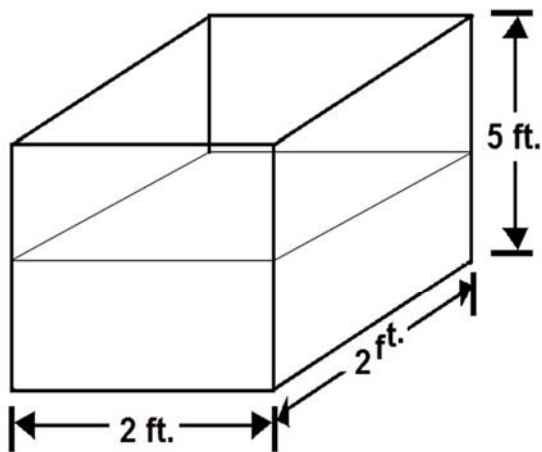
$$V = (L) (W) (D)$$

$$(25) (75) (10) (7.48)$$

$$25' \times 75' \times 10' \times 7.48 = 46750 \text{ gallons}$$

1. Convert 10 cubic feet to gallons of water.

There is 7.48 gallons in one cubic foot.



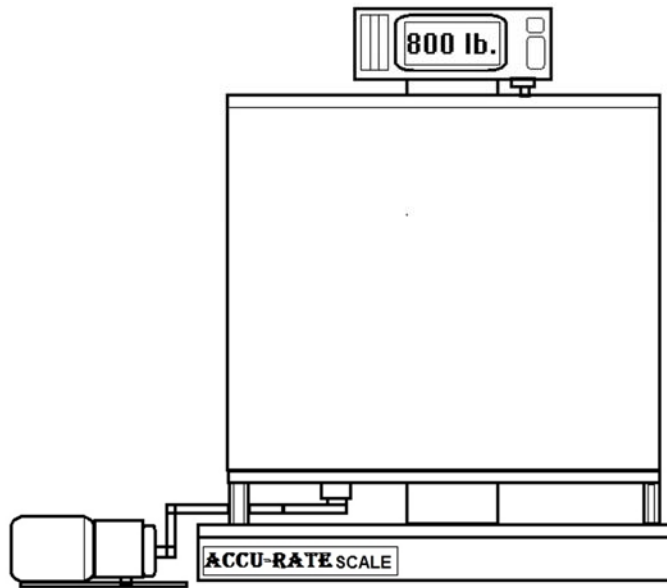
Convert 10 cu.ft. to gallons of water :

$$(10 \text{ ft.}^3) (7.48)$$

$$\text{Multiply } 10 \text{ ft.}^3 \times 7.48 = \quad \text{gallons}$$

CONVERTING CUBIC FEET TO GALLONS OF WATER

2. The liquid in a tank weighs 800 pounds, how many gallons are in the tank?



LIQUID IN A TANK WEIGHS 800 lbs. / HOW MANY GALLONS ARE IN THE TANK:

800 lbs. DIVIDED BY 8.34 lbs./gal.

$$\frac{800 \text{ lbs.}}{8.34 \text{ lbs./gal.}} =$$

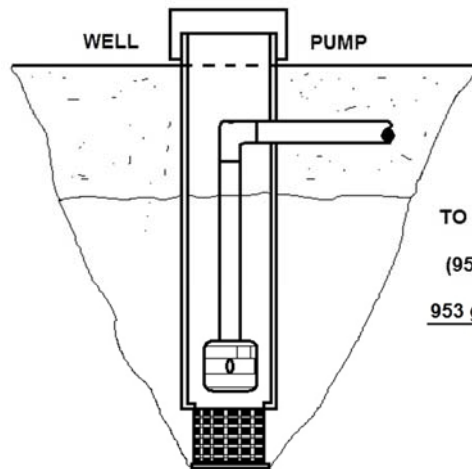
CONVERTING POUNDS TO GALLONS

Practice Questions, no answers provided

A1. Convert 75 cubic feet to gallons of water.

B1. The liquid in a tank weighs 50 pounds, how many gallons are in the tank?

3. Convert a flow rate of 953 gallons per minute to million gallons per day.
There is 1440 minutes in a day.



CONVERT FLOW RATE OF 953 GALLONS PER MINUTE
TO MILLION GALLONS PER DAY (there are 1440 minutes a day)

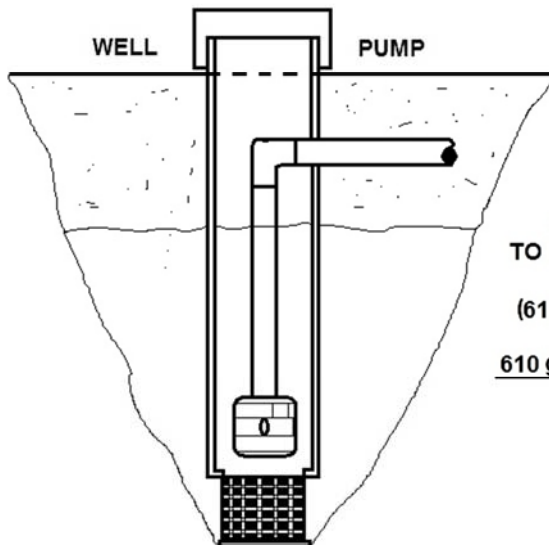
$$(953) (1440) / 1,000,000$$

$$\frac{953 \text{ gal./min.} \times 1440 \text{ min./day}}{1,000,000 \text{ MGD}} = \quad / \text{MG/day}$$

**CONVERTING GALLONS PER MINUTE TO
MILLION GALLONS PER DAY**

4. Convert a flow rate of 610 gallons per minute to millions of gallons per day.

$$1 \text{ MG} = \frac{100,000 \text{ Gallons}}{24 \text{ Hours (fill time)}}$$



CONVERT FLOW RATE OF 953 GALLONS PER MINUTE
TO MILLION GALLONS PER DAY (there are 1440 minutes a day)

$$(610) (1440) / 1,000,000$$

$$\frac{610 \text{ gal./min.} \times 1440 \text{ min./day}}{1,000,000 \text{ MGD}} = \quad / \text{MG/day}$$

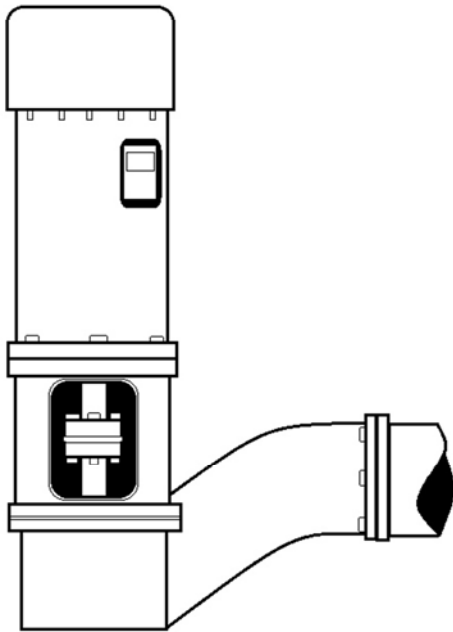
**CONVERTING GALLONS PER MINUTE TO
MILLION GALLONS PER DAY**

Practice Questions, no answers provided

A2. Convert a flow rate of 14,750 gallons per minute to million gallons per day.

B2. Convert a flow rate of 5880 gallons per minute to millions of gallons per day.

5. Convert a flow of 550 gallons per minute to gallons per second.



**CONVERT A FLOW 550 GALLONS PER MINUTE
TO GALLONS PER SECOND**

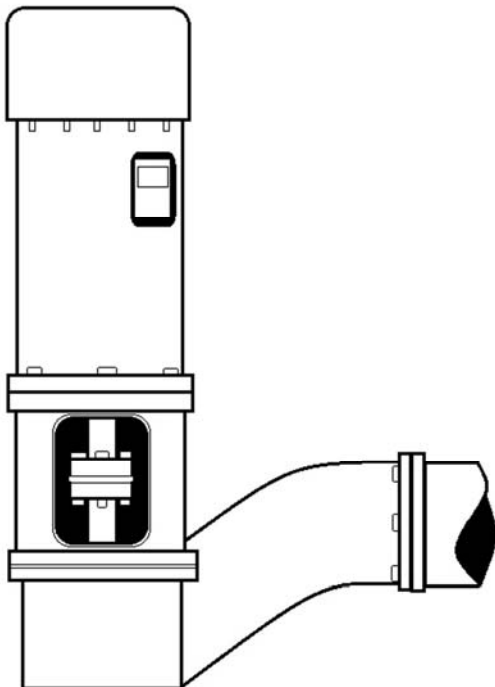
$$(550) / (60)$$

550 divided by 60

$$\frac{550 \text{ gal./ min.}}{60 \text{ sec./ min.}} = \text{gal./sec.}$$

CONVERTING GALLONS PER MINUTE TO GALLONS PER SECOND

6. Now, convert this number to liters per second.



**CONVERT A FLOW 550 GALLONS PER MINUTE
TO GALLONS PER SECOND**

$$(550) / (60)$$

550 divided by 60

$$\frac{550 \text{ gal./ min.}}{60 \text{ sec./ min.}} = 9.167 \text{ gal./sec.}$$

NOW CONVERT 9.167 gal./sec. to Liters per second

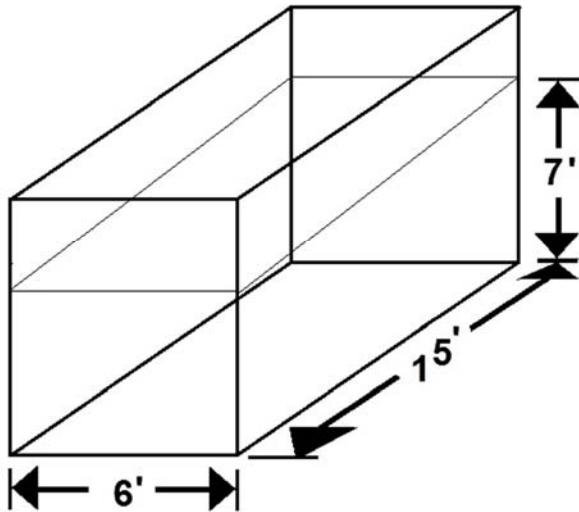
$$(9.167) \times (3.79)$$

$$9.167 \times 3.79$$

$$9.167 \text{ gal./sec.} \times 3.79 \text{ liters/gal.} = \text{liters/sec.}$$

7. A tank is 6' X 15' x 7' and can hold a maximum of _____ gallons of water.

$$V = (L) (W) (D) \times 7.48 =$$



A TANK 6' x 15' x 7' HOLDS A MAXIMUM OF _____ GALLONS OF WATER

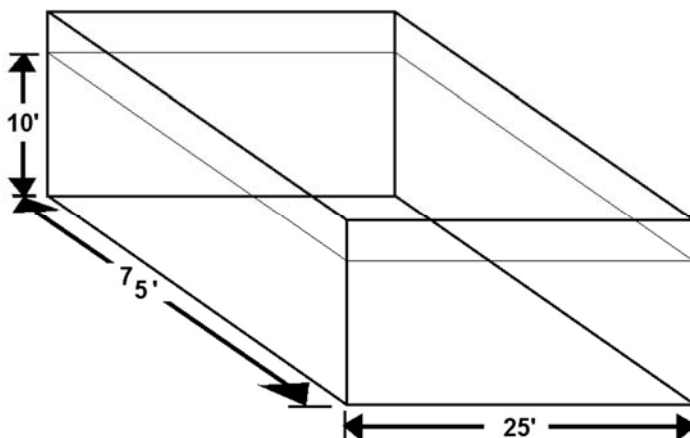
$$V = (L) (W) (D) \times 7.48$$

$$V = (6') (15') (7') (7.48)$$

$$6' \times 15' \times 7' \times 7.48 = \quad \text{gallons}$$

8. A tank is 25' X 75' X 10' what is the volume of water in gallons?

$$V = (L) (W) (D) \times 7.48 =$$



A TANK IS 25' x 75' x 10', WHAT IS THE VOLUME OF WATER IN GALLONS

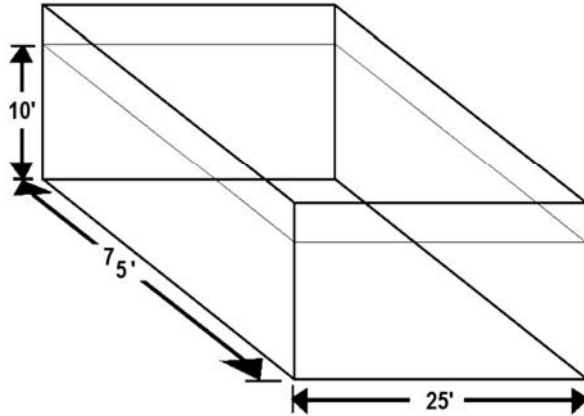
$$V = (L) (W) (D)$$

$$(25) (75) (10) (7.48)$$

$$25' \times 75' \times 10' \times 7.48 = \quad \text{gallons}$$

9. In Liters?

$$V = (L) (W) (D) \times 7.48 = \underline{\hspace{2cm}} \times 3.785$$



A TANK IS 25' x 75' x 10', WHAT IS THE VOLUME OF WATER IN LITERS

$$V = (L) (W) (D)$$

$$(25) (75) (10) (7.48)$$

$$25' \times 75' \times 10' \times 7.48 = 46750 \text{ gallons}$$

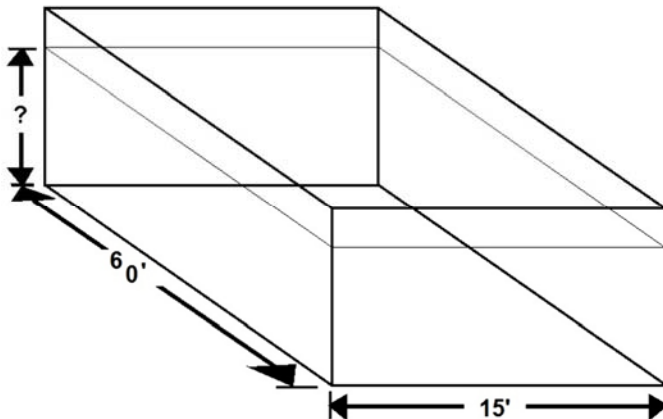
$$1 \text{ GALLON} = 3.79 \text{ LITERS}$$

$$V = (L) (W) (D) \times 7.48 = 46750 \text{ gallons} \times 3.79$$

$$V = \hspace{1cm} \text{Liters}$$

10. A tank holds 67,320 gallons of water. The length is 60' and the width is 15'. How deep is the tank?

$$\text{Gallons } \underline{\hspace{2cm}} \div 7.48 = \underline{\hspace{2cm}} \quad 60 \times 15 =$$



A TANK HOLDS 67,320 GALLONS OF WATER. THE LENGTH IS 60' AND THE WIDTH IS 15'. HOW DEEP IS THE TANK?

$$\text{Gallons } \underline{67,320} / 7.48 = \underline{9000 \text{ gal.}}$$

$$60' \times 15' = 900 \text{ ft.}$$

$$\frac{9000 \text{ gal.}}{900 \text{ ft.}} = \hspace{1cm} \text{ft.}$$

Practice Questions, no answers provided

A3. Convert a flow of 733 gallons per minute to gallons per second.

B3. Now, convert this number to liters per second.

C3. A tank is 20' X 20' x 40' and can hold a maximum of _____ gallons of water.

D3. In Liters?

$$V = (L) (W) (D) \times 7.48 = \underline{\hspace{2cm}} \times 3.785$$

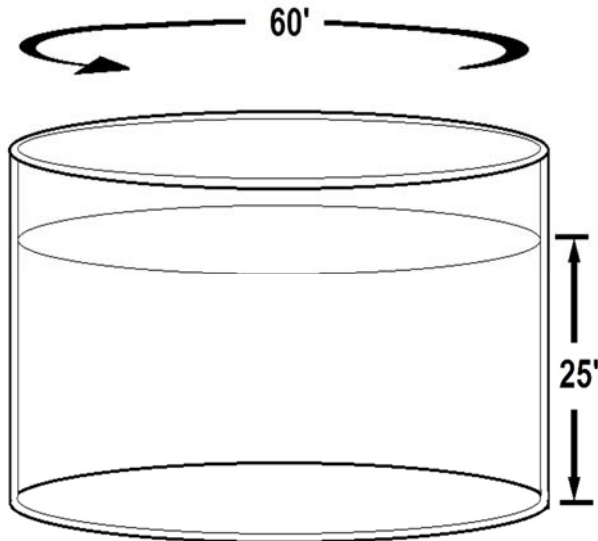
E3. A tank holds 85,000 gallons of water. The length is 75' and the width is 14'. How deep is the tank?

11. The diameter of a tank is 60' and the depth is 25'. How many gallons does it hold?

Cylinder Formula

$$V = (.785) (D^2) (d)$$

$$.785 \times 60' \times 60' \times 25' \times 7.48 =$$



THE DIAMETER OF A TANK IS 60' AND A DEPTH OF 25'.
HOW MANY GALLONS DOES IT HOLD.

$$V = (.785) (D^2) (d)$$

$$.785 \times 60 \times 60 \times 25 \times 7.48 = 528,462 \text{ gallons}$$

GALLONS

Practice Questions, no answers provided

A4. The diameter of a tank is 30' and the depth is 5'. How many gallons does it hold?

B4. The diameter of a tank is 160' and the depth is 30'. How many gallons does it hold?

C4. The diameter of a tank is 33' and the depth is 20'. How many gallons does it hold?

D4. The diameter of a tank is 5' and the depth is .5'. How many gallons does it hold?

Cubic Feet Information

There is no universally agreed symbol but the following are used:

cubic feet, cubic foot, cubic ft

cu ft, cu feet, cu foot

ft₃, feet 3, foot 3

feet₃, foot₃, ft₃

feet/-3, foot/-3, ft/-3

Water/Wastewater Treatment Production Math Numbering System

In water/wastewater treatment, we express our production numbers in Million Gallon numbers. Example 2,000,000 or 2 million gallons would be expressed as 2 MG or 2 MGD.

$$1 \text{ MG} = \frac{100,000 \text{ Gallons}}{24 \text{ Hours (fill time)}}$$

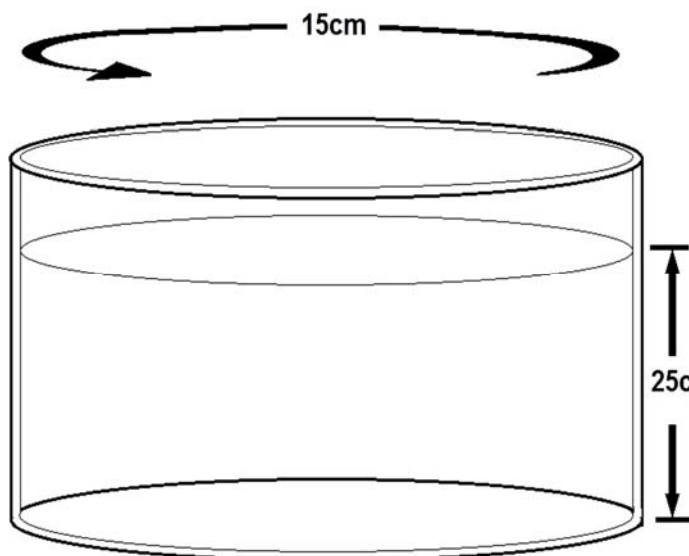
FILL TIME= 2.4 Hours

Hint. A million has six zeroes; you can always divide your final number by 1,000,000 or move the decimal point to the left six places. Example 528,462 would be expressed .56 MGD.

12. The diameter of a tank is 15 Centimeters or cm and the depth is 25 cm, what is the volume in liters?

$$2.54\text{cm} = 1 \text{ inch}, 12 \text{ inches} = 1 \text{ foot}$$
$$15 \text{ cm} \div 2.54 \text{ cm} \div 12 \text{ inches} = .492 \text{ feet}$$

$$.785 \times .492' \times .492' \times \underline{\hspace{1cm}}' = \underline{\hspace{1cm}} \times 7.48 = \underline{\hspace{1cm}} \times 3.785 \text{ L} =$$



THE DIAMETER OF A TANK IS 15 Centimeters OR cm, WHAT IS THE VOLUME IN Liters.

$$2.54\text{cm} = 1 \text{ inch}, 12 \text{ inches} = 1 \text{ foot}$$

$$15\text{cm} / 2.54\text{cm} / 12 \text{ inches} = .492 \text{ feet}$$

$$25\text{cm} / 2.54 / 12 \text{ inches} = .82 \text{ feet}$$

$$.785 \times .492' \times .492' \times .82 \times 7.48 = 1.17$$

$$1.17 \times 3.785 \text{ Liters} = \underline{\hspace{1cm}} \text{ Liters}$$

Percentage and Fractions

Let's look again at the sequence of numbers 1000, 100, 10, 1, and continue the pattern to get new terms by dividing previous terms by 10:

$$\begin{aligned}.1 &= 1/10 \\ .01 &= 1/100 \\ .001 &= 1/1000\end{aligned}$$



So just as the digits to the left of the decimal represent 1's, 10's, 100's, and so forth, digits to the right of the decimal point represent 1/10's, 1/100's, 1/1000's, and so forth.

Let's express 5% as a decimal. $5 \div 100 = 0.05$ or you can move the decimal point to the left two places.

Changing a fraction to a decimal:

Divide the numerator by the denominator

A. $5/10$ (five tenths) = five divided by ten:

$$\begin{array}{r} .5 \\ \text{-----} \\ 10 \overline{) 5.0} \\ \underline{50} \\ 0 \end{array}$$

So $5/10$ (five tenths) = .5 (five tenths).

B. How about $1/2$ (one half) or 1 divided by 2 ?

$$\begin{array}{r} .5 \\ \text{-----} \\ 2 \overline{) 1.0} \\ \underline{10} \\ 0 \end{array}$$

So $1/2$ (one half) = .5 (five tenths)

Notice that equivalent fractions convert to the same decimal representation.

$8/12$ is a good example. $8 \div 12 = .66666666$ or rounded off to .667

How about $6/12$ or 6 inches? .5 or half a foot

Flow and Velocity

This depends on measuring the average velocity of flow and the cross-sectional area of the channel and calculating the flow from:

$$Q(\text{m}^3/\text{s}) = A(\text{m}^2) \times V(\text{m}/\text{s})$$

Or

$$Q = A \times V$$

Q CFM = Cubic Ft, Inches, Yards of time, Sec, Min, Hrs, Days

A = Area, squared Length X Width

V f/m = Inch, Ft, Yards, Per Time, Sec, Min, Ft or Speed

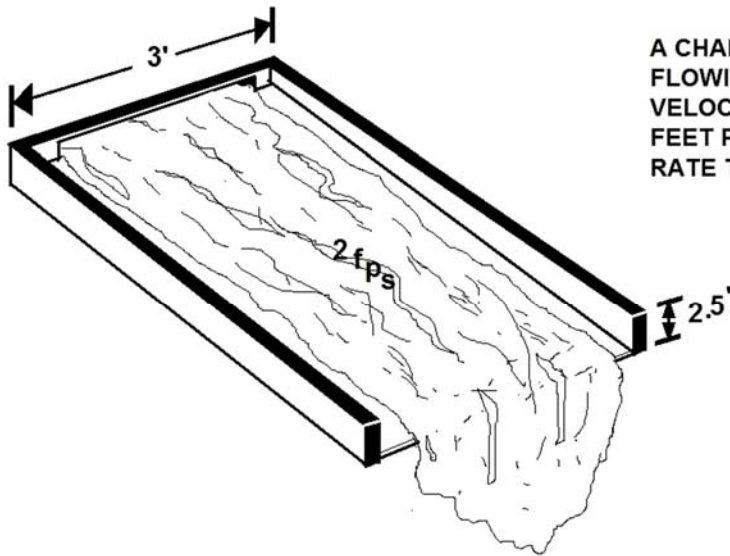
13. A channel is 3 feet wide and has water flowing to a depth of 2.5 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel?

$$Q = A \times V$$

$$Q = 7.5 \text{ sq. ft.} \times 2 \text{ fps} \quad \text{What is } Q?$$

$$A = 3' \times 2.5' = 7.5$$

$$V = 2 \text{ fps}$$



A CHANNEL IS 3 FEET WIDE AND HAS WATER FLOWING TO A DEPTH OF 2.5 FEET. IF THE VELOCITY THROUGH THE CHANNEL IS 2 fps OR FEET PER SECOND, WHAT IS THE cfs FLOW RATE THROUGH THE CHANNEL.

$$Q = A \times V$$

$$A = 3\text{ft.} \times 2.5\text{ft}$$

$$A = 7.5 \text{ ft}^2$$

$$V = 2\text{ft./sec.}$$

$$Q = 7.5 \text{ ft}^2 \times 2\text{ft./sec.}$$

$$Q = \quad \text{/sec.}$$

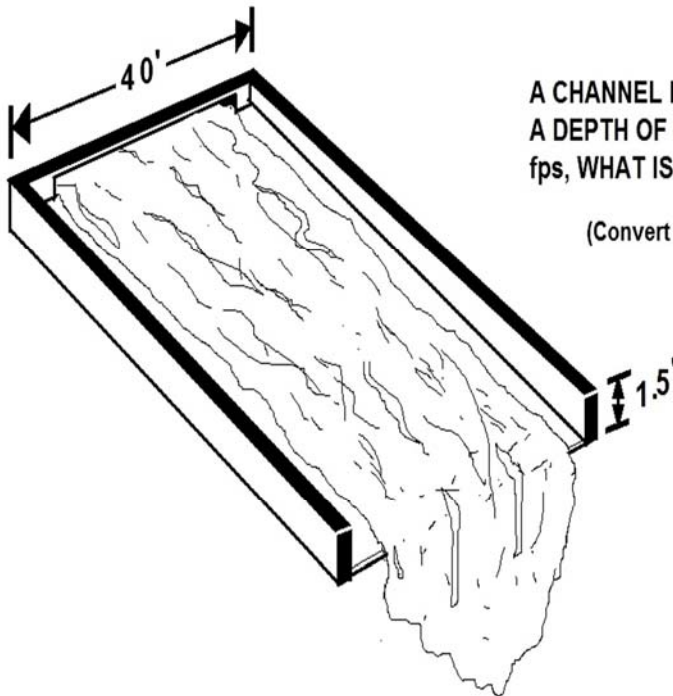
14. A channel is 40 inches wide and has water flowing to a depth of 1.5 ft. If the velocity of the water is 2.3 fps, what is the cfs flow in the channel? $Q = A \times V$
First we must convert 40 inches to feet.

$$40 \div 12'' = 3.333 \text{ feet}$$

$$A = 3.333' \times 1.5' = 4.999 \text{ or round up to } 5$$

$$V = 2.3 \text{ fps}$$

We can round this answer up.



A CHANNEL IS 40 INCHES WIDE AND HAS WATER FLOWING TO A DEPTH OF 1.5 FEET. IF THE VELOCITY OF THE WATER IS 2.3 fps, WHAT IS THE cfs FLOW IN THE CHANNEL.

(Convert inches to feet first by dividing by 12 to get feet)

$$Q = A \times V$$

$$A = (40/12 = 3.33\text{ft.}) \times (1.5\text{ft})$$

$$A = 4.995 \text{ (Round to } 5)$$

$$V = 2.3 \text{ ft/sec.}$$

$$Q = 2.3 \text{ ft/sec.} \times 5\text{ft}$$

$$Q = \quad \text{cf/sec.}$$

15. A channel is 3 feet wide and has a water flow at a velocity of 1.5 fps. If the flow through the channel is 8.1 cfs, what is the depth of the water?

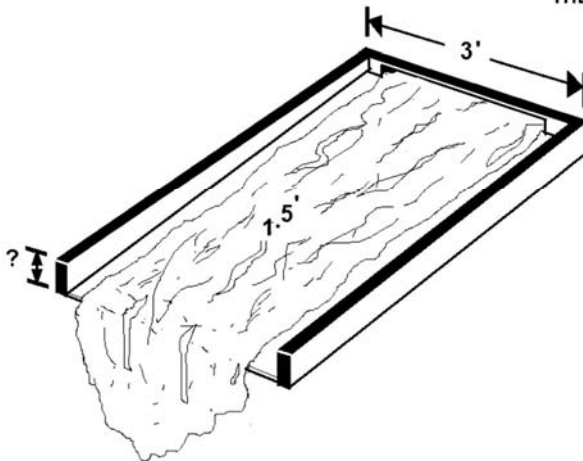
$$Q = 8.1 \text{ cfs}$$

$$V = 1.5 \text{ fps}$$

$$A = ?$$

$$8.1 \div 1.5 = \underline{\hspace{1cm}} \text{ Total Area}$$

A CHANNEL IS 3 FEET WIDE AND HAS A WATER FLOW AT A VELOCITY OF 1.5 ft/sec. IF THE FLOW THROUGH THE CHANNEL IS 8.1 cf/sec., WHAT IS THE DEPTH OF THE WATER.



$$Q = A \times V$$

$$A = ?$$

$$V = 1.5 \text{ ft./sec.}$$

$$Q = 8.1 \text{ cf/sec.}$$

$$(8.1) / (1.5) = 5.4 \text{ ft.}$$

$$A =$$

16. The flow through a 6 inch diameter pipe is moving at a velocity of 3 ft/sec. What is the cfs flow rate through the pipeline?

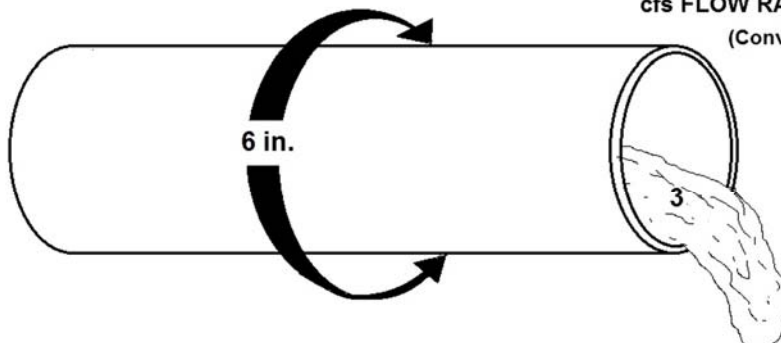
$$Q =$$

$$A = .785 \times .5' \times .5' =$$

$$V = 3 \text{ fps}$$

THE FLOW THROUGH A 6 inch DIAMETER PIPE IS MOVING AT A VELOCITY OF 3 ft./sec. WHAT IS THE cfs FLOW RATE THROUGH THE PIPELINE

(Convert inches to feet by dividing by 12 to get feet)



$$Q = A \times V$$

$$A = (6/12 = .5 \text{ ft.}) \times (.785) \times (.785)$$

$$.785 \times .5' \times .5' = .20 \text{ ft.}$$

$$V = 3 \text{ ft./sec.}$$

$$.20 \text{ ft.} \times 3 \text{ ft./sec.} = .6 \text{ cf/sec.}$$

$$Q = \text{ cf/sec.}$$

17. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?

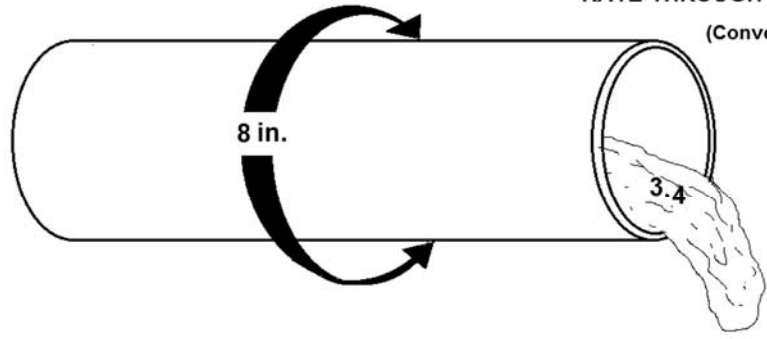
$$Q = \text{_____ cfs} \times 60 \text{ sec/min} \times 7.48 = \text{_____ gpm}$$

$$A = .785 \times .667' \times .667'$$

$$V = 3.4 \text{ fps}$$

AN 8 inch DIAMETER PIPE HAS WATER FLOWING AT A VELOCITY OF 3.4 ft./sec. WHAT IS THE gpm (gal./min.) FLOW RATE THROUGH THE PIPE.

(Convert inches to feet by dividing by 12 to get feet)



Q = A X V

A = (8/12 = .667 ft.) (.785) (D²) X (.785)

.785 X .667' X .667' = .35 ft.

V = 3.4 ft/sec.

.35 ft. X 3.4 ft./sec. = 1.19 cf/sec.

Q = 1.19 cf/sec. X 60 sec./min. X 7.48 =

Q = _____ gal./min.

18. A 6 inch diameter pipe delivers 280 gpm. What is the velocity of flow in the pipe in ft/sec?

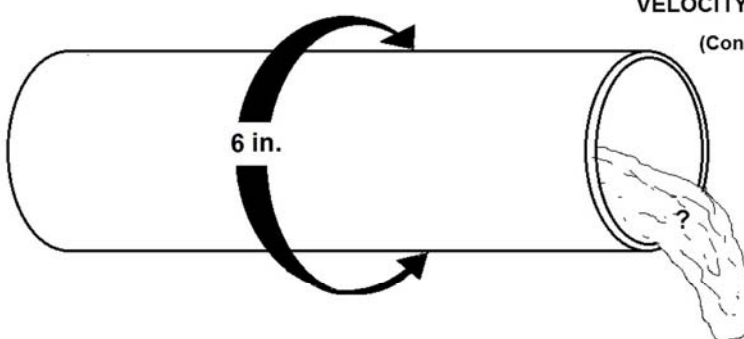
Take the water out of the pipe. $280 \text{ gpm} \div 7.48 \div 60 \text{ sec/min} = \text{_____ cfs}$

$$Q =$$

$$A = .785 \times .5' \times .5' =$$

$$V =$$

A 6 inch PIPE DELIVERS 280 gal./min. WHAT IS THE VELOCITY IN THE PIPE IN ft./sec.
(Convert inches to feet by diving by 12 to get feet)



$Q = A \times V$
 $A = (6/12 = .5 \text{ ft.}) (.785)$
 $(D^2) (.785)$
 $.785 \times .5' \times .5' = .20 \text{ ft.}$
 $V = ?$
 $Q = 280 \text{ gal./min.}$
 (Take the water out of the pipe)
 $Q = (280 \text{ gal./min.}) / (7.48) / (60 \text{ sec./min.}) = .623 \text{ cf/sec.}$
 (Divide the Q by the A to get the V)
 $(.623 \text{ cf/sec.}) / (.20 \text{ ft.}) =$
 $V = \quad \text{ft./sec.}$

19. A new section of 12 inch diameter pipe is to be disinfected before it is placed in service. If the length is 2000 feet, how many gallons of 5% NaOCl will be needed for a dosage of 200 mg/L?

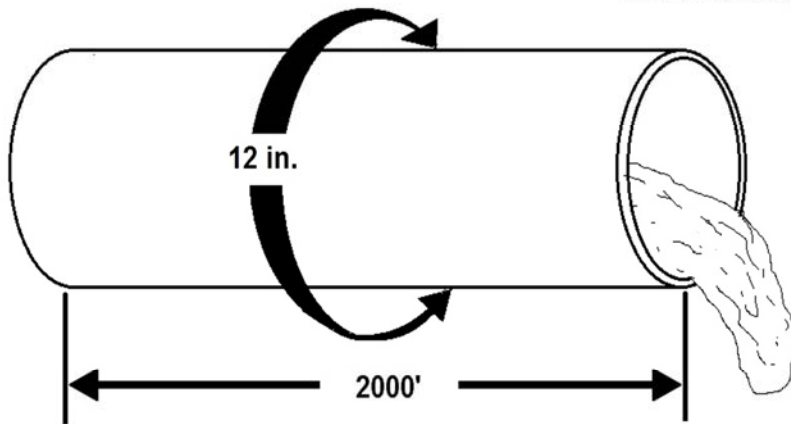
Cylinder Formula
 $V = (.785) (D^2) (d)$

$$.785 \times 1' \times 1' \times 2000' = \underline{\hspace{2cm}} \text{ cu.ft.} \times 7.48 = \underline{\hspace{2cm}} \div 1,000,000 = \underline{\hspace{2cm}} \text{ MG}$$

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal if 100% concentrate.
 If not, divide the lbs/day by the given %

$$0.0117436 \text{ MG} \times 200 \text{ mg/L} \times 8.34 = \underline{\hspace{2cm}} \text{ lbs/day} \div .05 =$$

A NEW SECTION OF 12 inch DIAMETER PIPE IS TO BE DISINFECTED BEFORE IT IS PLACED IN SERVICE. IF THE LENGTH IS 2000 ft., HOW MANY GALLONS OF 5% NaOCl WILL BE NEEDED FOR A DOSAGE OF 200 mg/L.



CYLINDER FORMULA

$$V = (.785) (D^2) (L)$$

$$.785 \times 1.0 \times 1.0 \times 2000 = 1570'$$

$$1570' \times 7.48 = 11,743.6$$

$$11,743.6 / 1,000,000 \text{ MG} = 0.012 \text{ MGD}$$

$$0.012 \times 200 \times 8.34 = 19.59 \text{ lbs./day}$$

$$19.59 \text{ lbs.} / 0.05 \% = 391.8 \text{ gallons}$$

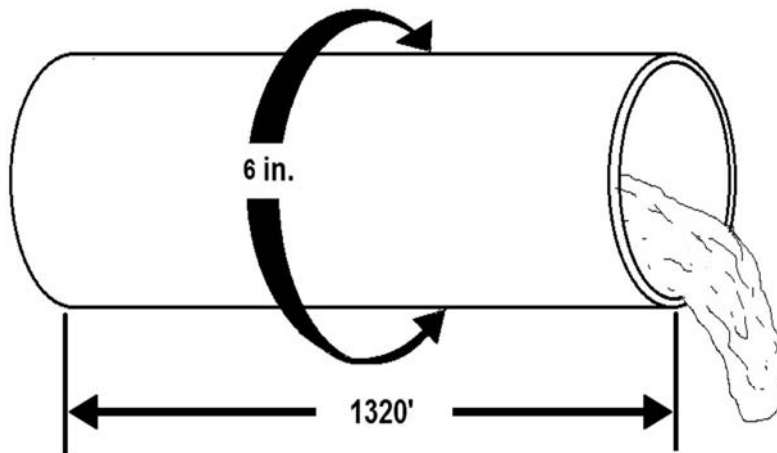
$$V = \quad \text{gallons}$$

20. A section of 6 inch diameter pipe is to be filled with water. The length of the pipe is 1320 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 3 mg/L?

$$.785 \times .5' \times .5' \times 1320' \times 7.48 = \underline{\hspace{2cm}} \text{ Make it MGD}$$

Pounds per day formula = Flow X Dose X 8.34 X .454 Grams per pound

A SECTION OF 6 inch PIPE IS TO BE FILLED WITH WATER. THE LENGTH OF THE PIPE IS 1320 ft. LONG. HOW MANY KILOGRAMS OF CHLORINE WILL BE NEEDED FOR A CHLORINE DOSE OF 3 mg/L.



CYLINDER FORMULA

$$V = (.785) (D^2) (L)$$

$$.785 \times .5 \times .5 \times 1320 = 259.05$$

$$259.05 \times 7.48 \times = 1937.694$$

$$1937.694 / 1,000,000 \text{ MG} = 0.002$$

$$0.002 \times 3 \text{ mg/L} \times 8.34 = 0.050 \text{ lbs/day}$$

$$0.050 \text{ lbs.} \times .454 \text{ gram} = 0.023 \text{ Kg/day}$$

Kg/day

Practice Questions, no answers provided

A5. A channel is 5 feet wide and has water flowing to a depth of 2 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel?

$$Q = A \times V$$

B5. A channel is 36 inches wide and has water flowing to a depth of 2.5 ft. If the velocity of the water is 2.0 fps, what is the cfs flow in the channel?

$$Q = A \times V$$

C5. A channel is 2 feet wide and has a water flow at a velocity of 3.5 fps. If the flow through the channel is 5.5 cfs, what is the depth of the water?

D5. The flow through a 8 inch diameter pipe is moving at a velocity of 5 ft/sec. What is the cfs flow rate through the pipeline?

E5. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?

F5. A 6 inch diameter pipe delivers 55 gpm. What is the velocity of flow in the pipe in ft/sec?

G5. A new section of 18 inch diameter pipe is to be disinfected before it is placed in service. If the length is 5000 feet, how many gallons of 5% NaOCl will be needed for a dosage of 200 mg/L?

Cylinder Formula

$$V = (.785) (D^2) (d)$$

H5. A section of 18 inch diameter pipe is to be filled with water. The length of the pipe is 1200 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 2 mg/L?

$$\text{Pounds per day formula} = \text{Flow} \times \text{Dose} \times 8.34 \times .454 \text{ Grams per pound}$$

Chlorine Dose Example

$$\text{DOSE , mg/L} = \frac{(332) \text{ lbs. / day}}{(5.27) \text{ MGD} \times 8.34 \text{ lbs./mg/L/MG}}$$

$$\text{DOSE , mg/L} = (7.6) \text{ mg/L}$$

DOSE CALCULATION EXAMPLE

Chlorine Residual Formula

$$\text{Dose, mg / L} = \text{Demand, mg / L} + \text{Residual, mg / L}$$

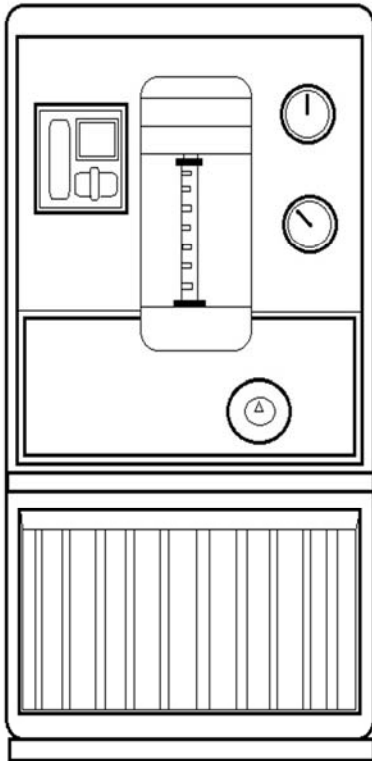
How To Calculate Chlorine Dose

$$(\text{mg / L Cl}_2) (\text{MGD flow}) (8.34 \text{ lbs. / gal.}) = \text{lbs. / day Cl}_2$$

Formula To Convert : mg/L TO lbs./day

21. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 3.4 MGD with a chlorine dose of 3.35 mg/L? Answer in rear of this section.

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

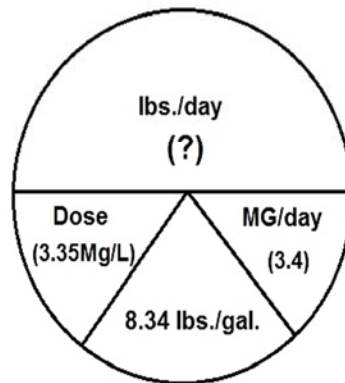


DETERMINE THE CHLORINATOR SETTING IN POUNDS PER 24 HOUR PERIOD TO TREAT 3.4 MGD WITH A CHLORINE DOSE OF 3.35 mg/L.

FLOW = (MGD) (DOSE) (Mg/L) X 8.34 lbs/gal.

3.4 MGD X 3.35 Mg/L = 94.9926 lbs./day (round to 95)

lbs./day



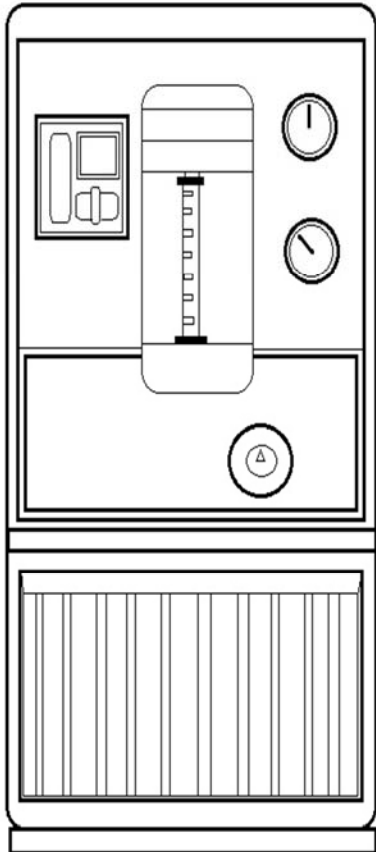
PIE CHART FORMULA CAN BE USED TO CALCULATE lbs./day.

(DOSE) X (8.34) X (MG/day) = lbs./day

22. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 85 GPM. Approximately how much will odor control cost annually if chlorine is \$0.17 per pound?

85 gpm X 1440 min/day = _____ gpd ÷ 1,000,000 = _____ MGD

_____ MGD X 15 mg/L X 8.34 lbs/gal X \$0.17 per pound X 365 days/year =



TO CORRECT AN ODOR PROBLEM, YOU USE CHLORINE CONTINUOUSLY AT A DOSAGE OF 15 mg/L AND A FLOW RATE OF 85 GPM. APPROXIMATELY HOW MUCH WILL ODOR CONTROL COST ANNUALLY IF CHLORINE IS \$0.17 PER POUND.

CONVERT GPM TO gal/day.: 85 GPM X 1440 min./day = 122,400 gal./day.

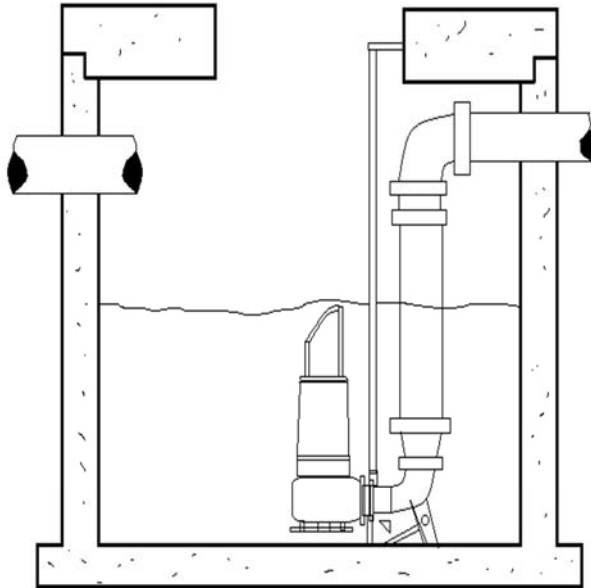
NOW CONVERT TO MGD: 122,400 divided by 1,000,000 = .1224 MGD.

.1224 MGD X 15 mg/L X 8.34 lbs./gal. X \$ 0.17 per/Lb. X 365 days/year =

COST =

23. A wet well measures 8 feet by 10 feet and 3 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in millions of gallons per day (MGD).

Build it, fill it, and do what it says, hint: X 9 X 24



A WET WELL MEASURES 8 feet BY 10 feet AND 3 feet IN DEPTH BETWEEN THE HIGH AND LOW LEVELS. A PUMP EMPTIES THE WET WELL BETWEEN THE HIGH AND LOW LEVELS 9 TIMES PER HOUR, 24 HOURS A DAY. NEGLECTING INFLOW DURING PUMP CYCLE, CALCULATE THE FLOW INTO THE PUMP STATION IN MILLION OF GALLONS PER DAY (MGD).

(Build it / Fill it / and Do What it says, hint: X 9 X 24)

$$(L) (W) (d) = (8) \times (10) \times (3) = 240 \text{ ft}^3$$

(CONVERT TO GALLONS: X 7.48)

$$240 \text{ ft}^3 \times 7.48 = 1795.2 \text{ gals.}$$

DETERMINE HOW MANY CYCLES IN 24 hrs.:
9 times hour X 24 hrs./day = 216 times/day.

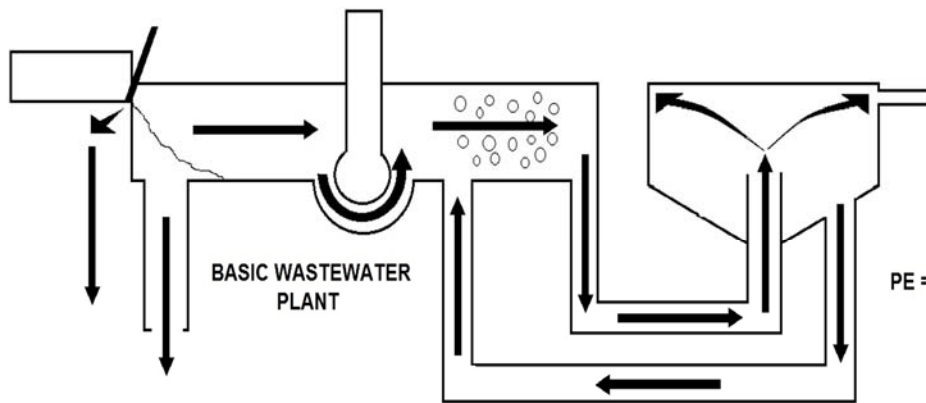
$$1795.2 \text{ gals.} \times 216 \text{ times/day} = 387763.2 \text{ gals./day}$$

CONVERT THIS TO MGD BY DIVIDING BY 1,000,000.

$$387763.2 \text{ gals./day} / 1,000,000 = .388 \text{ MGD}$$

INFLOW = MGD

24. A sewage treatment plant has a flow of 0.7 MGD and a BOD of 225 mg/L. On the basis of a national average of 0.2 lbs BOD per capita per day, what is the approximate population equivalent of the plant?



A SEWAGE TREATMENT PLANT HAS A FLOW OF 0.7 MGD AND A BOD OF 225 mg/L. ON THE BASIS OF A NATIONAL AVERAGE OF 0.2 lbs. BOD PER CAPITA PER DAY, WHAT IS THE APPROXIMATE POPULATION EQUIVALENT OF THE PLANT?

$$PE = \frac{(\text{FLOW/MGD}) (\text{BOD mg/L}) (8.34)}{\text{lbs. day/per person}}$$

$$\frac{(0.7/\text{MGD}) (225\text{mg/L}) (8.34)}{0.2 \text{ lbs. day/per person}}$$

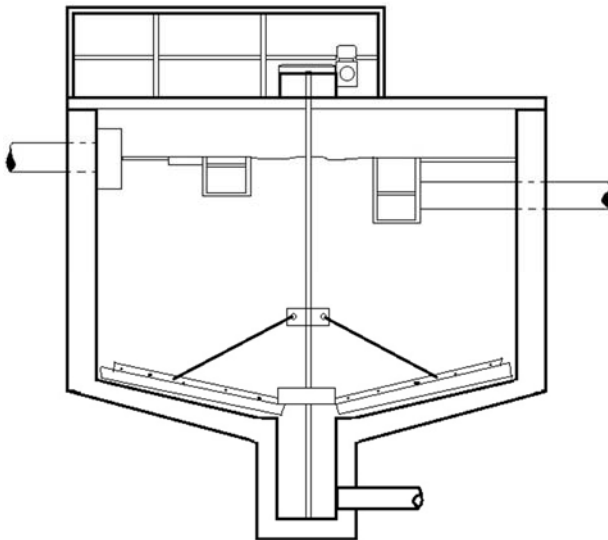
$$\frac{1313.55}{0.2} =$$

25. What is the detention time of a clarifier with a 250,000 gallon capacity if it receives a flow of 3.0 MGD?

DT= Volume in Gallons X 24 Divided by MGD

$$.25 \text{ MG} \times 24 \text{ hrs} \div 3.0 \text{ MGD} = \underline{\hspace{2cm}} \text{ Hours of DT}$$

Always convert gallons to MG



WHAT IS THE DETENTION TIME OF A CLARIFIER WITH A 250,000 GALLON CAPACITY IF IT RECEIVES A FLOW OF 3.0 MGD.

DT = VOLUME IN GALLONS X 24 DIVIDED BY MGD

CONVERT GALLONS TO MG/DAY. BY DIVIDING BY 1,000,000.

$$250,000 \text{ gal.} / 1,000,000 = .25 \text{ MGD.}$$

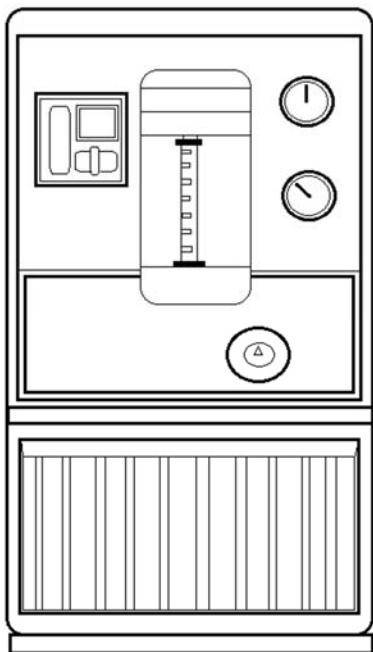
$$.25 \text{ MGD} \times 24 \text{ hrs./day divided BY } 3.0 \text{ MGD} = 2.0$$

DT = hours.

Practice Questions

A6. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 5.4 MGD with a chlorine dose of 2.35 mg/L?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

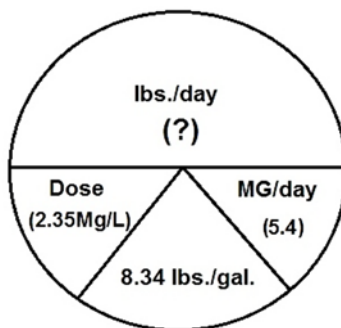


DETERMINE THE CHLORINATOR SETTING IN POUNDS PER 24 HOUR PERIOD TO TREAT 5.4 MGD WITH A CHLORINE DOSE OF 2.35 mg/L.

FLOW = (MGD) (DOSE) (Mg/L) X 8.34 lbs/gal.

5.4 MGD X 2.35 Mg/L = 105.83 lbs./day (round to 106)

106 lbs./day



PIE CHART FORMULA CAN BE USED TO CALCULATE lbs./day.

(DOSE) X (8.34) X (MG/day) = lbs./day

B6. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 7 GPM. Approximately how much will odor control cost annually if chlorine is \$0.15 per pound?



TO CORRECT AN ODOR PROBLEM, YOU USE CHLORINE CONTINUOUSLY AT A DOSAGE OF 15 mg/L AND A FLOW RATE OF 7 GPM. APPROXIMATELY HOW MUCH WILL ODOR CONTROL COST ANNUALLY IF CHLORINE IS \$0.15 PER POUND?

FIRST CONVERT gal./min TO MGD

(7gal./min.) (1440 min./day) = 10,080 gal./day

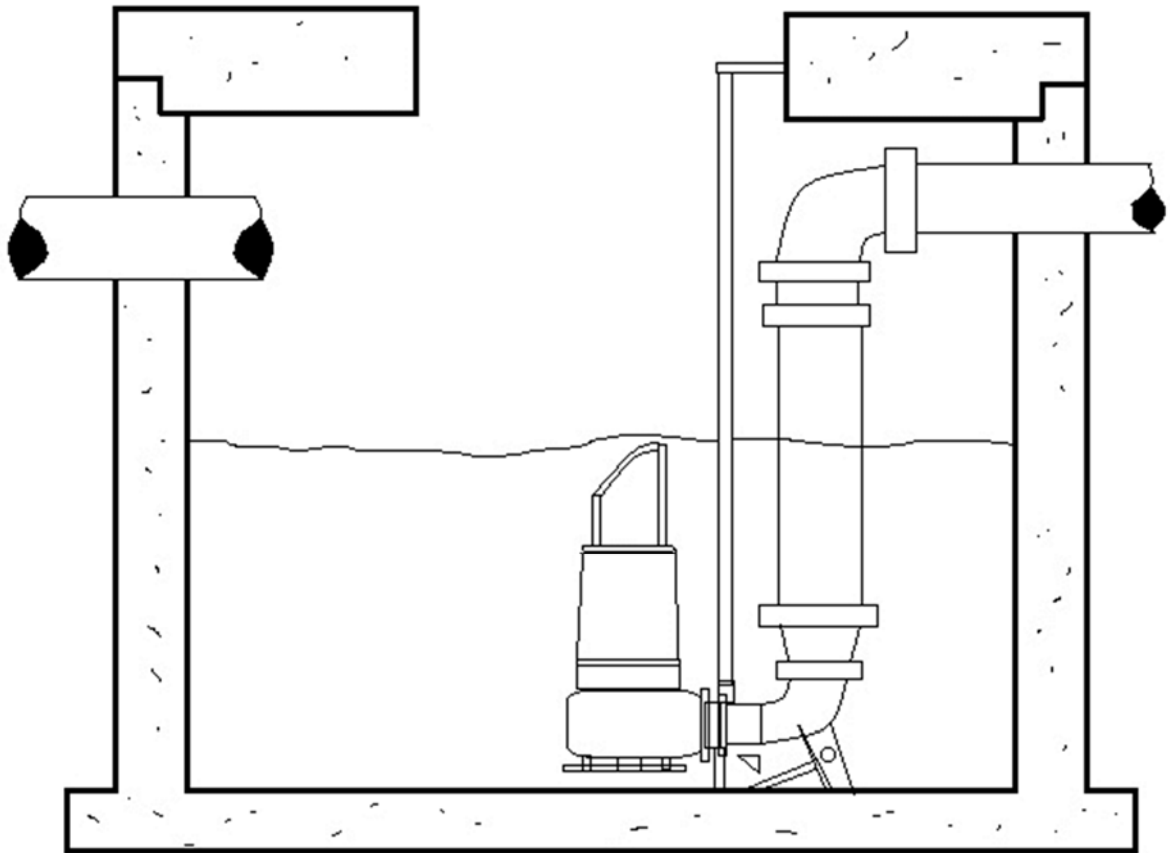
DIVIDE gal./day BY 1,000,000 TO GET MGD

10,080 / 1,000,000 = 0.010 MGD

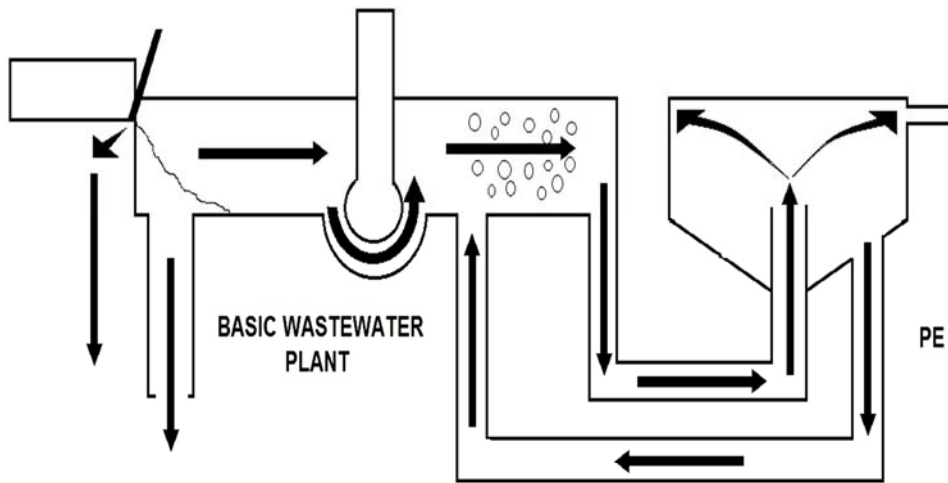
(0.010 MGD) (15 mg/L) (8.34 lbs./gal.) (\$0.15/lb.) (365 days/year)= \$68.49

\$ 68.49 ANNUAL COST

C6. A wet well measures 12 feet by 15 feet and 11 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in millions of gallons per day (MGD).



D6. A sewage treatment plant has a flow of 1.3 MGD and a BOD of 25 mg/L. On the basis of a national average of 0.2 lbs BOD per capita per day, what is the approximate population equivalent of the plant?



A SEWAGE TREATMENT PLANT HAS A FLOW OF 1.3 MGD AND A BOD OF 25 mg/L. ON THE BASIS OF A NATIONAL AVERAGE OF 0.2 lbs. BOD PER CAPITA PER DAY, WHAT IS THE APPROXIMATE POPULATION EQUIVALENT OF THE PLANT?

$$PE = \frac{(\text{FLOW/MGD}) (\text{BOD mg/L}) (8.34)}{\text{lbs. day/per person}}$$

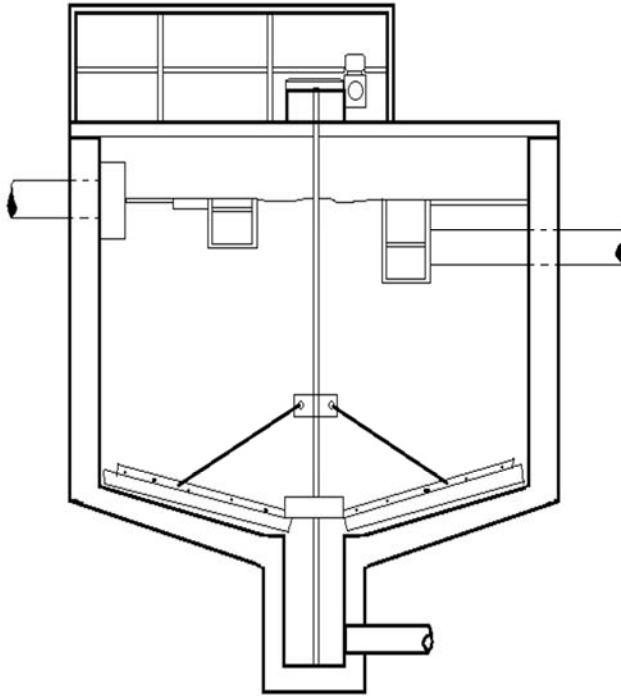
$$\frac{(1.3 / \text{MGD}) (25 \text{ mg/L}) (8.34)}{0.2 \text{ lbs. day/per person}}$$

$$\frac{271.5}{0.2} = 1355.25$$

1355.25 Population Equivalent

E6. What is the detention time of a clarifier with a 750,000 gallon capacity if it receives a flow of 10.0 MGD?

$$DT = \text{Volume in Gallons} \times 24 \text{ Divided by MGD}$$



WHAT IS THE DETENTION TIME OF A CLARIFIER WITH A 750,000 GALLON CAPACITY IF IT RECEIVES A FLOW OF 10.0 MGD.

$$DT = \text{VOLUME IN GALLONS} \times 24 \text{ DIVIDED BY MDG}$$

CONVERT GALLONS TO MG/DAY. BY DIVIDING BY 1,000,000.

$$750,000 \text{ gal.} / 1,000,000 = .75 \text{ MGD.}$$

$$.75 \text{ MGD} \times 24 \text{ hrs./day divided BY } 10.0 \text{ MGD} = 1.8$$

$$DT = 1.8 \text{ hours.}$$

Metric Math Section

The metric system is known for its simplicity. All units of measurement in the metric system are based on decimals—that is, units that increase or decrease by multiples of ten. A series of Greek decimal prefixes is used to express units of ten or greater; a similar series of Latin decimal prefixes is used to express fractions. For example, deca equals ten, hecto equals one hundred, kilo equals one thousand, mega equals one million, giga equals one billion, and tera equals one trillion.

For units below one, deci equals one-tenth, centi equals one-hundredth, milli equals one-thousandth, micro equals one-millionth, nano equals one-billionth, and pico equals one-trillionth.

1 ppm = 1 pound per million pounds / or

120,000 Gallons of Water = 1,000,000 pounds

1 ppm = 1 pound per 120,000 Gallons of Water

**Milligrams Per liter
(Parts Per Million)**

1 Gram (weight) = 1,000 milligrams (and)

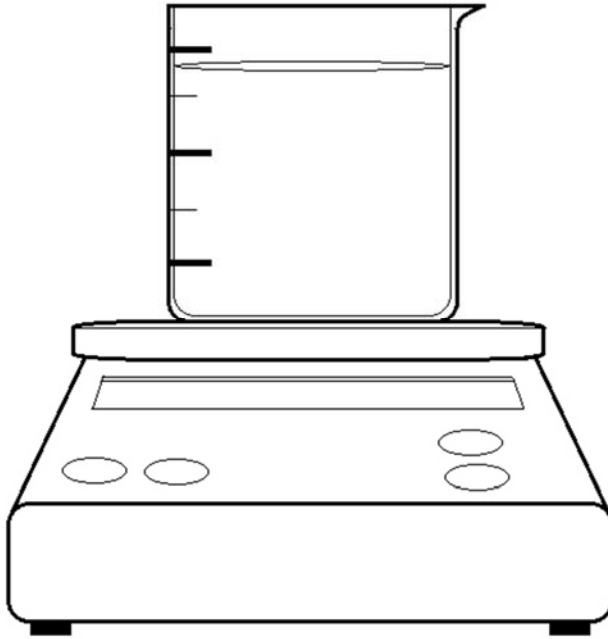
1 Liter of Water Weighs 1,000 GRAMS (so)

1 Liter of Water = 1,000,000 milligrams (1,000 X 1,000)(so)

**1 Milligram in one Liter of Water = 1 milligram per liter (or)
One Part in a Million Parts**

**Milligrams Per Liter
(Refers to a Weight Ratio)**

26. How many grams equal 4,500 mg?
Just simply divide by 1,000.



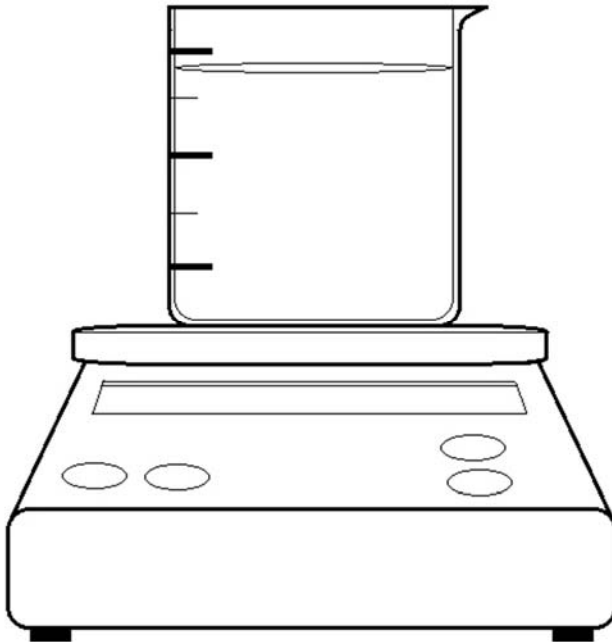
HOW MANY GRAM EQUAL 4,500mg.

**Just divide by 1,000
(there are 1,000 mg in a gram)**

$$\frac{4500}{1000} = \text{Grams}$$

Practice Questions

A7. How many grams equal 7,500 mg?

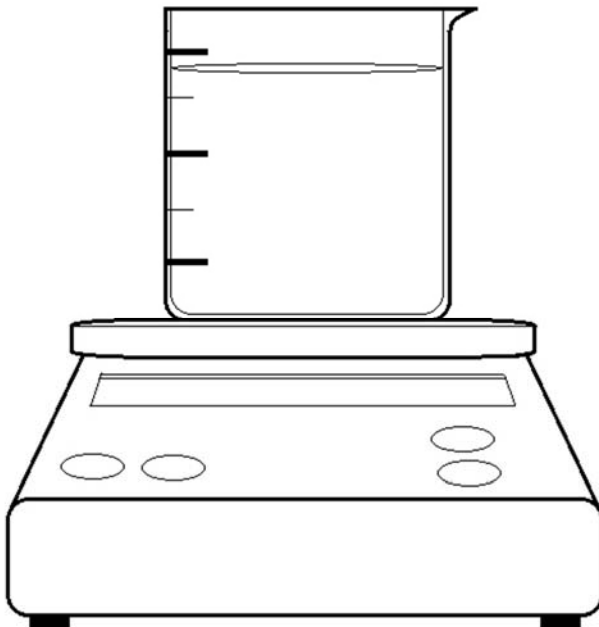


HOW MANY GRAM EQUAL 7,500mg.

Just divide by 1,000
(there are 1,000 mg in a gram)

$$\frac{7500}{1000} = 7.5 \text{ Grams}$$

B7. How many grams equal 12,500 mg?



HOW MANY GRAM EQUAL 12,500mg.

Just divide by 1,000
(there are 1,000 mg in a gram)

$$\frac{12500}{1000} = 12.5 \text{ Grams}$$

Temperature

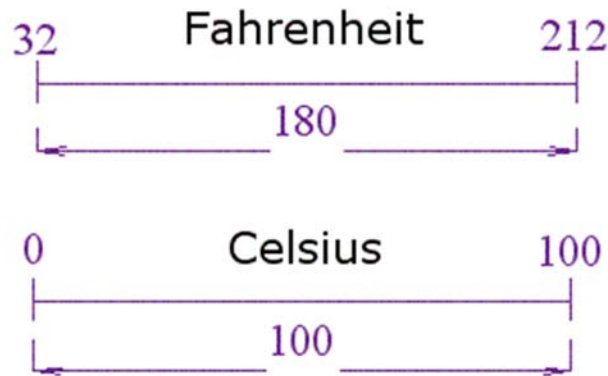
There are two main temperature scales. The Fahrenheit Scale (used in the US), and the Celsius Scale (part of the Metric System, used in most other Countries)

They both measure the same thing (temperature!), just using different numbers.

If you freeze water, it measures 0° in Celsius, but 32° in Fahrenheit

If you boil water, it measures 100° in Celsius, but 212° in Fahrenheit

The difference between freezing and boiling is 100° in Celsius, but 180° in Fahrenheit.



Conversion Method

Looking at the diagram, notice:

The scales start at a different number (32 vs. 0), so we will need to add or subtract 32

The scales rise at a different rate (180 vs. 100), so we will also need to multiply

And this is how it works out:

To convert from Celsius to Fahrenheit, first multiply by 180/100, then add 32

To convert from Fahrenheit to Celsius, first subtract 32, then multiply by 100/180

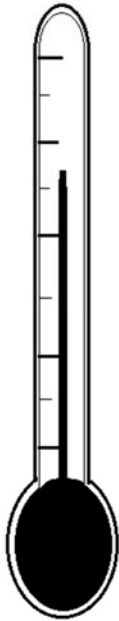
Note: 180/100 can be simplified to 9/5, and likewise 100/180=5/9.

$$^{\circ}\text{F} = (^{\circ}\text{C} \times 9/5) + 32 \quad 9/5 = 1.8$$

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 5/9 \quad 5/9 = .555$$

27. Convert 20 degrees Celsius to degrees Fahrenheit.

$$20^{\circ} \times 1.8 + 32 = F$$



CONVERT 20 degrees CELSIUS TO degrees FAHRENHEIT

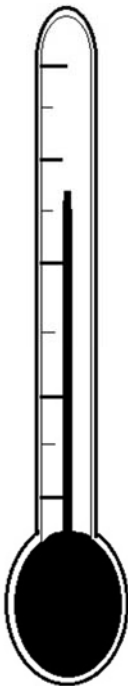
**To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.**

$$(20) (1.8) + 32 = 68$$

$$20^{\circ} \text{C} =$$

28. Convert 4 degrees Celsius to degrees Fahrenheit.

$$4^{\circ} \times 1.8 + 32 = F$$



CONVERT 4 degrees CELSIUS TO degrees FAHRENHEIT

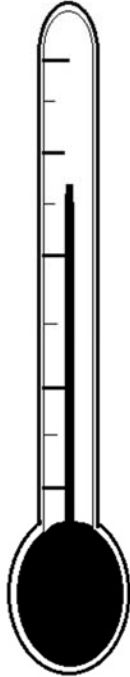
**To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.**

$$(4) (1.8) + 32 = 39.2$$

$$4^{\circ} \text{C} =$$

Practice Questions

A8. Convert 22 degrees Celsius to degrees Fahrenheit.



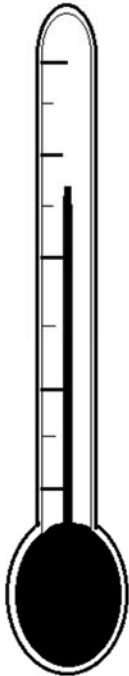
CONVERT 22 degrees CELSIUS TO degrees FAHRENHEIT

To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

$$(22) (1.8) + 32 = 71.6$$

$$22^{\circ}\text{C} = 71.6^{\circ}\text{F}$$

B8. Convert 2 degrees Celsius to degrees Fahrenheit.



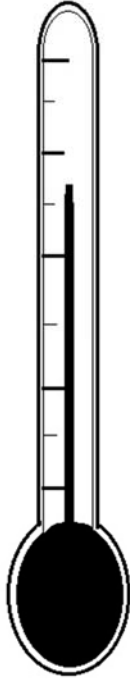
CONVERT 2 degrees CELSIUS TO degrees FAHRENHEIT

To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

$$(2) (1.8) + 32 = 35.6$$

$$2^{\circ}\text{C} = 35.6^{\circ}\text{F}$$

C8. Convert 82 degrees Fahrenheit to degrees Celsius.



CONVERT 82 degrees FAHRENHEIT TO degrees CELSIUS

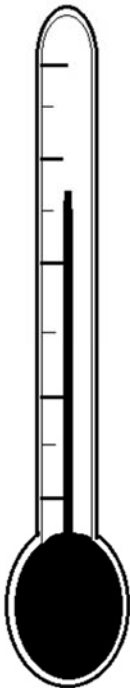
To convert Fahrenheit to Celsius :

First subtract by 32 then multiply by .555

$$82 - 32 (.555) = 27.75$$

$$82^{\circ}\text{F} = 27.75^{\circ}\text{C}$$

D8. Convert 33 degrees Fahrenheit to degrees Celsius.



CONVERT 33 degrees FAHRENHEIT TO degrees CELSIUS

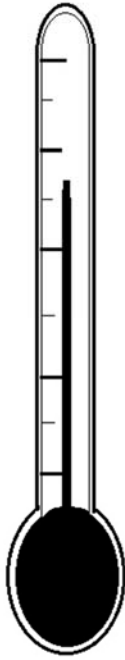
To convert Fahrenheit to Celsius :

First subtract by 32 then multiply by .555

$$33 - 32 (.555) = .555$$

$$33^{\circ}\text{F} = .555^{\circ}\text{C}$$

E8. Convert 72 degrees Fahrenheit to degrees Celsius.



CONVERT 72 degrees FAHRENHEIT TO degrees CELCIUS

To convert Fahrenheit to Celcius :

First subtract by 32 then multiply by .555

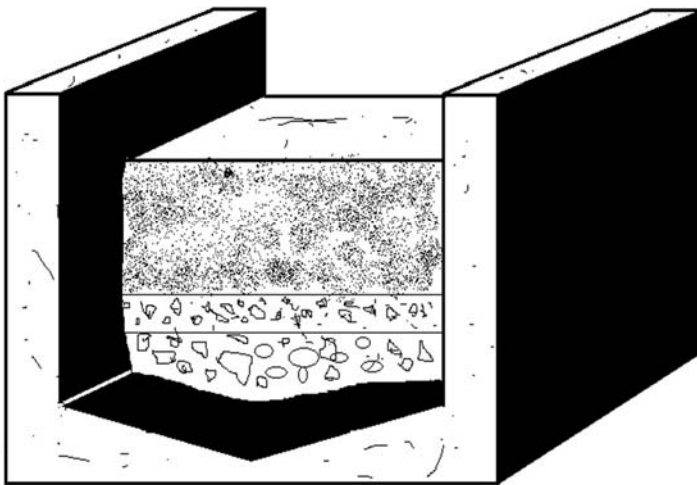
$$72 - 32 (.555) = 22.2$$

$$72^{\circ}\text{F} = 22.2^{\circ}\text{C}$$

Water Treatment Filters

29. A 19 foot wide by 31 foot long rapid sand filter treats a flow of 2,050 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

GPM ÷ Square Feet



A 19 FOOT WIDE BY 31 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 2,050 gal/min. CALCULATE THE FILTRATION RATE IN GALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

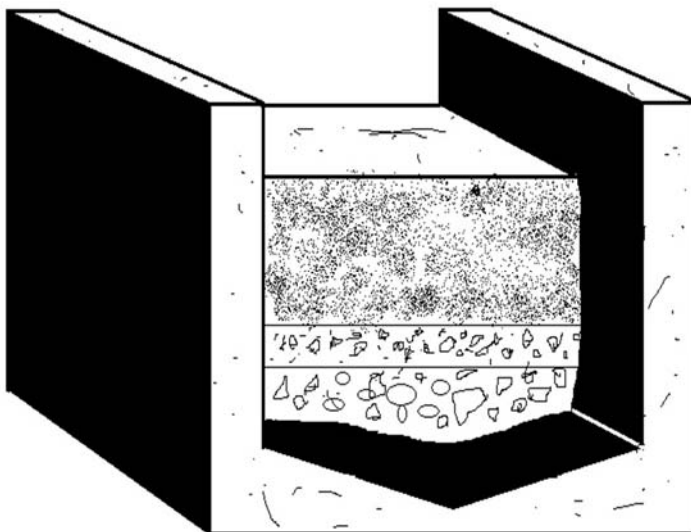
Determine Square Feet:

(W) (H)

$$(19) (31) = 598 \text{ ft}^2$$

$$\frac{2050 \text{ gal/min}}{598 \text{ ft}^2} =$$

30. A 26 foot wide by 36 foot wide long rapid sand filter treats a flow of 2,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



A 26 FOOT WIDE BY 36 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 2,500 gal/min. CALCULATE THE FILTRATION RATE IN GALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:

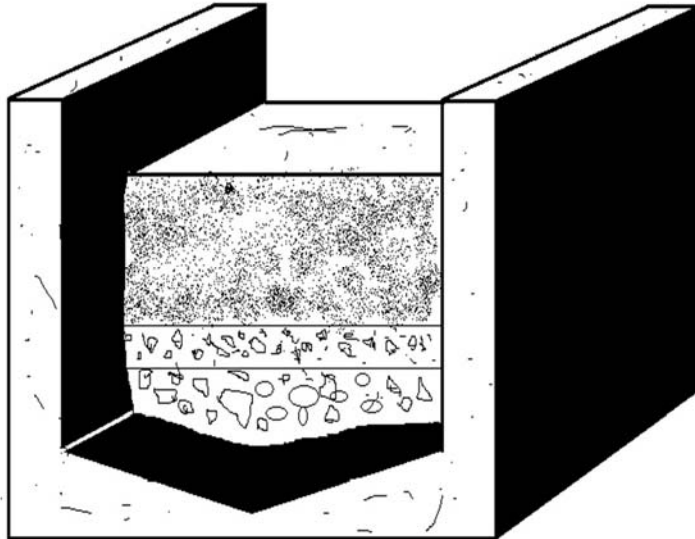
(W) (H)

$$(26) (36) = 936 \text{ ft}^2$$

$$\frac{2500 \text{ gal/min}}{936 \text{ ft}^2} =$$

Practice Questions

A9. A 25 foot wide by 25 foot long rapid sand filter treats a flow of 300 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



A 25 FOOT WIDE BY 25 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 300 gal/min. CALCULATE THE FILTRATION RATE IN GALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

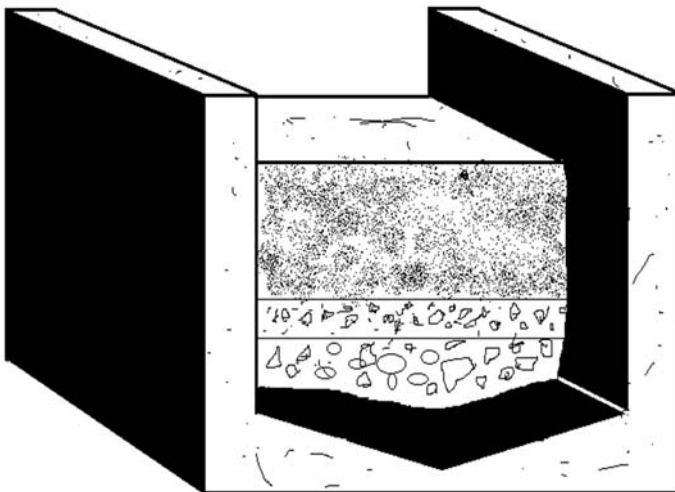
Determine Square Feet:

(W) (H)

$$(25) (25) = 625 \text{ ft}^2$$

$$\frac{300 \text{ gal/min}}{625 \text{ ft}^2} = .48 \text{ gal/min./ft}^2$$

B9. A 30 foot wide by 30 foot wide long rapid sand filter treats a flow of 1,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.



A 30 FOOT WIDE BY 30 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 1,500 gal/min. CALCULATE THE FILTRATION RATE IN GALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:

(W) (H)

$$(30) (30) = 900 \text{ ft}^2$$

$$\frac{1500 \text{ gal/min}}{900 \text{ ft}^2} = 1.67 \text{ gal/min./ft}^2$$

Chemical Dose

31. A pond has a surface area of 51,500 square feet and the desired dose of a chemical is 6.5 lbs per acre. How many pounds of the chemical will be needed?

43,560 Square feet in an acre

$$51,500 \div 43,560 = \underline{\hspace{1cm}} \times 6.5 =$$

32. A pond having a volume of 6.85 acre feet equals how many millions of gallons?

Practice Questions, no answers provided

A10. A pond has a surface area of 75,000 square feet and the desired dose of a chemical is 5.5 lbs per acre. How many pounds of the chemical will be needed?

B10. A pond having a volume of 13,000 acre feet equals how many millions of gallons?

33. Alum is added in a treatment plant process at a concentration of 10.5 mg/L. What should the setting on the feeder be in pounds per day if the plant is treating 3.5 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

$$\text{GPD} = \frac{\text{GALLONS}}{\text{MINUTE}} \times \frac{60 \text{ MINUTES}}{\text{HOUR}} \times \frac{24 \text{ HOURS}}{\text{DAY}}$$

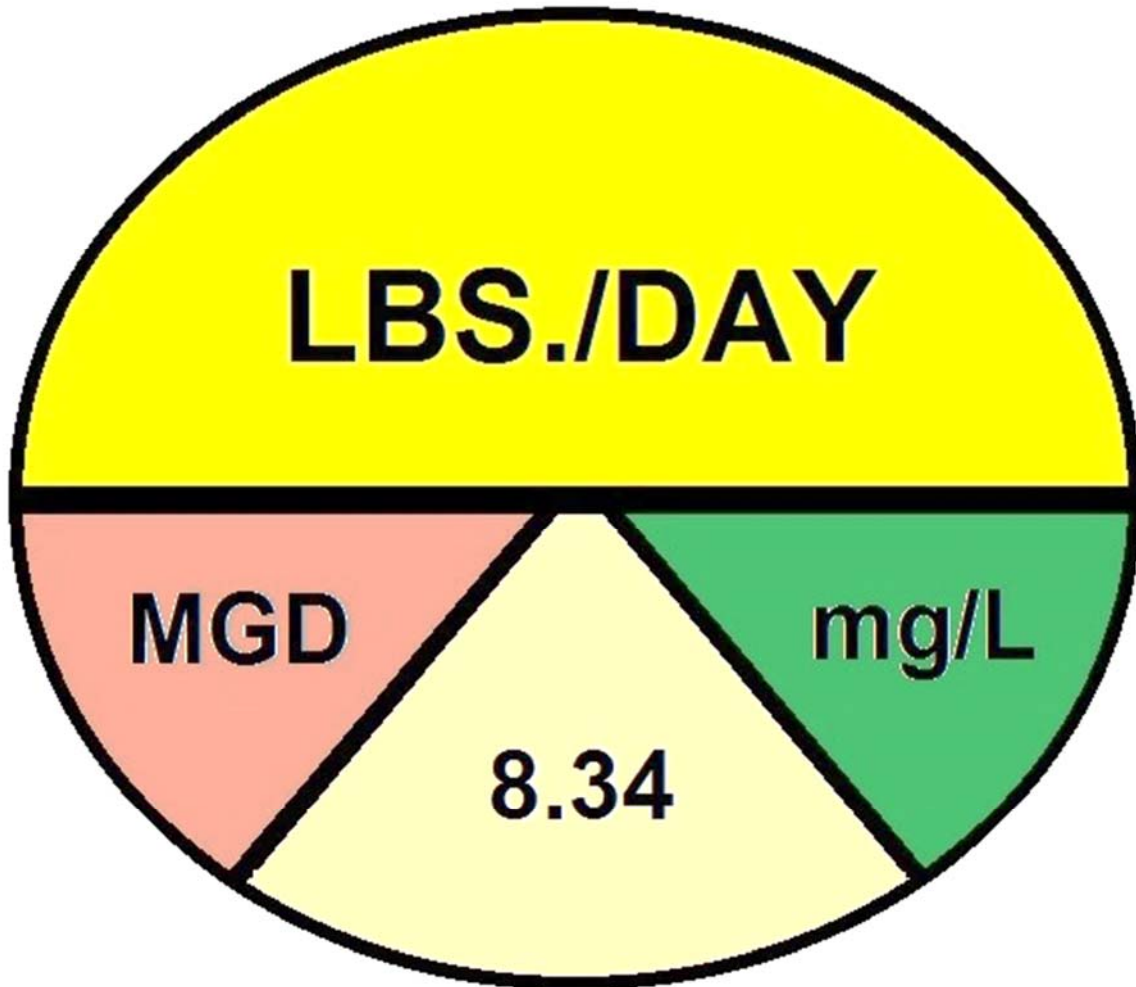
$$\text{GT} = \frac{\text{CHLORINE \%} \times 10,000}{1 \text{ PPM}}$$

$$\frac{\text{GPD}}{\text{GT}} = \text{GALLONS OF CHLORINE PER 24 HOURS}$$

GPD= Gallon Per Day GT= Gallons Treated
--

$$(\text{mg} / \text{L Cl}_2) (\text{MGD flow}) (8.34 \text{ lbs.} / \text{gal.}) = \text{lbs.} / \text{day Cl}_2$$

Formula To Convert : mg/L TO lbs./day



POUNDS FORMULA WHEEL

Practice Questions, no answers provided

A11. Alum is added in a treatment plant process at a concentration of 4.5 mg/L. What should the setting on the feeder be in pounds per day if the plant is treating 23.5 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

Q=AV Review

34. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the GPM flow rate through the pipe?

$$Q = 1.18 \text{ CFS} \times 60 \text{ Seconds} \times 7.48 \text{ GAL/CU.FT} = 532 \text{ GPM}$$

$$A = .785 \times .667 \times .667 \times 1 = .349 \text{ Sq. Ft.}$$

$$V = 3.4 \text{ Feet per second}$$

35. A 6 inch diameter pipe delivers 280 GPM. What is the velocity of flow in the pipe in Ft/Sec?

$$280 \text{ GPM} \div 60 \text{ seconds in a minute} \div 7.48 \text{ gallons in a cu.ft.} = .623 \text{ CFS}$$

$$Q = .623$$

$$A = .785 \times .5 \times .5 = .196 \text{ Sq. Ft.}$$

$$V = 3.17 \text{ Ft/Second}$$

Practice Questions, no answers provided

A12. An 36 inch diameter pipe has water flowing at a velocity of 1.4 fps. What is the GPM flow rate through the pipe?

B12. An 18 inch diameter pipe delivers 80 GPM. What is the velocity of flow in the pipe in Ft/Sec?

Short Math Answers

1. 46750
2. $800 \div 8.34 = 95.92$ gallons
3. 1372320 or 1.3 MGD
4. $610 \times 1441 = 878400$ or 0.87 MGD
5. $550 \div 60 = 9.167$ gpm
6. $9.167 \times 3.785 = 34.697$ Liters
7. 630 Area 4712.4 gallons
8. $18,750 \text{ cu. ft.} \times 7.48 = 140250$ gallons
9. 177182.5
10. 10 feet deep
11. 528462 or .5 MG
12. $1.166 \text{ Gallons} \times 3.785 = 4.4131$ Liters
13. 15 cfs
14. 11.5 cfs
15. 5.4
16. .58875 or .6 cfs
17. 534.7 or 533 gpm
18. 3.115 or 3.2 ft/sec
19. 46.9 gal
20. .02 kg
21. 94.9 lbs/day
22. \$950.12
23. .388 or .39 MGD
24. 6567.75
25. 2 hrs
26. 4.5 grams
27. 68° F
28. 39.2° F
29. 3.43 gpm/sq.ft.
30. 2.67 gpm/sq.ft.
31. 7.68 lbs
32. 2.231 MG
33. 306.495
34. 532 gpm
35. 3.2 fps

Glossary

A

ABIOGENESIS: The concept of spontaneous generation (that life can come from non-life). This idea was refuted by Pasteur.

ABIOTIC: The non-living components of an organism's environment. The term abiotic is also used to denote a process which is not facilitated by living organisms.

ABORAL: Pertaining to the region of the body opposite that of the mouth. Normally used to describe radially symmetrical animals.

ABSCISIC ACID (ABA): A plant hormone that generally acts to inhibit growth, promote dormancy, and help the plant withstand stressful conditions.

ABSENCE OF OXYGEN: The complete absence of oxygen in water described as Anaerobic.

ABSOLUTE ZERO: A theoretical condition concerning a system at zero Kelvin where a system does not emit or absorb energy (all atoms are at rest).

ABSORPTION SPECTRUM: The range of a material's ability to absorb various wavelengths of light. The absorption spectrum is studied to evaluate the function of photosynthetic pigments.

ACCESSORY PIGMENT: A photosynthetic pigment which absorbs light and transfers energy to chlorophylls during photosynthesis. Because accessory pigments have different absorption optima than chlorophylls, presence of accessory pigments allows photosynthetic systems to absorb light more efficiently than would be possible otherwise.

ACCURACY: How close a value is to the actual or true value; also see precision. How closely an instrument measures the true or actual value.

ACELLULAR: Not within cells. Sometimes used as a synonym for unicellular (but multinucleate). Unicellular also pertains to single-celled organisms.

ACETYL COA: Acetyl CoenzymeA is the entry compound for the Krebs cycle in cellular respiration; formed from a fragment of pyruvic acid attached to a coenzyme.

ACETYLCHOLINE: A neurotransmitter substance that carries information across vertebrate neuromuscular junctions and some other synapses.

ACID AND BASE ARE MIXED: When an acid and a base are mixed, an explosive reaction occurs and decomposition products are created under certain conditions.

ACID ANHYDRIDE: A compound with two acyl groups bound to a single oxygen atom.

ACID DISSOCIATION CONSTANT: An equilibrium constant for the dissociation of a weak acid.

ACID RAIN: Rain that is excessively acidic due to the presence of acid: causing pollutants in the atmosphere. Pollutants include nitrogen and sulfur oxides due to burning of coal and oil.

ACID: Slowly add the acid to water while stirring. An operator should not mix acid and water or acid to a strong base.

ACIDOSIS: A condition whereby the hydrogen ion concentration of the tissues is increased (and pH decreased). Respiratory acidosis is due to the retention of CO₂; metabolic acidosis by retention of acids due either to kidney failure or diarrhea.

ACOELOMATE: Lacking a coelom.

ACQUIRED IMMUNITY: Results from exposure to foreign substances or microbes (also called natural immunity).

ACROSOME: An organelle at the tip of a sperm cell that helps the sperm penetrate the egg.

ACTH (adrenocorticotrophic hormone): A proteinaceous hormone from the anterior pituitary that stimulates the adrenal cortex. Used to stimulate the production of cortisol.

ACTIN: A globular protein that links into chains, two of which twist helically about each other, forming microfilaments in muscle and other contractile elements in cells.

ACTINIDES: The fifteen chemical elements that are between actinium (89) and lawrencium (103).

ACTION POTENTIAL: The stimulus-triggered change in the membrane potential of an excitable cell, caused by selective opening and closing of ion channels.

ACTION SPECTRUM: A graph which illustrates the relationship between some biological activity and wavelength of light.

ACTIVATED CARBON FILTRATION: Can remove organic chemicals that produce off-taste and odor. These compounds are not dangerous to health but can make the water unpleasant to drink.

Carbon filtration comes in several forms, from small filters that attach to sink faucets to large tanks that contain removable cartridges. Activated carbon filters require regular maintenance or they can become a health hazard.

ACTIVATED CHARCOAL (GAC or PAC): Granular Activated Charcoal or Powered Activated Charcoal. Used for taste and odor removal. A treatment technique that is not included in the grading of a water facility.

ACTIVATED COMPLEX: A structure that forms because of a collision between molecules while new bonds are formed.

ACTIVATED SLUDGE PROCESS: A biological wastewater treatment process in which a mixture of wastewater and biologically enriched sludge is mixed and aerated to facilitate aerobic decomposition by microbes.

ACTIVATED SLUDGE: The biologically active solids in an activated sludge process wastewater treatment plant.

ACTIVATING ENZYME: An enzyme that couples a low-energy compound with ATP to yield a high-energy derivative.

ACTIVATION ENERGY: In a chemical reaction, the initial investment required to energize the bonds of the reactants to an unstable transition state that precedes the formation of the products. The minimum energy that must be input to a chemical system.

ACTIVE SITE: That specific portion of an enzyme that attaches to the substrate by means of weak chemical bonds.

ACTIVE TRANSPORT: The movement of a substance across a biological membrane against its concentration or electrochemical gradient with the help of energy input and specific transport proteins.

ADAPTATION: Any genetically controlled characteristic that increases an organism's fitness, usually by helping the organism to survive and reproduce in the environment it inhabits.

ADAPTIVE RADIATION: This refers to the rapid evolution of one or a few forms into many different species that occupy different habitats within a new geographical area.

ADDITION REACTION: Within organic chemistry, when two or more molecules combine to make a larger one.

ADHESION: In chemistry, the phenomenon whereby one substance tends to cling to another substance. Water molecules exhibit adhesion, especially toward charged surfaces.

ADP (Adenosine diphosphate): A doubly phosphorylated organic compound that can be further phosphorylated to form ATP.

ADRENAL GLAND: An endocrine gland located adjacent to the kidney in mammals. It is composed of an outer cortex, and a central medulla, each involved in different hormone-mediated phenomena.

ADRENALIN: A hormone produced by the pituitary that stimulates the adrenal cortex.

ADSORB: Hold on a surface.

ADSORPTION CLARIFIERS: The concept of the adsorption clarifier package plant was developed in the early 1980s. This technology uses an up-flow clarifier with low-density plastic bead media, usually held in place by a screen. This adsorption media is designed to enhance the sedimentation/clarification process by combining flocculation and sedimentation into one step. In this step, turbidity is reduced by adsorption of the coagulated and flocculated solids onto the adsorption media and onto the solids already adsorbed onto the media. Air scouring cleans adsorption clarifiers followed by water flushing. Cleaning of this type of clarifier is initiated more often than filter backwashing because the clarifier removes more solids. As with the tube-settler type of package plant, the sedimentation/clarification process is followed by mixed-media filtration and disinfection to complete the water treatment.

ADSORPTION: *Not to be confused with absorption.* Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a film of molecules or atoms (the adsorbate). It is different from absorption, in which a substance diffuses into a liquid or solid to form a solution. The term sorption encompasses both processes, while desorption is the reverse process. Adsorption is present in many natural physical, biological, and chemical systems, and is widely used in industrial applications such as activated charcoal, synthetic resins, and water purification. Adsorption, ion exchange, and chromatography are sorption processes in which certain adsorbates are selectively transferred from the fluid phase to the surface of insoluble, rigid particles suspended in a vessel or packed in a column. Similar to surface tension, adsorption is

a consequence of surface energy. In a bulk material, all the bonding requirements (be they ionic, covalent, or metallic) of the constituent atoms of the material are filled by other atoms in the material. However, atoms on the surface of the adsorbent are not wholly surrounded by other adsorbent atoms, and therefore can attract adsorbates. The exact nature of the bonding depends on the details of the species involved, but the adsorption process is generally classified as physisorption (characteristic of weak van der Waals forces) or chemisorption (characteristic of covalent bonding).

ADVANCED: New, unlike the ancestral condition.

AERATION: The addition of air or oxygen to water or wastewater, usually by mechanical means, to increase dissolved oxygen levels and maintains aerobic conditions. The mixing of air into a liquid or solid.

AEROBIC DIGESTION: Sludge stabilization process involving direct oxidation of biodegradable matter and oxidation of microbial cellular material.

AEROBIC: The condition of requiring oxygen; an aerobe is an organism which can live and grow only in the presence of oxygen.

AGE STRUCTURE: The relative numbers of individuals of each age in a population.

AGGLOMERATION: A jumbled cluster or mass of varied parts. The act or process of agglomerating.

AGNATHAN: A member of a jawless class of vertebrates represented today by the lampreys and hagfishes.

AGONISTIC BEHAVIOR: A type of behavior involving a contest of some kind that determines which competitor gains access to some resource, such as food or mates.

AIDS (acquired immune deficiency syndrome): A condition in which the body's helper T lymphocytes are destroyed, leaving the victim subject to opportunistic diseases.

AIR ENTRAINMENT: The dissolution or inclusion of air bubbles into water.

AIR GAP SEPARATION: A physical separation space that is present between the discharge vessel and the receiving vessel; for an example, a kitchen faucet.

AIR HOOD: The most suitable protection when working with a chemical that produces dangerous fumes.

ALCOHOL: Any of a class of organic compounds in which one or more - OH groups are attached to a carbon compound.

ALDEHYDE: An organic molecule with a carbonyl group located at the end of the carbon skeleton.

ALGAE: Microscopic plants that are free-living and usually live in water. They occur as single cells floating in water, or as multicellular plants like seaweed or strands of algae that attach to rocks.

ALKALI METALS: The metals of Group 1 on the periodic table.

ALKALINE: Having a pH of more than 7. Alkaline solutions are also said to be basic.

ALKALINITY: Alkalinity or AT is a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate. Alkalinity is closely related to the acid neutralizing capacity (ANC) of a solution and ANC is often incorrectly used to refer to alkalinity. However, the acid neutralizing capacity refers to the combination of the solution and solids present (e.g., suspended matter, or aquifer solids), and the contribution of solids can dominate the ANC (see carbonate minerals below). The alkalinity is equal to the stoichiometric sum of the bases in solution. In the natural environment carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. Other common natural components that can contribute to alkalinity include borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulfide. Solutions produced in a laboratory may contain a virtually limitless number of bases that contribute to alkalinity. Alkalinity is usually given in the unit mEq/L (milliequivalent per liter). Commercially, as in the pool industry, alkalinity might also be given in the unit ppm or parts per million. Alkalinity is sometimes incorrectly used interchangeably with basicity. For example, the pH of a solution can be lowered by the addition of CO₂. This will reduce the basicity; however, the alkalinity will remain unchanged.

ALKALINE EARTH METALS: The metals of Group 2 on the periodic table.

ALLANTOIS: One of the four extraembryonic membranes found associated with developing vertebrates; it serves in gas exchange and as a repository for the embryo's nitrogenous waste. In humans, the allantois is involved in early blood formation and development of the urinary bladder.

ALLELE: Alternate forms of a gene which may be found at a given location (locus) on members of a homologous set of chromosomes. Structural variations between alleles may lead to different phenotypes for a given trait.

ALLOMER: A substance that has different composition than another, but has the same crystalline structure.

ALLOMETRIC: The variation in the relative rates of growth of various parts of the body, which helps shape the organism.

ALLOPATRIC SPECIATION: A type of speciation which occurs when a population becomes segregated into two populations by some sort of geographic barrier (also called geographic speciation). This phenomenon is presumed to have been the mechanism whereby many species of organisms evolved.

ALLOPOLYPLOID: A common type of polyploid species resulting from two different species interbreeding and combining their chromosomes.

ALL-OR-NONE: (event) An action that occurs either completely or not at all, such as the generation of an action potential by a neuron.

ALLOSTERIC ENZYME: An enzyme that can exist in two or more conformations.

ALLOSTERIC SITE: A receptor on an enzyme molecule which is remote from the active site. Binding of the appropriate molecule to the allosteric site changes the conformation of the active site, making it either more or less receptive to the substrate.

ALLOTROPY: Elements that can have different structures (and therefore different forms), such as Carbon (diamonds, graphite, and fullerene).

ALPHA AND BETA RADIOACTIVITY: Represent two common forms of radioactive decay. Radioactive elements have atomic nuclei so heavy that the nucleus will break apart, or disintegrate spontaneously. When decay occurs, high-energy particles are released. These high-energy particles are called radioactivity. Although radioactivity from refined radioactive elements can be dangerous, it is rare to find dangerous levels of radioactivity in natural waters. An alpha particle is a doubly-charged helium nucleus comprised of two protons, two neutrons, and no electrons. A beta particle is a high-speed electron. Alpha particles do not penetrate matter easily, and are stopped by a piece of paper. Beta particles are much more penetrating and can pass through a millimeter of lead.

ALPHA HELIX: A spiral shape constituting one form of the secondary structure of proteins, arising from a specific hydrogen bonding structure.

ALTERNATION OF GENERATIONS: Occurrences of a multicellular diploid form, the sporophyte, with a multicellular haploid form, the gametophyte.

ALTERNATIVE DISINFECTANTS: Disinfectants - other than chlorination (halogens) - used to treat water, e.g. ozone, ultraviolet radiation, chlorine dioxide, and chloramine. There is limited experience and scientific knowledge about the by-products and risks associated with the use of alternatives.

ALTRUISM: The willingness of an individual to sacrifice its fitness for the benefit of another.

ALUMINUM SULFATE: The chemical name for Alum. The molecular formula of Alum is $\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$. It is a cationic polymer.

ALVEOLUS: One of the dead-end, multilobed air sacs that constitute the gas exchange surface of the lungs.

AMINO ACID: An organic molecule possessing a carboxyl (COOH) and amino group. Amino acids serve as the monomers of polypeptides and proteins.

AMINO GROUP: A functional group consisting of a nitrogen atom bonded to two hydrogens; can act as a base in solution, accepting a hydrogen ion and acquiring a charge of +1.

AMINOACYL: tRNA synthetases- A family of enzymes, at least one for each amino acid, that catalyze the attachment of an amino acid to its specific tRNA molecule.

AMMONIA: A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water. Most ammonia in water is present as the ammonium ion rather than as ammonia.

AMMONIA: NH_3 A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water. Most ammonia in water is present as the ammonium ion rather than as ammonia.

AMMONIATOR: AA control device which meters gaseous ammonia directly into water under positive pressure.

AMOEBIA: Amoeba (sometimes amoeba or ameba, plural amoebae) is a genus of protozoa that moves by means of pseudopods, and is well-known as a representative unicellular organism. The

word amoeba or ameba is variously used to refer to it and its close relatives, now grouped as the Amoebozoa, or to all protozoa that move using pseudopods, otherwise termed amoeboids.

(Movement) A streaming locomotion characteristic of Amoeba and other protists, as well as some individual cells, such as white blood cells, in animals.

AMP (Adenosine monophosphate): A singly phosphorylated organic compound that can be further phosphorylated to form ADP.

AMYLASE: A starch-digesting enzyme.

ANABOLISM: A metabolic pathway of biosynthesis that consumes energy to build a large molecule from simpler ones.

ANAEROBIC CONDITIONS: When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with Reduction in the stratified waters.

ANAEROBIC DIGESTION: Sludge stabilization process where the organic material in biological sludges are converted to methane and carbon dioxide in an airtight reactor.

ANAEROBIC: Without oxygen. An organism which lives in the absence of oxygen is called an anaerobe. An abnormal condition in which color and odor problems are most likely to occur.

ANAEROBIC: An abnormal condition in which color and odor problems are most likely to occur.

ANAGENESIS: A pattern of evolutionary change involving the transformation of an entire population, sometimes to a state different enough from the ancestral population to justify renaming it as a separate species; also called phyletic.

ANALOGOUS: Characteristics of organisms which are similar in function (and often in structure) but different in embryological and/or evolutionary origins.

ANALYST: The analyst must have at least 2 years of college lecture and laboratory course work in microbiology or a closely related field. The analyst also must have at least 6 months of continuous bench experience with environmental protozoa detection techniques and IFA microscopy, and must have successfully analyzed at least 50 water and/or wastewater samples for *Cryptosporidium* and *Giardia*. Six months of additional experience in the above areas may be substituted for two years of college.

ANCESTRAL TRAIT: Trait shared by a group of organisms as a result of descent from a common ancestor.

ANEROID: Using no fluid, as in aneroid barometer.

ANEUPLOIDY: A chromosomal aberration in which certain chromosomes are present in extra copies or are deficient in number.

ANION: Negatively charge ions.

ANISOGAMOUS: Reproducing by the fusion of gametes that differ only in size, as opposed to gametes that are produced by oogamous species. Gametes of oogamous species, such as egg cells and sperm, are highly differentiated.

ANNUAL: A plant that completes its entire life cycle in a single year or growing season.

ANODE: The positive side of a dry cell battery or a cell.

ANOXIC: A biological environment that is deficient in molecular oxygen, but may contain chemically bound oxygen, such as nitrates and nitrites.

ANTERIOR: Referring to the head end of a bilaterally symmetrical animal.

ANTHROPOMORPHISM: Attributing a human characteristic to an inanimate object or a species other than a human.

ANTIBIOTIC: A chemical that kills or inhibits the growth of bacteria, often via transcriptional or translational regulation.

ANTIBODY: A protein, produced by the B lymphocytes of the immune system that binds to a particular antigen.

ANTICODON: The specialized base triplet on one end of a tRNA molecule that associates with a particular complementary codon on an mRNA molecule during protein synthesis.

ANTIDIURETIC HORMONE: A hormone important in osmoregulation (it acts to reduce the elimination of water from the body).

ANTIGEN: A foreign macromolecule that does not belong to the host organism and that elicits an immune response.

APOMORPHIC CHARACTER: A derived phenotypic character, or homology, that evolved after a branch diverged from a phylogenetic tree.

APOSEMATIC COLORATION: Serving as a warning, with reference particularly to colors and structures that signal possession of defensive device.

AQUEOUS SOLUTION: A solution in which water is the solvent.

AQUIFER PARAMETERS: Referring to such attributes as specific capacity, aquifer storage, transmissivity, hydraulic conductivity, gradient, and water levels. Refers to all of the components of Darcy's Law and related parameters.

ARCHAEBACTERIA: A lineage of prokaryotes, represented today by a few groups of bacteria inhabiting extreme environments. Some taxonomists place archaeobacteria in their own kingdom, separate from the other bacteria.

ARCHENTERON: The endoderm-lined cavity formed during the gastrulation process that develops into the digestive tract of the animal.

ARISTOTLE: A Greek philosopher often credited as the first to use empirical and deductive methods in logic.

AROMATICITY: Chemical property of conjugated rings that results in unusual stability. See also benzene.

ARTIFICIAL SELECTION: The selective breeding of domesticated plants and animals to encourage the occurrence of desirable traits.

AS NITROGEN: An expression that tells how the concentration of a chemical is expressed mathematically. The chemical formula for the nitrate ion is NO_3 , with a mass of 62. The concentration of nitrate can be expressed either in terms of the nitrate ion or in terms of the principal element, nitrogen. The mass of the nitrogen atom is 14. The ratio of the nitrate ion mass to the nitrogen atom mass is 4.43. Thus a concentration of 10 mg/L nitrate expressed as nitrogen would be equivalent to a concentration of 44.3 mg/L nitrate expressed as nitrate ion. When dealing with nitrate numbers it is very important to know how numeric values are expressed.

AS: The chemical symbol of Arsenic.

ASCUS: The elongate spore sac of a fungus of the Ascomycota group.

ASEPTIC: Free from the living germs of disease, fermentation, or putrefaction.

ASEXUAL: A type of reproduction involving only one parent that produces genetically identical offspring by budding or division of a single cell or the entire organism into two or more parts.

ASSORTATIVE MATING: A type of nonrandom mating in which mating partners resemble each other in certain phenotypic characters.

ASYMMETRIC CARBON: A carbon atom covalently bonded to four different atoms or groups of atoms.

ASYNCHRONOUS: Not occurring at the same time.

ATOM: The general definition of an ion is an atom with a positive or negative charge. Electron is the name of a negatively charged atomic particle.

ATOMIC NUMBER: The number representing an element which corresponds with the number of protons within the nucleus.

ATOMIC ORBITAL: The region where the electron of the atom may be found.

ATOMIC THEORY: The physical theory of the structure, properties and behavior of the atom.

ATOMIC WEIGHT: The total atomic mass, which is the mass in grams of one mole of the atom (relative to that of ^{12}C , which is designated as 12).

ATP (Adenosine triphosphate): A triply phosphorylated organic compound that functions as "energy currency" for organisms, thus allowing life forms to do work; it can be hydrolyzed in two steps (first to ADP and then to AMP) to liberate 7.3 Kcal of energy per mole during each hydrolysis.

ATPASE: An enzyme that functions in producing or using ATP.

AUTOGENOUS MODEL: A hypothesis which suggests that the first eukaryotic cells evolved by the specialization of internal membranes originally derived from prokaryotic plasma membranes.

AUTOIMMUNE DISEASE: An immunological disorder in which the immune system goes awry and turns against itself.

AUTONOMIC NERVOUS SYSTEM: A subdivision of the motor nervous system of vertebrates that regulates the internal environment; consists of the sympathetic and parasympathetic subdivisions.

AUTOPOLYPLOID: A type of polyploid species resulting from one species doubling its chromosome number to become tetraploids, which may self-fertilize or mate with other tetraploids.

AUTOSOME: Chromosomes that are not directly involved in determining sex.

AUTOTROPH: An organism which is able to make organic molecules from inorganic ones either by using energy from the sun or by oxidizing inorganic substances.

AUXIN: One of several hormone compounds in plants that have a variety of effects, such as phototropic response through stimulation of cell elongation, stimulation of secondary growth, and development of leaf traces and fruit.

AUXOTROPH: A nutritional mutant that is unable to synthesize and that cannot grow on media lacking certain essential molecules normally synthesized by wild-type strains of the same species.

AVOGADRO'S NUMBER: Is the number of particles in a mole of a substance (6.02×10^{23}).

AXON: A typically long outgrowth, or process, from a neuron that carries nerve impulses away from the cell body toward target cells.

AXONEME: An internal flagellar structure that occurs in some protozoa, such as *Giardia*, *Spironucleus*, and *Trichomonas*.

B

BACKFLOW PREVENTION: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquid, gases, or solid substances back in to the public potable (drinking) water supply. See Cross-connection control.

BACKFLOW: To reverse the natural and normal directional flow of a liquid, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect.

BACKSIPHONAGE: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point.

BACTERIA: Small, one-celled animals too small to be seen by the naked eye. Bacteria are found everywhere, including on and in the human body. Humans would be unable to live without the bacteria that inhabit the intestines and assist in digesting food. Only a small percentage of bacteria cause disease in normal, healthy humans. Other bacteria can cause infections if they get into a cut or wound. Bacteria are the principal concern in evaluating the microbiological quality of drinking water, because some of the bacteria-caused diseases that can be transmitted by drinking water are potentially life-threatening.

BACTERIOPHAGE: Any of a group of viruses that infect specific bacteria, usually causing their disintegration or dissolution. A bacteriophage (from 'bacteria' and Greek phagein, 'to eat') is any one of a number of viruses that infect bacteria. The term is commonly used in its shortened form, phage. Typically, bacteriophages consist of an outer protein hull enclosing genetic material. The genetic material can be ssRNA (single stranded RNA), dsRNA, ssDNA, or dsDNA between 5 and 500 kilo base pairs long with either circular or linear arrangement. Bacteriophages are much smaller than the bacteria they destroy - usually between 20 and 200 nm in size.

BACTERIUM: A unicellular microorganism of the Kingdom Monera. Bacteria are prokaryotes; their cells have no true nucleus. Bacteria are classified into two groups based on a difference in cell walls, as determined by Gram staining.

BALANCED POLYMORPHISM: A type of polymorphism in which the frequencies of the coexisting forms do not change noticeably over many generations.

BARITE: Processed barium sulfate often used to increase drilling fluid densities in mud rotary.

BAROMETER: A device used to measure the pressure in the atmosphere.

BARR BODY: The dense object that lies along the inside of the nuclear envelope in cells of female mammals, representing the one inactivated X chromosome.

BASAL BODY: A cell structure identical to a centriole that organizes and anchors the microtubule assembly of a cilium or flagellum.

BASE PAIRING: Complementary base pairing refers to the chemical affinities between specific base pairs in a nucleic acid: adenine always pairs with thymine, and guanine always pairs with cytosine. In pairing between DNA and RNA, the uracil of RNA always pairs with adenine. Complementary base pairing is not only responsible for the DNA double helix, but it is also essential for various in vitro techniques such as PCR (polymerase chain reaction). Complementary base pairing is also known as Watson-Crick pairing.

BASE: A substance that reduces the hydrogen ion concentration in a solution.

BASE: A substance that accepts a proton and has a high pH; a common example is sodium hydroxide (NaOH).

BASEMENT MEMBRANE: The floor of an epithelial membrane on which the basal cells rest.

BASIDIUM: The spore-bearing structure of Basidiomycota.

BATESIAN MIMICRY: A type of mimicry in which a harmless species looks like a different species that is poisonous or otherwise harmful to predators.

B-CELL LYMPHOCYTE: A type of lymphocyte that develops in the bone marrow and later produces antibodies, which mediate humoral immunity.

BEHAVIORAL ECOLOGY: A heuristic approach based on the expectation that Darwinian fitness (reproductive success) is improved by optimal behavior.

BELT PRESS: A dewatering device utilizing two opposing synthetic fabric belts, revolving over a series of rollers to “squeeze” water from the sludge.

BENCH TEST: A small-scale test or study used to determine whether a technology is suitable for a particular application.

BENIGN TUMOR: A noncancerous abnormal growth composed of cells that multiply excessively but remain at their place of origin in the body.

BENTHIC: Pertaining to the bottom region of an aquatic environment.

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE (BAT): A level of technology based on the best existing control and treatment measures that are economically achievable within the given industrial category or subcategory.

BEST MANAGEMENT PRACTICES (BMPs): Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the U.S. BMPs also include treatment requirements, operating procedures and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE (BPT): A level of technology represented by the average of the best existing wastewater treatment performance levels within an industrial category or subcategory.

BEST PROFESSIONAL JUDGMENT (BPJ): The method used by a permit writer to develop technology-based limitations on a case-by-case basis using all reasonably available and relevant data.

BETA PLEATED SHEET: A zigzag shape, constituting one form of the secondary structure of proteins formed of hydrogen bonds between polypeptide segments running in opposite directions.

BILATERAL SYMMETRY: The property of having two similar sides, with definite upper and lower surfaces and anterior and posterior ends. The Bilateria are members of the branch of Eumetazoa (Kingdom Animalia) which possess bilateral symmetry.

BILE: A mixture of substances containing bile salts, which emulsify fats and aid in their digestion and absorption.

BINARY FISSION: The kind of cell division found in prokaryotes, in which dividing daughter cells each receive a copy of the single parental chromosome.

BINOMIAL NOMENCLATURE: Consisting of two names. In biology, each organism is given a *genus* name and a species name (i.e., the human is *Homo sapiens*).

BIOCHEMICAL OXYGEN DEMAND (BOD): The BOD test is used to measure the strength of wastewater. The BOD of wastewater determines the milligrams per liter of oxygen required during stabilization of decomposable organic matter by aerobic bacteria action. Also, the total milligrams of oxygen required over a five-day test period to biologically assimilate the organic contaminants in one liter of wastewater maintained at 20 degrees Centigrade.

BIOCHEMISTRY: The chemistry of organisms.

BIOGENESIS: A central concept of biology, that living organisms are derived from other living organisms (contrasts to the concept of abiogenesis, or spontaneous generation, which held that life could be derived from inanimate material).

BIOGEOCHEMICAL CYCLE: A circuit whereby a nutrient moves between both biotic and abiotic components of ecosystems.

BIOGEOGRAPHY: The study of the past and present distribution of species.

BIOLOGICAL MAGNIFICATION: Increasing concentration of relatively stable chemicals as they are passed up a food chain from initial consumers to top predators.

BIOLOGICAL SPECIES: A population or group of populations whose members have the potential to interbreed. This concept was introduced by Ernst Mayr.

BIOMASS: The total weight of all the organisms, or of a designated group of organisms, in a given area

BIOME: A large climatic region with characteristic sorts of plants and animals.

BIOSOLIDS: Solid organic matter recovered from municipal wastewater treatment that can be beneficially used, especially as a fertilizer. "Biosolids" are solids that have been stabilized within the treatment process, whereas "sludge" has not.

BIOSPHERE: The region on and surrounding the earth which is capable of supporting life. Theoretically, the concept may be ultimately expanded to include other regions of the universe.

BMR: The basal metabolic rate is the minimal energy (in kcal) required by a homeotherm to fuel itself for a given time. Measured within the thermoneutral zone for a postabsorptive animal at rest.

BODY FEED: Coating or bulking material added to the influent of material to be treated. This adds "body" to the material during filtration cycle.

BOILING POINT ELEVATION: The process where the boiling point is elevated by adding a substance.

BOILING POINT: The temperature in which the substance starts to boil.

BOILING: The phase transition of liquid vaporizing.

BOND: The attraction and repulsion between atoms and molecules that is a cornerstone of chemistry.

Both measurements (mg/L or KH) are usually expressed "as CaCO_3 " – meaning the amount of hardness expressed as if calcium carbonate was the sole source of hardness. Every bicarbonate ion only counts for half as much carbonate hardness as a carbonate ion does. If a solution contained 1 liter of water and 50 mg NaHCO_3 (baking soda), it would have a carbonate hardness of about 18 mg/L as CaCO_3 . If you had a liter of water containing 50 mg of Na_2CO_3 , it would have a carbonate hardness of about 29 mg/L as CaCO_3 . Carbonate hardness supplements non-carbonate (a.k.a. "permanent") hardness where hard ions are associated with anions such as Chloride that do not precipitate out of solution when heated. Carbonate hardness is removed from water through the process of softening. Softening can be achieved by adding lime in the form of $\text{Ca}(\text{OH})_2$, which reacts first with CO_2 to form calcium carbonate precipitate, reacts next with multi-valent cations to remove carbonate hardness, then reacts with anions to replace the non-carbonate hardness due to multi-valent cations with non-carbonate hardness due to calcium. The process requires recarbonation through the addition of carbon-dioxide to lower the pH which is raised during the initial softening process.

BREAK POINT CHLORINATION: The process of chlorinating the water with significant quantities of chlorine to oxidize all contaminants and organic wastes and leave all remaining chlorine as free chlorine.

BRIDGING: The tendency of sediment, filter, or seal media to create an obstruction if installed in too small an annulus or to rapidly. Also can occur within filter packs requiring development.

BROMINE: Chemical disinfectant (HALOGEN) that kills bacteria and algae. This chemical disinfectant has been used only on a very limited scale for water treatment because of its handling difficulties. This chemical causes skin burns on contact, and a residual is difficult to obtain.

BRONSTED-LOWREY ACID: A chemical species that donates a proton.

BRONSTED-LOWREY BASE: A chemical species that accepts a proton.

BUFFER: Chemical that resists pH change, e.g. sodium bicarbonate

BUFFERED SOLTION: An aqueous solution consisting of a weak acid and its conjugate base or a weak base and its conjugate acid that resists changes in pH when strong acids or bases are added.

BULKING SLUDGE: A phenomenon that occurs in activated sludge plants whereby the sludge occupies excessive volumes and will not concentrate readily. This condition refers to a decrease in the ability of the sludge to settle and consequent loss over the settling tank weir. Bulking in activated sludge aeration tanks is caused mainly by excess suspended solids (SS) content. Sludge bulking in the final settling tank of an activated sludge plant may be caused by improper balance of the BOD load, SS concentration in the mixed liquor, or the amount of air used in aeration. A poor or slow settling activated sludge that results from the prevalence of filamentous organisms.

BURETTE (also BURET): Glassware used to dispense specific amounts of liquid when precision is necessary (e.g. titration and resource dependent reactions).

C

Ca: The chemical symbol for calcium.

CADMIUM: A contaminant that is usually not found naturally in water or in very small amounts.

CAKE: Dewatered sludge material with a satisfactory solids concentration to allow handling as a solid material.

CALCIUM HARDNESS: A measure of the calcium salts dissolved in water.

CALCIUM ION: Is divalent because it has a valence of +2.

CALCIUM, MAGNESIUM AND IRON: The three elements that cause hardness in water.

CaOCl₂·4H₂O: The molecular formula of Calcium hypochlorite.

CARBON DIOXIDE GAS: The pH will decrease and alkalinity will change as measured by the Langelier index after pumping carbon dioxide gas into water.

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CARBONATE HARDNESS: Carbonate hardness is the measure of Calcium and Magnesium and other hard ions associated with carbonate (CO₃²⁻) and bicarbonate (HCO₃⁻) ions contained in a solution, usually water. It is usually expressed either as parts per million (ppm or mg/L), or in degrees (KH - from the German "Karbonathärte"). One German degree of carbonate hardness is equivalent to about 17.8575 mg/L. Both measurements (mg/L or KH) are usually expressed "as CaCO₃" – meaning the amount of hardness expressed as if calcium carbonate was the sole source of hardness. Every bicarbonate ion only counts for half as much carbonate hardness as a carbonate ion does. If a solution contained 1 liter of water and 50 mg NaHCO₃ (baking soda), it would have a carbonate hardness of about 18 mg/L as CaCO₃. If you had a liter of water containing 50 mg of Na₂CO₃, it would have a carbonate hardness of about 29 mg/L as CaCO₃.

CARBONATE, BICARBONATE AND HYDROXIDE: Chemicals that are responsible for the alkalinity of water.

CAROLUS LINNAEUS: Swedish botanist and originator of the binomial nomenclature system of taxonomic classification

CATALYST: A chemical compound used to change the rate (either to speed up or slow down) of a reaction, but is regenerated at the end of the reaction.

CATHODIC PROTECTION: An operator should protect against corrosion of the anode and/or the cathode by painting the copper cathode. Cathodic protection interrupts corrosion by supplying an electrical current to overcome the corrosion-producing mechanism. Guards against stray current corrosion.

CATION: Positively charged ion.

CAUSTIC SODA: Also known as sodium hydroxide and is used to raise pH.

CAUSTIC: NaOH (also called Sodium Hydroxide) is a strong chemical used in the treatment process to neutralize acidity, increase alkalinity or raise the pH value.

CEILING AREA: The specific gravity of ammonia gas is 0.60. If released, this gas will accumulate first at the ceiling area. Cl₂ gas will settle on the floor.

CELL POTENTIAL: The force in a galvanic cell that pulls electron through reducing agent to oxidizing agent.

CENTRATE: The liquid remaining after solids have been removed in a centrifuge.

CENTRIFUGAL FORCE: That force when a ball is whirled on a string that pulls the ball outward. On a centrifugal pump, it is that force which throws water from a spinning impeller.

CENTRIFUGAL PUMP: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.

CENTRIFUGE: A dewatering device relying on centrifugal force to separate particles of varying density such as water and solids. Equipment used to separate substances based on density by rotating the tubes around a centered axis

CESIUM (also Caesium): Symbol Cs- A soft, silvery-white ductile metal, liquid at room temperature, the most electropositive and alkaline of the elements, used in photoelectric cells and to catalyze hydrogenation of some organic compounds.

CHAIN OF CUSTODY (COC): A record of each person involved in the possession of a sample from the person who collects the sample to the person who analyzes the sample in the laboratory.

CHELATION: A chemical process used to control scale formation in which a chelating agent "captures" scale-causing ions and holds them in solution.

CHEMICAL FEED RATE: Chemicals are added to the water in order to improve the subsequent treatment processes. These may include pH adjusters and coagulants. Coagulants are chemicals, such as alum, that neutralize positive or negative charges on small particles, allowing them to stick together and form larger particles that are more easily removed by sedimentation (settling) or filtration. A variety of devices, such as baffles, static mixers, impellers and in-line sprays, can be used to mix the water and distribute the chemicals evenly.

CHEMICAL LAW: Certain rules that pertain to the laws of nature and chemistry.

CHEMICAL OXIDIZER: KMnO_4 is used for taste and odor control because it is a strong oxidizer which eliminates many organic compounds.

CHEMICAL OXIDIZER: KMnO_4 or Potassium Permanganate is used for taste and odor control

CHEMICAL OXYGEN DEMAND (COD): The milligrams of oxygen required to chemically oxidize the organic contaminants in one liter of wastewater.

CHEMICAL REACTION RATE: In general, when the temperature decreases, the chemical reaction rate also decreases. The opposite is true for when the temperature increases.

CHEMICAL REACTION: The change of one or more substances into another or multiple substances.

CHEMICAL SLUDGE: Sludge resulting from chemical treatment processes of inorganic wastes that are not biologically active.

CHEMISORPTION: (or chemical adsorption) Is adsorption in which the forces involved are valence forces of the same kind as those operating in the formation of chemical compounds.

CHLORAMINES: A group of chlorine ammonia compounds formed when chlorine combines with organic wastes in the water. Chloramines are not effective as disinfectants and are responsible for eye and skin irritation as well as strong chlorine odors.

CHLORINATION: The process in water treatment of adding chlorine (gas or solid hypochlorite) for purposes of disinfection.

CHLORINE DEMAND: Amount of chlorine required to react on various water impurities before a residual is obtained. Also, means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.

CHLORINE FEED: Chlorine may be delivered by vacuum-controlled solution feed chlorinators. The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.

CHLORINE, FREE: Chlorine available to kill bacteria or algae. The amount of chlorine available for sanitization after the chlorine demand has been met. Also known as chlorine residual.

CHLORINE: A chemical used to disinfect water. Chlorine is extremely reactive, and when it comes in contact with microorganisms in water it kills them. Chlorine is added to swimming pools to keep the water safe for swimming. Chlorine is available as solid tablets for swimming pools. Some public water system's drinking water treatment plants use chlorine in a gas form because of the large volumes required. Chlorine is very effective against algae, bacteria and viruses. Protozoa are resistant to chlorine because they have thick coats; protozoa are removed from drinking water by filtration.

CHRONIC: A stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of an organism. The measurement of chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.

CIRCULATION: The continual flow of drilling fluid from injection to recovery and recirculation at the surface.

CLARIFIER: A settling tank used to remove suspended solids by gravity settling. Commonly referred to as sedimentation or settling basins, they are usually equipped with a motor driven chain and flight or rake mechanism to collect settled sludge and move it to a final removal point.

CLEAR WELL: A large underground storage facility sometimes made of concrete. A clear well or a plant storage reservoir is usually filled when demand is low. The final step in the conventional filtration process, the clearwell provides temporary storage for the treated water. The two main purposes for this storage are to have filtered water available for backwashing the filter and to provide detention time (or contact time) for the chlorine (or other disinfectant) to kill any microorganisms that may remain in the water.

CIO₂: The molecular formula of Chlorine dioxide.

COAGULATION: The best pH range for coagulation is between 5 and 7. Mixing is an important part of the coagulation process you want to complete the coagulation process as quickly as possible. A chemical added to initially destabilize, aggregate, and bind together colloids and emulsions to improve settleability, filterability, or drainability.

COLIFORM TESTING: The effectiveness of disinfection is usually determined by Coliform bacteria testing. A positive sample is a bad thing and indicates that you have bacteria contamination.

COLIFORM: Bacteria normally found in the intestines of warm-blooded animals. Coliform bacteria are present in high numbers in animal feces. They are an indicator of potential contamination of water. Adequate and appropriate disinfection effectively destroys coliform bacteria. Public water systems are required to deliver safe and reliable drinking water to their customers 24 hours a day, 365 days a year. If the water supply becomes contaminated, consumers can become seriously ill. Fortunately, public water systems take many steps to ensure that the public has safe, reliable drinking water. One of the most important steps is to regularly test the water for coliform bacteria. Coliform bacteria are organisms that are present in the environment and in the feces of all warm-blooded animals and humans. Coliform bacteria will not likely cause illness. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system. Most pathogens that can contaminate water supplies come from the feces of humans or animals. Testing drinking water for all possible pathogens is complex, time-consuming, and expensive. It is relatively easy and inexpensive to test for coliform bacteria. If coliform bacteria are found in a water sample, water system operators work to find the source of contamination and restore safe drinking water. There are three different groups of coliform bacteria; each has a different level of risk.

COLLOID: Mixture of evenly dispersed substances, such as many milks.

COLLOIDAL SUSPENSIONS: Because both iron and manganese react with dissolved oxygen to form insoluble compounds, they are not found in high concentrations in waters containing dissolved oxygen except as colloidal suspensions of the oxide.

COLORIMETRIC MEASUREMENT: A means of measuring an unknown chemical concentration in water by measuring a sample's color intensity.

COMBINED CHLORINE: The reaction product of chlorine with ammonia or other pollutants, also known as chloramines.

COMBUSTION: An exothermic reaction between an oxidant and fuel with heat and often light

COMMUNITY WATER SYSTEM: A water system which supplies drinking water to 25 or more of the same people year-round in their residences.

COMPLIANCE CYCLE: A 9-calendar year time-frame during which a public water system is required to monitor. Each compliance cycle consists of 3 compliance periods.

COMPLIANCE PERIOD: A 3-calendar year time-frame within a compliance cycle.

COMPOSITE SAMPLE: A water sample that is a combination of a group of samples collected at various intervals during the day. A combination of individual samples of water or wastewater taken at predetermined intervals to minimize the effect of variability of individual samples. To have significant meaning, samples for laboratory tests on wastewater should be representative of the wastewater. The best method of sampling is proportional composite sampling over several hours during the day. Composite samples are collected because the flow and characteristics of the wastewater are continually changing. A composite sample will give a representative analysis of the wastewater conditions.

COMPOSTING: Stabilization process relying on the aerobic decomposition of organic matter in sludge by bacteria and fungi.

COMPOUND: A substance that is made up of two or more chemically bonded elements.

CONDENSATION: The process that changes water vapor to tiny droplets or ice crystals.

CONDUCTOR: Material that allows electric flow more freely.

CONTACT STABILIZATION PROCESS: Modification of the activated sludge process where raw wastewater is aerated with activated sludge for a short time prior to solids removal and continued aeration in a stabilization tank.

CONTACT TIME: If the water temperature decreases from 70°F (21°C) to 40°F (4°C). The operator needs to increase the detention time to maintain good disinfection of the water.

CONTAINS THE ELEMENT CARBON: A simple definition of an organic compound.

CONTAMINANT: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

CONTAMINATION: A degradation in the quality of groundwater in result of the it's becoming polluted with unnatural or previously non-existent constituents.

CONTROL TASTE AND ODOR PROBLEMS: KMnO₄ Potassium permanganate is a strong oxidizer commonly used to control taste and odor problems.

COPPER: The chemical name for the symbol Cu.

CORROSION: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

CORROSION: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

CORROSIVITY: The Langelier Index measures corrosivity.

COUPON: A coupon placed to measure corrosion damage in the water mains.

COVALENT BOND: Chemical bond that involves sharing electrons.

CROSS-CONNECTION: A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow. Might be the source of an organic substance causing taste and odor problems in a water distribution system.

CROSS-CONTAMINATION: The mixing of two unlike qualities of water. For example, the mixing of good water with a polluting substance like a chemical.

CRYPTOSPORIDIUM: A disease-causing parasite, resistant to chlorine disinfection. It may be found in fecal matter or contaminated drinking water. Cryptosporidium is a protozoan pathogen of the Phylum Apicomplexa and causes a diarrheal illness called cryptosporidiosis. Other apicomplexan pathogens include the malaria parasite Plasmodium, and Toxoplasma, the causative agent of toxoplasmosis. Unlike Plasmodium, which transmits via a mosquito vector, Cryptosporidium does not utilize an insect vector and is capable of completing its life cycle within a single host, resulting in cyst stages which are excreted in feces and are capable of transmission to a new host.

CRYSTAL: A solid that is packed with ions, molecules or atoms in an orderly fashion.

CUVETTE: Glassware used in spectroscopic experiments. It is usually made of plastic, glass or quartz and should be as clean and clear as possible.

CYANOBACTERIA: Cyanobacteria, also known as blue-green algae, blue-green bacteria or Cyanophyta, is a phylum of bacteria that obtain their energy through photosynthesis. The name "cyanobacteria" comes from the color of the bacteria (Greek: kyanós = blue). They are a significant component of the marine nitrogen cycle and an important primary producer in many areas of the ocean, but are also found on land.

CYANURIC ACID: White, crystalline, water-soluble solid, C₃H₃O₃N₃·2H₂O, used chiefly in organic synthesis. Chemical used to prevent the decomposition of chlorine by ultraviolet (UV) light.

CYST: A phase or a form of an organism produced either in response to environmental conditions or as a normal part of the life cycle of the organism. It is characterized by a thick and environmentally resistant cell wall.

D

DAILY MAXIMUM LIMITATIONS: The maximum allowable discharge of pollutants during a 24 hour period. Where daily maximum limitations are expressed in units of mass, the daily discharge is the total mass discharged over the course of the day. Where daily maximum limitations are expressed in terms of a concentration, the daily discharge is the arithmetic average measurement of the pollutant concentration derived from all measurements taken that day.

DANGEROUS CHEMICALS: The most suitable protection when working with a chemical that produces dangerous fumes is to work under an air hood.

DARCY'S LAW: ($Q=KIA$) A fundamental equation used in the groundwater sciences to determine aquifer characteristics, where Q =Flux, K =Hydraulic Conductivity (Permeability), I = Hydraulic Gradient (change in head), and A = Cross Sectional Area of flow.

DECANT: Separation of a liquid from settled solids by removing the upper layer of liquid after the solids have settled.

DECIBELS: The unit of measurement for sound.

DECOMPOSE: To decay or rot.

DECOMPOSITION OF ORGANIC MATERIAL: The decomposition of organic material in water produces taste and odors.

DEIONIZATION: The removal of ions, and in water's case mineral ions such as sodium, iron and calcium.

DELIQUESCENT: Substances that absorb water from the atmosphere to form liquid solutions.

DEMINERALIZATION PROCESS: Mineral concentration of the feed water is the most important consideration in the selection of a demineralization process. Acid feed is the most common method of scale control in a membrane demineralization treatment system.

DENITRIFICATION: A biological process by which nitrate is converted to nitrogen gas.

DENTAL CAVES PREVENTION IN CHILDREN: The main reason that fluoride is added to a water supply.

DEPOLARIZATION: The removal of hydrogen from a cathode.

DEPOSITION: Settling of particles within a solution or mixture.

DESICCANT: When shutting down equipment which may be damaged by moisture, the unit may be protected by sealing it in a tight container. This container should contain a desiccant.

DESORPTION: Desorption is a phenomenon whereby a substance is released from or through a surface. The process is the opposite of sorption (that is, adsorption and absorption). This occurs in a system being in the state of sorption equilibrium between bulk phase (fluid, i.e. gas or liquid solution) and an adsorbing surface (solid or boundary separating two fluids). When the concentration (or pressure) of substance in the bulk phase is lowered, some of the sorbed substance changes to the bulk state. In chemistry, especially chromatography, desorption is the ability for a chemical to move with the mobile phase. The more a chemical desorbs, the less likely it will adsorb, thus instead of sticking to the stationary phase, the chemical moves up with the solvent front. In chemical separation processes, stripping is also referred to as desorption as one component of a liquid stream moves by mass transfer into a vapor phase through the liquid-vapor interface.

DETENTION LAG: Is the period of time between the moment of change in a chlorinator control system and the moment when the change is sensed by the chlorine residual indicator.

DEVELOPMENT: The cleaning of the well and bore once construction is complete.

DIATOMACEOUS EARTH: A fine silica material containing the skeletal remains of algae.

DIGESTER: A tank or vessel used for sludge digestion.

DIGESTION: The biological decomposition of organic matter in sludge resulting in partial gasification, liquefaction, and mineralization of putrescible and offensive solids.

DIPOLE MOMENT: The polarity of a polar covalent bond.

DIPOLE: Electric or magnetic separation of charge.

DIRECT CURRENT: A source of direct current (DC) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.

DISINFECT: The application of a chemical to kill most, but not all, microorganisms that may be present. Chlorine is added to public water drinking systems drinking water for disinfection. Depending on your state rule, drinking water must contain a minimum of 0.2 mg/L free chlorine. Disinfection makes drinking water safe to consume from the standpoint of killing pathogenic microorganisms

including bacteria and viruses. Disinfection does not remove all bacteria from drinking water, but the bacteria that can survive disinfection with chlorine are not pathogenic bacteria that can cause disease in normal healthy humans.

DISINFECTION BY-PRODUCTS (DBPs): The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer. Chlorine is added to drinking water to kill or inactivate harmful organisms that cause various diseases. This process is called disinfection. However, chlorine is a very active substance and it reacts with naturally occurring substances to form compounds known as disinfection byproducts (DBPs). The most common DBPs formed when chlorine is used are trihalomethanes (THMs), and haloacetic acids (HAAs).

DISINFECTION: The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites.

DISSOLUTION or SOLVATION: The spread of ions in a monosaccharide.

DISSOLVED OXYGEN: Can be added to zones within a lake or reservoir that would normally become anaerobic during periods of thermal stratification.

DISSOLVED SOLIDS: Solids in solution that cannot be removed by filtration with a 0.45 micron filter.

DISTILLATION, REVERSE OSMOSIS AND FREEZING: Processes that can be used to remove minerals from the water.

DOUBLE BOND: Sharing of two pairs of electradsodes.

DRY ACID: A granular chemical used to lower pH and or total alkalinity.

E

E. COLI, Escherichia coli: A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

EARTH METAL: See alkaline earth metal.

E. COLI, Escherichia coli: A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

ECDYSONE: A steroid hormone that triggers molting in arthropods.

ECOLOGICAL EFFICIENCY: The ratio of net productivity at one trophic level to net productivity at the next lower level.

ECOLOGICAL NICHE: The sum total of an organism's utilization of the biotic and abiotic resources of its environment. The fundamental niche represents the theoretical capabilities and the realized niche represents the actual role.

ECOLOGY: The study of how organisms interact with their environments.

ECOSYSTEM: The sum of physical features and organisms occurring in a given area.

ECTODERM: The outermost tissue layer of an animal embryo. Also, tissue derived from an embryonic ectoderm.

ECTOTHERM: An organism that uses environmental heat and behavior to regulate its body temperature.

EDWARD JENNER: A pioneer of vaccination; used vaccination with material from cowpox lesions to protect people against smallpox.

EFFECTIVENESS OF CHLORINE: The factors which influence the effectiveness of chlorination the most are pH, turbidity and temperature. Effectiveness of Chlorine decreases occurs during disinfection in source water with excessive turbidity.

EFFECTOR: The part of an organism that produces a response to a stimulus.

EFFLUENT: Partially or completely treated water or wastewater flowing out of a basin or treatment plant.

ELECTRIC CHARGE: A measured property (coulombs) that determine electromagnetic interaction

ELECTRICAL SYNAPSE: A junction between two neurons separated only by a gap junction, in which the local currents sparking the action potential pass directly between the cells.

ELECTROCARDIOGRAM: A plot of electrical activity of the heart over the cardiac cycle; measured via multiple skin electrodes.

ELECTROCHEMICAL CELL: Using a chemical reaction's current, electromotive force is made

ELECTROCHEMICAL GRADIENT: Combined electrostatic and osmotic-concentration gradient, such as the chemiosmotic gradient of mitochondria and chloroplasts.

ELECTROGENIC PUMP: An ion transport protein generating voltage across a membrane.

ELECTROLYTE: A solution that conducts a certain amount of current and can be split categorically as weak and strong electrolytes.

ELECTROMAGNETIC RADIATION: A type of wave that can go through vacuums as well as material and classified as a self-propagating wave.

ELECTROMAGNETIC SPECTRUM: The entire spectrum of radiation; ranges in wavelength from less than a nanometer to more than a kilometer.

ELECTROMAGNETISM: Fields that have electric charge and electric properties that change the way that particles move and interact.

ELECTROMOTIVE FORCE: A device that gains energy as electric charges pass through it.

ELECTRON MICROSCOPE: A microscope that focuses an electron beam through a specimen, resulting in resolving power a thousandfold greater than that of a light microscope. A transmission EM is used to study the internal structure of thin sections of cells; a scanning EM is used to study the ultrastructure of surfaces.

ELECTRON SHELLS: An orbital around the atom's nucleus that has a fixed number electrons (usually two or eight).

ELECTRON TRANSPORT CHAIN: A series of enzymes found in the inner membranes of mitochondria and chloroplasts. These are involved in transport of protons and electrons either across the membrane during ATP synthesis.

ELECTRON: A subatomic particle with a net charge that is negative. The name of a negatively charged atomic particle.

ELECTRONEGATIVITY: A property exhibited by some atoms whereby the nucleus has a tendency to pull electrons toward itself.

ELECTRONIC CHARGE UNIT: The charge of one electron (1.6021×10^{-19} coulomb).

ELECTROSTATIC FORCE: The attraction between particles with opposite charges.

ELECTROSTATIC GRADIENT: The free-energy gradient created by a difference in charge between two points, generally the two sides of a membrane.

ELEMENT: Any substance that cannot be broken down into another substance by ordinary chemical means. An atom that is defined by its atomic number.

ELEMENTARY BUSINESS PLAN: Technical Capacity, Managerial Capacity, and Financial Capacity make up the elementary business plan. To become a new public water system, an owner shall file an elementary business plan for review and approval by state environmental agency.

ELIMINATION: The release of unabsorbed wastes from the digestive tract.

EMERGENCY RESPONSE TEAM: A local team that is thoroughly trained and equipped to deal with emergencies, e.g. chlorine gas leak. In case of a chlorine gas leak, get out of the area and notify your local emergency response team in case of a large uncontrolled chlorine leak.

EMERGENT PROPERTY: A property exhibited at one level of biological organization but not exhibited at a lower level. For example, a population exhibits a birth rate, an organism does not.

EMPIRICAL FORMULA: Also called the simplest formula, gives the simplest whole number ratio of atoms of each element present in a compound.

EMULSION: A suspension, usually as fine droplets of one liquid in another. A mixture made up of dissimilar elements, usually of two or more mutually insoluble liquids that would normally separate into layers based on the specific gravity of each liquid.

ENDERGONIC: A phenomenon which involves uptake of energy.

ENDOCRINE: A phenomenon which relates to the presence of ductless glands of the type typically found in vertebrates. The endocrine system involves hormones, the glands which secrete them, the molecular hormone receptors of target cells, and interactions between hormones and the nervous system.

ENDOCYTOSIS: A process by which liquids or solid particles are taken up by a cell through invagination of the plasma membrane.

ENDODERM: The innermost germ layer of an animal embryo.

ENDODERMIS: A plant tissue, especially prominent in roots, that surrounds the vascular cylinder; all endodermal cells have Casparian strips.

ENDOMEMBRANE SYSTEM: The system of membranes inside a eukaryotic cell, including the membranous vesicles which associate with membrane sheets and/or tubes.

ENDOMETRIUM: The inner lining of the uterus, which is richly supplied with blood vessels that provide the maternal part of the placenta and nourish the developing embryo.

ENDONUCLEASE: An enzyme that breaks bonds within nucleic acids. A restriction endonuclease is an enzyme that breaks bonds only within a specific sequence of bases.

ENDOPLASMIC RETICULUM: A system of membrane-bounded tubes and flattened sacs, often continuous with the nuclear envelope, found in the cytoplasm of eukaryotes. Exists as rough ER, studded with ribosomes, and smooth ER, lacking ribosomes.

ENDORPHIN: A hormone produced in the brain and anterior pituitary that inhibits pain perception.

ENDOSKELETON: An internal skeleton.

ENDOSPERM: A nutritive material in plant seeds which is triploid (3n) and results from the fusion of three nuclei during double fertilization.

ENDOSYMBIOTIC: 1) An association in which the symbiont lives within the host 2) A widely accepted hypothesis concerning the evolution of the eukaryotic cell: the idea that eukaryotes evolved as a result of symbiotic associations between prokaryote cells. Aerobic symbionts ultimately evolved into mitochondria; photosynthetic symbionts became chloroplasts.

ENDOTHELIUM: The innermost, simple squamous layer of cells lining the blood vessels; the only constituent structure of capillaries.

ENDOTHERMIC: In chemistry, a phenomenon in which energy is absorbed by the reactants. In physiology, this term concerns organisms whose thermal relationship with the environment is dependent substantially on internal production of heat.

ENDOTOXIN: A component of the outer membranes of certain gram-negative bacteria responsible for generalized symptoms of fever and ache.

ENERGY: A system's ability to do work. The capacity to do work by moving matter against an opposing force.

ENHANCED COAGULATION: The process of joining together particles in water to help remove organic matter.

ENHANCER: A DNA sequence that recognizes certain transcription factors that can stimulate transcription of nearby genes.

ENTAMOEBIA HISTOLYTICA: *Entamoeba histolytica*, another water-borne pathogen, can cause diarrhea or a more serious invasive liver abscess. When in contact with human cells, these amoebae are cytotoxic. There is a rapid influx of calcium into the contacted cell, it quickly stops all membrane movement save for some surface blebbing. Internal organization is disrupted, organelles lyse, and the cell dies. The amoeba may eat the dead cell or just absorb nutrients released from the cell.

ENTERIC: Rod-shaped, gram-negative, aerobic but can live in certain anaerobic conditions; produce nitrite from nitrate, acids from glucose; include *Escherichia coli*, *Salmonella* (over 1000 types), and *Shigella*.

ENTEROVIRUS: A virus whose presence may indicate contaminated water; a virus that may infect the gastrointestinal tract of humans.

ENTHALPY: Measure of the total energy of a thermodynamic system (usually symbolized as H).

ENTROPY: The amount of energy not available for work in a closed thermodynamic system (usually symbolized as S).

ENVELOPE: 1) (nuclear) The surface, consisting of two layers of membrane, that encloses the nucleus of eukaryotic cells. 2) (virus) A structure which is present on the outside of some viruses (exterior to the capsid).

ENVIRONMENT: Water, air, and land, and the interrelationship that exists among and between water, air and land and all living things. The total living and nonliving aspects of an organism's internal and external surroundings.

ENZYME: A protein, on the surface of which are chemical groups so arranged as to make the enzyme a catalyst for a chemical reaction. A protein that speeds up (catalyzes) a reaction.

EPICOTYL: A portion of the axis of a plant embryo above the point of attachment of the cotyledons; forms most of the shoot.

EPIDERMIS: The outermost portion of the skin or body wall of an animal.

EPINEPHRINE: A hormone produced as a response to stress; also called adrenaline.

EPIPHYTE: A plant that nourishes itself but grows on the surface of another plant for support, usually on the branches or trunks of tropical trees.

EPISOME: Genetic element at times free in the cytoplasm, at other times integrated into a chromosome.

EPISTASIS: A phenomenon in which one gene alters the expression of another gene that is independently inherited.

EPITHELIUM: An animal tissue that forms the covering or lining of all free body surfaces, both external and internal.

EPITOPE: A localized region on the surface of an antigen that is chemically recognized by antibodies; also called antigenic determinant.

EPPENDORF TUBE: Generalized and trademarked term used for a type of tube; see microcentrifuge.

EQUATION: A precise representation of the outcome of a chemical reaction, showing the reactants and products, as well as the proportions of each.

EQUILIBRIUM: In a reversible reaction, the point at which the rate of the forward reaction equals that of the reverse reaction. (Constant) At equilibrium, the ratio of products to reactants. (potential) The membrane potential for a given ion at which the voltage exactly balances the chemical diffusion gradient for that ion.

ERNST MAYR: Formulated the biological species concept.

ERYTHROCYTE: A red blood corpuscle.

ESOPHAGUS: An anterior part of the digestive tract; in mammals it leads from the pharynx to the stomach.

ESSENTIAL: 1) An amino or fatty acid which is required in the diet of an animal because it cannot be synthesized. 2) A chemical element required for a plant to grow from a seed and complete the life cycle.

ESTIVATION: A physiological state characterized by slow metabolism and inactivity, which permits survival during long periods of elevated temperature and diminished water supplies.

ESTRADIOL: 1,3,5(10)-estratriene- 3,17 beta-diol C₁₈H₂₄O₂. This is the natural hormone - present in pure form in the urine of pregnant mares and in the ovaries of pigs.

ESTROGEN: Any of a group of vertebrate female sex hormones.

ESTROUS CYCLE: In female mammals, the higher primates excepted, a recurrent series of physiological and behavioral changes connected with reproduction.

ESTRUS: The limited period of heat or sexual receptivity that occurs around ovulation in female mammals having estrous cycles.

ESTUARY: That portion of a river that is close enough to the sea to be influenced by marine tides.

ETHYLENE: The only gaseous plant hormone, responsible for fruit ripening, growth inhibition, leaf abscission, and aging.

EUBACTERIA: The lineage of prokaryotes that includes the cyanobacteria and all other contemporary bacteria except archaeobacteria.

EUCHROMATIN: The more open, unraveled form of eukaryotic chromatin, which is available for transcription.

EUCOELOMATE: An animal whose body cavity is completely lined by mesoderm, the layers of which connect dorsally and ventrally to form mesenteries.

EUGLENA: Euglena are common protists, of the class Euglenoidea of the phylum Euglenophyta. Currently, over 1000 species of Euglena have been described. Marin et al. (2003) revised the genus so and including several species without chloroplasts, formerly classified as Astasia and Khawkinia. Euglena sometimes can be considered to have both plant and animal features.

Euglena gracilis has a long hair-like thing that stretches from its body. You need a very powerful microscope to see it. This is called a flagellum, and the euglena uses it to swim. It also has a red eyespot. Euglena gracilis uses its eyespot to locate light. Without light, it cannot use its chloroplasts to make itself food.

EUKARYOTE: A life form comprised of one or more cells containing a nucleus and membrane-bound organelles. Included are members of the Kingdoms Protista, Fungi, Plantae and Animalia.

EUMETAZOA: Members of the subkingdom that includes all animals except sponges.

EUTROPHIC: A highly productive condition in aquatic environments which owes to excessive concentrations of nutrients which support the growth of primary producers.

EVAGINATED: Folded or protruding outward.

EVAPORATIVE COOLING: The property of a liquid whereby the surface becomes cooler during evaporation, owing to the loss of highly kinetic molecules to the gaseous state.

EVOLUTION: A theory that all of the changes that have transformed life on earth from its earliest beginnings to the diversity that characterizes it today. As used in biology, the term evolution means descent with change. See Intelligent Design.

EVOLUTION: Any process of formation or growth; development: the evolution of a language; the evolution of the airplane. A product of such development; something evolved: The exploration of space is the evolution of decades of research.

EXCITABLE CELLS: A cell, such as a neuron or a muscle cell that can use changes in its membrane potential to conduct signals.

EXCITATORY POSTSYNAPTIC POTENTIAL: An electrical change (depolarization) in the membrane of a postsynaptic neuron caused by the binding of an excitatory neurotransmitter from a presynaptic cell to a postsynaptic receptor. This phenomenon facilitates generation of an action potential in the PSP.

EXCRETION: Release of materials which arise in the body due to metabolism (e.g., CO_2 , NH_3 , H_2O).

EXERGONIC: A phenomenon which involves the release of energy.

EXOCYTOSIS: A process by which a vesicle within a cell fuses with the plasma membrane and releases its contents to the outside.

EXON: A part of a primary transcript (and the corresponding part of a gene) that is ultimately either translated (in the case of mRNA) or utilized in a final product, such as tRNA.

EXOSKELETON: An external skeleton, characteristic of members of the phylum, Arthropoda.

EXOTHERMIC: A process or reaction that is accompanied by the creation of heat.

EXOTOXIN: A toxic protein secreted by a bacterial cell that produces specific symptoms even in the absence of the bacterium.

EXPONENTIAL: (population growth) The geometric increase of a population as it grows in an ideal, unlimited environment.

EXTRAEMBRYONIC MEMBRANES: Four membranes (yolk sac, amnion, chorion, allantois) that support the developing embryo in reptiles, birds, and mammals.

EXTRINSIC: External to, not a basic part of; as in extrinsic isolating mechanism.

F

F PLASMID: The fertility factor in bacteria, a plasmid that confers the ability to form pili for conjugation and associated functions required for transfer of DNA from donor to recipient.

F: The chemical symbol of Fluorine.

F1 GENERATION: The first filial or hybrid offspring in a genetic cross-fertilization.

F2 GENERATION: Offspring resulting from interbreeding of the hybrid F1 generation.

FACILITATED DIFFUSION: Passive movement through a membrane involving a specific carrier protein; does not proceed against a concentration gradient.

FACULTATIVE: An organism which exhibits the capability of changing from one habit or metabolic pathway to another, when conditions warrant. (anaerobe) An organism that makes ATP by aerobic respiration if oxygen is present but that switches to fermentation under anaerobic conditions.

FARADAY CONSTANT: A unit of electrical charge widely used in electrochemistry and equal to $\sim 96,500$ coulombs. It represents 1 mol of electrons, or the Avogadro number of electrons: 6.022×10^{23} electrons. $F = 96\,485.339\,9(24)$ C/mol.

FARADAY'S LAW OF ELECTROLYSIS: A two part law that Michael Faraday published about electrolysis. The mass of a substance altered at an electrode during electrolysis is directly proportional to the quantity of electricity transferred at that electrode. The mass of an elemental material altered at an electrode is directly proportional to the element's equivalent weight.

FAT: A biological compound consisting of three fatty acids linked to one glycerol molecule.

FATE MAP: A means of tracing the fates of cells during embryonic development.

FATTY ACID: A long carbon chain carboxylic acid. Fatty acids vary in length and in the number and location of double bonds; three fatty acids linked to a glycerol molecule form fat.

FAUCET WITH AN AERATOR: When collecting a water sample from a distribution system, a faucet with an aerator should not be used as a sample location.

FAUNA: The animals of a given area or period.

FEATURE DETECTOR: A circuit in the nervous system that responds to a specific type of feature, such as a vertically moving spot or a particular auditory time delay.

FECAL COLIFORM: A group of bacteria that may indicate the presence of human or animal fecal matter in water. Total coliform, fecal coliform, and *E. coli* are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. *E. coli* is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform. If total coliform is present, the sample will also be tested for either fecal coliform or *E. coli*, depending on the lab testing method.

FECES: Indigestible wastes discharged from the digestive tract.

FEEDBACK: The process by which a control mechanism is regulated through the very effects it brings about. Positive feedback is when the effect is amplified; negative feedback is when the effect tends toward restoration of the original condition. Feedback inhibition is a method of metabolic control in which the end-product of a metabolic pathway acts as an inhibitor of an enzyme within that pathway.

FERMENTATION: Anaerobic production of alcohol, lactic acid or similar compounds from carbohydrate resulting from glycolysis.

FERRIC CHLORIDE: An iron salt commonly used as a coagulant. Chemical formula is FeCl_3 .

FIBRIN: The activated form of the blood-clotting protein fibrinogen, which aggregates into threads that form the fabric of the clot.

FIBROBLAST: A type of cell in loose connective tissue that secretes the protein ingredients of the extracellular fibers.

FIBRONECTINS: A family of extracellular glycoproteins that helps embryonic cells adhere to their substrate as they migrate.

FILTER AID: A polymer or other material added to improve the effectiveness of the filtration process.

FILTER CAKE: The layer of solids that is retained on the surface of a filter.

FILTER CLOGGING: An inability to meet demand may occur when filters are clogging.

FILTER PRESS: A dewatering device where sludge is pumped onto a filtering medium and water is forced out of the sludge, resulting in a "cake".

FILTER: A device utilizing a granular material, woven cloth or other medium to remove pollutants from water, wastewater or air.

FILTRATE: Liquid remaining after removal of solids with filtration.

FILTRATION METHODS: The conventional type of water treatment filtration method includes coagulation, flocculation, sedimentation, and filtration. Direct filtration method is similar to conventional except that the sedimentation step is omitted. Slow sand filtration process does not require pretreatment, has a flow of 0.1 gallons per minute per square foot of filter surface area, and is simple to operate and maintain. The Diatomaceous earth method uses a thin layer of fine siliceous material on a porous plate. This type of filtration medium is only used for water with low turbidity. Sedimentation, adsorption, and biological action treatment methods are filtration processes that involve a number of interrelated removal mechanisms. Demineralization is primarily used to remove total dissolved solids from industrial wastewater, municipal water, and seawater.

FILTRATION RATE: A measurement of the volume of water applied to a filter per unit of surface area in a given period of time.

FILTRATION: The process of passing water through materials with very small holes to strain out particles. Most conventional water treatment plants used filters composed of gravel, sand, and anthracite. These materials settle into a compact mass that forms very small holes. Particles are filtered out as treated water passes through these holes. These holes are small enough to remove microorganisms including algae, bacteria, and protozoans, but not viruses. Viruses are eliminated from drinking water through the process of disinfection using chlorine. A series of processes that physically removes particles from water. A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.

FINISHED WATER: Treated drinking water that meets minimum state and federal drinking water regulations.

FLOC SHEARING: Likely to happen to large floc particles when they reach the flocculation process.

FITNESS: The extent to which an individual passes on its genes to the next generation. Relative fitness is the number of offspring of an individual compared to the mean.

FIXATION: 1) Conversion of a substance into a biologically more usable form, for example, CO₂ fixation during photosynthesis and N₂ fixation. 2) Process of treating living tissue for microscopic examination.

FIXED ACTION PATTERN (FAP): A highly stereotyped behavior that is innate and must be carried to completion once initiated.

FLACCID: Limp; walled cells are flaccid in isotonic surroundings, where there is no tendency for water to enter.

FLAGELLIN: The protein from which prokaryotic flagella are constructed.

FLAGELLUM: A long whip-like appendage that propels cells during locomotion in liquid solutions. The prokaryote flagellum is comprised of a protein, flagellin. The eukaryote flagellum is longer than a cilium, but as a similar internal structure of microtubules in a "9 + 2" arrangement.

FLAME CELL: A flagellated cell associated with the simplest tubular excretory system, present in flatworms: it acts to directly regulate the contents of the extracellular fluid.

FLOC SHEARING: Likely to happen to large floc particles when they reach the flocculation process.

FLOC SHEARING: Likely to happen to large floc particles when they reach the flocculation process.

FLOCCULANTS: Flocculants, or flocculating agents, are chemicals that promote flocculation by causing colloids and other suspended particles in liquids to aggregate, forming a floc. Flocculants are used in water treatment processes to improve the sedimentation or filterability of small particles. For example, a flocculant may be used in swimming pool or drinking water filtration to aid removal of microscopic particles which would otherwise cause the water to be cloudy and which would be difficult or impossible to remove by filtration alone. Many flocculants are multivalent cations such as aluminum, iron, calcium or magnesium. These positively charged molecules interact with negatively charged particles and molecules to reduce the barriers to aggregation. In addition, many of these chemicals, under appropriate pH and other conditions such as temperature and salinity, react with water to form insoluble hydroxides which, upon precipitating, link together to form long chains or meshes, physically trapping small particles into the larger floc.

FLOCCULATION BASIN: A compartmentalized basin with a reduction of speed in each compartment. This set-up or basin will give the best overall results.

FLOCCULATION: The process of bringing together destabilized or coagulated particles to form larger masses that can be settled and/or filtered out of the water being treated. Conventional coagulation–flocculation–sedimentation practices are essential pretreatments for many water purification systems—especially filtration treatments. These processes agglomerate suspended solids together into larger bodies so that physical filtration processes can more easily remove them. Particulate removal by these methods makes later filtering processes far more effective. The process is often followed by gravity separation (sedimentation or flotation) and is always followed by filtration. A chemical coagulant, such as iron salts, aluminum salts, or polymers, is added to source water to facilitate bonding among particulates. Coagulants work by creating a chemical reaction and eliminating the negative charges that cause particles to repel each other. The coagulant-source water mixture is then slowly stirred in a process known as flocculation. This water churning induces particles to collide and clump together into larger and more easily removable clots, or “flocs.” The process requires chemical knowledge of source water characteristics to ensure that an effective coagulant mix is employed. Improper coagulants make these treatment methods ineffective. The ultimate effectiveness of coagulation/flocculation is also determined by the efficiency of the filtering process with which it is paired.

FLOOD RIM: The point of an object where the water would run over the edge of something and begin to cause a flood.

FLORA: The plants of a given area or period.

FLOW CYTOMETER: A particle-sorting instrument capable of counting protozoa.

FLOW MUST BE MEASURED: A recorder that measures flow is most likely to be located in a central location.

FLUID FEEDER: An animal that lives by sucking nutrient-rich fluids from another living organism.

FLUID MOSAIC MODEL: The currently accepted model of cell membrane structure, which envisions the membrane as a mosaic of individually inserted protein molecules drifting laterally in a fluid bilayer of phospholipids.

FLUORIDE FEEDING: Always review fluoride feeding system designs and specifications to determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and correct.

FLUORIDE: High levels of fluoride may stain the teeth of humans. This is called Mottling. This chemical must not be overfed due to a possible exposure to a high concentration of the chemical. The most important safety considerations to know about fluoride chemicals are that all fluoride chemicals are extremely corrosive. These are the substances most commonly used to furnish fluoride ions to water: Sodium fluoride, Sodium silicofluoride and Hydrofluosilicic acid.

FLUX: The term flux describes the rate of water flow through a semipermeable membrane. When the water flux decreases through a semipermeable membrane, it means that the mineral concentration of the water is increasing.

FLY ASH: The noncombustible particles in flue gas. Often used as a body feed or solidification chemical.

FOLLICLE STIMULATING HORMONE (FSH): A gonadotropic hormone of the anterior pituitary that stimulates growth of follicles in the ovaries of females and function of the seminiferous tubules in males.

FOLLICLE: A jacket of cells around an egg cell in an ovary.

FOOD CHAIN: Sequence of organisms, including producers, consumers, and decomposers, through which energy and materials may move in a community.

FOOD WEB: The elaborate, interconnected feeding relationships in an ecosystem.

FOOT CANDLE: Unit of illumination; the illumination of a surface produced by one standard candle at a distance of one foot.

FORMATION OF TUBERCLES: This condition is of the most concern regarding corrosive water effects on a water system. It is the creation of mounds of rust inside the water lines.

Formation: A series of layers, deposits, or bodies of rock, which are geologically similar and related in depositional environment or origin. A formation can be clearly distinguished relative to bounding deposits or formations due to its particular characteristics and composition.

FORMULA: A precise representation of the structure of a molecule or ion, showing the proportion of atoms which comprise the material.

FOUNDER EFFECT: The difference between the gene pool of a population as a whole and that of a newly isolated population of the same species.

FRACTIONATION: An experimental technique which involves separation of parts of living tissue from one another using centrifugation.

Fracture: A discrete break in a rock or formation.

FRAGMENTATION: A mechanism of asexual reproduction in which the parent plant or animal separates into parts that reform whole organisms.

FRAMESHIFT MUTATION: A mutation occurring when the number of nucleotides inserted or deleted is not a multiple of 3, thus resulting in improper grouping into codons.

FREE CHLORINE RESIDUAL: Regardless of whether pre-chlorination is practiced or not, a free chlorine residual of at least 10 mg/L should be maintained in the clear well or distribution reservoir immediately downstream from the point of post-chlorination. The reason for chlorinating past the breakpoint is to provide protection in case of backflow.

FREE CHLORINE: In disinfection, chlorine is used in the form of free chlorine or as hypochlorite ion.

FREE ENERGY OF ACTIVATION: See Activation energy.

FREE ENERGY: Usable energy in a chemical system; energy available for producing change.

FREE OIL: Non-emulsified oil that separates from water, in a given period of time.

FREEZING: Phase transition from liquid to solid.

FREQUENCY DEPENDENT SELECTION: A decline in the reproductive success of a morph resulting from the morph's phenotype becoming too common in a population; a cause of balanced polymorphism in populations.

FREQUENCY: Number of cycles per unit of time. Unit: 1 hertz = 1 cycle per 1 second.

FUNCTIONAL GROUP: One of several groups of atoms commonly found in organic molecules. A functional group contributes somewhat predictable properties to the molecules which possess them.

FUNDAMENTAL NICHE: The total resources an organism is theoretically capable of utilizing.

G

G: (protein) A membrane protein that serves as an intermediary between hormone receptors and the enzyme adenylate cyclase, which converts ATP to cAMP in the second messenger system in non-steroid hormone action. Depending on the system, G proteins either increase or decrease cAMP production.

G1 PHASE: The first growth phase of the cell cycle, consisting of the portion of interphase before DNA synthesis is initiated.

G2 PHASE: The second growth phase of the cell cycle, consisting of the portion of interphase after DNA synthesis but before mitosis.

GAIA HYPOTHESIS: An idea, first formulated by James E. Lovelock in 1979, which suggests that the biosphere of the earth exists as a "superorganism" which exhibits homeostatic self-regulation of the environment-biota global system.

GALVANIC CELL: Battery made up of electrochemical with two different metals connected by salt bridge.

GAMETANGIUM: The reproductive organ of bryophytes, consisting of the male antheridium and female archegonium; a multi-chambered jacket of sterile cells in which gametes are formed.

GAMETE: A sexual reproductive cell that must usually fuse with another such cell before development begins; an egg or sperm.

GAMETOPHYTE: A haploid plant that can produce gametes.

GANGLION: A structure containing a group of cell bodies of neurons.

GAP JUNCTION: A narrow gap between plasma membranes of two animal cells, spanned by protein channels. They allow chemical substances or electrical signals to pass from cell to cell.

GAS: Particles that fill their container though have no definite shape or volume.

GASTRULA: A two-layered, later three-layered, animal embryonic stage.

GASTRULATION: The process by which a blastula develops into a gastrula, usually by an involution of cells.

GATED ION CHANNEL: A membrane channel that can open or close in response to a signal, generally a change in the electrostatic gradient or the binding of a hormone, transmitter, or other molecular signal.

GEL ELECTROPHORESIS: In general, electrophoresis is a laboratory technique used to separate macromolecules on the basis of electric charge and size; the technique involves application of an electric field to a population of macromolecules which disperse according to their electric mobilities. In gel electrophoresis, the porous medium through which the macromolecules move is a gel.

GEL: Colloid in which the suspended particles form a relatively orderly arrangement.

GENE AMPLIFICATION: Any of the strategies that give rise to multiple copies of certain genes, thus facilitating the rapid synthesis of a product (such as rRNA for ribosomes) for which the demand is great.

GENE CLONING: Formation by a bacterium, carrying foreign genes in a recombinant plasmid, of a clone of identical cells containing the replicated foreign genes.

GENE DELIVERY: This is a general term for the introduction of new genetic elements into the genomes of living cells. The delivery problem is essentially conditioned by the fact that the new genetic elements are usually large, and by the presence of the outer cell membrane and the nuclear membrane acting as barriers to incorporation of the new DNA into the genome already present in the nucleus. Viruses possess various natural biochemical methods for achieving gene delivery; artificial gene delivery is one of the essential problems of "genetic engineering". The most important barrier is apparently the outer cell membrane, which is essentially a lipid barrier, and introduction of any large complex into the cell requires a fusion of one kind or another with this membrane. Liposomes, which consist of lipid membranes themselves, and which can fuse with outer cell membranes, are thus potential vehicles for delivery of many substances, including DNA.

GENE FLOW: The movement of genes from one part of a population to another, or from one population to another, via gametes.

GENE POOL: The sum total of all the genes of all the individuals in a population.

GENE REGULATION: Any of the strategies by which the rate of expression of a gene can be regulated, as by controlling the rate of transcription.

GENE: The hereditary determinant of a specified characteristic of an individual; specific sequences of nucleotides in DNA.

GENETIC DRIFT: Change in the gene pool as a result of chance and not as a result of selection, mutation, or migration.

GENETIC RECOMBINATION: The general term for the production of offspring that combine traits of the two parents.

GENETICS: The science of heredity; the study of heritable information.

GENOME: The cell's total complement of DNA.

GENOMIC EQUIVALENCE: The presence of all of an organism's genes in all of its cells.

GENOMIC IMPRINTING: The parental effect on gene expression. Identical alleles may have different effects on offspring depending on whether they arrive in the zygote via the ovum or via the sperm.

GENOMIC LIBRARY: A set of thousands of DNA segments from a genome, each carried by a plasmid or phage.

GENOTYPE: The particular combination of genes present in the cells of an individual.

GENUS: A taxonomic category above the species level, designated by the first word of a species' binomial Latin name.

GEOCHEMISTRY: The chemistry of and chemical composition of the Earth.

GIARDIA LAMBLIA: *Giardia lamblia* (synonymous with *Lamblia intestinalis* and *Giardia duodenalis*) is a flagellated protozoan parasite that colonizes and reproduces in the small intestine, causing giardiasis. The giardia parasite attaches to the epithelium by a ventral adhesive disc, and reproduces via binary fission. Giardiasis does not spread via the bloodstream, nor does it spread to other parts of the gastro-intestinal tract, but remains confined to the lumen of the small intestine.

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GIARDIASIS, HEPATITIS OR TYPHOID: Diseases that may be transmitted through the contamination of a water supply but not AIDS.

GIBBS ENERGY: Value that indicates the spontaneity of a reaction (usually symbolized as G).

GIS – GRAPHIC INFORMATION SYSTEM: Detailed information about the physical locations of structures such as pipes, valves, and manholes within geographic areas with the use of satellites.

GLIAL CELL: A non-conducting cell of the nervous system that provides support, insulation, and protection for the neurons.

GLIDING: Rod-shaped, gram-negative, mostly aerobic; glide on secreted slimy substances; form colonies, frequently with complex fruiting structures.

GLOMERULUS: A capillary bed within Bowman's capsule of the nephron; the site of ultrafiltration.

GLUCOSE: A six carbon sugar which plays a central role in cellular metabolism.

GLYCOCALYX: The layer of protein and carbohydrates just outside the plasma membrane of an animal cell; in general, the proteins are anchored in the membrane, and the carbohydrates are bound to the proteins.

GLYCOGEN: A long, branched polymer of glucose subunits that is stored in the muscles and liver of animals and is metabolized as a source of energy.

GLYCOLYSIS: A metabolic pathway which occurs in the cytoplasm of cells and during which glucose is oxidized anaerobically to form pyruvic acid.

GLYCOPROTEIN: A protein with covalently linked sugar residues. The sugars may be bound to OH side chains of the polypeptide (O: linked) or the amide nitrogen of asparagine side chains (N: linked).

GLYCOSIDIC: A type of bond which links monosaccharide subunits together in di- or polysaccharides.

GLYOXYSOME: A type of microbody found in plants, in which stored lipids are converted to carbohydrates.

GOLGI APPARATUS: A system of concentrically folded membranes found in the cytoplasm of eukaryotic cells. Plays a role in the production and release of secretory materials such as the digestive enzymes manufactured in the pancreas.

GONADOTROPIN: Refers to a member of a group of hormones capable of promoting growth and function of the gonads. Includes hormones such as follicle stimulating hormone (FSH) and luteinizing hormone (LH) which are stimulatory to the gonads.

GOOD CONTACT TIME, pH and LOW TURBIDITY: These are factors that are important in providing good disinfection when using chlorine.

GPM: Gallons per minute.

GRAB SAMPLE: A sample which is taken from a water or wastestream on a one-time basis with no regard to the flow of the water or wastestream and without consideration of time. A single grab sample should be taken over a period of time not to exceed 15 minutes. A single water or wastewater sample taken at a time and place representative of total discharge.

GRADED POTENTIAL: A local voltage change in a neuron membrane induced by stimulation of a neuron, with strength proportional to the strength of the stimulus and lasting about a millisecond.

GRANUM: A stack-like grouping of photosynthetic membranes in a chloroplast

GRAVITROPISM: A response of a plant or animal in response to gravity.

GRAVITY BELT THICKENER: A sludge dewatering device utilizing a filter belt to promote gravity drainage of water. Usually precedes additional dewatering treatment.

GRAVITY FILTER: A filter that operates at atmospheric pressure.

GRAVITY THICKENING: A sedimentation basin designed to operate at high solids loading rates.

GREENHOUS EFFECT: The warming of the Earth due to atmospheric accumulation of carbon dioxide which absorbs infrared radiation and slows its escape from the irradiated Earth.

GREGOR MENDEL: The first to make quantitative observations of the patterns of inheritance and proposing plausible explanations for them.

GROWTH FACTOR: A protein that must be present in a cell's environment for its normal growth and development.

GT: Represents (Detention time) x (mixing intensity) in flocculation.

GUARD CELL: A specialized epidermal cell that regulates the size of stoma of a leaf.

GYMNOSPERM: A vascular plant that bears naked seeds not enclosed in any specialized chambers.

H

H₂SO₄: The molecular formula of Sulfuric acid.

HABIT: In biology, the characteristic form or mode of growth of an organism.

HABITAT: The kind of place where a given organism normally lives.

HABITUATION: The process that results in a long-lasting decline in the receptiveness of interneurons to the input from sensory neurons or other interneurons (sensitization, adaptation).

HALF: The average amount of time it takes for one-half of a specified quantity of a substance to decay or disappear.

HALIDES: A halide is a binary compound, of which one part is a halogen atom and the other part is an element or radical that is less electronegative than the halogen, to make a fluoride, chloride, bromide, iodide, or astatide compound. Many salts are halides. All Group 1 metals form halides with the halogens and they are white solids. A halide ion is a halogen atom bearing a negative charge. The halide anions are fluoride (F), chloride (Cl), bromide (Br), iodide (I) and astatide (At). Such ions are present in all ionic halide salts.

HALL EFFECT: Refers to the potential difference (Hall voltage) on the opposite sides of an electrical conductor through which an electric current is flowing, created by a magnetic field applied perpendicular to the current. Edwin Hall discovered this effect in 1879.

HALOACETIC ACIDS: Haloacetic acids are carboxylic acids in which a halogen atom takes the place of a hydrogen atom in acetic acid. Thus, in a monohaloacetic acid, a single halogen would replace a hydrogen atom. For example, chloroacetic acid would have the structural formula CH₂ClCO₂H. In the same manner, in dichloroacetic acid two chlorine atoms would take the place of two hydrogen atoms (CHCl₂CO₂H).

HALOGENS: Group 7 on the Periodic Table and are all non-metals.

HAPLOID: The condition of having only one kind of a given type of chromosome.

HARD WATER: Hard water causes a buildup of scale in household hot water heaters. Hard water is a type of water that has high mineral content (in contrast with soft water). Hard water primarily consists of calcium (Ca^{2+}), and magnesium (Mg^{2+}) metal cations, and sometimes other dissolved compounds such as bicarbonates and sulfates. Calcium usually enters the water as either calcium carbonate (CaCO_3), in the form of limestone and chalk, or calcium sulfate (CaSO_4), in the form of other mineral deposits. The predominant source of magnesium is dolomite ($\text{CaMg}(\text{CO}_3)_2$). Hard water is generally not harmful. The simplest way to determine the hardness of water is the lather/froth test: soap or toothpaste, when agitated, lathers easily in soft water but not in hard water. More exact measurements of hardness can be obtained through a wet titration. The total water 'hardness' (including both Ca^{2+} and Mg^{2+} ions) is read as parts per million or weight/volume (mg/L) of calcium carbonate (CaCO_3) in the water. Although water hardness usually only measures the total concentrations of calcium and magnesium (the two most prevalent, divalent metal ions), iron, aluminum, and manganese may also be present at elevated levels in some geographical locations.

HARDNESS: A measure of the amount of calcium and magnesium salts in water. More calcium and magnesium lead to greater hardness. The term "hardness" comes from the fact that it is hard to get soap suds from soap or detergents in hard water. This happens because calcium and magnesium react strongly with negatively-charged chemicals like soap to form insoluble compounds.

HARDY-WEINBERG THEOREM: An axiom maintaining that the sexual shuffling of genes alone cannot alter the overall genetic makeup of a population.

HARTSHORN: The antler of a hart, formerly used as a source of ammonia. Ammonium carbonate.

HAUSTORIUM: In parasitic fungi, a nutrient-absorbing hyphal tip that penetrates the tissues of the host but remains outside the host cell membranes.

Haversian System: One of many structural units of vertebrate bone, consisting of concentric layers of mineralized bone matrix surrounding lacunae, which contain osteocytes, and a central canal, which contains blood vessels and nerves.

HAZARDS OF POLYMERS: Slippery and difficult to clean-up are the most common hazards associated with the use of polymers in a water treatment plant.

HEAD: The measure of the pressure of water expressed in feet of height of water. 1 PSI = 2.31 feet of water or 1 foot of head equals about a half a pound of pressure or .433 PSI. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).

HEADWORKS: The facility at the "head" of the water source where water is first treated and routed into the distribution system.

HEALTH ADVISORY: An EPA document that provides guidance and information on contaminants that can affect human health and that may occur in drinking water, but which the EPA does not currently regulate in drinking water.

HEAT OF VAPORIZATION: The amount of energy absorbed by a substance when it changes state to a gas. Water absorbs approximately 580 calories per gram when it changes from liquid water to water vapor.

HEAT: The total amount of kinetic energy due to molecular motion in a body of matter. Heat is energy in its most random form.

HEAT: Energy transferred from one system to another by thermal interaction.

HELPER T CELL: A type of T cell that is required by some B cells to help them make antibodies or that helps other T cells respond to antigens or secrete lymphokines or interleukins.

HEMAGGLUTININ: A surface antigen on influenza viruses which controls infectivity by associating with receptors on host erythrocytes or other cells.

HEMATOPOIESIS: The formation of blood.

HEMATOPOIETIC STEM CELLS: Cells found in the bone marrow of adult mammals which give rise to erythroid stem cells, lymphoid stem cells, and myeloid stem cells. Such cells give rise to erythrocytes and a variety of types of lymphocytes and leucocytes.

HEMOGLOBIN: An iron-containing respiratory pigment found in many organisms.

HEMOLymph: In invertebrates with open circulatory systems, the body fluid that bathes tissues.

HEMOPHILIA: A genetic disease resulting from an abnormal sex-linked recessive gene, characterized by excessive bleeding following injury.

HEPATIC: Pertaining to the liver.

HEREDITY: A biological phenomenon whereby characteristics are transmitted from one generation to another by virtue of chemicals (i.e. DNA) transferred during sexual or asexual reproduction.

HERPESVIRUS: A double stranded DNA virus with an enveloped, icosahedral capsid.

HERTZ: The term used to describe the frequency of cycles in an alternating current (AC) circuit. A unit of frequency equal to one cycle per second.

HETEROCHROMATIN: Non-transcribed eukaryotic chromatin that is so highly compacted that it is visible with a light microscope during interphase.

HETEROCHRONY: Evolutionary changes in the timing or rate of development.

HETEROCYST: A specialized cell that engages in nitrogen fixation on some filamentous cyanobacteria.

HETEROGAMY: The condition of producing gametes of two different types (contrast with isogamy).

HETEROMORPHIC: A condition in the life cycle of all modern plants in which the sporophyte and gametophyte generations differ in morphology.

HETEROSPOROUS: Referring to plants in which the sporophyte produces two kinds of spores that develop into unisexual gametophytes, either male or female.

HETEROTROPH: An organism dependent on external sources of organic compounds as a means of obtaining energy and/or materials. Such an organism requires carbon ("food") from its environment in an organic form. (synonym-organotroph).

HETEROTROPHIC PLATE COUNT: A test performed on drinking water to determine the total number of all types of bacteria in the water.

HETEROZYGOTE ADVANTAGE: A mechanism that preserves variation in eukaryotic gene pools by conferring greater reproductive success on heterozygotes over individuals homozygous for any one of the associated alleles.

HETEROZYGOUS: The condition whereby two different alleles of the gene are present within the same cell.

HF: The molecular formula of Hydrofluoric acid.

HIGH TURBIDITY CAUSING INCREASED CHLORINE DEMAND: May occur or be caused by the inadequate disinfection of water.

HISTAMINE: A substance released by injured cells that causes blood vessels to dilate during an inflammatory response.

HISTOLOGY: The study of tissues.

HISTONE: A type of protein characteristically associated with the chromosomes of eukaryotes.

HIV-1: Acute human immunodeficiency virus type 1 is the subtype of HIV (human immune deficiency virus) that causes most cases of AIDS in the Western Hemisphere, Europe, and Central, South, and East Africa. HIV is a retrovirus (subclass lentivirus), and retroviruses are single: stranded RNA viruses that have an enzyme called reverse transcriptase. With this enzyme the viral RNA is used as a template to produce viral DNA from cellular material. This DNA is then incorporated into the host cell's genome, where it codes for the synthesis of viral components. An HIV-1 infection should be distinguished from AIDS. Acquired immunodeficiency syndrome (AIDS) is a secondary immunodeficiency syndrome resulting from HIV infection and characterized by opportunistic infections, malignancies, neurologic dysfunction, and a variety of other syndromes.

HOLOBLASTIC: A type of cleavage in which there is complete division of the egg, as in eggs having little yolk (sea urchin) or a moderate amount of yolk (frog).

HOME RANGE: An area within which an animal tends to confine all or nearly all its activities for a long period of time.

HOMEODOMAIN: Specific sequences of DNA that regulate patterns of differentiation during development of an organism.

HOMEOSTASIS: A phenomenon whereby a state or process (for example, within an organism) is regulated automatically despite the tendency for fluctuations to occur.

HOMEOTHERMIC: Capable of regulation of constancy with respect to temperature.

HOMEOTIC GENES: Genes that control the overall body plan of animals by controlling the developmental fate of groups of cells.

HOMEOTIC: (mutation) A mutation in genes regulated by positional information that results in the abnormal substitution of one type of body part in place of another.

HOMOLOGOUS CHROMOSOMES: Chromosomes bearing genes for the same characters.

HOMOLOGOUS STRUCTURES: Characters in different species which were inherited from a common ancestor and thus share a similar ontogenetic pattern.

HOMOLOGY: Similarity in characteristics resulting from a shared ancestry.

HOMOPLASY: The presence in several species of a trait not present in their most common ancestor. Can result from convergent evolution, reverse evolution, or parallel evolution.

HOMOSPOROUS: Referring to plants in which a single type of spore develops into a bisexual gametophyte having both male and female sex organs.

HOMOZYGOUS: Having two copies of the same allele of a given gene.

HORMONE: A control chemical secreted in one part of the body that affects other parts of the body.

HOST RANGE: The limited number of host species, tissues, or cells that a parasite (including viruses and bacteria) can infect.

HUMORAL IMMUNITY: The type of immunity that fights bacteria and viruses in body fluids with antibodies that circulate in blood plasma and lymph, fluids formerly called humors.

HYBRID VIGOR: Increased vitality (compared to that of either parent stock) in the hybrid offspring of two different, inbred parents.

HYBRID: In evolutionary biology, a cross between two species. In genetics, a cross between two genetic types.

HYBRIDIZATION: The process whereby a hybrid results from interbreeding two species; 2) DNA hybridization is the comparison of whole genomes of two species by estimating the extent of hydrogen bonding that occurs between single-stranded DNA obtained from the two species.

HYBRIDOMA: A hybrid cell that produces monoclonal antibodies in culture, formed by the fusion of a myeloma cell with a normal antibody-producing lymphocyte.

HYDRATED LIME: The calcium hydroxide product that results from mixing quicklime with water. Chemical formula is CaOH_2 .

HYDRATION SHELL: A "covering" of water molecules which surrounds polar or charged substances in aqueous solutions. The association is due to the charged regions of the polar water molecules themselves.

hydraulic conductivity: A primary factor in Darcy's Law, the measure of a soil or formations ability to transmit water, measured in gallons per day (gpd) See also Permeability and Darcy's Law.

HYDRIDES: Hydride is the name given to the negative ion of hydrogen, H. Although this ion does not exist except in extraordinary conditions, the term hydride is widely applied to describe compounds of hydrogen with other elements, particularly those of groups 1–16. The variety of compounds formed by hydrogen is vast, arguably greater than that of any other element. Various metal hydrides are currently being studied for use as a means of hydrogen storage in fuel cell-powered electric cars and batteries. They also have important uses in organic chemistry as powerful reducing agents, and many promising uses in hydrogen economy.

HYDROCARBON: Any compound made of only carbon and hydrogen.

HYDROCHLORIC AND HYPOCHLOROUS ACIDS: HCL and HOCL: The compounds that are formed in water when chlorine gas is introduced.

HYDROFLUOSILICIC ACID: (H_2SiF_6) a clear, fuming corrosive liquid with a pH ranging from 1 to 1.5. Used in water treatment to fluoridate drinking water.

HYDROGEN BOND: A type of bond formed when the partially positive hydrogen atom of a polar covalent bond in one molecule is attracted to the partially negative atom of a polar covalent bond in another.

HYDROGEN ION: A single proton with a charge of +1. The dissociation of a water molecule (H_2O) leads to the generation of a hydroxide ion (OH^-) and a hydrogen ion (H^+).

HYDROGEN SULFIDE OR CHLORINE GAS: These chemicals can cause olfactory fatigue.

HYDROGEN SULFIDE: A toxic gas formed by the anaerobic decomposition of organic matter. Chemical formula is H_2S .

Hydrologic Cycle: (Water Cycle) The continual process of precipitation (rain and snowfall), evaporation (primarily from the oceans), percolation (recharge to groundwater), runoff (surface water), and transpiration (plants) constituting the renew ability and recycling of each component.

HYDROLYSIS: The chemical reaction that breaks a covalent bond through the addition of hydrogen (from a water molecule) to the atom forming one side of the original bond, and a hydroxyl group to the atom on the other side.

HYDROPHILIC: Having an affinity for water.

HYDROPHOBIC INTERACTION: A type of weak chemical bond formed when molecules that do not mix with water coalesce to exclude the water.

HYDROPHOBIC: The physicochemical property whereby a substance or region of a molecule resists association with water molecules. Does not mix readily with water.

HYDROSTATIC: Pertaining to the pressure and equilibrium of fluids. A hydrostatic skeleton is a skeletal system composed of fluid held under pressure in a closed body compartment; the main skeleton of most cnidarians, flatworms, nematodes, and annelids.

HYDROXYL GROUP: A functional group consisting of a hydrogen atom joined to an oxygen atom by a polar covalent bond. Molecules possessing this group are soluble in water and are called alcohols.

HYDROXYL ION: The OH⁻ ion.

HYGROSCOPIC: Absorbing or attracting moisture from the air.

HYPEROSMOTIC: A solution with a greater solute concentration than another, a hypoosmotic solution. If the two solutions are separated from one another by a membrane permeable to water, water would tend to move from the hypo- to the hyperosmotic side.

HYPERPOLARIZATION: An electrical state whereby the inside of the cell is made more negative relative to the outside than was the case at resting potential. A neuron membrane is hyperpolarized if the voltage is increased from the resting potential of about -70 mV, reducing the chance that a nerve impulse will be transmitted.

HYPERTROPHY: Abnormal enlargement, excessive growth.

HYPHA: A fungal filament.

HYPOCHLORITE (OCL⁻) AND ORGANIC MATERIALS: Heat and possibly fire may occur when hypochlorite is brought into contact with an organic material.

HYPOCHLORITE AND ORGANIC MATERIALS: Heat and possibly fire may occur when hypochlorite is brought into contact with an organic material.

HYPOCOTYL: The portion of the axis of a plant embryo below the point of attachment of the cotyledons; forms the base of the shoot and the root.

HYPOLIMNION: The layer of water in a thermally stratified lake that lies below the thermocline, is noncirculating, and remains perpetually cold.

HYPOOSMOTIC SOLUTION: A solution with a lesser solute concentration than another, a hyperosmotic solution. If the two solutions are separated from one another by a membrane permeable to water, water would tend to move from the hypo- to the hyperosmotic side.

HYPOTHESIS: A formal statement of supposition offered to explain observations. Note that a hypothesis is only useful if it can be tested. Even if correct, it is not scientifically useful if untestable.

HYPOTHETICO-DEDUCTIVE: A method used to test hypotheses. If deductions formulated from the hypothesis are tested and proven false, the hypothesis is rejected.

I

IMAGINAL DISK: An island of undifferentiated cells in an insect larva, which are committed (determined) to form a particular organ during metamorphosis to the adult.

IMBIBITION: The soaking of water into a porous material that is hydrophilic.

IMMUNE RESPONSE: 1) A primary immune response is the initial response to an antigen, which appears after a lag of a few days. 2) A secondary immune response is the response elicited when the animal encounters the same antigen at a later time. The secondary response is normally more rapid, of greater magnitude and of longer duration than the primary response.

IMMUNOGLOBULINE: The class of proteins comprising the antibodies.

IMMUNOLOGICAL: 1) Immunological distance is the amount of difference between two proteins as measured by the strength of the antigen: antibody reaction between them. 2) Immunological tolerance is a mechanism by which an animal does not mount an immune response to the antigenic determinants of its own macromolecules.

IMMUNOMAGNETIC SEPARATION (IMS): A purification procedure that uses microscopic, magnetically responsive particles coated with an antibodies targeted to react with a specific pathogen in a fluid stream. Pathogens are selectively removed from other debris using a magnetic field.

IMPERVIOUS: Not allowing, or allowing only with great difficulty, the movement of water.

IMPRINTING: A type of learned behavior with a significant innate component, acquired during a limited critical period.

In practice, water with an LSI between -0.5 and +0.5 will not display enhanced mineral dissolving or scale forming properties. Water with an LSI below -0.5 tends to exhibit noticeably increased dissolving abilities while water with an LSI above +0.5 tends to exhibit noticeably increased scale forming properties.

In Series: Several components being connected one to the other without a bypass, requiring each component to work dependent on the one before it.

IN SERIES: Several components being connected one to the other without a bypass, requiring each component to work dependent on the one before it.

IN SITU: Treatment or disposal methods that do not require movement of contaminated material.

IN VITRO FERTILIZATION: Fertilization of ova in laboratory containers followed by artificial implantation of the early embryo in the mother's uterus.

INCINERATION: The process of reducing the volume of a material by burning and reducing to ash if possible.

INCLINED PLATE SEPARATOR: A series of parallel inclined plates that can be used to increase the efficiency of clarifiers and gravity thickeners.

INCOMPLETE DOMINANCE: A type of inheritance in which F1 hybrids have an appearance that is intermediate between the phenotypes of the parental varieties.

INDETERMINATE: 1) A type of cleavage exhibited during the embryonic development in deuterostomes, in which each cell produced by early cleavage divisions retains the capacity to develop into a complete embryo; 2) A type of growth exhibited by plants: they continue to grow as long as they live, because they always retain meristematic cells capable of undergoing mitosis.

INDICATOR: A special compound added to solution that changes color depending on the acidity of the solution; different indicators have different colors and effective pH ranges.

INDIRECT REUSE: The beneficial use of reclaimed water into natural surface waters or groundwater.

INDUCED FIT: The change in shape of the active site of an enzyme so that it binds more snugly to the substrate, induced by entry of the substrate.

INDUCTION: 1) The ability of one group of embryonic cells to influence the development of another. 2) A method in logic which proceeds from the specific to general and develops a general statement which explains all of the observations. Commonly used to formulate scientific hypotheses.

INDUSTRIAL MELANISM: Melanism which has resulted from blackening of environmental surfaces (tree bark, etc.) by industrial pollution. This favors survival of melanic forms such as moths which rest on tree bark and are less likely to be seen by predators.

INDUSTRIAL WASTEWATER: Liquid wastes resulting from industrial processes.

INFECTIOUS PATHOGENS/MICROBES/GERMS: Are considered disease-producing bacteria, viruses and other microorganisms.

INFECTIOUS: 1) An infectious disease is a disease caused by an infectious microbial or parasitic agent. 2) Infectious hepatitis is the former name for hepatitis A. 3) Infectious mononucleosis is an acute disease that affects many systems, caused by the Epstein: Barr virus.

Infiltration: The percolation of fluid into soil or formation. See also percolation.

INFLAMMATORY RESPONSE: A line of defense triggered by penetration of the skin or mucous membranes, in which small blood vessels in the vicinity of an injury dilate and become leakier, enhancing infiltration of leukocytes; may also be widespread in the body.

INFLUENT: Water or wastewater flowing into a basin or treatment plant.

INFORMATION COLLECTION RULE: ICR EPA collected data required by the Information Collection Rule (May 14, 1996) to support future regulation of microbial contaminants, disinfectants, and disinfection byproducts. The rule was intended to provide EPA with information on chemical byproducts that form when disinfectants used for microbial control react with chemicals already present in source water (disinfection byproducts (DBPs)); disease-causing microorganisms (pathogens), including Cryptosporidium; and engineering data to control these contaminants.

INGESTION: A heterotrophic mode of nutrition in which other organisms or detritus are eaten whole or in pieces.

INHIBITORY POSTSYNAPTIC POTENTIAL: An electrical charge (hyperpolarization) in the membrane of a postsynaptic neuron caused by the binding of an inhibitory neurotransmitter from a presynaptic cell to a postsynaptic receptor.

INITIAL MONITORING YEAR: An initial monitoring year is the calendar year designated by the Department within a compliance period in which a public water system conducts initial monitoring at a point of entry.

INITIAL PRECISION AND RECOVERY (IPR): Four aliquots of spiking suspension analyzed to establish the ability to generate acceptable precision and accuracy. An IPR is performed prior to the first time this method is used and any time the method or instrumentation is modified.

INNER CELL MASS: A cluster of cells in a mammalian blastocyst that protrudes into one end of the cavity and subsequently develops into the embryo proper and some of the extraembryonic membranes.

INORGANIC CHEMISTRY: A part of chemistry concerned with inorganic compounds.

INORGANIC COMPOUND: Compounds that contain no carbon or contain only carbon bound to elements other than hydrogen.

INORGANIC COMPOUND: Compounds that do not contain carbon, though there are exceptions.

INORGANIC CONTAMINANTS: Mineral-based compounds such as metals, nitrates, and asbestos. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities. EPA has set legal limits on 15 inorganic contaminants.

INORGANIC IONS: Present in all waters. Inorganic ions are essential for human health in small quantities, but in larger quantities they can cause unpleasant taste and odor or even illness. Most community water systems will commonly test for the concentrations of seven inorganic ions: nitrate, nitrite, fluoride, phosphate, sulfate, chloride, and bromide. Nitrate and nitrite can cause an illness in infants called methemoglobinemia. Fluoride is actually added to the drinking water in some public water systems to promote dental health. Phosphate, sulfate, chloride, and bromide have little direct effect on health, but high concentrations of inorganic ions can give water a salty or briny taste.

INOSITOL TRIPHOSPHATE: The second messenger, which functions as an intermediate between certain non-steroid hormones and the third messenger, a rise in cytoplasmic Ca^{++} concentration.

INSERTION: A mutation involving the addition of one or more nucleotide pairs to a gene.

INSIGHT LEARNING: The ability of an animal to perform a correct or appropriate behavior on the first attempt in a situation with which it has had no prior experience.

INSOLUBLE COMPOUNDS: are types of compounds cannot be dissolved. When iron or manganese reacts with dissolved oxygen (DO) insoluble compound are formed.

INSULATOR: Material that resists the flow of electric current.

INSULIN: The vertebrate hormone that lowers blood sugar levels by promoting the uptake of glucose by most body cells and promoting the synthesis and storage of glycogen in the liver; also stimulates protein and fat synthesis; secreted by endocrine cells of the pancreas called islets of Langerhans.

INTAKE FACILITIES: One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for cathodic protection.

INTEGRAL PROTEIN: A protein of biological membranes that penetrates into or spans the membrane.

INTERBREED: To breed with another kind or species; hybridize.

INTERFERON: A chemical messenger of the immune system, produced by virus: infected cells and capable of helping other cells resist the virus.

INTERLEUKIN: 1: A chemical regulator (cytokine) secreted by macrophages that have ingested a pathogen or foreign molecule and have bound with a helper T cell; stimulates T cells to grow and divide and elevates body temperature. Interleukin: 2, secreted by activated T cells, stimulates helper T cells to proliferate more rapidly.

INTERMEDIATE FILAMENT: A component of the cytoskeleton that includes all filaments intermediate in size between microtubules and microfilaments.

INTERNEURON: An association neuron; a nerve cell within the central nervous system that forms synapses with sensory and motor neurons and integrates sensory input and motor output.

INTERNODE: The segment of a plant stem between the points where leaves are attached.

INTERSTITIAL CELLS: Cells scattered among the seminiferous tubules of the vertebrate testis that secrete testosterone and other androgens, the male sex hormones.

INTERSTITIAL FLUID: The internal environment of vertebrates consisting of the fluid filling the spaces between cells.

INTERTIDAL ZONE: The shallow zone of the ocean where land meets water.

INTRINSIC RATE OF INCREASE: The difference between number of births and number of deaths, symbolized as r_{max} ; maximum population growth rate.

INTROGRESSION: Transplantation of genes between species resulting from fertile hybrids mating successfully with one of the parent species.

INTRON: The noncoding, intervening sequence of coding region (exon) in eukaryotic genes.

INVAGINATION: The buckling inward of a cell layer, caused by rearrangements of microfilaments and microtubules; an important phenomenon in embryonic development.

INVERSION: 1) An aberration in chromosome structure resulting from an error in meiosis or from mutagens; reattachment in a reverse orientation of a chromosomal fragment to the chromosome from which the fragment originated. 2) A phenomenon which occurs during early development of sponges at which time the external ciliated cells become inward-directed.

INVERTEBRATE: An animal without a backbone; invertebrates make up about 95% of animal species.

ION EXCHANGE: An effective treatment process used to remove iron and manganese in a water supply. The hardness of the source water affects the amount of water an ion exchange softener may treat before the bed requires regeneration.

ION: A charged chemical formed when an atom or group of atoms has more or less electrons than protons (rather than an equal number). A molecule that has gained or lost one or more electrons.

IONIC BOND: A chemical bond due to attraction between oppositely charged ions.

IONIZATION: The breaking up of a compound into separate ions.

IRON AND MANGANESE: Fe and Mn In water they can usually be detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

IRON AND MANGANESE: In water they can usually be detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

IRON BACTERIA: Perhaps the most troublesome consequence of iron and manganese in the water is they promote the growth of a group of microorganism known as Iron Bacteria.

IRON FOULING: You should look for an orange color on the resin and backwash water when checking an ion exchange unit for iron fouling

IRON: Fe The elements iron and manganese are undesirable in water because they cause stains and promote the growth of iron bacteria.

IRRUPTION: A rapid increase in population density often followed by a mass emigration.

ISOGAMY: A condition in which male and female gametes are morphologically indistinguishable.

ISOMER: Molecules consisting of the same numbers and kinds of atoms, but differing in the way in which the atoms are combined.

ISOSMOTIC: Solutions of equal concentration with respect to osmotic pressure.

ISOTOPE: An atomic form of an element, containing a different number of neutrons than another isotope. Isotopes vary from one another with respect to atomic mass.

It is also worth noting that the LSI is temperature sensitive. The LSI becomes more positive as the water temperature increases. This has particular implications in situations where well water is used. The temperature of the water when it first exits the well is often significantly lower than the temperature inside the building served by the well or at the laboratory where the LSI measurement is made.

IUPAC: International Union of Pure and Applied Chemistry

J

JODIUM: Latin name of the halogen element iodine.

JOULE: The SI unit of energy, defined as a newton-meter.

JUXTAGLOMERULAR APPARATUS (JGA): Specialized tissue located near the afferent arteriole that supplies blood to the kidney glomerulus; JGA raises blood pressure by producing renin, which activates angiotensin.

K

K- SELECTION: The concept that life history of the population is centered upon producing relatively few offspring that have a good chance of survival.

KARYOGAMY: The fusion of nuclei of two cells, as part of syngamy.

KARYOTYPE: A method of classifying the chromosomes of a cell in relation to number, size and type.

KEYSTONE PREDATOR: A species that maintains species richness in a community through predation of the best competitors in the community, thereby maintaining populations of less competitive species.

KILL = $C \times T$: Where other factors are constant, the disinfecting action may be represented by: Kill = $C \times T$. Kill = $C \times T$. C = Chlorine T = Contact time.

KILOCALORIE: A thousand calories; the amount of heat energy required to raise the temperature of 1 kilogram of water by primary C.

KIN SELECTION: A phenomenon of inclusive fitness, used to explain altruistic behavior between related individuals.

KINESIS: A change in activity rate in response to a stimulus.

KINETIC ENERGY: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head. The energy of motion. Moving matter does work by transferring some of its kinetic energy to other matter.

KINETICS: A sub-field of chemistry specializing in reaction rates.

KINETOCHORE: A specialized region on the centromere that links each sister chromatid to the mitotic spindle.

KINGDOM: A taxonomic category, the second broadest after domain.

KREBS CYCLE: A chemical cycle involving eight steps that completes the metabolic breakdown of glucose molecules to carbon dioxide; occurs within the mitochondrion; the second major stage in cellular respiration. Also called citric acid cycle or tricarboxylic acid (TCA) cycle.

L

L.O.T.O.: If a piece of equipment is locked out, the key to the lock-out device the key should be held by the person who is working on the equipment. The tag is an identification device and the lock is a physical restraint.

LABORATORY BLANK: See Method blank

LABORATORY CONTROL SAMPLE (LCS): See Ongoing precision and recovery (OPR) standard

LACRIMATION: The secretion of tears, esp. in abnormal abundance Also, lachrymation, lachrimation.

LACTEAL: A tiny lymph vessel extending into the core of the intestinal villus and serving as the destination for absorbed chylomicrons.

LACTIC ACID: Gram-positive, anaerobic; produce lactic acid through fermentation; include Lactobacillus, essential in dairy product formation, and Streptococcus, common in humans.

LAGGING STRAND: A discontinuously synthesized DNA strand that elongates in a direction away from the replication fork.

LAMARCK: Proposed, in the early 1800s, that evolutionary change may occur via the inheritance of acquired characteristics. This idea, which has since been discredited, holds that the changes in characteristics which occur during an individual's life can be passed on to its offspring.

LAND APPLICATION: The disposal of wastewater or municipal solids onto land under controlled conditions.

LAND DISPOSAL: Application of municipal wastewater solids to the soil without production of usable agricultural products.

LANDFILL: A land disposal site that employs an engineering method of solid waste disposal to minimize environmental hazards and protect the quality of surface and subsurface waters.

LANGELIER INDEX: A measurement of Corrosivity. The water is becoming corrosive in the distribution system causing rusty water if the Langelier index indicates that the pH has decreased from the equilibrium point. Mathematically derived factor obtained from the values of calcium hardness, total alkalinity, and pH at a given temperature. A Langelier index of zero indicates perfect water balance (i.e., neither corroding nor scaling). The Langelier Saturation Index (sometimes Langelier Stability Index) is a calculated number used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. Langelier developed a method for predicting the pH at which water is saturated in calcium carbonate (called pHs). The LSI is expressed as the difference between the actual system pH and the saturation pH.

LANTHANIDES: Elements 57 through 71.

LARVA (pl. larvae): A free-living, sexually immature form in some animal life cycles that may differ from the adult in morphology, nutrition, and habitat.

LATERAL LINE SYSTEM: A mechanoreceptor system consisting of a series of pores and receptor units (neuromasts) along the sides of the body of fishes and aquatic amphibians; detects water movements made by an animal itself and by other moving objects.

LATERAL MERISTEMS: The vascular and cork cambia, cylinders of dividing cells that run most of the length of stems and roots and are responsible for secondary growth.

LATTICE: Unique arrangement of atoms or molecules in a crystalline liquid or solid.

LAW OF INDEPENDENT ASSORTMENT: Mendel's second law, stating that each allele pair segregates independently during gamete formation; applies when genes for two traits are located on different pairs of homologous chromosomes.

LAW OF MOTION: An object in motion stay in motion an object in rest stays in rest unless an unbalanced force acts on it.

LAW OF SEGREGATION: Mendel's first law, stating that allele pairs separate during gamete formation, and then randomly re-form pairs during the fusion of gametes at fertilization.

LEACHATE: Fluid that trickles through solid materials or wastes and contains suspended or dissolved materials or products of the solids.

LEACHING: A chemical reaction between water and metals that allows for removal of soluble materials.

LEAD AND COPPER: Initial tap water monitoring for lead and copper must be conducted during 2 consecutive 6-month periods.

LEADING STRAND: The new continuously complementary DNA strand synthesized along the template strand in the 5' → 3' direction.

LEUKOCYTE: A white blood cell; typically functions in immunity, such as phagocytosis or antibody production.

LEVELS OF ORGANIZATION: A basic concept in biology is that organization is based on a hierarchy of structural levels, with each level building on the levels below it.

LICHEN: An organism formed by the symbiotic association between a fungus and a photosynthetic alga.

LIFE: (table) A table of data summarizing mortality in a population.

LIGAMENT: A type of fibrous connective tissue that joins bones together at joints.

LIGAND: A ligand is a molecule that binds specifically to a receptor site of another molecule. A ligase is an enzyme which catalyzes such a reaction. For example, a DNA ligase is an enzyme which catalyzes the covalent bonding of the 3' end of a new DNA fragment to the 5' end of a growing chain.

LIGASE: Ligases are enzymes that catalyze the "stitching together" of polymer fragments. DNA ligase, for example, catalyzes phosphodiester bond formation between two DNA fragments, and this enzyme is involved in normal DNA replication, repair of damaged chromosomes, and various in vitro techniques in genetic engineering that involve linking DNA fragments.

LIGHT: Portion of the electromagnetic spectrum which is visible to the naked eye. Also called "visible light."

LIGNIN: A hard material embedded in the cellulose matrix of vascular plant cell walls that functions as an important adaptation for support in terrestrial species.

LIBIC SYSTEM: A group of nuclei (clusters of nerve cell bodies) in the lower part of the mammalian forebrain that interact with the cerebral cortex in determining emotions; includes the hippocampus and the amygdala.

LIME SODA SOFTENING: In a lime soda softening process, the pH of the water is raised to 11.0. In a lime softening process, excess lime is frequently added to remove Calcium and Magnesium Bicarbonate. The minimum hardness which can be achieved by the lime-soda ash process is 30 to 40 mg/L as calcium carbonate. The hardness due to noncarbonate hardness is most likely to determine the choice between lime softening and ion exchange to remove hardness.

LIME SOFTENING: Lime softening is primarily used to "soften" water—that is to remove calcium and magnesium mineral salts. But it also removes harmful toxins like radon and arsenic. Though there is no consensus, some studies have even suggested that lime softening is effective at removal of Giardia. Hard water is a common condition responsible for numerous problems. Users often recognize hard water because it prevents their soap from lathering properly. However, it can also cause buildup ("scale") in hot water heaters, boilers, and hot water pipes. Because of these inconveniences, many treatment facilities use lime softening to soften hard water for consumer use. Before lime softening can be used, managers must determine the softening chemistry required. This is a relatively easy task for groundwater sources, which remain more constant in their composition. Surface waters, however, fluctuate widely in quality and may require frequent changes to the softening chemical mix. In lime softening, lime and sometimes sodium carbonate are added to the water as it enters a combination solids contact clarifier. This raises the pH (i.e., increases alkalinity) and leads to the precipitation of calcium carbonate. Later, the pH of the effluent from the clarifier is reduced again, and the water is then filtered through a granular media filter. The water chemistry requirements of these systems require knowledgeable operators, which may make lime softening an economic challenge for some very small systems.

LIME STABILIZATION: The addition of lime to untreated sludge to raise the pH to 12 for a minimum of 2 hours to chemically inactivate microorganisms.

LIME: Is a chemical that may be added to water to reduce the corrosivity. When an operator adds lime to water, Calcium and magnesium become less soluble. The term generally used to describe ground limestone (calcium carbonate), hydrated lime (calcium hydroxide), or burned lime (calcium oxide).

LINKED GENES: Genes that are located on the same chromosomes.

LIPID: One of a family of compounds, including fats, phospholipids, and steroids, that are insoluble in water.

LIPOPROTEIN: A protein bonded to a lipid; includes the low-density lipoproteins (LDLS) and high-density lipoproteins (HDLS) that transport fats and cholesterol in the blood.

LIPOSOME: Liposomes are vesicles (spherules) in which the lipid molecules are spontaneously arranged into bilayers with hydrophilic groups exposed to water molecules both outside the vesicle and in the core.

LIQUID: A state of matter which takes the shape of its container.

LISTED HAZARDOUS WASTE: The designation for a waste material that appears on an EPA list of specific hazardous wastes or hazardous waste categories.

LOCUS: A particular place along the length of a certain chromosome where a specified allele is located.

LOGISTIC POPULATION GROWTH: A model describing population growth that levels off as population size approaches carrying capacity.

LONDON DISERSION FORCES: A weak intermolecular force.

LSI = pH - pHs

LSI = pH (measured) - pHs

LYMPHOCYTE: Lymphocytes (lymph cells, lympho- leukocytes) are a type of leukocyte (white blood cell) responsible for the immune response. There are two classes of lymphocytes: 1) the B- cells, when presented with a foreign chemical entity (antigen), change into antibody producing plasma cells; and, 2) the T- cells interact directly with foreign invaders such as bacteria and viruses. The T- cells express various surface marker macromolecules. For example, CD4+ is the notation for a specific expressed T- cell surface marker that can be identified by assay.

LYSIS: The destruction of a cell by rupture of the plasma membrane.

LYSOGENIC CYCLE: A type of viral replication cycle in which the viral genome becomes incorporated into the bacterial host chromosome as a prophage.

LYSOSOME: A membrane-bounded organelle found in eukaryotic cells (other than plants). Lysosomes contain a mixture of enzymes that can digest most of the macromolecules found in the rest of the cell. An enzyme in perspiration, tears, and saliva that attacks bacterial cell walls.

LYTIC CYCLE: A type of viral replication cycle resulting in the release of new phages by death or lysis of the host cell.

M

M PHASE: The mitotic phase of the cell cycle, which includes mitosis and cytokinesis.

M.S.D.S.: Material Safety Data Sheet, now S.D.S. (Safety Data Sheet). A safety document must an employer provide to an operator upon request.

MACROEVOLUTION: Evolutionary change on a grand scale, encompassing the origin of novel designs, evolutionary trends, adaptive radiation, and mass extinction.

MACROMOLECULE: A giant molecule of living matter formed by the joining of smaller molecules, usually by condensation synthesis. Polysaccharides, proteins, and nucleic acids are macromolecules.

MACROPHAGE: An amoeboid cell that moves through tissue fibers, engulfing bacteria and dead cells by phagocytosis.

MAGNESIUM HARDNESS: Measure of the magnesium salts dissolved in water – it is not a factor in water balance.

MAJOR HISTOCOMPATIBILITY COMPLEX: A large set of cell surface antigens encoded by a family of genes. Foreign MHC markers trigger T-cell responses that may lead to rejection of transplanted tissues and organs.

MAKEUP WATER: Fluid introduced in a recirculating stream to maintain an equilibrium of temperature, solids concentration or other parameters. Also refers to the quantity of water required to make a solution.

MALIGNANT TUMOR: A cancerous growth; an abnormal growth whose cells multiply excessively, have altered surfaces, and may have unusual numbers of chromosomes and/or aberrant metabolic processes.

MALPIGHIAN TUBULE: A unique excretory organ of insects that empties into the digestive tract, removes nitrogenous wastes from the blood, and functions in osmoregulation.

MANTLE: A heavy fold of tissue in mollusks that drapes over the visceral mass and may secrete a shell.

MARBLE AND LANGELIER TESTS: Are used to measure or determine the corrosiveness of a water source.

MASS NUMBER: The sum of the number of protons plus the number of neutrons in the nucleus of an atom; unique for each element and designated by a superscript to the left of the elemental symbol.

MATRIX SPIKE (MS): A sample prepared by adding a known quantity of organisms to a specified amount of sample matrix for which an independent estimate of target analyte concentration is available. A matrix spike is used to determine the effect of the matrix on a method's recovery efficiency.

MATRIX: The nonliving component of connective tissue, consisting of a web of fibers embedded in homogeneous ground substance that may be liquid, jellylike, or solid.

MATTER: Anything that takes up space and has mass.

MAXIMUM CONTAMINANT LEVEL (MCLs): The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL.

MAXIMUM CONTAMINANT LEVEL GOAL (MCLG): The level of a contaminant at which there would be no risk to human health. This goal is not always economically or technologically feasible, and the goal is not legally enforceable.

MCL for TURBIDITY: Turbidity is undesirable because it causes health hazards. An MCL for turbidity was established by the EPA because turbidity does not allow for proper disinfection.

MEASURE CORROSION DAMAGE: A coupon such as a strip of metal and is placed to measure corrosion damage in the distribution system in a water main.

MECHANICAL SEAL: A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such tolerances as to prevent the passage of water between them. Held in place with spring pressure.

MECHANORECEPTOR: A sensory receptor that detects physical deformations in the body environment associated with pressure, touch, stretch, motion, and sound.

MEDIAN BODIES: Prominent, dark-staining, paired organelles consisting of microtubules and found in the posterior half of *Giardia*. In *G. intestinalis* (from humans), these structures often have a claw-hammer shape, while in *G. muris* (from mice), the median bodies are round.

MEDIUM WATER SYSTEM: More than 3,300 persons and 50,000 or fewer persons.

MEDULLA OBLONGATA: The lowest part of the vertebrate brain; a swelling of the hindbrain dorsal to the anterior spinal cord that controls autonomic, homeostatic functions, including breathing, heart and blood vessel activity, swallowing, digestion, and vomiting.

MEDUSA: The floating, flattened, mouth-down version of the cnidarian body plan. The alternate form is the polyp.

MEGAPASCAL: A unit of pressure equivalent to 10 atmospheres of pressure.

MEGGER: Used to test the insulation resistance on a motor.

MEIOSIS: A two-stage type of cell division in sexually reproducing organisms that results in gametes with half the chromosome number of the original cell.

MELTING: The phase change from a solid to a liquid.

MEMBRANE POTENTIAL: The charge difference between the cytoplasm and extracellular fluid in all cells, due to the differential distribution of ions. Membrane potential affects the activity of excitable cells and the transmembrane movement of all charged substances.

MEMBRANE: A thin barrier that permits passage of particles of a certain size or of particular physical or chemical properties.

M-ENDO BROTH: The coliform group are used as indicators of fecal pollution in water, for assessing the effectiveness of water treatment and disinfection, and for monitoring water quality. m-Endo Broth is used for selectively isolating coliform bacteria from water and other specimens using the membrane filtration technique. m-Endo Broth is prepared according to the formula of Fifiield and Schaufus.¹ It is recommended by the American Public Health Association in standard total coliform membrane filtration procedure for testing water, wastewater, and foods.^{2,3} The US EPA specifies using m-Endo Broth in the total coliform methods for testing water using single-step, two-step, and delayed incubation membrane filtration methods.

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MESENTERIES: Membranes that suspend many of the organs of vertebrates inside fluid- filled body cavities.

MESODERM: The middle primary germ layer of an early embryo that develops into the notochord, the lining of the coelom, muscles, skeleton, gonads, kidneys and most of the circulatory system.

MESOSOME: A localized infolding of the plasma membrane of a bacterium.

MESSENGER: (RNA) A type of RNA synthesized from DNA in the genetic material that attaches to ribosomes in the cytoplasm and specifies the primary structure of a protein.

METABOLISM: The sum total of the chemical and physical changes constantly taking place in living substances.

METAL: Chemical element that is a good conductor of both electricity and heat and forms cations and ionic bonds with non-metals.

METALIMNION: Thermocline, middle layer of a thermally stratified lake which is characterized by a rapid decrease in temperature in proportion to depth.

METALLOID: Metalloid is a term used in chemistry when classifying the chemical elements. On the basis of their general physical and chemical properties, nearly every element in the periodic table can be termed either a metal or a nonmetal. A few elements with intermediate properties are, however, referred to as metalloids. (In Greek metallon = metal and eidos = sort)

METAMORPHOSIS: The resurgence of development in an animal larva that transforms it into a sexually mature adult.

METANEPHRIDIUM: A type of excretory tubule in annelid worms that has internal openings called nephrostomes that collect body fluids and external openings called nephridiopores.

METASTASIS: The spread of cancer cells beyond their original site.

METAZOAN: A multicellular animal. Among important distinguishing characteristics of Metazoa are cell differentiation and intercellular communication. For certain multicellular colonial entities such as sponges, some biologists prefer the term "parazoa".

METHANE: Methane is a chemical compound with the molecular formula CH₄. It is the simplest alkane, and the principal component of natural gas. Methane's bond angles are 109.5 degrees. Burning methane in the presence of oxygen produces carbon dioxide and water. The relative abundance of methane and its clean burning process makes it a very attractive fuel. However, because it is a gas at normal temperature and pressure, methane is difficult to transport from its source. In its natural gas form, it is generally transported in bulk by pipeline or LNG carriers; few countries still transport it by truck.

METHYLENE BLUE: A heterocyclic aromatic chemical compound with the molecular formula C₁₆H₁₈N₃SCl.

METHOD BLANK: An aliquot of reagent water that is treated exactly as a sample, including exposure to all glassware, equipment, solvents, and procedures that are used with samples. The method blank is used to determine if analytes or interferences are present in the laboratory environment, the reagents, or the apparatus.

Mg/L: Stands for "milligrams per liter." A common unit of chemical concentration. It expresses the mass of a chemical that is present in a given volume of water. A milligram (one one-thousandth of a gram) is equivalent to about 18 grains of table salt. A liter is equivalent to about one quart.

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MICROBE OR MICROBIAL: Any minute, simple, single-celled form of life, especially one that causes disease.

MICROBIAL CONTAMINANTS: Microscopic organisms present in untreated water that can cause waterborne diseases.

MICROBE OR MICROBIAL: Any minute, simple, single-celled form of life, especially one that causes disease.

MICROBIOLOGICAL: Is a type of analysis in which a composite sample unacceptable.

MICROBODY: A small organelle, bounded by a single membrane and possessing a granular interior. Peroxisomes and glyoxysomes are types of microbodies.

MICROCENTRIFUGE: A small plastic container that is used to store small amounts of liquid.

MICROEVOLUTION: A change in the gene pool of a population over a succession of generations.

MICROFILAMENT: Minute fibrous structure generally composed of actin found in the cytoplasm of eukaryotic cells. They play a role in motion within cells.

MICROFILTRATION: A low pressure membrane filtration process that removes suspended solids and colloids generally larger than 0.1 micron diameter.

MICROORGANISMS: Very small animals and plants that are too small to be seen by the naked eye and must be observed using a microscope. Microorganisms in water include algae, bacteria, viruses, and protozoa. Algae growing in surface waters can cause off-taste and odor by producing the chemicals MIB and geosmin. Certain types of bacteria, viruses, and protozoa can cause disease in humans. Bacteria are the most common microorganisms found in treated drinking water. The great majority of bacteria are not harmful. In fact, humans would not be able to live without the bacteria that inhabit the intestines. However, certain types of bacteria called coliform bacteria can signal the presence of possible drinking water contamination.

MICROSCOPE: An instrument which magnifies images either by using lenses in an optical system to bend light (light microscope) or electromagnets to direct the movement of electrons (electron microscope).

MICROTUBULE: A minute tubular structure found in centrioles, spindle apparatus, cilia, flagella, and other places in the cytoplasm of eukaryotic cells. Microtubules play a role in movement and maintenance of shape.

MICROVILLUS: Collectively, fine, fingerlike projections of the epithelial cells in the lumen of the small intestine that increase its surface area.

MILLIGRAMS PER LITER: (mg/L) A common unit of measurement of the concentration of a material in solution.

MILLILITER: One one-thousandth of a liter. A liter is a little more than a quart. A milliliter is about two drops from an eye dropper.

MIMICRY: A phenomenon in which one species benefits by a superficial resemblance to an unrelated species. A predator or species of prey may gain a significant advantage through mimicry.

MISCIBLE: Capable of being mixed together.

MISSENSE: (mutation) The most common type of mutation involving a base-pair substitution within a gene that changes a codon, but the new codon makes sense, in that it still codes for an amino acid.

MITOCHONDRIAL MATRIX: The compartment of the mitochondrion enclosed by the inner membrane and containing enzymes and substrates for the Krebs cycle.

MITOCHONDRION: An organelle that occurs in eukaryotic cells and contains the enzymes of the citric acid cycle, the respiratory chain, and oxidative phosphorylation. A mitochondrion is bounded by a double membrane.

MITOSIS: A process of cell division in eukaryotic cells conventionally divided into the growth period (interphase) and four stages: prophase, metaphase, anaphase, and telophase. The stages conserve chromosome number by equally allocating replicated chromosomes to each of the daughter cells.

MIXED LIQUOR SUSPENDED SOLIDS: Suspended solids in the mixture of wastewater and activated sludge undergoing aeration in the aeration basin.

MODEM SYNTHESIS: A comprehensive theory of evolution emphasizing natural selection, gradualism, and populations as the fundamental units of evolutionary change; also called Neo-Darwinism.

MOISTURE AND POTASSIUM PERMANGANATE: The combination of moisture and potassium permanganate produces heat.

MOISTURE: If a material is hygroscopic, it must be protected from water.

MOLARITY: A common measure of solute concentration, referring to the number of moles of solute in 1 L of solution.

MOLD: A rapidly growing, asexually reproducing fungus.

MOLE: Abbreviated mol : a measurement of an amount of substance; a single mole contains approximately 6.022×10^{23} units or entities. A mole of water contains 6.022×10^{23} H₂O molecules.

MOLE: The number of grams of a substance that equals its molecular weight in daltons and contains Avogadro's number of molecules.

MOLECULAR FORMULA: A type of molecular notation indicating only the quantity of the constituent atoms.

MOLECULAR ORBITAL: Region where an electron can be found in a molecule (as opposed to an atom).

MOLECULAR WEIGHT: The molecular mass (abbreviated Mr) of a substance, formerly also called molecular weight and abbreviated as MW, is the mass of one molecule of that substance, relative to the unified atomic mass unit u (equal to 1/12 the mass of one atom of carbon-12). This is distinct from the relative molecular mass of a molecule, which is the ratio of the mass of that molecule to 1/12 of the mass of carbon 12 and is a dimensionless number. Relative molecular mass is abbreviated to Mr.

MOLECULE: Two or more atoms of one or more elements held together by ionic or covalent chemical bonds. A chemically bonded number of atoms that are electrically neutral.

MOLTING: A process in arthropods in which the exoskeleton is shed at intervals to allow growth by secretion of a larger exoskeleton.

MONERA: The kingdom of life forms that includes all of the bacteria.

MONOCLONAL ANTIBODY: A defensive protein produced by cells descended from a single cell; an antibody that is secreted by a clone of cells and, consequently, is specific for a single antigenic determinant.

MONOECIOUS: Referring to an organism having the capacity of producing both sperm and eggs.

MONOHYBRID CROSS: A breeding experiment that employs parental varieties differing in a single character.

MONOMER: A small molecule, two or more of which can be combined to form oligomers (consisting of a few monomers) or polymers (consisting of many monomers).

MONOPHYLETIC: A term used to describe any taxon derived from a single ancestral form that gave rise to no species in other taxa.

MONOSACCHARIDE: A simple sugar; a monomer.

MONOZYGOTIC TWINS: Monozygotic twins are genetically identical, derived from the division and autonomous development of a single zygote (fertilized egg).

MORPHOGENESIS: The development of body shape and organization during ontogeny.

MORPHOSPECIES: Species defined by their anatomical features.

MOSAIC EVOLUTION: The evolution of different features of an organism at different rates.

MOSAIC: A pattern of development, such as that of a mollusk, in which the early blastomeres each give rise to a specific part of the embryo. In some animals, the fate of the blastomeres is established in the zygote.

MOTOR NERVOUS SYSTEM: In vertebrates, the component of the peripheral nervous system that transmits signals from the central nervous system to effector cells.

MOTTLING: High levels of fluoride may stain the teeth of humans.

MPF: M: phase promoting factor: A protein complex required for a cell to progress from late interphase to mitosis; the active form consists of cyclin and cdc2, a protein kinase.

MUCOSA: Refers to the mucous tissue lining various tubular structures in the body.

MUD BALLS IN FILTER MEDIA: Is a possible result of an ineffective or inadequate filter backwash.

MULLERIAN MIMICRY: A mutual mimicry by two unpalatable species.

MULTIGENE FAMILY: A collection of genes with similar or identical sequences, presumably of common origin.

MUNICIPAL WASTE: The combined solid and liquid waste from residential, commercial and industrial sources.

MUNICIPAL WASTEWATER TREATMENT PLANT (MWTP): Treatment works designed to treat municipal wastewater.

MURIATIC ACID: An acid used to reduce pH and alkalinity. Also used to remove stain and scale.

MUST: This action, activity, or procedural step is required.

MUTAGEN: A chemical or physical agent that interacts with DNA and causes a mutation.

MUTAGENESIS: The creation of mutations.

MUTATION: A spontaneous or induced change in a gene's or chromosome's structure or number. The resulting individual is termed a mutant.

MUTUALISM: A symbiotic relationship in which both the host and the symbiont benefit.

MYCELIUM: The densely branched network of hyphae in a fungus.

MYCOBACTERIUM: Pleomorphic spherical or rod-shaped, frequently branching, no gram stain, aerobic; commonly form yellow pigments; include Mycobacterium tuberculosis, cause of tuberculosis.

MYCOPLASMA: Spherical, commonly forming branching chains, no gram stain, aerobic but can live in certain anaerobic conditions; without cell walls yet structurally resistant to lysis; among smallest of bacteria; named for superficial resemblance to fungal hyphae (myco-means "fungus").

MYCOTOXIN: A toxin produced by a fungus.

MYELIN SHEATH: An insulating coat of cell membrane from Schwann cells that is interrupted by nodes of Ranvier where saltatory conduction occurs.

MYOFIBRILS: Fibrils arranged in longitudinal bundles in muscle cells (fibers); composed of thin filaments of actin and a regulatory protein and thick filaments of myosin.

MYOGLOBIN: An oxygen-storing, pigmented protein in muscle cells.

MYOSIN: A type of protein filament that interacts with actin filaments to cause cell movement, such as contraction in muscle cells.

N

NAD⁺: Nicotinamide adenine dinucleotide (oxidized); a coenzyme present in all cells that assists enzymes in transferring electrons during the redox reactions of metabolism.

NANO-FILTRATION: A specialty membrane filtration process that rejects solutes larger than approximately one nanometer (10 angstroms) in size.

NANOMETER: A unit of measure (length). 1 nm is equal to 1×10^{-9} m, or 1/1,000,000 mm.

NaOCl: Is the molecular formula of Sodium hypochlorite.

NaOH: Is the molecular formula of Sodium hydroxide.

NASCENT: Coming into existence; emerging.

NATURAL ORGANIC MATTER: Organic matter present in natural waters.

NEAT: Conditions with a liquid reagent or gas performed with no added solvent or co-solvent.

NEGATIVE CONTROL: See Method blank.

NEGATIVE FEEDBACK: A primary mechanism of homeostasis, whereby a change in a physiological variable that is being monitored triggers a response that counteracts the initial fluctuation.

NEURAMINIDASE: A surface enzyme possessed by some influenza viruses which help the virus penetrate the mucus layer protecting the respiratory epithelium and also plays a role in budding of new virus particles from infected cells.

NEURON: A nerve cell; the fundamental unit of the nervous system, having structure and properties that allow it to conduct signals by taking advantage of the electrical charge across its cell membrane.

NEUROSECRETORY CELLS: Cells that receive signals from other nerve cells, but instead of signaling to an adjacent nerve cell or muscle, release hormones into the blood stream.

NEUROTRANSMITTER: The chemical messenger released from the synaptic terminals of a neuron at a chemical synapse that diffuses across the synaptic cleft and binds to and stimulates the postsynaptic cell.

NEUTRAL VARIATION: Genetic diversity that confers no apparent selective advantage.

NEUTRALIZATION REACTIONS: Chemical reactions between acids and bases where water is an end product.

NEUTRALIZATION: The chemical process that produces a solution that is neither acidic nor alkaline. Usually with a pH between 6 and 8.

NEUTRINO: A particle that can travel at speeds close to the speed of light and are created as a result of radioactive decay.

NEUTRON: An uncharged subatomic particle of about the same size and mass as a proton.

NH₄⁺: The molecular formula of the Ammonium ion.

NITRATES: A dissolved form of nitrogen found in fertilizers and sewage by-products that may leach into groundwater and other water sources. Nitrates may also occur naturally in some waters. Over time, nitrates can accumulate in aquifers and contaminate groundwater.

NITROGEN AND PHOSPHORUS: Pairs of elements and major plant nutrients that cause algae to grow.

NITROGEN: Nitrogen is a nonmetal, with an electronegativity of 3.0. It has five electrons in its outer shell and is therefore trivalent in most compounds. The triple bond in molecular nitrogen (N₂) is one of the strongest in nature. The resulting difficulty of converting (N₂) into other compounds, and the ease (and associated high energy release) of converting nitrogen compounds into elemental N₂, have dominated the role of nitrogen in both nature and human economic activities. At atmospheric pressure

molecular nitrogen condenses (liquefies) at 77 K (-195.8 °C) and freezes at 63 K (-210.0 °C) into the beta hexagonal close-packed crystal allotropic form. Below 35.4 K (-237.6 °C) nitrogen assumes the alpha cubic crystal allotropic form. Liquid nitrogen, a fluid resembling water, but with 80.8% of the density, is a common cryogen. Unstable allotropes of nitrogen consisting of more than two nitrogen atoms have been produced in the laboratory, like N₃ and N₄.^[1] Under extremely high pressures (1.1 million atm) and high temperatures (2000 K), as produced under diamond anvil conditions, nitrogen polymerizes into the single bonded diamond crystal structure, an allotrope nicknamed "nitrogen diamond."

NITROGEN-FIXING: Rod-shaped, gram-negative, aerobic; convert atmospheric nitrogen gas to ammonium in soil; include *Azotobacter*, a common genus.

NO₃-: The molecular formula of the Nitrate ion.

NOBLE GASES: Group 18 elements, those whose outer electron shell is filled.

NOMENCLATURE: The method of assigning names in the classification of organisms.

NON-CARBONATE HARDNESS: The portion of the total hardness in excess of the alkalinity.

NON-CARBONATE IONS: Water contains non-carbonate ions if it cannot be softened to a desired level through the use of lime only.

NONCOMPETITIVE INHIBITOR: A substance that reduces the activity of an enzyme by binding to a location remote from the active site, changing its conformation so that it no longer binds to the substrate.

NONCYCLIC ELECTRON FLOW: A route of electron flow during the light reactions of photosynthesis that involves both photosystems and produces ATP, NADPH, and oxygen; the net electron flow is from water to NADP⁺.

NONCYCLIC PHOTOPHOSPHORYLATION: The production of ATP by noncyclic electron flow.

NONDISJUNCTION: An accident of meiosis or mitosis, in which both members of a pair of homologous chromosomes or both sister chromatids fail to separate normally.

NON-METAL: An element which is not metallic.

NON-POINT SOURCE POLLUTION: Air pollution may leave contaminants on highway surfaces. This non-point source pollution adversely impacts reservoir water and groundwater quality.

NON-POINT SOURCE POLLUTION: Air pollution may leave contaminants on highway surfaces. This non-point source pollution adversely impacts reservoir water and groundwater quality.

NONPOLAR: Electrically symmetrical. For example, in many molecules with covalent bonds, the electrons are shared equally; the poles are electrically neutral.

NONSENSE MUTATION: A mutation that changes an amino acid codon to one of the three stop codons, resulting in a shorter and usually nonfunctional protein.

NON-TRANSIENT, NON-COMMUNITY WATER SYSTEM: A water system which supplies water to 25 or more of the same people at least six months per year in places other than their residences. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.

NORM OF REACTION: The range of phenotypic possibilities for a single genotype, as influenced by the environment.

NORMALITY: It is the number of equivalent weights of solute per liter of solution. Normality highlights the chemical nature of salts: in solution, salts dissociate into distinct reactive species (ions such as H⁺, Fe³⁺, or Cl⁻). Normality accounts for any discrepancy between the concentrations of the various ionic species in a solution. For example, in a salt such as MgCl₂, there are two moles of Cl⁻ for every mole of Mg²⁺, so the concentration of Cl⁻ as well as of Mg²⁺ is said to be 2 N (read: "two normal"). Further examples are given below. A normal is one gram equivalent of a solute per liter of solution. The definition of a gram equivalent varies depending on the type of chemical reaction that is discussed - it can refer to acids, bases, redox species, and ions that will precipitate. It is critical to note that normality measures a single ion which takes part in an overall solute. For example, one could determine the normality of hydroxide or sodium in an aqueous solution of sodium hydroxide, but the normality of sodium hydroxide itself has no meaning. Nevertheless it is often used to describe solutions of acids or bases, in those cases it is implied that the normality refers to the H⁺ or OH⁻ ion. For example, 2 Normal sulfuric acid (H₂SO₄), means that the normality of H⁺ ions is 2, or that the molarity of the sulfuric acid is 1. Similarly for 1 Molar H₃PO₄ the normality is 3 as it contains three H⁺ ions.

NTNCWS: Non-transient non-community water system.

NTU (Nephelometric turbidity unit): A measure of the clarity or cloudiness of water.

NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY: Technique that exploits the magnetic properties of certain nuclei, useful for identifying unknown compounds.

NTU: (Nephelometric turbidity unit): A measure of the clarity or cloudiness of water.

NUCLEAR: 1) (envelope) The surface, consisting of two layers of membrane, that encloses the nucleus of eukaryotic cells. 2) (pore) An opening of the nuclear envelope which allows for the movement of materials between the nucleus and surrounding cytoplasm.

NUCLEAR: Of or pertaining to the atomic nucleus.

NUCLEASE: This term refers to any enzyme that acts on nucleic acids, e.g., Dnase, Rnase, endonuclease, etc.

NUCLEIC: (acid) A polymer composed of nucleotides that are joined by covalent bonds (phosphodiester linkages) between the phosphate of one nucleotide and the sugar of the next nucleotide.

NUCLELUS: A small, generally spherical body found within the nucleus of eukaryotic cells. The site of ribosomal RNA synthesis.

NUCLEOID: The region that harbors the chromosome of a prokaryotic cell. Unlike the eukaryotic nucleus, it is not bounded by a membrane.

NUCLEOLUS (pl. nucleoli): A specialized structure in the nucleus, formed from various chromosomes and active in the synthesis of ribosomes.

NUCLEOSIDE: An organic molecule consisting of a nitrogenous base joined to a five- carbon sugar.

NUCLEOSOME: The basic, beadlike unit of DNA packaging in eukaryotes, consisting of a segment of DNA wound around a protein core composed of two copies of each of four types of histone.

NUCLEOTIDE: The basic chemical unit (monomer) of a nucleic acid. A nucleotide in RNA consists of one of four nitrogenous bases linked to ribose, which in turn is linked to phosphate. In DNA, deoxyribose is present instead of ribose.

NUCLEUS: A membrane-bound organelle containing genetic material. Nuclei are a prominent internal structure seen both in *Cryptosporidium* oocysts and *Giardia* cysts. In *Cryptosporidium* oocysts, there is one nucleus per sporozoite. One to four nuclei can be seen in *Giardia* cysts.

NUCLEUS: The membrane bound organelle of eukaryotic cells that contains the cell's genetic material. Also the central region of an atom composed of protons and neutrons.

NUCLEUS: The center of an atom made up of neutrons and protons, with a net positive charge.

NULL: In the scientific method, the hypothesis which one attempts to falsify.

NUMBER DENSITY: A measure of concentration of countable objects (atoms, molecules, etc.) in space; number per volume.

O

O₃: The molecular formula of ozone.

OLIGOTROPHIC: A reservoir that is nutrient-poor and contains little plant or animal life. An oligotrophic ecosystem or environment is one that offers little to sustain life. The term is commonly utilized to describe bodies of water or soils with very low nutrient levels. It derives etymologically from the Greek oligo (small, little, few) and trophe (nutrients, food). Oligotrophic environments are of special interest for the alternative energy sources and survival strategies upon which life could rely.

ONGOING PRECISION AND RECOVERY (OPR) STANDARD: A method blank spiked with known quantities of analytes. The OPR is analyzed exactly like a sample. Its purpose is to assure that the results produced by the laboratory remain within the limits specified in this method for precision and recovery.

OOCYST AND CYST STOCK SUSPENSION: See Stock suspension.

OOCYST: The encysted zygote of some sporozoa; e.g., *Cryptosporidium*. The oocyst is a phase or form of the organism produced as a normal part of the life cycle of the organism. It is characterized by a thick and environmentally resistant outer wall.

ORBITAL: May refer to either an atomic orbital or a molecular orbital.

ORGANIC CHEMISTRY: A part of chemistry concerned with organic compounds.

ORGANIC COMPOUND: Compounds that contain carbon.

ORGANIC MATTER: Substances containing carbon compounds, usually of animal or vegetable origin.

ORGANIC PRECURSORS: Natural or man-made compounds with chemical structures based upon carbon that, upon combination with chlorine, leading to trihalomethane formation.

ORGANIC: Relating to, or derived from, a living thing. A description of a substance that contains carbon atoms linked together by carbon-carbon bonds.

OSMOSIS: Osmosis is the process by which water moves across a semi permeable membrane from a low concentration solute to a high concentration solute to satisfy the pressure differences caused by the solute.

OVER-RANGE PROTECTION DEVICES: Mechanical dampers, snubbers and an air cushion chamber are examples of surging and over range protection devices.

OXIDE: An oxide is a chemical compound containing at least one oxygen atom as well as at least one other element. Most of the Earth's crust consists of oxides. Oxides result when elements are oxidized by oxygen in air. Combustion of hydrocarbons affords the two principal oxides of carbon, carbon monoxide and carbon dioxide. Even materials that are considered to be pure elements often contain a coating of oxides. For example, aluminum foil has a thin skin of Al_2O_3 that protects the foil from further corrosion.

OXIDIZING: The process of breaking down organic wastes into simpler elemental forms or by products. Also used to separate combined chlorine and convert it into free chlorine.

OXYGEN DEFICIENT ENVIRONMENT: One of the most dangerous threats to an operator upon entering a manhole.

OZONE DOES NOT PROVIDE A RESIDUAL: One of the major drawbacks to using ozone as a disinfectant.

OZONE: Ozone or trioxygen (O_3) is a triatomic molecule, consisting of three oxygen atoms. It is an allotrope of oxygen that is much less stable than the diatomic O_2 . Ground-level ozone is an air pollutant with harmful effects on the respiratory systems of animals. Ozone in the upper atmosphere filters potentially damaging ultraviolet light from reaching the Earth's surface. It is present in low concentrations throughout the Earth's atmosphere. It has many industrial and consumer applications. Ozone, the first allotrope of a chemical element to be recognized by science, was proposed as a distinct chemical compound by Christian Friedrich Schönbein in 1840, who named it after the Greek word for smell (ozein), from the peculiar odor in lightning storms. The formula for ozone, O_3 , was not determined until 1865 by Jacques-Louis Soret and confirmed by Schönbein in 1867. Ozone is a powerful oxidizing agent, far better than dioxygen. It is also unstable at high concentrations, decaying to ordinary diatomic oxygen (in about half an hour in atmospheric conditions): $2 \text{O}_3 = 3 \text{O}_2$.

P

PAC: A disadvantage of using PAC is it is very abrasive and requires careful maintenance of equipment. One precaution that should be taken in storing PAC is that bags of carbon should not be stored near bags of HTH. Removes tastes and odors by adsorption only. Powdered activated carbon frequently used for taste and odor control because PAC is non-specific and removes a broad range of compounds. Jar tests and threshold odor number testing determines the application rate for powdered activated carbon. Powdered activated carbon, or PAC, commonly used for in a water treatment plant for taste and odor control. Powdered activated carbon may be used with some success in removing the precursors of THMs.

PARAMECIUM: Paramecia are a group of unicellular ciliate protozoa formerly known as slipper animalcules from their slipper shape. They are commonly studied as a representative of the ciliate group. Simple cilia cover the body which allows the cell to move with a synchronous motion (like a caterpillar). There is also a deep oral groove containing inconspicuous compound oral cilia (as found in other peniculids) that is used to draw food inside. They generally feed upon bacteria and other small cells. Osmoregulation is carried out by a pair of contractile vacuoles, which actively expel water absorbed by osmosis from their surroundings. Paramecia are widespread in freshwater environments, and are especially common in scums. Paramecia are attracted by acidic conditions. Certain single-celled eukaryotes, such as Paramecium, are examples for exceptions to the

universality of the genetic code (translation systems where a few codons differ from the standard ones).

PARTS PER MILLION (PPM): A common unit of measure used to express the number of parts of a substance contained within a million parts of a liquid, solid, or gas.

PASTEURIZATION: A process for killing pathogenic organisms by applying heat for a specific period of time.

PATHOGENS: Disease-causing pathogens; waterborne pathogens A pathogen may contaminate water and cause waterborne disease.

Pb: The chemical symbol of Lead.

PCE: abbr. perchloroethylene. Known also as perc or tetrachloroethylene, perchloroethylene is a clear, colorless liquid with a distinctive, somewhat ether-like odor. It is non-flammable, having no measurable flashpoint or flammable limits in air. Effective over a wide range of applications, perchloroethylene is supported by closed loop transfer systems, stabilizers and employee exposure monitoring.

PERKINESIS: The aggregation resulting from random thermal motion of fluid molecules.

pCi/L: Picocuries per liter A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.

PEAK DEMAND: The maximum momentary load placed on a water treatment plant, pumping station or distribution system.

PEPTIDOGLYCAN: A polymer found in the cell walls of prokaryotes that consists of polysaccharide and peptide chains in a strong molecular network. Also called mucopeptide, murein.

PERKINESIS: The aggregation resulting from random thermal motion of fluid molecules.

PERMEATE: The term for water which has passed through the membrane of a reverse osmosis unit.

PERMEATE: The term for water which has passed through the membrane of a reverse osmosis unit. The liquid that passes through a membrane.

pH OF SATURATION: The ideal pH for perfect water balance in relation to a particular total alkalinity level and a particular calcium hardness level, at a particular temperature. The pH where the Langelier Index equals zero.

pH: A unit of measure which describes the degree of acidity or alkalinity of a solution. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. The term pH is derived from "p", the mathematical symbol of the negative logarithm, and "H", the chemical symbol of Hydrogen. The definition of pH is the negative logarithm of the Hydrogen ion activity. $pH = -\log[H^+]$.

PHENOL RED: Chemical reagent used for testing pH in the range of 6.8 - 8.4.

PHENOLPHTHALEIN/TOTAL ALKALINITY: The relationship between the alkalinity constituent's bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity measurement.

PHOSPHATE, NITRATE AND ORGANIC NITROGEN: Nutrients in a domestic water supply reservoir may cause water quality problems if they occur in moderate or large quantities.

PHOTON: A carrier of electromagnetic radiation of all wavelength (such as gamma rays and radio waves).

PHYSICAL CHEMICAL TREATMENT: Treatment processes that are non-biological in nature.

PHYSISORPTION: (Or physical adsorption) Is adsorption in which the forces involved are intermolecular forces (van der Waals forces) of the same kind as those responsible for the imperfection of real gases and the condensation of vapors, and which do not involve a significant change in the electronic orbital patterns of the species involved. The term van der Waals adsorption is synonymous with physical adsorption, but its use is not recommended.

PICOCURIE: A unit of radioactivity. "Pico" is a metric prefix that means one one-millionth of one one-millionth. A picocurie is one one-millionth of one one-millionth of a Curie. A Curie is that quantity of any radioactive substance that undergoes 37 billion nuclear disintegrations per second. Thus a picocurie is that quantity of any radioactive substance that undergoes 0.037 nuclear disintegrations per second.

PIEZOMETRIC SURFACE: See potentiometric surface.

PIN FLOC: Small flocculated particle size.

PLANKTON: The aggregate of passively floating, drifting, or somewhat motile organisms occurring in a body of water, primarily comprising microscopic algae and protozoa.

PLASMA: State of matter similar to gas in which a certain portion of the particles are ionized.

PLUNGER: See Surge-block.

POINT OF ENTRY: POE.

POINT SOURCE DISCHARGE: A pipe, ditch, channel or other container from which pollutants may be discharged.

POLLUTANT: A substance, organism or energy form present in amounts that impair or threaten an ecosystem to the extent that its current or future uses are prevented.

POLLUTION: To make something unclean or impure. See Contaminated.

POLYMER: A type of chemical when combined with other types of coagulants aid in binding small suspended particles to larger particles to help in the settling and filtering processes. Chemical used for flocculation in dewatering. Also known as a "polyelectrolyte" which is a substance made of giant molecules formed by the union of simple smaller molecules.

POLYPHOSPHATES: Chemicals that may be added to remove low levels of iron and manganese.

POSITIVE CONTROL: See Ongoing precision and recovery standard.

POST TREATMENT: Treatment of finished water or wastewater to further enhance its quality.

POST-CHLORINE: Where the water is chlorinated to make sure it holds a residual in the distribution system.

POST-CHLORINE: Where the water is chlorinated to make sure it holds a residual in the distribution system.

POTABLE: Good water which is safe for drinking or cooking purposes. Non-Potable: A liquid or water that is not approved for drinking.

POTENTIAL ENERGY: The energy that a body has by virtue of its position or state enabling it to do work.

PPM: Abbreviation for parts per million.

PRE-CHLORINE: Where the raw water is dosed with a large concentration of chlorine.

PRECIPITATE: A solid that separates from a solution.

PRECIPTATION: The phenomenon that occurs when a substance held in solution passes out of solution into a solid form.

PRELIMINARY TREATMENT: Treatment steps including comminution, screening, grit removal, pre-aeration, and/or flow equalization that prepares wastewater influent for further treatment.

PRESIPATATE: Formation of a solid in a solution or inside another solid during a chemical reaction or by diffusion in a solid.

PRESSURE FILTER: Filter unit enclosed in a vessel that may be operated under pressure.

PRESSURE HEAD: The height of a column of water capable of being maintained by pressure. See also Total Head, Total Dynamic Head.

PRESSURE MEASUREMENT: Bourdon tube, Bellows gauge and Diaphragm are commonly used to measure pressure in waterworks systems. A Bellows-type sensor reacts to a change in pressure.

PRESSURE: Pressure is defined as force per unit area. It is usually more convenient to use pressure rather than force to describe the influences upon fluid behavior. The standard unit for pressure is the Pascal, which is a Newton per square meter. For an object sitting on a surface, the force pressing on the surface is the weight of the object, but in different orientations it might have a different area in contact with the surface and therefore exert a different pressure.

PREVENTION: To take action. Stop something before it happens.

PRIMARY CLARIFIER: Sedimentation basin that precedes secondary wastewater treatment.

PRIMARY SLUDGE: Sludge produced in a primary waste treatment unit.

PRIMARY TREATMENT: Treatment steps including sedimentation and/or fine screening to produce an effluent suitable for biological treatment.

PROCESS WASTEWATER: Wastewater generated during manufacture or production processes.

PROCESS WATER: Water that is used for, or comes in contact with an end product or the materials used in an end product.

PROPIONIC ACID: Rod-shaped, pleomorphic, gram-positive, anaerobic; ferment lactic acid; fermentation produces holes in Swiss cheese from the production of carbon dioxide.

PROTIST: Any of a group of eukaryotic organisms belonging to the kingdom Protista according to some widely used modern taxonomic systems. The protists include a variety of unicellular, coenocytic, colonial, and multicellular organisms, such as the protozoans, slime molds, brown algae, and red algae. A unicellular protist in taxonomic systems in which the protists are considered to form a kingdom.

PROTOCTIST: Any of various unicellular eukaryotic organisms and their multicellular, coenocytic, or colonial descendants that belong to the kingdom Protoctista according to some taxonomic systems. The protoctists include the protozoans, slime molds, various algae, and other groups. In many new classification systems, all protoctists are considered to be protists.

PROTON, NEUTRON AND ELECTRON: Are the 3 fundamental particles of an atom.

PROTON: A positive unit or subatomic particle that has a positive charge.

PROTONATION: The addition of a proton (H^+) to an atom, molecule, or ion.

PROTOZOA: Microscopic animals that occur as single cells. Some protozoa can cause disease in humans. Protozoa form cysts, which are specialized cells like eggs that are very resistant to chlorine. Cysts can survive the disinfection process, then "hatch" into normal cells that can cause disease. Protozoa must be removed from drinking water by filtration, because they cannot be effectively killed by chlorine.

PSEUDOMONAD: Rod-shaped (straight or curved) with polar flagella, gram-negative, aerobic; can use up to 100 different compounds for carbon and energy.

PTFE: Polytetrafluoroethylene.

PUBLIC NOTIFICATION: An advisory that EPA requires a water system to distribute to affected consumers when the system has violated MCLs or other regulations. The notice advises consumers what precautions, if any, they should take to protect their health.

PUBLIC WATER SYSTEM (PWS): Any water system which provides water to at least 25 people for at least 60 days annually. There are more than 170,000 PWSs providing water from wells, rivers and other sources to about 250 million Americans. The others drink water from private wells. There are differing standards for PWSs of different sizes and types.

PUMPING LIFT: The height to which water must be pumped or lifted to, feet of head.

PWS: 3 types of public water systems. Community water system, non-transient non-community water system, transient non-community water system.

Q

QUANTA: It is the minimum amount of bundle of energy.

QUANTITATIVE TRANSFER: The process of transferring a solution from one container to another using a pipette in which as much solution as possible is transferred, followed by rinsing of the walls of the source container with a small volume of rinsing solution (e.g., reagent water, buffer, etc.), followed by transfer of the rinsing solution, followed by a second rinse and transfer.

QUANTUM MECHANICS: The study of how atoms, molecules, subatomic particles, etc. behave and are structured.

QUARKS: Elementary particle and a fundamental constituent of matter.

QUICKLIME: A calcium oxide material produced by calcining limestone to liberate carbon dioxide, also called "calcined lime" or "pebble lime", commonly used for pH adjustment. Chemical formula is CaO .

R

RADIATION: Energy in the form of waves or subatomic particles when there is a change from high energy to low energy states.

RADIOACTIVE DECAY: The process of an unstable atomic nucleus losing energy by emitting radiation.

RADIOCHEMICALS: (Or radioactive chemicals) Occur in natural waters. Naturally radioactive ores are particularly common in the Southwestern United States, and some streams and wells can have dangerously high levels of radioactivity. Total alpha and beta radioactivity and isotopes of radium and strontium are the major tests performed for radiochemicals. The federal drinking water standard for gross alpha radioactivity is set at 5 picocuries per liter.

RAW SEWAGE: Untreated wastewater and its contents.

RAW SLUDGE: Undigested sludge recently removed from a sedimentation basin.

RAW TURBIDITY: The turbidity of the water coming to the treatment plant from the raw water source.

RAW WATER: Water that has not been treated in any way; it is generally considered to be unsafe to drink.

REAGENT: A substance used in a chemical reaction to measure, detect, examine, or produce other substances.

REAGENT WATER BLANK: see Method blank.

REAGENT WATER: Water demonstrated to be free from the analytes of interest and potentially interfering substances at the method detection limit for the analyte.

REAGENT: A substance used in a chemical reaction to measure, detect, examine, or produce other substances.

RECHARGE: The infiltration component of the hydrologic cycle. Often used in the context of referring to: The infiltration of water back into an aquifer, resulting in the restoration of lost storage and water levels which had been decreased due to pumping and/or natural discharges from the aquifer.

RECLAIMED WATER: Wastewater that has been treated to a level that allows for its reuse for a beneficial purpose.

RECLAMATION: The process of improving or restoring the condition of land or other material to a better or more useful state.

RECORDER, FLOW: A flow recorder that measures flow is most likely to be located anywhere in the plant where a flow must be measured and in a central location.

RECYCLING: The process by which recovered materials are transformed into new products.

RED WATER AND SLIME: Iron bacteria are undesirable in a water distribution system because of red water and slime complaints.

REDOX POTENTIAL: Reduction potential (also known as redox potential, oxidation / reduction potential or ORP) is the tendency of a chemical species to acquire electrons and thereby be reduced. Each species has its own intrinsic reduction potential; the more positive the potential, the greater the species' affinity for electrons and tendency to be reduced. In aqueous solutions, the reduction potential is the tendency of the solution to either gain or lose electrons when it is subject to change by introduction of a new species. A solution with a higher (more positive) reduction potential than the new species will have a tendency to gain electrons from the new species (i.e. to be reduced by oxidizing the new species) and a solution with a lower (more negative) reduction potential will have a tendency to lose electrons to the new species (i.e. to be oxidized by reducing the new species).

RELATIVE STANDARD DEVIATION (RSD): The standard deviation divided by the mean times 100.

RELAY LOGIC: The name of a popular method of automatically controlling a pump, valve, chemical feeder, and other devices.

RESERVOIR: An impoundment used to store water.

RESIDENCE TIME: The period of time that a volume of liquid remains in a tank or system.

RESIDUAL DISINFECTION PROTECTION: A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).

RESPIRATION: Intake of oxygen and discharge of carbon dioxide as a result of biological oxidation.

RETURN ACTIVATED SLUDGE: Settled activated sludge that is returned to mix with raw or primary settled wastewater.

REVERSE OSMOSIS: Forces water through membranes that contain holes so small that even salts cannot pass through. Reverse osmosis removes microorganisms, organic chemicals, and inorganic chemicals, producing very pure water. For some people, drinking highly purified water exclusively can upset the natural balance of salts in the body. Reverse osmosis units require regular maintenance or they can become a health hazard.

RICKETTSIA: Spherical or rod-shaped, gram-negative, aerobic; cause Rocky Mountain spotted fever and typhus; closely related to Agrobacterium, a common gall-causing plant bacterium.

ROBERT HOOKE: Coined the term "cell" to describe the structures he saw while examining a piece of cork using a microscope.

ROTAMETER: The name of transparent tube with a tapered bore containing a ball is often used to measure the rate of flow of a gas or liquid.

ROTARY DRUM SCREEN: Cylindrical screen used to remove floatable and suspended solids.

ROTIFER: Rotifers get their name (derived from Greek and meaning "wheel-bearer"; they have also been called wheel animalcules) from the corona, which is composed of several ciliated tufts around the mouth that in motion resemble a wheel. These create a current that sweeps food into the mouth, where it is chewed up by a characteristic pharynx (called the mastax) containing a tiny, calcified, jaw-like structure called the trophi. The cilia also pull the animal, when unattached, through the water. Most free-living forms have pairs of posterior toes to anchor themselves while feeding. Rotifers have bilateral symmetry and a variety of different shapes. There is a well-developed cuticle which may be thick and rigid, giving the animal a box-like shape, or flexible, giving the animal a worm-like shape; such rotifers are respectively called loricate and illoricate.

RSD: See Relative standard deviation.

S

S- BLOCK ELEMENTS: Group 1 and 2 elements (alkali and alkaline metals), which includes Hydrogen and Helium.

S.T.P.: Standard temperature and pressure standard temperature and pressure the temperature of 0°C and pressure of 1 atmosphere, usually taken as the conditions when stating properties of gases.

SAFE YIELD: A possible consequence when the "safe yield" of a well is exceeded and water continues to be pumped from a well, is land subsidence around the well will occur. Safe yield refers to a long-term balance between the water that is naturally and artificially recharged to an aquifer and the groundwater that is pumped out. When more water is removed than is recharged, the aquifer is described as being out of safe yield. When the water level in the aquifer then drops, we are said to be mining groundwater.

SALINE SOLUTION: General term for NaCl in water.

SALT BRIDGE: Devices used to connection reduction with oxidation half-cells in an electrochemical cell.

SALTS ARE ABSENT: Is a strange characteristic that is unique to water vapor in the atmosphere.

SALTS: Ionic compounds composed of anions and cations.

SAMPLE: The water that is analyzed for the presence of EPA-regulated drinking water contaminants. Depending on the regulation, EPA requires water systems and states to take samples from source water, from water leaving the treatment facility, or from the taps of selected consumers. **Sampling Location:** A location where soil or cuttings samples may be readily and accurately collected.

SANITARY SURVEY: Persons trained in public health engineering and the epidemiology of waterborne diseases should conduct the sanitary survey. The importance of a detailed sanitary survey of a new water source cannot be overemphasized. An on-site review of the water sources, facilities, equipment, operation, and maintenance of a public water systems for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water. The purpose of a non-regulatory sanitary survey is to identify possible biological and chemical pollutants which might affect a water supply.

SANITIZER: A disinfectant or chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.

SATURATED ZONE: Where an unconfined aquifer becomes saturated beneath the capillary fringe.

SATURATION INDEX: See Langelier's Index.

SATURATOR: A device which produces a fluoride solution for the fluoride process. Crystal-grade types of sodium fluoride should be fed with a saturator. Overfeeding must be prevented to protect public health when using a fluoridation system.

SCADA: A remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to with stand. If the level controller may be set with

too close a tolerance 45 could be the cause of a control system that is frequently turning a pump on and off.

SCALE: Crust of calcium carbonate, the result of unbalanced water. Hard insoluble minerals deposited (usually calcium bicarbonate) which forms on pool and spa surfaces and clog filters, heaters and pumps. Scale is caused by high calcium hardness and/or high pH. The regular use of stain prevention chemicals can prevent scale.

SCHMUTZDECKE: German, "grime or filth cover", sometimes spelt schmutzedecke) is a complex biological layer formed on the surface of a slow sand filter. The schmutzdecke is the layer that provides the effective purification in potable water treatment, the underlying sand providing the support medium for this biological treatment layer. The composition of any particular schmutzdecke varies, but will typically consist of a gelatinous biofilm matrix of bacteria, fungi, protozoa, rotifera and a range of aquatic insect larvae. As a schmutzdecke ages, more algae tend to develop, and larger aquatic organisms may be present including some bryozoan, snails and annelid worms.

SCHRODINGER EQUATION: Quantum state equation which represents the behavior of an electron around an atom.

SCREENINGS PRESS: A mechanical press used to compact and/or dewater material removed from mechanical screening equipment.

SCROLL AND BASKET: The two basic types of centrifuges used in water treatment.

SCRUBBER: A device used to removal particulates or pollutant gases from combustion or chemical process exhaust streams.

SCUM: Floatable materials found on the surface of primary and secondary settling tanks consisting of food wastes, grease, fats, paper, foam, and similar matter.

SEAL: For wells: to abandon a well by filling up the well with approved seal material including cementing with grout from a required depth to the land surface.

SECONDARY CLARIFIER: A clarifier following a secondary treatment process, designed for gravity removal of suspended matter.

SECONDARY DRINKING WATER STANDARDS: Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

SECONDARY SLUDGE: The sludge from the secondary clarifier in a wastewater treatment plant.

SECONDARY TREATMENT: The treatment of wastewater through biological oxidation after primary treatment.

SEDIMENT: Grains of soil, sand, gravel, or rock deposited by and generated by water movement.

SEDIMENTATION BASIN: A quiescent tank used to remove suspended solids by gravity settling. Also called clarifiers or settling tanks, they are usually equipped with a motor driven rake mechanism to collect settled sludge and move it to a central discharge point.

SEDIMENTATION BASIN: Where the thickest and greatest concentration of sludge will be found. Twice a year sedimentation tanks should be drained and cleaned if the sludge buildup interferes with the treatment process.

SEDIMENTATION: The process of suspended solid particles settling out (going to the bottom of the vessel) in water. The removal of settleable suspended solids from water or wastewater by gravity in a quiescent basin or clarifier.

SEMICONDUCTOR: An electrically conductive solid that is between a conductor and an insulator.

SENSOR: A float and cable system are commonly found instruments that may be used as a sensor to control the level of liquid in a tank or basin.

SEPTIC: Condition characterized by bacterial decomposition under anaerobic conditions.

SESSILE: Botany. attached by the base, or without any distinct projecting support, as a leaf issuing directly from the stem. Zoology. permanently attached; not freely moving.

SETTLEABILITY: The tendency of suspended solids to settle.

SETTLEABLE SOLIDS: That portion of suspended solids which are of a sufficient size and weight to settle to the bottom of an Imhoff cone in one hour.

SETTLED SLUDGE VOLUME: Volume of settled sludge measured at predetermined time increments for use in process control calculations.

SETTLED SOLIDS: Solids that have been removed from the raw water by the coagulation and settling processes.

SEWAGE: Liquid or waterborne wastes polluted or fouled from households, commercial or industrial operations, along with any surface water, storm water or groundwater infiltration.

SEWER GAS: A gas mixture produced by anaerobic decomposition of organic matter usually containing high percentages of methane and hydrogen sulfide.

SHEATHED: Filamentous, gram-negative, aerobic; "swarmer" (colonizing) cells form and break out of a sheath; sometimes coated with metals from environment.

SHOCK LOAD: A sudden hydraulic or organic load to a treatment plant, also descriptive of a change in the material being treated.

SHOCK: Also known as superchlorination or break point chlorination. Ridding a water of organic waste through oxidization by the addition of significant quantities of a halogen.

SHORT-CIRCUITING: Short Circuiting is a condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable since it may result in shorter contact, reaction or settling times in comparison with the presumed detention times.

SHOULD: This action, activity, or procedural step is suggested but not required.

SINGLE BOND: Sharing of one pair of electrons.

SINGLE PHASE POWER: The type of power used for lighting systems, small motors, appliances, portable power tools and in homes.

SINUSOID: A curve described by the equation $y = a \sin x$, the ordinate being proportional to the sine of the abscissa.

SINUSOIDAL: Mathematics. Of or pertaining to a sinusoid. Having a magnitude that varies as the sine of an independent variable: a sinusoidal current.

SLOP OIL: Separator skimmings and tramp oil generated during refinery startup, shutdown or abnormal operation.

SLUDGE BASINS: After cleaning sludge basins and before returning the tanks into service the tanks should be inspected, repaired if necessary, and disinfected.

SLUDGE BLANKET: The accumulated sludge suspended in a clarifier or other enclosed body of water.

SLUDGE DEWATERING: The removal of a portion or majority of the water contained in sludge by means of a filter press, centrifuge or other mechanism.

SLUDGE DRYING BED: A closed area consisting of sand or other porous material upon which sludge is dewatered by gravity drainage and evaporation.

SLUDGE REDUCTION: Organic polymers are used to reduce the quantity of sludge. If a plant produces a large volume of sludge, the sludge could be dewatered, thickened, or conditioned to decrease the volume of sludge. Turbidity of source water, dosage, and type of coagulant used are the most important factors which determine the amount of sludge produced in a treatment of water.

SLUDGE: Accumulated and concentrated solids generated within a treatment process that have not undergone a stabilization process.

SLURRY: A mixture of a solid and a liquid that facilitates the transfer of the solid into a treatment solution.

SMALL WATER SYSTEM: 3,300 or fewer persons.

SOC: A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.

SOC: Synthetic organic chemical. A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.

SODA ASH: Chemical used to raise pH and total alkalinity (sodium carbonate).

SODIUM BICARBONATE: Commonly used to increase alkalinity of water and stabilize pH.

SODIUM BISULFATE: Chemical used to lower pH and total alkalinity (dry acid).

SODIUM HYDROXIDE: Also known as caustic soda, a by-product chlorine generation and often used to raise pH.

SOFTENING WATER: When the water has a low alkalinity it is advantageous to use soda ash instead of caustic soda for softening water.

SOFTENING: The process that removes the ions which cause hardness in water.

SOL: A suspension of solid particles in liquid. Artificial examples include sol-gels.

SOLAR DRYING BEDS OR LAGOONS: Are shallow, small-volume storage pond where sludge is concentrated and stored for an extended periods.

SOLAR DRYING BEDS, CENTRIFUGES AND FILTER PRESSES: Are procedures used in the dewatering of sludge.

SOLDER: A fusible alloy used to join metallic parts.

SOLID: One of the states of matter, where the molecules are packed close together, there is a resistance of movement/deformation and volume change; see Young's modulus.

SOLID WASTE: Garbage, refuse, sludge and other discarded material resulting from community activities or commercial or industrial operations.

SOLID, LIQUID AND VAPOR: 3 forms of matter.

SOLUBILITY: The amount of a substance that can dissolve in a solution under a given set of conditions.

SOLUTE: The part of the solution that is mixed into the solvent (NaCl in saline water).

SOLUTION: Homogeneous mixture made up of multiple substances. It is made up of solutes and solvents.

SOLVENT: The part of the solution that dissolves the solute (H₂O in saline water).

SPADNS: The lab reagent called SPADNS solution is used in performing the Fluoride test.

SPADNS: The lab reagent called SPADNS solution is used in performing the Fluoride test.

SPECTROSCOPY: Study of radiation and matter, such as X-ray absorption and emission spectroscopy.

SPEED OF LIGHT: The speed of anything that has zero rest mass ($E_{\text{rest}} = mc^2$ where m is the mass and c is the speed of light).

SPIKING SUSPENSION: Diluted stock suspension containing the organism(s) of interest at a concentration appropriate for spiking samples.

SPIRILLUM: Spiral-shaped, gram-negative, aerobic; include *Bdellovibrio*, predatory on other bacteria.

SPIRIT OF HARTSHORN: A colorless, pungent, suffocating, aqueous solution of about 28.5 percent ammonia gas: used chiefly as a detergent, for removing stains and extracting certain vegetable coloring agents, and in the manufacture of ammonium salts.

SPIROCHETE: Spiral-shaped, gram-negative, mostly anaerobic; common in moist environments, from mammalian gums to coastal mudflats; complex internal structures convey rapid movement; include *Treponemapallidum*, cause of syphilis.

SPLIT FLOW CONTROL SYSTEM: This type of control system is to control the flow to each filter influent which is divided by a weir.

SPOROZOITE: A motile, infective stage of certain protozoans; e.g., *Cryptosporidium*. There are four sporozoites in each *Cryptosporidium* oocyst, and they are generally banana-shaped.

SPRAY BOTTLE OF AMMONIA: An operator should use ammonia to test for a chlorine leak around a valve or pipe. You will see white smoke if there is a leak.

SPRING PRESSURE: Is what maintains contact between the two surfaces of a mechanical seal.

STABILIZATION POND: A large shallow basin used for wastewater treatment by natural processes involving the use of algae and bacteria to accomplish biological oxidation of organic matter.

STANDARD CONDITIONS FOR TEMPERATURE AND PRESSURE or SATP : A standardization used in order compare experimental results (25 °C and 100.000 kPa).

STANDPIPE: A water tank that is taller than it is wide. Should not be found in low point.

STATE OF MATTER: Matter having a homogeneous, macroscopic phase; gas, plasma, liquid, and solid are the most well-known (in increasing concentration).

STERILIZED GLASSWARE: The only type of glassware that should be used in testing for coliform bacteria.

STOCK SUSPENSION: A concentrated suspension containing the organism(s) of interest that is obtained from a source that will attest to the host source, purity, authenticity, and viability of the organism(s).

STORAGE TANKS: Three types of water usage that determine the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage. Equalization storage is the

volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protects the interior about 3-5 years.

STUFFING BOX: That portion of the pump that houses the packing or mechanical seal.

SUBATOMIC PARTICLES: Particles that are smaller than an atom; examples are protons, neutrons and electrons.

SUBLIMATION: A phase transition from solid to limewater fuel or gas.

SUBNATANT: Liquid remaining beneath the surface of floating solids.

SUBSTANCE: Material with definite chemical composition.

SUCCESSION: Transition in the species composition of a biological community, often following ecological disturbance of the community; the establishment of a biological community in an area virtually barren of life.

SULFATE- AND SULFUR- REDUCING: Commonly rod-shaped, mostly gram-negative, anaerobic; include *Desulfovibrio*, ecologically important in marshes.

SULFATE: Will readily dissolve in water to form an anion. Sulfate is a substance that occurs naturally in drinking water. Health concerns regarding sulfate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfate. Of particular concern are groups within the general population that may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations.

SULFIDE: The term sulfide refers to several types of chemical compounds containing sulfur in its lowest oxidation number of -2. Formally, "sulfide" is the dianion, S^{2-} , which exists in strongly alkaline aqueous solutions formed from H_2S or alkali metal salts such as Li_2S , Na_2S , and K_2S . Sulfide is exceptionally basic and, with a $pK_a > 14$, it does not exist in appreciable concentrations even in highly alkaline water, being undetectable at $pH < \sim 15$ (8 M NaOH). Instead, sulfide combines with electrons in hydrogen to form HS^- , which is variously called hydrogen sulfide ion, hydrosulfide ion, sulfhydryl ion, or bisulfide ion. At still lower pH's (<7), HS^- converts to H_2S , hydrogen sulfide. Thus, the exact sulfur species obtained upon dissolving sulfide salts depends on the pH of the final solution. Aqueous solutions of transition metals cations react with sulfide sources (H_2S , $NaSH$, Na_2S) to precipitate solid sulfides. Such inorganic sulfides typically have very low solubility in water and many are related to minerals. One famous example is the bright yellow species CdS or "cadmium yellow". The black tarnish formed on sterling silver is Ag_2S . Such species are sometimes referred to as salts. In fact, the bonding in transition metal sulfides is highly covalent, which gives rise to their semiconductor properties, which in turn is related to the practical applications of many sulfide materials.

SULFUR- AND IRON- OXIDIZING: Commonly rod-shaped, frequently with polar flagella, gram-negative, mostly anaerobic; most live in neutral (nonacidic) environment.

SUPERNATANT: The liquid layer which forms above the sludge in a settling basin.

SURFACE SEAL: The upper portion of a wells construction where surface contaminants are adequately prevented from entering the well, normally consisting of surface casing and neat cement grout.

SURFACE WATER SOURCES: Surface water sources such as a river or lake are primarily the result of Runoff.

SURFACE WATER: Water that is open to the atmosphere and subject to surface runoff; generally, lakes, streams, rivers.

SURFACTANT: Surfactants reduce the surface tension of water by adsorbing at the liquid-gas interface. They also reduce the interfacial tension between oil and water by adsorbing at the liquid-liquid interface. Many surfactants can also assemble in the bulk solution into aggregates. Examples of such aggregates are vesicles and micelles. The concentration at which surfactants begin to form micelles is known as the critical micelle concentration or CMC. When micelles form in water, their tails form a core that can encapsulate an oil droplet, and their (ionic/polar) heads form an outer shell that maintains favorable contact with water. When surfactants assemble in oil, the aggregate is referred to as a reverse micelle. In a reverse micelle, the heads are in the core and the tails maintain favorable contact with oil. Surfactants are also often classified into four primary groups; anionic, cationic, non-ionic, and zwitterionic (dual charge).

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SUSCEPTIBILITY WAIVER: A waiver that is granted based upon the results of a vulnerability assessment.

SUSPENDED SOLIDS: Solids captured by filtration through a 0.45 micron filter membrane.

SYNCHRONY: Simultaneous occurrence; synchronism.

T

TALC: A mineral representing the one on the Mohs Scale and composed of hydrated magnesium silicate with the chemical formula $H_2Mg_3(SiO_3)_4$ or $Mg_3Si_4O_{10}(OH)_2$.

TASTE AND ODORS: The primary purpose to use potassium permanganate in water treatment is to control taste and odors. Anaerobic water undesirable for drinking water purposes because of color and odor problems are more likely to occur under these conditions. Taste and odor problems in the water may happen if sludge and other debris are allowed to accumulate in a water treatment plant.

TCE, trichloroethylene: A solvent and degreaser used for many purposes; for example dry cleaning, it is a common groundwater contaminant. Trichloroethylene is a colorless liquid which is used as a solvent for cleaning metal parts. Drinking or breathing high levels of trichloroethylene may cause nervous system effects, liver and lung damage, abnormal heartbeat, coma, and possibly death. Trichloroethylene has been found in at least 852 of the 1,430 National Priorities List sites identified by the Environmental Protection Agency (EPA).

TDS: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried. Demineralization may be necessary in a treatment process if the water has a very high value Total Dissolved Solids.

TDS-TOTAL DISSOLVED SOLIDS: An expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal sol) suspended form. Generally, the operational definition is that the solids (often abbreviated TDS) must be small enough to survive filtration through a sieve size of two micrometers. Total dissolved solids are normally only discussed for freshwater systems, since salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant (e.g. it is not deemed to be associated with health effects), but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants. Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried. Demineralization may be necessary in a treatment process if the water has a very high value Total Dissolved Solids.

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TELEMETERING: The use of a transmission line with remote signaling to monitor a pumping station or motors. Can be used to accomplish accurate and reliable remote monitoring and control over a long distribution system.

TEMPERATURE SAMPLE: This test should be performed immediately in the field, this is a grab sample.

TEMPERATURE SAMPLE: This test should be performed immediately in the field, a grab sample.

TEMPERATURE: The average energy of microscopic motions of particles.

TERTIARY TREATMENT: The use of physical, chemical, or biological means to improve secondary wastewater effluent quality.

THE RATE DECREASES: In general, when the temperature decreases, the chemical reaction rate decreases also.

THEORY: A model describing the nature of a phenomenon.

THERMAL CONDUCTIVITY: A property of a material to conduct heat (often noted as k).

THERMOCHEMISTRY: The study of absorption/release of heat within a chemical reaction.

THERMODYNAMIC STABILITY: When a system is in its lowest energy state with its environment (equilibrium).

THERMODYNAMICS: The study of the effects of changing temperature, volume or pressure (or work, heat, and energy) on a macroscopic scale.

THERMOMETER: Device that measures the average energy of a system.

THICKENING, CONDITIONING AND DEWATERING: Common processes that are utilized to reduce the volume of sludge.

THICKENING: A procedure used to increase the solids content of sludge by removing a portion of the liquid.

THOMAS MALTHUS: Formulated the concept that population growth proceeds at a geometric rate.

TIME FOR TURBIDITY BREAKTHROUGH AND MAXIMUM HEADLOSS: Are the two factors which determine whether or not a change in filter media size should be made.

TITRATION: A method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.

TITRATION: The process of titrating one solution with another, also called volumetric analysis. A method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.

TITRIMETRIC: Chemistry. Using or obtained by titration. Titrimetrically, adverb.

TOROID: A surface generated by the revolution of any closed plane curve or contour about an axis lying in its plane. The solid enclosed by such a surface.

TORR: A unit to measure pressure (1 Torr is equivalent to 133.322 Pa or 1.3158×10^{-3} atm).

TOTAL ALKALINITY: A measure of the acid-neutralizing capacity of water which indicates its buffering ability, i.e. measure of its resistance to a change in pH. Generally, the higher the total alkalinity, the greater the resistance to pH change.

TOTAL COLIFORM: Total coliform, fecal coliform, and E. coli are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. E. coli is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform. If total coliform is present, the sample will also be tested for either fecal coliform or E. coli, depending on the lab testing method.

TOTAL DISSOLVED SOLIDS (TDS): The accumulated total of all solids that might be dissolved in water. The weight per unit volume of all volatile and non-volatile solids dissolved in a water or wastewater after a sample has been filtered to remove colloidal and suspended solids.

TOTAL DYNAMIC HEAD: The pressure (psi) or equivalent feet of water, required for a pump to lift water to its point of storage overcoming elevation head, friction loss, line pressure, drawdown and pumping lift.

TOTAL SOLIDS: The sum of dissolved and suspended solids in a water or wastewater.

TOTAL SUSPENDED SOLIDS: The measure of particulate matter suspended in a sample of water or wastewater.

TOXIC: Capable of causing an adverse effect on biological tissue following physical contact or absorption.

TRANSIENT, NON-COMMUNITY WATER SYSTEM: TNCWS A water system which provides water in a place such as a gas station or campground where people do not remain for long periods of time. These systems do not have to test or treat their water for contaminants which pose long-term health risks because fewer than 25 people drink the water over a long period. They still must test their water for microbes and several chemicals. A Transient Non-community Water System: Is not required to sample for VOC's.

TRANSITION METAL: Elements that have incomplete d sub-shells, but also may be referred to as the d-block elements.

TRANSURANIC ELEMENT: Element with atomic number greater than 92; none of the transuranic elements are stable.

TREATABILITY STUDY: A study in which a waste is subjected to a treatment process to determine treatment and/or to determine the treatment efficiency or optimal process conditions for treatment.

TREATED WATER: Disinfected and/or filtered water served to water system customers. It must meet or surpass all drinking water standards to be considered safe to drink.

TRICHALOMETHANES (THM): Four separate compounds including chloroform, dichlorobromomethane, dibromochloromethane, and bromoform. The most common class of disinfection by-products created when chemical disinfectants react with organic matter in water during the disinfection process. See Disinfectant Byproducts.

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TRIPLE BOND: The sharing of three pairs of electrons within a covalent bond (example N₂).

TRIPLE POINT: The place where temperature and pressure of three phases are the same (Water has a special phase diagram).

TUBE SETTLERS: This modification of the conventional process contains many metal tubes that are placed in the sedimentation basin, or clarifier. These tubes are approximately 1 inch deep and 36 inches long, split-hexagonal shape and installed at an angle of 60 degrees or less. These tubes provide for a very large surface area upon which particles may settle as the water flows upward. The slope of the tubes facilitates gravity settling of the solids to the bottom of the basin, where they can be collected and removed. The large surface settling area also means that adequate clarification can be obtained with detention times of 15 minutes or less. As with conventional treatment, this sedimentation step is followed by filtration through mixed media.

TUBERCLES: The creation of this condition is of the most concern regarding corrosive water effects on a water system. Tubercles are formed due to joining dissimilar metals, causing electro-chemical reactions. Like iron to copper pipe. We have all seen these little rust mounds inside cast iron pipe.

TUNDALL EFFECT: The effect of light scattering by colloidal (mixture where one substance is dispersed evenly through another) or suspended particles.

TURBIDIMETER: Monitoring the filter effluent turbidity on a continuous basis with an in-line instrument is a recommended practice. Turbidimeter is best suited to perform this measurement.

TURBIDITY: A measure of the cloudiness of water caused by suspended particles. A qualitative measurement of water clarity which results from suspended matter that scatters or otherwise interferes with the passage of light through the water.

U

U.S. ENVIRONMENTAL PROTECTION AGENCY: In the United States, this agency responsible for setting drinking water standards and for ensuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce.

ULTRAFILTRATION: A low pressure membrane filtration process which separates solutes up to 0.1 micron size range.

UN NUMBER: A four digit code used to note hazardous and flammable substances.

UNCERTAINTY PRINCIPLE: Knowing the location of a particle makes the momentum uncertain, while knowing the momentum of a particle makes the location uncertain.

UNCERTAINTY: A characteristic that any measurement that involves estimation of any amount cannot be exactly reproducible.

UNDER PRESSURE IN STEEL CONTAINERS: After chlorine gas is manufactured, it is primarily transported in steel containers.

UNIT CELL: The smallest repeating unit of a lattice.

UNIT FACTOR: Statements used in converting between units.

UNIT FILTER RUN VOLUME (UFRV): One of the most popular ways to compare filter runs. This technique is the best way to compare water treatment filter runs.

UNIVERSAL OR IDEAL GAS CONSTANT: Proportionality constant in the ideal gas law ($0.08206 \text{ L}\cdot\text{atm}/(\text{K}\cdot\text{mol})$).

UP FLOW CLARIFIER: Clarifier where flocculated water flows upward through a sludge blanket to obtain floc removal by contact with flocculated solids in the blanket.

V

VALENCE BOND THEORY: A theory explaining the chemical bonding within molecules by discussing valencies, the number of chemical bonds formed by an atom.

VALENCE ELECTRON: The outermost electrons of an atom, which are located in electron shells.

VAN DER WAALS FORCE: One of the forces (attraction/repulsion) between molecules.

VAN'T HOFF FACTOR: Ratio of moles of particles in solution to moles of solute dissolved.

VAPOR PRESSURE: Pressure of vapor over a liquid at equilibrium.

VAPOR: The gaseous phase of a material that is in the solid or liquid state at standard temperature and pressure.

VAPOR: When a substance is below the critical temperature while in the gas phase.

VAPORIZATION: Phase change from liquid to gas.

VELOCITY HEAD: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

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VENTURI: If water flows through a pipeline at a high velocity, the pressure in the pipeline is reduced. Velocities can be increased to a point that a partial vacuum is created.

VIBRIO: Rod- or comma-shaped, gram-negative, aerobic; commonly with a single flagellum; include *Vibrio cholerae*, cause of cholera, and luminescent forms symbiotic with deep-water fishes and squids.

VIRION: A complete viral particle, consisting of RNA or DNA surrounded by a protein shell and constituting the infective form of a virus.

VIRUSES: Very small disease-causing microorganisms that are too small to be seen even with microscopes. Viruses cannot multiply or produce disease outside of a living cell.

VISCOSITY: The resistance of a liquid to flow (oil).

VITRIFICATION: Vitrification is a process of converting a material into a glass-like amorphous solid that is free from any crystalline structure, either by the quick removal or addition of heat, or by mixing with an additive. Solidification of a vitreous solid occurs at the glass transition temperature (which is lower than melting temperature, T_m , due to super cooling). When the starting material is solid, vitrification usually involves heating the substances to very high temperatures. Many ceramics are produced in such a manner. Vitrification may also occur naturally when lightning strikes sand, where the extreme and immediate heat can create hollow, branching rootlike structures of glass, called fulgurite. When applied to whiteware ceramics, vitreous means the material has an extremely low permeability to liquids, often but not always water, when determined by a specified test regime. The microstructure of whiteware ceramics frequently contain both amorphous and crystalline phases.

VOC WAIVER: The longest term VOC waiver that a public water system using groundwater could receive is 9 years.

VOID: An opening, gap, or space within rock or sedimentary formations formed at the time of origin or deposition.

VOLATILE ORGANIC COMPOUNDS (VOCs): Solvents used as degreasers or cleaning agents. Improper disposal of VOCs can lead to contamination of natural waters. VOCs tend to evaporate very easily. This characteristic gives VOCs very distinct chemical odors like gasoline, kerosene, lighter fluid, or dry cleaning fluid. Some VOCs are suspected cancer-causing agents. Volatile organic compounds (VOCs) are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. A wide range of carbon-based molecules, such as aldehydes, ketones, and other light hydrocarbons are VOCs. The term often is used in a legal or regulatory context and in such cases the precise definition is a matter of law. These definitions can be contradictory and may contain "loopholes"; e.g. exceptions, exemptions, and exclusions. The United States Environmental Protection Agency defines a VOC as any organic compound that participates in a photoreaction; others believe this definition is very broad and vague as organics that are not volatile in the sense that they vaporize under normal conditions can be considered volatile by this EPA definition. The term may refer both to well characterized organic compounds and to mixtures of variable composition.

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VOLATILE: A substance that evaporates or vaporizes at a relatively low temperature.

VOLT: One joule of work per coulomb - the unit of electrical potential transferred.

VOLTAGE: Voltage (sometimes also called electric or electrical tension) is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts.[1] It measures the potential energy of an electric field to cause an electric current in an electrical conductor. Depending on the difference of electrical potential it is called extra low voltage, low voltage, high voltage or extra high voltage. Specifically Voltage is equal to energy per unit charge.

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VOLTIMETER: Instrument that measures the cell potential.

VOLUMETRIC ANALYSIS: See titration.

VOLUTE: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharge by the impeller.

VORTEX: The helical swirling of water moving towards a pump.

VORTICELLA: Vorticella is a genus of protozoa, with over 100 known species. They are stalked inverted bell-shaped ciliates, placed among the peritrichs. Each cell has a separate stalk anchored onto the substrate, which contains a contractile fibril called a myoneme. When stimulated this shortens, causing the stalk to coil like a spring. Reproduction is by budding, where the cell undergoes longitudinal fission and only one daughter keeps the stalk. Vorticella mainly lives in freshwater ponds and streams - generally anywhere protists are plentiful. Other genera such as Carchesium resemble Vorticella but are branched or colonial.

VULNERABILITY ASSESSMENT: An evaluation of drinking water source quality and its vulnerability to contamination by pathogens and toxic chemicals.

W

WAIVERS: Monitoring waivers for nitrate and nitrite are prohibited.

WASTE ACTIVATED SLUDGE: Excess activated sludge that is discharged from an activated sludge treatment process.

WASTEWATER: Liquid or waterborne wastes polluted or fouled from households, commercial or industrial operations, along with any surface water, storm water or groundwater infiltration.

WATER H₂O: A chemical substance, a major part of cells and Earth, and covalently bonded.

WATER HAMMER: A surge in a pipeline resulting from the rapid increase or decrease in water flow. Water hammer exerts tremendous force on a system and can be highly destructive.

WATER PURVEYOR: The individuals or organization responsible to help provide, supply, and furnish quality water to a community.

WATER QUALITY CRITERIA: Comprised of both numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

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WATER QUALITY STANDARD: A statute or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

WATER QUALITY: The 4 broad categories of water quality are: Physical, chemical, biological, radiological. Pathogens are disease causing organisms such as bacteria and viruses. A positive bacteriological sample indicates the presence of bacteriological contamination. Source water monitoring for lead and copper be performed when a public water system exceeds an action level for lead or copper.

WATER RECLAMATION: The restoration of wastewater to a state that will allow its beneficial reuse.

WATER VAPOR: A characteristic that is unique to water vapor in the atmosphere is that water does not contain any salts.

WATERBORNE DISEASE: A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).

WATERSHED: An area that drains all of its water to a particular water course or body of water. The land area from which water drains into a stream, river, or reservoir.

WAVE FUNCTION: A function describing the electron's position in a three-dimensional space.

Weathered: The existence of rock or formation in a chemically or physically broken down or decomposed state. Weathered material is in an unstable state.

WHOLE EFFLUENT TOXICITY: The total toxic effect of an effluent measured directly with a toxicity test.

WORK: The amount of force over distance and is in terms of joules (energy).

WPCF: Water Pollution Control Facility

WTP: Water Treatment Plant

WWTP: Wastewater Treatment Plant

X

X-RAY DIFFRACTION: A method for establishing structures of crystalline solids using single wavelength X-rays and looking at diffraction pattern.

X-RAY PHOTOELECTRON SPECTROSCOPY: A spectroscopic technique to measure composition of a material.

X-RAY: Form of ionizing, electromagnetic radiation, between gamma and UV rays.

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