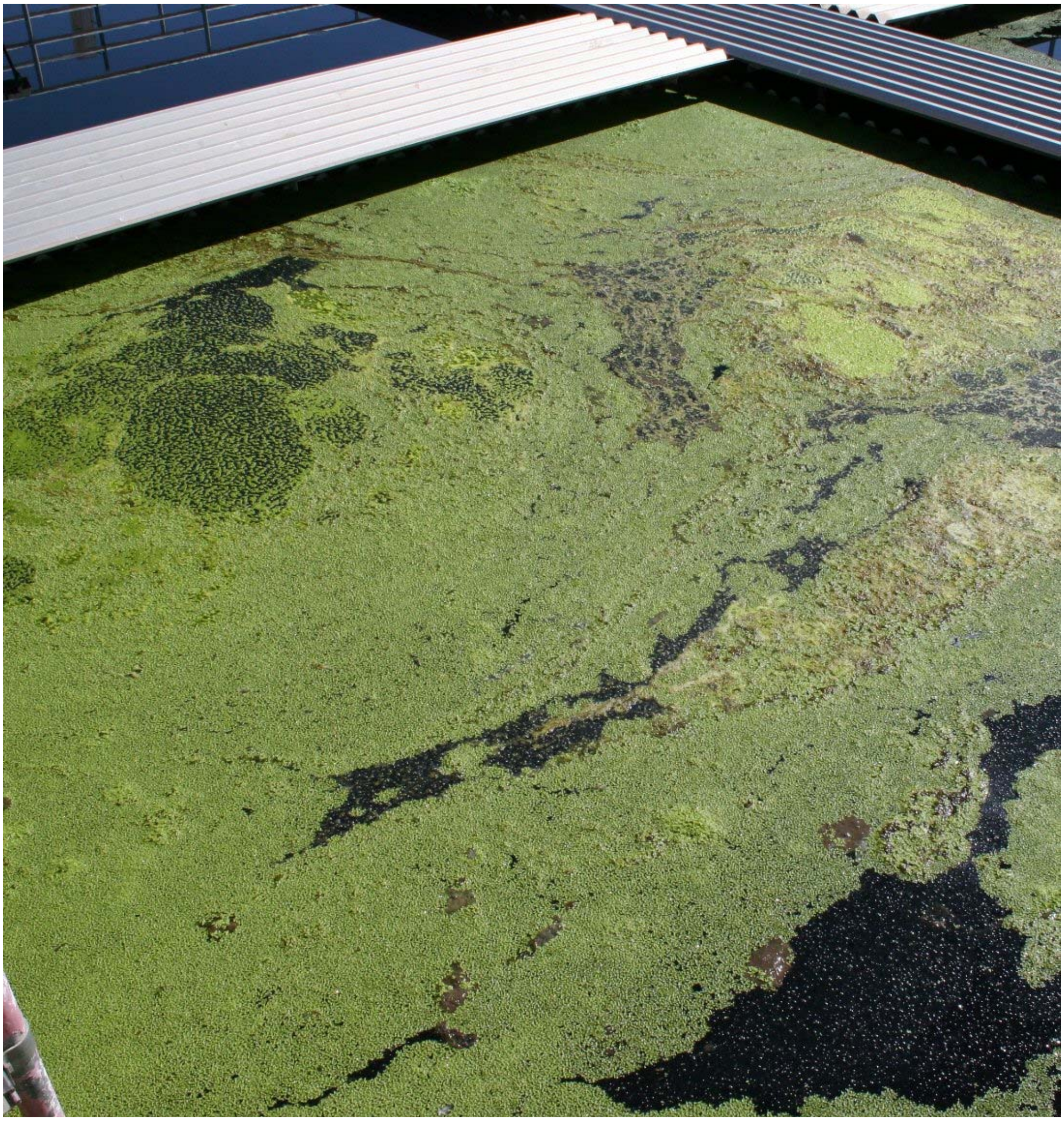
WASTEWATER TREATMENT CERTIFICATION REVIEW



Technical Learning College

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TLC
P.O. Box 3060
Chino Valley, AZ 86323

Course Description

Wastewater Treatment Certification Review CEU Training Course
Review of wastewater 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 Clean Water Act and conventional wastewater treatment principles. This study guide will present basic and complex math principles and formulas for wastewater 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 wastewater treatment principles and properly calculate complex mathematical formulas for: pounds per day, volume, flow and related wastewater treatment formulas.

Proper calculation of concentration is contingent upon accurate determination of volume of wastewater 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 Wastewater 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 receipt of this 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 Wastewater 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 wastewater treatment operators in the safe and effective maintenance and operation of conventional wastewater treatment procedures, sampling techniques and related daily operations in order to pass and understand operator certification requirements*.

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This course contains general EPA's CWA federal rule requirements. Please be aware that each state implements wastewater/safety/environment regulations that may be more stringent than EPA's regulations. Check with your state environmental agency for more information.

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

Common Wastewater Acronyms and Terms

A/E Contract - Architectural and Engineering Contracts

AMSA - Association of Metropolitan Sewerage Agencies

BOD - Biochemical Oxygen Demand

COD - Chemical Oxygen Demand

CSO - Combined Sewer Overflow

D&D - Drying and Dewatering Facility

DNR - Department of Natural Resources

EPA or USEPA - United States Environmental Protection Agency

GIS - Geographic Information System

HHWP - Household Hazardous Waste Collection Program

I/I - Infiltration and Inflow

I&C - Instrumentation and Control System

IWPP - Industrial Waste Pretreatment Program

ISS - Inline Storage System

LIMS - Laboratory Information Management Systems

MBDT - Minority Business Development and Training

MBE - Minority Business Enterprise

MGD - Million gallons per day

P2 - Pollution Prevention Initiative

QA/QC - Quality Assurance and Quality Control

Confined Space

S/W/MBE - Small, Women's, Minority Business Enterprise

SSES - Sewer System Evaluation Survey

TAT - Technical Advisory Team

WAS - Waste Activated Sludge

WPAP - Water Pollution Abatement Program

WWTP - Wastewater Treatment Plants

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 $25 processing fee.

All downloads are electronically tracked and monitored for security purposes.

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.

This course contains EPA's federal rule requirements. Please be aware that each state implements drinking water/wastewater/safety regulations may be more stringent than EPA's or OSHA's regulations. Check with your state environmental agency for more information.

Key Wastewater Words *Memorize these terms.*

Amine A functional group consisting of "$-NH_2$."

Amino acid A functional group that consists of a carbon with a carboxylic acid, "-COOH" and an amine, "$-NH_2$." These compounds are the building blocks for proteins.

Anabolism Biosynthesis, the production of new cellular materials from other organic or inorganic chemicals.

Anaerobes A group of organisms that do not require *molecular* oxygen. These organisms, as well as all known life forms, require oxygen. These organisms obtain their oxygen from inorganic ions such as nitrate or sulfate or from protein.

Anaerobic process A process that only occurs in the absence of molecular oxygen.

Anoxic process A process that occurs only at very low levels of molecular oxygen or in the absence of molecular oxygen.

Biochemical oxygen demand (BOD) The amount of oxygen required to oxidize any organic matter present in water during a specified period of time, usually 5 days. It is an indirect measure of the amount of organic matter present in water.

Carbonaceous biochemical oxygen demand (CBOD) The amount of oxygen required to oxidize any carbon containing matter present in water.

Chemical oxygen demand (COD) The amount of oxygen required to oxidize any organic matter in the water using harsh chemical conditions.

Decomposers Organisms that utilize energy from wastes or dead organisms. Decomposers complete the cycle by returning nutrients to the soil or water and carbon dioxide to the air or water.

Denitrification The anoxic biological conversion of nitrate to nitrogen gas. It occurs naturally in surface waters low in oxygen, and it can be engineered in wastewater treatment systems.

Deoxygenation The consumption of oxygen by the different aquatic organisms as they oxidized materials in the aquatic environment.

Endogenous Respiration $CsH_7N0_2 + 50_2$ + microbe.~ $-5CO_2 + 2H_20$ + NHJ + energy (new cells) + (oxygen) + (bacteria) ~ (carbon dioxide) + (Water) + (ammonia) + (energy) It should be noted that nitrification (i.e. conversion of ammonia to nitrites and then to nitrates), tends to occur in the extended aeration process. While nitrification may be a desirable occurrence, it also causes depletion in alkalinity. The loss of alkalinity lowers the pH in the reactor which may reduce the efficiency and effectiveness of BOD removal. Nitrification may be suppressed by increasing sludge wastage rates in order to reduce aeration time and sludge retention time.

Facultative A group of microorganisms which prefer or preferentially use molecular oxygen when available, but are capable of using other pathways for energy and synthesis if molecular oxygen is not available.

F/M Ratio Another method for control is wasting to maintain a constant food-to-microorganism (F:M or F/M) ratio. With this method, the operator will try to increase or decrease the MLVSS to match an increase or decrease in the BOD entering the plant. Most plants will operate best at a specific F/M ratio between 0.05 - 0.1. If the optimum F/M has been determined from experience and can be maintained, a good effluent may be produced with consistent plant operation. The F/M ratio is to be calculated at least weekly and related to the efficiency of treatment plant operation. An F/M ratio between 0.05 - 0.15 BOD/lb MLSS is usually considered acceptable for an extended aeration process.

Nitrification The biological oxidation of ammonia and ammonium sequentially to nitrite and then nitrate. It occurs naturally in surface waters, and can be engineered in wastewater treatment systems. The purpose of nitrification in wastewater treatment systems is a reduction in the oxygen demand resulting from the ammonia.

Nitrogen fixation The conversion of atmospheric (or dissolved) nitrogen gas into nitrate by microorganisms.

Nitrogenous oxygen demand (NOD) The amount of oxygen required to oxidize any ammonia present in water.

NPDES The National Pollutant Discharge Elimination System. The discharge criteria and permitting system established by the U.S. EPA as a result of the Clean Water Act and its subsequent amendments or the permit required by each discharger as a result of the Clean Water Act.

MCRT Mean Cell Residence Time The average time that a given unit of cell mass stays in the activated sludge biological reactor. It is typically calculated as the total mixed liquor suspended solids in the biological reactor divided by the combination of solids in the effluent and solids wasted.

Mixed liquor suspended solids (MLSS) The total suspended solids concentration in the activated sludge tank.

Mixed liquor volatile suspended solids (MLVSS) The volatile suspended solids concentration in the activated sludge tank.

Organic compound Any compound containing carbon except for the carbonates (carbon dioxide, the carbonates and bicarbonates), the cyanides, and cyanates.

Organic nitrogen - Nitrogen contained as amines in organic compounds such as amino acids and proteins.

Oxidative phosphorylation The synthesis of the energy storage compound adenosine triphosphate (ATP) from adenosine diphosphate (ADP) using a chemical substrate and molecular oxygen.

Secondary treatment In wastewater treatment, the conversion of the suspended, colloidal and dissolved organics remaining after primary treatment into a microbial mass with is then removed in a second sedimentation process. Secondary treatment includes **both** the biological process and the associated sedimentation process.

Sludge A mixture of solid waste material and water. Sludges result from the concentration of contaminants in water and wastewater treatment processes. Typical wastewater sludges contain from 0.5 to 10 percent solid matter. Typical water treatment sludges contain 8 to 10 percent solids.

Thiols Organic compounds which contain the "-SH" functional group. Also called mercaptans.

Total dissolved solids (TDS) is the amount of dissolved matter in the water.

Total solids (TS) is the amount of organic and inorganic matter that is contained in water.

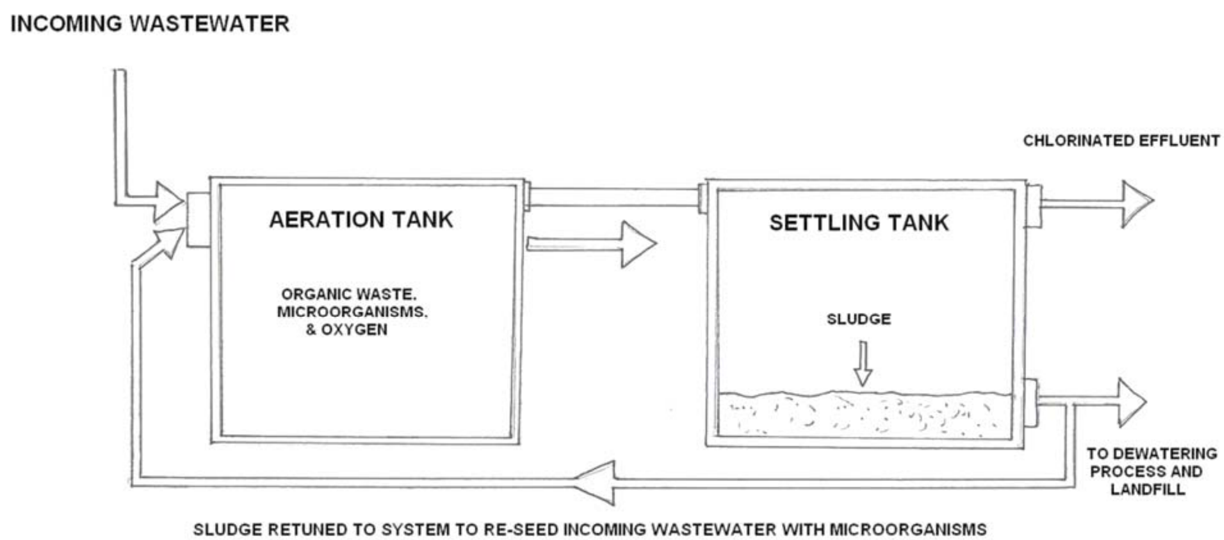
Total suspended solids (TSS) is the amount of suspended (filterable) matter in water.

Ultimate biochemical oxygen demand (BOD_u) The total amount of oxygen required to oxidize any organic matter present in a water, i.e. after an extended period, such as 20 or 30 days.

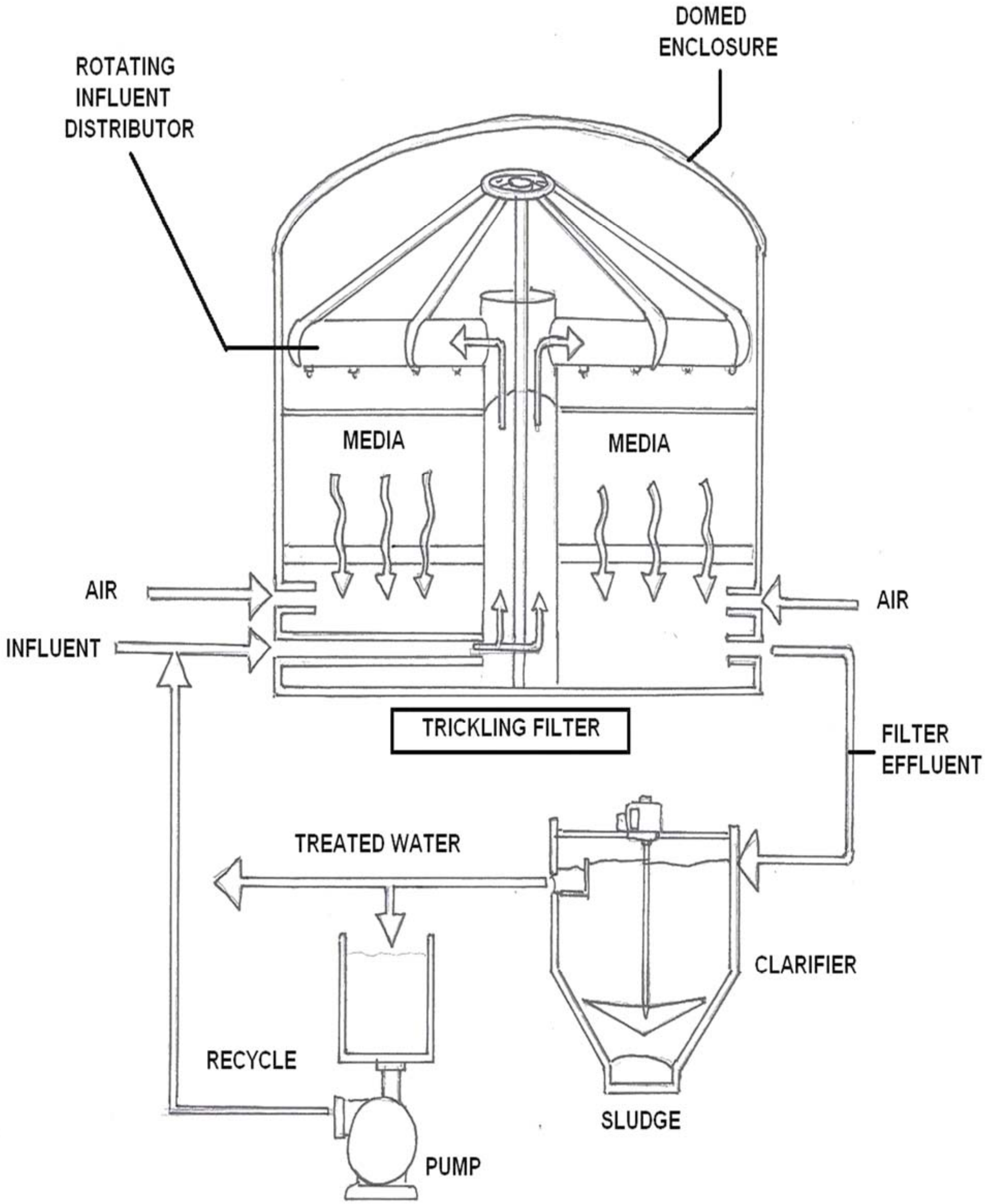
Virus A submicroscopic genetic constituent that can alternate between two distinct phases. As a virus particle, or virion, it is DNA or RNA enveloped in an organic capsule. As an intracellular virus, it is viral DNA or RNA inserted into the host organism's DNA or RNA.

Volatile A material that will vaporize easily.

Volatile solids (VS) is the amount of matter which volatilizes (or burns) when a water sample is heated to 550EC.



ACTIVATED SLUDGE WASTEWATER TREATMENT PROCESS


DOMED ENCLOSURE
ROTATING INFLUENT DISTRIBUTOR
MEDIA
MEDIA
AIR
AIR
INFLUENT
TRICKLING FILTER
FILTER EFFLUENT
TREATED WATER
CLARIFIER
RECYCLE
SLUDGE
PUMP

Utility Counter-Terrorism Chapter 1

Defending against and responding to Catastrophic Threats*.* The expertise, technology, and material needed to build the deadliest 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 vulnerabilit**y**. 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.

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*"?

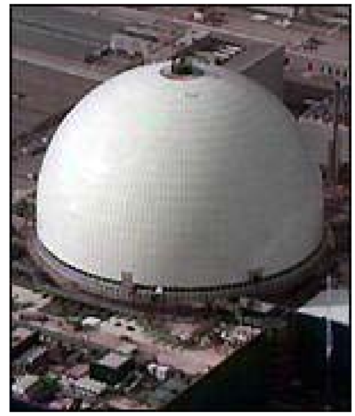
Ever thought about the access Trash Collection or Delivery Vehicles have and the potential for Terrorist to use these trucks for a bomb or to sneak into your facility?

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 infra-structure 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 and 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

Wastewater Treatment Chapter 2

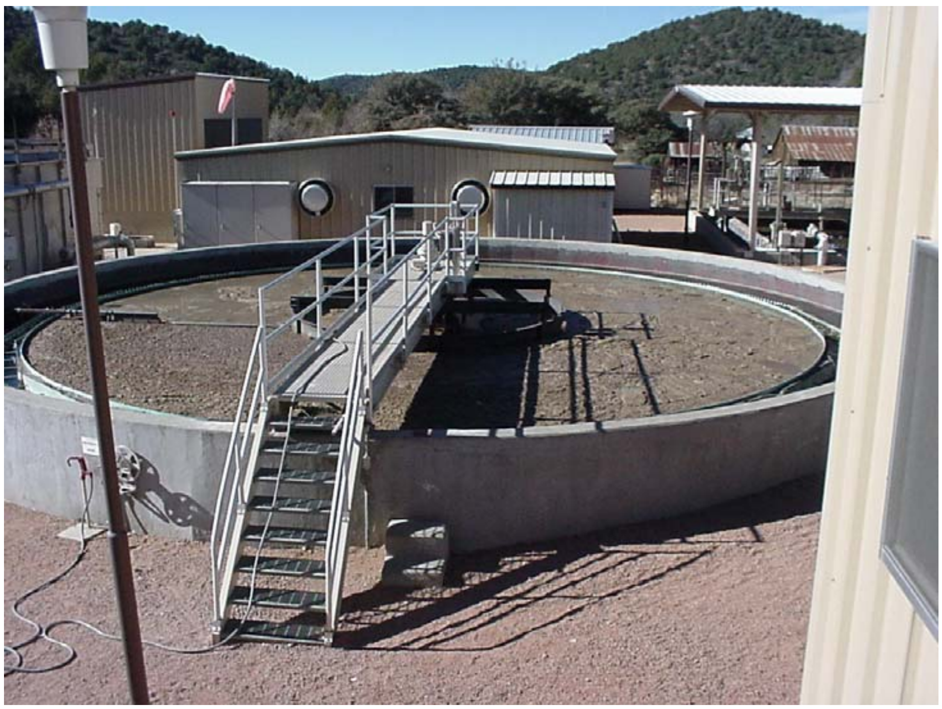
One of the most common forms of pollution control in the United States is *wastewater treatment.* The country has a vast system of collection sewers, pumping stations, and treatment plants. Sewers collect the wastewater from homes, businesses, and many industries, and deliver it to plants for treatment. Most treatment plants were built to clean wastewater for discharge into streams or other receiving waters, or for reuse.

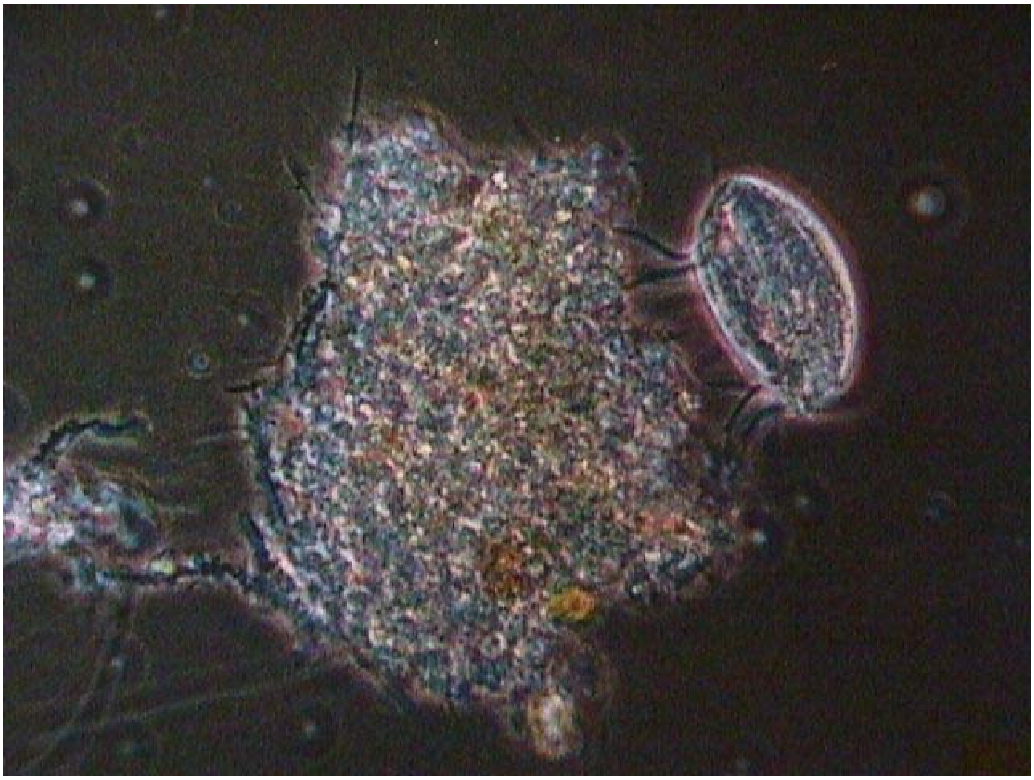
Years ago, when sewage was dumped into waterways, a natural process of purification began. First, the sheer volume of clean water in the stream diluted wastes. Bacteria and other small organisms in the water consumed the sewage and other organic matter, turning it into new bacterial cells; carbon dioxide and other products.

Today's higher populations and greater volume of domestic and industrial wastewater require that communities give nature a helping hand. The basic function of wastewater treatment is to speed up the natural processes by which water is purified.

There are two basic stages in the treatment of wastes, *primary* and *secondary,* both of which are outlined here.

In the primary stage, solids are allowed to settle and removed from wastewater. The secondary stage uses biological processes to further purify wastewater. Sometimes, these stages are combined into one operation.





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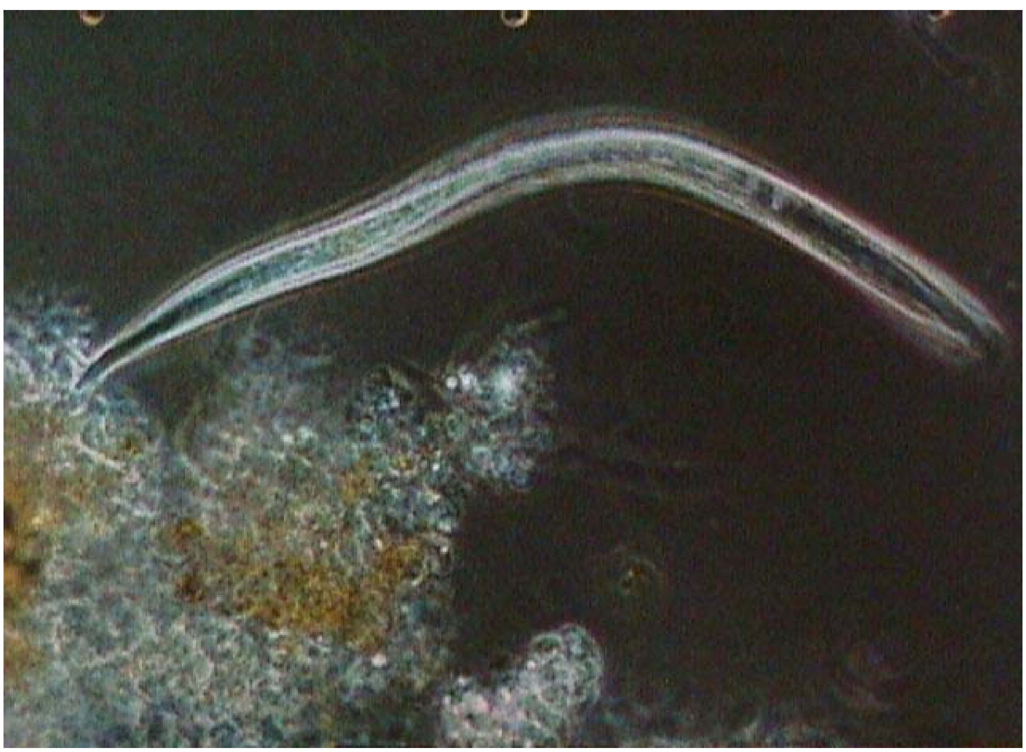
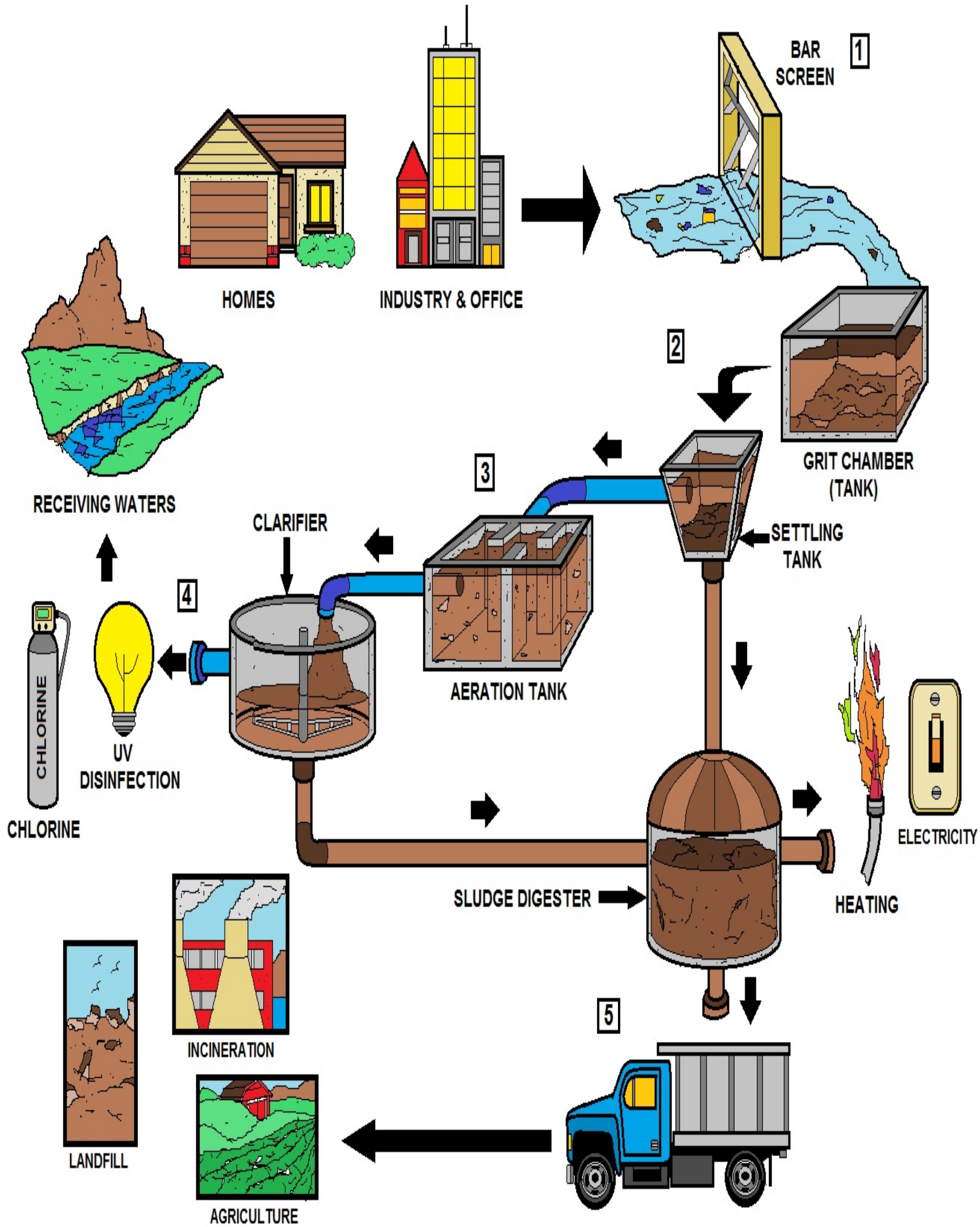
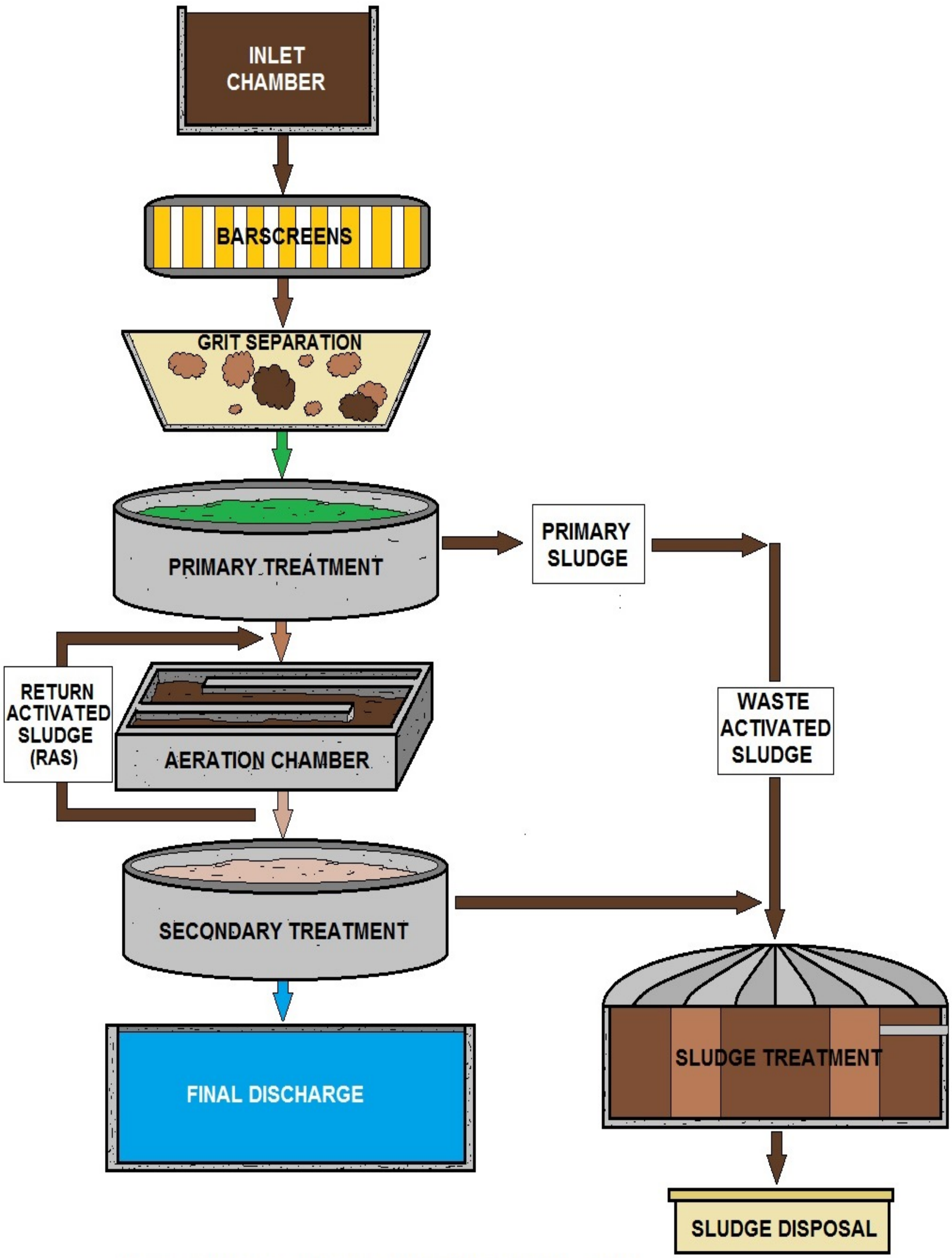


Nematode



WASTEWATER TREATMENT PROCESS



WASTEWATER TREATMENT PLANT (SLUDGE REMOVAL BASICS)

What is in Wastewater?

Wastewater is mostly water by weight. Other materials make up only a small portion of wastewater, but can be present in large enough quantities to endanger public health and the environment. Because practically anything that can be flushed down a toilet, drain, or sewer can be found in wastewater, even household sewage contains many potential pollutants. The wastewater components that should be of most concern to homeowners and communities are those that have the potential to cause disease or detrimental environmental effects.

Organisms
Many different types of organisms live in wastewater and some are essential contributors to treatment. A variety of bacteria, protozoa, and worms work to break down certain carbon-based (organic) pollutants in wastewater by consuming them. Through this process, organisms turn wastes into carbon dioxide, water, or new cell growth.

Bacteria and other microorganisms are particularly plentiful in wastewater and accomplish most of the treatment. Most wastewater treatment systems are designed to rely in large part on biological processes.

Pathogens
Many disease-causing viruses, parasites, and bacteria also are present in wastewater and enter from almost anywhere in the community. These pathogens often originate from people and animals that are infected with or are carriers of a disease. Graywater and blackwater from typical homes contain enough pathogens to pose a risk to public health. Other likely sources in communities include hospitals, schools, farms, and food processing plants.

Some illnesses from wastewater-related sources are relatively common. Gastroenteritis can result from a variety of pathogens in wastewater, and cases of illnesses caused by the parasitic protozoa Giardia lambia and Cryptosporidium are not unusual in the U.S. Other important wastewater-related diseases include hepatitis A, typhoid, polio, cholera, and dysentery. Outbreaks of these diseases can occur as a result of drinking water from wells polluted by wastewater, eating contaminated fish, or recreational activities in polluted waters. Some illnesses can be spread by animals and insects that come in contact with wastewater.

Even municipal drinking water sources are not completely immune to health risks from wastewater pathogens. Drinking water treatment efforts can become overwhelmed when water resources are heavily polluted by wastewater. For this reason, wastewater treatment is as important to public health as drinking water treatment.

Organic Matter
Organic materials are found everywhere in the environment. They are composed of the carbon-based chemicals that are the building blocks of most living things. Organic materials in wastewater originate from plants, animals, or synthetic organic compounds, and enter wastewater in human wastes, paper products, detergents, cosmetics, foods, and from agricultural, commercial, and industrial sources.

Organic compounds normally are some combination of carbon, hydrogen, oxygen, nitrogen, and other elements. Many organics are proteins, carbohydrates, or fats and are biodegradable, which means they can be consumed and broken down by organisms. However, even biodegradable materials can cause pollution. In fact, too much organic matter in wastewater can be devastating to receiving waters.

Large amounts of biodegradable materials are dangerous to lakes, streams, and oceans, because organisms use dissolved oxygen in the water to break down the wastes. This can reduce or deplete the supply of oxygen in the water needed by aquatic life, resulting in fish kills, odors, and overall degradation of water quality. The amount of oxygen organisms need to break down wastes in wastewater is referred to as the biochemical oxygen demand (BOD) and is one of the measurements used to assess overall wastewater strength.

Some organic compounds are more stable than others and cannot be quickly broken down by organisms, posing an additional challenge for treatment. This is true of many synthetic organic compounds developed for agriculture and industry.

In addition, certain synthetic organics are highly toxic. Pesticides and herbicides are toxic to humans, fish, and aquatic plants and often are disposed of improperly in drains or carried in stormwater. In receiving waters, they kill or contaminate fish, making them unfit to eat. They also can damage processes in treatment plants. Benzene and toluene are two toxic organic compounds found in some solvents, pesticides, and other products. New synthetic organic compounds are being developed all the time, which can complicate treatment efforts.

Oil and Grease

Fatty organic materials from animals, vegetables, and petroleum also are not quickly broken down by bacteria and can cause pollution in receiving environments. When large amounts of oils and greases are discharged to receiving waters from community systems, they increase BOD and they may float to the surface and harden, causing aesthetically unpleasing conditions. They also can trap trash, plants, and other materials, causing foul odors, attracting flies and mosquitoes and other disease vectors. In some cases, too much oil and grease causes septic conditions in ponds and lakes by preventing oxygen from the atmosphere from reaching the water.

Onsite systems also can be harmed by too much oil and grease, which can clog onsite system drain field pipes and soils, adding to the risk of system failure. Excessive grease also adds to the septic tank scum layer, causing more frequent tank pumping to be required. Both possibilities can result in significant costs to homeowners.

Petroleum-based waste oils used for motors and industry are considered hazardous waste and should be collected and disposed of separately from wastewater.

Inorganics

Inorganic minerals, metals, and compounds, such as sodium, potassium, calcium, magnesium, cadmium, copper, lead, nickel, and zinc are common in wastewater from both residential and nonresidential sources. They can originate from a variety of sources in the community including industrial and commercial sources, stormwater, and inflow and infiltration from cracked pipes and leaky manhole covers. Most inorganic substances are relatively stable, and cannot be broken down easily by organisms in wastewater.

Large amounts of many inorganic substances can contaminate soil and water. Some are toxic to animals and humans and may accumulate in the environment. For this reason, extra treatment steps are often required to remove inorganic materials from industrial wastewater sources.

For example, heavy metals which are discharged with many types of industrial wastewaters, are difficult to remove by conventional treatment methods. Although acute poisonings from heavy metals in drinking water are rare in the U.S., potential long-term health effects of ingesting small amounts of some inorganic substances over an extended period of time are possible.

Nutrients
Wastewater often contains large amounts of the nutrients nitrogen and phosphorus in the form of nitrate and phosphate, which promote plant growth. Organisms only require small amounts of nutrients in biological treatment, so there normally is an excess available in treated wastewater. In severe cases, excessive nutrients in receiving waters cause algae and other plants to grow quickly depleting oxygen in the water. Deprived of oxygen, fish and other aquatic life die, emitting foul odors.

Nutrients from wastewater have also been linked to ocean "red tides" that poison fish and cause illness in humans. Nitrogen in drinking water may contribute to miscarriages and is the cause of a serious illness in infants called methemoglobinemia or "blue baby syndrome."

Solids ***Know this for your exam***
Solid materials in wastewater can consist of organic and/or inorganic materials and organisms. The solids must be significantly reduced by treatment or they can increase BOD when discharged to receiving waters and provide places for microorganisms to escape disinfection. They also can clog soil absorption fields in onsite systems.
* Settleable solids -Certain substances, such as sand, grit, and heavier organic and inorganic materials settle out from the rest of the wastewater stream during the preliminary stages of treatment. On the bottom of settling tanks and ponds, organic material makes up a biologically active layer of sludge that aids in treatment.
* Suspended solids -Materials that resist settling may remain suspended in wastewater. Suspended solids in wastewater must be treated, or they will clog soil absorption systems or reduce the effectiveness of disinfection systems.
* Dissolved solids -Small particles of certain wastewater materials can dissolve like salt in water. Some dissolved materials are consumed by microorganisms in wastewater, but others, such as heavy metals, are difficult to remove by conventional treatment. Excessive amounts of dissolved solids in wastewater can have adverse effects on the environment.

Gases
Certain gases in wastewater can cause odors, affect treatment, or are potentially dangerous. Methane gas, for example, is a byproduct of anaerobic biological treatment and is highly combustible. Special precautions need to be taken near septic tanks, manholes, treatment plants, and other areas where wastewater gases can collect.

The gases hydrogen sulfide and ammonia can be toxic and pose asphyxiation hazards. Ammonia as a dissolved gas in wastewater also is dangerous to fish. Both gases emit odors, which can be a serious nuisance. Unless effectively contained or minimized by design and location, wastewater odors can affect the mental well-being and quality of life of residents. In some cases, odors can even lower property values and affect the local economy.

Dispose of Household Hazardous Wastes Safely
Many household products are potentially hazardous to people and the environment and never should be flushed down drains, toilets, or storm sewers. Treatment plant workers can be injured and wastewater systems can be damaged as a result of improper disposal of hazardous materials.

Other hazardous chemicals cannot be treated effectively by municipal wastewater systems and may reach local drinking water sources. When flushed into septic systems and other onsite systems, they can temporarily disrupt the biological processes in the tank and soil absorption field, allowing hazardous chemicals and untreated wastewater to reach groundwater.

Some examples of hazardous household materials include motor oil, transmission fluid, antifreeze, paint, paint thinner, varnish, polish, wax, solvents, pesticides, rat poison, oven cleaner, and battery fluid. Many of these materials can be recycled or safely disposed of at community recycling centers.

Other Important Wastewater Characteristics
In addition to the many substances found in wastewater, there are other characteristics system designers and operators use to evaluate wastewater. For example, the color, odor, and turbidity of wastewater give clues about the amount and type of pollutants present and treatment necessary. The following are some other important wastewater characteristics that can affect public health and the environment, as well as the design, cost, and effectiveness of treatment.

Temperature
The best temperatures for wastewater treatment probably range from 77 to 95 degrees Fahrenheit. In general, biological treatment activity accelerates in warm temperatures and slows in cool temperatures, but extreme hot or cold can stop treatment processes altogether. Therefore, some systems are less effective during cold weather and some may not be appropriate for very cold climates.

Wastewater temperature also affects receiving waters. Hot water, for example, which is a byproduct of many manufacturing processes, can be a pollutant. When discharged in large quantities, it can raise the temperature of receiving streams locally and disrupt the natural balance of aquatic life.

pH
The acidity or alkalinity of wastewater affects both treatment and the environment. Low pH indicates increasing acidity, while a high pH indicates increasing alkalinity (a pH of 7 is neutral). The pH of wastewater needs to remain between 6 and 9 to protect organisms. Acids and other substances that alter pH can inactivate treatment processes when they enter wastewater from industrial or commercial sources.

Flow
Whether a system serves a single home or an entire community, it must be able to handle fluctuations in the quantity and quality of wastewater it receives to ensure proper treatment is provided at all times. Systems that are inadequately designed or hydraulically overloaded may fail to provide treatment and allow the release of pollutants to the environment.

To design systems that are both as safe and as cost-effective as possible, engineers must estimate the average and maximum (peak) amount of flows generated by various sources.

Because extreme fluctuations in flow can occur during different times of the day and on different days of the week, estimates are based on observations of the minimum and maximum amounts of water used on an hourly, daily, weekly, and seasonal basis. The possibility of instantaneous peak flow events that result from several or all water-using appliances or fixtures being used at once also is taken into account.

The number, type, and efficiency of all water-using fixtures and appliances at the source is factored into the estimate (for example, the number and amount of water normally used by faucets, toilets, and washing machines), as is the number of possible users or units that can affect the amount of water used (for example, the number of residents, bedrooms, customers, students, patients, seats, or meals served).

According to studies, water use in many homes is lowest from about midnight to 5 a.m., averaging less than one gallon per person per hour, but then rises sharply in the morning around 6 am. to a little over 3 gallons per person per hour.

During the day, water use drops off moderately and rises again in the early evening hours. Weekly peak flows may occur in some homes on weekends, especially when all adults work during the week. In U.S. homes, average water use is approximately 45 gallons per person per day, but may range from 35 to 60 gallons or more.

Peak flows at stores and other businesses typically occur during business hours and during meal times at restaurants. Rental properties, resorts, and commercial establishments in tourist areas may have extreme flow variations seasonally.

Estimating flow volumes for centralized treatment systems is a complicated task, especially when designing a new treatment plant in a community where one has never existed previously.

Engineers must allow for additional flows during wet weather due to inflow and infiltration of extra water into sewers. Excess water can enter sewers through leaky manhole covers and cracked pipes and pipe joints, diluting wastewater, which affects its overall characteristics. This can increase flows to treatment plants sometimes by as much as three or four times the original design load.

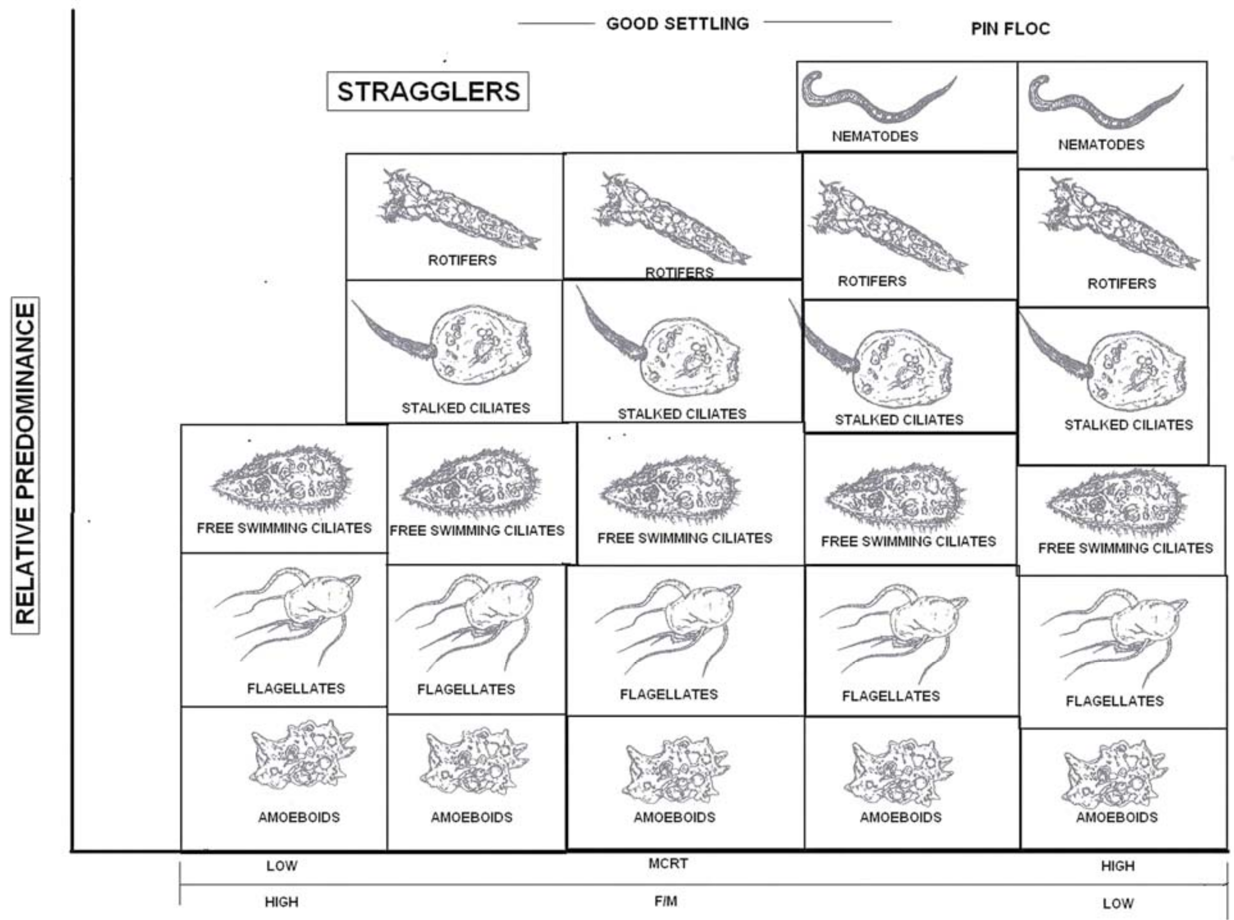
The main focus of wastewater treatment plants is to reduce the BOD and COD in the effluent discharged to natural waters, meeting state and federal discharge criteria. Wastewater treatment plants are designed to function as "microbiology farms," where bacteria and other microorganisms are fed oxygen and organic waste.

Treatment of wastewater usually involves biological processes such as the activated sludge system in the secondary stage after preliminary screening to remove coarse particles and primary sedimentation that settles out suspended solids.

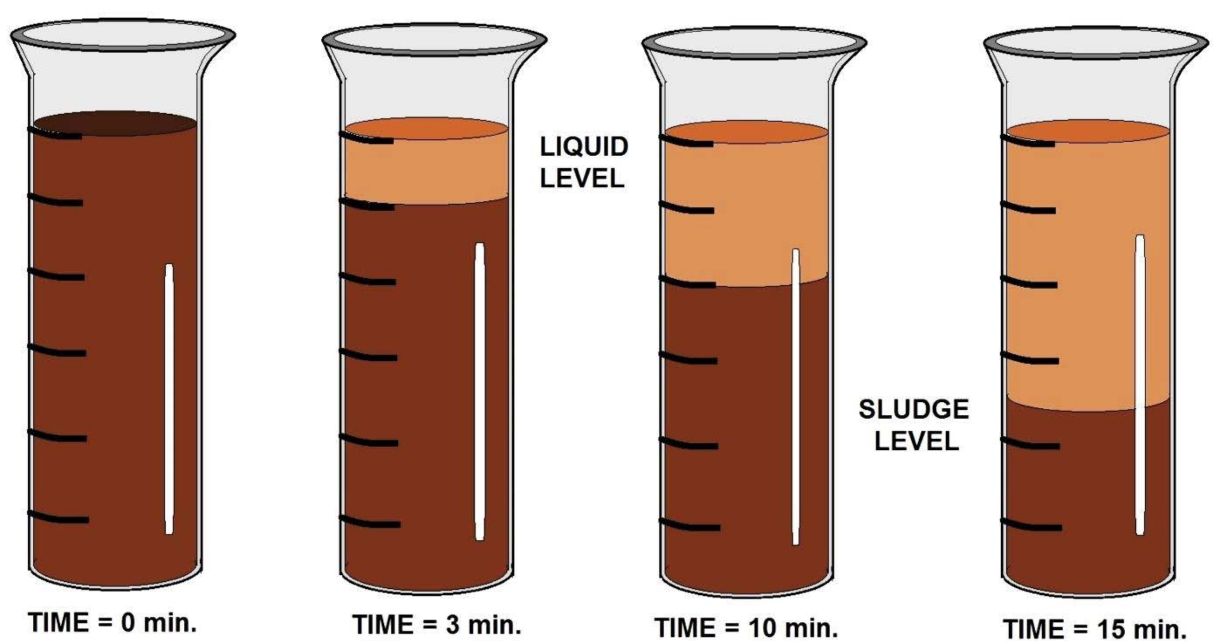
These secondary treatment steps are generally considered environmental biotechnologies that harness natural self-purification processes contained in bioreactors for the biodegradation of organic matter and bioconversion of soluble nutrients in the wastewater.

Application Specific Microbiology
Each wastewater stream is unique, and so too are the community of microorganisms that process it. This "application-specific microbiology" is the preferred methodology in wastewater treatment affecting the efficiency of biological nutrient removal.

The right laboratory-prepared bugs are more efficient in organics removal-if they have the right growth environment. This efficiency is multiplied if microorganisms are allowed to grow as a layer-a biofilm-on specifically designed support media. In this way, optimized biological processing of a waste stream can occur. To reduce the startup phase for growing a mature biofilm one can also purchase "application specific bacterial cultures" from appropriate microbiology vendors.



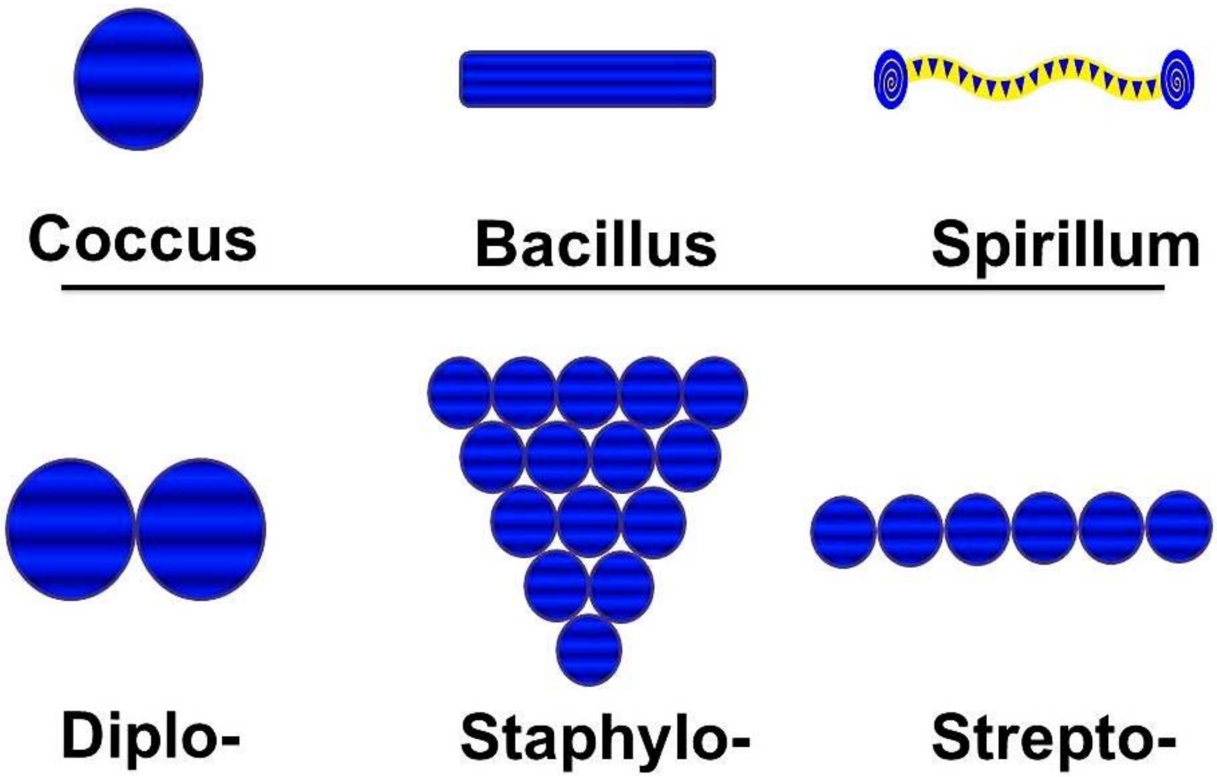
WASTEWATER TREATMENT MICROLIFE

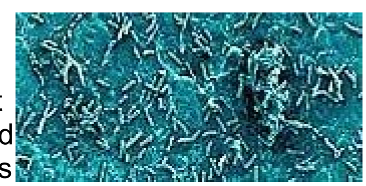


Bacteria

Bacteria come in a variety of shapes. The simplest shape is a round sphere or ball. Bacteria formed like this are called cocci (singular coccus). The next simplest shape is cylindrical. Cylindrical bacteria are called rods (singular rod). Some bacteria are basically rods but instead of being straight they are twisted or bent or curved, sometimes in a spiral - these bacteria are called spirilla (singular spirillum). Spirochaetes are tightly coiled up bacteria.

Tasty for sure! If you haven't gotten to accidentally taste these bugs, guess what? You will one day soon. All of us get the chance to have a taste, one way or another.



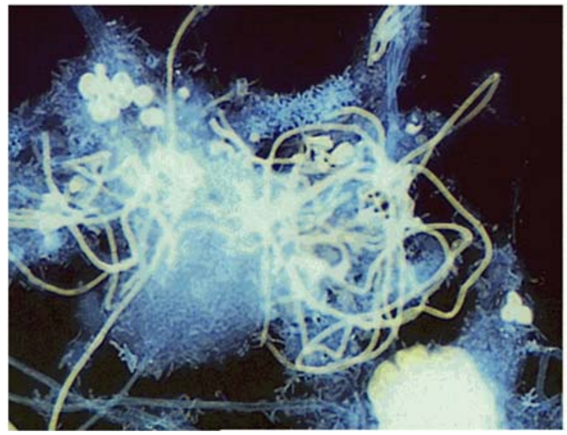


Bacteria are friendly creatures; you never find one bacteria on its own. They tend to live together in clumps, chains or planes. When they live in chains, one after the other, they are called filamentous bacteria - these often have long thin cells. When they tend to collect in a plane or a thin layer over the surface of an object they are called a biofilm. Many bacteria exist as a biofilm and the study of biofilms is very important. Biofilm bacteria secrete sticky substances that form a sort of gel in which they live. The plaque on your teeth that causes tooth decay is a biofilm.

Filamentous Bacteria
Filamentous Bacteria are a type of bacteria that can be found in a wastewater treatment system. They function similar to floc forming bacteria in that they degrade BOD quite well. In small amounts, they are quite good to a biomass. They can add stability and a backbone to the floc structure that keeps the floc from breaking up or shearing due to turbulence from pumps, aeration or transfer of the water.

In large amounts they can cause many problems. Filaments are bacteria and fungi that grow in long thread-like strands or colonies.

Site Specific Bacteria
Aeration and biofilm building are the key operational parameters that contribute to the efficient degradation of organic matter (BOD/COD removal). Over time, the application specific bacteria become site specific as the biofilm develops and matures and is even more efficient in treating that site-specific waste stream.



Facultative Bacteria
Most of the bacteria that absorb the organic material in a wastewater treatment system are facultative in nature. This means they are adaptable to survive and multiply in either anaerobic or aerobic conditions. The nature of individual bacteria is dependent upon the environment in which they live. Usually, facultative bacteria will be anaerobic unless there is some type of mechanical or biochemical process used to add oxygen to the wastewater. When bacteria are in the process of being transferred from one environment to the other, the metamorphosis from anaerobic to aerobic state (and vice versa) takes place within a couple of hours.

Anaerobic Bacteria
Anaerobic bacteria live and reproduce in the absence of free oxygen. They utilize compounds such as sulfates and nitrates for energy and their metabolism is substantially reduced. In order to remove a given amount of organic material in an anaerobic treatment system, the organic material must be exposed to a significantly higher quantity of bacteria and/or detained for a much longer period of time. A typical use for anaerobic bacteria would be in a septic tank. The slower metabolism of the anaerobic bacteria dictates that the wastewater be held several days in order to achieve even a nominal 50% reduction in organic material. That is why septic tanks are always followed by some type of effluent treatment and disposal process.

The advantage of using the anaerobic process is that electromechanical equipment is not required. Anaerobic bacteria release hydrogen sulfide as well as methane gas, both of which can create hazardous conditions. Even as the anaerobic action begins in the collection lines of a sewer system, deadly hydrogen sulfide or explosive methane gas can accumulate and be life threatening.

Aerobic Bacteria
Aerobic bacteria live and multiply in the presence of free oxygen. Facultative bacteria always achieve an aerobic state when oxygen is present. While the name "aerobic" implies breathing air, dissolved oxygen is the primary source of energy for aerobic bacteria. The metabolism of aerobes is much higher than for anaerobes. This increase means that 90% fewer organisms are needed compared to the anaerobic process, or that treatment is accomplished in 90% less time. This provides a number of advantages including a higher percentage of organic removal. The by-products of aerobic bacteria are carbon dioxide and water.

Aerobic bacteria live in colonial structures called floc and are kept in suspension by the mechanical action used to introduce oxygen into the wastewater. This mechanical action exposes the floc to the organic material while treatment takes place. Following digestion, a gravity clarifier separates and settles out the floc. Because of the mechanical nature of the aerobic digestion process, maintenance and operator oversight are required.

Activated Sludge
Aerobic floc in a healthy state are referred to as activated sludge. While aerobic floc has a metabolic rate approximately ten times higher than anaerobic sludge, it can be increased even further by exposing the bacteria to an abundance of oxygen. Compared to a septic tank, which takes several days to reduce the organic material, an activated sludge tank can reduce the same amount of organic material in approximately 4-6 hours. This allows a much higher degree of overall process efficiency. In most cases treatment efficiencies and removal levels are so much improved that additional downstream treatment components are dramatically reduced or totally eliminated.

Filamentous Organisms
The majority of filamentous organisms are bacteria, although some of them are classified as algae, fungi or other life forms. There are a number of types of filamentous bacteria which proliferate in the activated sludge process. Filamentous organisms perform several different roles in the process, some of which are beneficial and some of which are detrimental. When filamentous organisms are in low concentrations in the process, they serve to strengthen the floc particles. This effect reduces the amount of shearing in the mechanical action of the aeration tank and allows the floc particles to increase in size.

Larger floc particles are more readily settled in a clarifier. Larger floc particles settling in the clarifier also tend to accumulate smaller particulates (surface adsorption) as they settle, producing an even higher quality effluent. Conversely, if the filamentous organisms reach too high a concentration, they can extend dramatically from the floc particles and tie one floc particle to another (interfloc bridging) or even form a filamentous mat of extra-large size. Due to the increased surface area without a corresponding increase in mass, the activated sludge will not settle well. This results in less solids separation and may cause a washout of solid material from the system. In addition, air bubbles can become trapped in the mat and cause it to float, resulting in a floating scum mat. Due to the high surface area of the filamentous bacteria, once they reach an excess concentration, they can absorb a higher percentage of the organic material and inhibit the growth of more desirable organisms.

Protozoans and Metazoans
In a wastewater treatment system, the next higher life form above bacteria is protozoans. These single-celled animals perform three significant roles in the activated sludge process. These include floc formation, cropping of bacteria and the removal of suspended material. Protozoans are also indicators of biomass health and effluent quality. Because protozoans are much larger in size than individual bacteria, identification and characterization is readily performed. Metazoans are very similar to protozoans except that they are usually multi-celled animals. Macroinvertebrates such as nematodes and rotifers are typically found only in a well-developed biomass. The presence of protozoans and metazoans and the relative abundance of certain species can be a predictor of operational changes within a treatment plant. In this way, an operator is able to make adjustments and minimize negative operational effects simply by observing changes in the protozoan and metazoan population.

Dispersed Growth
Dispersed growth is material suspended within the activated sludge process that has not been adsorbed into the floc particles. This material consists of very small quantities of colloidal (too small to settle out) bacteria as well as organic and inorganic particulate material. While a small amount of dispersed growth in between the floc particles is normal, excessive amounts can be carried through a secondary clarifier. When discharged from the treatment plant, dispersed growth results in higher effluent solids.

Taxonomy
Taxonomy is the science of categorizing life forms according to their characteristics. Eighteen different categories are used to define life forms from the broadest down to the most specific. They are: Kingdom, Phylum, Subphylum, Superclass, Class, Subclass, Cohort, Superorder, Order, Suborder, Superfamily, Family, Subfamily, Tribe, Genus, Subgenus, Species and Subspecies. Identifying the genus is usually specific enough to determine the role of the organisms found in a wastewater treatment system.

Process Indicators
Following taxonomic identification, enumeration and evaluation of the characteristics of the various organisms and structures present in a wastewater sample, the information can be used to draw conclusions regarding the treatment process. Numerous industry references, such as WASTEWATER BIOLOGY: THE MICROLIFE by the Water Environment Federation, can be used to provide a comprehensive indication of the conditions within a treatment process.

As an example, within most activated sludge processes, the shape of the floc particles can indicate certain environmental or operational conditions. A spherical floc particle indicates immature floc, as would be found during start-up or a process recovery. A mature floc particle of irregular shape indicates the presence of a beneficial quantity of filamentous organisms and good quality effluent.

An excess of dispersed growth could indicate a very young sludge, the presence of toxic material, excess mechanical aeration or an extended period of time at low dissolved oxygen levels. Certain protozoans, such as amoebae and flagellates dominate during a system start-up.

Free swimming ciliates are indicative of a sludge of intermediate health and an effluent of acceptable or satisfactory quality. A predominance of crawling ciliates, stalked ciliates and metazoans is an indicator of sludge with excellent health and an effluent of high quality.

Filamentous Bacteria

Filamentous Bacteria have Positive aspects:
They are very good BOD removers
They add a backbone or rigid support network to the floc structure
Helps the floc structure to filter out fine particulate matter that will improve clarifier efficiency.
They help the floc to settle if in small amounts.
They reduce the amount of "pin" floc.

Filamentous Bacteria have Negative aspects:
They can interfere with separation and compaction of activated sludge and cause bulking when predominant.
They can affect the sludge volume index (SVI)
They can cause poor settling if dominant.
They can fill up a clarifier and make it hard to settle, causing TSS carryover
They can increase polymer consumption
They can increase solids production and cause solids handling costs to increase significantly

Filamentous Identification
Filamentous Identification should be used as a tool to monitor the health of the biomass when a filament problem is suspected. Filamentous Identification is used to determine the type of filaments present so that a cause can be found and corrections can be made to the system to alleviate future problems.

All filamentous bacteria usually have a process control variation associated with the type of filament present that can be implemented to change the environment present and select out for floc forming bacteria instead. Killing the filaments with chlorine or peroxide will temporarily remove the filaments, but technically it is a Band-Aid. A process change must be made or the filaments will return with time eventually. Find out what filaments are present, find out the cause associated with them and make a process change for a lasting fix to the problems.

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

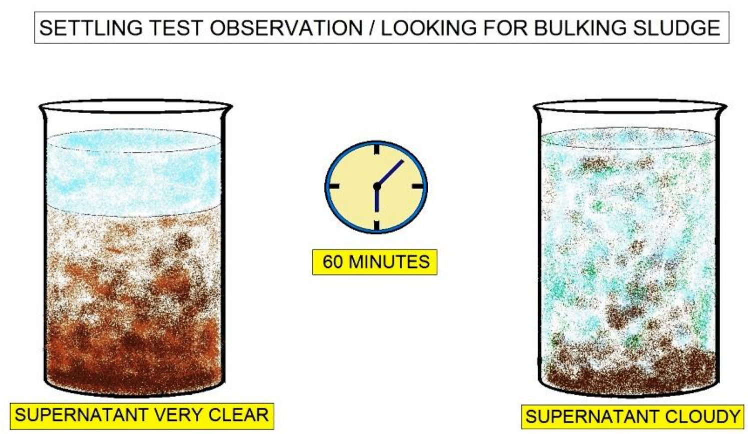
Here are most of the major filaments:

Filaments, their causes and suggested controls

Low DO Filaments	**Control**
Type 1701	Adjust the aeration rates or
S. natans	F/M (based on aeration solids)
Type 021N	Long RAS lines or sludge held too long
Thiothrix I & II	in the clarifier can sometimes cause the
H. hydrossis	growth of low DO filaments even if the aeration
N. limicola	basin has sufficient DO.
Type 1863	

Some filaments have more than one version of the filament species, with slightly different characteristics for identification.
N. Limicola I
N. Limicola II
N. Limicola III
Thiothrix I
Thiothrix II

Filamentous Identification
Filaments can be internal or external and they can be free of the floc structures or found intertwined in the floc. Most labs think that filaments need to be extending from the floc in order to be a problem. That is not true. Internal filaments can cause more problems than external filaments. Think of internal filaments causing a structure like a sponge. It will retain water easily and be harder to dewater, will be hard to compress and will take up more space, thereby increasing solids handling costs.



Filaments present in the system do not always have to mean a problem. Some filaments are good if they form a strong backbone and add a rigid network to the floc. They help give the floc more structure and settle faster. Filaments are good BOD degraders also. They are only a problem when they become dominant. If filament abundance is in the abundant or excessive range, having a Filamentous Identification performed is recommended.

When Gram and Neisser stains are performed for filamentous Identification, the types of filaments found present will be noted on the Floc Characterization sheet to the right of the filament section and will be noted on the Cover Sheet.

A Filament Causes sheet, Filamentous Predominance sheet and corrective actions will be given and included also with the report. A Filamentous Worksheet will be included. Individual sheets on the actual filaments present in the sample will be included with more information on that particular filament.

Other Wastewater Treatment Components ***Memorize this section***

Biochemical Oxygen Demand
Biochemical Oxygen Demand (BOD or BOD5) is an indirect measure of biodegradable organic compounds in water, and is determined by measuring the dissolved oxygen decrease in a controlled water sample over a five-day period.

During this five-day period, aerobic (oxygen-consuming) bacteria decompose organic matter in the sample and consume dissolved oxygen in proportion to the amount of organic material that is present. In general, a high BOD reflects high concentrations of substances that can be biologically degraded, thereby consuming oxygen and potentially resulting in low dissolved oxygen in the receiving water.

The BOD test was developed for samples dominated by oxygen-demanding pollutants like sewage. While its merit as a pollution parameter continues to be debated, BOD has the advantage of a long period of record.

Nutrients
Nutrients are chemical elements or compounds essential for plant and animal growth. Nutrient parameters include ammonia, organic nitrogen, Kjeldahl nitrogen, nitrate nitrogen (for water only) and total phosphorus. High amounts of nutrients have been associated with eutrophication, or over fertilization of a water body, while low levels of nutrients can reduce plant growth and (for example) starve higher level organisms that consume phytoplankton.

Organic Carbon
Most organic carbon in water occurs as partly degraded plant and animal materials, some of which are resistant to microbial degradation. Organic carbon is important in the estuarine food web and is incorporated into the ecosystem by photosynthesis of green plants, then consumed as carbohydrates and other organic compounds by higher animals. In another process, formerly living tissue containing carbon is decomposed as detritus by bacteria and other microbes.

Total organic carbon
(**TOC**) bears a direct relationship with biological and chemical oxygen demand; high levels of TOC can result from human sources, the high oxygen demand being the main concern.

Priority Pollutants
Priority Pollutants refer to a list of 126 specific pollutants that includes heavy metals and specific organic chemicals. The priority pollutants are a subset of "*toxic pollutants*" as defined in the Clean Water Act.

These 126 pollutants were assigned a high priority for development of water quality criteria and effluent limitation guidelines because they are frequently found in wastewater. Many of the heavy metals, pesticides, and other chemicals listed below are on the priority pollutant list.

Heavy Metals (Total and Dissolved)

Heavy metals are elements from a variety of natural and human sources. Some key metals of concern and their primary sources are listed below:

- **Arsenic** from fossil fuel combustion and industrial discharges;
- **Cadmium** from corrosion of alloys and plated surfaces, electroplating wastes, and industrial discharges;
- **Chromium** from corrosion of alloys and plated surfaces, electroplating wastes, exterior paints and stains, and industrial discharges;
- **Copper** from corrosion of copper plumbing, anti-fouling paints, and electroplating wastes;
- **Lead** from leaded gasoline, batteries, and exterior paints and stains;
- **Mercury** from natural erosion and industrial discharges; and
- **Zinc** from tires, galvanized metal, and exterior paints and stains.

High levels of mercury, copper, and cadmium have been proven to cause serious environmental and human health problems in some bays around the world. Some of the sources listed above, such as lead in gasoline and heavy metals in some paints, are now being phased out by environmental regulations issued in the past ten years.

Pesticides
Typical pesticides and herbicides include DDT, Aldrin, Chlordane, Endosulfan, Endrin, Heptachlor, and Diazinon. Some of the more persistent compounds including DDT and dioxin (not a pesticide) are subject to stringent regulation including outright bans.

Polycyclic Aromatic Hydrocarbons (PAHs)
Polycyclic Aromatic Hydrocarbons include a family of semi-volatile organic pollutants such as naphthalene, anthracene, pyrene, and benzo(a)pyrene.

Polychlorinated Biphenyls (PCBs)
Polychlorinated biphenyls are organic chemicals that formerly had widespread use in electrical transformers and hydraulic equipment. This class of chemicals is extremely persistent in the environment and has been proven to **bioconcentrate** in the food chain, thereby leading to environmental and human health concerns in areas such as the Great Lakes.

*Because of the potential to accumulate in the food chain, PCBs were intensely regulated and subsequently prohibited from manufacture by the Toxic Substances Control Act (**TSCA**) of 1976. Disposal of PCBs is tightly restricted by TSCA.*

Basic Wastewater Treatment Processes

1. Plant Influent: Waste enters the treatment facility through the municipal sewer system. Raw wastewater enters the treatment facility at the beginning of the treatment plant, referred to as the "*headworks*" of the plant. The wastewater is then pumped to the wastewater treatment facility using pumps. *Preliminary treatment* removes large objects from the wastewater to help prevent clogging of pipes and damaging the treatment equipment. The debris that is removed during preliminary treatment is typically hauled to a landfill for disposal.

2. Coarse Bar Screen: Metal bars collect large debris such as rags, wood, plastics, etc.

3. Grit Removal: The wastewater flows through a channel, allowing dense, inorganic material to settle on the bottom. Scrapers, hoppers and clam buckets remove the collected grits.

4. Primary Settling: The wastewater flows into large settling tanks which allow suspended solids and organic material to sink to the bottom of this tank.

Head Works Bar Screen↑

The raw sludge that settles to the bottom of this tank is removed through hoppers and sent through the digestion process.

Primary Treatment
As sewage enters a plant for treatment, it flows through a *screen,* which removes large floating objects such as rags and sticks that might clog pipes or damage equipment. After sewage has been screened, it passes into a *grit chamber,* where cinders, sand, and small stones settle to the bottom.

A grit chamber is particularly important in communities with combined sewer systems where sand or gravel may wash into sewers along with stormwater. After screening is completed and grit has been removed, sewage still contains organic and inorganic matter along with other suspended solids.

These solids are minute particles that can be removed from sewage in a *sedimentation tank.* When the speed of the flow through one of these tanks is reduced, the suspended solids will gradually sink to the bottom, where they form a mass of solids called *raw primary biosolids formerly called sludge.*

Biosolids are usually removed from tanks by pumping, after which it may be treated further for use as a fertilizer, or disposed of in a landfill or incinerated.

Over the years, primary treatment alone has been unable to meet many communities' demands for higher water quality. To meet them, cities and industries normally treat to a *secondary treatment level,* and in some cases, also use advanced treatment to remove nutrients and other contaminants.

Processed Sludge that can be applied to farm fields and used as a fertilizer.

5. Phosphorous Removal: Partially treated wastewater is drawn from the top of the settling tanks and in some treatment facilities, chemicals are added to remove phosphorous.

6. Aeration Basins: Large aeration basins or tanks mix the partially treated wastewater with oxygen to support bacteria which devour organic waste. The bacteria levels are managed to provide the most efficient removal process.

Aeration Basins are used in a process referred to as activated sludge. Activated sludge is a biological process where oxygen is bubbled through the water, providing aeration. The microorganisms or "**bugs**" are suspended in the wastewater by the aeration. The mixture is known as "**mixed liquor**." The bugs breakdown the wastes to carbon dioxide and water.

The mixed liquor is discharged to the final clarifiers to settle out the microorganisms which are then returned to the aeration basin. Excess biosolids, which have settled out, are sent to the solids handling processes. Similar to Primary Clarifiers are ***Secondary Clarifiers***, these slow the speed of the wastewater to allow solids to settle out of the wastewater.

Clarifiers are used to settle out microorganisms from the activated sludge process. Clarifiers typically have rotating arms; these are used to remove scum from the surface of the water.

Clarifiers are usually either round or rectangular in shape. The sludge or ***biosolids*** are collected at the bottom of the clarifier and sent to a digester for further treatment.

Primary Sedimentation
With the screening completed and the grit removed, wastewater still contains dissolved organic and inorganic constituents along with suspended solids. The suspended solids consist of minute particles of matter that can be removed from the wastewater with further treatment such as sedimentation or gravity settling, chemical coagulation, or filtration. Pollutants that are dissolved or are very fine and remain suspended in the wastewater are not removed effectively by gravity settling.

Secondary Treatment

After the wastewater has been through Primary Treatment processes, it flows into the next stage of treatment called secondary. Secondary treatment processes can remove up to 90 percent of the organic matter in wastewater by using biological treatment processes. The two most common conventional methods used to achieve secondary treatment are attached growth processes and suspended growth processes.

The *secondary stage* of treatment removes about 85 percent of the organic matter in sewage by making use of the bacteria in it. The principal secondary treatment techniques used in secondary treatment are *the trickling filter* and the *activated sludge process.* After effluent leaves the sedimentation tank in the primary stage it flows or is pumped to a facility using one or the other of these processes. A trickling filter is simply a bed of stones from three to six feet deep through which sewage passes. More recently, interlocking pieces of corrugated plastic or other synthetic media have also been used in trickling beds. Bacteria gather and multiply on these stones until they can consume most of the organic matter.

The cleaner water trickles out through pipes for further treatment. From a trickling filter, the partially treated sewage flows to another sedimentation tank to remove excess bacteria. The trend today is towards the use of the activated sludge process instead of trickling filters. The activated sludge process speeds up the work of the bacteria by bringing air and sludge heavily laden with bacteria into close contact with sewage.

Anaerobic Digester

After the sewage leaves the settling tank in the primary stage, it is pumped into an *aeration tank,* where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. During this time, the bacteria break down the organic matter into harmless by-products. The sludge, now activated with additional billions of bacteria and other tiny organisms, can be used again by returning it to the aeration tank for mixing with air and new sewage. From the aeration tank, the partially treated sewage flows to another sedimentation tank for removal of excess bacteria.

Attached Growth Processes
In attached growth (or fixed film) processes, the microbial growth occurs on the surface of stone or plastic media. Wastewater passes over the media along with air to provide oxygen. Attached growth process units include trickling filters, biotowers, and rotating biological contactors. Attached growth processes are effective at removing biodegradable organic material from the wastewater. A trickling filter is simply a bed of media (typically rocks or plastic) through which the wastewater passes. The media ranges from three to six feet deep and allows large numbers of microorganisms to attach and grow. Older treatment facilities typically used stones, rocks, or slag as the media bed material. New facilities may use beds made of plastic balls, interlocking sheets of corrugated plastic, or other types of synthetic media. This type of bed material often provides more surface area and a better environment for promoting and controlling biological treatment than rock.

Bacteria, algae, fungi and other microorganisms grow and multiply, forming a microbial growth or slime layer (biomass) on the media. In the treatment process, the bacteria use oxygen from the air and consume most of the organic matter in the wastewater as food. As the wastewater passes down through the media, oxygen-demanding substances are consumed by the biomass and the water leaving the media is much cleaner. However, portions of the biomass also slough off the media and must settle out in a secondary treatment tank.

Suspended Growth Processes
Similar to the microbial processes in attached growth systems, suspended growth processes are designed to remove biodegradable organic material and organic nitrogen-containing material by converting ammonia nitrogen to nitrate unless additional treatment is provided. In suspended growth processes, the microbial growth is suspended in an aerated water mixture where the air is pumped in, or the water is agitated sufficiently to allow oxygen transfer.

Suspended growth process units include variations of activated sludge, oxidation ditches and sequencing batch reactors. The suspended growth process speeds up the work of aerobic bacteria and other microorganisms that break down the organic matter in the sewage by providing a rich aerobic environment where the microorganisms suspended in the wastewater can work more efficiently. In the aeration tank, wastewater is vigorously mixed with air and microorganisms acclimated to the wastewater in a suspension for several hours.

This allows the bacteria and other microorganisms to break down the organic matter in the wastewater. The microorganisms grow in number and the excess biomass is removed by settling before the effluent is discharged or treated further. Now activated with millions of additional aerobic bacteria, some of the biomass can be used again by returning it to an aeration tank for mixing with incoming wastewater. The activated sludge process, like most other techniques, has advantages and limitations. The units necessary for this treatment are relatively small, requiring less space than attached growth processes. In addition, when properly operated and maintained, the process is generally free of flies and odors. However, most activated sludge processes are more costly to operate than attached growth processes due to higher energy use to run the aeration system.

The effectiveness of the activated sludge process can be impacted by elevated levels of toxic compounds in wastewater unless complex industrial chemicals are effectively controlled through an industrial pretreatment program. An adequate supply of oxygen is necessary for the activated sludge process to be effective. The oxygen is generally supplied by mixing air with the sewage and biologically active solids in the aeration tanks by one or more of several different methods. Mechanical aeration can be accomplished by drawing the sewage up from the bottom of the tank and spraying it over the surface, thus allowing the sewage to absorb large amounts of oxygen from the atmosphere. Pressurized air can be forced out through small openings in pipes suspended in the wastewater. A combination of mechanical aeration and forced aeration can also be used. Also, relatively pure oxygen, produced by several different manufacturing processes, can be added to provide oxygen to the aeration tanks. From the aeration tank, the treated wastewater flows to a sedimentation tank (secondary clarifier), where the excess biomass is removed. Some of the biomass is recycled to the head end of the aeration tank, while the remainder is “wasted” from the system. The waste biomass and settled solids are treated before disposal or reuse as biosolids.

Other Treatment Options

New pollution problems have placed additional burdens on wastewater treatment systems. Today’s pollutants, such as heavy metals, chemical compounds, and toxic substances, are more difficult to remove from water. Rising demands on the water supply only aggravates the problem.

The increasing need to reuse water calls for better wastewater treatment. These challenges are being met through better methods of removing pollutants at treatment plants, or through prevention of pollution at the source.

Pretreatment of industrial waste, for example, removes many troublesome pollutants at the beginning, not the end, of the pipeline. To return more usable water to receiving lakes and streams, new methods for removing pollutants are being developed.

Advanced waste treatment techniques in use or under development range from biological treatment capable of removing nitrogen and phosphorus to physical-chemical separation techniques such *filtration, carbon adsorption, distillation,* and *reverse osmosis.*

These wastewater treatment processes, alone or in combination, can achieve almost any degree of pollution control desired. Waste effluents purified by such treatment can be used for industrial, agricultural, or recreational purposes, or even drinking water supplies.

Fine air diffusers used for aeration.

1. Final Settling: The cleanest wastewater is drawn from the top of the aeration tanks through spillways. By this point the water is already quite clear. Polymers may be added to concentrate any remaining material. Once again, suspended particles settle to the bottom and are removed by scrapers or hoppers.

2. Disinfection: The cleanest water is drawn from the surface and disinfected with chlorine or ultra-violet light to kill bacteria.

3. De-chlorination: The treated water is de-chlorinated. The treated water is tested to ensure it meets the EPA standards and is returned to the original water source. Before the treated water is discharged to the receiving stream, samples are taken. The samples are then analyzed in a laboratory. An automatic sampler will automatically take samples at designated times. The samples are then kept refrigerated in the sampler until the sample can be analyzed in the lab.

Sludge* Memorize all of this section
Sludge is generated through the sewage treatment process. Primary sludge, material that settles out during primary treatment, often has a strong odor and requires treatment prior to disposal. Secondary sludge is the extra microorganisms from the biological treatment processes. The goals of sludge treatment are to stabilize the sludge and reduce odors, remove some of the water and reduce volume, decompose some of the organic matter and reduce volume, kill disease causing organisms and disinfect the sludge.

Untreated sludge is about 97 percent water. Settling the sludge and decanting off the separated liquid removes some of the water and reduces the sludge volume. Settling can result in a sludge with about 96 to 92 percent water. More water can be removed from sludge by using sand drying beds, vacuum filters, filter presses, and centrifuges resulting in sludge with between 80 to 50 percent water. This dried sludge is called a sludge cake. Aerobic and anaerobic digestion are used to decompose organic matter to reduce volume.

Digestion also stabilizes the sludge to reduce odors. Caustic chemicals can be added to sludge or it may be heat treated to kill disease-causing organisms. Following treatment, liquid and cake sludge is usually spread on fields, returning organic matter and nutrients to the soil.

Wastewater treatment processes require careful management to ensure the protection of the water body that receives the discharge. Trained and certified treatment plant operators' measure and monitor the incoming sewage, the treatment process and the final effluent.

4. Sludge Digestion: Sludge from the final settling tanks is drawn from the bottom of the tanks and pumped to the primary settling tank. Not only does this sludge have a high water content, but it also contains oxygen and bacteria which improve the efficiency of the treatment process. The gravity belt thickener is one way to reduce the amount of water in the biosolids before further treatment. The volume reduction is occurring from the loss of water. Thickening of the biosolids improves digester operation and reduces the cost of sludge digestion. Aerobic sludge digestion produces a sludge that has higher water content.

Thermal
Heat reduces the capacity of water to retain oxygen. In some areas, water used for cooling is discharged to streams at elevated temperatures from power plants and industries. Even discharges from wastewater treatment plants and storm water retention ponds affected by summer heat can be released at temperatures above that of the receiving water, and elevate the stream temperature. Unchecked discharges of waste heat can seriously alter the ecology of a lake, a stream, or estuary.

***The following are suggested control methods: * Memorize all of this section**

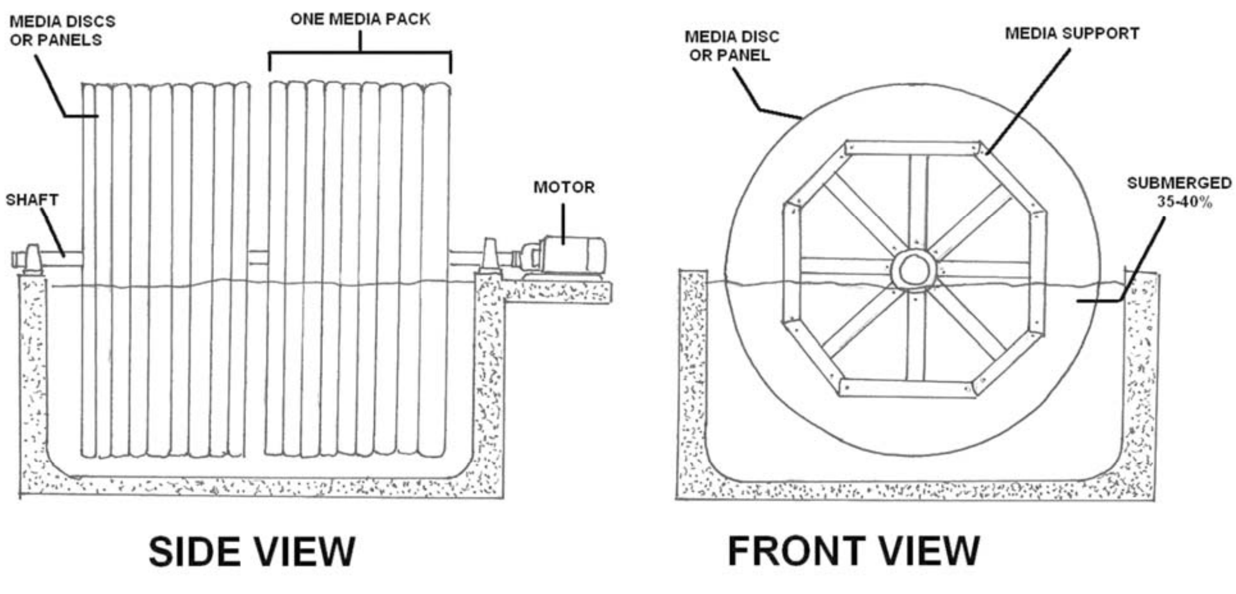
- Feeding of raw sludge to an anaerobic digester should be done when the solids content of the sludge is <3.5%.
- Aeration or high turbulence of wastewater will cause hydrogen sulfide to be stripped or carried out by the air.
- An air supply valve improperly adjusted could be a cause of dead spots in aeration tanks.
- Anaerobic sludge digestion produces liquids that may be difficult to treat when returned to the plant.
- The Elutriation process is used to reduce the sludge alkalinity.
- If a primary sludge is allowed to go septic, H_2S, CO_2 and CH_4 gases will be produced.
- If septic sludge is put into a gravity sludge thickener it will reduce efficiency and lower solids concentration.
- In gravity thickening of wastewater sludge, gravity forces are used to separate solids from the sludge being treated. Secondary sludge's are not well suited for gravity thickening because it contains Bound water. One factor that would allow for greater volumes of water to drain from the sludge in a belt filter press is to increase the belt speed.
- Sludge floating to the surface of a secondary clarifier could be resolved by increasing MCRT to greater than 6 days.
- The drying time and the time required to remove sludge information should be used by operators to determine the optimum depth to apply sludge on a sand drying bed.
- The following are typical loading guidelines for activated sludge: High-rate: COD >1, BOD >.5, Conventional: COD 0.5 to 1.0, BOD 0.25 to 0.5, Extended aeration: COD <0.2 lbs, BOD <.10 lbs.
- The purpose of a Venturi-type restriction on a belt filter press is to provide turbulence to mix polymer with the flow.
- When lime is mixed with sludge to improve dewatering the pH should be around11.5 to 12.0.
- When making changes to correct a problem in an activated sludge package plant, it might take at least 3 or more days before the correction shows.

5. Primary Digest: Sludge removed throughout the process is pumped to digesters for processing. Anaerobic bacteria consume organic waste in the digesters. This process produces gases which can be used to fuel plant boilers and heat facilities.

Final Clarifiers are also used to settle out microorganisms, or "bugs," from the activated sludge process. Clarifiers are usually either round or rectangular in shape. Once the wastewater leaves the final clarifier, it is typically disinfected, to remove any bacteria. The solids are sent to a solids handling system, such as a solids thickener.

***Additional Control Methods and Information.**

- The method for preserving a Sulfide sample is to add 2 mL 1 M zinc acetate & 1 N NaOH to pH >9 and store at 4°C.
- According to the Water Quality Criteria for effluent, the suggested limit of Nitrite and Nitrate as N for livestock and wildlife is 10 mg/L.
- Bacteria is produce by binary fission which is called the generation time. The ***E. coli*** bacteria is found in the intestinal tract of humans and warm-blooded animals. The generation time of this bacteria in a broth medium is about 17 minutes.
- Changing conditions or abnormal conditions can upset the microorganisms in the activated sludge process. If the sludge is bulking in the clarifier you probably have low DO concentration.
- Coliform bacteria, originating from the intestines of warm-blooded animals, are tested for in wastewater because they can be indication of the presence of disease-producing organisms that can be associated with them. The Membrane filter method test method is approved by NPDES to determine Total Coliform analysis.
- During the Contact stabilization process, it is recommended that the sample used for microscopic observations be taken at the end of the zone.
- Hydrogen peroxide has been used as an oxidant to control odors. Inability to treat ammonia is one the disadvantages of using hydrogen peroxide.



ROTATING BIOLOGICAL CONTACTOR

Digester Review Statements* Memorize all of this section

An operator can correct excessive foam in an aerobic digester when the DO is high, pH is 7, and the O_2 uptake is stable by lowering the air intake to reduce turbulence. Sodium Hydroxide is not beneficial to the digestion process.

The efficient cleaning of a digester demands that operators follow appropriate safety rules.

You can determine the organic loading on a digester by measuring the volatile solids loading per cubic foot per day.

Protozoa can be called "*indicator organisms*." Their presence or absence indicates the amount of bacteria in the activated sludge and the degree of treatment. The following are part of the protozoa family: Mastigophora, Amoeba and Suctoria.

Sulfide can exist in wastewater in three forms depending on the pH: S^{2-} ion, HS^- ion, or H_2S gas. At the ideal temperature, S_2 ion, 90% would form at a pH of 14?

Chlorine and Disinfection* Memorize all of this section

To complete secondary treatment, effluent from the sedimentation tank is usually ***disinfected*** with chlorine before being discharged into receiving waters. Chlorine is fed into the water to kill pathogenic bacteria, and to reduce odor. Done properly, chlorination will kill more than 99 percent of the harmful bacteria in an effluent. Some municipalities now manufacture chlorine solution on site to avoid transporting and storing large amounts of chlorine, sometimes in a gaseous form. Federal law now requires the removal of excess chlorine before discharge to surface waters by a process called dechlorination. Alternatives to chlorine disinfection, such as ultraviolet light or ozone, are also being used in situations where chlorine in treated sewage effluents may be harmful to fish and other aquatic life.

The most important use of chlorine in the treatment of wastewater is for disinfection. When chlorine reacts quickly and completely with ammonia in wastewater, Monochloramines is produced.

A regular program of scheduled preventive maintenance is essential to keep a chlorinator functioning properly.

If the operator notices that the chlorinator will not feed chlorine, the first thing an operator should check is the chlorine supply gauges.

Chlorine residual samples should be taken daily from the effluent of a pond.

During the night shift, the operator notes that the chlorine residual analyzer recorder controller is not maintaining the chlorine residual properly. The electrodes may be fouled and should be cleaned; they are the most probable cause of the problem.

During your inspection of the chlorine feed system, you find that there is no chlorine gas pressure at the chlorinator. You check and find the chlorine cylinder is full and the valve is open--you may have a plugged or damaged pressure-reducing valve.

In order to meet NPDES permit coliform requirements, 4.5 mg/L is the required chlorine residual at the outlet of the chlorine contact basin.

$NH_3 + Cl_2 = NH_2Cl + CHI$, $NH_2Cl + Cl_2 = NHCl_2 + HCl$, $NHCl_2 + Cl_2 = NCl_3 + HCl$ and Monochloramine, NH_2Cl all of these represent the reaction of ammonia with chlorine.

Procedures and equipment for operating and maintaining chlorination and sulfonation systems are very similar, but you should be aware of the differences. Sulfur dioxide gas pressures are lower than chlorine gas pressure at the same temperature.

Wastewater facilities may be required to provide chlorination services for the following activities: disinfection of effluent, process control of activated sludge and seasonal odor control.

If the operator determines that the Coliform count fails to meet required standards for disinfection; the operator checks the contact time and finds that short-circuiting has occurred in the contact chamber. Installing baffling in the contact chamber could correct this problem.

The presence or absence of oxygen establishes whether hydrogen sulfide will exist. If more than 1.0 mg/L of oxygen is present, it will oxidize to form thiosulfate. The scale of a spectrophotometer is generally graduated two ways. If Units of Absorbance are used, a logarithmic scale of non-equal divisions is graduated from 0.0 - 2.0. The volatile solids test measures the amount of organic material when it is performed on solids.

Wastewater is relatively rich in phosphorus compounds. The forms of phosphorus found in wastewater are commonly classified into three categories. Orthophosphate measures the amount of inorganic phosphorus in the sample of wastewater as measured by the direct colormetric analysis procedure.

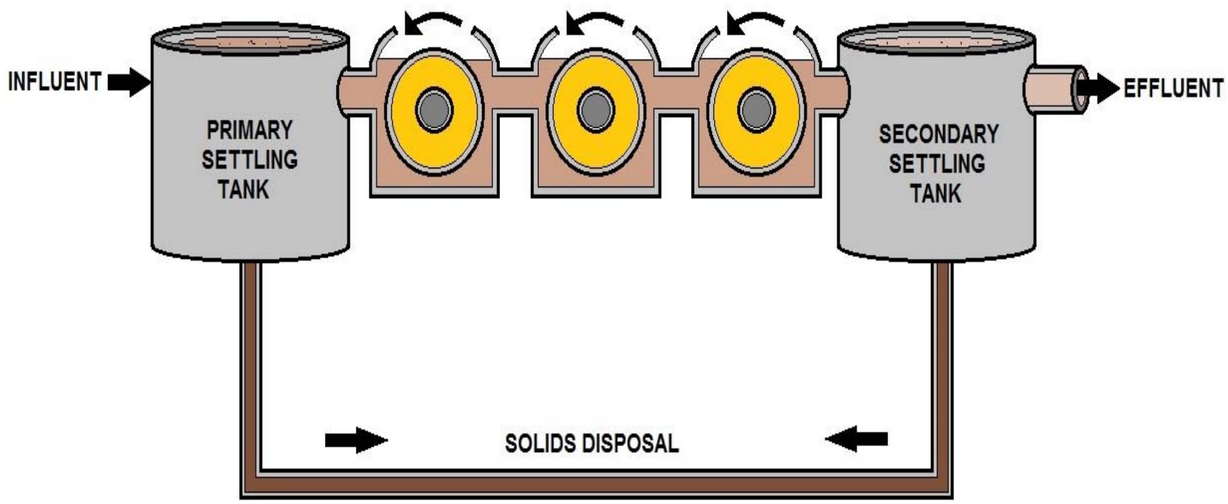
Dewatering Process*
Vacuum filter or centrifuge systems remove water from the processed sludge to thicken it. The water removed in the process is pumped to the primary settling tank to reenter the treatment process.

Depending on **NPDES Permit**, the concentrated sludge, or bio-solid waste is taken away for incineration or conversion into fertilizer.

The end product of anaerobic digestion is a biologically stable substance that has nutrient and soil-enhancing properties, referred to as *Biosolids*. Biosolids are typically stored until the material can be land applied or disposed of in a landfill. Much of the biosolids produced is applied to farmland. Biosolids contain many of the same nutrients as commercial fertilizers, including valuable organic matter, nitrogen, phosphorus, calcium, magnesium, and micronutrients, such as zinc and iron.

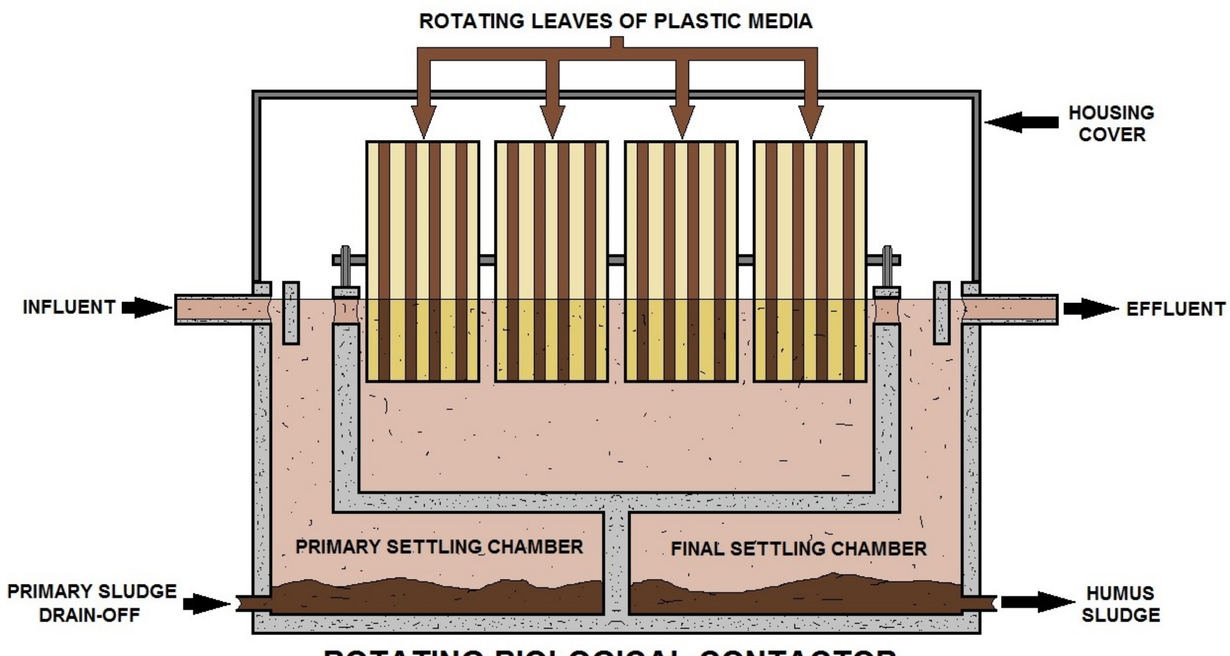
While not a complete replacement for chemical fertilizers in terms of nutrient ratios, biosolids do some things that chemical fertilizers can't do. They are composed of organic matter that promotes necessary bacterial activity and improves the structure, texture, and water retention characteristics of the soil.

These properties stimulate growth of vegetation, which helps reduce soil erosion and improve crop yields. Biosolids also provide trace metals and nutrients that commercial fertilizers do not have.



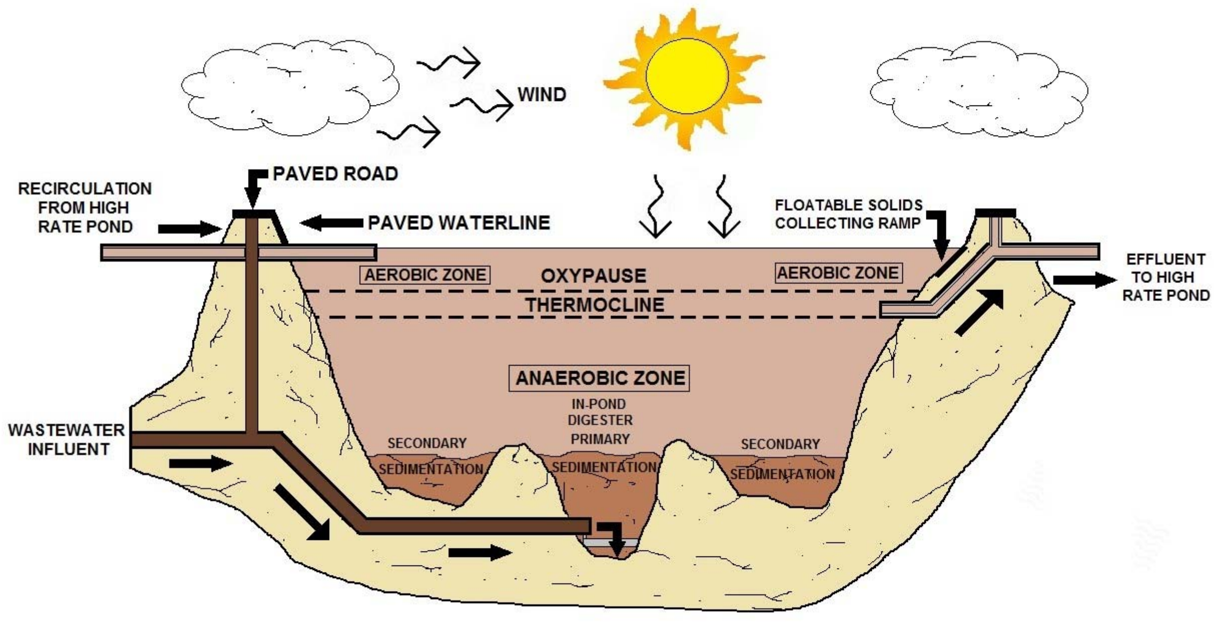
ROTATING BIOLOGICAL CONTACTOR

The **rotating biological contactor** (RBC) is a fixed film biological secondary treatment device. The basic process is similar to that occurring in the trickling filter. In operation, a media, consisting of a series of circular disks mounted side by side on a common shaft is rotated through the wastewater flow.



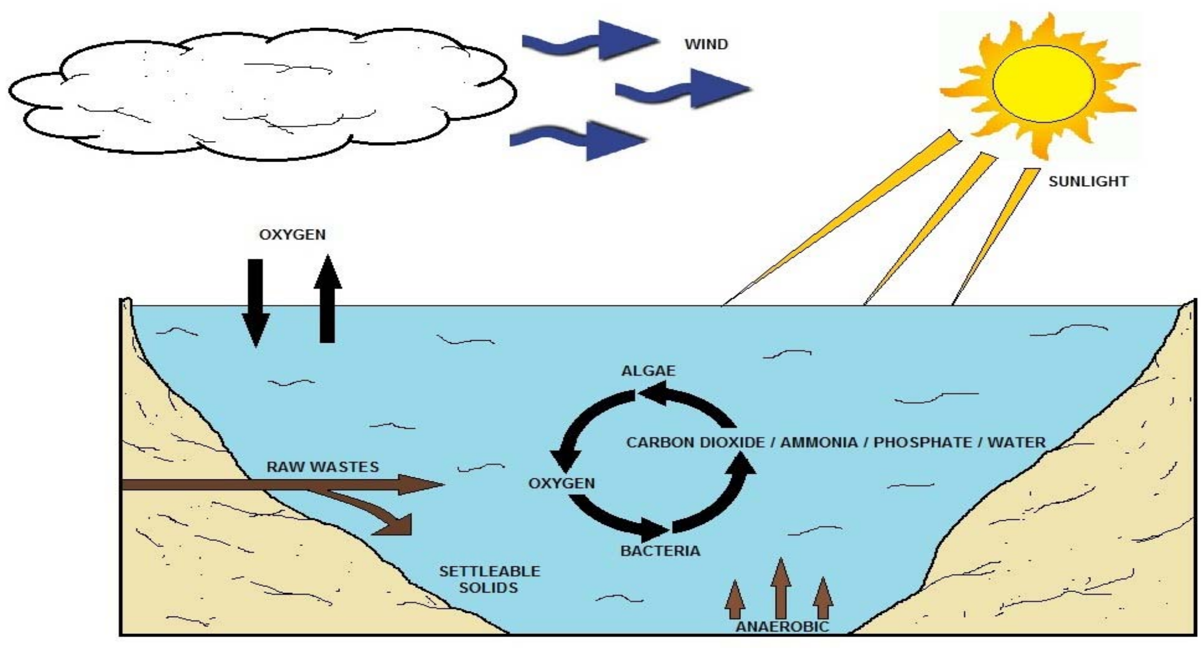
ROTATING BIOLOGICAL CONTACTOR
(INTEGRAL TYPE)

RBC's with integral units' treats unsettled sewage and has the capability of providing primary and secondary settling in the unit.



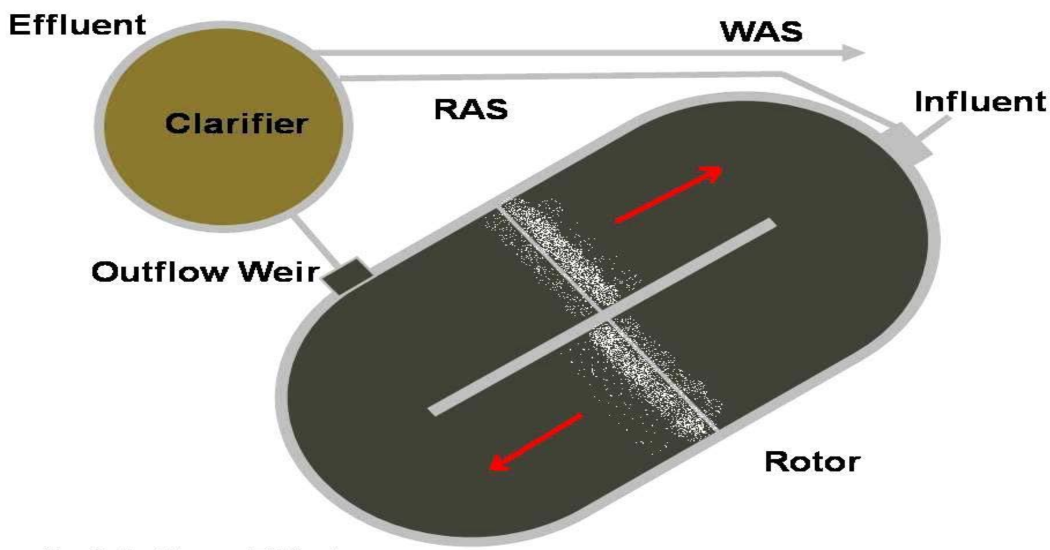
AEROBIC / ANAEROBIC POND

The most often used ponds in domestic wastewater treatment are the stabilization pond and facultative lagoon. The stabilization pond is designed to be aerobic throughout its depth and the facultative lagoon will be anaerobic at the bottom and aerobic at the top. Stabilization ponds provide secondary biological treatment and are the most commonly used wastewater pond. Stabilization ponds must be preceded by some form of primary treatment to reduce the solids entering the pond.



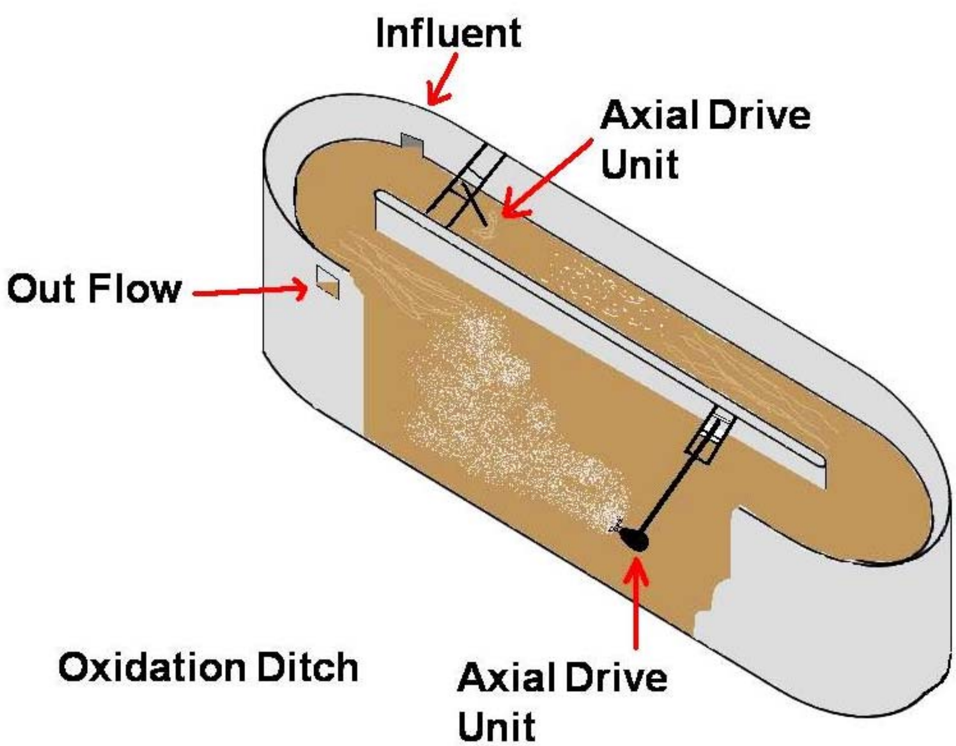
SECONDARY FACULATIVE POND

Respiration in lakes recycles organic carbon arising from photosynthesis back to inorganic carbon. Prior to this transformation, the organic carbon is potentially available to support secondary production.

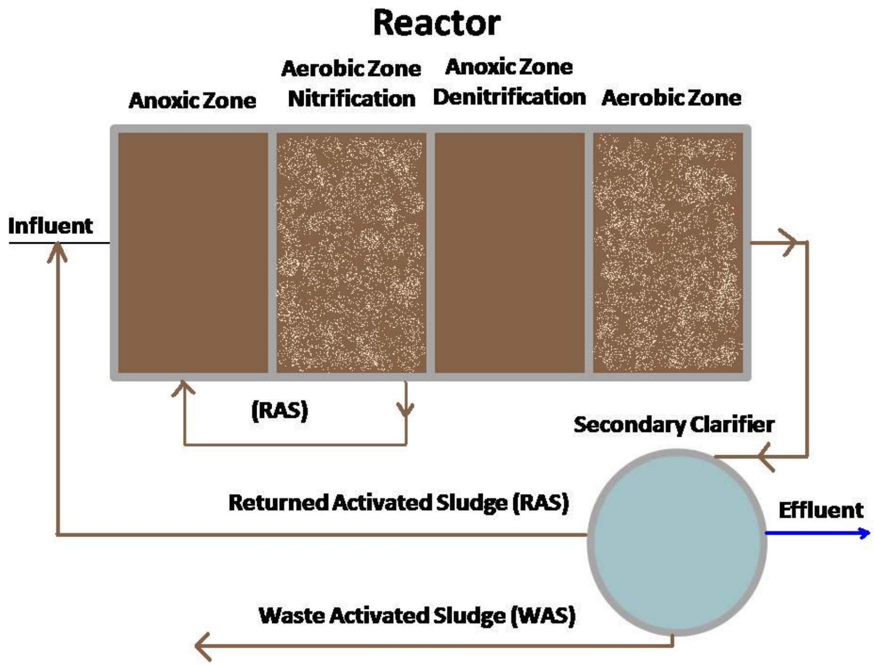


Oxidation Ditch

An oxidation ditch is a modified activated sludge biological treatment process that utilizes long solids retention times (SRTs) to remove biodegradable organics. Oxidation ditches are typically complete mix systems, but they can be modified to approach plug flow conditions.



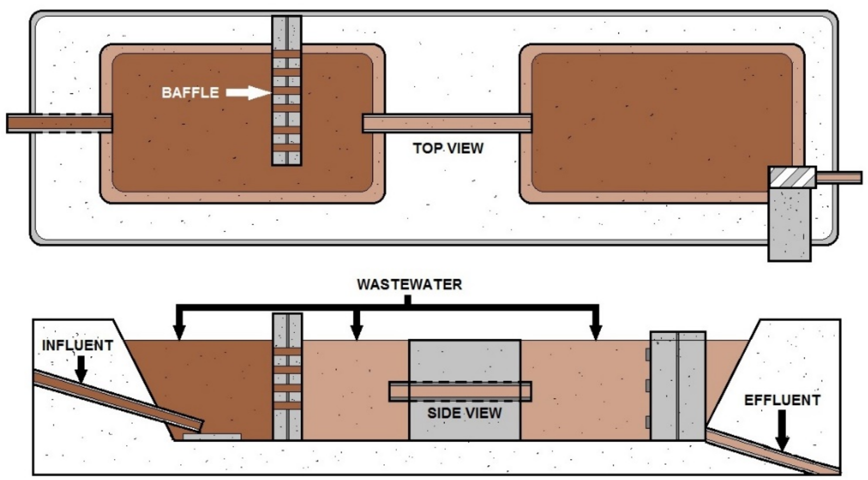
Oxidation Ditch



A nitrification-denitrification four stage Bardenpho flow diagram

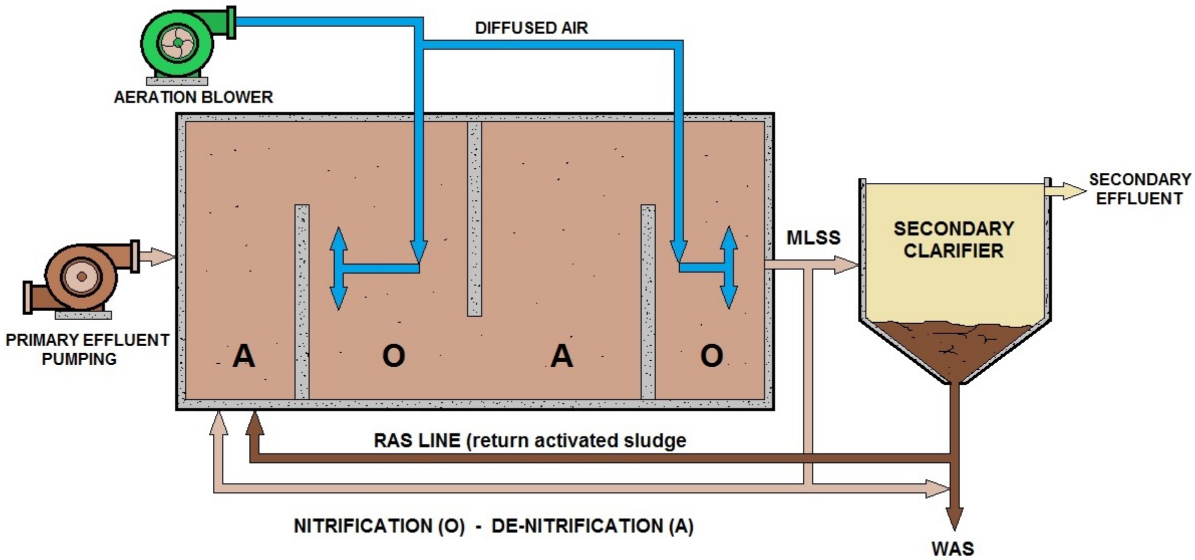
Nitrification is a process of nitrogen compound oxidation (effectively, loss of electrons from the nitrogen atom to the oxygen atoms):

1. $2\ NH_3 + 3\ O_2 \rightarrow 2\ NO_2^- + 2\ H_2O + 2\ H^+$ (Nitrosomonas)
2. $2\ NO_2^- + 1\ O_2 \rightarrow 2\ NO_3^-$ (Nitrobacter, Nitrospina)
3. $NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$
4. $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$
5.



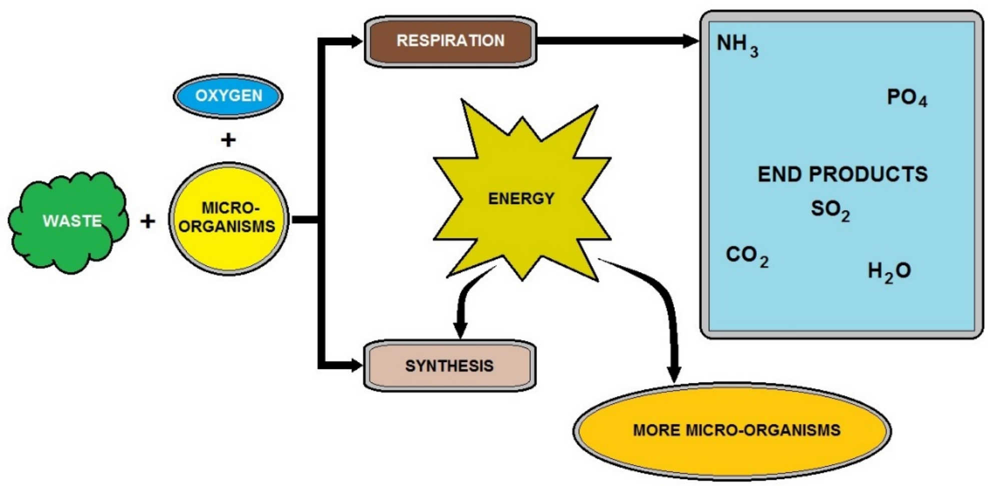
THREE CELL LAGOON
WASTEWATER TREATMENT SYSTEM

The original lagoon system consists of one aerated cell (Basin 1), followed by a non-aerated polishing cell (Basin 2) and a final chlorine contact chamber. This system has a third non-aerated cell (Basin 3) for sludge settling.



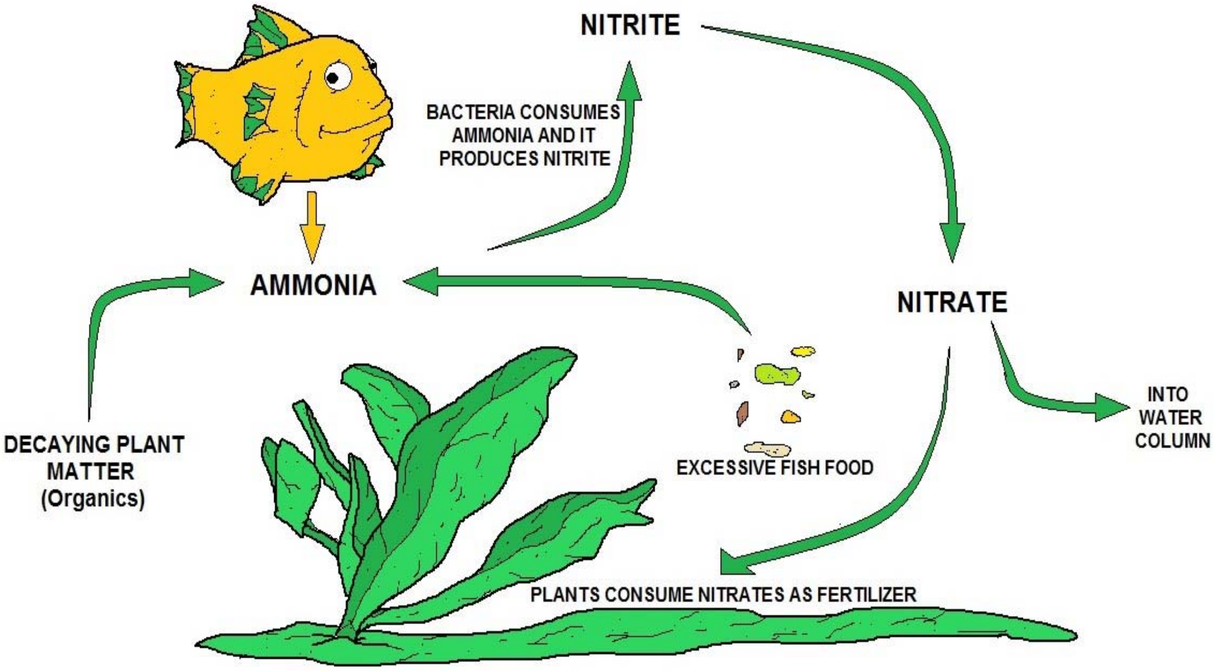
ACTIVATED SLUDGE PROCESS

Activated sludge is a biological process that utilizes microorganisms to convert organic and certain inorganic matter from wastewater into cell mass. The activated sludge is then separated from the liquid by clarification. The settled sludge is either returned, returned activated sludge (RAS) or wasted, waste activated sludge (WAS).



BASICS OF WASTEWATER MICROORGANISMS BREAKDOWN

The principle role microorganisms have in the activated sludge process is to convert dissolved and particulate organic matter, measured as biochemical oxygen demand (BOD), into cell mass. In a conventional activated sludge process, microorganisms use oxygen to break down organic matter (food) for their growth and survival. Over time and as wastewater moves through the aeration basin, food (BOD) decreases with a resultant increase in cell mass (MLSS concentration). The end product is shown above in the picture.



NITROGEN CYCLE IN PONDS

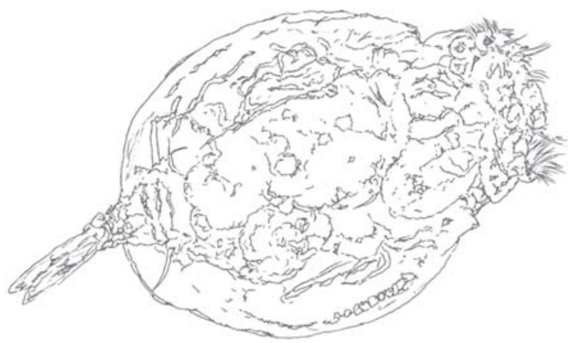
Ammonia to nitrite to nitrate process in fresh water.

AMOEBOID

"Amoeboid" and "amoeba" are used interchangeably. Amoeboids move using pseudopodia, which are bulges of cytoplasm. Amoebas breathe using their entire cell membrane that is constantly immersed in water. Excess water can cross into the cytosol. Amoebas have a contractile vacuole to expel excess water.

CHLAMYDOMONAS

Chlamydomonas reinhardtii is known to remove nitrogen and phosphorus from wastewater.

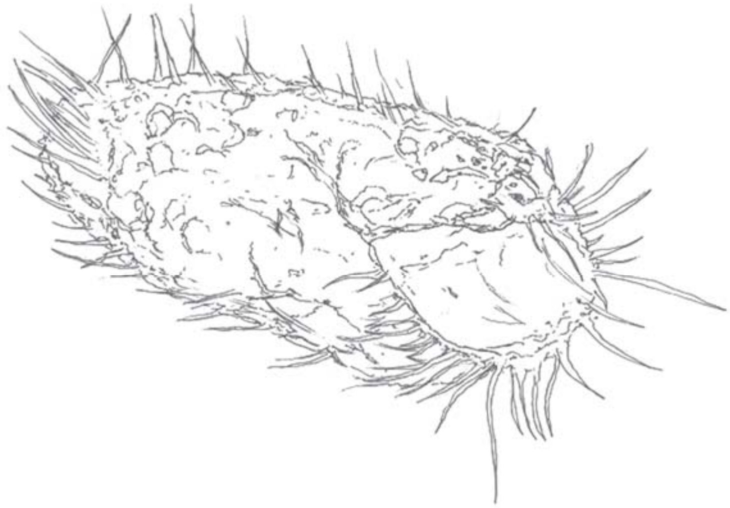


ROTIFER EUCHLANIS

Euchlanis is commonly found in activated sludge when effluent quality is good. It requires a continual supply of dissolved oxygen, evidence that aerobic conditions have been sustained.

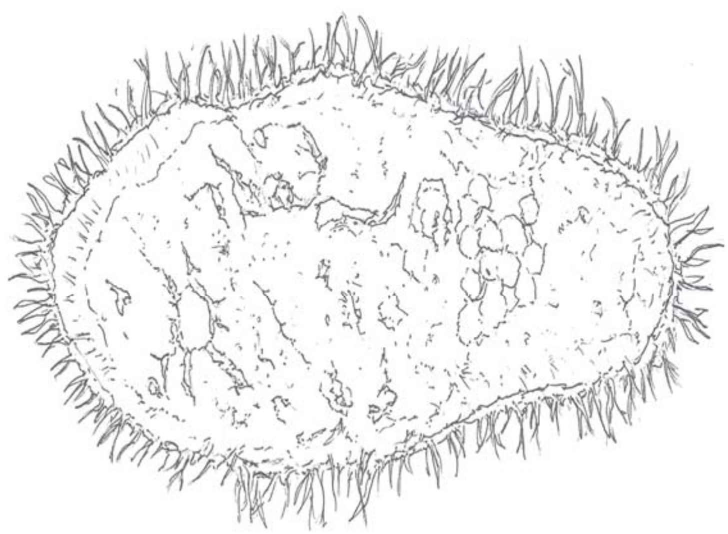
ROTIFER CALYCIFLORUS

This particular Rotifer is a great indicator bug for fresh and brackish water. With the increasing use of antibiotics, wastewater facilities are noticing passage through the treatment process. The toxicity effects the reproduction of the organisms in the water.



STYLONYCHIA MYTILUS

This ciliate is heavy metal resistant, Stylonychia mytilus, isolated from industrial wastewater has been shown to be potential bioremediator of contaminated wastewater. The ability of Stylonychia to take up variety of heavy metals from the medium could be exploited for metal detoxification and environmental clean-up operations.



PARAMECIUM

Paramecium which is a Ciliate feeds on bacteria, not on dissolved organics. They are usually an indicator of good quality sludge and typically found in young to medium age sludge.

Tertiary Treatment

Tertiary treatment is normally applied in WWTP with extremely high demands on phosphorus removal. After the secondary clarifier the coagulant is added, precipitating phosphorus which is removed in a tertiary sedimentation tank or a sand filter. The main objective of the tertiary treatments is the removal of dissolved nitrogen and phosphorous compounds of the purification plant effluent, with the aim to limit their eutrophying effect in the receiver water body. Also the phytodepuration treatments can be considered tertiary treatments. There can also be a final disinfecting treatment, when the receiver water body is intended for a use requiring a particular hygienic-sanitary safeguard (ex. bathing).

The Tertiary Filtration stage consists of a physical process of the filtration of the overflow from the *Secondary Clarification* process through a bed of sand. This is accomplished using the newly constructed Traveling Bridge Filters or the previously existing Rapid Sand Filters.

Under normal operating conditions the Traveling Bridge Filters are utilized due to their increased efficiency over the Rapid Sand Filters which are then used as backup units. Both units operate using the same process of filtration through a bed of sand, however, the Traveling Bridge Filters utilize a bridge which backwashes (cleans) the filter as it travels down its length. This minimizes the percentage of the filter unused when the filter is being backwashed. In comparison, the Rapid Sand Filters consist of three cells which lose an entire cell with each backwash. The filtered wastewater then passes on to the *Disinfection* stage.

Nitrogen Removal
Nitrogen is found in domestic wastewater mostly in the form of ammonia and organic nitrogen. Its removal is a process of biological nature and occurs in two phases.

1. In the first phase (called nitrification), the ammonia is oxidized to nitrate, thanks to a series of bacteria mediated reactions: NH_3, NO_2^-, NO_3^-. In this phase the *Nitrosomonas* oxidize the ammonia to nitrite and the *nitrifying bacteria* oxidize the nitrite to nitrate.
2. In the second phase, the nitrates are denitrified to molecular nitrogen by means of two different genus of bacteria (*Pseudomonas, Bacillus*) using the nitrates as oxidizing compound in place of oxygen.

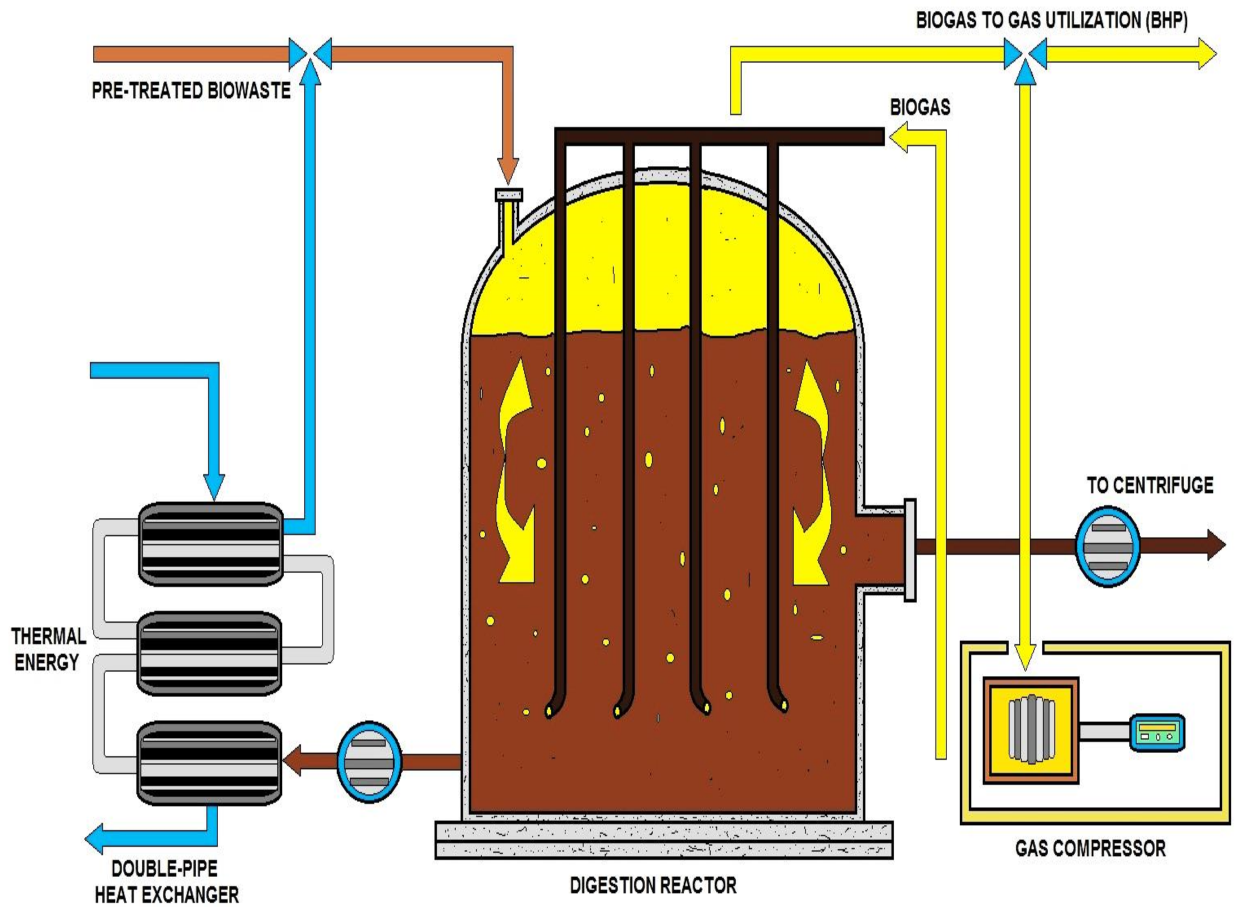
The first phase has to occur in an aerobic environment, and a tank similar to which is used for active sludge is used, while the second phase has to occur in anoxic environment in such a way that the bacteria use the nitrate, instead of oxygen, as electron acceptors.

There are also physical/chemical processes which can remove nitrogen, especially ammonia; they are not as economical for domestic wastewater, but might be suited for an industrial location where no other biological processes are in use. (These methods include alkaline air stripping, ion exchange, and "*breakpoint*" chlorination.)

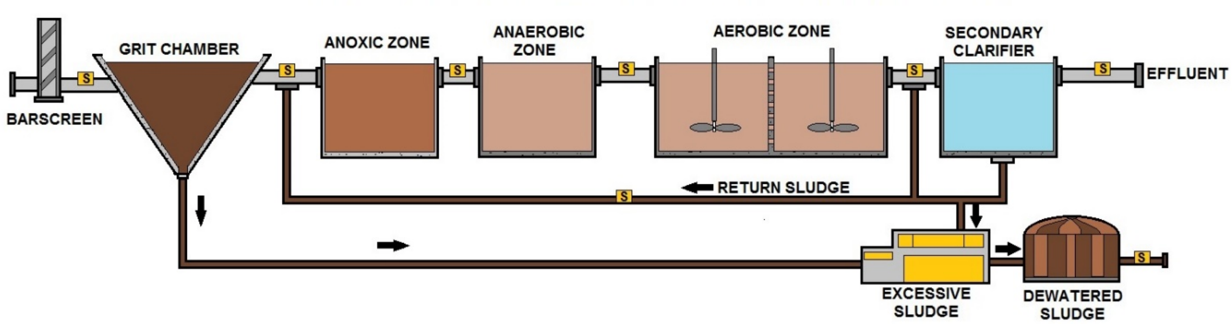
Phosphorus Removal
Phosphorous removal is most commonly done by chemical precipitation with iron or aluminum compounds, such as ferric chloride or alum (aluminum sulfate). The solids which are produced can be settled along with other sludges, depending on where in the treatment train the process takes place. *"Lime",* or calcium hydroxide, also works, but makes the water very alkaline, which has to be corrected, and produces more sludge.

There is also a biological process for phosphorus removal, which depends on designing an activated sludge system in such a way as to promote the development of certain types of bacteria which have the ability to accumulate excess phosphorus within their cells.

The basic principle of the phosphorous biological removal systems contemplates a depurative unit where it alternates an anaerobic condition and an aerobic one, inducing a high phosphorous intake by the bacteria. These methods mainly convert dissolved phosphorus into particulate form. For treatment plants which are required to discharge only very low concentrations of total phosphorus, it is common to have a sand filter as a final stage, to remove most of the suspended solids which may contain phosphorus.



SINGLE-STAGE DIGESTION REACTOR



BASIC WASTEWATER TREATMENT PLANT AND SAMPLING POINTS

Trickling Filter

A trickling filter provides aerobic treatment of the wastewater. The wastewater is generally pumped from a compartment of the septic tank, dispersed over a media bed, and allowed to drain back into the tank. The wastewater is aerated as it flows over the media.

A Trickling Filter consists of a rotating arm that sprays wastewater over a filter medium. The filter medium can consist of rocks, plastic, or other material. The filter material is coarse, allowing air to flow through the media. This process does not actually filter material out, however. Bacteria grow on the filter material. The bacteria then absorb and consume the waste as it trickles through the filter, improving the quality of the wastewater.

The water is collected at the bottom of the filter for further treatment. Excessive sloughing or biological growth on a trickling filter is an indication of filter ponding. The following are recommendations for preventing odors in a trickling filter: Maintain aerobic conditions in the sewer system, use of masking agents and check and clear filter ventilation. The following solution will help prevent trickling filters from freezing: *Decrease the recirculation.*

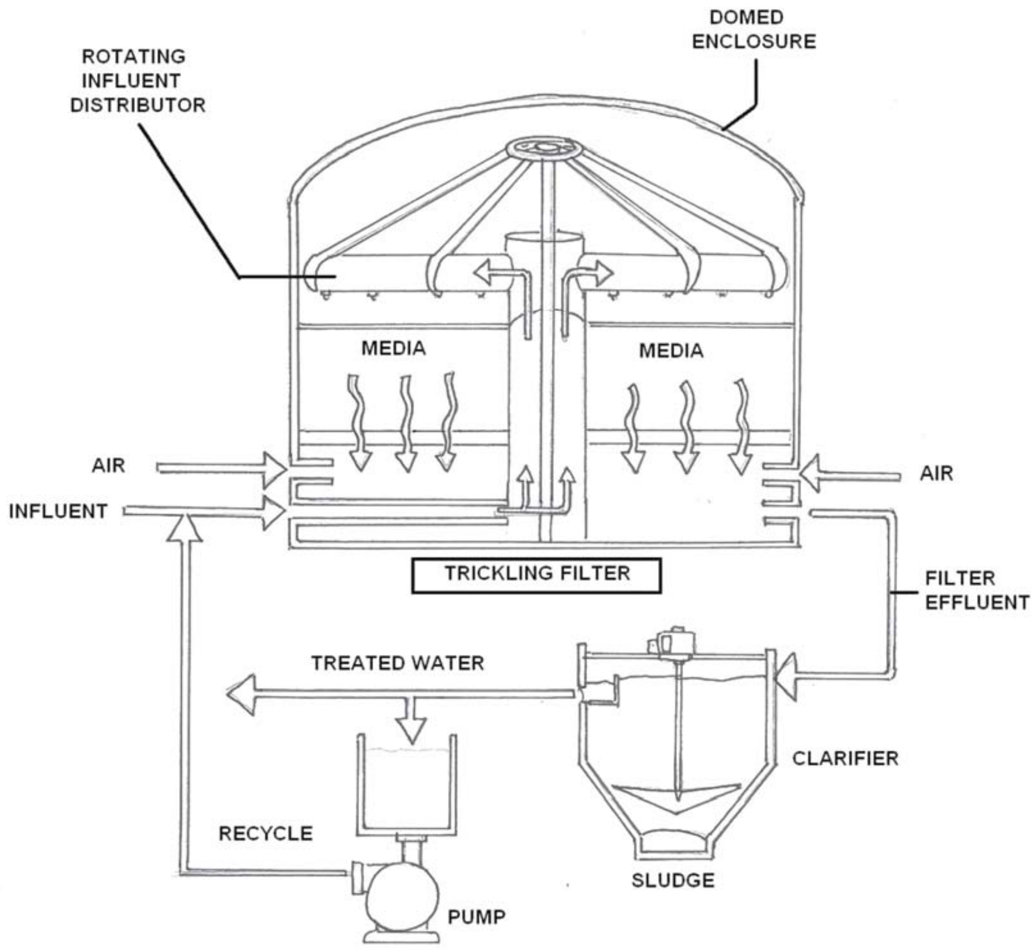
More on Digesters
Aerobic Treatment Units
Aerobic treatment units use a biological process to transform dissolved and solid pollutants into gases, cell mass and non-gradable material (EPA Manual). The treatment process occurs in a mixed state with a variety of microorganisms living together that can decompose a broad range of materials. The organisms live in an aerobic environment where free oxygen is available for the organism respiration. It is important to maintain an active population of microbes to carry out the breakdown of the solids.

Anaerobic Digestion
Anaerobic digestion is the biological degradation of organic matter in an oxygen free atmosphere. Anaerobic digestion converts the biosolids into carbon dioxide, methane, hydrogen sulfide, other gases, and water. What is left behind is a biologically stable residue, referred to as *biosolids*. Typically, the biosolids are reused as a soil amendment. The biosolids are rich in nutrients and provide a good alternative to fertilizer.

More on Tertiary Filtration
Sand Filters
Sand filters are a biological and physical wastewater treatment component consisting of an under drained bed of sand to which pre-treated effluent is periodically applied. A sand filter purifies the water through three main mechanisms: filtration, chemical sorption, and assimilation.

Wetland Systems
Wetland systems are used to remove biological materials, suspended solids, nutrients, and pathogens from the wastewater. The constructed wetland wastewater treatment system consists of three components: septic tank, constructed wetland, and land application system. The wetland needs to have a sufficient cross sectional area to accept the water flow entering the wetland.

More on Basic Wastewater Flow Patterns



Chromium Reduction Procedure
Since Hexavalent Chromium cannot form an insoluble hydroxide, the chromium in segregated waste streams must be reduced to the trivalent state before it can precipitate as Chromium Hydroxide by the addition of alkali. Common reducing agents are Sulfur Dioxide gas and Sodium Metabisulfite, with other alternatives available.

Basic Equipment Includes:
- a reaction tank,
- mixer,
- chemical feed system,
- oxidation reduction potential (**ORP**) meter/controller,
- pH meter/controller,
- transfer pumps, and
- level controls.

Sulfur dioxide is more often used at large treatment plants due to its lower cost, but it does require both an expensive chemical feed system and a ventilation system.

The reduction process is operated between a pH of 2 and 3. Acid added to maintain this pH increases the need for alkali reagent addition during the metal removal step that follows. Conventional chromium reduction processes produce an effluent with less than 0.1 mg/l Hexavalent Chromium.

Cyanide Oxidation (Cyanide Destruction)

Segregated cyanide-bearing waste streams are oxidized using alkaline chlorination to convert toxic cyanides to harmless carbon and nitrogen compounds. A properly operated process can reduce cyanide concentrations to less than 1.0 mg/l. Free dissolved hydrogen cyanide is easily oxidized by this process. Stable cyanide complexes, such as ferrocyanides or ferricyanides are unaffected by chlorination. Copper, Nickel, and precious metal complexes can also be oxidized, but at slower rates than free cyanide. Because of the potential for violent reactions between hypochlorite and concentrated cyanide wastes, batch treatment by electrolytic oxidation and thermal destruction is recommended.

There are usually two stages for the chlorination process, although a one step process is feasible if monitored properly. In the first stage, sodium hypochlorite (NaOCl) is added to the wastewater either as a direct addition or as chlorine gas and sodium hydroxide. The gas addition is about half as expensive as direct NaOCl addition, but requires special handling equipment. Also in the first stage, the NaOCl oxidizes the Cyanide to Cyanate at a pH of 10 or more. Retention time can be up to 60 minutes. In the second stage, additional NaOCl is added to oxidize the remaining cyanide to carbon dioxide and nitrogen at a pH of 8.5. Second stage retention time is 30 to 60 minutes.

Alternatives to chlorination include: ozone oxidation, alternative chemistries (Hydrogen Peroxide and Calcium Hypochlorite), electrochemical oxidation, thermal oxidation, and precipitation.

Metals Removal
Hydroxide precipitation is the standard method used to remove heavy metals from metal finishing shop wastewater. The process consists of pretreatment, precipitation, flocculation, and settling.

Metal removal pretreatment is conducted to deal with compounds that are either resistant to the precipitation process or interfere with it. Chemicals used for pretreatment include Ferrous or Aluminum Sulfate, Sodium Hydrosulfite, Soda Ash and Sodium Dithiocarbamate (DTC). Pretreatment can sometimes be combined with precipitation and the combined process referred to as "*co-treatment*."

In precipitation, soluble metals are converted to insoluble metal hydroxides by adding caustic soda or lime. Other alkali - including magnesium hydroxide, calcium chloride, sodium carbonate, and sodium bicarbonate - can be added alone or in combination. The pH is initially adjusted to between 8.5 and 10.0. Batch residence time is usually 15 to 30 minutes. The pH set-point is determined by the species of metal being precipitated, since each metal hydroxide has its own characteristic solubility and some are amphoteric (solubility minimum occurs at a specific pH and increases sharply at higher or lower pH).

A compromise must be made establishing the set-point for wastewater containing multiple metal hydroxides. After precipitation, the level of residual dissolved solids depends on:

- **the pH set-point,**
- **the metal species present mixture in the wastewater, and**
- **the concentration of interfering compounds.**

Flocculation is accomplished by adding chemicals to form aggregates that are easily separated in a clarifier. Inorganic chemicals, such as alum and ferrous sulfate, can be used as well as polymer-type flocculants. The polymers take on the charge density and valence of the metal hydroxides and their structural length allows particles to aggregate together.

Clarification is the removal of insoluble particles by gravity settling. Blanket and plate type settlers are the most successful. The blanket type relies on mixing in a sludge blanket to promote particle growth and reduce the concentration of fine particles.

The plate settler has a series of inclined plates, between which the water flows. Insoluble particles impinge on the plate surface and slide down to the base of the separator. A clarifier in good operation will have from 5 - 50 mg/l of suspended solids in the overflow.

If the overflow is cloudy or contains suspended solids in excess of 50 mg/l, a polishing filter may be necessary.

Alternatives to clarifiers for removing metal hydroxides after precipitation are:

- **Direct filtration,**
- **Dissolved air flotation, and**
- **Membrane filtration.**

The dilute sludge generated from the precipitation/clarification process contains between 0.5 and 3% solids and must be dewatered. Thickening equipment can increase solids content to between 2 and 5 %, reducing the volume of sludge. This volume reduction decreases the capital and operating costs for subsequent sludge processing steps.
Sludge is further dewatered by using a mechanical devices or by thermal dehydration. The filter

press is the most popular type among the mechanical devices. The mechanical devices can produce a sludge with 10 to 60% solids and thermal dehydration can produce a waste material up to 90% solids.

Filter cake from filter press contains 10% - 60% solids. Sludge dryers can increase solids content to 90%.

Dehydration units have been the most frequently purchased devices for pollution prevention in recent years. The sludge generated from conventional treatment is classified as hazardous waste and must be dealt with under RCRA guidelines.

Effluent Polishing

Sand polish filters are used for removal of solids. Sand is layered in the filtration tank according to size with the fine particles at the top. Older filter designs use only the top few inches of sand as the fluid flows downward and the filtered solids form a mat on the surface.

Newer designs allow upward feed flow and continuous backwash.

Sand filters perform well, providing the optimum turnover rate has been established. Frequent backwashing is necessary to maintain the desired turnover rate since the surface area is smaller than with other pre-coated backwash filters.

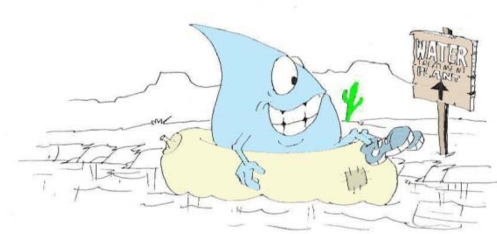
Top photograph, Effluent from secondary clarifiers.
Bottom photograph, Denitrification in a secondary clarifier.

Lab tech removing filter for TSS analysis.

Chapter 2 Highlights* *Memorize all of this section*

Physical Wastewater Treatment Process
Physical processes were some of the earliest methods to remove solids from wastewater, usually by passing wastewater through screens to remove debris and solids. In addition, solids that are heavier than water will settle out from wastewater by gravity. Particles with entrapped air float to the top of water and can also be removed. These physical processes are employed in many modern wastewater treatment facilities today.

Biological
In nature, bacteria and other small organisms in water consume organic matter in sewage, turning it into new bacterial cells, carbon dioxide, and other by-products. The bacteria normally present in water must have oxygen to do their part in breaking down the sewage. In the 1920s, scientists observed that these natural processes could be contained and accelerated in systems to remove organic material from wastewater. With the addition of oxygen to wastewater, masses of microorganisms grew and rapidly metabolized organic pollutants. Any excess microbiological growth could be removed from the wastewater by physical processes.

Chemical

Chemicals can be used to create changes in pollutants that increase the removal of these new forms by physical processes. Simple chemicals such as alum, lime or iron salts can be added to wastewater to cause certain pollutants, such as phosphorus, to floc or bunch together into large, heavier masses which can be removed faster through physical processes. Over the past 30 years, the chemical industry has developed synthetic inert chemicals known as polymers to further improve the physical separation step in wastewater treatment. Polymers are often used at the later stages of treatment to improve the settling of excess microbiological growth or biosolids.

Oxygen-Demanding Substances
Dissolved oxygen is a key element in water quality that is necessary to support aquatic life. A demand is placed on the natural supply of dissolved oxygen by many pollutants in wastewater. This is called biochemical oxygen demand, or BOD, and is used to measure how well a sewage treatment plant is working. If the effluent, the treated wastewater produced by a treatment plant, has a high content of organic pollutants or ammonia, it will demand more oxygen from the water and leave the water with less oxygen to support fish and other aquatic life.

Organic matter and ammonia are “oxygen-demanding” substances. Oxygen-demanding substances are contributed by domestic sewage and agricultural and industrial wastes of both plant and animal origin, such as those from food processing, paper mills, tanning, and other manufacturing processes. These substances are usually destroyed or converted to other compounds by bacteria if there is sufficient oxygen present in the water, but the dissolved oxygen needed to sustain fish life is used up in this break down process.

Grit Chamber
After the wastewater has been screened, it may flow into a grit chamber where sand, grit, cinders, and small stones settle to the bottom. Removing the grit and gravel that washes off streets or land during storms is very important, especially in cities with combined sewer systems.

Large amounts of grit and sand entering a treatment plant can cause serious operating problems, such as excessive wear of pumps and other equipment, clogging of aeration devices, or taking up capacity in tanks that is needed for treatment. In some plants, another finer screen is placed after the grit chamber to remove any additional material that might damage equipment or interfere with later processes. The grit and screenings removed by these processes must be periodically collected and trucked to a landfill for disposal or incinerated.

Pathogens
Disinfection of wastewater and chlorination of drinking water supplies has reduced the occurrence of waterborne diseases such as typhoid fever, cholera, and dysentery, which remain problems in underdeveloped countries while they have been virtually eliminated in the U.S. Infectious micro-organisms, or pathogens, may be carried into surface and groundwater by sewage from cities and institutions, by certain kinds of industrial wastes, such as tanning and meat packing plants, and by the contamination of storm runoff with animal wastes from pets, livestock and wild animals, such as geese or deer.

Humans may come in contact with these pathogens either by drinking contaminated water or through swimming, fishing, or other contact activities. Modern disinfection techniques have greatly reduced the danger of waterborne disease.

Nutrients
Carbon, nitrogen, and phosphorus are essential to living organisms and are the chief nutrients present in natural water. Large amounts of these nutrients are also present in sewage, certain industrial wastes, and drainage from fertilized land.

Conventional secondary biological treatment processes do not remove the phosphorus and nitrogen to any substantial extent -- in fact, they may convert the organic forms of these substances into mineral form, making them more usable by plant life.

When an excess of these nutrients over stimulates the growth of water plants, the result causes unsightly conditions, interferes with drinking water treatment processes, and causes unpleasant and disagreeable tastes and odors in drinking water.

The release of large amounts of nutrients, primarily phosphorus but occasionally nitrogen, causes nutrient enrichment which results in excessive growth of algae. Uncontrolled algae growth blocks out sunlight and chokes aquatic plants and animals by depleting dissolved oxygen in the water at night. The release of nutrients in quantities that exceed the affected waterbody' s ability to assimilate them results in a condition called eutrophication or cultural enrichment.

Inorganic and Synthetic Organic Chemicals
A vast array of chemicals are included in this category. Examples include detergents, household cleaning aids, heavy metals, pharmaceuticals, synthetic organic pesticides and herbicides, industrial chemicals, and the wastes from their manufacture. Many of these substances are toxic to fish and aquatic life and many are harmful to humans. Some are known to be highly poisonous at very low concentrations. Others can cause taste and odor problems, and many are not effectively removed by conventional wastewater treatment.

Lagoons
A wastewater lagoon or treatment pond is a scientifically constructed pond, three to five feet deep, that allows sunlight, algae, bacteria, and oxygen to interact. Biological and physical treatment processes occur in the lagoon to improve water quality. The quality of water leaving the lagoon, when constructed and operated properly, is considered equivalent to the effluent from a conventional secondary treatment system.

However, winters in cold climates have a significant impact on the effectiveness of lagoons, and winter storage is usually required. Lagoons have several advantages when used correctly. They can be used for secondary treatment or as a supplement to other processes. While treatment ponds require substantial land area and are predominantly used by smaller communities, they account for more than one-fourth of the municipal wastewater treatment facilities in this country. Lagoons remove biodegradable organic material and some of the nitrogen from wastewater.

Stabilization Ponds
The proper operation of a stabilization pond with surface aeration includes frequent cycling of aerators. Allowing the water surface to fluctuate in stabilization ponds will help to control shoreline aquatic vegetation. Frequent wind for mixing will have the greatest positive effect on the operation of a stabilization pond. Planting low-growing spreading grass would be the best method to prevent erosion by surface runoff to a pond or dike not exposed to wave action. Stabilization ponds will most likely have problems with mosquitoes if emergent weeds are allowed to grow near the shore. Discharge restricted to specific periods best describes the batch operation of a lagoon system.

Sequencing Batch Reactors (SBR) are a variation of the activated sludge process where all treatment processes occur in one tank that is filled with wastewater and drawn down to discharge after treatment is complete.

Settleable Solids are solids that are heavier than water and settle out of water by gravity.

Soil Absorption Field is a subsurface area containing a trench or bed with a minimum depth of 12 inches of clean stones and a system of piping through which treated wastewater effluent is distributed into the surrounding soil for further treatment and disposal.

Slow Rate Land Treatment involves the controlled application of wastewater to vegetated land at a few inches of liquid per week.

Suspended Solids are the small particles suspended in water or wastewater.

Trickling Filter is a fixed film process that involves a tank, usually filled with a bed of rocks, stones or synthetic media, to support bacterial growth used to treat wastewater.

Ultraviolet Radiation (UV) is a disinfection process where wastewater is exposed to UV light for disinfection.

Virus is the smallest form of a pathogen which can reproduce within host cells.

Wastewater Treatment Plant is a facility involving a series of tanks, screens, filters, and other treatment processes by which pollutants are removed from water.

Suggested Control and Operation Methods* Memorize all of this section

$Ca(OH)_2$ has been used in wastewater treatment for many years. Usually it was used as a coagulant, especially treating industrial waste. The correct name for $Ca(OH)_2$ is Hydrated lime.

A typical set point to start backwashing a rapid-sand filter is at 7 feet of head loss.

Air to solids (**A/S**) ratio is important in process control and could affect a dissolved air flotation **(DAF)** unit.

COD is an alternative to BOD for measuring the pollutional strength of wastewater. Bearing in mind that the BOD and COD tests involve separate and distinct reactions, the primary disadvantage of the COD test is that Chloride may interfere with the chemical reaction.

A development of white biomass over most of a Rotating Biological Contactor (**RBC**) disc area could be resolved by adjusting baffles between first and second stages to increase total surface area in the first stage.

By adding H_2SO_4, at the headworks, this would lower the pH. Highly acidic or alkaline wastes can be very hazardous and dangerous to personnel, treatment processes, and equipment.

Hydrogen sulfide generation is greatest when temperatures are above 30°C.

If the motor bearings on a RBC are running above 200°F, the following corrective actions could be taken: Lubricate bearings per manufacturer's instruction, check torque and alignment of bearings and Make sure the shaft is properly aligned.

Maintenance of the sulfur dioxide system should be part of a preventive maintenance program. It is recommended that the sulfonators be cleaned every year or more frequently if necessary.

Some aeration tubing systems require cleaning on a weekly basis. Anhydrous hydrogen chloride can be used to remove deposits of carbonate on the tubing slits and biological slime from inside the tubing.

Temperature or weather conditions promoting growth may cause excessive algae in the effluent of a pond.
The electrical potential required to transfer electrons from one compound or element to another is called: Oxidation reduction potential.

The Secchi disc is used to determine the clarity of a clarifier.

The suggested schedule for lubricating all valves stems, inspecting and greasing motor bearings is semi-annually.

If your plant is designed with a series of finishing ponds and the operator notifies you that there is excessive BOD in the effluent that has the potential to cause your plant to be out of compliance. You've calculated the organic loading and it indicates an overload. You can correct this problem by using pumps to recirculate the pond contents.

Hydrogen peroxide has been used as an oxidant to control odors. Inability to treat ammonia is one the disadvantages of using hydrogen peroxide.

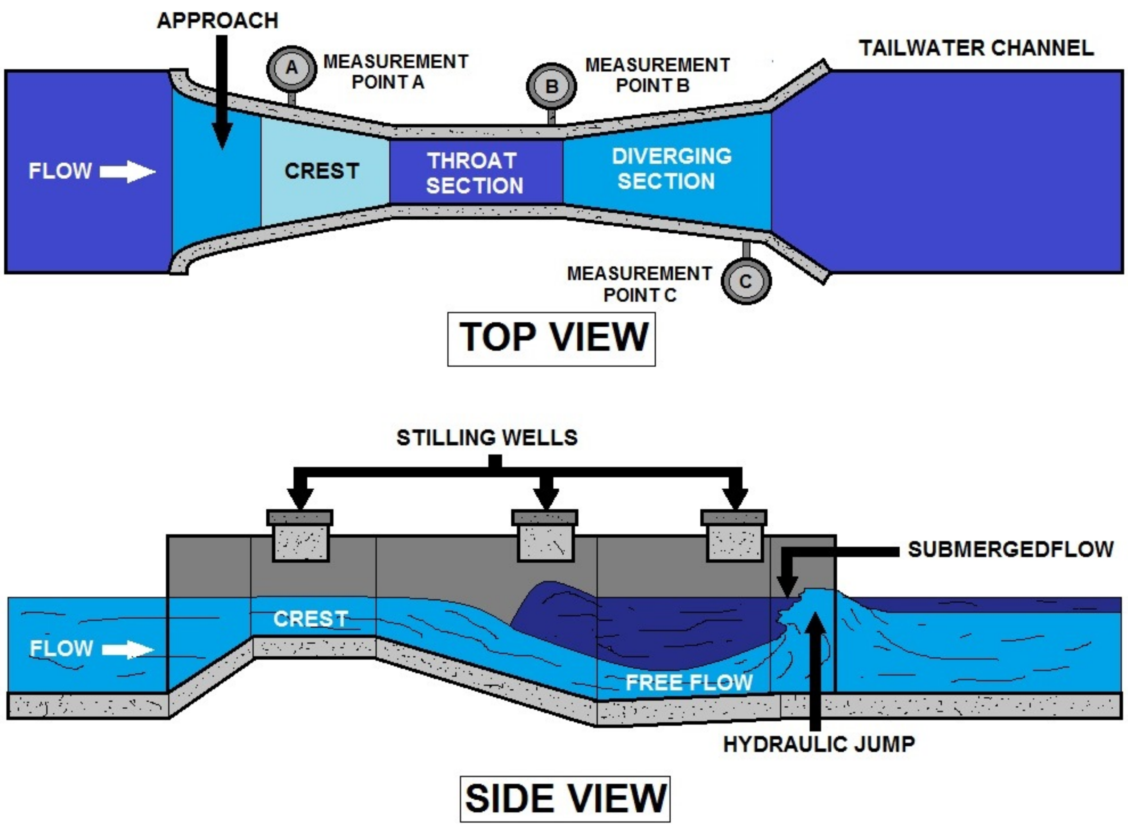
Operators should be familiar with a pond's characteristics at various times of the day. The pH and the dissolved oxygen is at the lowest point at sunrise.

Flow measurement devices are most commonly at the plant headworks.

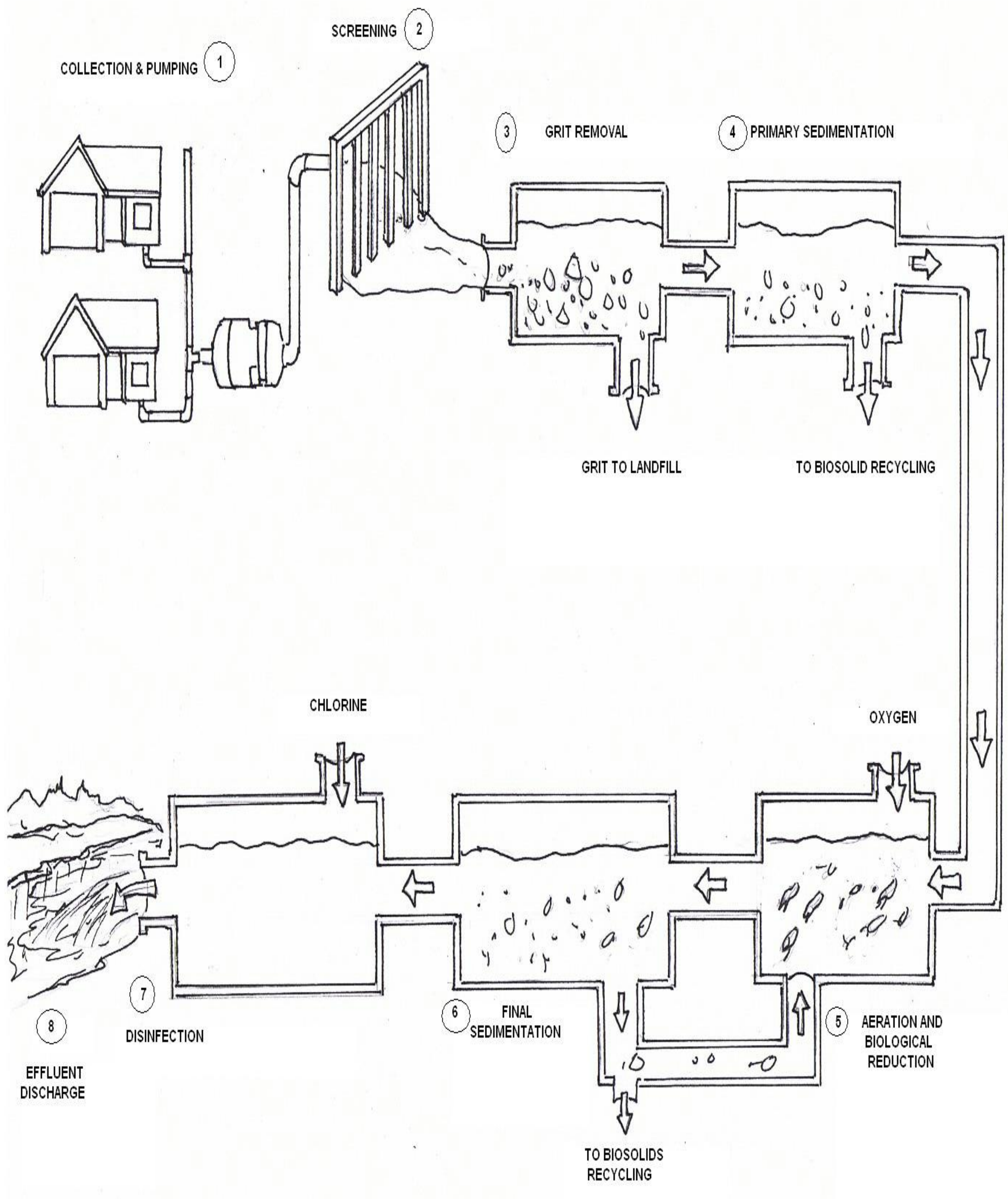
A Parshall flume is a common flow measurement method and is most commonly used in wastewater treatment measurement.

The process of adding a chemical compound drop by drop until a desired change occurs is known as Titration.

The more familiar an operator becomes with the operation of a pond, the more accurate they become with visual observations. A deep green sparkling color in the wastestream usually indicates industrial facilities or operations.



PARSHALL FLUME



TREATMENT OF SEWAGE DIAGRAM

Activated Sludge Section Chapter 3

Memorize the Key Terms to pass your exam.

Aerobic (AIR-O-bick)- A condition in which free or dissolved oxygen is present in the aquatic environment.

Aerobic Bacteria – Bacteria which will live and reproduce only in an environment containing oxygen. **(Aerobes)**

Anaerobic (AN-air O-bick) - A condition in which *"free"* or dissolved oxygen is not present in the aquatic environment.

Anaerobic Bacteria – Bacteria that thrive without the presence of oxygen. **(Anaerobes)**

Saprophytic bacteria – Bacteria that break down complex solids to volatile acids.

Methane Fermenters – Bacteria that break down the volatile acids to methane (CH_4) carbon dioxide (CO_2) and water (H_2O).

Oxidation – The addition of oxygen to an element or compound, or removal of hydrogen or an electron from an element or compound in a chemical reaction. The opposite of reduction.

Reduction – The addition of hydrogen, removal of oxygen or addition of electrons to an element or compound. Under <u>anaerobic</u> conditions in wastewater, sulfur compounds or elemental sulfur are reduced to H_2S or sulfide ions.

Activated Sludge Methods

We have some wastewater treatment plants that grow the microorganisms (Bugs) in large tanks. To have enough oxygen in the tanks we add oxygen by blowing air into the tank that is full of wastewater and microorganisms. The air is bubbled in the water and mixes *"the bugs"* and food and oxygen together. When we treat wastewater this way, we call it the activated sludge method. With all of this food and air the microbes grow and multiply very rapidly.

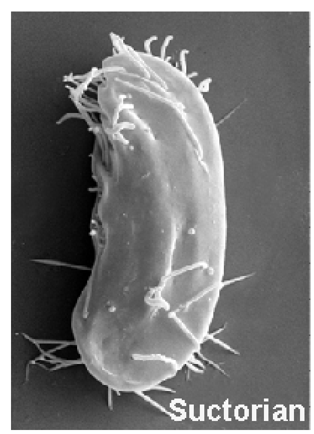
Pretty soon the population of bugs gets too large and some of them need to be removed to make room for new bugs to grow. We remove the excess bugs by sedimentation in the same kind of tanks used for primary treatment. In the tank, the bugs sink to the bottom and we remove them. The settled bugs are also called waste activated sludge. The waste sludge is treated separately, and the remaining wastewater is now much cleaner. In fact, after primary and secondary treatment, about 85% or more of all pollutants in the wastewater have been removed and it goes on to Disinfection.

Bugs

Four (4) groups of bugs do most of the *"eating"* in the activated sludge process. The first group is the bacteria which eat the dissolved organic compounds. The second and third groups of bugs are microorganisms known as the free-swimming and stalked ciliates. These larger bugs eat the bacteria and are heavy enough to settle by gravity. The fourth group is a microorganism, known as Suctoria, which feed on the larger bugs and assist with settling.

The interesting thing about the bacteria that eat the dissolved organics, is that they have no mouth. The bacteria have an interesting property--their "fat reserve" is stored on the outside of their body. This fat layer is sticky and is what the organics adhere to. Once the bacteria have "contacted" their food, they start the digestion process.

A chemical enzyme is sent out through the cell wall to break up the organic compounds. This enzyme, known as hydrolytic enzyme, breaks the organic molecules into small units which are able to pass through the cell wall of the bacteria.



In wastewater treatment, this process of using bacteria-eating-bugs in the presence of oxygen to reduce the organics in water is called activated sludge. The first step in the process, the contact of the bacteria with the organic compounds, takes about 20 minutes. The second step is the breaking up, ingestion and digestion processes, which takes four (4) to 24 hours.

The fat storage property of the bacteria is also an asset in settling. As the bugs "bump" into each other, the fat on each of them sticks together and causes flocculation of the non-organic solids and biomass. From the aeration tank, the wastewater, now called mixed liquor, flows to a secondary clarification basin to allow the flocculated biomass of solids to settle out of the water. The solids biomass, which is the activated sludge, contains millions of bacteria and other microorganisms and is used again by returning it to the influent of the aeration tank for mixing with the primary effluent and ample amounts of air.

Basic System Components of Activated Sludge

In the basic "activated" sludge process, emphasis on "*activated*", the wastewater enters an aerated tank (the dome) where previously developed biological floc particles are brought into contact with the organic matter (foot-long hot dogs) of the wastewater.

The organic matter is a carbon and an energy source for the bug's cell growth and is converted into cell tissue and the oxidized end product is mainly carbon dioxide, CO_2. The substance in the sports dome is referred to as mixed liquor. The stuff in the mixed liquor is suspended solids and consists mostly of microorganisms, suspended matter, and non-biodegradable suspended matter (*MLVSS*).

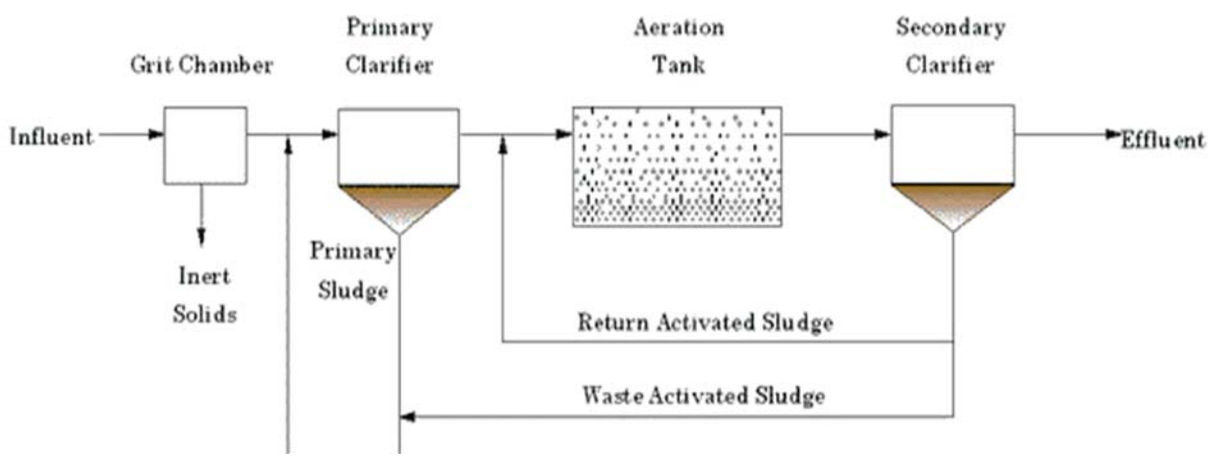
The make-up of the microorganisms are around 70 to 90% organic and 10 to 30% inorganic matter. The makeup of cells varies depending on the chemical composition of the wastewater and the specific characteristics of the organisms in the biological mass. The picture below shows the basic outline of an aeration tank. Just remember that pretreatment is crucial prior to the activated sludge process.

Before we dive into the tank, in the space provided, list three key components of pretreatment (headworks) and how each benefits the process.

1.

2.

3.



Back to the mixed liquor, as it leaves the aeration tank, it usually goes to a clarifier to separate the suspended solids (SS) from the treated wastewater. The concentrated biological solids then are recycled back to the aeration tank, as returned activated sludge (RAS), to maintain a concentrated population of bugs (the team players) to treat the wastewater.

Before we start the game we need to make sure we have a stadium and all components are in place and operating properly. In the space provided, define the following terms: ***See Glossary in Rear***.

Anaerobic:

Aerobic:

DO:

BOD:

COD:

Process Design

Let's first look at the different aeration tank designs and how they function. We will focus on the following:

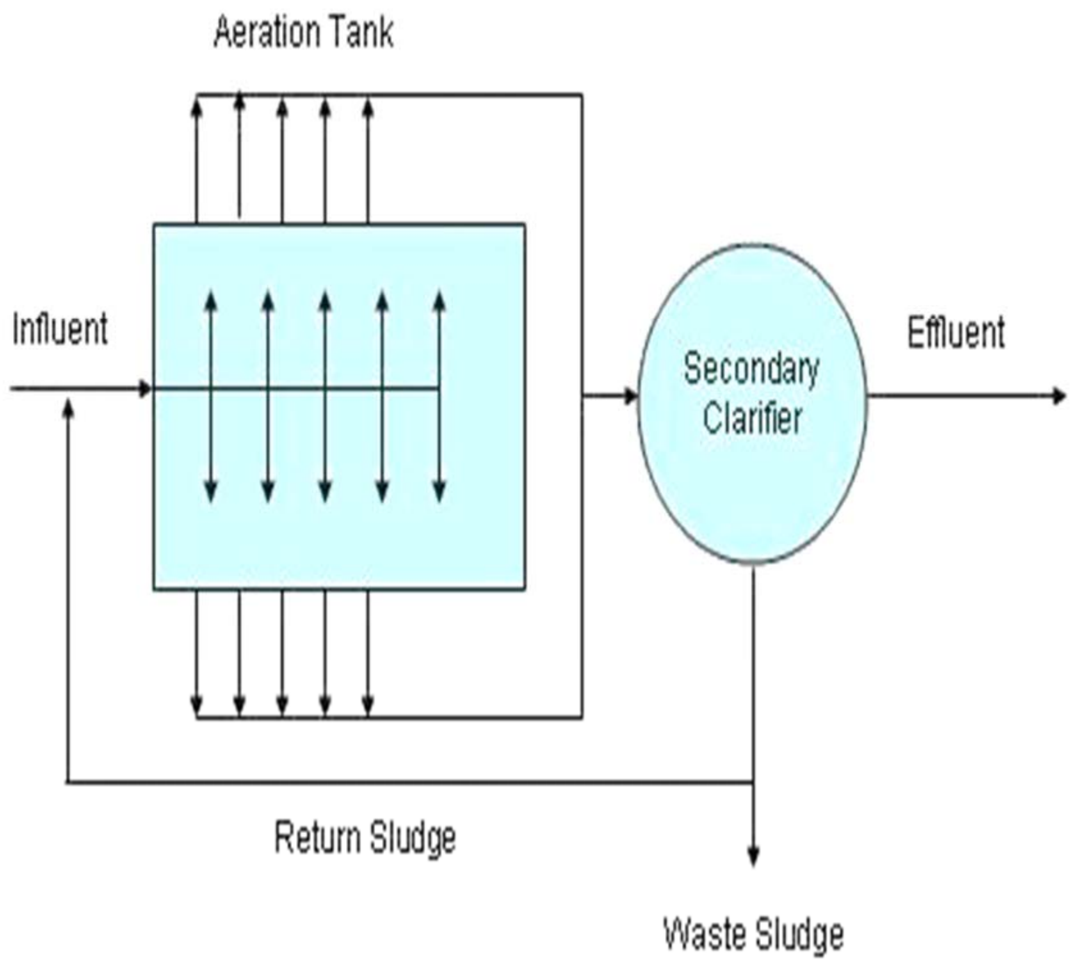
- ✓ Complete Mix Activated Sludge Process
- ✓ Plug Flow Activated Sludge Process
- ✓ Contact Stabilization Activated Sludge Process
- ✓ Step Feed Activated Sludge Process
- ✓ Extended Aeration Activated Sludge Process
- ✓ Oxidation Ditch Activated Sludge Process
- ✓ High Purity Oxygen Activated Sludge Process

Complete Mix Activated Sludge Process

In a complete mix activated sludge process, the mixed liquor is similar throughout the aeration tank. The operating characteristics measured in terms of solids, oxygen uptake rate (OUR), MLSS, and soluble BOD 5 concentration are identical throughout the tank.

Because the entire tank contents are the same quality as the tank effluent, there is a very low level of food available at any time to a large mass of microorganisms. This is the major reason why the complete mix modification can handle surges in the organic loading without producing a change in effluent quality. The type of air supply used could be either diffused air or a mechanical aerator.

Complete mix process may be resistant to shock loads but is susceptible to filamentous growths.

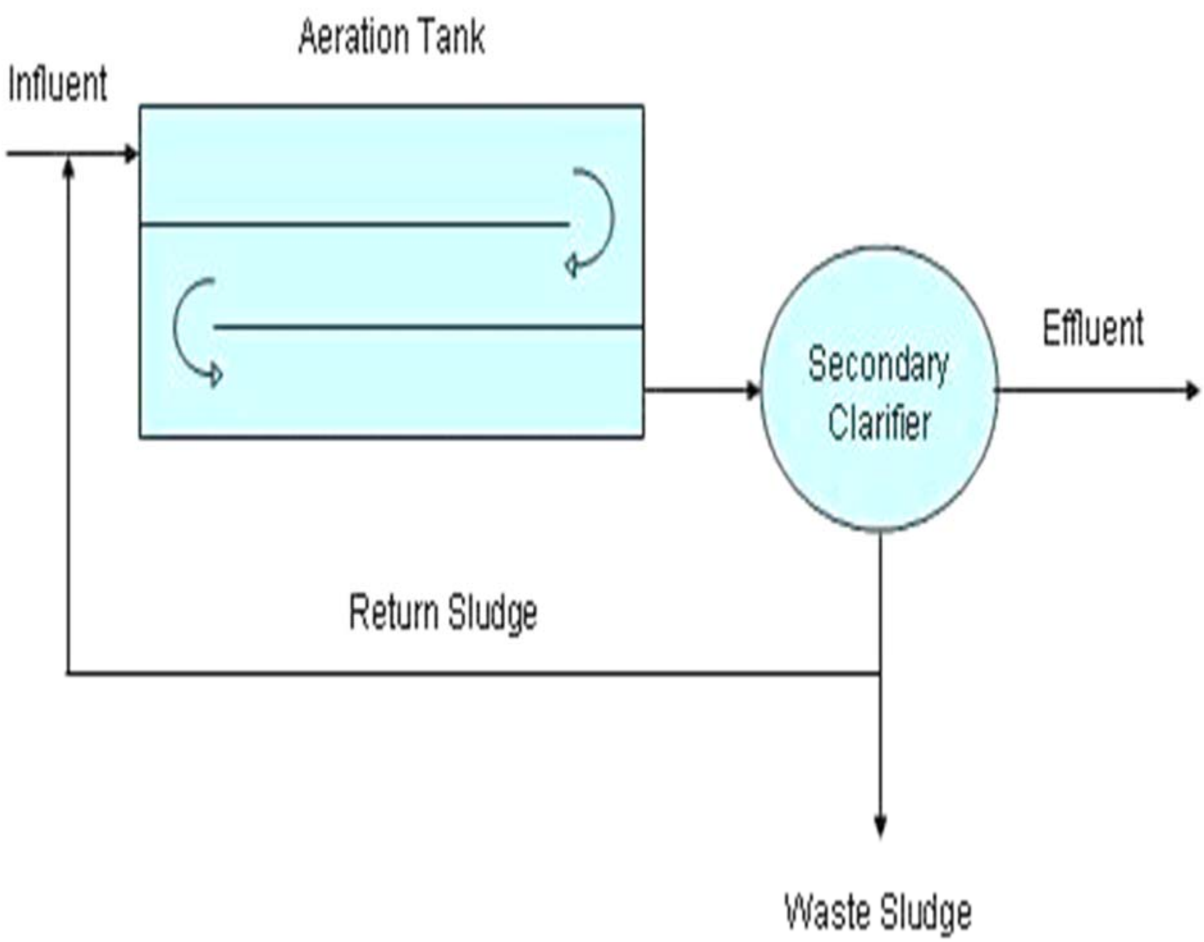


Plug Flow Activated Sludge Process

Plug flow tanks are the oldest and most common form of aeration tank. They were designed to meet the mixing and gas transfer requirements of diffused aeration systems. One characteristic of the plug flow configuration is a very high organic loading on the MLSS in the initial part of the tank. The loading is then reduced and the organic material in the raw wastewater is oxidized.

At the end of the tank, depending on detention time, the oxygen consumption may primarily be the result of endogenous respiration or nitrification; we will talk more about this a little later. The same characteristics are present when the aeration tank is partitioned into a series of compartments.

Each compartment must have the oxygen supply and design to meet the individual compartment needs. Plug flow configurations have the ability to avoid "*bleed through*" or the passage of untreated organics during peak flow. These configurations are often preferred when high effluent DO's are sought because only a small section of the tank will operate at a high DO. In a complete mix configuration, the entire tank must operate at the elevated DO.



Contact Stabilization Activated Sludge Process

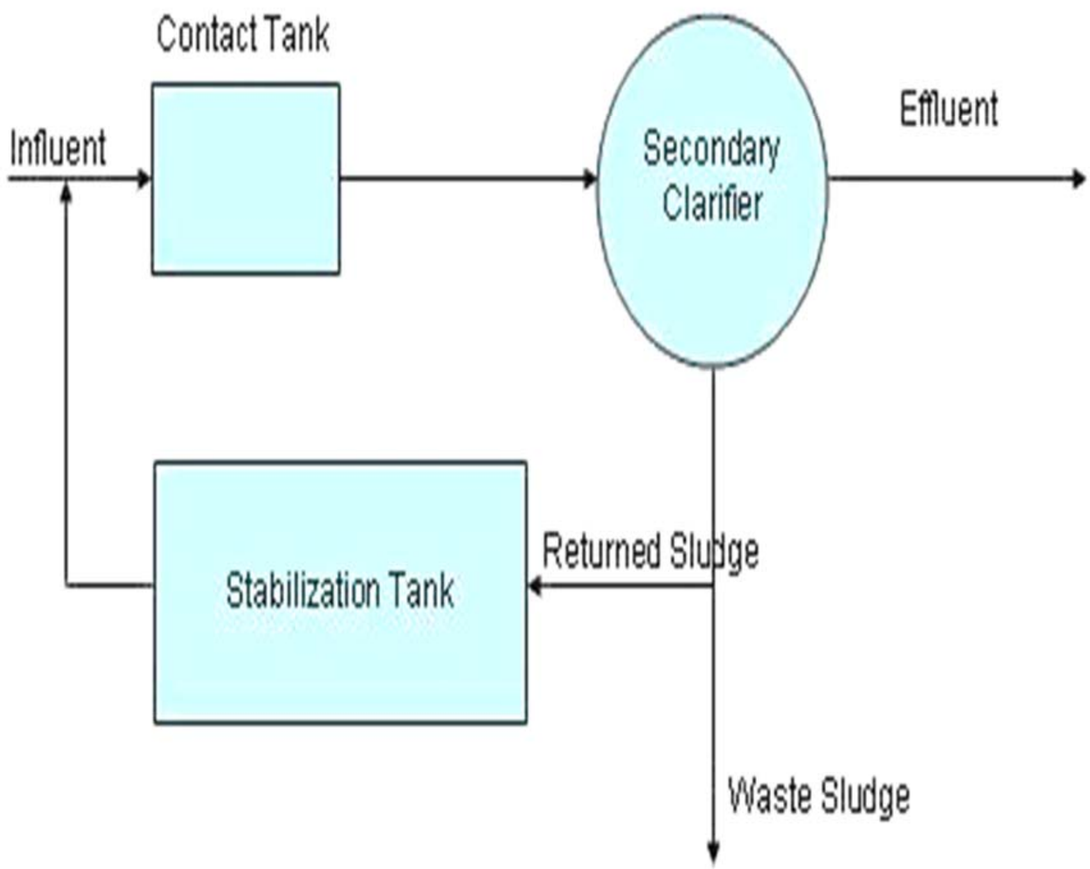
Contact stabilization activated sludge is both a process and a specific tank configuration. The contact stabilization encompasses a short-term contact tank, secondary clarifier, and a sludge stabilization tank with about six times the detention time used in the contact tank.

Contact stabilization is best for smaller flows in which the MCRT desired is quite long.

Therefore, aerating return sludge can reduce tank requirements by as much as 30 to 40 % versus that required in an extended aeration system. The volumes for the contact and stabilization tanks are often equal in size and secondary influent arrangements.

What does this all mean?

They can be operated either in parallel as an extended aeration facility or as a contact stabilization unit. This flexibility makes them suitable for future expansion to conventional activated sludge, without increasing the aeration tank, by merely adding more clarification capacity.



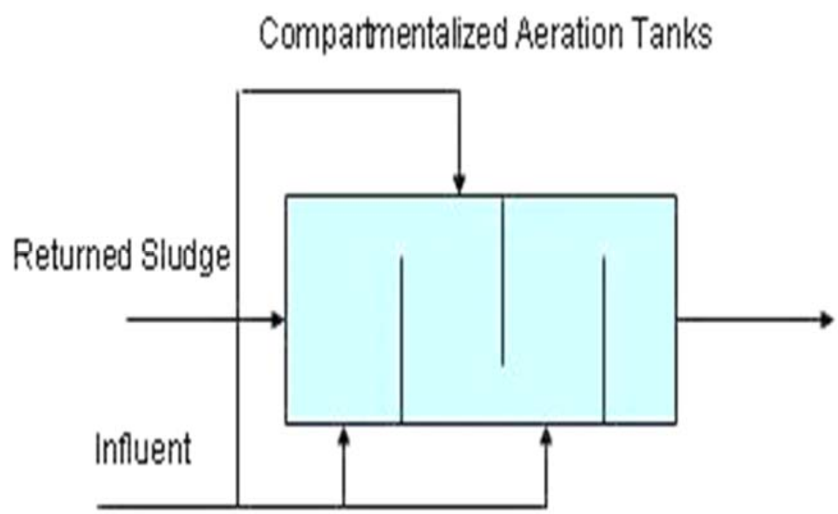
Step Feed Activated Sludge Process

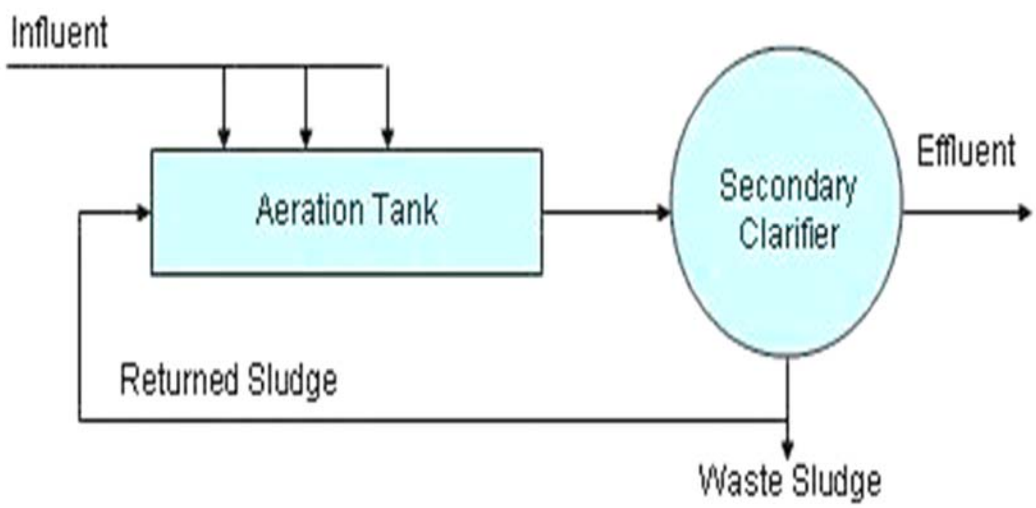
Step feed is a modification of the plug flow configuration in which the secondary influent is fed at two or more points along the length of the aeration tank.

With this arrangement, oxygen uptake requirements are relatively even and the need for tapered aeration is eliminated.

Step feed configurations generally use diffused aeration equipment. The step feed tank may be either the long rectangular or the folded design. Secondary influent flow is added at two or more points to the aeration tank usually in the first 50 to 75% of the length.

It is also possible to use the same process approach by compartmentalizing the tank and directing flow lengthwise through the compartments. Usually the last compartment does not receive any raw waste.





Extended Aeration Activated Sludge Process

The extended aeration process uses the same flow scheme as the complete mix or plug flow processes but retains the wastewater in the aeration tank for 18 hours or more.

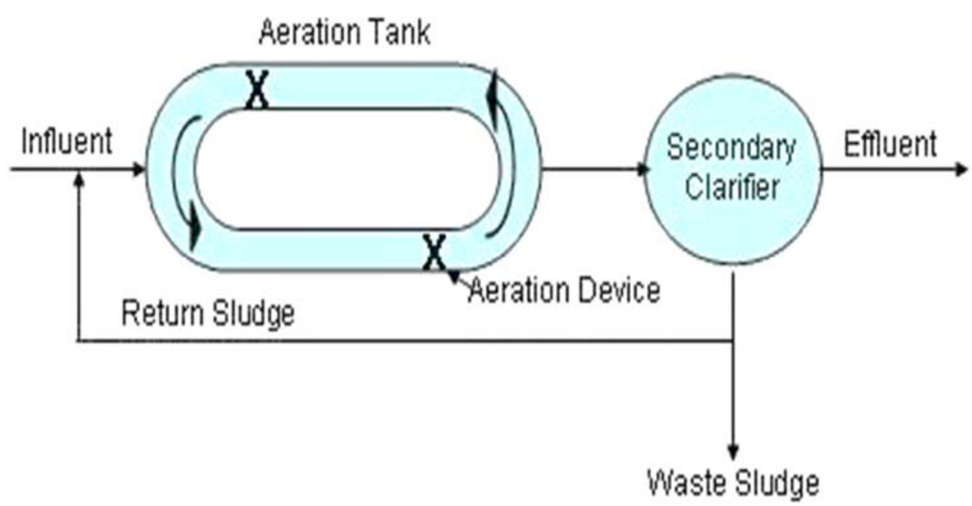
This process operates at a high MCRT (low F/M) resulting in a condition where there is not enough food in the system to support all of the microorganisms present. The microorganisms therefore compete very actively for the remaining food and even use their own cell structure for food.

This highly competitive situation results in a highly treated effluent with low sludge production. (Many extended aeration systems do not have primary clarifiers and they are package plants used by small communities.)

The main disadvantages of this system are the large oxygen requirements per unit of waste entering the plant and the large tank volume needed to hold the wastes for the extended period.

Oxidation Ditch Activated Sludge Process
The oxidation ditch is a variation of the extended aeration process. The wastewater is pumped around a circular or oval pathway by a mechanical aerator/pumping device at one or more points along the flow pathway. In the aeration tank, the mixed liquor velocity is maintained between 0.8 and 1.2 fps in the channel to prevent solids from settling.

Oxidation ditches use mechanical brush disk aerators, surface aerators, and jet aerator devices to aerate and pump the liquid flow. Combination diffused aeration and pumping devices are commonly used in Europe.



High Purity Oxygen Activated Sludge Process

The most common high purity oxygen activated sludge process uses a covered and staged aeration tank configuration. The wastewater, return sludge, and oxygen feed gas enter the first stage of this system and flow concurrently through the tank.

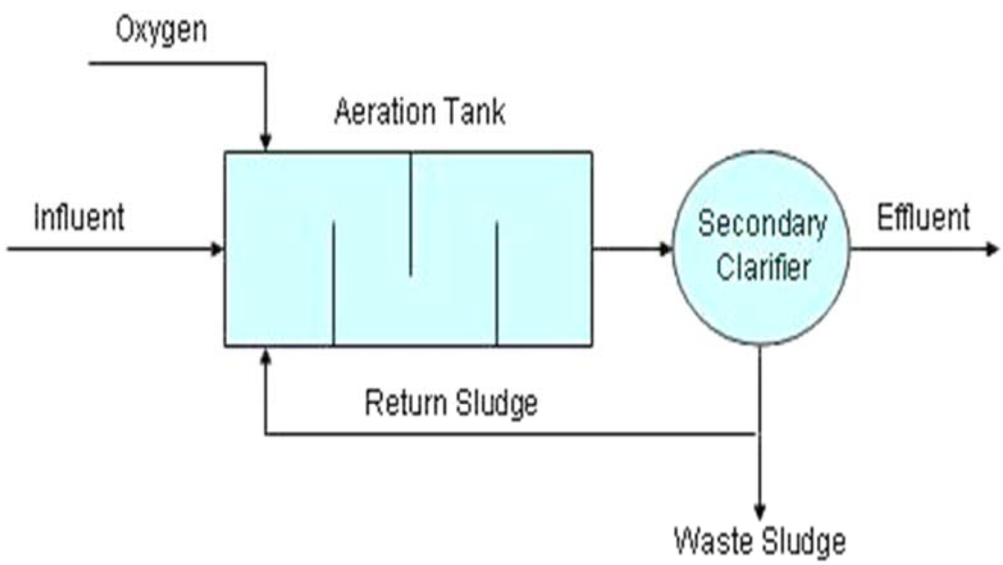
The tanks in this system are covered to retain the oxygen gas and permit a high degree of oxygen use. A prime advantage of the staged reactor configuration of the oxygenation system is the system's ability to match the biological uptake rate with the available oxygen gas purity.

The dissolution of oxygen and the mixing of the biological solids within each stage of the system are accomplished with either surface aeration devices or with submerged turbine-aeration systems. The selection of either of these two types of dissolution systems largely depends on the aeration tank geometry selected.

The particular configuration of oxygenation tank selected for a given system, that is, size of each stage, number of stages per aeration tank, and number of parallel aeration tanks, is determined by several parameters including waste characteristics, plant size, land availability, and treatment requirements.

Other than the aeration tank, the other key factor in an oxygen activated sludge system is the oxygen gas source. There are three sources of oxygen supply: liquid oxygen storage, cryogenic oxygen generation, and pressure-swing adsorption generation.

The first of these requires no mechanical equipment other than a storage tank that is replenished by trucked-in liquid oxygen. This method is economically feasible for small (less than 4 mgd) or temporary installations.



Aeration Section

There are several designs and applications for aerators:

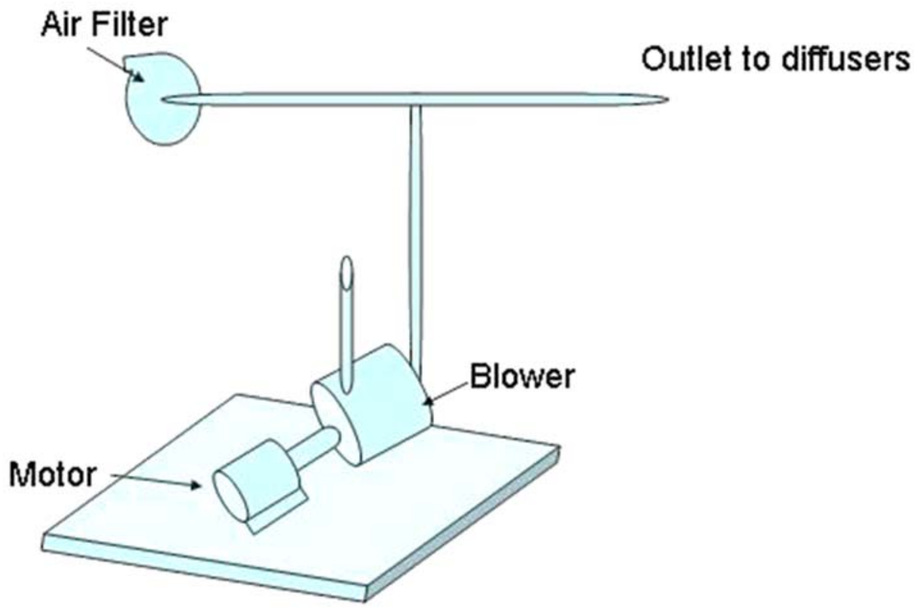
- ✓ Diffused Aerators
- ✓ Mechanical Surface Aerators
- ✓ Submerged Turbine Aerators

The two most common types of aeration systems are subsurface diffusion and mechanical aeration. Diffused air systems have been around longer than you. Opened tubes were used or perforated pipes located at the bottom of aeration tanks. But a more efficient process was desired, born to the process, porous plate diffusers. In the diffused air system, compressed air is introduced near the bottom of the tank. Let's look at the definition for diffused aeration:

"The injection of a gas, air or oxygen, below a liquid surface."

There are a variety of hybrid air diffusion systems used in the process; we will focus on the basic components.

The following diagram highlights the main parts of the diffused aeration system.



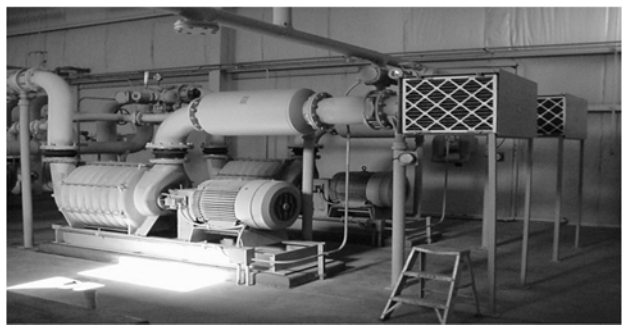
Blowers

In the diffused aeration system, blowers are used to circulate the tank's contents by the air-lift effect. The air filter on the blower removes dirt from the air, and therefore helps prevent diffuser clogging. Before all this begins we need a power source to drive the blower. Usually electric motors are used but in remote locations, gas or diesel engines can be used as well. In some states, solar energy is available to provide the power.

As illustrated in the picture below, the rotation of the motor shaft is transferred to the blower shaft by means of a flexible coupling or through drive belts. The blowers that we will refer to are centrifugal blowers.

The centrifugal blower works like a centrifugal pump or a fan. Rotating impellers or fans cause movement of the air through the blowers. You have an intake side that takes in the air and the discharge side the forces the air out. The number of impellers you have will determine if it is a multi-stage or single stage blower. The picture below illustrates the major components of a centrifugal blower.

A lobe blower utilizes positive displacement; it also has an intake and a discharge side. The lobes turn in opposite directions in the casing. As they turn, the air is drawn in through the blower inlet and is trapped. The lobes keep turning, open the blower discharge, and force the trapped air through the outlet. Usually an electric motor drives the blower with belt pulleys or flexible couplings.



Before we continue let's review what you just read about the blowers and motors.

1. What are two ways that the motor and the blowers can be attached?

2. When using flexible couplings, what are some maintenance concerns to consider?

Blowers may be provided with additional equipment. For example, safeguards can be installed to protect equipment and operators. Temperature sensors can be used for bearing housing; vibration sensors protect the unit by shutting it down if limits are exceeded. Condensation drains should be provided on the bottom of blowers to drain off any accumulated moisture.

The compressed air from the blowers moves into a system of pipes and valves. The amount of air supplied from the blower is controlled by regulating valves mounted on the intake and/or discharge side of the blower. Usually butterfly valves are used and depending on your budget, you could have manually operated or use automation.

Blowers usually discharge to a common manifold, so check valves are installed at the discharge of each blower. The intake and discharge pipes are called the air mains. They are connected by a flexible connection to allow for vibration and heat expansion in the piping. In the winter months, the best place to be is in the blower room.

There is a pressure relief valve on the discharge manifold to protect the blower from excessive back pressure overload. When this occurs the operator will be awakened on the midnight shift. Pressure gauges are used in several areas on the discharge side of the blowers. In some cases, you may see them on the intake side for use in calculations of pump efficiency. On the intake side, where air is supplied, you would have some type of filtering to remove dirt particles that could clog the diffusers. It also protects the blowers from excessive wear. Replaceable filter units are the simplest for operations. Bag house dust collectors are bulky and expensive, though maintenance may be less. In some cases, electrostatic precipitators may be an advantage, shocking if operators are not careful, in areas of poor air quality. Most systems have utilized pressure drop measuring to indicate when it is time to replace or clean the units.

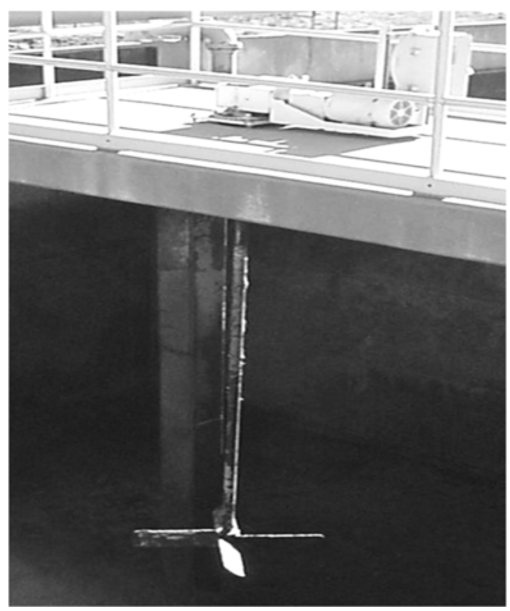
Diffusers

There are many different design layouts and patterns of diffuser placement. Systems that allow longer and more complete contact between the air and the liquid are preferred. We will focus on fine bubble (porous) diffusers and coarse bubble (nonporous). Coarse bubble diffusion devices or large-hole diffusers produce larger bubbles than porous plates, porous tubes, or synthetic socks. The larger bubbles provide less surface area for air-liquid contact and will result in less oxygen transfer efficiency than that obtained with fine bubble diffusers.

Answer this question:

An air stone like the ones used in aquariums is a good example of a?
A. ***Porous material***
B. ***Nonporous material***

Mechanical Aeration



There are several main types of mechanical aeration devices. The floating and fixed bridge aerators are quite common. Some use a blade to agitate the tank's surface and disperse air bubbles into the aeration liquor. Others circulate the mixed liquor by an updraft or downdraft pump or turbine. This action produces surface and subsurface turbulence, while diffusing air through the mixed liquor.

The motor speeds are usually in the 1800 rpm range. **This speed is reduced to the 30 to 70 rpm range with** gear reducers.

Most vertical motors are mounted on a gear reduction unit as seen in the picture on the right.

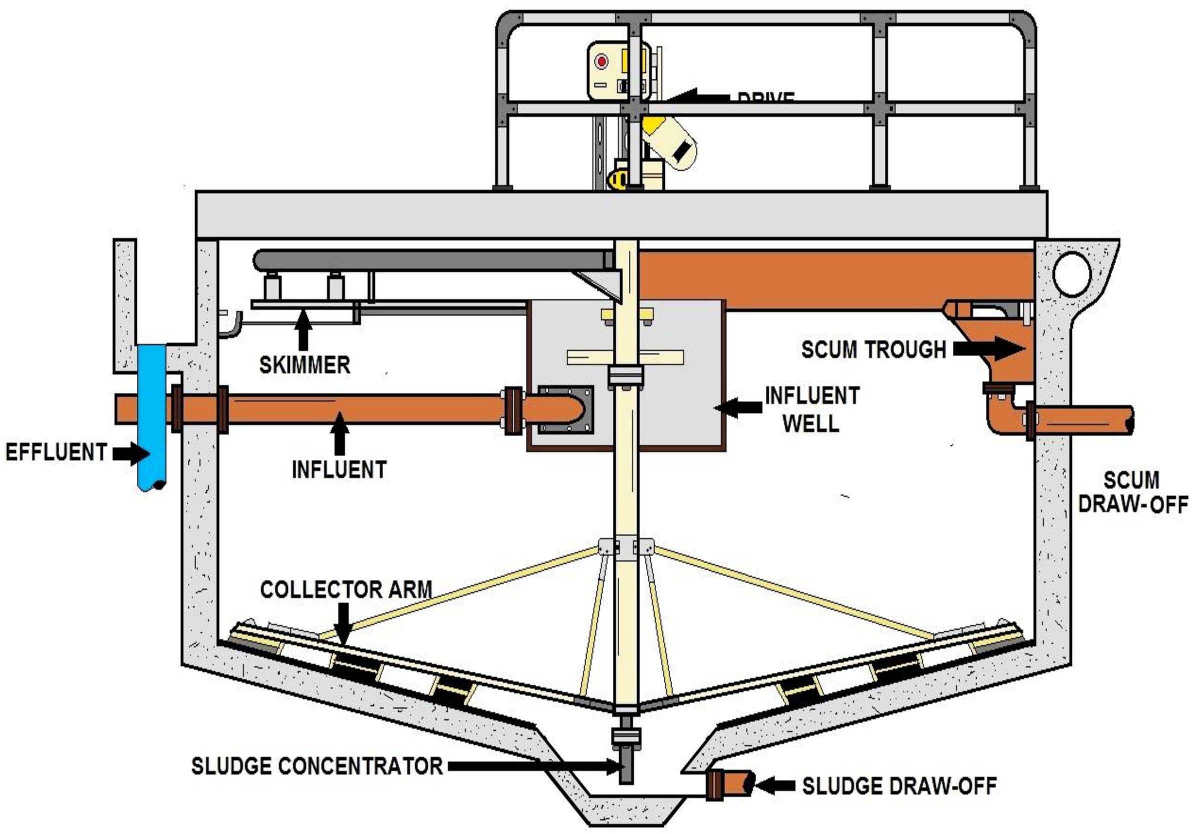
The impeller drive shaft can be enclosed in a housing connected directly to the gear box. There is a bearing at the bottom of the shaft that steadies and aligns this shaft. This bearing needs lubrication; always check your manufacturers recommendations.

Some plants use an oxidation ditch in which rotating brushes, blades, or disks are rotated, partially submerged, in the mixed liquor. The turbulence produced traps the air bubbles and keeps the mixed liquor in motion.

Other systems use both compressed air and a mechanical device to trap the bubbles. In one such system, submerged turbine aeration, air is injected below a rotating turbine blade that shears and disperses the air.

Submerged turbine applications have also used a draft tube operating in a downdraft-pumping mode.

Jet and Aspirator Aerators provide oxygen transfer by mixing pressurized air and water within a nozzle and then discharging the mixture into the aeration tank. The velocity of the discharged liquid and the rising air plume provide the necessary mixing action.



CIRCULAR CLARIFIER AND COLLECTOR MECHANISM

Secondary Clarifiers

Because microorganisms are continually produced, a way must be provided for wasting some of the generated biological solids produced. This is generally done from the round or rectangular shaped Clarifiers.

Let's first look at the components of a rectangular clarifier. Most are designed with scrapers on the bottom to move the settled activated sludge to one or more hoppers at the influent end of the tank. It could have a screw conveyor or a 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.

The activated sludge is removed from the hopper(s) and returned by a sludge pump to the aeration tank or wasted. Since we mentioned return and wasted what do the following terms represent?

RAS:

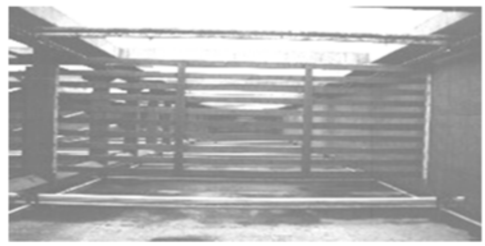
WAS:

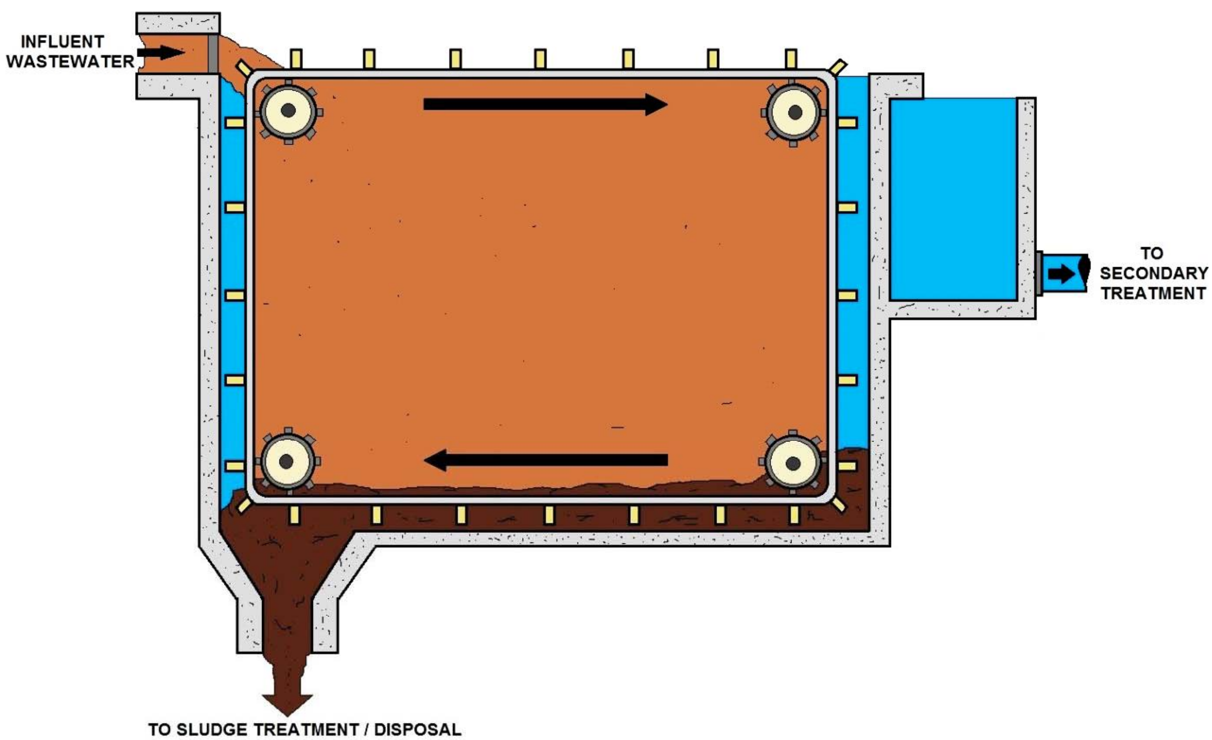
Scum Removal Equipment

Scum removal equipment is desirable on secondary clarifiers. Skimmers are either of the type that rotates automatically or manually. The most important thing to consider is the sludge and scum collection mechanism. We will talk about "*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.





**WASTEWATER SLUDGE REMOVAL
(CHAIN AND FLIGHT SKIMMING BASIN)**

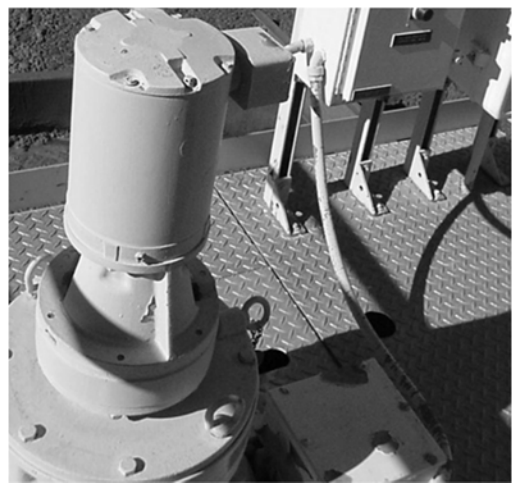
Scum Removal Equipment

In some circular or square tanks rotating scrapers are used. The diagram below shows typical Scum removal equipment.

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

There is also some related equipment that we will consider briefly. Let's look at the drive unit first. There are three main parts to the drive unit: the motor (or gear motor); the gear reducer; and the turntable.

The motor is connected to a gear reduction unit which is commonly connected to additional gearing. The drive cage is rotated around a center column by the motor and gear reduction unit. Although the drive motor runs at about 1800 rpm, the gear reducer lowers the output speed so that the sludge collector mechanism goes through one revolution every 20 to 30 minutes. Usually the motors used on clarifier mechanisms are totally enclosed, fan cooled motors, suitable for outside operation.



The horsepower of the motor is dependent on the size of the clarifier.

The motor drives the chain and sprocket which drives the worm gear. The worm gear drives the gear that is mounted on a shaft that drives the turntable.

The motor shaft speed is reduced by a series of gear reducers.

We looked at the main parts of the drive unit; now let's take a look at the sludge collector and the scum removal system mechanism. The main parts of the unit are: the rake arm; the scraper blades; the adjustable squeegees; the surface skimmer; the scum baffles; and the scum box.

The surface skimmer rotates at the same speed as the collector mechanism and is usually supported by the collector rake arm. The scum baffle prevents scum from flowing over the effluent weir. The surface skimmer collects the scum and deposits it in the scum box.

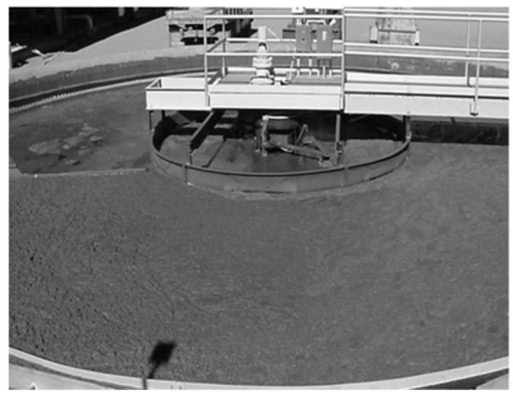
The stilling well or influent baffle projects above the liquid and directs the influent downwards to assist in the settling of suspected solids and reduce short circuiting. Another important part of the secondary clarifier is the effluent weir, launder and pipe.

An effluent weir goes around the circumference of the tank and allows clarified liquid to flow evenly from the tank. The effluent launder collects the tank overflow and takes it to a low point in the launder where a pipe is used to take the effluent to the chlorine contact basin or other means of treatment.

Some clarifiers may have a scum trough heater. The scum removal system rotates around the clarifier at a very slow rate. In subfreezing temperatures, the scum box and pipe could freeze. This problem can be overcome by using immersion heaters, or putting infrared lamps over the scum box. Some clarifiers are covered.

As you have read, depending on the design and operation of the process, activated sludge has several interrelated components:

1. Single aeration tank or multiple aeration tanks designed for completely mixed or plug flow.



2. An aeration source to provide adequate oxygen and mixing: sources can be compressed air, mechanical aeration, or pure oxygen.

3. A clarifier to separate the biological solids (activated sludge) from the treated wastewater.

4. A means of collecting the biological solids in the clarifier and recycling most of them (return activated sludge, RAS) to the aeration tank.

5. A means of removing or wasting excess biological solids (waste activated sludge, WAS) from the system.

6. What is the purpose of the flights and chains?

7. What is used to prevent wear of the flights at the bottom of the tank?

8. What is used to prevent damage to the unit during overloads? What could have caused the overload?

The Microlife

We talked about the basic components and designs of the activated sludge now let's look at the main "Team Players". Your process will respond to whatever direction you give it. You can run your plant (the team) to always try for the better or be content with the way it is. To get the best, it takes work!

Most activated sludge processes are used to degrade carbonaceous BOD. It is also possible to design and/or operate the basic system to oxidize ammonia (nitrification).

Many plants are now designed to achieve nitrification. Other system modifications include phosphorus removal and biological denitrification. Activated sludge plants are usually designed from pilot plant and laboratory studies.

From this approach, it is possible to design a process based on the amount of time the sludge spends in the system, generally termed mean cell residence time (MCRT), or on the amount of food provided to the bacteria in the aeration tank (the food-to-microorganism ratio, F/M). What does this mean?

Suppose a person ate 10 pounds of hot dogs (**BOD**) and weighed 200 pounds (**MLSS**).

What is the ratio of food to weight?

It would be 10 lbs. to 200 lbs. If we divide 200 into 10, the ratio is .05 or 5%. 200 lbs is the answer.

Is this getting you hungry?

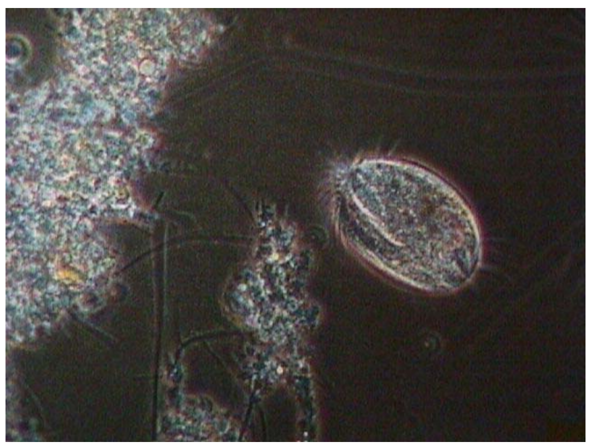
Common wastewater sampling bottles

F/M and MCRT

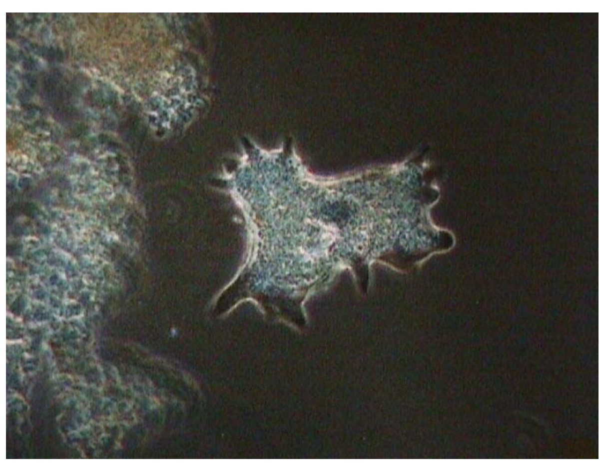
The following are some general statements about F/M and MCRT assuming that the environmental conditions are properly controlled.

a. The optimum operating point of either helps obtain the desired effluent concentration.
b. Both provide a means for maintaining the best effluent and sludge quality.
c. Both techniques attempt to regulate rate of growth, metabolism, and stabilization of food matter.
d. Both techniques indicate the solids level needed to stabilize the food and attain sludge quality.
e. The desired solids level is controlled by wasting.
    1. To maintain – waste amount of net daily
    2. To increase – decrease waste rate
    3. To decrease – increase waste rate
f. They are interrelated so changing one control changes the other.
g. Once the control point is set, it should remain constant until change in effluent or sludge quality requires a change.

The operating control point is that point when the best effluent and sludge quality is obtained for the existing conditions.



Ciliate



Amoeba

“Team Players”
Activated Sludge Microorganisms

Before we look at the bugs themselves, let’s look at eating habits. Have you ever met a person who was a picky eater?

You have people who will put their noses up at some things, and others who would eat anything. Predators typically eat from a narrow set of prey, while omnivores and scavengers eat from a broader food selection.

- Swimming and gliding ciliates engulf bacteria or other prey.

- Stalked ciliates attach to the biomass and vortex suspended bacteria into their gullets, while crawlers break bacteria loose from the floc surface.

- Predators feed mostly on stalked and swimming ciliates. The omnivores, such as most rotifers, eat whatever is readily available, while the worms feed on the floc or prey on larger organisms. Microorganisms are directly affected by their treatment environment.

- Changes in food, dissolved oxygen, temperature, pH, total dissolved solids, sludge age, presence of toxins, and other factors create a dynamic environment for the treatment organisms.

Food (organic loading) regulates microorganism numbers, diversity, and species when other factors are not limiting. The relative abundance and occurrence of organisms at different loadings can reveal why some organisms are present in large numbers while others are absent.

Aerobic Bacteria
The aerobic bacteria that occur are similar to those found in other treatment processes such as activated sludge. Three functional groups occur: freely dispersed, single bacteria; floc-forming bacteria; and filamentous bacteria. All function similarly to oxidize organic carbon (BOD) to produce CO2 and new bacteria (new sludge).

Many bacterial species that degrade wastes grow as single bacteria dispersed in the wastewater. Although these readily oxidize BOD, they do not settle and hence often leave the lagoon system in the effluent as solids (TSS). These tend to grow in lagoons at high organic loading and low oxygen conditions. More important are the floc-forming bacteria, those that grow in a large aggregate (floc) due to exocellular polymer production (the glycocalyx). This growth form is important as these flocs degrade BOD and settle at the end of the process, producing a low TSS effluent.

A number of filamentous bacteria occur in lagoons, usually at specific growth environments. These generally do not cause any operational problems in lagoons, in contrast to activated sludge where filamentous bulking and poor sludge settling is a common problem. Most heterotrophic bacteria have a wide range in environmental tolerance and can function effectively in BOD removal over a wide range in pH and temperature.

Aerobic BOD removal generally proceeds well from pH 6.5 to 9.0 and at temperatures from 3-4 °C to 60- 70°C (mesophilic bacteria are replaced by thermophilic bacteria at temperatures above 35°C). BOD removal generally declines rapidly below 3-4°C and ceases at 1-2°C.

A very specialized group of bacteria occurs to some extent in lagoons (and other wastewater treatment systems) that can oxidize ammonia via nitrite to nitrate, termed nitrifying bacteria. These bacteria are strict aerobes and require a redox potential of at least +200 m V (Holt et al., 1994).

It was once thought that only two bacteria were involved in nitrification: Nitrosomonas europaea, which oxidizes ammonia to nitrite, and Nitrobacter winogradskyi, which oxidizes nitrite to nitrate. It is now known that at least 5 genera of bacteria oxidize ammonia and at least three genera of bacteria oxidize nitrite (Holt et al., 1994).

Nitrifying Bacteria

Besides oxygen, these nitrifying bacteria require a neutral pH (7-8) and substantial alkalinity (these autotrophs use CO2 as a carbon source for growth). This indicates that complete nitrification would be expected at pond pH values between pH 7.0 and 8.5. Nitrification ceases at pH values above pH 9 and declines markedly at pH values below 7. This results from the growth inhibition of the nitrifying bacteria. Nitrification, however, is not a major pathway for nitrogen removal in lagoons. Nitrifying bacteria exists in low numbers in lagoons. They prefer attached growth systems and/or high MLSS sludge systems.

Anaerobic Bacteria

Anaerobic, heterotrophic bacteria that commonly occur in lagoons are involved in methane formation (acid-forming and methane bacteria) and in sulfate reduction (sulfate reducing bacteria). Anaerobic methane formation involves three different groups of anaerobic bacteria that function together to convert organic materials to methane via a three step process.

General anaerobic degraders - many genera of anaerobic bacteria hydrolyze proteins, fats, and poly saccharides present in wastewater to amino acids, short-chain peptides, fatty acids, glycerol, and mono- and di-saccharides. These have a wide environmental tolerance in pH and temperature.

Photosynthetic Organisms

Acid-forming bacteria - this diverse group of bacteria converts products from above under anaerobic conditions to simple alcohols and organic acids such as acetic, propionic, and butyric. These bacteria are hardy and occur over a wide pH and temperature range. Methane forming bacteria - these bacteria convert formic acid, methanol, methylamine, and acetic acid under anaerobic conditions to methane. Methane is derived in part from these compounds and in part from CO2 reduction.

Methane bacteria are environmentally sensitive and have a narrow pH range of 6.5- 7.5 and require temperatures > 14° C.

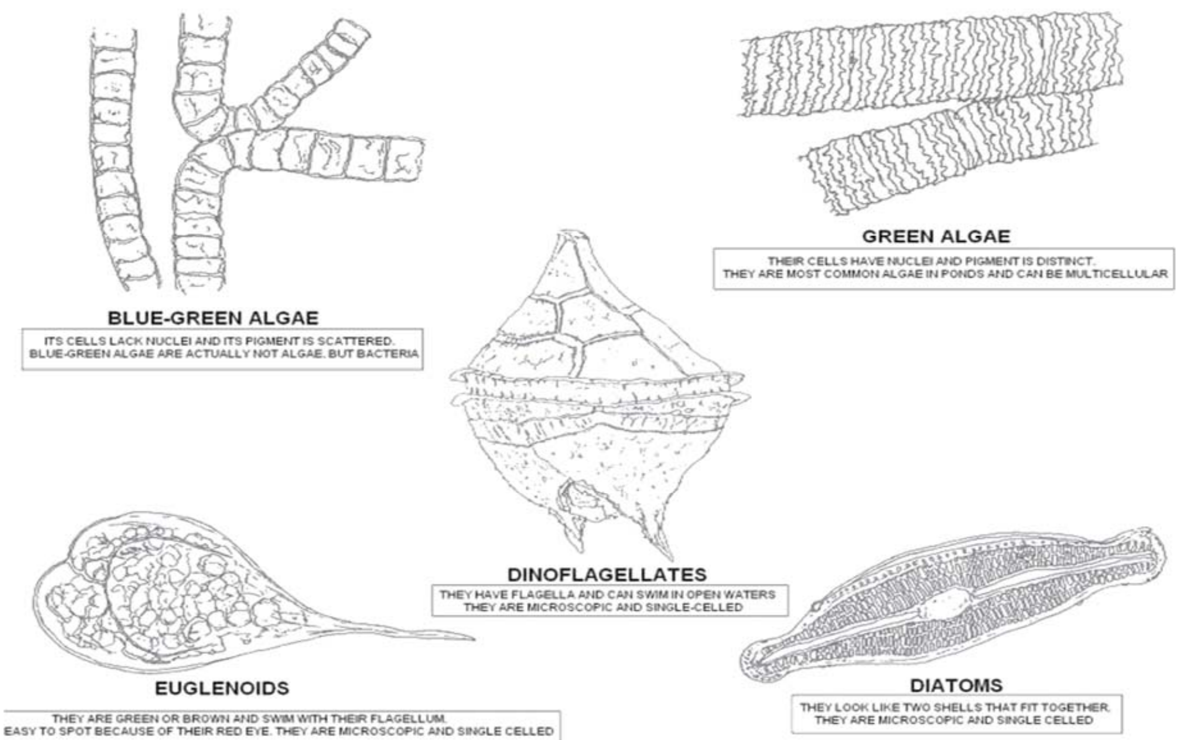
Note that the products of the acid formers (principally acetic acid) become the substrate for the methane producers.

A problem exists at times where the acid formers overproduce organic acids, lowering the pH below where the methane bacteria can function (a pH < 6.5). This can stop methane formation and lead to a buildup of sludge in a lagoon with a low pH. In an anaerobic fernmenter, this is called a *"stuck digester"*.

Also, methane fermentation ceases at cold temperature, probably not occurring in most lagoons in the wintertime in cold climates. A number of anaerobic bacteria (14 genera reported to date (Bolt et al., 1994)) called sulfate reducing bacteria can use sulfate as an electron acceptor, reducing sulfate to hydrogen sulfide. This occurs when BOD and sulfate are present and oxygen is absent. Sulfate reduction is a major cause of odors in ponds.

Anaerobic, photosynthetic bacteria occur in all lagoons and are the predominant photosynthetic organisms in anaerobic lagoons, The anaerobic sulfur bacteria, generally grouped into the red and green sulfur bacteria and represented by about 28 genera (Ehrlich, 1990), oxidize reduced sulfur compounds (H2S) using light energy to produce sulfur and sulfate, Here, H2S is used in place of H2O as used by algae and green plants, producing S04- instead of O2. All are either strict anaerobes or microaerophilic.

Most common are Chromatium, Thiocystis, and Thiopedia, which can grow in profusion and give a lagoon a pink or red color. Finding them is most often an indication of organic overloading and anaerobic conditions in an intended aerobic system. Conversion of odorous sulfides to sulfur and sulfate by these sulfur bacteria is a significant odor control mechanism in facultative and anaerobic lagoons, and can be desirable.



Algae

Algae are aerobic organisms that are photosynthetic and grow with simple inorganic compounds CCO2, NH3, NO3-, and PO4--) using light as an energy source.
**Note that algae produce oxygen during the daylight hours and consume oxygen at night.

Algae are desirable in lagoons as they generate oxygen needed by bacteria for waste stabilization. Three major groups occur in lagoons, based on their chlorophyll type: brown algae (diatoms), green algae, and red algae. The predominant algal species at any given time is dependent on growth conditions, particularly temperature, organic loading, oxygen status, nutrient availability, and predation pressures. A fourth type of "algae" common in lagoons is the cyano-bacteria or blue-green bacteria.

These organisms grow much as the true algae, with the exception that most species can fix atmospheric nitrogen. Blue-green bacteria often bloom in lagoons and some species produce odorous and toxic by-products.

Blue-Green Bacteria
Blue-green bacteria appear to be favored by poor growth conditions including high temperature, low light, low nutrient availability (many fix nitrogen) and high predation pressure. Common blue-green bacteria in waste treatment systems include **Aphanothece, Microcystis, Oscillatoria** and **Anabaena.**

Algae can bloom in lagoons at any time of the year (even under the ice) ; however, a succession of algal types occurs over the season. There is also a shift in the algal species present in a lagoon through the season, caused by temperature and rotifer and Daphnia predation. Diatoms usually predominate in the wintertime at temperatures <60°F. In the early spring when predation is low and lagoon temperatures increase above 60°F, green algae such as Chlorella, Chlamydomonas, and Euglena often predominate in waste treatment lagoons.

The predominant green algae change to species with spikes or horns such as Scenesdesmus, Micractinium, and Ankistrodesmus later in the season when Rotifers and Daphnia are active (these species survive predation better).
Algae grow at warmer temperatures, longer detention time, and when inorganic minerals needed for growth are in excess. Alkalinity (inorganic carbon) is the only nutrient likely to be limiting for algal growth in lagoons. Substantial sludge accumulation in a lagoon may become soluble upon warming in the spring, releasing algal growth nutrients and causing an algal bloom.

Sludge resolution of nutrients is a major cause of high algal growth in a lagoon, requiring sludge removal from the lagoon for correction.

Treatment Lagoon
The pH at a treatment lagoon is determined by the various chemical species of alkalinity that are present. The main species present are carbon dioxide (COJ, bicarbonate ion (HCO3), and carbonate ion (CO3=). High amounts of CO2 yield a low lagoon pH, while high amounts of CO3= yield a high lagoon pH.

Bacterial growth on BOD releases CO_2 which subsequently dissolves in water to yield carbonic acid (H_2CO_3). This rapidly dissociates to bicarbonate ion, increasing the lagoon alkalinity. Bacterial oxidation of BOD causes a decrease in lagoon pH due to CO_2 release.

Algal growth in lagoons has the opposite effect on lagoon pH, raising the pH due to algal use for growth of inorganic carbon (CO_2 and HCO31. Algal growth reduces the lagoon alkalinity which may cause the pH to increase if the lagoon alkalinity (pH buffer capacity) is low. Algae can grow to such an extent in lagoons (a bloom) that they consume for photosynthesis all of the CO_2 and HCO_3^--present, leaving only carbonate ($CO_3^{=}$) as the pH buffering species.

This causes the pH of the lagoon to become alkaline. pH values of 9.5 or greater are common in lagoons during algal blooms, which can lead to lagoon effluent pH violations (in most states this is pH = 9). It should be noted that an increase in the lagoon pH caused by algal growth can be beneficial. Natural disinfection of pathogens is enhanced at higher pH. Phosphorus removal by natural chemical precipitation is greatly enhanced at pH values greater than pH = 8.5. In addition, ammonia stripping to the atmosphere is enhanced at higher pH values (NH_3 is strippable, not NH_4^+).

Protozoans and Microinvertebrates
Many higher life forms (animals) develop in lagoons. These include protozoans and micro-invertebrates such as rotifers, daphnia, annelids, chironomids (midge larvae), and mosquito larvae (often termed the zooplankton). These organisms play a role in waste purification by feeding on bacteria and algae and promoting flocculation and settling of particulate material.

Protozoans are the most common higher life forms in lagoons with about 250 species identified in lagoons to date (Curds, 1992). Rotifers and daphnia are particularly important in controlling algal overgrowth and these often ***"bloom"*** when algal concentrations are high.

These microinvertebrates are relatively slow growing and generally only occur in systems with a detention time of >10 days. Mosquitoes grow in lagoons where shoreline vegetation is not removed and these may cause a nuisance and public health problem.

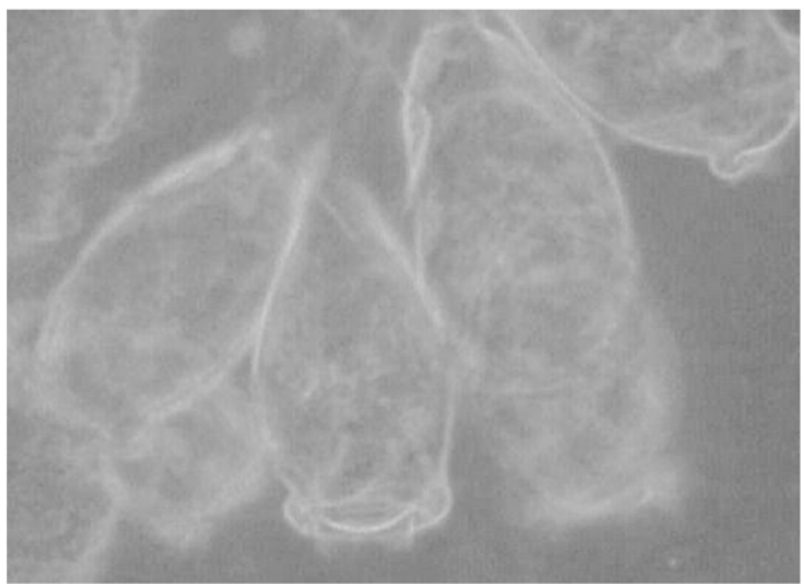
Culex tarsalis, the vector of Western Equine Encephalitis in the western U.S., grows well in wastewater lagoons (USEPA, 1983). The requirement for a minimum lagoon bank slope and removal of shoreline vegetation by most regulatory agencies is based on the public health need to reduce mosquito vectors.

Paramecium sp.

Paramecium is a medium size to large (100-300 m) swimming ciliate, commonly observed in activated sludge, sometimes in abundant numbers. The body is either foot-shaped or cigar-shaped, and somewhat flexible. Paramecium is uniformly ciliated over the entire body surface with longer cilia tufts at the rear of the cell.

Paramecium swims with a smooth gliding motion. It may also be seen paired up with another Paramecium which makes a good diagnostic key. The cell has either one or two large water cavities which are also identification tools. This swimmer moves freely in the water column as it engulfs suspended bacteria. It has a large feeding groove used to trap bacteria and form the food cavities that move throughout the body as digestion occurs. Paramecium is described as a filter-feeding ciliate because its cilia move and filter bacteria from the water.

Vorticella sp.



Vorticella is a stalked ciliate. There are at least a dozen species found in activated sludge ranging in length from about 30 to 150 m.

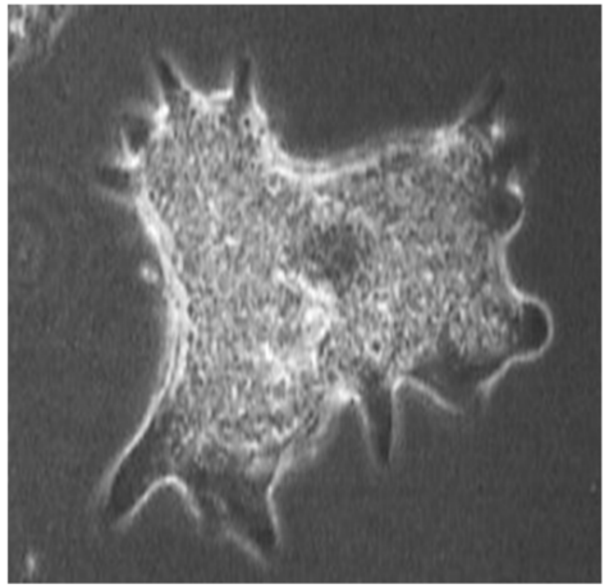
These organisms are oval to round shaped, have a contractile stalk, a domed feeding zone, and a water vacuole located near the terminal end of the feeding cavity.

One organism is found on each stalk except during cell division. After reproducing, the offspring develops a band of swimming cilia and goes off to form its own stalk. The evicted organism is called a "*swarmer*."

Vorticella feeds by producing a vortex with its feeding cilia. The vortex draws bacteria into its gullet. Vorticella's principal food source is suspended bacteria. The contracting stalk provides some mobility to help the organism capture bacteria and avoid predators.

The stalk resembles a coiled spring after its rapid contraction. Indicator: If treatment conditions are bad, for example low DO or toxicity, Vorticella will leave their stalks. Therefore, a bunch of empty stalks indicates poor conditions in an activated sludge system. Vorticella sp. are present when the plant effluent quality is high.

Euglypha sp.



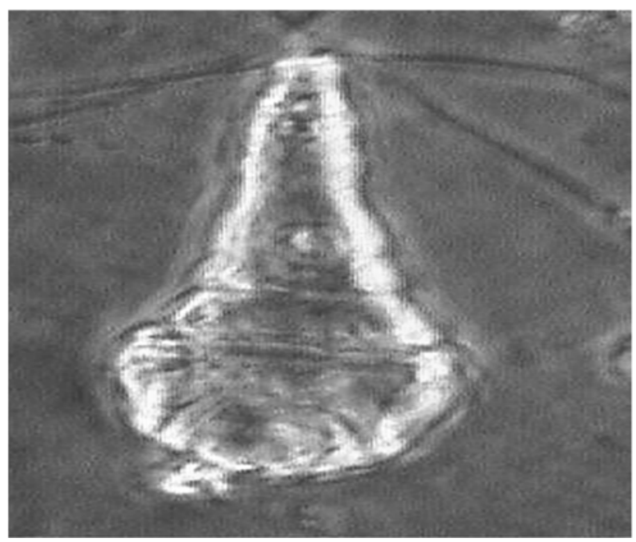
Euglypha (70-100 æm) is a shelled (testate) amoeba. Amoebas have jelly-like bodies. Motion occurs by extending a portion of the body (pseudopodia) outward. Shelled amoebas have a rigid covering which is either secreted or built from sand grains or other extraneous materials.

The secreted shell of this Euglypha sp. consists of about 150 oval plates. Its spines project backward from the lower half of the shell. Euglypha spines may be single or in groups of two or three. The shell has an opening surrounded by 8-11 plates that resemble shark teeth under very high magnification.

The shell of Euglypha is often transparent, allowing the hyaline (watery) body to be seen inside the shell. The pseudopodia extend outward in long, thin, rays when feeding or moving. Euglypha primarily eats bacteria.

Indicator: Shelled amoebas are common in soil, treatment plants, and stream bottoms where decaying organic matter is present. They adapt to a wide range of conditions and therefore are not good indicator organisms.

Euchlanis sp.



This microscopic animal is a typical rotifer. Euchlanis is a swimmer, using its foot and cilia for locomotion. In common with other rotifers, it has a head rimmed with cilia, a transparent body, and a foot with two strong swimming toes.

The head area, called the "corona," has cilia that beat rhythmically, producing a strong current for feeding or swimming.

Euchlanis is an omnivore, meaning that its varied diet includes detritus, bacteria, and small protozoa. Euchlanis has a glassy shell secreted by its outer skin. The transparent body reveals the brain, stomach, intestines, bladder, and reproductive organs.

A characteristic of rotifers is their mastax, which is a jaw-like device that grinds food as it enters the stomach. At times the action of the mastax resembles the pulsing action of a heart. Rotifers, however, have no circulatory system. Indicator: Euchlanis is commonly found in activated sludge when effluent quality is good. It requires a continual supply of dissolved oxygen, evidence that aerobic conditions have been sustained.

Review Basic Process

As previously noted, the activated sludge process can be used to remove carbonaceous BOD and also ammonia (nitrification). We can take the wastewater oxygen demand separated into two categories: carbonaceous and nitrogenous.

Carbonaceous BOD Removal

The carbonaceous demand should be expressed as a function of the number of days that the demand will be measured; 3-day, 5-day (most common), 7-day, and 20-day time periods are commonly used. To obtain only carbonaceous oxygen demand, it may be necessary to inhibit nitrification by adding chemicals.

The rate and extent of BOD5 (5-day BOD) removal in primary treated (settled) or untreated waste-water depends on the relative quantities of soluble, colloidal, and suspended BOD5, and a soluble BOD5 content of approximately 20 to 40% of the total. These proportions may vary, particularly in warmer climates where long collection system residence times and the higher wastewater temperatures may result in a higher proportion of soluble BOD5. This is caused by the bacterial degradation of a portion of the colloidal and settleable fractions.

With a typical municipal wastewater, a well-designed activated sludge process should achieve a carbonaceous, soluble BOD5 effluent quality of 5mg/L or less. Similarly, with clarifiers designed to maximize solids removal at peak flows and adequate process control, the average SS in the effluent should not exceed 15 mg/L. On a practical basis, an effluent with 20/20 mg/L BOD5 and SS should be attained, assuming proper operation. Potential capabilities of the process are 10/15 mg/L Bod5 and SS. To consistently achieve values lower than 10/15 mg/L, some type of tertiary treatment is required.

Nitrification

Of the total oxygen demand exerted by the wastewater, there is often a sizeable fraction associated with the oxidation of ammonia to nitrate. The autotrophic bacteria Nitrosomonas and Nitrobacter are responsible for this two-state conversion. Being autotrophic, these nitrifying organisms must reduce oxidized carbon compounds in the wastewater, such as C02 and its related ionic species, for cell growth. As a result, this characteristic markedly affects the ability of the nitrifying organisms to compete in a mixed culture.

The nitrifying bacteria obtain their energy by oxidizing ammonia nitrogen to nitrite nitrogen and then to nitrate nitrogen. Because very little energy is obtained from these oxidation reactions, and because energy is needed to change CO2 to cellular carbon, the population of nitrifiers in activated sludge is relatively small. When compared to the normal bacteria in activated sludge, the nitrifying bacteria have a slower reproduction rate.

Nitrifying organisms are present to some extent in all domestic wastewaters. However, some wastewaters are not nitrified in existing plants because they are designed for the higher growth rate of bacteria responsible for carbonaceous removal. As the MCRT is increased, nitrification generally takes place.

The longer MCRT prevents nitrifying organisms from being lost from the system when carbonaceous wasting occurs or, more accurately, the longer MCRT permits the build-up of an adequate population of nitrifiers.

Because of the longer MCRT required for nitrification, some systems are designed to achieve nitrification in the second stage of a two-stage activated sludge system.

The oxygen demand for complete nitrification is high. For most domestic wastewaters, it will increase the oxygen supply and power requirements by 30 to 40% because complete nitrification requires from 4.3 to 4.6 lb. of oxygen for each lb. of ammonia nitrogen (4.3 to 4.6 mg/mg) converted into nitrate, and wastewaters generally contain 10 to 30 mg/L of reduced nitrogen. Nitrification systems generally are not operated at intermediate (40 to 80%) removals; stable operation is achieved when essentially complete nitrification (greater than 90%) occurs.

Minimum acceptable dissolved oxygen (**DO**) concentrations of 2 to 3 mg/L have been reported, but nitrification appears to be inhibited when the oxygen concentration is lower than 1 mg/L.

Optimum growth of nitrifying bacteria has been observed in the pH range of 8 to 9 although other ranges have been reported. A substantial reduction in nitrification activity usually occurs at pH levels below 7, although nitrification can occur at low pH.

While nitrification occurs over a wide temperature range, temperature reduction results in a slower reaction rate.

The temperature effect is made less severe by increasing the MCRT. During the conversion of ammonia to nitrate, mineral acidity is produced. If insufficient alkalinity is present, the system's pH will drop and nitrification may be inhibited.

Bacteria Highlights, memorize this section for the exam.

A change in the numbers or predominance of microorganisms in activated sludge is usually gradual. The time required for a complete shift from one species to another will normally be seen in: 2 to 3 MCRT's.

A large amount of long filamentous bacteria will prevent good settling.

Endogenous respiration of microorganisms in an extended aeration plant will: complete the oxidation process of an organic material.

Nocardia causes frothing. Saprophytic bacteria produces the most acid in an anaerobic digester.

The best location for microscopic examination of activated sludge in a conventional system is: at the effluent end of the aeration system. The examination can reveal a predominant number of rotifers and nematodes, this condition indicates that the F/M ratio is too low and this would be normal in an EXTENDED AERATION process.

Sludge Highlights, memorize this section for the exam.

A belt filter press may contain a Venturi type restriction whose purpose is to provide turbulence to mix polymer with the flow. The ability of a belt press to dewater sludge is dependent upon: Sludge type and conditioning and the hydraulic loading and belt speed.

The dry chemical should be weighed out and mixed with water when using them for sludge conditioning.

Anaerobic digested sludge is different from aerobic sludge because Aerobic sludge has a higher water content.

During the colder winter months, operational changes in the activated sludge plant should include decreasing sludge wasting. This is generally true that cooler temps result in bugs slowing down.

Ferric chloride is a type of chemical conditioner most commonly used for sludge conditioning.

Thickening or dewatering sludge affects transportation or storage by reducing the sludge volume handled.

If sludge is septic and could be placed in a gravity sludge thickener, the final results are that gases may be produced and causing the sludge to rise.

In sludge incineration, a complete oxidation of the sludge depends upon the ratio of fuel and air supplied.

More food will be available and more oxygen will be required if primary sludge is added to the aerobic digester.

The ability to rotate one-ton chlorine cylinders is a safety feature. Because it would give to much ease to roll, is the reason it is advised to not to use roller bearings.

The primary reason that causes the sludge to rise during a settleability test is that denitrification is taking place.

The drying time and the time required to remove sludge should be used to determine the optimum depth to apply sludge on a sand drying bed.

The purpose of elutriation of sludge is to reduce the sludge's alkalinity.

The sludge dredged from a long term storage lagoon is usually 6 to 12% solids.

The sludge in the secondary clarifier is going septic, a few causes could be: Return rate too low, holding solids to long and returned sludge pump off or lines plugged.

Digester Highlights, memorize this section for the exam.

A trickling filter process is experiencing minor ponding problems on part of the media surface. The Operator should increase the recirculation rate over the surface.

While inspecting a trickling filter, the rotating distributor should be stopped and tied down before you climb onto the media.

Providing adequate ventilation to the filter media is one of the designed purposes of an under drain system in a trickling filter.

Laboratory Highlights

When reading an acid level from a glass burette or any type of beaker or column, the measurement is taken at the bottom of the meniscus or curve.

Increasing the air flow in the re-aeration zone by decreasing the RAS flow or decreasing the WAS flow to decrease the F/M. These process changes will lower the SVI.

Operators often use lab analysis, equipment maintenance logs, and process control logs to monitor plant treatment performance.

Percent by concentration is the form that you would use to report your solids analysis.

Polyelectrolytes are high-molecular-weight substances that are formed by either a natural or synthetic process. Cationic is positive charged.

Always shake or mix a sample before performing a suspended solids test.

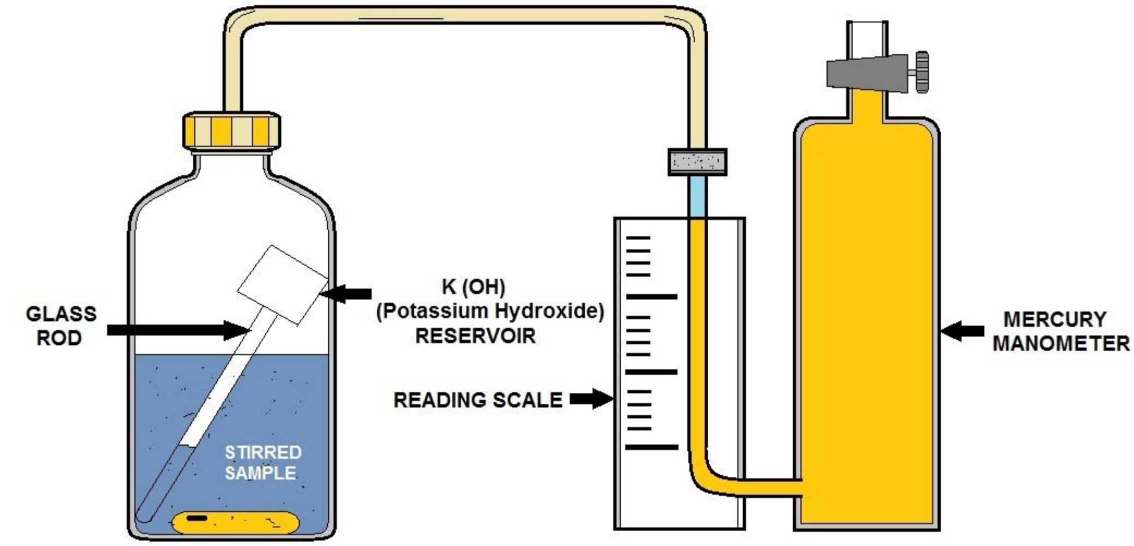
The recommended preservation for Ammonia is to add $H2SO^4$, to a pH <2, and store at 4°C.

The volatile solids test measures the amount of organic material when it is performed on solids.

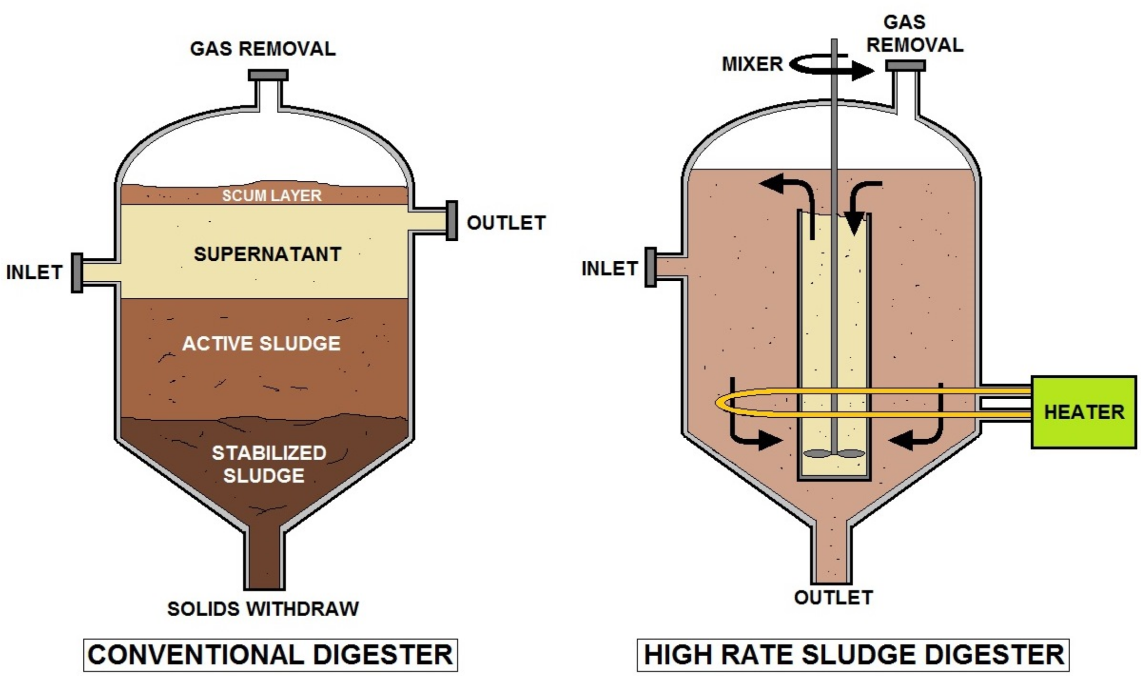
The Winkler Method lab test is used for analyzing DO.

Volatile liquids will vaporize or evaporate easily at room temperature.

When mixing Lime to sludge for dewatering, the pH should be in the 11.5 to 12.0 range.



MANOMETRIC DEVICE TO ESTIMATE BOD OF WASTEWATER



TYPES OF WASTEWATER SLUDGE DIGESTERS

Return and Waste Activated Sludge Systems

The RAS system pumps the settled sludge from the secondary clarifier back to the aeration tank. It is important that this system return the RAS to the aeration tank before the microorganisms deplete all the DO. The RAS must also be as concentrated as possible and the flow must be accurately measured and controlled.

To accomplish this, the RAS pumping system must have a positive variable flow control device and the RAS flow must be adjustable between the minimum and maximum range for proper process control. The desired return flow to the aeration tank could also be automatically paced to secondary influent flow.

All activated sludge processes must have a WAS system to remove excess microorganisms. This is necessary to control the F/M and MCRT. If the process is to reliably meet discharge requirements, this system must provide a positive, flexible, and reliable means of removing excess microorganisms.

It is essential that the system have flow-metering and pumping equipment that function completely independent of other activated sludge control devices. The most positive and flexible system will include an independent pumping system with flow adjustability (for example, variable speed drive) and a flow meter that provides feedback into a flow-control device.

Such a system can be set for a given wasting rate with complete assurance that variable system head or concentration conditions will not affect its ability to remove the microorganisms required. WAS systems must have sufficient capacity to deal with both the hydraulic and/or organic load changes and process changes.

Aeration and DO Control
The purpose of aeration is two-fold: oxygen must be dissolved in the liquid in sufficient quantities to maintain the organisms and the contents of the tank must be sufficiently mixed to keep the sludge slid in suspension.

Mixing energy and oxygen transfer are provided through mechanical or diffused aeration. The amount of oxygen that has to be transferred by the aeration system is theoretically equal to the amount of oxygen required by the organisms in the system to oxidize the organic material.

The DO concentration in the aeration tank must be sufficient to sustain at ALL times the desirable microorganisms in the aeration tank, clarifier, and return sludge line back to the aeration tank.

When oxygen limits the growth of microorganisms, filamentous organisms may predominate and the settleability and quality of the activated sludge may be poor. On the other hand, over aeration can create excess turbulence and may result in the breakup of the biological floc and waste energy.

Poor settling and high effluent solids will result. For these reasons, it is very important to periodically monitor and adjust the aeration tank DO levels and, for diffused air systems, the air flow rates.

In practice, the DO concentration in the aeration tank should normally be maintained at about 1.5 to 4 mg/L in all areas of the aeration tank at all times for adequate microorganism activity. Poor sludge settling as a result of filamentous organisms has been associated with mixed liquor DO concentrations below 0.5 mg/L. Above 4 mg/L, treatment usually does not significantly improve but power usage increases aeration costs considerably.

RAS Control
To properly operate the activated sludge process, a good settling mixed liquor must be achieved and maintained. The MLSS are settled in a clarifier and then returned to the aeration tank as the RAS. This keeps a sufficient concentration of activated sludge in the aeration tanks so that the required degree of treatment can be obtained in the allotted time period. The return of activated sludge from the secondary clarifier to the aeration tank is a key control parameter of the process.

The secondary clarifiers have two basic functions:

- to clarify the secondary effluent through solids/liquid separation; and

- to rapidly collect and thicken the settled solids for return to the aeration tanks or wasting to the sludge processing facilities.

Constant Rate Versus Constant Percentage Return

There are two basic ways for returning sludge to the aeration tank:
- at a constant rate, independent of the secondary influent flow rate, and
- at a constant percentage of the varying secondary influent flow.

Clarifier size and hydraulics may limit the range of practical return adjustments. Regardless of calculated values, return rates should not be reduced to the level where slowly moving, thick clarifier sludge will plug the sludge withdrawal pipes.

Also, low return rates during the night should be increased to approach the anticipated higher return rates during the day before, rather than after, the increased wastewater flows actually reach the plant. Increasing the return sludge flow after the flow increase may cause a hydraulic overload condition resulting in a carryover of solids into the clarifiers (washout).

Constant Rate Control
Returning activated sludge at a constant flow rate that is independent of the secondary influent wastewater flow rate results in a continuously varying MLSS concentration that will be at a minimum during peak secondary influent flows and a maximum during minimum secondary influent flows.

The aeration tank and the secondary clarifier must be looked at as a system where the MLSS are stored in the aeration tank during minimum wastewater flow and then transferred to the clarifier as the wastewater flows initially increase.

The clarifier acts as a storage reservoir for the MLSS during periods of high flow. The clarifier has a constantly changing depth of sludge blanket as the MLSS moves from the aeration tank to the clarifier and vice versa.

Constant Percentage Control
The second approach is to pace the return flow at a fixed percentage of the influent wastewater flow rate (**Q**), at a constant R/Q. This may be done automatically with instruments, or manually with frequent adjustments. This approach keeps the MLSS and sludge blanket depths more constant throughout high and low flow periods and also tends to maintain a more constant F/M and MCRT.

Settleability
The settleability test can be used to estimate the desirable sludge return rate. This method uses the sludge volume in a 2-L settlemeter at the end of a 30-minute settling period to represent the underflow and the supernatant volume to represent the overflow.

Rotating Biological Contactors RBC
Rotating Biological Contactors is a remediation technology used in the secondary treatment of wastewater. This technology involves allowing wastewater to come in contact with a biological medium in order to facilitate the removal of contaminants.

In its simplest form, a rotating biological contactor consists of a series of discs or media blocks mounted on a shaft which is driven so that the media rotates at right angles to the flow of sewage. The discs or media blocks are normally made of plastic (polythene, PVC, expanded polystyrene) and are contained in a trough or tank so that about 40% of their area is immersed.

The biological growth that becomes attached to the media assimilates the organic materials in the wastewater. Aeration is provided by the rotating action, which exposes the media to the air after contacting them with the wastewater. The degree of wastewater treatment is related to the amount of media surface area and the quality and volume of the inflowing wastewater.

Rotating Biological Contactors can be supplied as part of an integral package plant to treat sewage from various communities. Integral units are provided in sizes of up to a 500 population equivalent. A smaller version is also available for small private installations. Modular systems can also be adapted to cater to populations of any number. Multiple units have been used for populations in excess of 5000.

Key Advantages

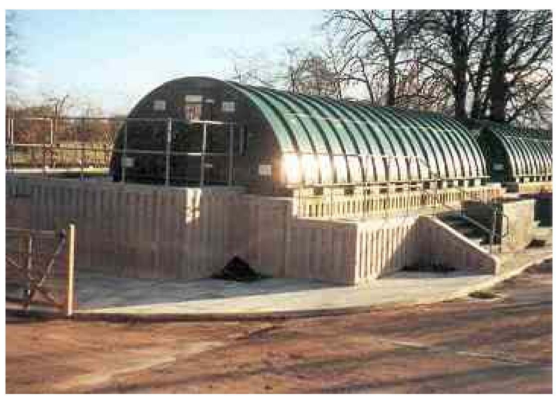
Short contact periods are required because of the large active surface.
Capable of handling a wide range of flows.
Sloughed biomass generally has good settling characteristics and can easily be separated from the waste stream.
Operating costs are low, as little skill is required in plant operation.
Retention times are short.
Low power requirements.
Low sludge production and excellent process control.

Problems

White biomass over most of a RBC disc can be resolved by increasing the age of the sludge.

RBC Principles

The principles of the rotating biological contactor originated in the early 1900's but its application to sewage treatment did not occur until the 1960's when the present system was developed. The process employed relies on the well-established principle of biological oxidation using naturally occurring organisms to ensure that even the most stringent effluent standards can be achieved.



Rotating Biological Contactors

Incoming flows of crude sewage enter the RBC primary settlement zone, which is designed to have a buffering capacity of balancing flows up to 6DWF. Settlement solids are retained in the tank's lower region while the partially clarified liquor passes forward to the biozone where it makes contact with the slowly rotating disks.

Contactors

Installation of Rotating Biological Contactors

Rotating Biological Contactors are available in sizes from 1100mm diameter up to 3800mm in diameter. The media packs that form the rotors are manufactured from vacuum formed black polyethylene sheets supported on the central shaft with a galvanized steel framework.

The central shaft is manufactured from mild steel tube, protected internally against corrosion and fitted with end stub shafts, which are supported on split bearings.

Gearbox and Drive mechanism →
Rotation is provided by a shaft mounted gearbox and motor fitted at one end.

Biozone
The rotor assembly is suspended within the biozone with 40% of the diameter submerged in the liquor at any one time. The disks slowly rotate and the continuous alternate exposure to air and sewage results in a growth of organisms known as biomass which adheres to the disks.

These organisms occur naturally in the sewage and carry out the purification process by feeding off the impurities present in the sewage. As they have a short life cycle, these organisms are continually shearing off the rotating disks and pass from the biozone to the final zone.

The biozone is fitted with a series of baffles between each bank of media, this is to prevent short circuiting and to ensure maximum performance.

The biomass passes from the biozone into the final settlement zone where it settles to form humus sludge. This is then regularly pumped out using either an air lift system or submersible pumps and returned to the primary zone.

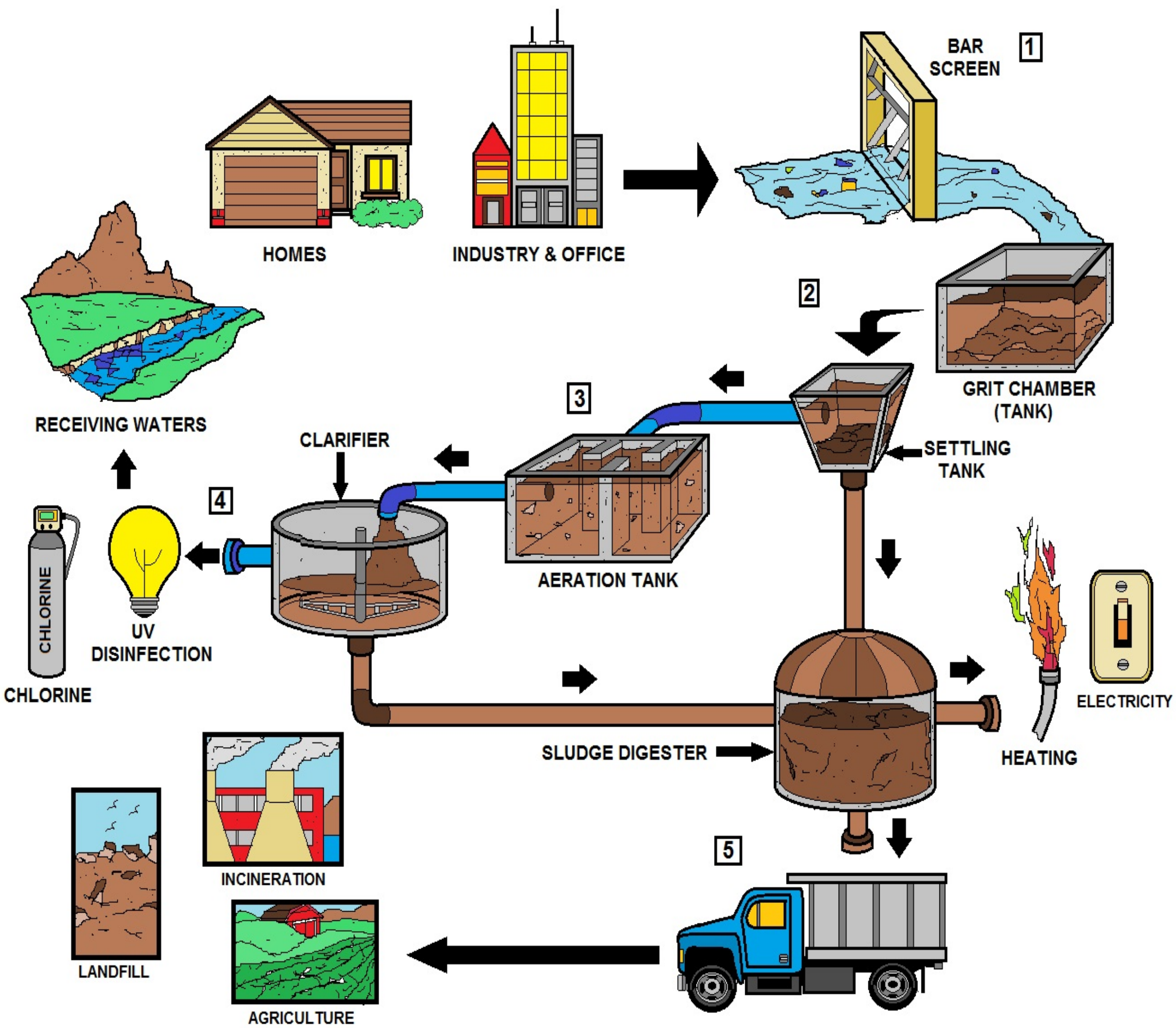
The clarified liquid decants from the top of the tank as effluent that can be discharged to a reed bed for further clarification or direct to a watercourse.

Trickling Filter Highlights *Memorize these statements for your exam.*

A trickling filter process is experiencing minor ponding problems on part of the media surface, the Operator should increase the recirculation rate over the surface.

While inspecting a trickling filter, the rotating distributor should be stopped and tied down before you climb onto the media.

Providing adequate ventilation to the filter media is one of the designed purposes of an under drain system in a trickling filter.



WASTEWATER TREATMENT PROCESS

Operator Highlights *Memorize these statements for your exam.*

A Parshall flume measures flow by the rise or head produced.

The Air to solids ratio affects the performance of a dissolved air flotation unit.

An Air Gap device or method is the best prevention of potable water contamination.

Gasoline and volatile organic solvents present in the sewer may cause: Corrosion of the sewer, Increase in resistance of flow, Precipitation of waste solids in the sewer and serious explosion hazards.

If the level of Carbon Dioxide increases in an anaerobic digester the pH will decrease.

In any type of centrifuge thickener, increasing the bowl speed (RPM) will produce a thicker sludge concentration.

Monthly reports are used in the preparation of the annual reports. Sludge pumped and solids concentration information should be included in this report about the primary clarifiers.

One way to hold down cost is to have a good, well organized maintenance program. The program would include all the following: Inventory, completed work orders and equipment repaired.

Solids can pass under the effluent baffle and into the effluent and might occur if the sludge blanket in a dissolved air flotation unit is allowed to build up and drop too far below the surface of the liquid.

The application of a free draining, non-cohesive material such as diatomaceous earth to a filtering media is known as Binding.

The following conditions are likely to occur if a weir at the headworks is used to measure flow: Dead water space will occur upstream of the weir, Organic deposits may cause odor problems and Solids deposition will cause inaccurate flow measurements.

The following items will cause turbidity in wastewater: Inorganic matter, Grit and finely divided organic matter.

The two main types of centrifuges used are: Basket and Scroll.

When entering a manhole the rungs inside may be: Corroded and unsafe to use

Sulfur dioxide is the most commonly used chemical for dechlorination.

Denitrification best describes an anoxic process that occurs when nitrite or nitrate ions are reduced to nitrogen gas and nitrogen bubbles are formed as a result.

In an aeration tank, nitrification is most likely to occur when: there is plenty of DO available.

Laboratory Highlights *Memorize these statements for your exam.*

When reading an acid level from a glass burette, the measurement is taken at the bottom of the meniscus or curve.

Increasing the air flow in the re-aeration zone by decreasing the RAS flow or decreasing the WAS flow to decrease the F/M--these process changes will lower the SVI.

Operators' often use lab analysis, equipment maintenance logs, and process control logs to monitor plant treatment performance.

Percent by concentration is the form that you would use to report solids analysis.

Polyelectrolytes are high-molecular-weight substances that are formed by either a natural or synthetic process. Cationic is positive charged.

Always shake or mix a sample before performing a suspended solids test.

The recommended preservation for Ammonia is to add H2SO^4, pH <2, and store at 4°C.

The volatile solids test measures the amount of organic material when it is performed on solids.

The Winkler Method lab test is used for analyzing DO.

Volatile liquids will vaporize or evaporate easily at room temperature.

When mixing Lime to sludge for dewatering, the pH should be in the 11.5 to 12.0 range.

When monitoring for changes in the effluent water quality, an operator may use a nephelometric instrumental procedure to determine Turbidity.

When running a Suspended Solids test, seal the filter paper to the funnel by passing about 20 ml of distilled water through the vacuum pump.

When using dry polymer dosages to perform a Jar test, it is suggested to increase the chemical increments by 5 lbs. to each ton.

You should take measurements of the DO in an aerobic digester with a probe in least 3 to 5 locations to monitor plant performance.

Sludge Volume Index (SVI)

Sludge Volume Index Lab
The Sludge Volume Index (**SVI**) of activated sludge is defined as the volume in milliliters occupied by 1g of activated sludge after settling for 30 minutes. The lower the (**SVI**), the better the settling quality of the aerated mixed liquor. Likewise, high (**SVI**) of 100 or less is considered a good settling sludge.

Calculation:
The results obtained from the suspended matter test and settleability test on aerated mixed liquor are used to obtain the SVI.

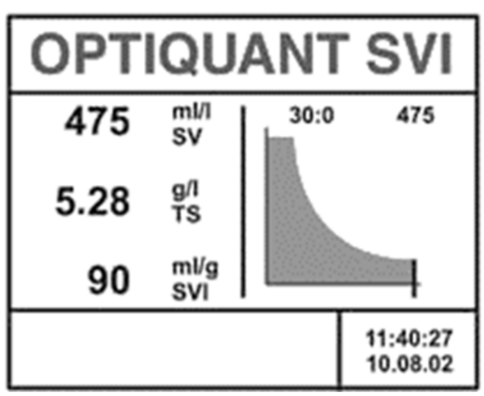
Calculation:

$$\textbf{SVI=} \quad \frac{\text{ml/L of sludge in settled mixed liquor in 30 min x 1000 mg/g}}{\text{mg/L of suspended matter in mixed liquor}}$$

At last! Automated sludge volume index monitoring
Your wastewater treatment facility relies on timely monitoring of pH, flow, phosphate, ammonia, nitrate, or DO. Now, real-time assessment of sludge conditions with the new OptiQuant SVI™ Sludge Volume and

Sludge Volume Index Analyzer complements these key control parameters.
Gone are manual samplings and hasty trips to the lab for analysis – it lets operators operate! No more re-mixing, dilutions, or questionable results. The SVI Analyzer's in-situ sampling yields an accurate, representative sample. It automatically detects bulking that signals upset conditions, gives operators better indication of upset root cause and corrective action, and provides on-the-spot response to chemical dosing adjustments. And the SVI Analyzer doesn't make more work for operators, because its unique sampling vessel construction discourages fouling. For complete information contact Hach at WWW.Hach.Com.

Operators select a graphical or numeric SVI controller display. The controller and sampling vessel provide sludge volume monitoring, while an optional OptiQuant™ TS-line suspended solids probe allows automatic calculation of sludge volume index.



Suspended Matter for Mixed Liquor and Return Sludge

Suspended matter in mixed liquor and return sludge can be used to determine process status, estimate the quantity of biomass, and evaluate the results of process adjustments.

Apparatus

- Buchner funnel and adaptor
- Filter flask
- Filter paper 110 mm diam, Whatman 1-4
- 103^0 drying oven
- Desiccator
- Balance
- Graduated Cylinder

Procedure

1. Dry the filter papers in oven at 103^0 c to remove all traces of moisture.

2. Remove papers from oven and desiccate to cool for approximately 5 minutes.

3. Weigh to the nearest 0.01g and record the mass (W_1)

4. Place the paper in the bottom of the Buchner funnel and carefully arrange so that the outer edges lay snugly along the side. Careful not to touch it with your finger. Use a glass rod. Wet the paper, turn on the vacuum and make a good seal, make a pocket covering the bottom of the funnel.

5. Add 20 to 100 mls of sample at a sufficient rate to keep the bottom of the funnel covered, but not fast enough to overflow the pocket made by the filter paper. Record the Volume used.

6. Remove the filter paper with tweezers. Dry in a 103^0 c oven for 30 minutes. Remove and desiccate. Reweigh the filter paper (W_2) to the nearest 0.01g.

Calculation:

mg/L Suspended Matter

$$\frac{(W_2) - (W_1) \times 1000 \text{ ML/L}}{\text{ML Sample}}$$

Where: (W_1) and (W_2) are expressed in mg.
(W_1) = mass of the prepared filter.
(W_2) = mass of the filter and sample after the filtration step.

Settleability Lab

The settled sludge volume of a biological suspension is useful for routine activated sludge plant control. Variations in temperature, sampling and agitation methods, diameter of the settling column, and time between sampling and start of the test can significantly affect results. The same procedure and apparatus should be used each time the test is performed.

Apparatus

-Two settling columns with a minimum volume of 1000 ml

- A 1000 ml or larger graduated cylinder or Mallory settlometer may be used as a settling column.

Procedure

The settleability test on activated sludge should be run immediately after the sample is taken. The mixed liquor sample should be taken at the effluent end of the aeration tanks, while the return sludge sample should be taken at some point between the final settling tank and the point at which the sludge is mixed with primary effluent.

1. Determine the settle ability of mixed liquor and return sludge by allowing 1000 mls of well mixed samples of each to settle in 1000 ml grad. Cylinder or Mallory settlometer. Care should be taken to minimize floc break up during the transfer of the sample to the cylinder.

2. After 30 minutes, record the volume occupied by the sludge to the nearest 5 ml.

3. The reading at the end of 30 minutes is generally used for plant control. Although settleability test on return sludge is not used in any of the calculations for activated sludge, the result is helpful in determining whether too much or too little sludge is being returned from the final settling tank.

Calculation: % Settled Sludge

$$\frac{\text{ml of sludge in settled mixed liquor or return sludge x 100}}{1000}$$

Sludge Volume Index Lab Report Worksheet

Suspended Mater Calculations:

(W_1) = ______ mg   Duplicate (W_1) = ________ mg

(W_2) = _______ mg   (W_2) = ________ mg

mls Sample = ________________ mls Sample = _______________ .

mg/L suspended matter = _______________ dup. ________________ .

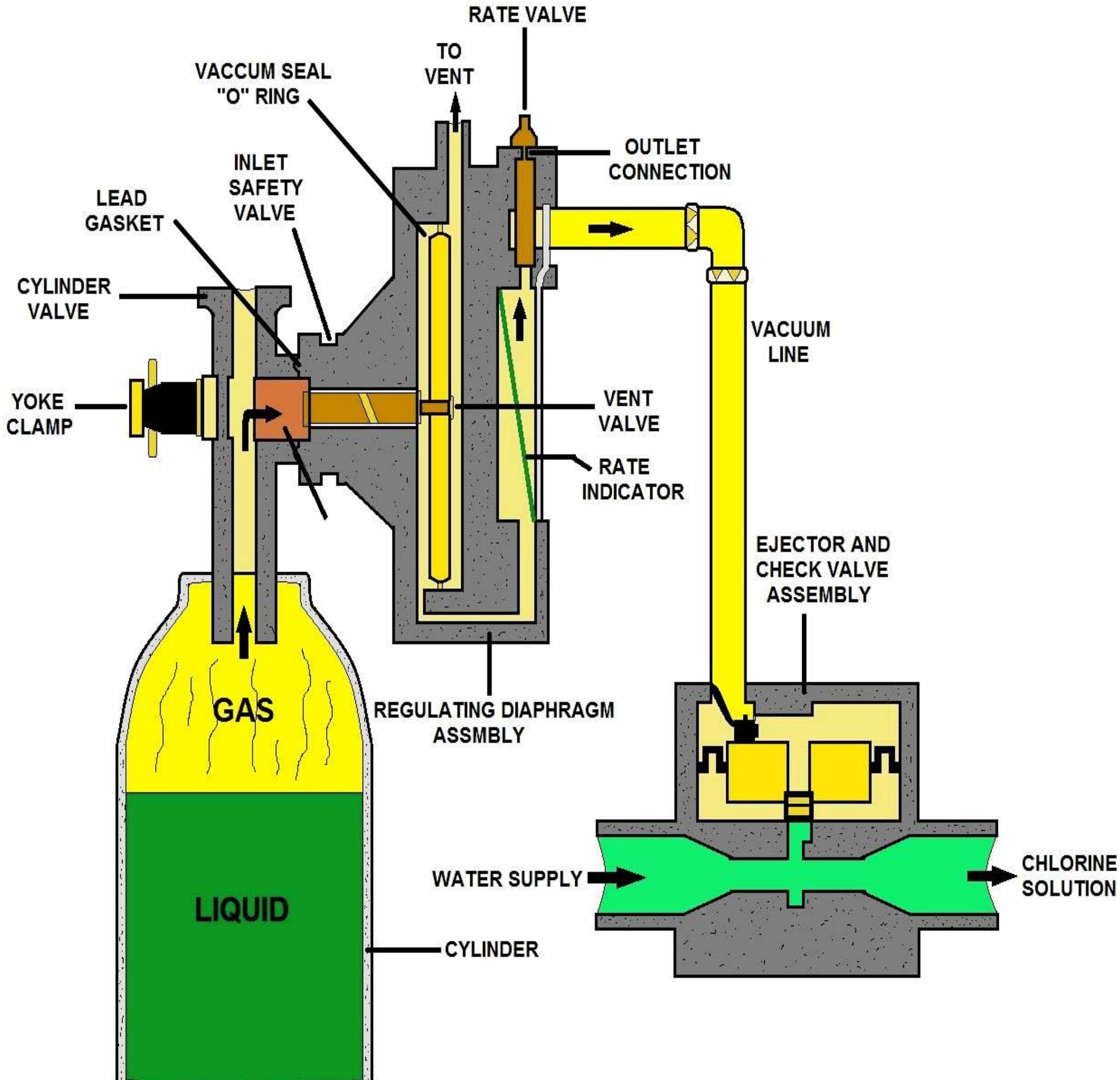
Settleability Calculations:

% settled sludge = __________________________

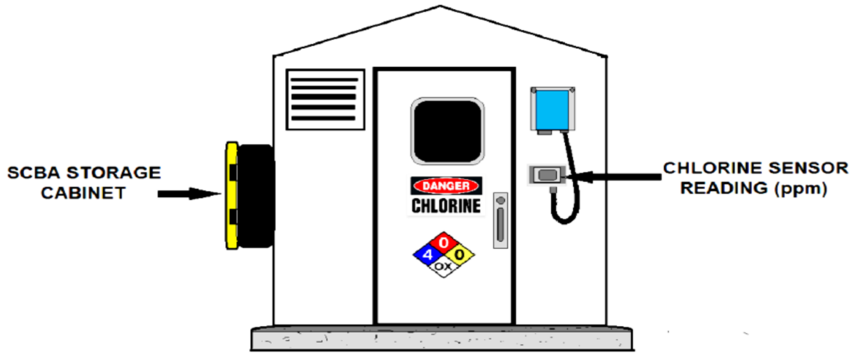
$$\frac{\text{(ml of sludge in settled mixed liquor or returned sludge x 100)}}{1000}$$

Sludge Volume Index Calculations:

$$\frac{\text{(ml of sludge in settled mixed liquor in 30 minutes x 1000 mg/g)}}{\text{mg/L of suspended matter in mixed liquor}}$$



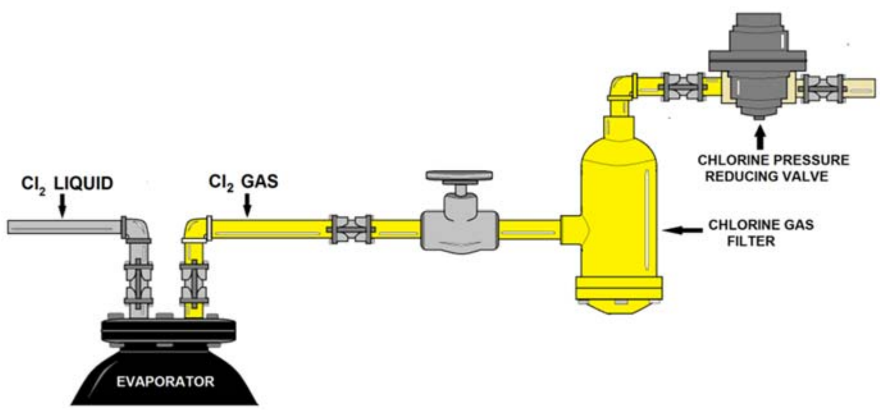
150 Lb. SINGLE CYLINDER CHLORINATOR



FIBERGLASS CHLORINE STORAGE SHELTER

The design of gas chlorine facilities should consider operator and public safety as well as maintaining long-term plant reliability and operation. Chlorination facilities are designed such that chlorine gas can be contained in the chlorine storage room. Doors and windows should be gas-tight to minimize escape of gaseous chlorine to the exterior atmosphere or building interior.

Leak detectors should be located 1 foot above the floor of the chlorine storage room and should activate an alarm when a chlorine leak occurs. It is preferable that the detector be capable of differentiating between two or more chlorine concentrations to alert personnel of the severity of the release. This would help determine the appropriate procedure for entrance to the room, ventilation, or other solutions. Self-contained breathing apparatus (SCBA) should not be located within the chlorine storage room. It is preferable that this equipment be located in a convenient location where personnel can easily access it in the event of an emergency.



The length of the chlorine gas and liquid chlorine pipelines should be as short as possible. All the safety equipment should be readily available and handy. The Plant should have provisions for exhausting chlorine gas, if a leak develops. Ideally a chlorine gas leak absorption system can be provided for gas leak evacuation and neutralization. An automatic or manual Shut - Off Valve and Pressure Relief Valve is also included for safe operation.

Chlorine

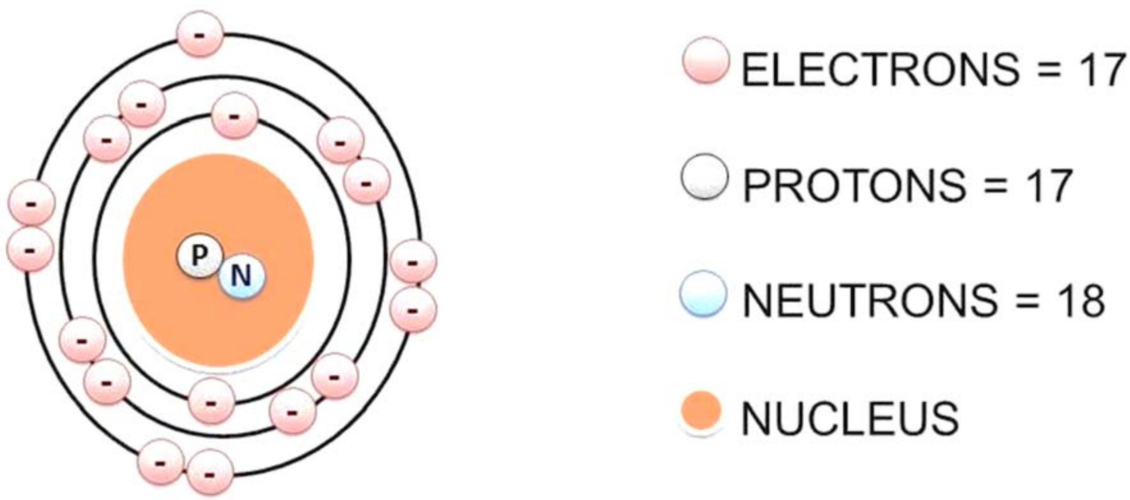
Formula: Cl_2
Structure: Not applicable.
Synonyms: Bertholite, molecular chlorine

Identifiers
1. CAS No.: 7782-50-5
2. RTECS No.: FO2100000
3. DOT UN: 1017 20
4. DOT label: Poison gas

Contact Chamber

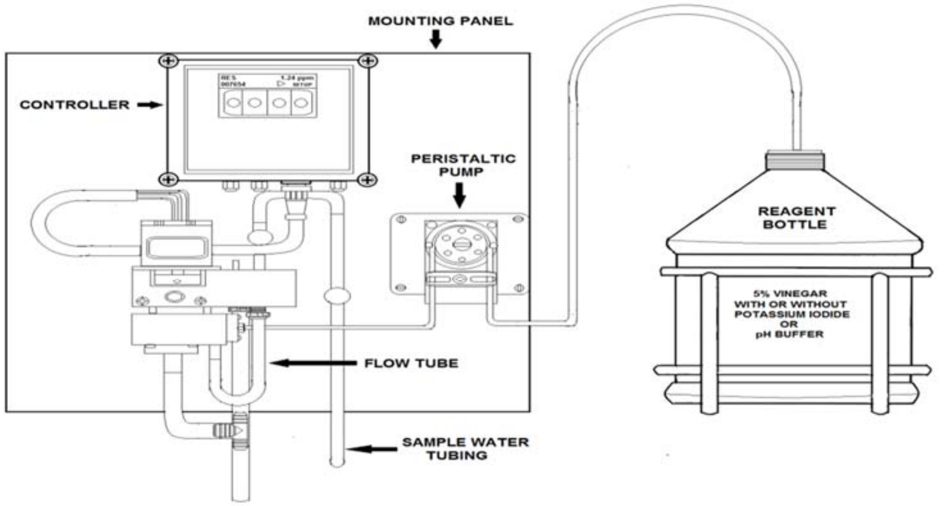
Appearance and odor

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 parts per million (**ppm**) parts of air have been reported. Prolonged exposures may result in olfactory fatigue.



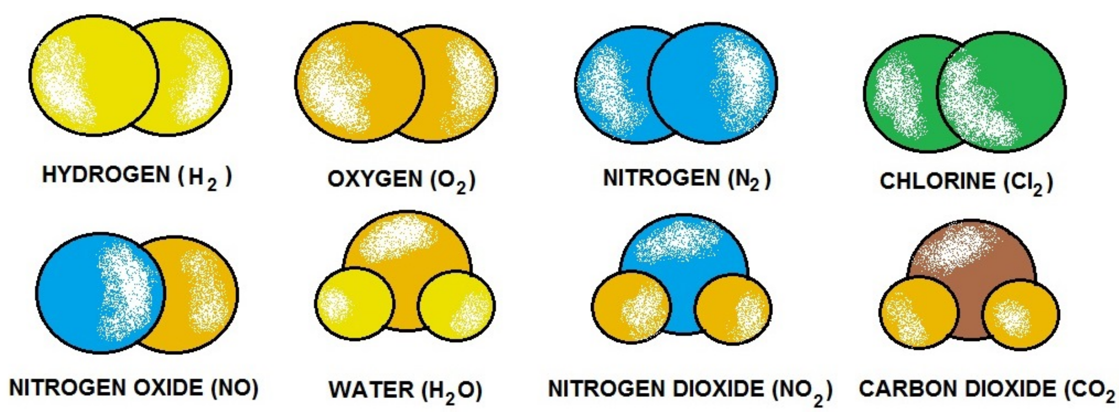
Physical Data

1. Molecular weight: 70.9
2. Boiling point (at 760 mm Hg): -34.6 degrees C (-30.28 degrees F)
3. Specific gravity (liquid): 1.41 at 20 degrees C (68 degrees F) and a pressure of 6.86 atm
4. Vapor density: 2.5
5. Melting point: -101 degrees C (-149.8 degrees F)
6. Vapor pressure at 20 degrees C (68 degrees F): 4,800 mm Hg
7. Solubility: Slightly soluble in water; soluble in alkalies, alcohols, and chlorides.
8. Evaporation rate: Data not available.



CHLORINE RESIDUAL ANALYZER

A true on-line, amperometric, chlorine residual analyzer requires a pH buffer to bring the sample pH down to a range where optimum free chlorine residuals can be accurately measured, ideally 4.0 to 4.5 pH. Any amperometric chlorine residual analyzer that claims buffers are not required uses either a pH buffered electrolyte in the probe, or makes an electronically simulated pH compensation (which is not a true chlorine residual reading). The vinegar reduces the pH in the sampling cell, which provides the current potential needed to measure chlorine residuals accurately.



Chlorine atoms can affect nitrogen oxides and ozone production, reducing the life cycle of methane gas. When exposed to the atmosphere, chlorine atoms can deplete the ozone. This reduces the ozone's ability to block ultraviolet rays, which can contribute to skin cancer in humans. It can also contribute to the greenhouse effect.

Modern Wastewater 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.

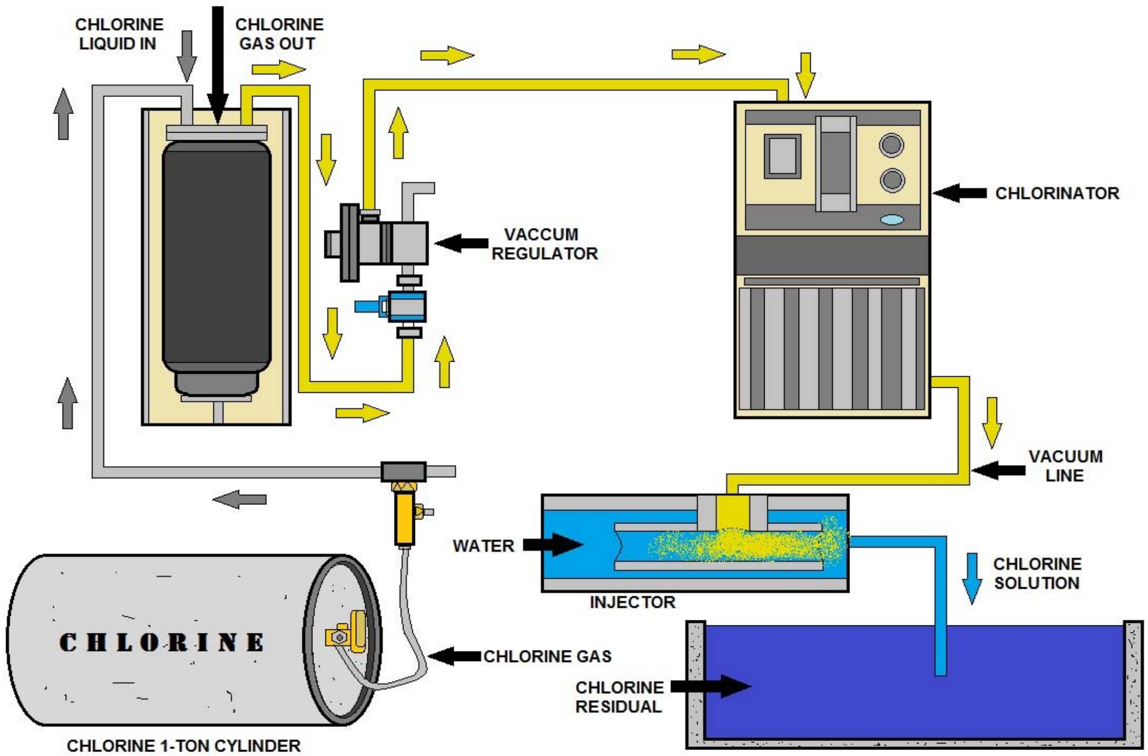
The opposite — high organic matter concentrations and high THM levels — is true when rivers or other surface waters are used as the source of the drinking water.

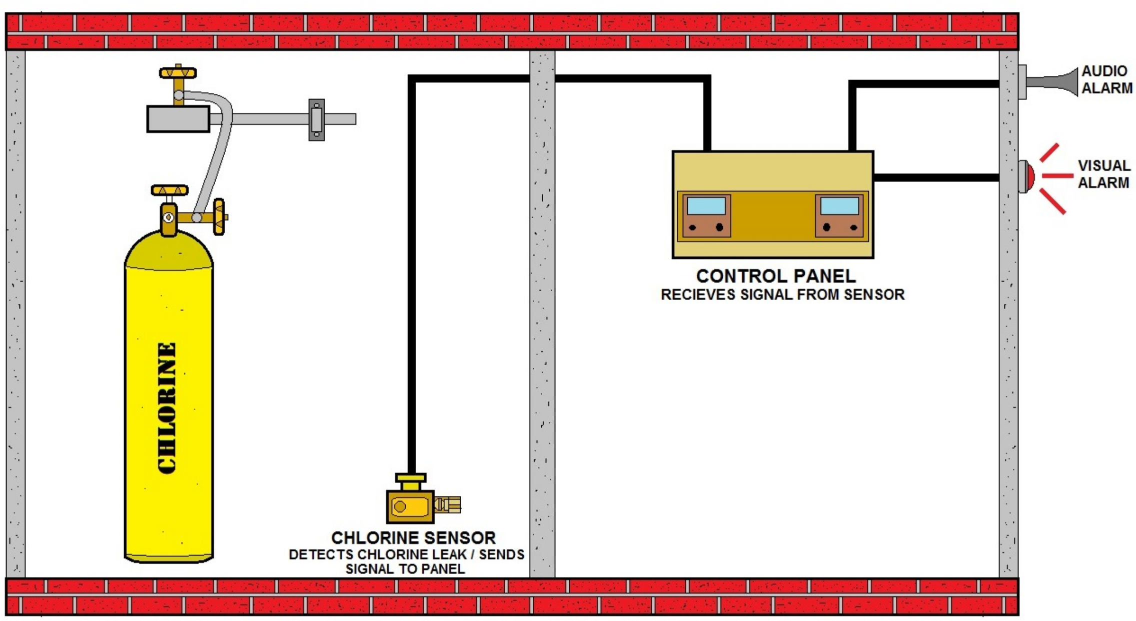
Health Effects
Laboratory animals exposed to very high levels of THMs have shown increased incidences of cancer. Also, several studies of cancer incidence in human populations have reported associations between long-term exposure to high levels of chlorination by-products and an increased risk of certain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

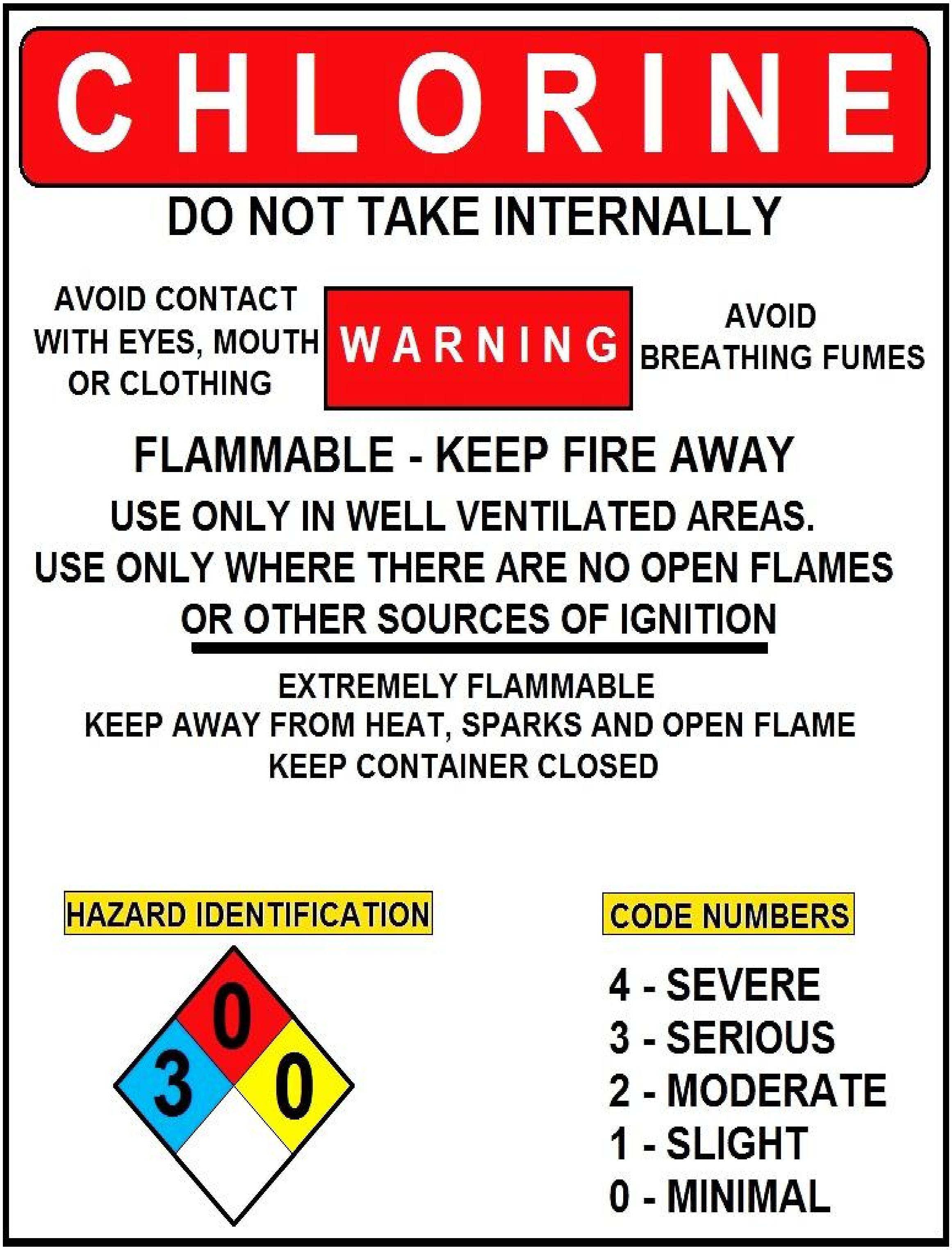
Possible relationships between exposure to high levels of THMs and adverse reproductive effects in humans have also been examined recently. In a California study, pregnant women who consumed large amounts of tap water containing elevated levels of THMs were found to have an increased risk of spontaneous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


CHLORINE
DO NOT TAKE INTERNALLY
AVOID CONTACT WITH EYES, MOUTH OR CLOTHING
WARNING
AVOID BREATHING FUMES
FLAMMABLE - KEEP FIRE AWAY
USE ONLY IN WELL VENTILATED AREAS.
USE ONLY WHERE THERE ARE NO OPEN FLAMES OR OTHER SOURCES OF IGNITION
EXTREMELY FLAMMABLE
KEEP AWAY FROM HEAT, SPARKS AND OPEN FLAME
KEEP CONTAINER CLOSED
HAZARD IDENTIFICATION
0
3
0
CODE NUMBERS
4 - SEVERE
3 - SERIOUS
2 - MODERATE
1 - SLIGHT
0 - MINIMAL

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 resolubulize, 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

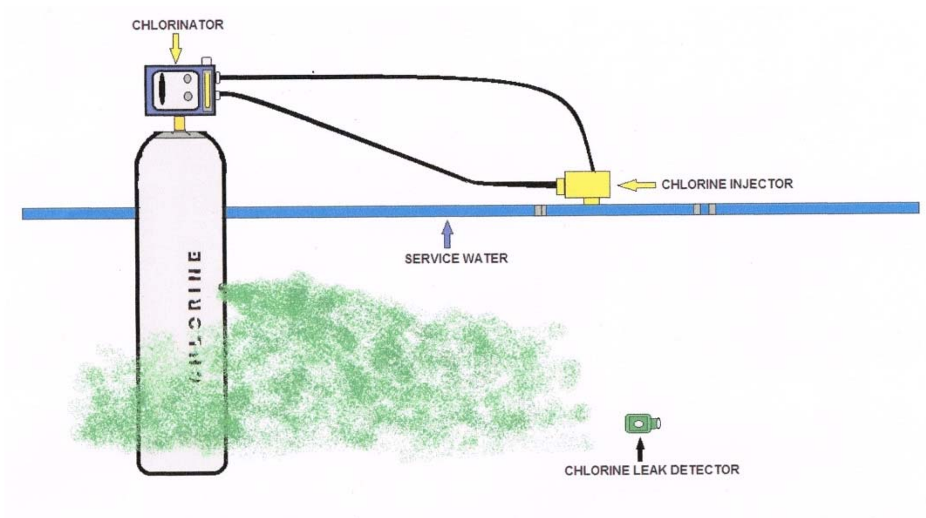
Chlorine is a greenish-yellow, noncombustible gas at room temperature and atmospheric pressure. The intermediate water solubility of chlorine accounts for its effect on the upper airway and the lower respiratory tract.

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.



150 lb. CHLORINE CYLINDER LEAKING FROM SIDEWALL

Although the idea that chlorine causes direct tissue damage by generating free oxygen radicals was once accepted, this idea is now controversial.

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.

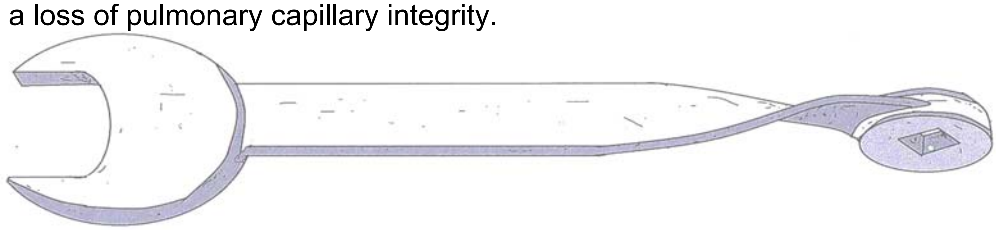
Hypochlorous acid may account for the toxicity of elemental chlorine and hydrochloric acid to the human body.

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.

Water and wastewater treatment plants use chlorine to reduce water levels of microorganisms that can spread disease to humans.

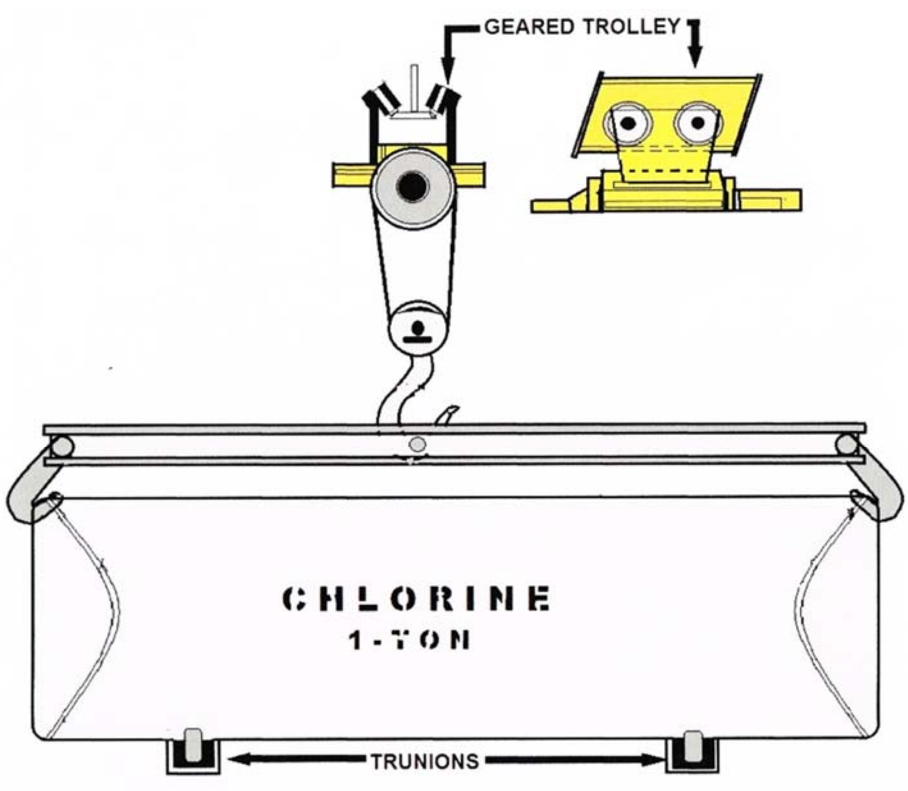
Exposure to chlorine can occur in the workplace or in the environment following releases to air, water, or land. People who use laundry bleach and swimming pool chemicals containing chlorine products are usually not exposed to chlorine itself. Chlorine is generally found only in industrial settings. 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 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.



CHLORINE 1 - TON CONTAINER
AND OVERHEAD CRANE

Chlorine is... *Key Points*

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 as 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.

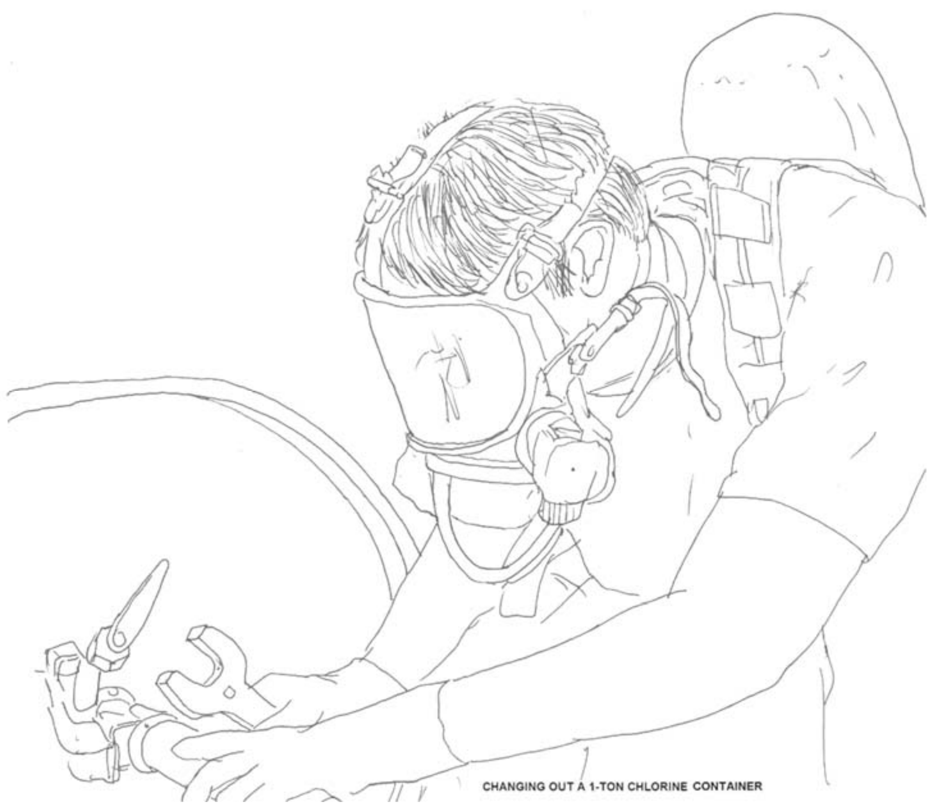
If you are helping other people remove their clothing, try to avoid touching any contaminated areas, and remove the clothing as quickly as possible.

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.



CHANGING OUT A 1-TON CHLORINE CONTAINER

		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	●	+	+	—	+	—	—	—	—	—	—
	Coventional pre-treat + OZONE + UF	—	●	—	—	+	—	—	—	—	—	—
	MF + UV	●	+	—	●	—	+	●	—	—	●	+
	Conventional pre-treat + UV	●	+	+	●	—	+	●	+	+	●	●
	Conventional pre-treat + OZONE + UV	+	●	+	+	+	—	—	+	+	●	+
	Alternative + Residual (2)	+	●	●	+	+	—	—	+	+	+	+

Conventional pre-treat = Coagulation / Sedimentation
UF - Ultafiltration 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

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, oxomonosilane, 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.

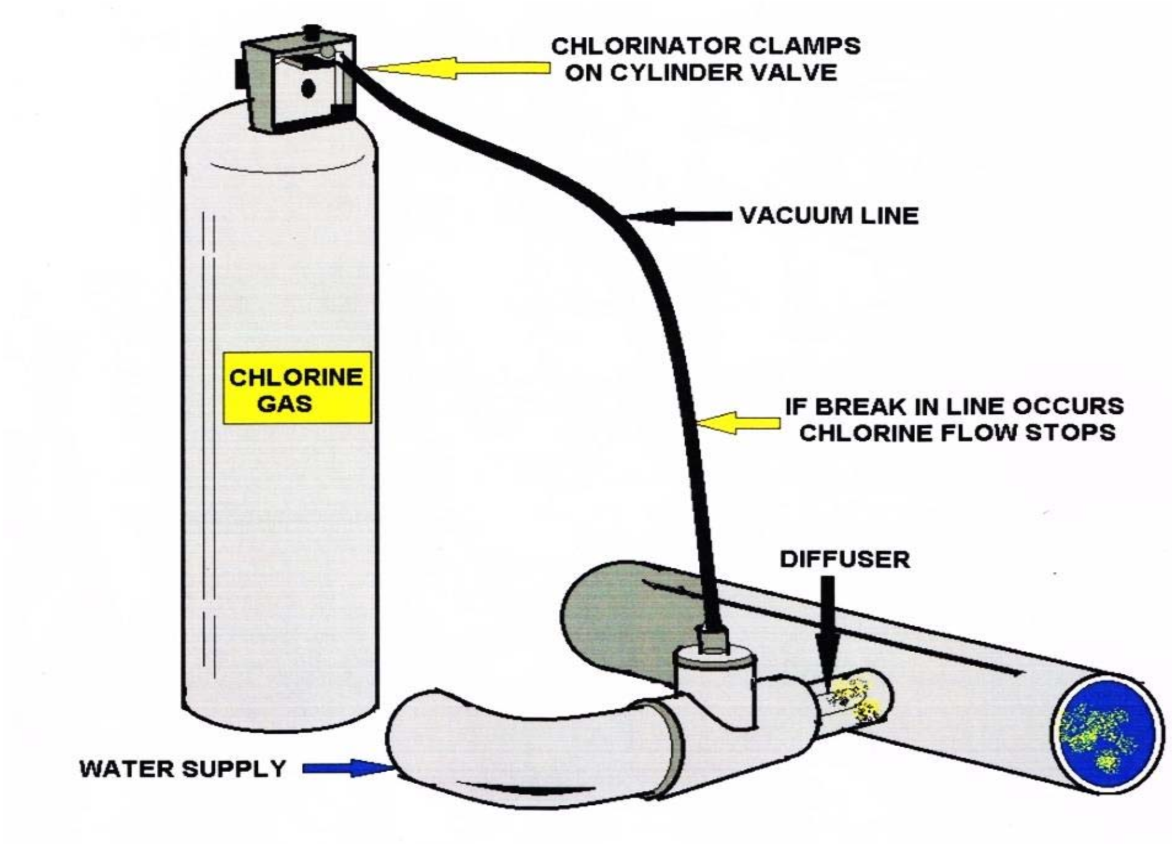
3. Flammable limits in air: Not applicable.

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.



*Chlorine storage room, notice the vents at the bottom and top. The bottom vent will allow the gas to ventilate because Cl2 gas is heavier than air.

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:

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.

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.

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.

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.

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.

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."

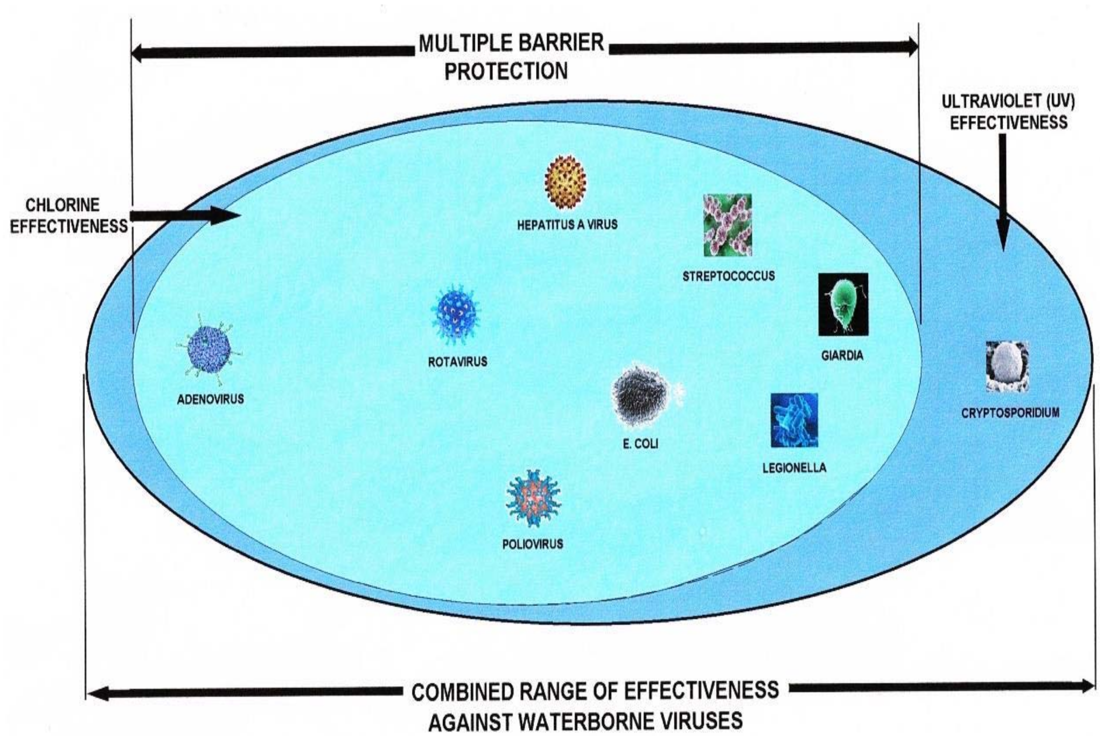
Alternative Disinfectants More information in the Alternative Section
Unknown Factors Associated with Alternatives
Scientific investigation of risk associated with alternative disinfectants and alternative disinfection by-products is limited. A decision by water facilities to switch from chlorination 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

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.



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."

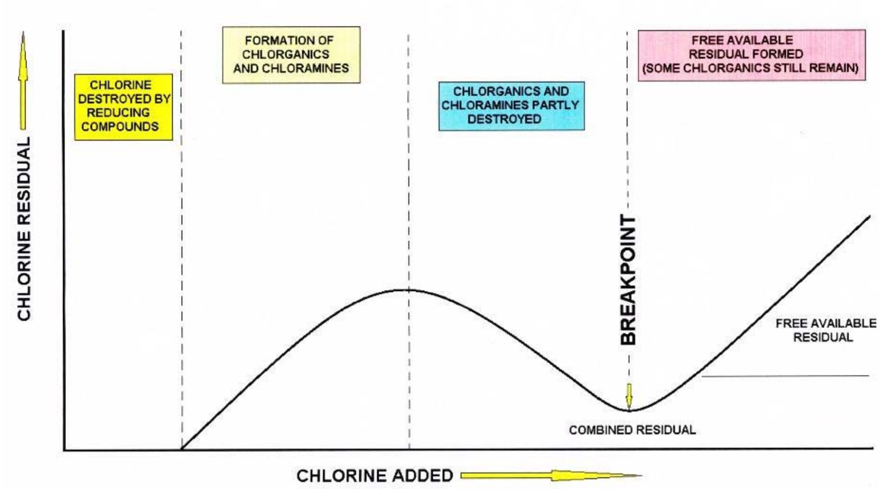
Released From the Salt of the Earth
Chlorine is produced industrially from the compound sodium chloride, one of the many salts found in geologic deposits formed from the slow evaporation of ancient seawater. When electricity is applied to a brine solution of sodium chloride, chlorine gas (Cl2), caustic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

$$\text{Salt} + \text{Water} \rightarrow \text{Chlorine gas} + \text{Caustic soda} + \text{Hydrogen gas}$$

$$2\,NaCl + 2\,H_2O \rightarrow Cl_2 + 2\,NaOH + H_2$$

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

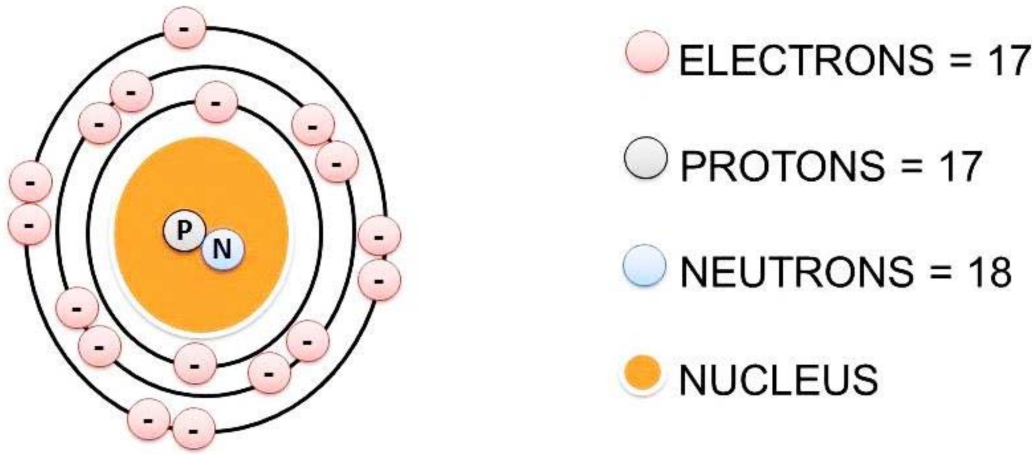
*** OSHA PEL**

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].

Chlorine's Atomic Structure



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.
Contact time (from Table 5) - gallons per minute for 50 gallon tank = 5 minutes
Multiply by 2 for a 100 gallon tank = 10 minutes.

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.

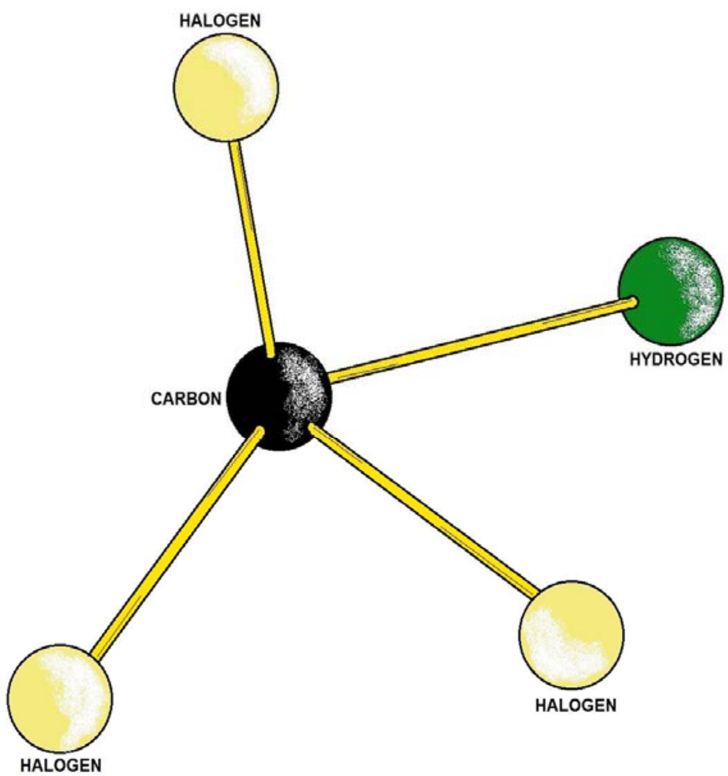
The necessary contact time for this concentration is reduced to less than five minutes (Table 4). The water will have a very strong chlorine smell. If this is not desirable, the chlorine can be removed just before it is used with a carbon filter (Note: may not be currently allowed under your Department 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.

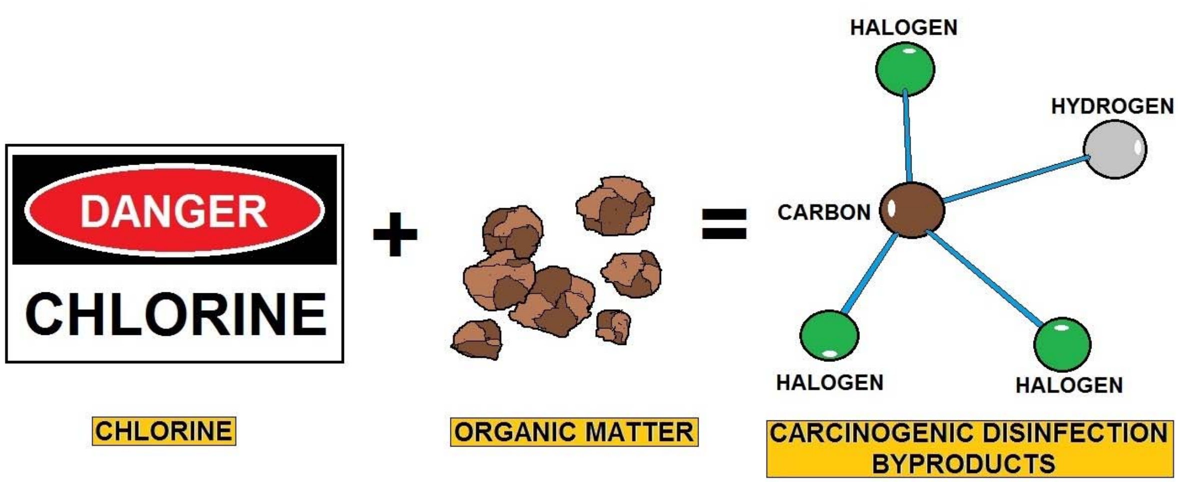
Oxidizing microbiocides are often found at the forefront of many cooling water treatment programs. In large volume or once-through cooling systems they are usually the primary biocide and often are the most cost-effective programs available to a plant. When selecting these economical and versatile chemicals, 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.

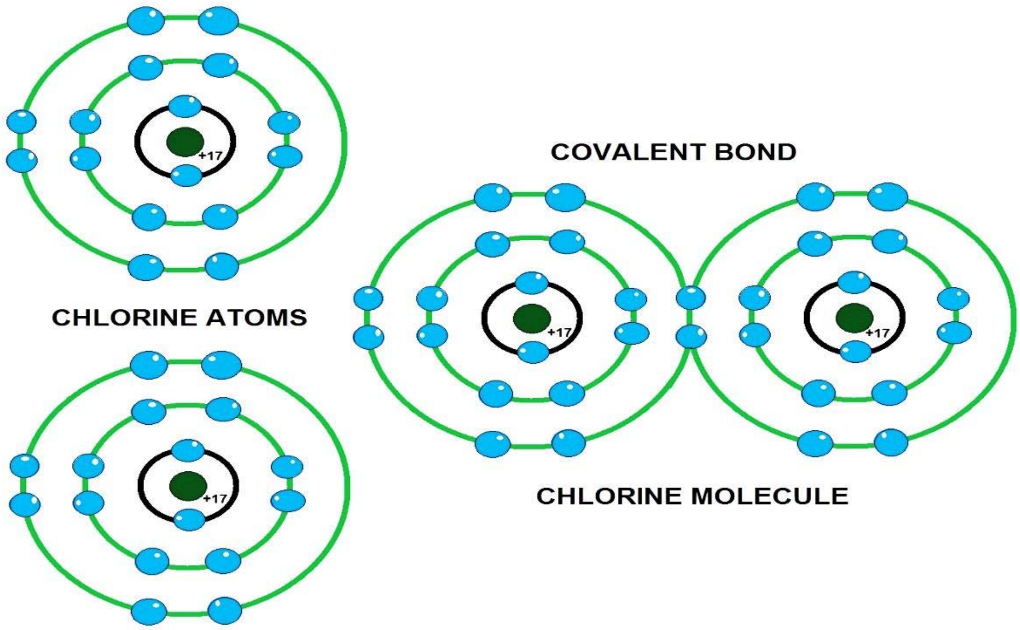
One oxidant is chlorine dioxide, which appears to provide an additional killing mechanism. Chlorine dioxide is able to diffuse readily through hydrophobic lipid layers of an organism, allowing it to react with cellular amino acids, which directly inhibits protein synthesis. Since amino acids are the basic building blocks of all cellular proteins, destruction of these molecules has a devastating effect on the microorganism.



TRIHALOMETHANE
(THM'S)



DISINFECTION BYPRODUCT PRODUCTION DIAGRAM



STRUCTURE OF A CHLORINE ATOM

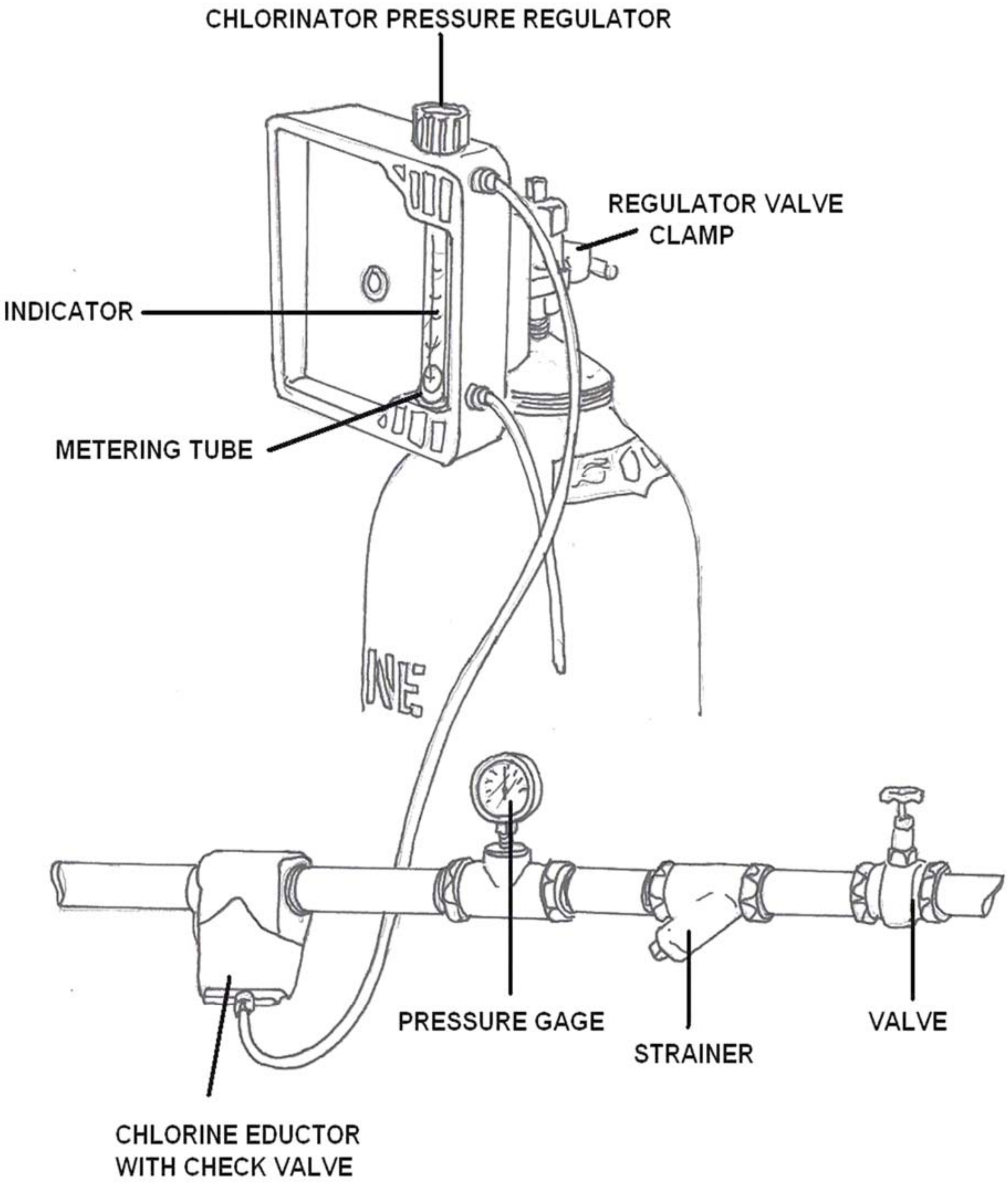
Chlorine Questions and Answer Review
Downstream from the point of post chlorination, what should the concentration of a free chlorine residual be in a clear well or distribution reservoir? 0.5 mg/L.

True or False. Even brief exposure to 1,000 ppm of Cl2 can be fatal. True

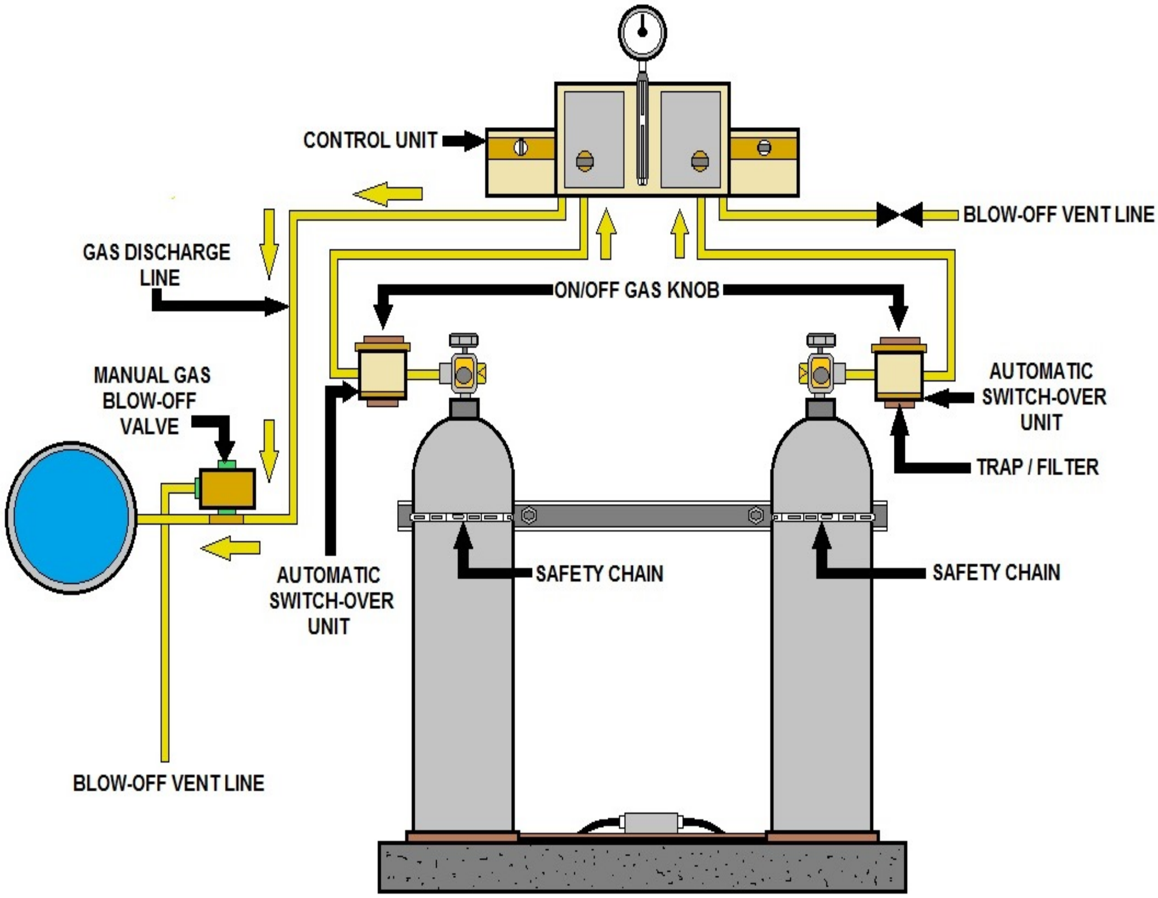
How does one determine the ambient temperature in a chlorine room? Use a regular thermometer because ambient temperature is simply the air temperature of the room.

How is the effectiveness of disinfection determined? From the results of coliform testing.

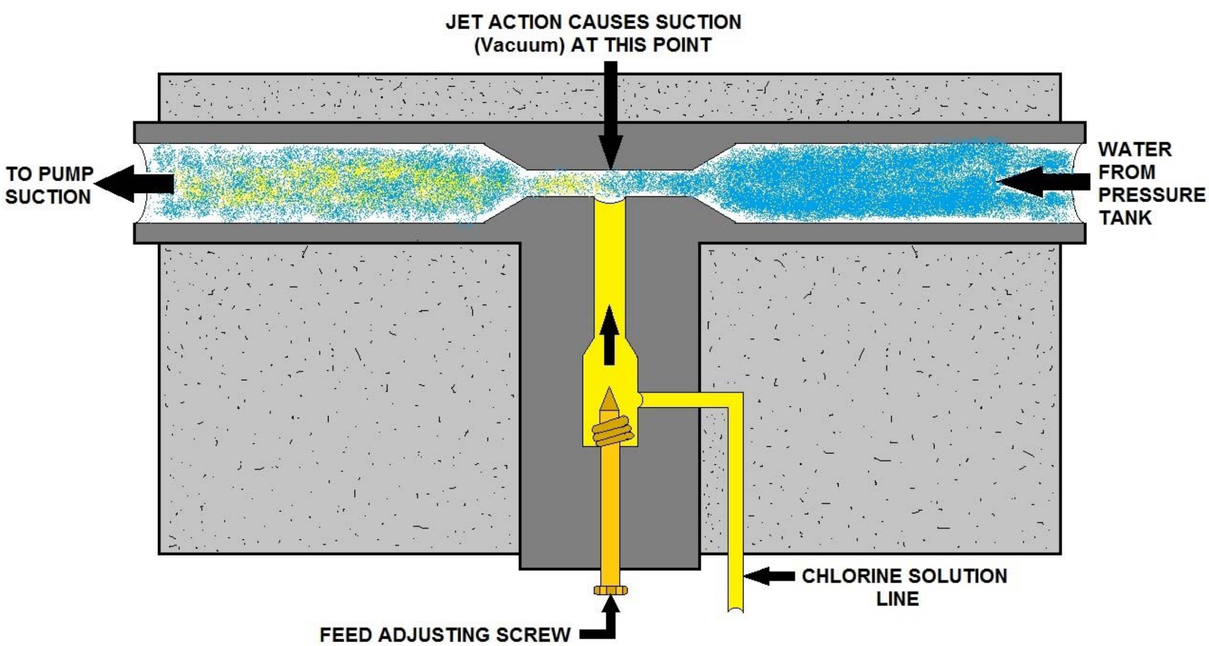
How often should chlorine storage ventilation equipment be checked? Daily.



BASIC CHLORINATOR INSTALLATION SYSTEM



TWO CYLINDER CHLORINE SCALE

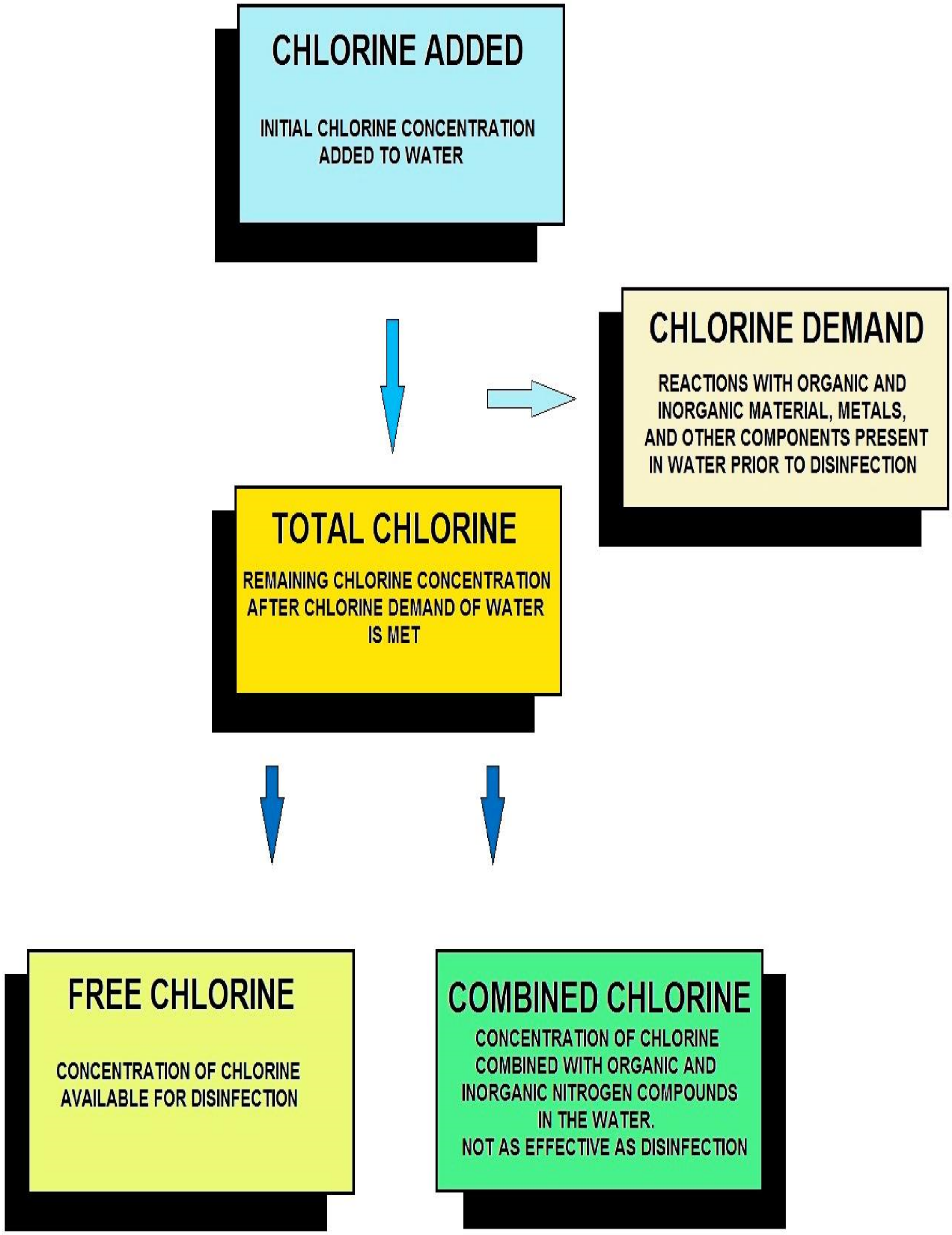


Chlorinator Components

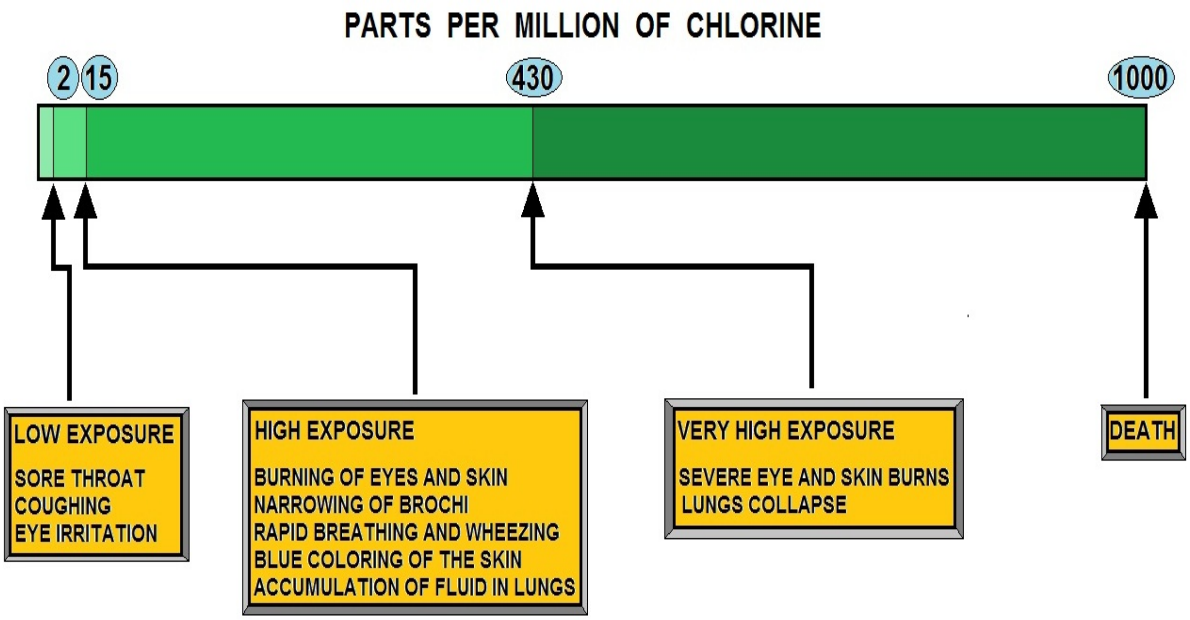
- ✓ Ejector
- ✓ Check Valve Assembly
- ✓ Rate Valve
- ✓ Diaphragm Assembly
- ✓ Interconnection Manifold
- ✓ Rotometer Tube and Float
- ✓ Pressure Gauge
- ✓ Gas Supply

Chlorine measurement devices or Rotometer.

Chlorine Safety Information: There is a fusible plug on every chlorine tank. This metal plug will melt at 158 to 165o F. This is to prevent a build-up of excessive pressure and the possibility of cylinder rupture due to fire or high temperatures.



CHLORINE DISINFECTION



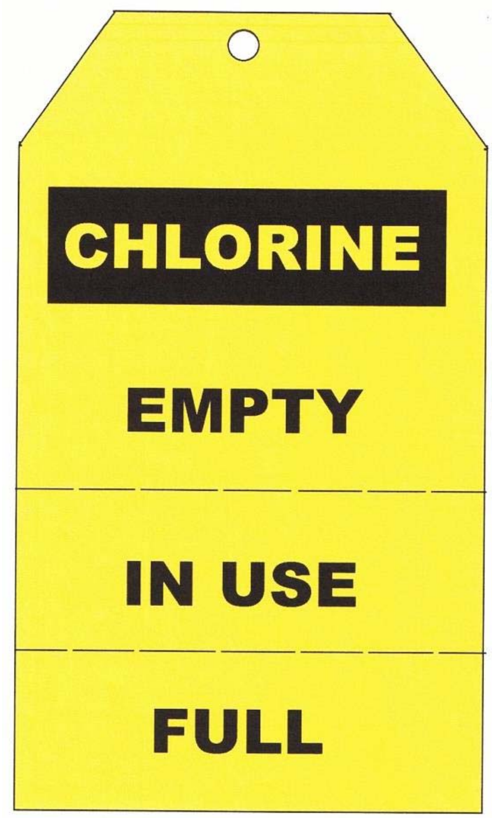
EFFECTS OF CHLORINE GAS ON HEALTH

SYMPTOM OF CHLORINE POISONING:
DIFFICULTY IN BREATHING, ACCUMULATION IN LUNGS
BURNING SENSATION IN MOUTH, THROAT SWELLING
THROAT AND STOMACH PAIN, VOMITING
ACIDITY LEVELS IN BODY CHANGE, LOW BLOOD PRESSURE
BURNING AND IRRITATION OF EYES, TEMPORARY LOSS OF VISION
TISSUE DAMAGE, BURNS AND IRRITATION OF THE SKIN

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.

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.

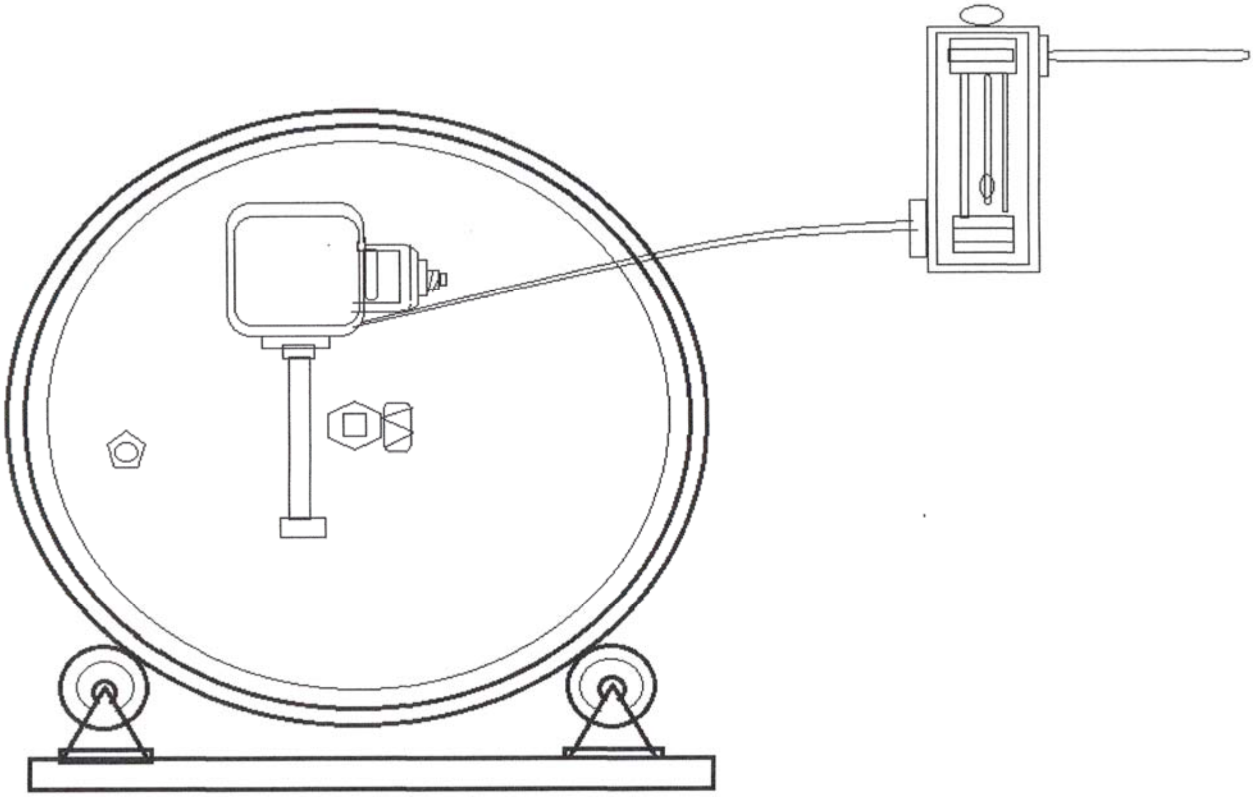
In Cases of Ingestion, Do Not Induce Emesis or Offer Activated Charcoal.
Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk; if the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Dilultants are contraindicated 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.

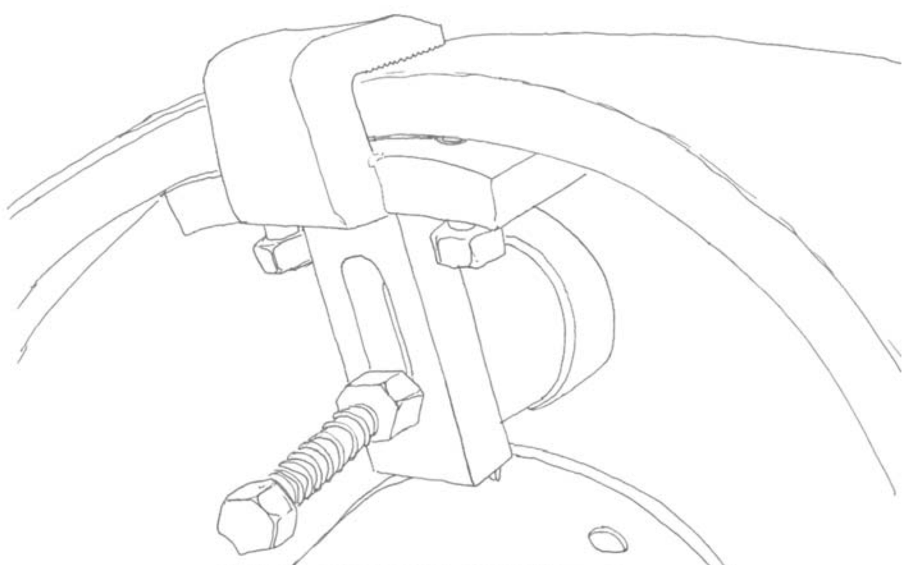
Support Zone
Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized 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. Dilultants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation.



CHLORINE 1 - TON CONTAINER



REPAIRING A FUSIBLE PLUG LEAK ON A 1-TON CHLORINE CONTAINER

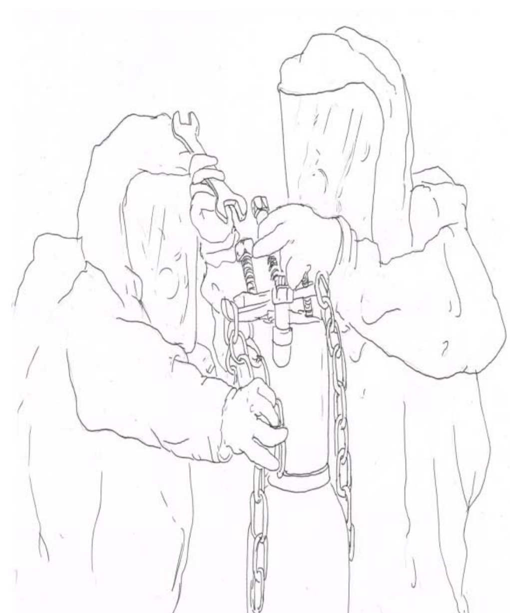
Chlorine Storage

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, oxomonosilane, 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:



REPAIRING A LEAK ON A 150 lb. CHLORINE CYLINDER USING THE CHLORINE REPAIR A-KIT

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.

Chemical Spill Procedure Example

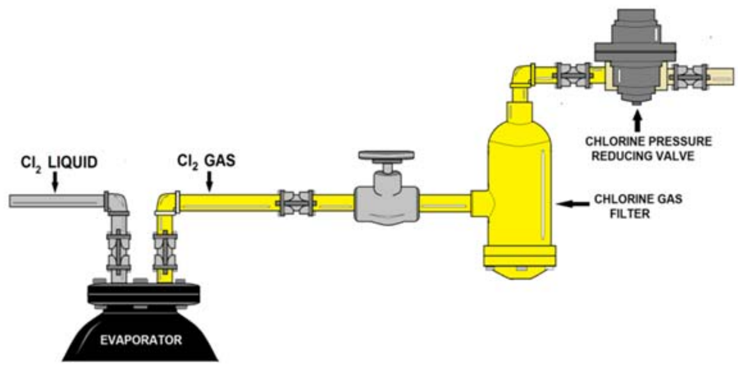
TOXIC CHEMICAL RELEASE: CHLORINE GAS, AMMONIA, AND LIQUID CHLORINE OR OTHER SUBSTANCE POSING IMMEDIATE HEALTH

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.

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 Chlorep/Supplier, fire department, police, Spill Report Center, according to your facility's policy.
6. Follow directions given by Chlorep/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.

SYMPTOM OF CHLORINE POISONING:
DIFFICULTY IN BREATHING, ACCUMULATION IN LUNGS
BURNING SENSATION IN MOUTH, THROAT SWELLING
THROAT AND STOMACH PAIN, VOMITING
ACIDITY LEVELS IN BODY CHANGE, LOW BLOOD PRESSURE
BURNING AND IRRITATION OF EYES, TEMPORARY LOSS OF VISION
TISSUE DAMAGE, BURNS AND IRRITATION OF THE SKIN

Chemical Equations, Oxidation States, and Balancing of Equations

Before we break down chlorine and other chemicals, let's start with this review of basic chemical equations.

Beginning
The common chemical equation could be A + B --> C + D. This is chemical A + chemical B, the two reacting chemicals will go to products C + D etc.

Oxidation
The term "oxidation" originally meant a reaction in which oxygen combines chemically with another substance, but its usage has long been broadened to include any reaction in which electrons are transferred.

Oxidation and reduction always occur simultaneously (redox reactions), and the substance which gains electrons is termed the oxidizing agent. For example, cupric ion is the oxidizing agent in the reaction: Fe (metal) + Cu++ --> Fe++ + Cu (metal); here, two electrons (negative charges) are transferred from the iron atom to the copper atom; thus the iron becomes positively charged (is oxidized) by loss of two electrons, while the copper receives the two electrons and becomes neutral (is reduced).

Electrons may also be displaced within the molecule without being completely transferred away from it. Such partial loss of electrons likewise constitutes oxidation in its broader sense and leads to the application of the term to a large number of processes, which at first sight might not be considered to be oxidation. Reaction of a hydrocarbon with a halogen, for example, CH4 + 2 Cl --> CH3Cl + HCl, involves partial oxidation of the methane; halogen addition to a double bond is regarded as an oxidation.

Dehydrogenation is also a form of oxidation; when two hydrogen atoms, each having one electron, are removed from a hydrogen-containing organic compound by a catalytic reaction with air or oxygen, as in oxidation of alcohol to aldehyde.

Oxidation Number
The number of electrons that must be added to or subtracted from an atom in a combined state to convert it to the elemental form; i.e., in barium chloride (BaCl2) the oxidation number of barium is +2 and of chlorine is -1. Many elements can exist in more than one oxidation state.

Now, let us look at some common ions. An ion is the reactive state of the chemical, and is dependent on its place within the periodic table.

Have a look at the "periodic table of the elements". It is arranged in columns of elements, there are 18 columns. You can see column one, H, Li, Na, K, etc. These all become ions as H+, Li+, K+, etc. The next column, column 2, Be, Mg, Ca etc. become ions Be2+, Mg2+, Ca2+, etc. Column 18, He, Ne, Ar, Kr are inert gases. Column 17, F, Cl, Br, I, ionize to a negative F-, Cl-, Br-, I-, etc.

What you now need to do is memorize the table of common ions, both positive ions and negative ions.

Using DPD Method for Chlorine Residuals
N, N – diethyl-p-phenylenediame

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.

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:

$Cl_2 + H_2O \rightarrow HOCl + HCl$
(chlorine gas) (water) (hypochlorous acid) (hydrochloric acid)

$CaOCl + H_2O \rightarrow 2HOCl + Ca(OH)$
(calcium hypochlorite) (water) (hypochlorous acid) (calcium hydroxide)

$NaOCl + H_2O \rightarrow HOCl + Na(OH)$
(sodium hypochlorite) (water) (hypochlorous acid) (sodium hydroxide)

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.

(OCl^-): $HOCl\ H^+ + OCl^-$ Also expressed $HOCl \rightarrow H^+ + OCl^-$
(hypochlorous acid) (hydrogen) (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).

CT = Concentration (mg/L) x 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/m(3))) 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 their 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.

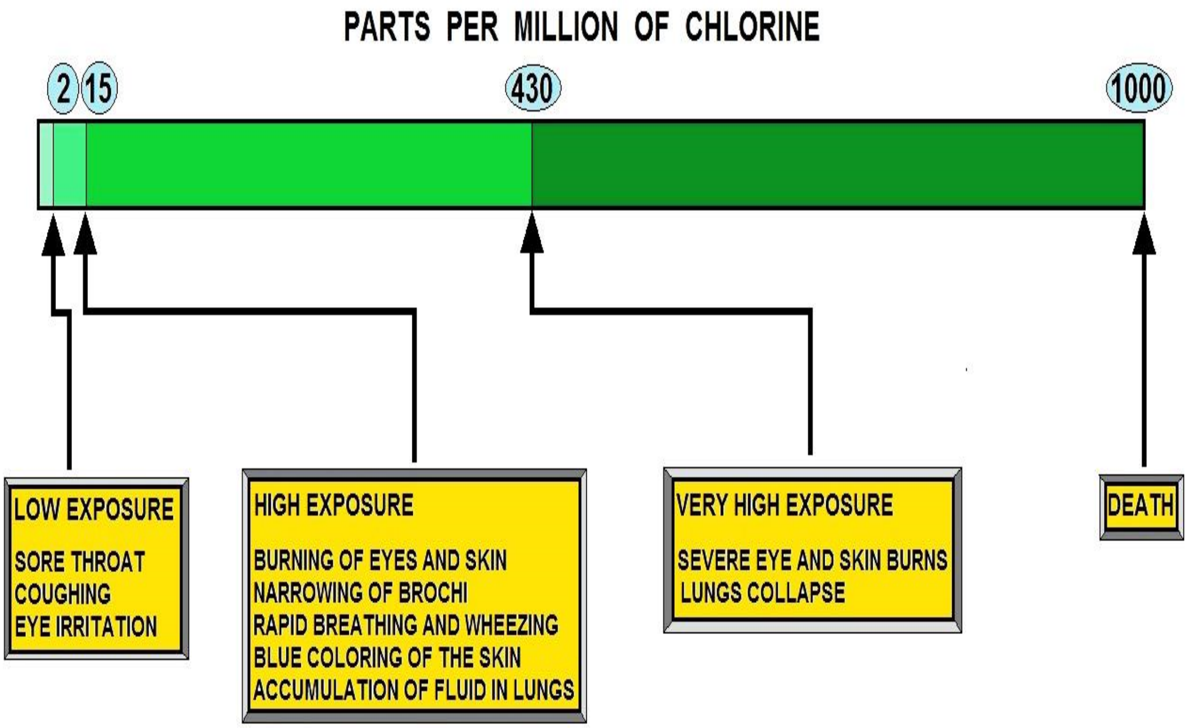
On a 1 ton container, the chlorine pressure reducing valve should be located downstream of the evaporator when using an evaporator. This is the liquid chlorine supply line and it is going to be made into chlorine gas.

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.



EFFECTS OF CHLORINE GAS ON HEALTH

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.

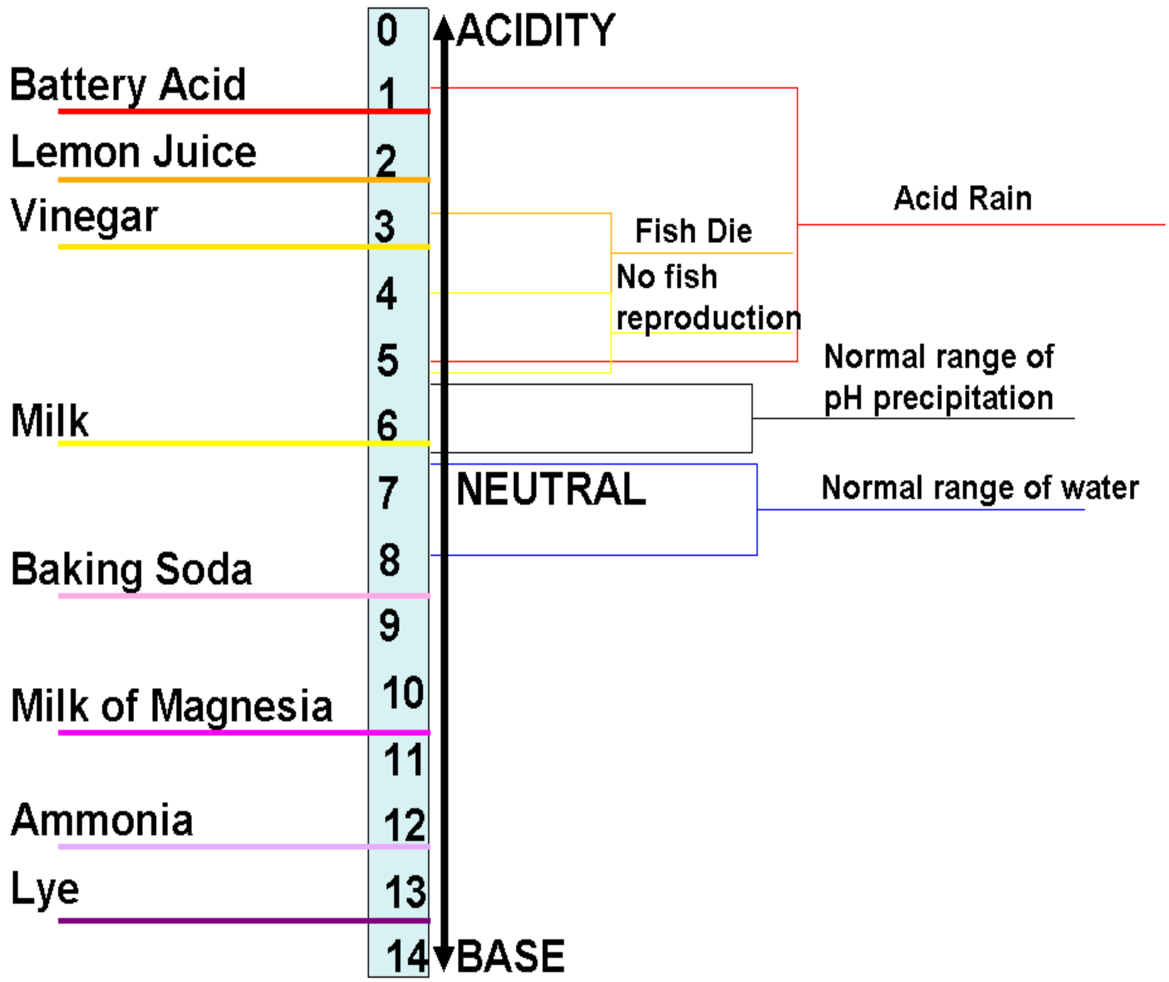
The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites.

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.

The 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.

Chlorine Supplement ***Know this section. Answers in 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?

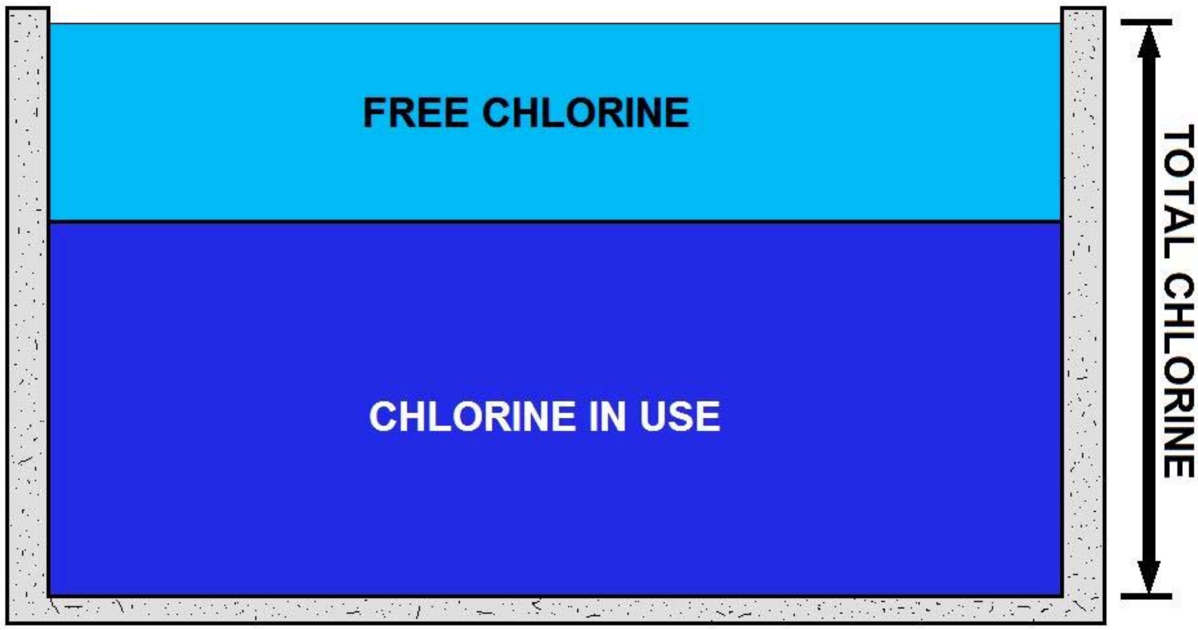
22. When chlorine gas is added to water, it rapidly hydrolyzes according to the reaction:

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.

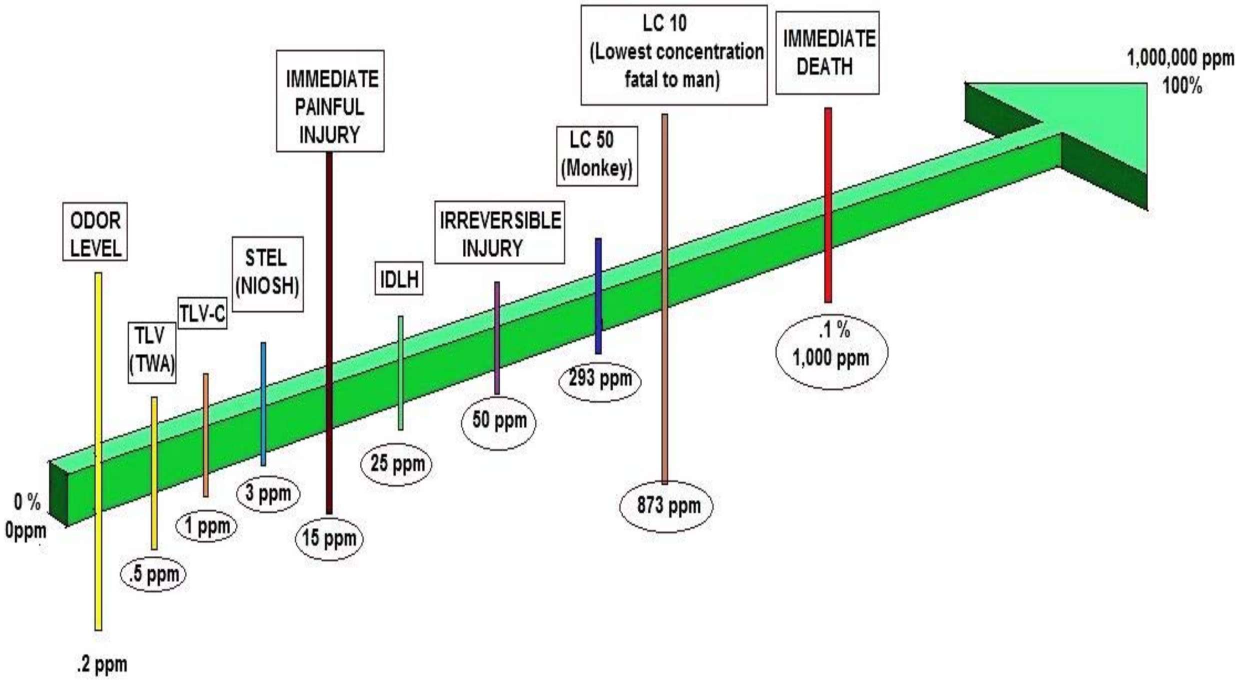
Chlorine Answers

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. $Cl_2 + H_2O \longrightarrow H^+ + Cl^- + HOCl$
23. $HOCl \longleftarrow\longrightarrow H^+ + OCl^-$
24. Hypochlorous acid

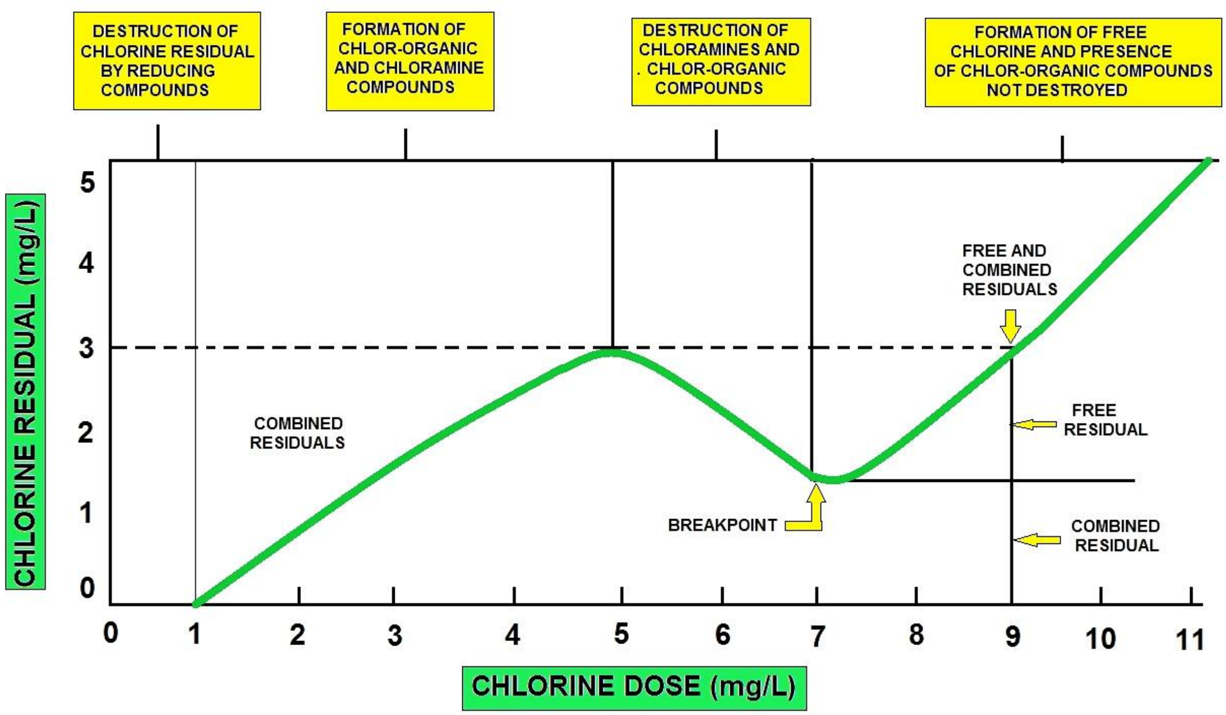


CHLORINE IN USE + FREE CHLORINE = TOTAL CHLORINE

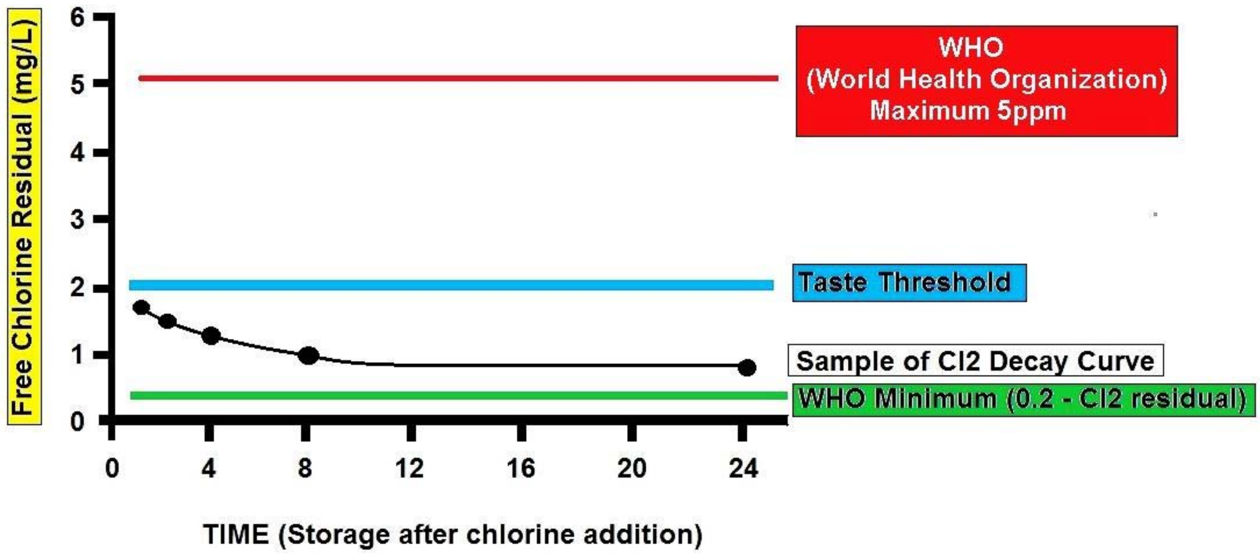
Chlorine Charts



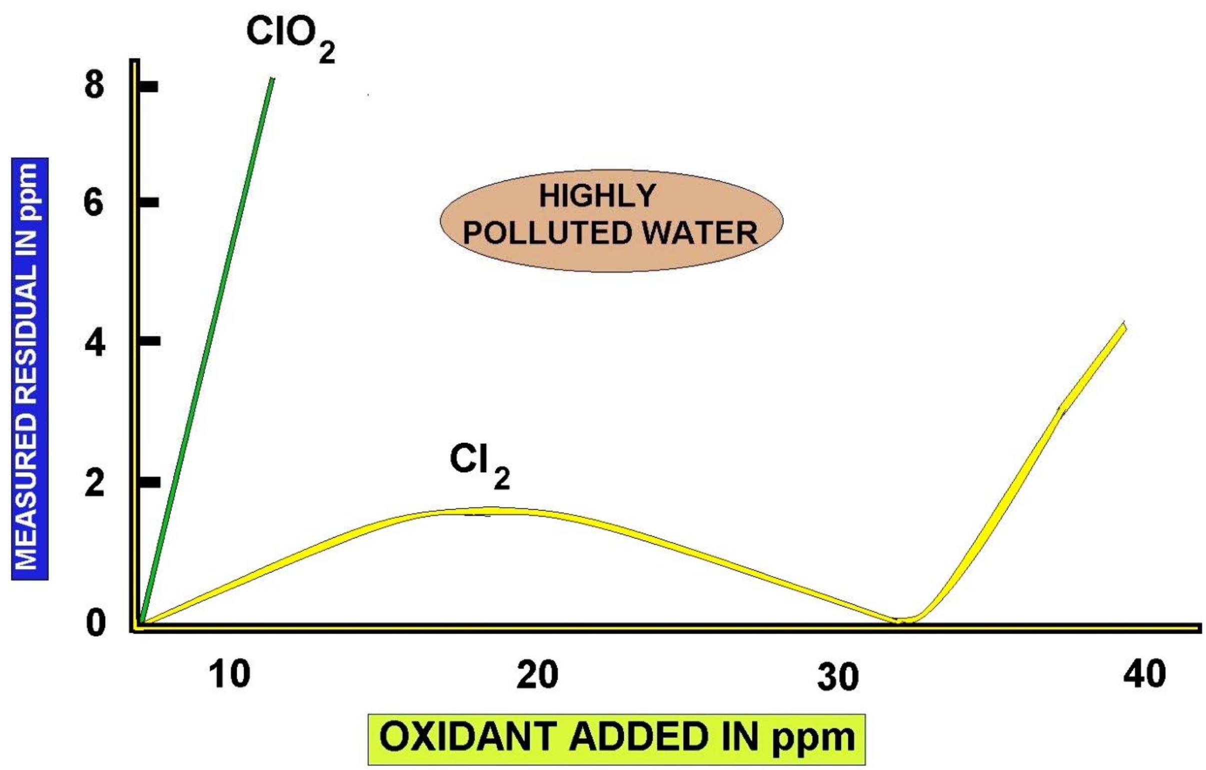
CHLORINE POISON LINES



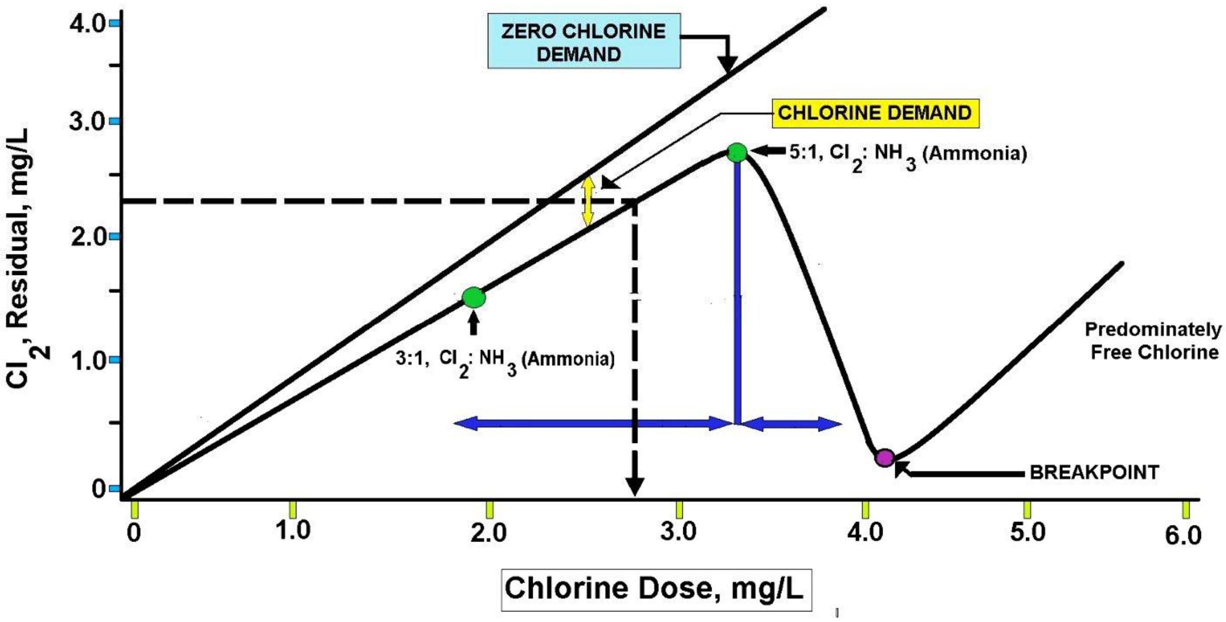
CHLORINE BREAKPOINT



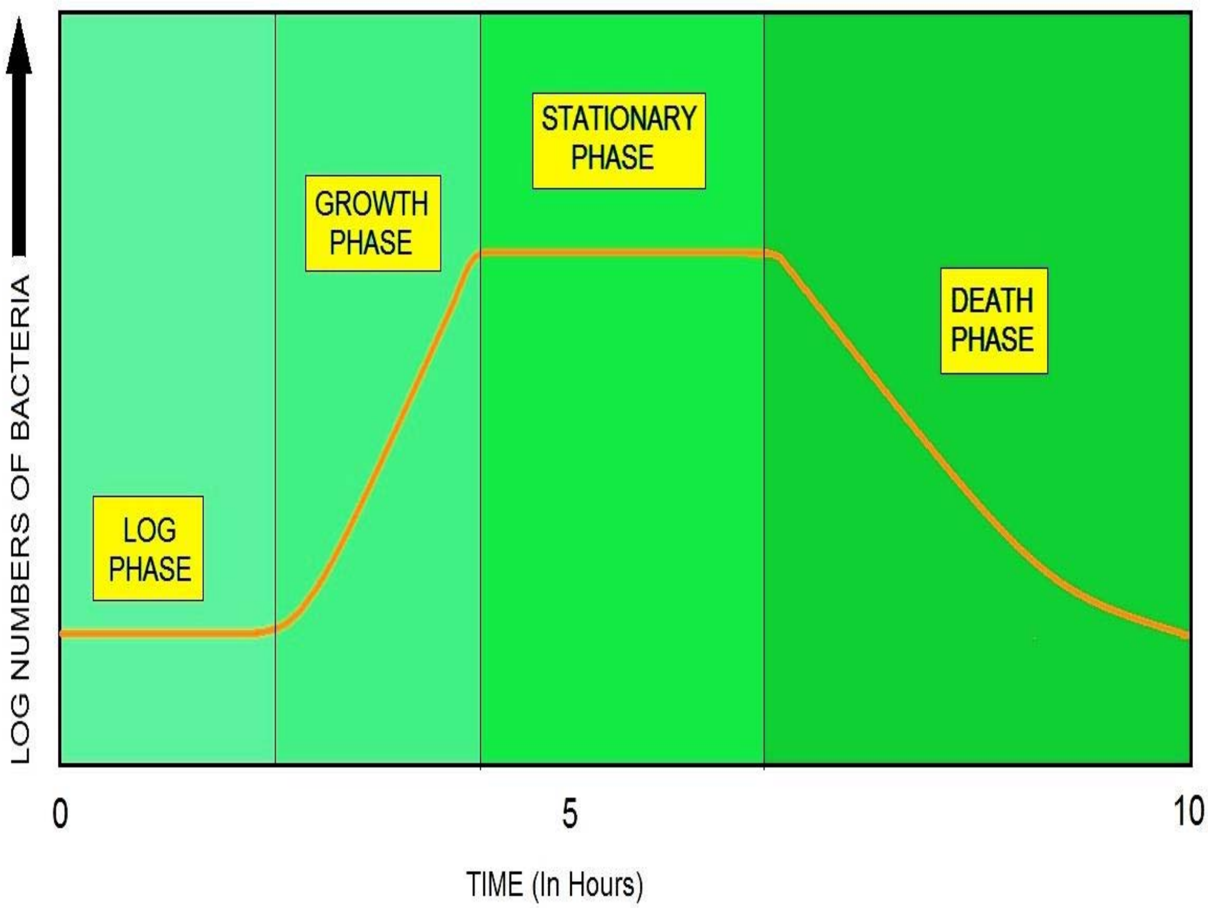
CHLORINE DECAY CURVE

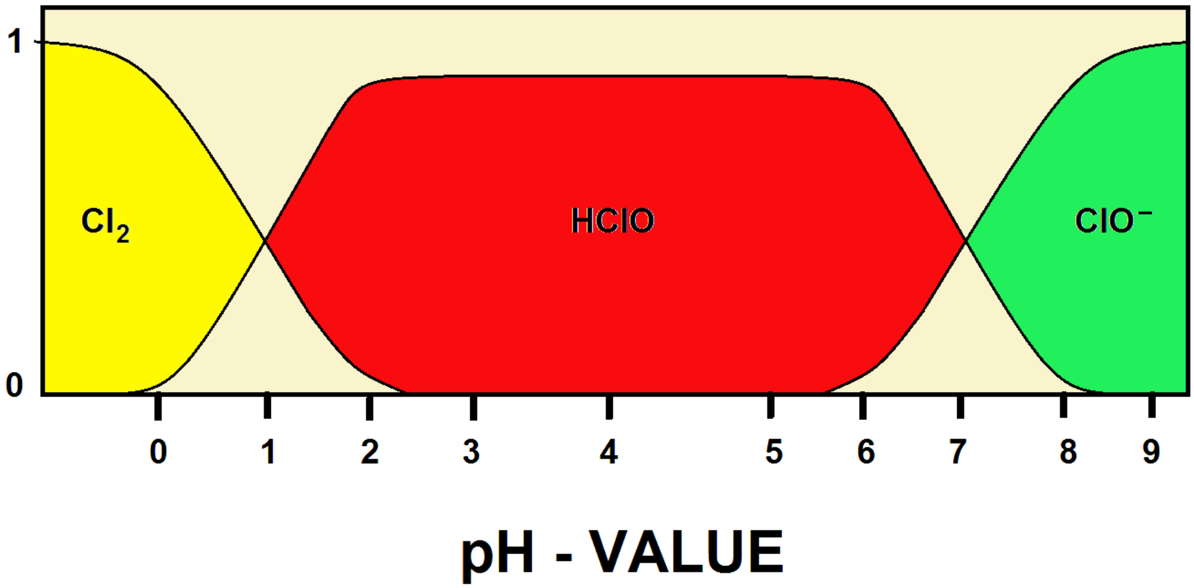


USING CHLORINE DIOXIDE vs CHLORINE



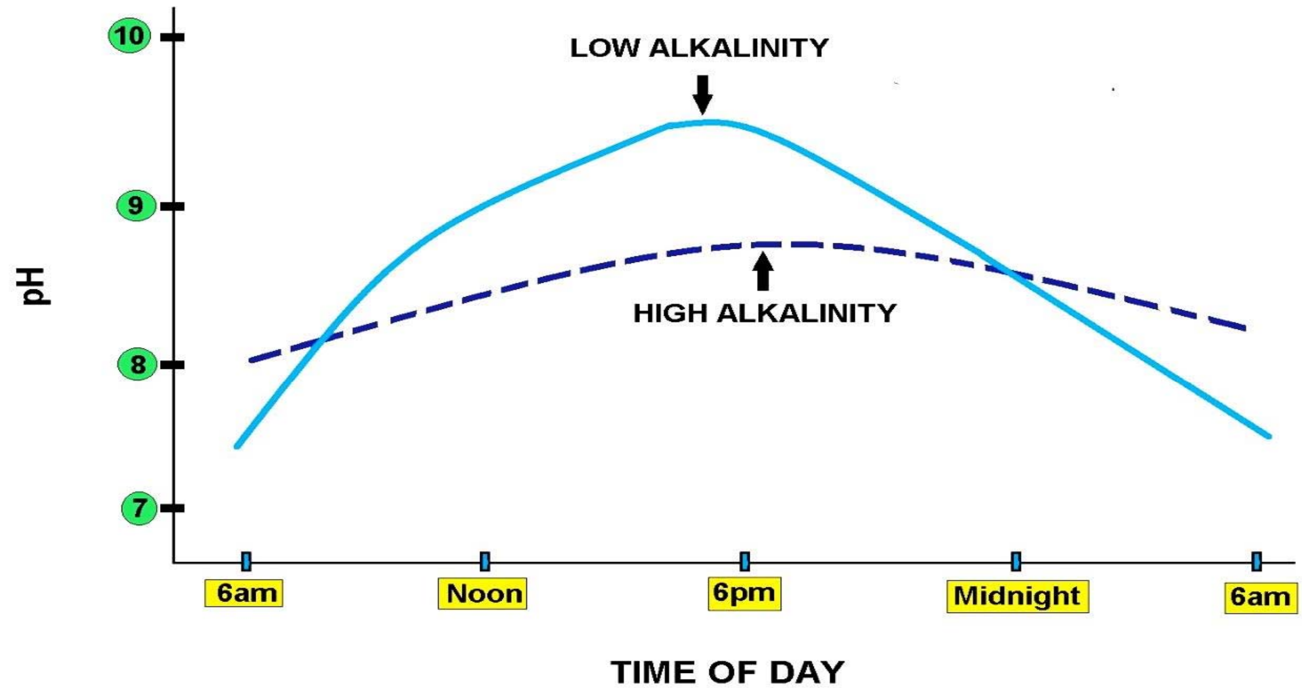
CHLORAMINATION



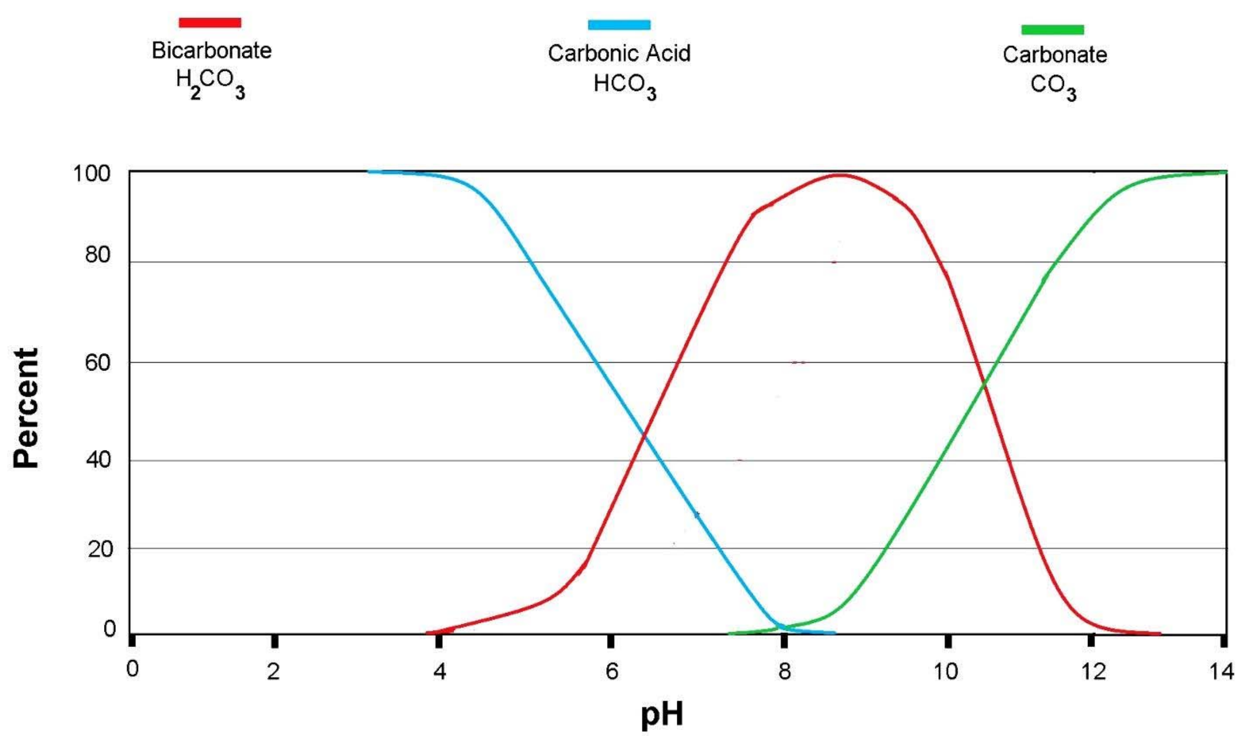


CONCENTRATION OF HYDROGEN IONS COMPARED TO DISTILLED H2O	pH	EXAMPLES OF SOLUTIONS AND THEIR RESPECTIVE pH
1/10,000,000	14	LIQUID DRAIN CLEANER CAUSTIC SODA
1/1,000,000	13	BLEACHES OVEN CLEANERS
1/100,000	12	SOAPY WATER
1/10,000	11	HOUSEHOLD AMMONIA (11.9)
1/1,000	10	MILK OF MAGNESIUM (10.5)
1/100	9	TOOTHPASTE (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

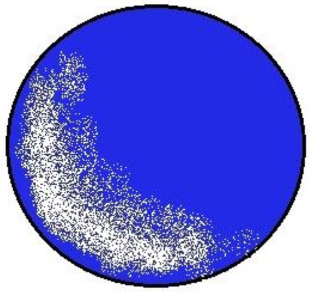
pH Scale



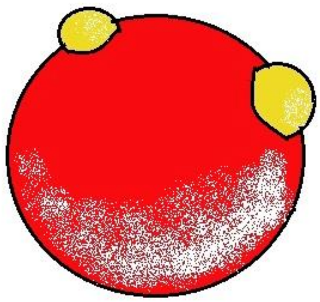
ALKALINITY



EFFECTS OF ALKALINITY FROM pH

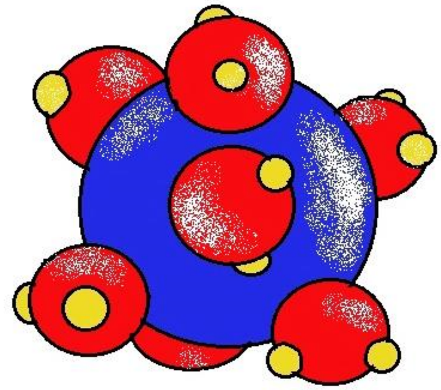


BARE CALCIUM ION

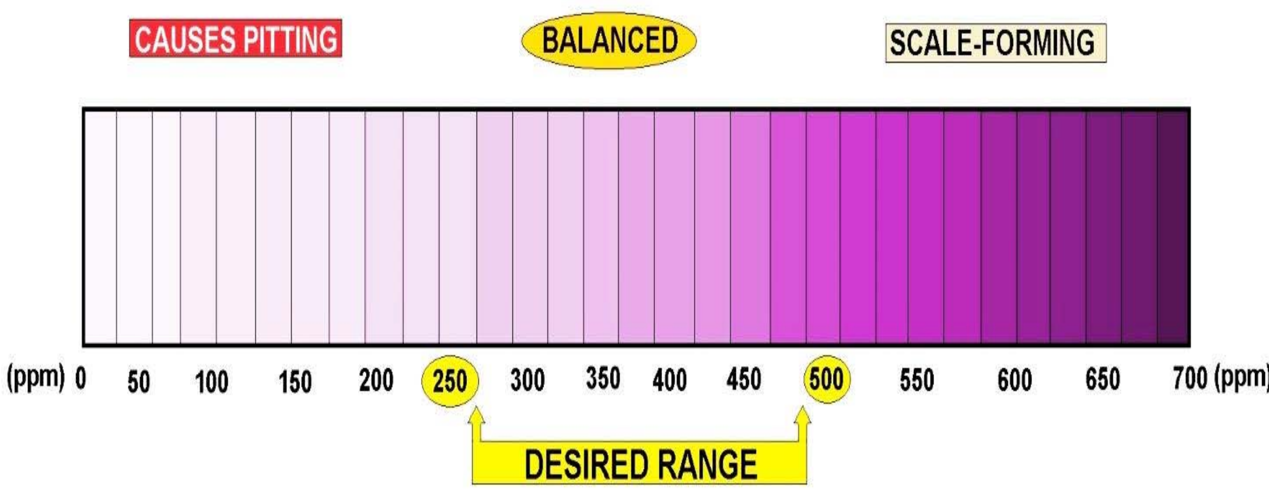


H_2O

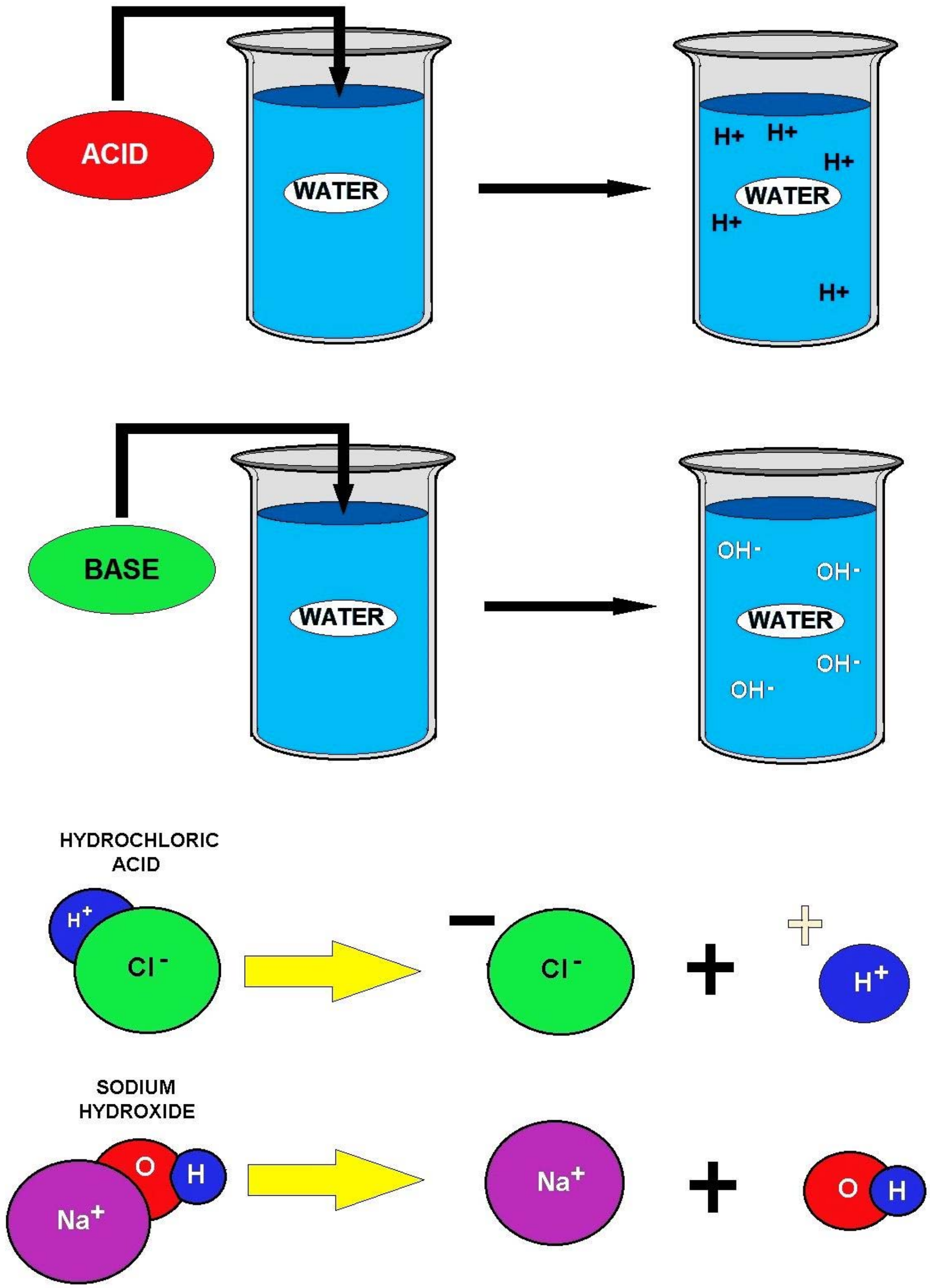
WATER MOLECULE



HYDRATED CALCIUM ION



CALCIUM HARDNESS MEASUREMENT



ACIDS AND BASES
(comparison)

	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

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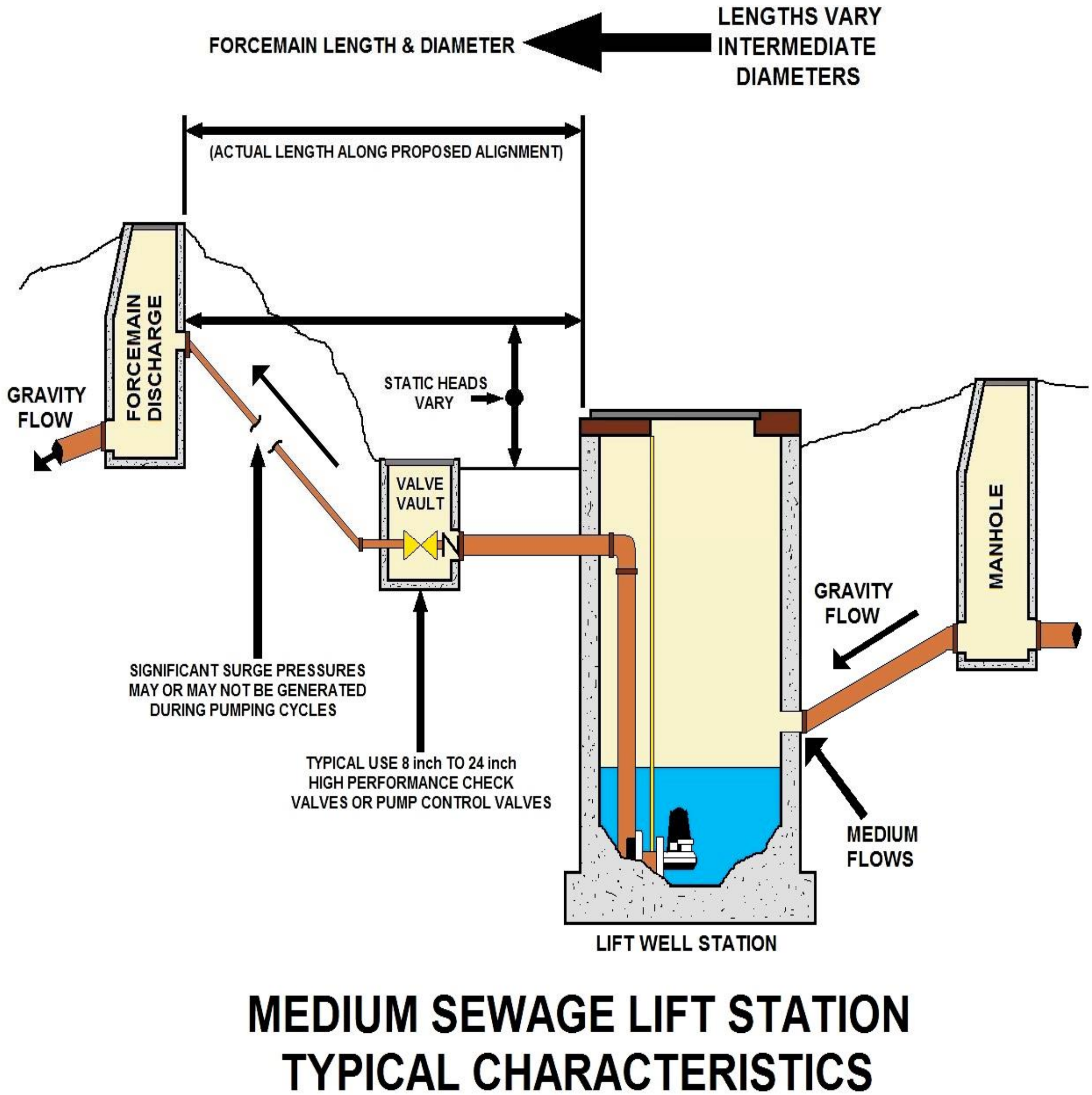
Pumps and Lift Stations Section Chapter 5



Lift Station: A facility in a sewer system consisting of a receiving chamber, pumping equipment and associated drive and control devices which collect and lift wastewater to a higher elevation when the continuance of the sewer at reasonable slopes would involve excessive trench depths; or that collects and raises wastewater through the use of force mains from areas too low to drain into available sewers. There should not be any odors coming from a Lift Station.

Pumping Station: A relatively large sewage pumping installation designed not only to lift sewage to a higher elevation but also to convey it through force mains to gravity flow points located relatively long distances from the pumping station.

Pump Stations (a.k.a. "Lift Station")

Sewer pipes are generally gravity driven. Wastewater flows slowly downhill until it reaches a certain low point. Then, pump or "lift" stations push the wastewater back uphill to a high point where gravity can once again take over the process.

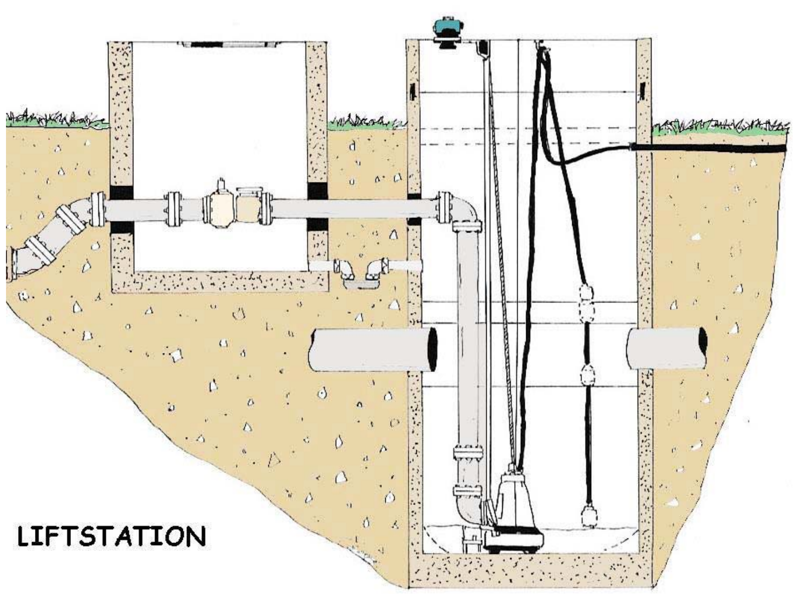
Lift stations are used in sanitary sewer systems where water is accumulated in wet wells and then pumped to a higher elevation. They are generally designed to operate continuously to keep sewerage from backing up through the system. That means that most lift stations have a backup electrical supply in the event that normal power is disrupted.

Most Wastewater Collection systems will have installed radio telemetry, or SCADA systems. The telemetry system is used to monitor and control pump stations via computer at the WW Collections facility.

This system gives up to the minute pump station status such as wet well level, pump performance, electrical power conditions, etc. This allows our technicians to prevent wastewater spills and protect public health. Using telemetry, we have the ability to identify potential problems instantaneously and take the proper steps to rectify the situation before it becomes a public health risk.

A lift station contains 4 main components:

- A wet well - usually 15+ ft. in depth and 8ft. in diameter - that houses two submersible pumps (there are some stations with up to 5 submersibles) of varying horsepower, discharging piping and floats that operate the pumps and keep a set level in the well.
- A dry well that houses the piping and valves that prevent backflow in the station, and can lock connection used to bypass the submersibles in an emergency situation.
- An electrical panel houses control for the submersible pumps. It also houses the telemetry used to monitor and control the station remotely.
- A “Log Book” or “Station Book” which contains the records and maps of the Lift Station’s area.



Small buried lift station.

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 from 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 part 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.

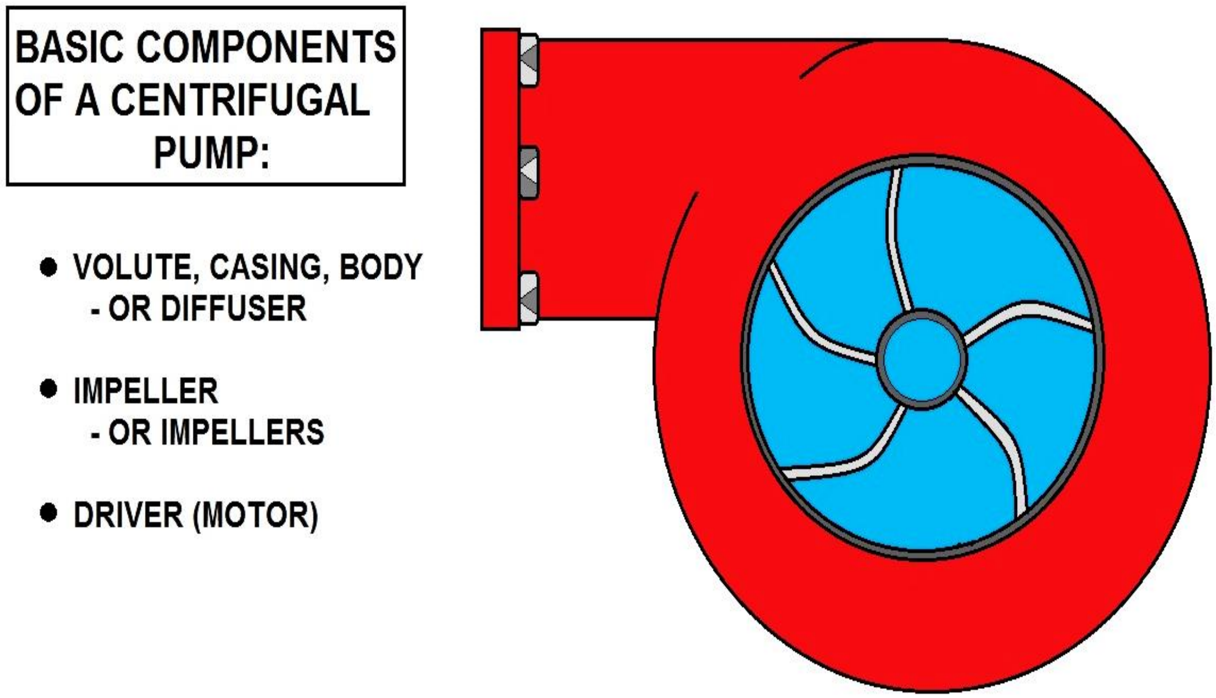
Vertical Pumps: Pumps in which the center line of the shaft runs vertically.

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 Pumps

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.



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.

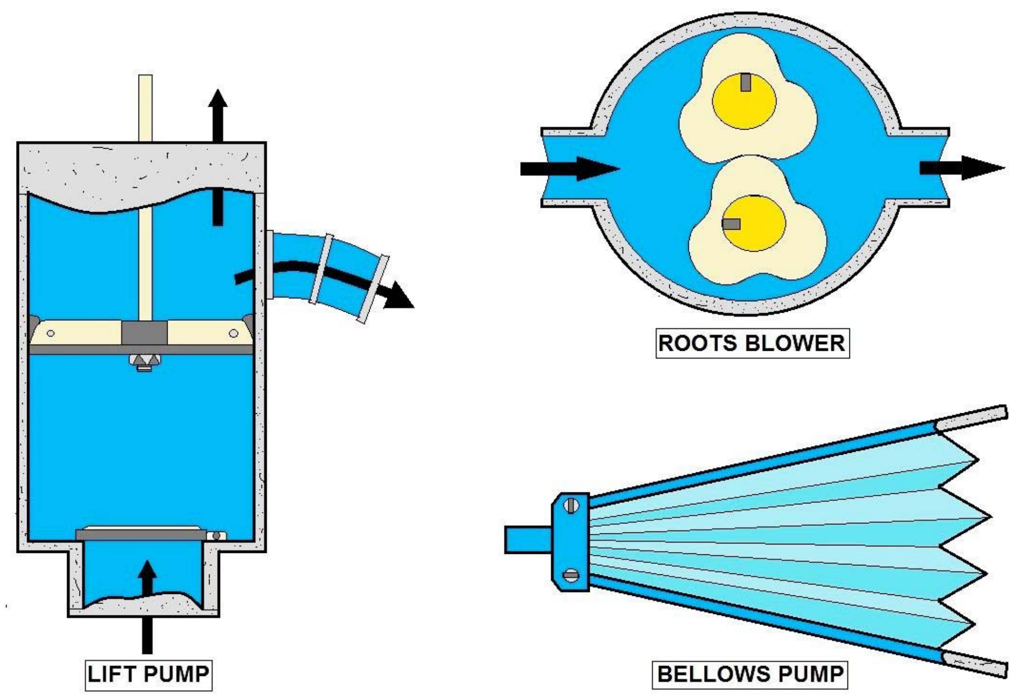
Some positive displacement pumps are shown below. The force and lift pumps are typically used for water. The force pump has two valves in the cylinder, while the lift pump has one valve in the cylinder and one in the piston. The maximum lift, or "suction," is determined by the atmospheric pressure, and 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.

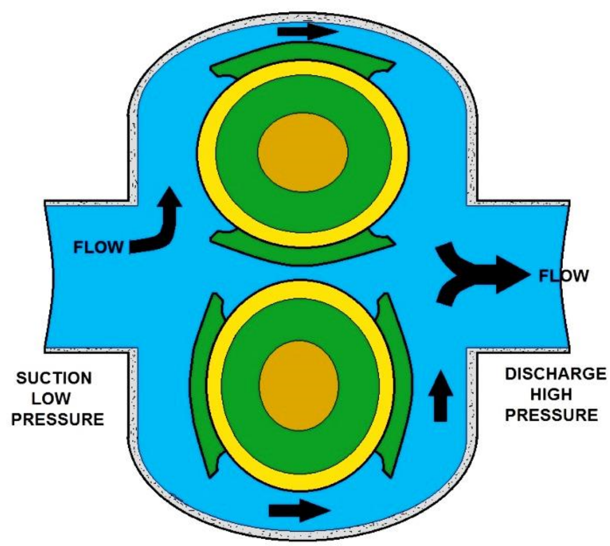
Positive Displacement Pumps

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.

What kind of mechanical device do you think is used to provide this positive displacement in the:

Plunger pump?

Diaphragm pump?

In the same way, the progressing cavity and the screw are two other types of mechanical action that can be used to provide movement of the liquid through the pump.

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.

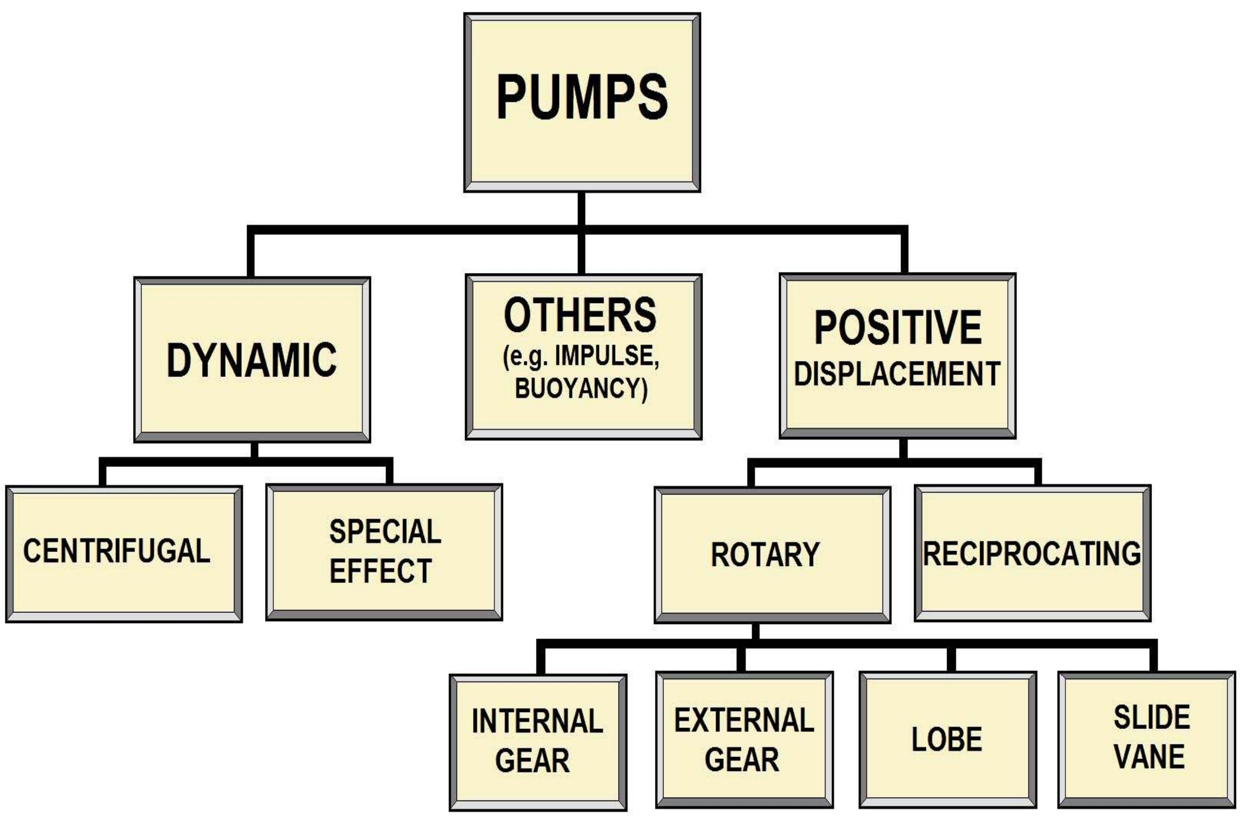
Diaphragm Pumps
In this type of pump, a diaphragm provides the mechanical action used to force liquid from the suction to the discharge side of the pump. The advantage the diaphragm has over the plunger is that the diaphragm pump does not come in contact with moving metal. This can be important when pumping abrasive or corrosive materials.

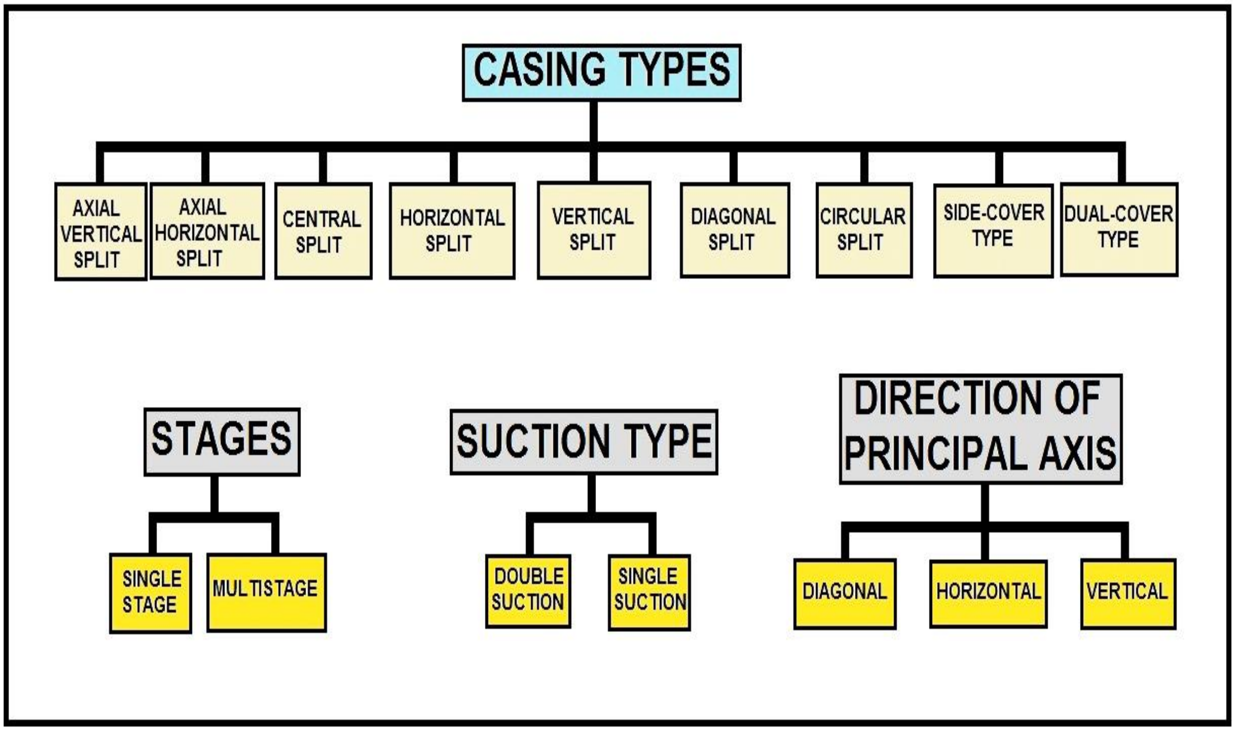
There are three main types of diaphragm pumps available:
1. Diaphragm sludge pump
2. Chemical metering or proportional pump
3. Air-powered double-diaphragm pump

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.



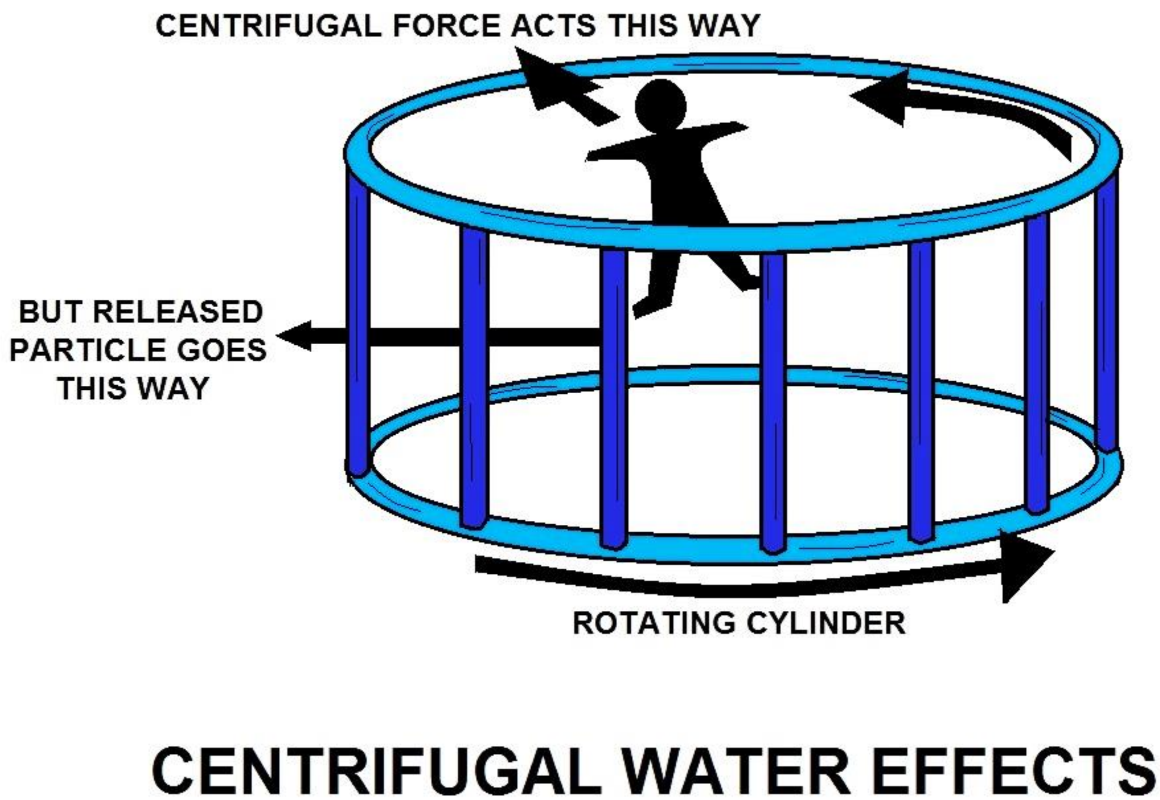


PUMP CONFIGURATIONS

Basic Water Pump

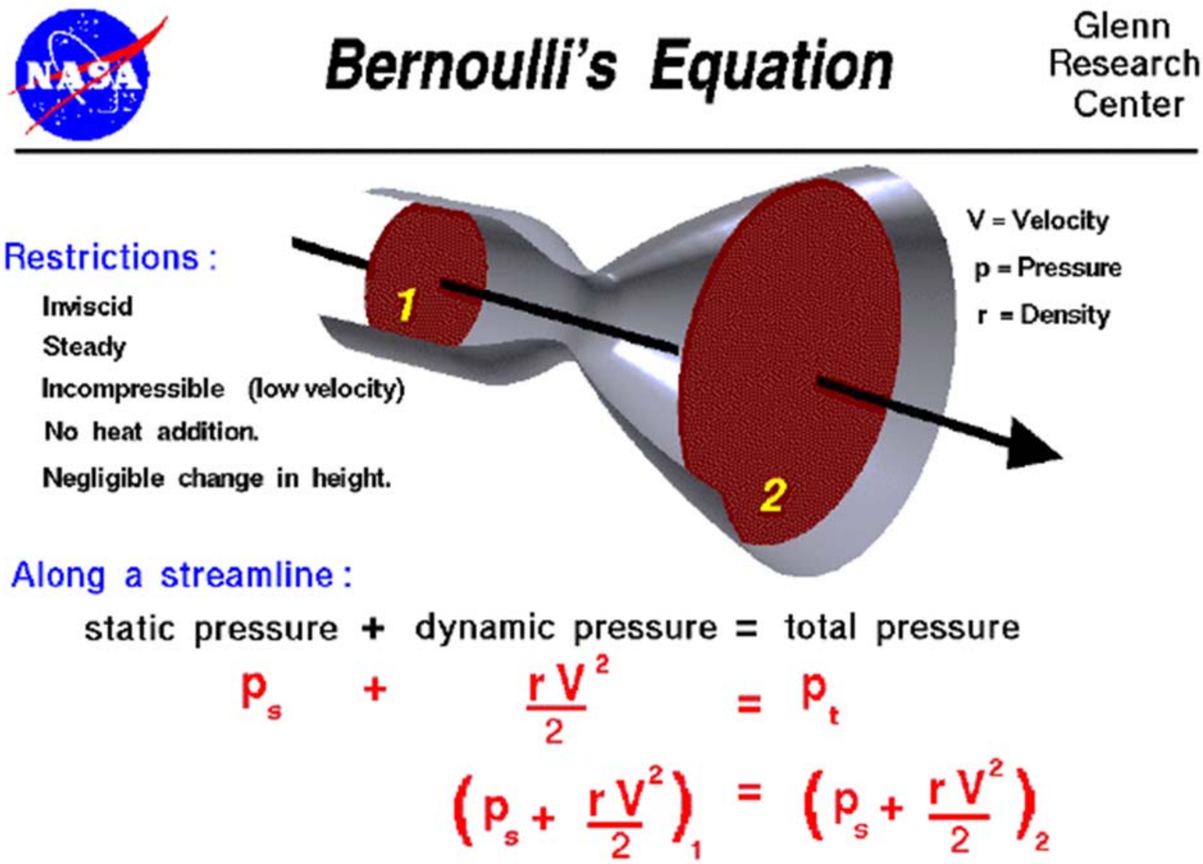
The water pump commonly found in our systems is centrifugal pumps. These pumps work by spinning water around in a circle inside a cylindrical pump housing. The pump makes the water spin by pushing it with an impeller. The blades of this impeller project outward from an axle like the arms of a turnstile 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:

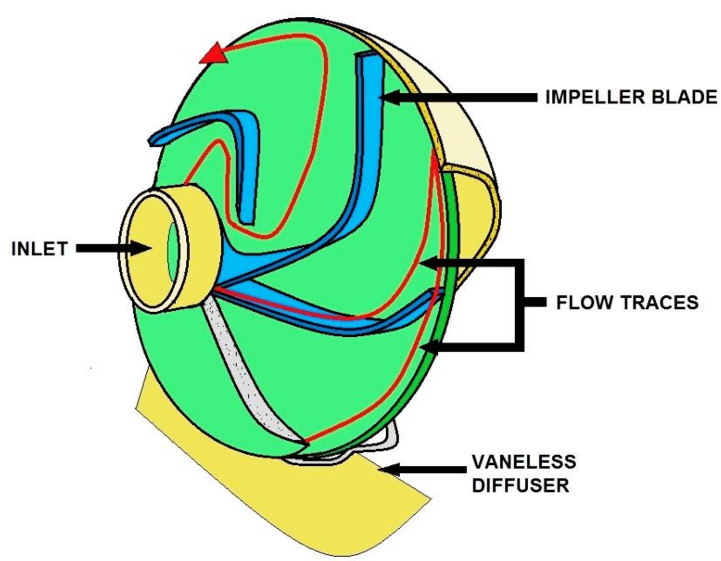


First, you can view the water between the impeller blades as an object traveling in a circle. Objects do not naturally travel in a circle--they need an inward force to cause them to accelerate inward as they spin. Without such an inward force, an object will travel in a straight line and will not complete 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.



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

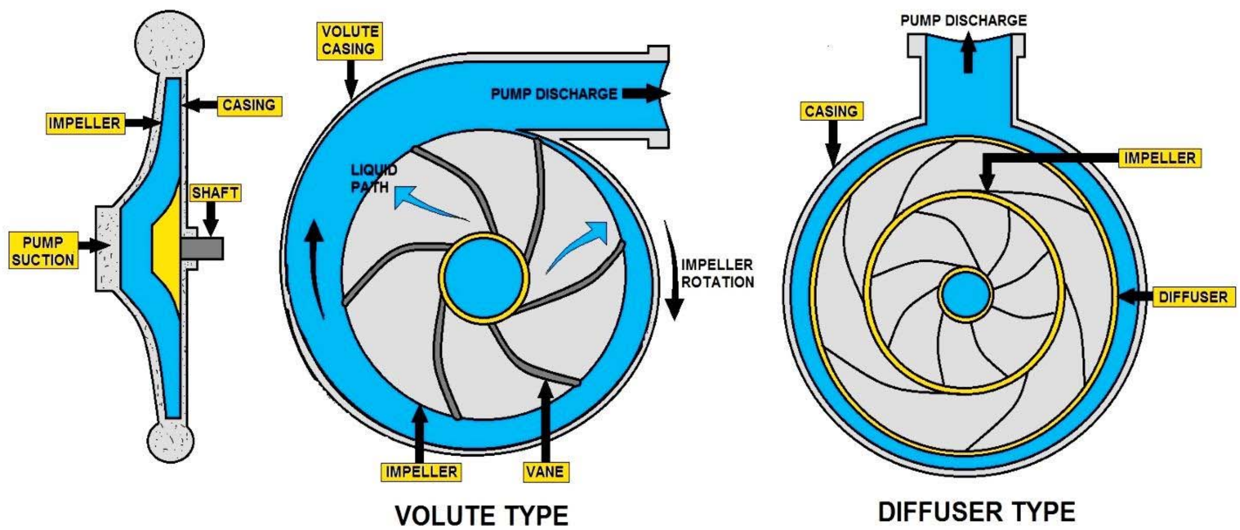
Centrifugal Pump Section

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.



TYPES OF CENTRIFUGAL PUMPS

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.

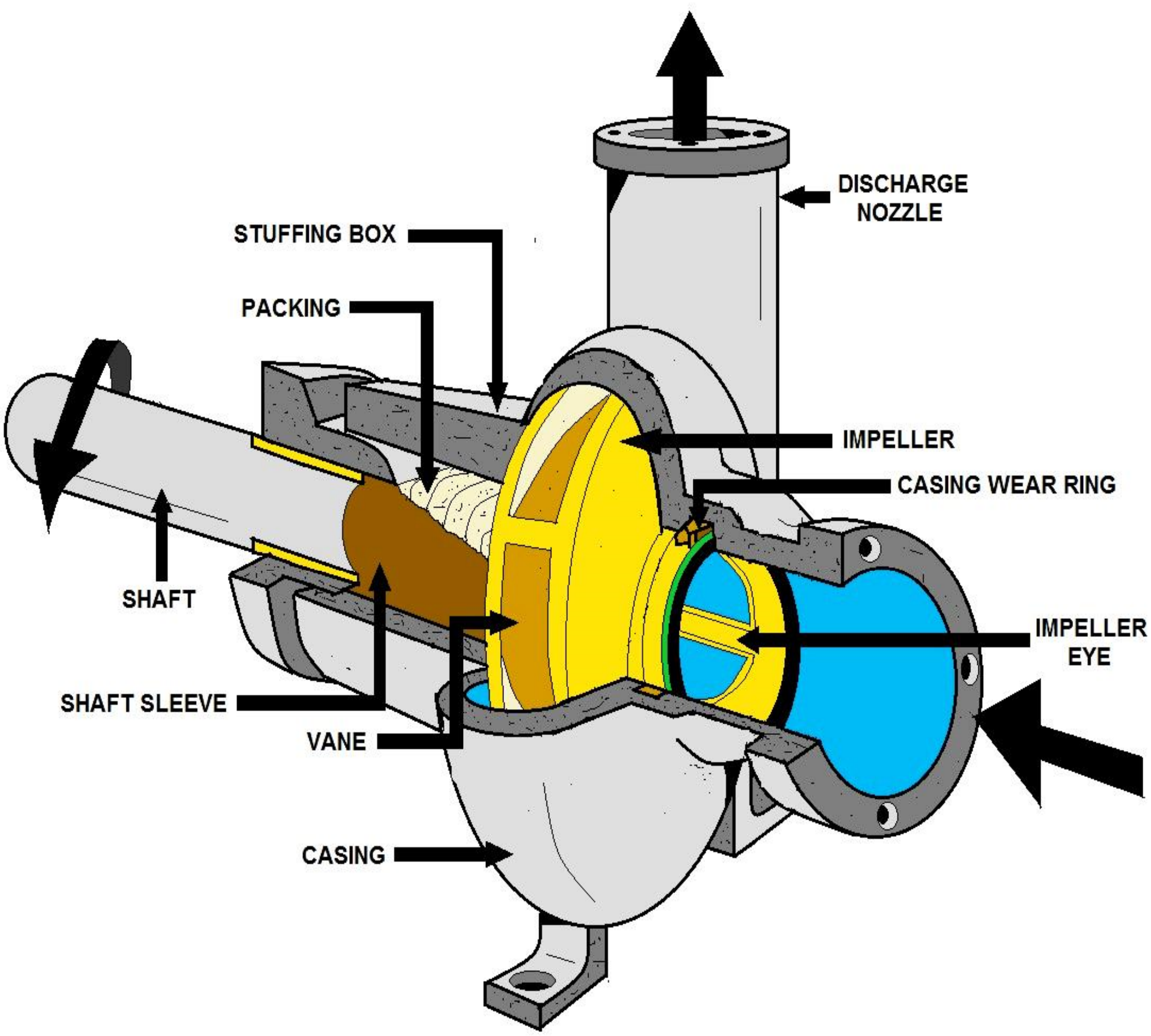
Recirculation lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor bound, in case the discharge is entirely shut off or the flow of fluid is stopped for extended periods.

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).

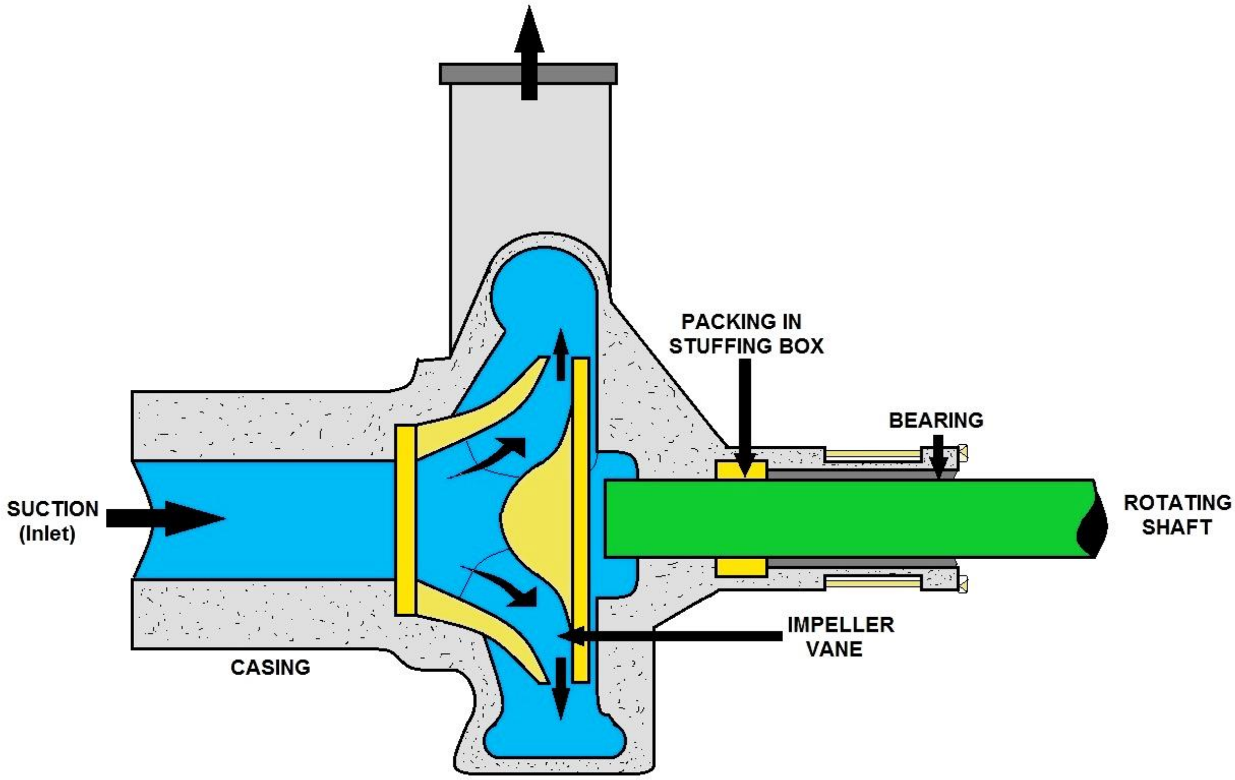
Water flinger rings are fitted on the shaft between the packing gland and the pump bearing housing. These flingers prevent water in the stuffing box from flowing along the shaft and entering the bearing housing.

Look at the components of the centrifugal pump.

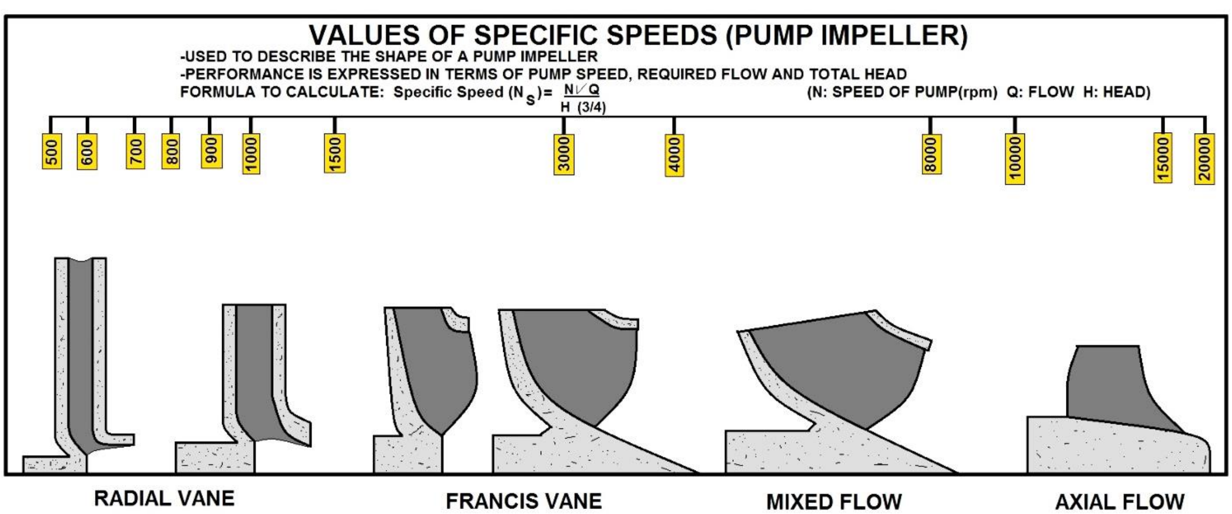


CENTRIFUGAL PUMP PARTS

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

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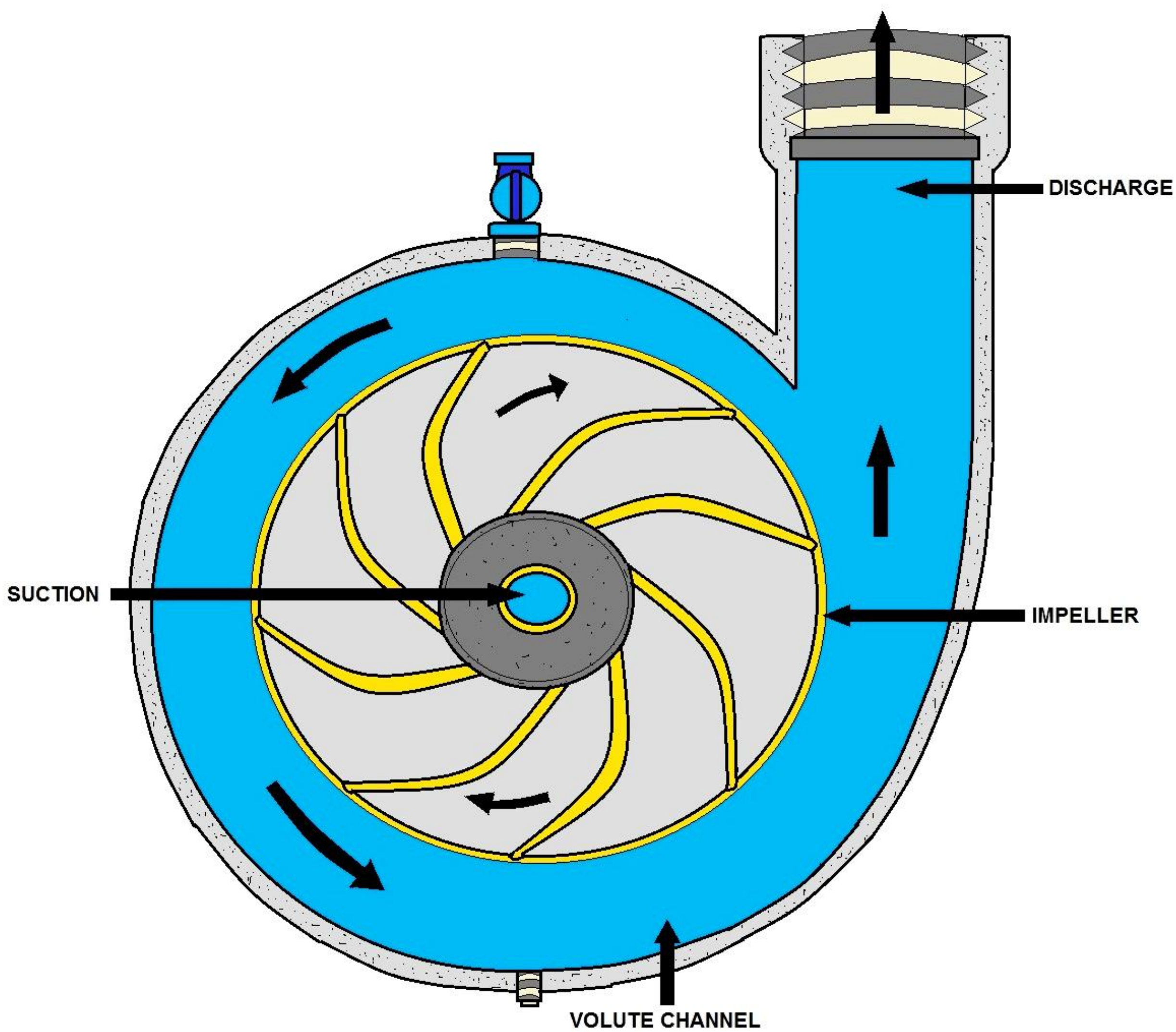


CENTRIFUGAL PUMP
PROGRESSIVE CAVITY TYPE

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:

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^{O} 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.

Speed Ratio = 2000/1750 = 1.14

From the laws of Affinity:
1) Capacity varies directly or:
1.14 X 210 GPM = 240 GPM
2) Head varies as the square or:

1.14 X 1.14 X 75 = 97.5' TDH
3) BHP varies as the cube or:

1.14 X 1.14 X 1.14 X 5.2 = 7.72 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:
Head = PSI X 2.31 / Specific Gravity

For Water it is:
Head = 14.7 X 2.31 / 1.0 = 34 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

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.

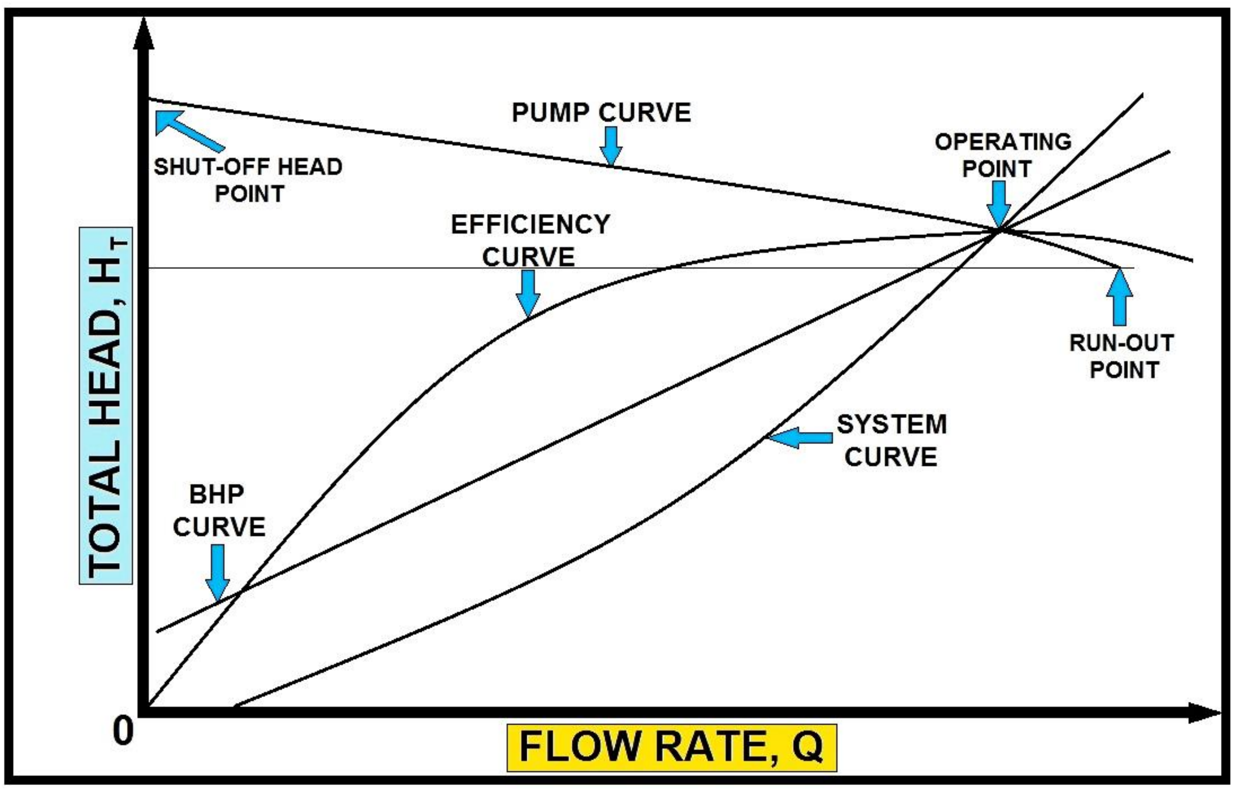
Axial flow impellers look like a propeller and create a flow that is parallel to the shaft.

PNUEMATIC SUBMERSIBLE PUMP

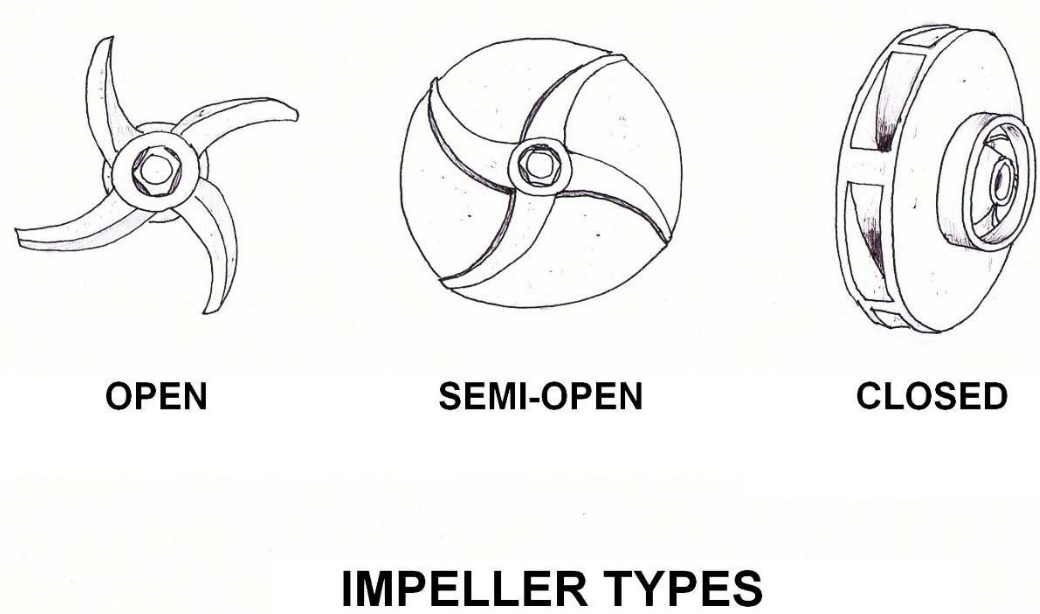
Pump Performance and Curves

Let's looks 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)



Submersible and grinder type pumps

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 suctions heads are subtracted from the pump discharge head.

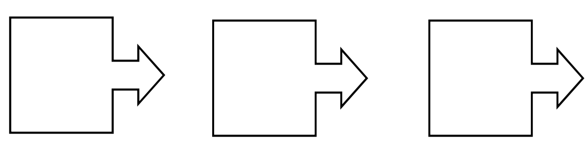
Total Dynamic Head (TDH) is the total height that a fluid is to be pumped, taking into account friction losses in the pipe.

TDH = Static Lift + Static Height + 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 viscose 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 hp = 33,000 ft-lbs/min

Motor Horsepower (mhp)

1 hp = 746 watts or .746 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

$$1 \text{ hp} = 0.746 \text{ kW} \quad \text{or} \quad \frac{(\text{hp})\ (746 \text{ watts/hp})}{1000 \text{ watts/kW}}$$

Well Calculations

1. Well drawdown

Drawdown ft = Pumping water level, ft - Static water level, ft

2. Well yield

$$\text{Well yield, gpm} = \frac{\text{Flow, gallons}}{\text{Duration of test, min}}$$

3. Specific yield

$$\text{Specific yield, gpm/ft} = \frac{\text{Well yield, gpm}}{\text{Drawdown, ft}}$$

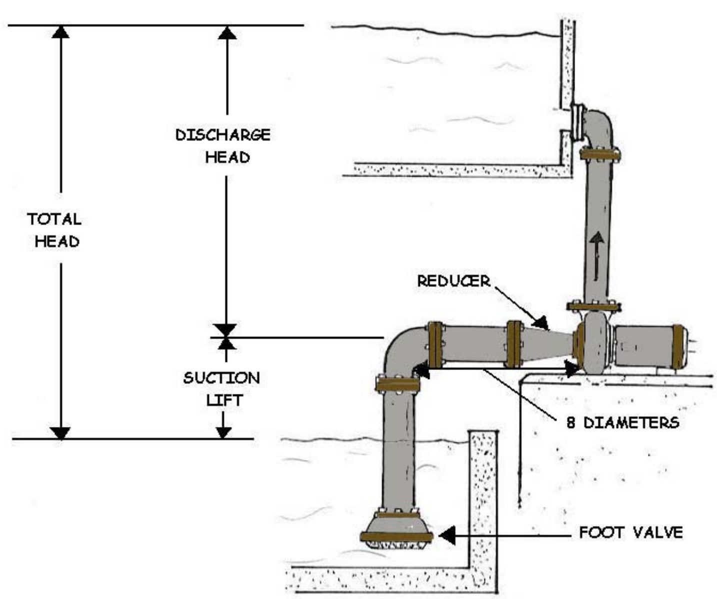
4. Deep well turbine pump calculations.

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.

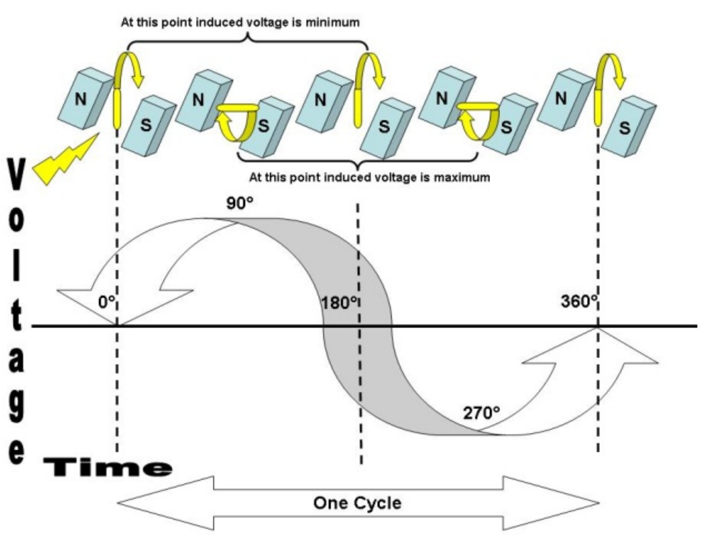
There are two general categories of electric motors:

- 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:

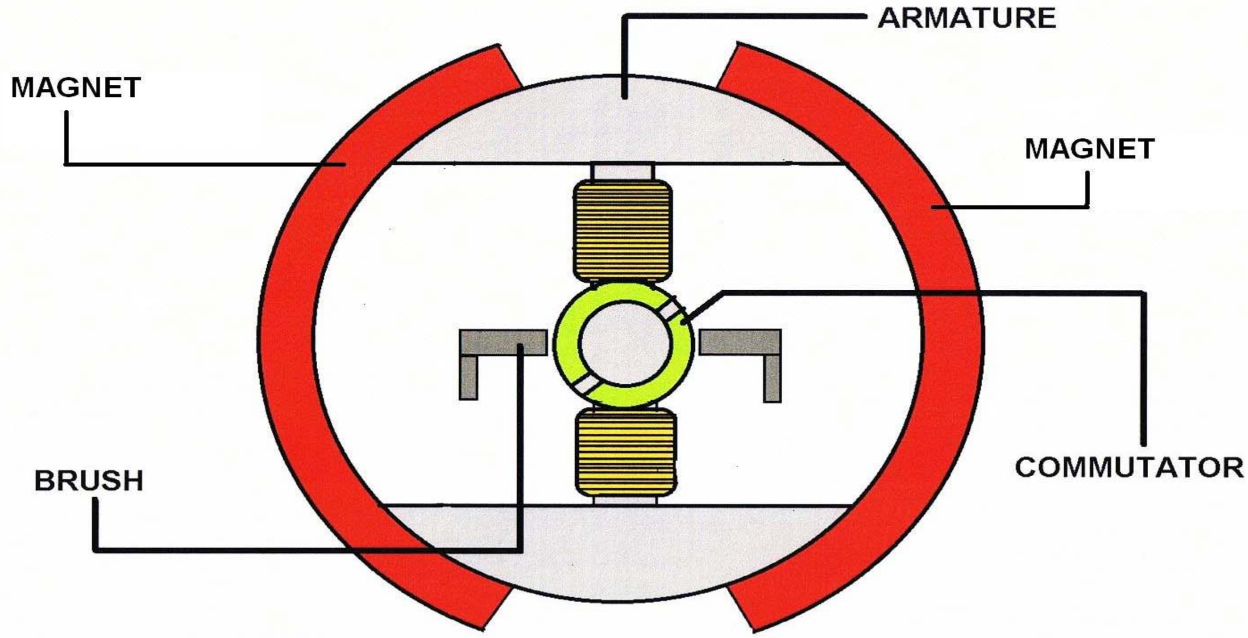
Hertz:

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.

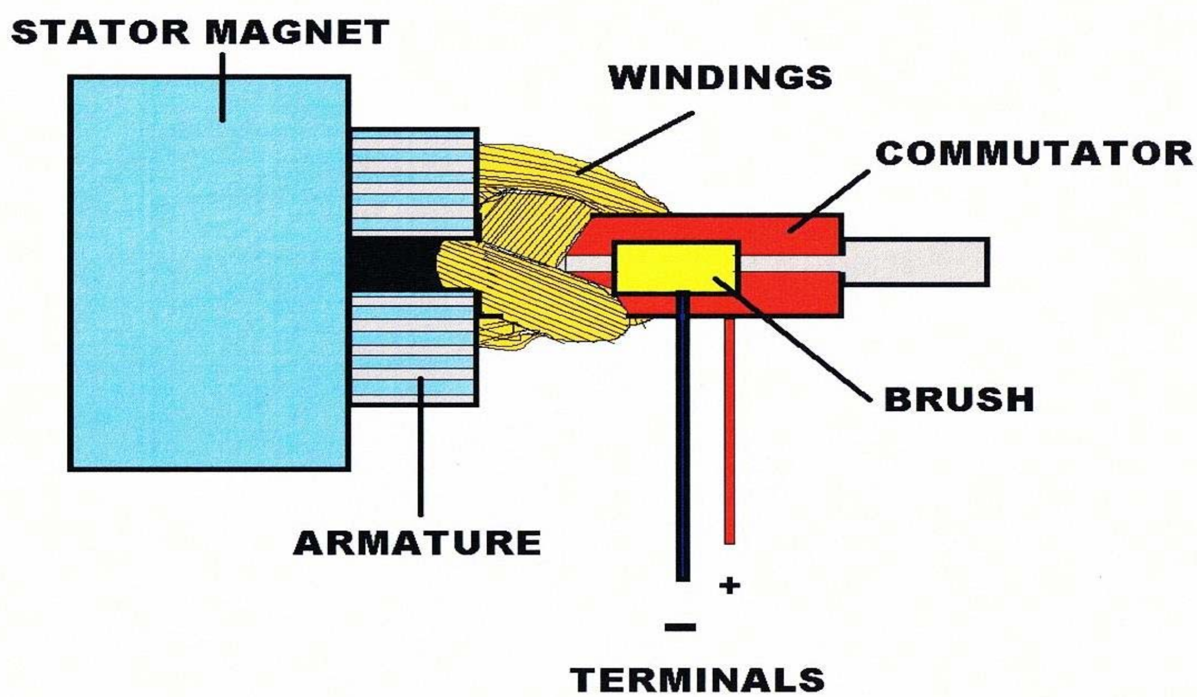
How do you think keeping the discharge valve closed on a centrifugal pump could reduce the start-up load?

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.

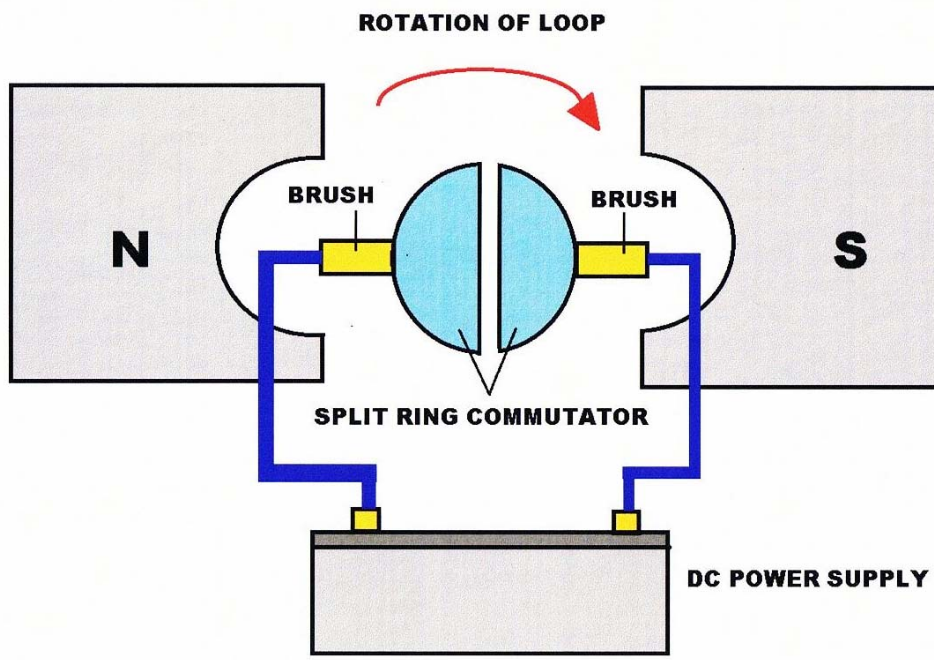
Can you think of any locations within your facility that requires special enclosures?



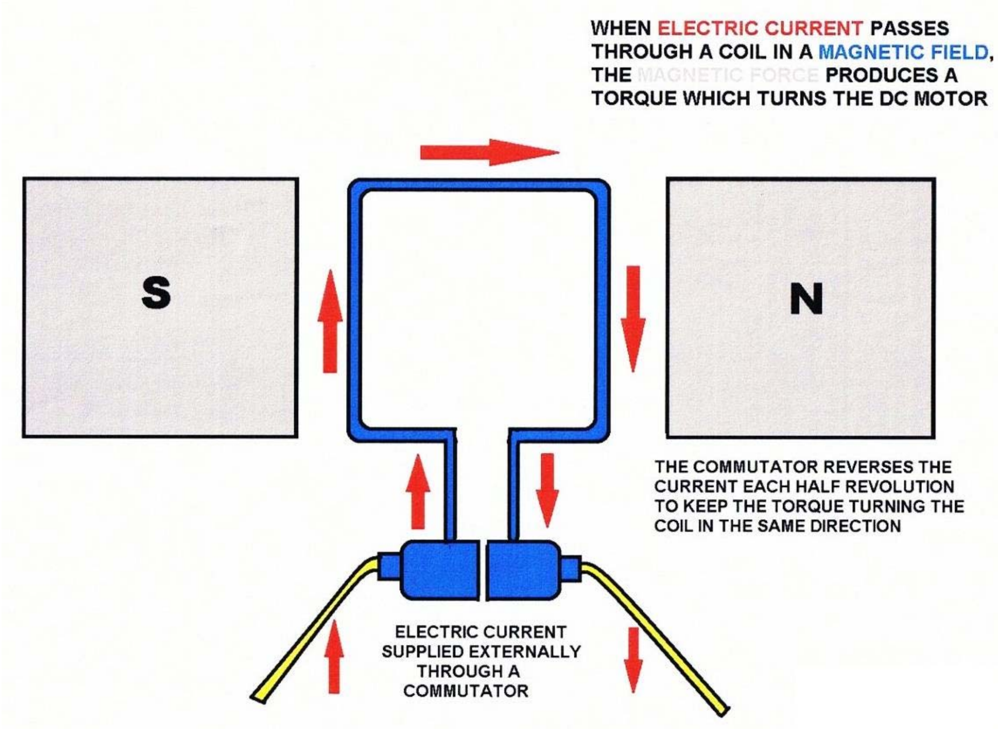
PARTS OF A DC MOTOR



BRUSHED DC MOTOR


ROTATION OF LOOP
N
BRUSH
BRUSH
S
SPLIT RING COMMUTATOR
DC POWER SUPPLY

DC MOTOR


WHEN ELECTRIC CURRENT PASSES THROUGH A COIL IN A MAGNETIC FIELD, THE MAGNETIC FORCE PRODUCES A TORQUE WHICH TURNS THE DC MOTOR
S
N
THE COMMUTATOR REVERSES THE CURRENT EACH HALF REVOLUTION TO KEEP THE TORQUE TURNING THE COIL IN THE SAME DIRECTION
ELECTRIC CURRENT SUPPLIED EXTERNALLY THROUGH A COMMUTATOR

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.

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:

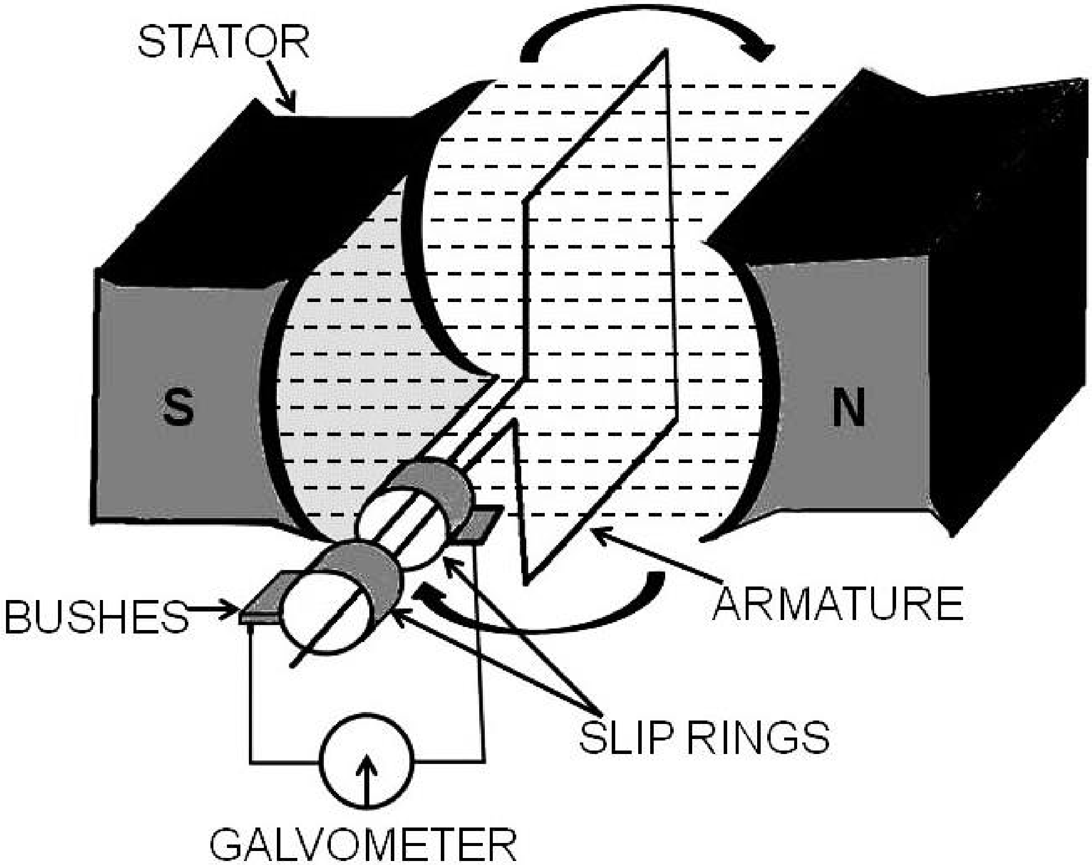
1. Remove the protective plugs and caps from the grease inlet and relief holes.
2. Pump grease in until fresh starts coming from the relief hole.

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.

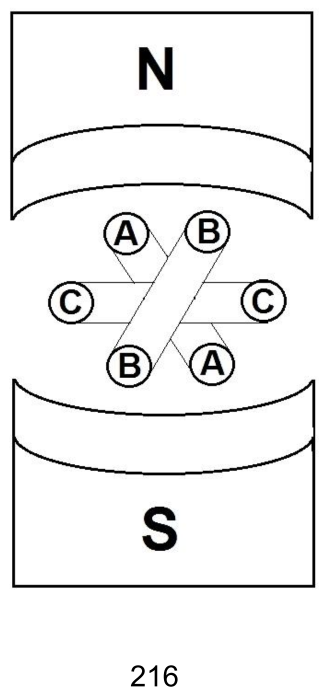
To change the oil in an oil lubricated motor, this is the usual approach:

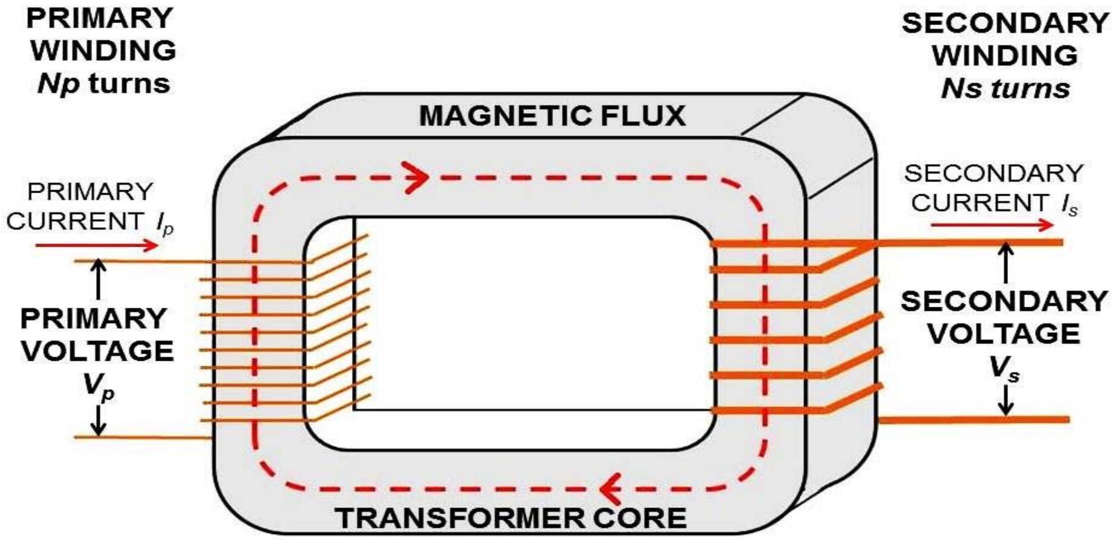
1. Remove all plugs and let the oil drain.
2. Check for metal shearing.
3. Replace the oil drain.
4. Add new oil until it is up to the oil level plug.
5. Replace the oil level and filter plug.

Never mix oils, since the additives of different oils when combined can cause breakdown of the oil.

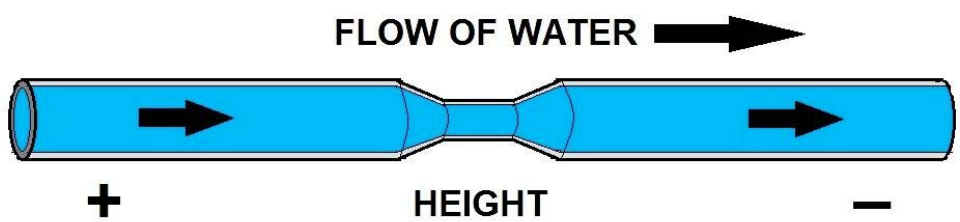


PRODUCTION OF AC CURRENT





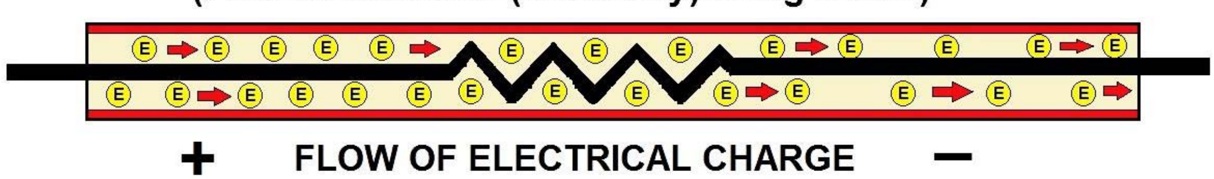
TRANSFORMER



Electricity flow can be compared to flow of water:

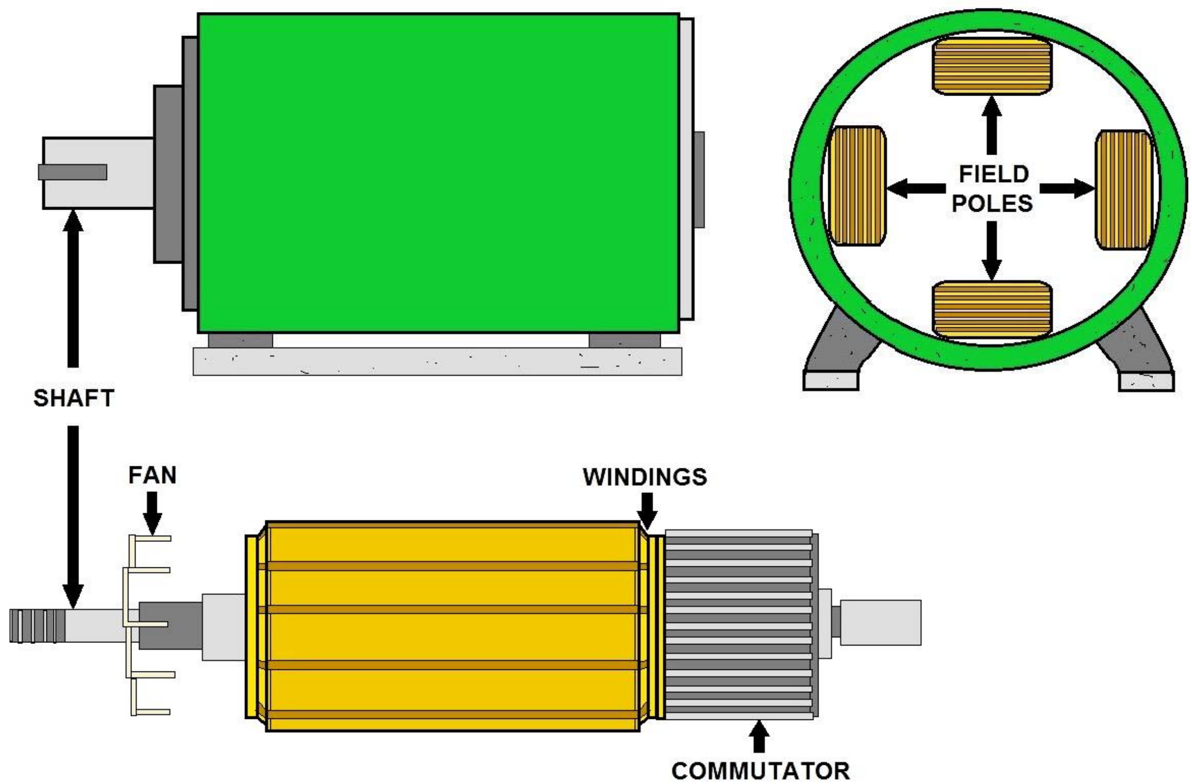
- When pressure is applied at one end of a pipe (or wire) then, water (or electricity) will come out the other end.

(Flow of electrons (electricity) along a wire)



BASIC ELECTRICITY CONCEPT

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.

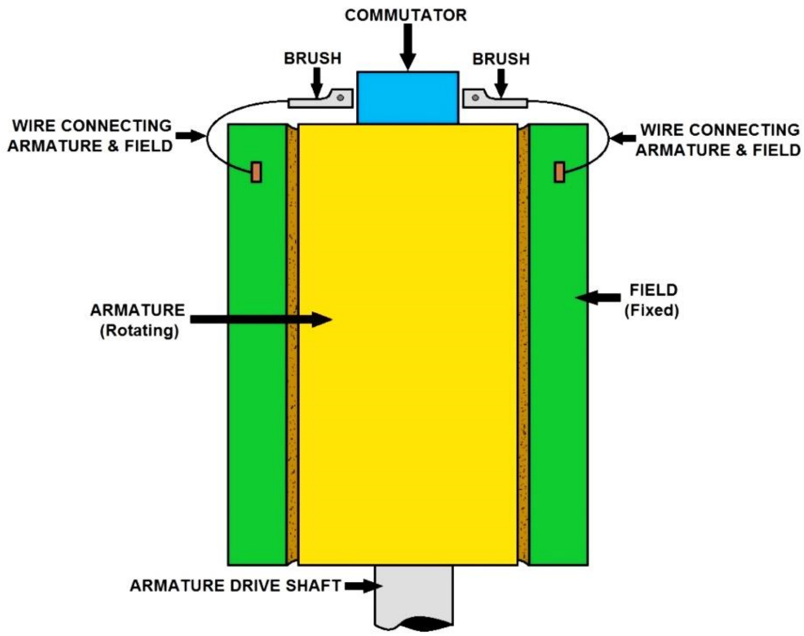


DIAGRAM SHOWING MECHANICAL CONSTRUCTION OF A DC SERIES WOUND MOTOR

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.

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.

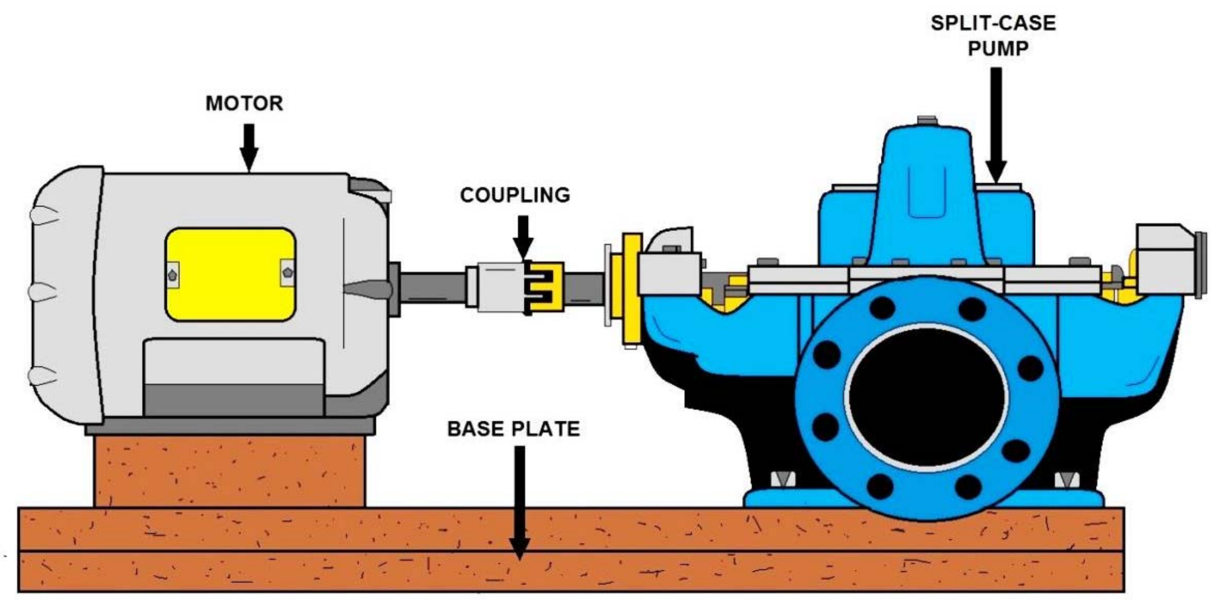
- It compensates for small amounts of misalignment between the pump and the motor.

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..

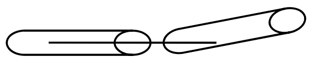


CLOSED COUPLED PUMP

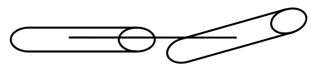
Alignment of Flexible and Rigid Couplings

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:



ANGULAR MISALIGNMENT



ANGULAR AND PARALLEL

PARALLEL MISALIGNMENT

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.

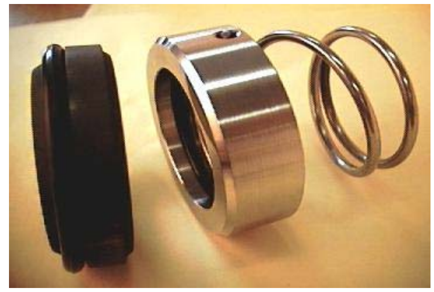
2. Properly installed mechanical seals eliminate leakoff on idle (vertical) pumps. This design prevents the leak (water) from bypassing the water flinger and entering the lower bearings.

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 suctions 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.

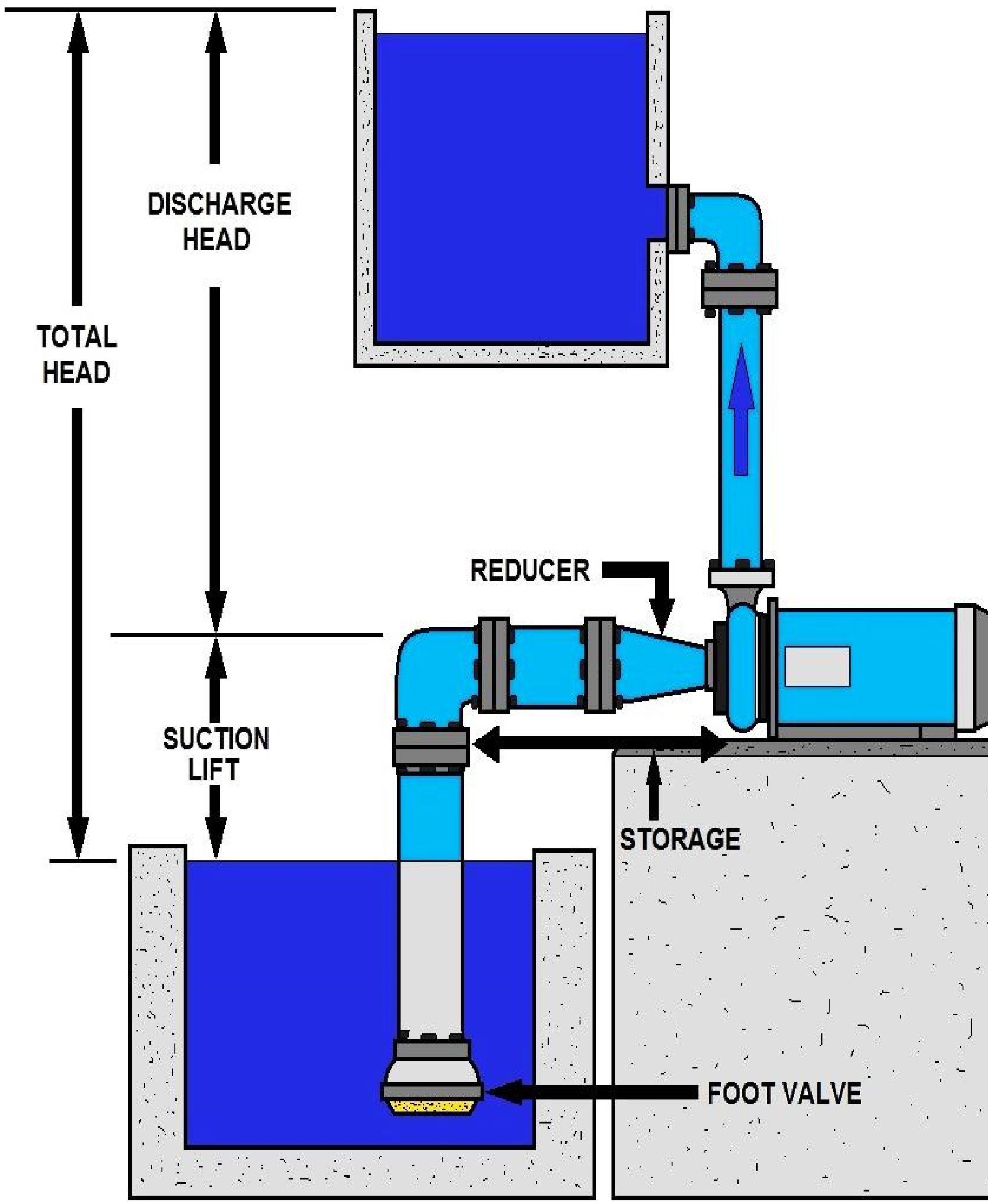
Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water, and various cooling systems). They not only conserve the fluid being pumped, but also improve system operation.

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.



PUMPING FACTORS

Pumping and Lift Station Chapter Highlights

Memorize these statements to pass your exam.

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 in the Stuffing Box.

A Centrifugal pump is consisting of an impeller fixed on a rotating shaft that is enclosed in a casing, and having 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. It is located at the bottom end of the suction on 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 would use multiple pumps for a parallel operation: To provide for a fluctuating demand, To provide an increased discharge head, To reduce the friction coefficient on a larger pump for greater efficiency.

The intent of a designer when multiple water pumps are installed for paralleled operation 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 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 which has a capacitor start motor will also have a high starting torque and a high starting current.

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. A two-pole motor achieves this speed.

The winding insulation may deteriorate and is the most likely choice for the result of grease coming in to contact with the windings for a motor.

An electric motor that has a frequency of 60Hz will have a maximum synchronous speed of 3600 rpms.

As the wear ring inside a centrifugal pump loses tolerance between the impeller and wear ring, 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.

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 restrictions by fittings.

Continuous leakage from a mechanical seal indicates an abnormal condition.

To properly maintain a standard three-phase variable speed synchronous AC motor you must have some idea of what to look for when examining the slip rings and brushes. The slip ring for a film should be examined before startup.

A qualified operator is testing an electrical circuit for proper voltage. The incoming voltage is 220 VAC, single-phase power. The operator places one of the tester leads on LI and the other on the neutral wire. The expected voltage when testing these two wires should be 110 volts.

Electric motors burn out for many reasons, but 70% of motor failures can be controlled by the operator and proper maintenance. The following are causes of motor insulation failure: Overloading the motor, Single phasing three phase motors, Contamination of the windings area.

Molded-case circuit breakers typically require little maintenance. Inspect for evidence of over-heating. Manually tripping the circuit breaker periodically and checking connections for tightness are recommended maintenance on these circuit breakers.

Replacing entire contact set when the surface is badly pitted and eroded with badly feathered and lifting edges is the recommended practice for maintaining the stationary and movable contacts in a motor starter.

The greatest cause of failure in electric motors is thermal overload.

The operator is testing a coil from a control relay using an ohmmeter. The power to coil must be off when using the ohmmeter to check out this type of component.

A circuit is tested with an Ohmmeter and is found to be defective. The most likely reading is Infinity.

Most failures at a lift station can be avoided by proper preventive maintenance.

The operator has just installed a repaired motor in a pumping station. The motor is started but it never comes up to speed. The following are possible reasons for the malfunction: Incorrect power supply, Motor is overloaded and/or incorrectly wired.

Enclosed electrode controls are sometimes used in lift stations to control pumps.

The operator is responding to an odor complaint at a lift station. The operator goes to the station and finds the source of the problem and corrects the situation; then the operator needs to notify the person who complained about the situation.

The pneumatic ejector at a small lift station is cycling too often. The flow into the tank is low but the ejector pumps frequently; a discharge valve stuck open may be the possible cause for this problem.

Check valves are installed on the discharge side of sump pumps in dry wells to prevent flooding of the dry well by backflow due to back siphoning.

Many pumps are outfitted with mechanical seals to prevent water from leaking out of the pump. The seal faces must be protected--keeping fresh water on the faces of the seal is an important maintenance task to be performed by the operator to prevent damage to the seal faces.

Relief valves on the discharge side of pumps are used in order to prevent injuries or severe damage to piston pumps.

Submersible pumps are commonly used in lift stations. Preventive maintenance is important to ensure that motor windings are not burned. A Megger is used to determine if moisture is entering the motor through the pump.

The following are considered a standard practice when installing packing rings in a pump: Stagger the joints of rings to avoid having tow joints at the same position. Cut packing rings so they are all the correct length. Packing rings should be of materials recommended by the pump manufacturer.

The operator has just changed the grease in the bearings of a motor, the Operator should run the motor for 30 minutes, then install the drain plug.

The operator has noticed the centrifugal pump is making noise and the efficiency of the pump is lowering. The pump is dismantled and the impeller has pits on all the vanes. This is usually caused by pump cavitation. Cavitation inside the pump is a possible cause of the pits.

The operator removes a submersible pump from a wet well. The pump is an oil-filed motor; the inspection plug is opened and a small amount of fluid is poured into a beaker. The fluid is an emulsion of oil and water. Mechanical seals that may be leaking could be the probable cause.

The term *Ambient Temperature* means the surrounding temperature.

A qualified operator is testing an electrical circuit for proper voltage. The incoming voltage is 220 **VAC**, single-phase power. The operator places one of the tester leads on **LI** and the other on the neutral wire. 110 volts is the expected voltage when testing these two wires.

Brinelling is tiny indentations high on the shoulder of the bearing race.

Motor Statements, *Memorize each statement.*

Three types of electrical power;
Single Phase, 110 VAC, overhead lights, power tools, etc.
Three Phase, equal power to all three leads.
D.C., backup power for emergency lighting.

Biggest Killer of Electric Motors;
Thermal Overload, usually the number one answer.
Improper Lubrication and Voltage Imbalance will kill a motor.
But never air locking; you can air lock a pump, but not a motor. Cold weather is also not a 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, and 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 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 requires cooling water to the seal faces. Use filtered effluent or tap water.

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 over greasing 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/ft^3?

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

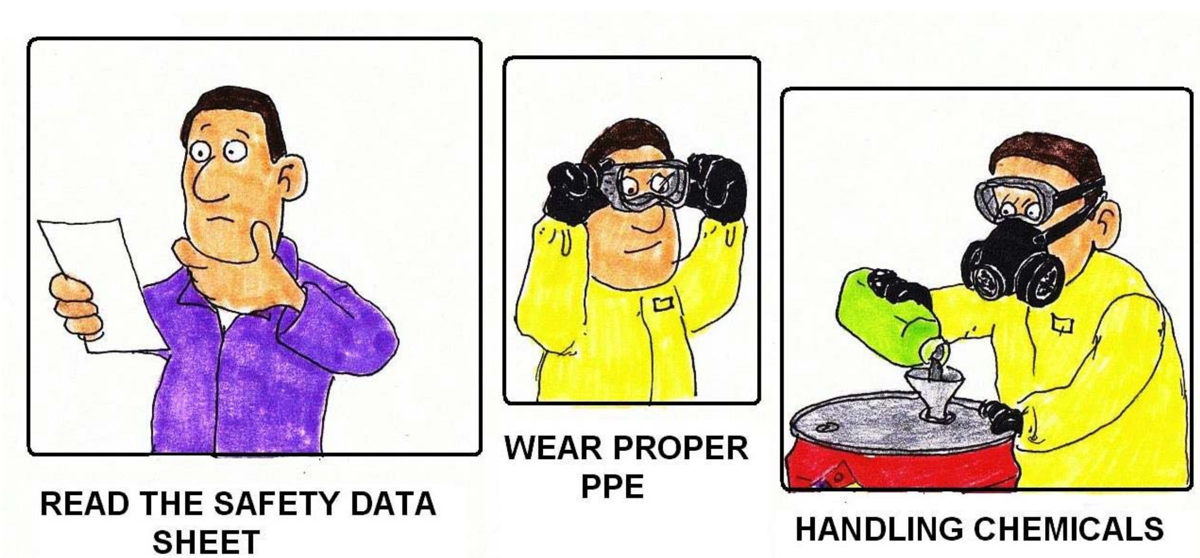
Answers for Pump Assignment

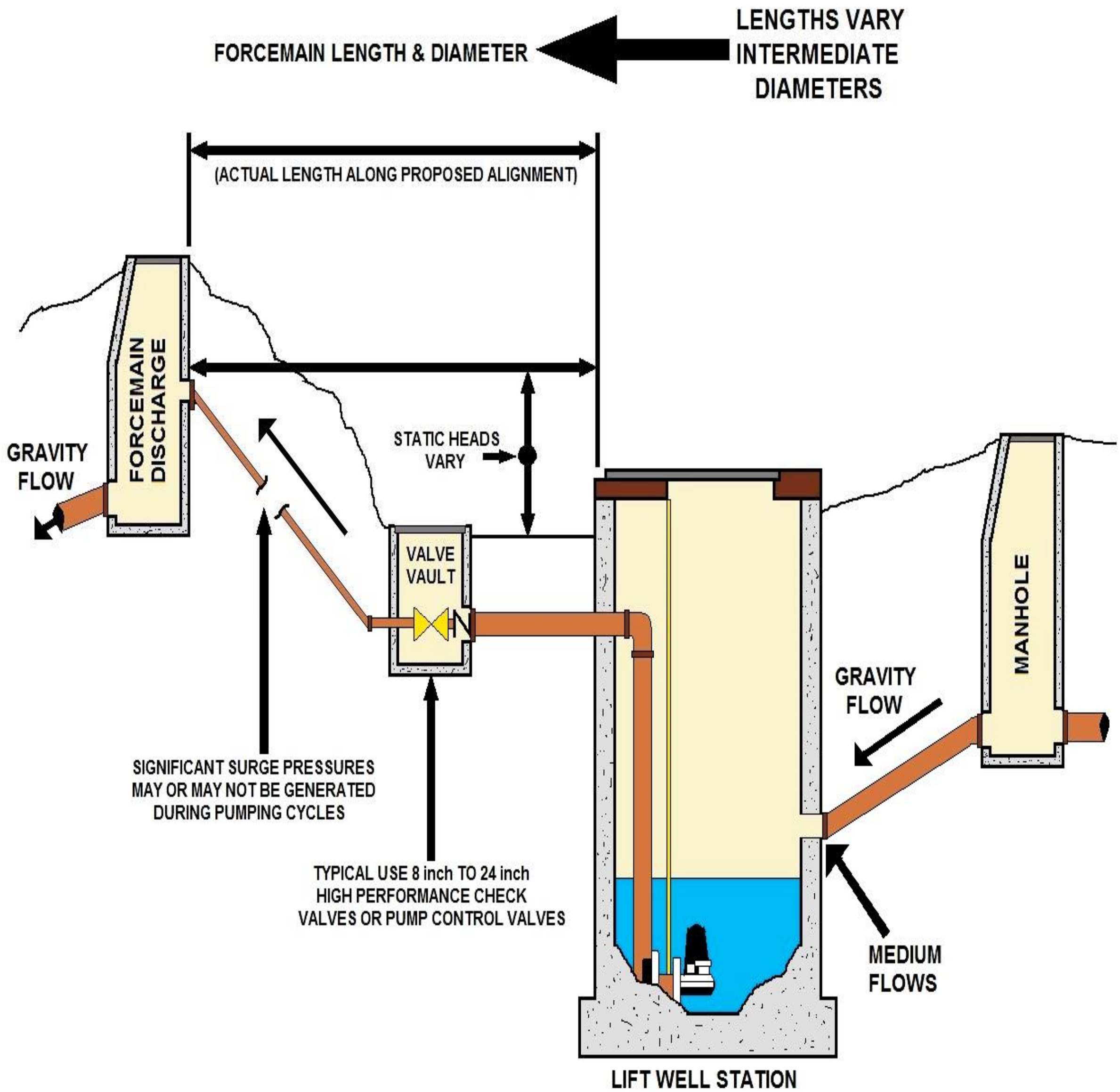
1. Run the motor for approximately 30 minutes before reinstalling the drain plug.
2. Periodic inspection of the packing and shaft sleeves
3. Through the seal water supply
4. Mechanical seals do not need routine adjustment
5. To prevent backflow due to back siphoning
6. Cavitation inside the pump
7. Several 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. Telemetering 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

Hydrogen Sulfide Section Chapter 6

The effects of sulfuric acid created by hydrogen sulfide gas.





MEDIUM SEWAGE LIFT STATION TYPICAL CHARACTERISTICS

Hydrogen Sulfide Gas

This Chapter provides answers to basic questions about hydrogen sulfide gas. It will explain what hydrogen sulfide gas is, where it is found, how it can affect your health, and what you can do to prevent or reduce exposure to it.

Hydrogen sulfide gas is also known as “sewer gas” because it is often produced by the decay of waste material. Hydrogen sulfide gas has a strong odor at low levels. At higher levels, your nose can become overwhelmed by the gas and you cannot smell it. At these higher levels, hydrogen sulfide gas can make you sick and even kill you.

Hydrogen Sulfide Gas

If you wait for a warning, it may be too late

Hydrogen sulfide is a powerful and deadly gas which smells like rotten eggs at low concentrations and has a sweet smell at high concentrations. But workers should not rely on the smell as a warning. At high concentrations H_2S may overcome one's sense of smell. The result could be instant death. Long exposure to low concentrations will also deaden the sense of smell.

What it is

H_2S is explosive - it will ignite and explode when subjected to a spark or ordinary flame - in any concentration from 4% to 44% of the air. It is also soluble in water and oil, so it may flow for a considerable distance from its origin before escaping above ground or in an entirely unexpected place. Because the vapor (gas) is heavier than air, it may travel for a long way until ignited and then flash back towards the source. Hydrogen sulfide is found in large amounts in the wastewater collection and treatment system.

H_2S Sources

H_2S is found widely in industry and few workers are warned of its dangers or their exposure. It is formed by the decomposition of organic materials, so it is found in sewers, and cesspools.

Health Effects of H_2S acute exposure

First of all, and most important, H_2S can kill you. The extent of acute poisoning danger depends on the concentration of H_2S in the atmosphere.

When you breathe in H_2S, it goes directly through your lungs and into your bloodstream. To protect itself, your body "oxidizes" (breaks down) the H_2S as rapidly as possible into a harmless compound. If you breathe in so much H_2S that your body can't oxidize all of it, the H_2S builds up in the blood and you become poisoned. The nervous centers in your brain which control breathing are paralyzed. Your lungs stop working and you asphyxiate - just as though someone had come up and put their hands around your neck and strangled you. A worker can be overcome by H_2S and lose consciousness in a few seconds. Luckily, if he is rescued in time and is given artificial respiration within a few minutes, the worker may recover. Either artificial mouth-to-mouth or an oxygen supply system of resuscitation will work if it is done in time, because, with an adequate source of oxygen and no further H_2S intake, the body will quickly break down the H_2S still in the blood.

This is acute poisoning. It can occur with no warning at all, since even the sense of smell may be overcome, and it can be fatal within a few seconds. Although acute poisoning is deadly if it is not caught in time, when caught and treated it is reversible and this is why rescue attempts with proper safety equipment are so important. Recent evidence has shown irreversible brain damage from acute high doses.

Chronic Effects

H_2S can also cause a wide range of sub-acute and chronic effects. At very low concentrations of 10-100 ppm. headache, dizziness, nausea and vomiting may develop, together with irritation of the eyes and respiratory tract (the lungs and trachea and bronchi, or air pipes from the nose and mouth to the lungs). The eyes become red, sore, inflamed, and sensitive to light. Respiratory system effects include cough, pain in the nose and throat, and painful breathing.

If exposure at low levels continues, the worker may develop a state of chronic poisoning. In addition to eye and respiratory tract irritation, there will be a slowed pulse rate, fatigue, insomnia, digestive disturbances, and cold sweats. More dangerous, if exposure at the level of 100 ppm (which results in eye and respiratory tract irritation and drowsiness after 15 minutes) lasts for several hours, it may result in death within the next 48 hours. Symptoms of chronic exposures at low levels are conjunctivitis (eye infections), headache, attack of dizziness, diarrhea, and loss of weight. Chronic hydrogen sulfide intoxication is marked by headaches, eye disorders, chronic bronchitis, and a grey-green line on the gums. Reports of nervous system disorders including paralysis, meningitis, and neurological problems have been reported, but not confirmed.

A study of workers and community residents of a California Wastewater Treatment facility forum complained of headaches, nausea, vomiting, depression, personality changes, nosebleeds and breathing difficulties. When compared to a non-exposed group of people, the exposed people showed abnormalities of color discrimination, hand-eye coordination, balance, and mood disturbances. In rats, exposure to hydrogen sulfide has caused teratogenic effects.

How much is safe?

The OSHA Permissible Exposure Limit (**PEL**) for a ceiling concentration is 20 ppm hydrogen sulfide, a level which may not ever be exceeded. The acceptable maximum peak, for 10 minutes only, once during an 8 hour day if there is no other measurable exposure, is 50 ppm. There is no time-weighted average because H_2S is so fast-acting that no fluctuations above 20 ppm are safe; only one peak per day is allowed. This level is too high and recent recommendations are that it be lowered to 10 ppm. You should remember, however, that H_2S is an invisible gas, floating freely and unpredictably, and a reading even below a 10 ppm Permissible Exposure Limit (**PEL**) may not guarantee your safety. There are no particular medical exams for exposure to H^2S.

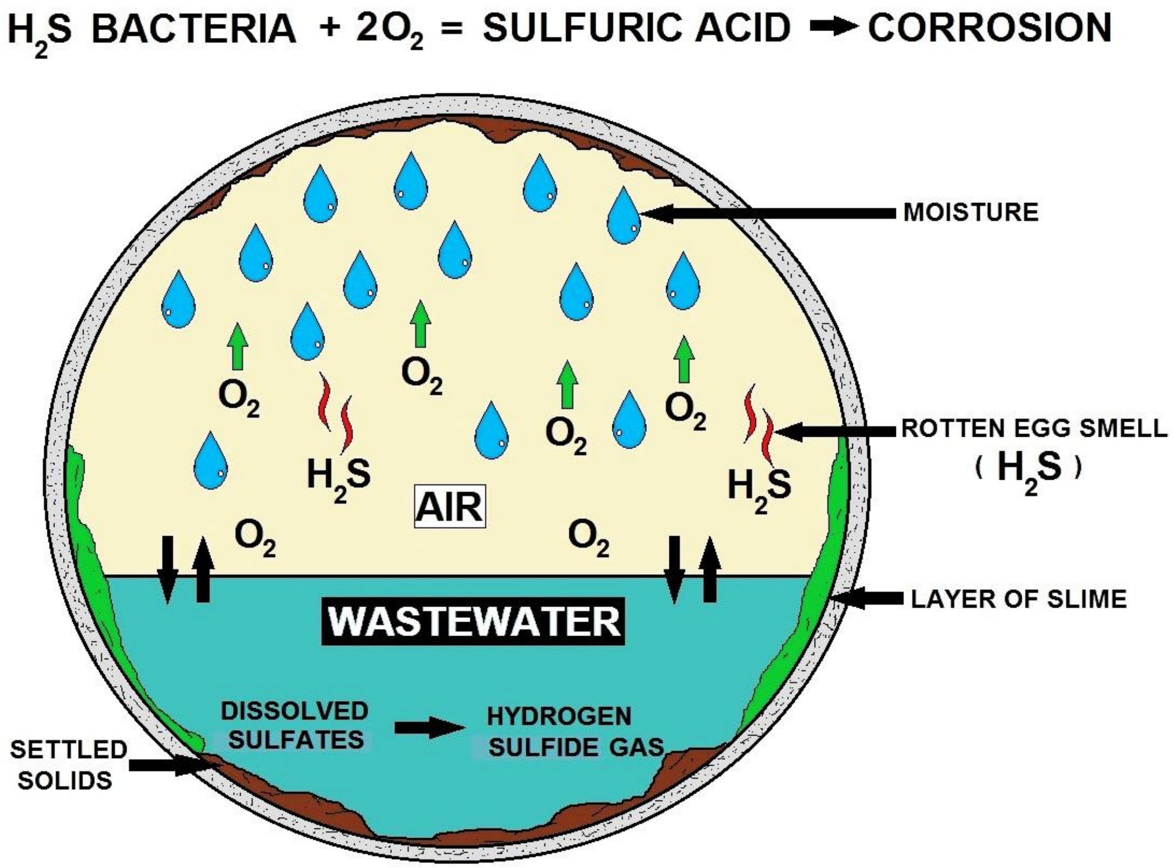
Work practices and emergency procedures

Whenever you enter a confined space such as a tank, make sure that you follow strict work practices, including a permit system. Make sure that the Confined Space Entry Standard 1910.146 is followed, that the air is continually monitored for the presence of H_2S, and that a buddy be stationed outside a confined space. Both of you should wear supplied air and lifelines and rescue equipment must be immediately available.

- **If you work with H_2S make sure that:**
  Your employer has trained you in the hazards of H_2S.
  Your employer has appropriate rescue equipment on-site.

Hazard Information Bulletin:
Following are excerpts from a Hazard Bulletin issued by OSHA after a fatality due to H_2S exposure.
Fundamentally, employers and employees must be alert to the fact that working with a **"closed system" does** not always ensure safety. Operations involving the opening of valves or pumps on otherwise closed systems, or working on such equipment that is not isolated or locked out, are particular sources of danger.

When a normally closed system is opened, the potential exists for releasing hazardous chemicals into the workers' breathing zones in unknown concentrations.



HOW CORROSION FORMS IN SEWER PIPING

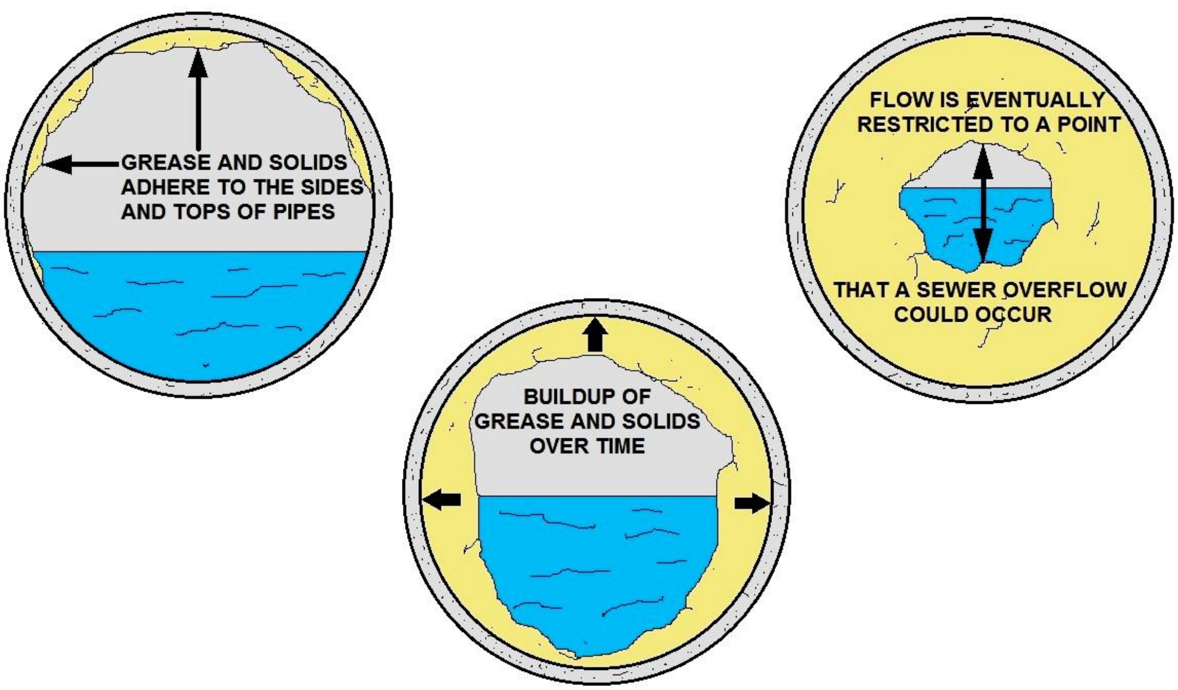
Hydrogen Sulfide Highlights ***Memorize this section for the exam.***

Hydrogen sulfide or H_2S problems are very common in the collection and wastewater system. There are many chemicals used to help or treat this problem. Here are a few used in the treatment of hydrogen sulfide problems: Salts of zinc, Lime, hydrogen peroxide, chlorine and magnesium hydroxide.

Hydrogen sulfide production in collection systems can cause a number of problems, including all of the following: Corrosion of the pipes and manholes, creation of hazardous atmospheres, and foul odors.

The best method of controlling hydrogen sulfide is to eliminate its habitat or growth area by keeping sewers cleaner, this will harbor fewer slime bacteria.

Here are some important statements regarding the reduction of hydrogen sulfide: Salts of zinc and iron may precipitate sulfides, lime treatments can also kill bacteria which produce hydrogen sulfide, but this creates a sludge disposal problem, but chlorination is effective at reducing the bacteria which produce hydrogen sulfide. Hydrogen sulfide conditions occur in the sewer system because of the lack of oxygen.

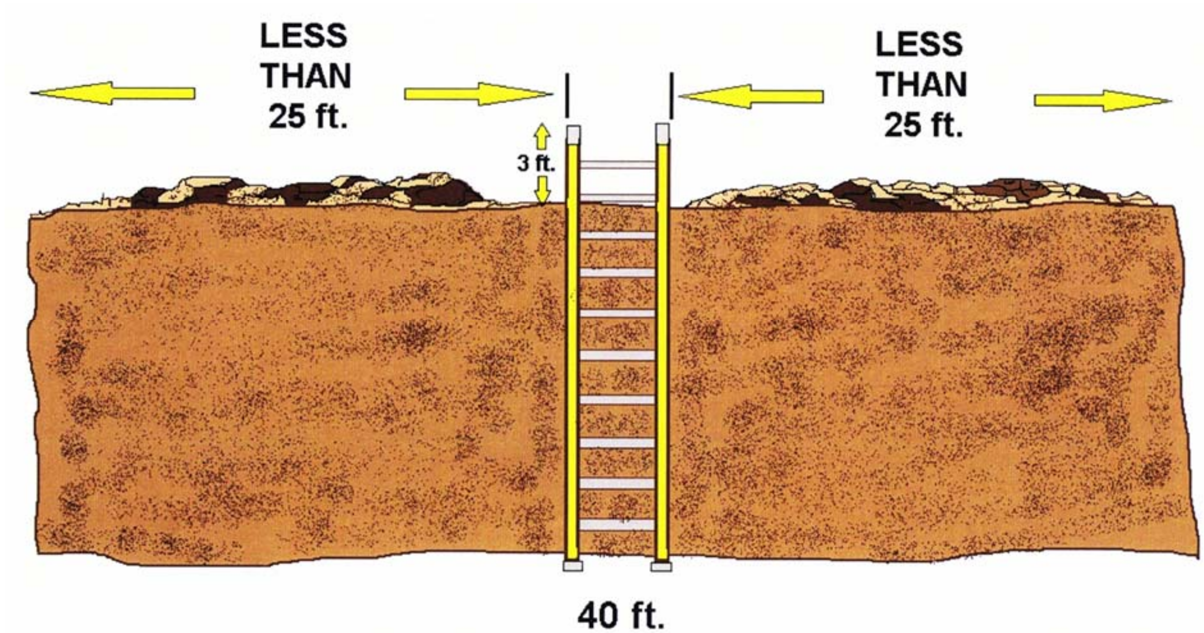


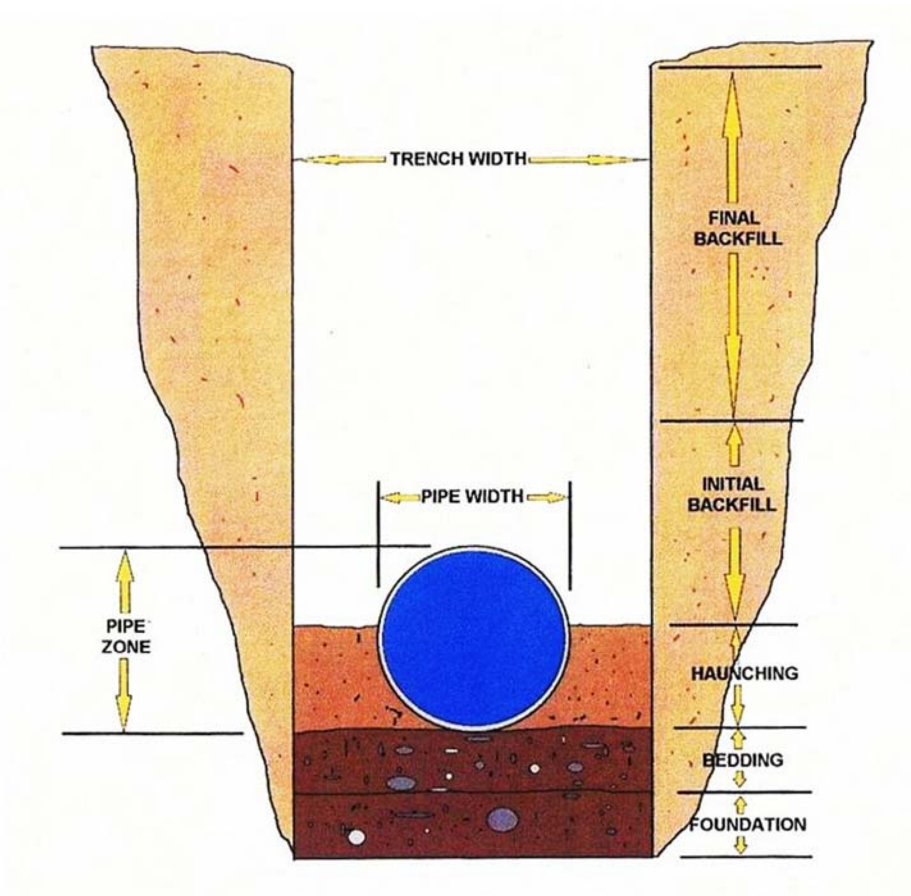
EFFECTS OF GREASE AND SOLIDS ON SEWER FLOW

Safety Section Chapter 7

Competent Person: One who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees. They have authorization to take prompt corrective measures to eliminate hazards.

The Competent Person also is trained and knowledgeable about soil analysis and the use of protective systems.





CROSS-SECTION OF A TRENCH

Lockout - Tagout Training
(LOTO)

Purpose
Control of Hazardous energy is the purpose of the Lockout-Tagout Policy. This policy establishes the requirements for isolation of both kinetic and potential electrical, chemical, thermal, hydraulic, pneumatic and gravitational energy prior to equipment repair, adjustment or removal. The Lockout-Tagout electrical safety policy is part of your overall Safety Program. If you do not understand this policy, it is your responsibly to ask your supervisor to have this policy explained to you. **Reference:** OSHA Standard 29 CFR 1910. 147, the control of hazardous energy.

Definitions
Authorized (Qualified) Employees are the only ones certified to lock and tagout equipment or machinery. Whether an employee is considered to be qualified will depend upon various circumstances in the workplace. It is likely for an individual to be considered "**qualified**" with regard to certain equipment in the workplace, but "unqualified" as to other equipment.

An employee who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training and who is under the direct supervision of a qualified person, is considered to be "**qualified**" for the performance of those duties.

Affected Employees are those employees who operate machinery or equipment upon which lockout or tagging out is required under this program. Training of these individuals will be less stringent in that it will include the purpose and use of the lockout procedures.

Other Employees are identified as those that do not fall into the authorized, affected or qualified employee category. Essentially, it will include all other employees. These employees will be provided instruction in what the program is and not to touch any machine or equipment when they see that it has been locked or tagged out.

Training
Authorized Employees Training **Example**

All maintenance employees and Department Supervisors will be trained to use the Lock and Tagout Procedures. The training will be conducted by the Supervisor or Safety Coordinator at time of initial hire. Retraining shall be held at least annually.

The training will consist of the following:
- Review of General Procedures.
- Review of Specific Procedures for machinery, equipment and processes.
- Location and use of Specific Procedures.
- Procedures when questions arise.

Affected Employee Training

- Only trained and authorized employees will repair, replace or adjust machinery, equipment or processes.
- Affected employees may not remove locks, locking devices or tags from machinery, equipment or circuits.
- Purpose and use of the lockout procedures.

Other Employee Training

- Only trained and authorized employees will repair, replace or adjust machinery or Equipment.
- Other employees may not remove locks, locking devices or tags from machinery, equipment or circuits.

Preparation for Lock and Tagout Procedures

A Lockout - Tagout survey will be conducted to locate and identify all energy sources to verify which switches or valves supply energy to machinery and equipment. Dual or redundant controls will need to be removed. A Tagout Schedule will be developed for each piece of equipment and machinery. This schedule describes the energy sources, location of disconnects, type of disconnect, special hazards and special safety procedures. The schedule will be reviewed each time to ensure employees properly lock and tag out equipment and machinery. If a Tagout Schedule does not exist for a particular piece of equipment, machinery and process, one must be developed prior to conducting a Lockout - Tagout. As repairs and/or renovations of existing electrical systems are made, standardized controls will be used. It is your departmental supervisor's responsibility to ensure that a schedule is made.

Routine Maintenance & Machine Adjustments

Lock and Tag out procedures are not required if equipment must be operating for proper adjustment. This rare exception may be used only by trained and authorized employees when specific procedures have been developed to safely avoid hazards with proper training. All consideration shall be made to prevent the need for an employee to break the plane of a normally guarded area of the equipment by use of tools and other devices.

SOP: General Lock and Tag out Procedures

Before working on, repairing, adjusting or replacing machinery and equipment, the following procedures will be utilized to place the machinery and equipment in a neutral or zero mechanical state.

Preparation for Shutdown

Before authorized or affected employees turn off a machine or piece of equipment, the authorized employee will have knowledge of the type and magnitude of the energy, the hazards of the energy to be controlled, and the means to control the energy. Notify all affected employees that the machinery, equipment or process will be out of service.

Machine or Equipment Shutdown
The machine or equipment will be turned off or shut down using the specific procedures for that specific machine. An orderly shutdown will be utilized to avoid any additional or increased hazards to employees as a result of equipment de-energization. If the machinery, equipment or process is in operation, follow normal stopping procedures (depress stop button, open toggle switch, etc.). Move switch or panel arms to "**Off**" or "**Open**" positions and close all valves or other energy isolating devices so that the energy source(s) is disconnected or isolated from the machinery or equipment.

Machine or Equipment Isolation
All energy control devices that are needed to control the energy to the machine or equipment will be physically located and operated in such a manner as to isolate the machine or equipment from the energy source.

Lockout or Tagout Device Application
Lockout or tagout devices will be affixed to energy isolating devices by authorized employees. Lockout devices will be affixed in a manner that will hold the energy isolating devices from the "safe" or "off" position.

Where tagout devices are used they will be affixed in such a manner that will clearly state that the operation or the movement of energy isolating devices from the "safe" or "off" positions is prohibited.

The tagout devices will be attached to the same point a lock would be attached. If the tag cannot be affixed at that point, the tag will be located as close as possible to the device in a position that will be immediately obvious to anyone attempting to operate the device. Lock and tag out all energy devices by the use of hasps, chains and valve covers with assigned individual lock(s).

Stored Energy
Following the application of the lockout or tagout devices to the energy isolating devices, all potential or residual energy will be relieved, disconnected, restrained, and otherwise rendered safe. Where the re-accumulation of stored energy to a hazardous energy level is possible, verification of isolation will be continued until the maintenance or servicing is complete. Stored energy (capacitors, springs, elevated members, rotating fly wheels, and hydraulic/air/gas/steam systems) must be relieved or restrained by grounding, repositioning, blocking and/or bleeding the system.

Verification of Isolation
Prior to starting work on machines or equipment that have been locked or tagged out, the authorized employees will verify that isolation or de-energization of the machine or equipment has been accomplished. After assuring that no Employee will be placed in danger, test all lock and tag outs by following the normal start up procedures (depress start button, etc.). ***Caution:*** After Test, place controls in neutral position.

Extended Lockout - Tagout
Should the shift change before the machinery or equipment can be restored to service, the lock and tag out must remain. If the task is reassigned to the next shift, those Employees must lock and tag out before the previous shift may remove their lock and tag.

Confined Space Safety Section

Definition of Confined Spaces Requiring an Entry Permit

A Confined space:

1. Is large enough or so configured that an employee can bodily enter and perform work.
2. Has limited or restricted means for entry or exit (i.e. tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
3. Is not designed for continuous employee occupancy.

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 of 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.

Confined Space

Purpose
The Confined Space Entry Program is provided to protect authorized employees that will enter confined spaces and may be exposed to hazardous atmospheres, engulfment in materials, conditions which may trap or asphyxiate due to converging or sloping walls, or contains any other safety or health hazards. **Reference**: OSHA-Permit-Required Confined Spaces (29 CFR 1910.146).

Scope ***Example***
You are required to recognize the dangers and hazards associated with Confined Spaces, and this program is designed to assist you in the safety of and compliance with the OSHA standards associated with such.

Most communities will utilize the Fire Department for all rescues and additional assistance dealing with confined spaces, understanding that most Fire Department operations utilize additional in house SOG's or SOP's pertaining to such operations.

Definitions
Confined space:
Is large enough or so configured that an employee can bodily enter and perform work.
Has limited or restricted means for entry or exit (i.e. tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
Is not designed for continuous employee occupancy.

Permit required confined space (permit space), is a confined space that has one or more of the following characteristics:
1. Contains or has a potential to contain a hazardous atmosphere.
2. Contains a material that has the potential for engulfing an entrant.
3. Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly covering walls or by a floor which slopes downward and tapers to a smaller cross-section.
4. Contains any other recognized serious safety or health hazard.

Each Permit-Required Confined Space will be marked
"Confined Space - Entry Permit Required".
CONFINED SPACE

Permitted Confined Space Entry Program

Purpose
The Permit Required Space (**PRCS**) Program is provided to protect authorized employees that will enter confined spaces and may be exposed to hazardous atmospheres, engulfment in materials, conditions which may trap or asphyxiate due to converging or sloping walls, or contains any other safety or health hazards.

Many workplaces contain confined spaces not designed for human occupancy which due to their configuration hinder employee activities including entry, work and exit. Asphyxiation is the leading cause of death in confined spaces.

Subpart P applies to all open excavations in the earth's surface.

- ✓ **All trenches are excavations.**
- ✓ **All excavations are not trenches.**

Permit Required Confined Space Entry General Rules
During all Confined Space Entries, the following Safety Rules must be strictly enforced:

1. Only authorized and trained employees may enter a confined space or act as safety watchmen, attendants, entrants, supervisors.

2. No smoking is permitted in a confined space or near entrance/exit area.

3. During confined space entries, a watchman or attendant must be present at all times.

4. Constant visual or voice communication will be maintained between the safety watchman or attendant and employees entering a confined space.

5. No bottom or side entry will be made, or work conducted, below the level of any hanging material or material which could cause engulfment.

6. Air and oxygen monitoring is required before entering any permit-required confined space. Oxygen levels in a confined space must be between 19.5 and 23.5 percent. Levels above or below will require the use of an SCBA or other approved air supplied respirator. Additional ventilation and oxygen level monitoring is required when welding is performed. The monitoring will check oxygen levels, Explosive gas levels and carbon monoxide levels. Entry will not be permitted if explosive gas is detected above one-half the Lower Explosive Limit (**LEL**).

7. To prevent injuries to others, all openings to confined spaces will be protected by barricades when covers are removed.

Confined Space Duties & Responsibilities

Examples of assignments
Employees
- Follow program requirements.
- Report any previously un-identified hazards associated with confined spaces.
- Do not enter any confined spaces that have not been evaluated for safety concerns.

Management
- Provide annual Confined Space training to all employees that may need confined space training.
- Ensure confined space assessments have been conducted.
- Annually review this program and all Entry Permits.

Rescue or Training Department
- Ensure proper training for entry & rescue teams.
- Provide proper equipment for entry & rescue teams.
- Ensure all permit required confined spaces are posted.
- Evaluate rescue teams and service to ensure they are adequately trained and prepared.
- Ensure rescue team at access during entry into spaces with IDLH atmospheres.
- Provide annual confined space awareness training to all employees that may need confined space awareness training.

Entry Supervisor
Entry supervisors are responsible for the overall permit space entry and must coordinate all entry procedures, tests, permits, equipment and other relevant activities. The following entry supervisor duties are required:
- ✓ Know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure.
- ✓ Verify by checking that the appropriate entries have been made on the permit, all tests specified by the permit have been conducted, and that all procedures and equipment specified by the permit are in place before endorsing the permit and allowing entry to begin.
- ✓ Terminate the entry and cancel the permit when the entry is complete or there is a need for terminating the permit.
- ✓ Verify that rescue services are available and that the means for summoning them are operable.
- ✓ Remove unauthorized persons who enter or attempt to enter the space during entry operations.
- ✓ Determine whenever responsibility for a permit space entry operation is transferred and at intervals dictated by the hazards and operations performed within the space that entry operations remain consistent with the permit terms and that acceptable entry conditions are maintained.

Entry Attendants

At least one attendant is required outside the permit space into which entry is authorized for the duration of the entry operation. Responsibilities include:

- ✓ To know the hazards that may be faced during entry, including information on the mode, signs or symptoms, and consequences of the exposure.
- ✓ To be aware of possible behavioral effects of hazard exposure on entrants.
- ✓ To continuously maintain an accurate count of entrants in the permit space and ensure a means to accurately identify authorized entrants.
- ✓ To remain outside the permit space during entry operations until relieved by another attendant (once properly relieved, they may participate in other permit space activities, including rescue if they are properly trained and equipped).
- ✓ To communicate with entrants as necessary to monitor entrant status and alert entrants of the need to evacuate.
- ✓ To monitor activities inside and outside the space to determine if it is safe for entrants to remain in the space and orders the entrants to immediately evacuate if: the attendant detects a prohibited condition, detects entrant behavioral effects of hazard exposure, detects a situation outside the space that could endanger the entrants; or if the attendant cannot effectively and safely perform all the attendant duties.
- ✓ To summon rescue and other emergency services as soon as the attendant determines the entrants need assistance to escape the permit space hazards.
- ✓ To perform non-entry rescues as specified by that rescue procedure and entry supervisor.
- ✓ Not to perform duties that might interfere with the attendants' primary duty to monitor and protect the entrants.

Take the following action when unauthorized persons approach or enter a permit space while entry is under way:

1. Warn the unauthorized persons that they must stay away from the permit space,
2. Advise unauthorized persons that they must exit immediately if they have entered the space, and
3. Inform the authorized entrants and the entry supervisor if unauthorized persons have entered the permit space.

Entrants

All entrants must: be authorized by the entry supervisor to enter permit spaces, have received the required training, use the proper equipment, and observe the entry procedures and permit.

Other Excavation and Confined Space Hazards

Flammable Atmospheres
A flammable atmosphere generally arises from enriched oxygen atmospheres, vaporization of flammable liquids, byproducts of work, chemical reactions, concentrations of combustible dusts, and desorption of chemicals from inner surfaces of the confined space. An atmosphere becomes flammable when the ratio of oxygen to combustible material in the air is neither too rich nor too lean for combustion to occur. Combustible gases or vapors will accumulate when there is inadequate ventilation in areas such as a confined space.

Flammable gases such as acetylene, butane, propane, hydrogen, methane, natural or manufactured gases or vapors from liquid hydrocarbons can be trapped in confined spaces, and since many gases are heavier than air, they will seek lower levels as in pits, sewers, and various types of storage tanks and vessels. In a closed top tank, it should also be noted that lighter than air gases may rise and develop a flammable concentration if trapped above the opening. The byproducts of work procedures can generate flammable or explosive conditions within a confined space.

Specific kinds of work such as spray painting can result in the release of explosive gases or vapors. Welding in a confined space is a major cause of explosions in areas that contain combustible gas.

Chemical reactions forming flammable atmospheres occur when surfaces are initially exposed to the atmosphere, or when chemicals combine to form flammable gases. This condition arises when dilute sulfuric acid reacts with iron to form hydrogen or when calcium carbide makes contact with water to form acetylene. Other examples of spontaneous chemical reactions that may produce explosions from small amounts of unstable compounds are acetylene-metal compounds, peroxides, and nitrates. In a dry state, these compounds have the potential to explode upon percussion or exposure to increased temperature.

Another class of chemical reactions that form flammable atmospheres arise from deposits of pyrophoric substances (carbon, ferrous oxide, ferrous sulfate, iron, etc.) that can be found in tanks used by the chemical and petroleum industry. These tanks containing flammable deposits will spontaneously ignite upon exposure to air.

Combustible dust concentrations are usually found during the process of loading, unloading, and conveying grain products, nitrated fertilizers, finely ground chemical products, and any other combustible material. High charges of static electricity, which rapidly accumulate during periods of relatively low humidity (below 50%), can cause certain substances to accumulate electrostatic charges of sufficient energy to produce sparks and ignite a flammable atmosphere. These sparks may also cause explosions when the right air or oxygen to dust or gas mixture is present.

Toxic Atmospheres
The substances to be regarded as toxic in a confined space can cover the entire spectrum of gases, vapors, and finely-divided airborne dust in industry.

Carbon Monoxide

Carbon monoxide (**CO**) is a hazardous gas that may build up in a confined space. This odorless, colorless gas that has approximately the same density as air, is formed from incomplete combustion of organic materials such as wood, coal, gas, oil, and gasoline; it can be formed from microbial decomposition of organic matter in sewers, silos, and fermentation tanks. Carbon monoxide is an insidious toxic gas because of its poor warning properties. Early stages of CO intoxication are nausea and headache.

Carbon monoxide may be fatal at 1000 ppm or 10% in air, and is considered dangerous at 200 ppm or 2%, because it forms Carboxyhemoglobin in the blood which prevents the distribution of oxygen in the body.

Carbon monoxide is a relatively abundant colorless, odorless gas, therefore, any untested atmosphere must be suspect. It must also be noted that a safe reading on a combustible gas indicator does not ensure that CO is not present. Carbon monoxide must be tested for specifically. The formation of CO may result from chemical reactions or work activities, therefore fatalities due to CO poisoning are not confined to any particular industry.

There have been fatal accidents in sewage treatment plants due to decomposition products and lack of ventilation in confined spaces. Another area where CO results as a product of decomposition is in the formation of silo gas in grain storage elevators. In another area, the paint industry, varnish is manufactured by introducing the various ingredients into a kettle, and heating them in an inert atmosphere, usually town gas, which is a mixture of carbon dioxide and nitrogen.

In welding operations, oxides of nitrogen and ozone are gases of major toxicologic importance, and incomplete oxidation may occur and carbon monoxide can form as a byproduct.

Irritant (Corrosive) Atmospheres

Irritant or corrosive atmospheres can be divided into primary and secondary groups. The primary irritants exert no systemic toxic effects (effects on the entire body). Examples of primary irritants are chlorine, ozone, hydrochloric acid, hydrofluoric acid, sulfuric acid, nitrogen dioxide, ammonia, and sulfur dioxide. A secondary irritant is one that may produce systemic toxic effects in addition to surface irritation. Examples of secondary irritants include benzene, carbon tetrachloride, ethyl chloride, trichloroethane, trichloroethylene, and chloropropene. Irritant gases vary widely among all areas of industrial activity.

They can be found in plastics plants, chemical plants, the petroleum industry, tanneries, refrigeration industries, paint manufacturing, and mining operations. Prolonged exposure at irritant or corrosive concentrations in a confined space may produce little or no evidence of irritation. This may result in a general weakening of the defense reflexes from changes in sensitivity. The danger in this situation is that the worker is usually not aware of any increase in his/her exposure to toxic substances.

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.

A confined space is defined as an area where existing ventilation is inadequate to remove contaminants or provide a sufficient air supply. Other criterion that defines confined space are areas that are difficult to enter or evacuate.

An atmospheric analyzer will have an audible and visible alarm that will warn when the flammable gases exceed 10%, sometimes expressed as 0.1. Atmospheric monitors continuously sample the atmosphere for the following levels: Toxicity, Oxygen, and Flammability.

Upon entering a confined space, your oxygen meter indicates an oxygen concentration of 23.9%. The appropriate course of action is to evacuate the area immediately. Keep the O_2 in the range of 19.5 to 23.5.

When a trench is dug for a new line or replacement of an old line, the trench should be dug and backfilled in such a manner to support the pipe. A rule of thumb as to the width of the trench is that the trench should be narrow as possible for safety and to increase pipe sidewall support.

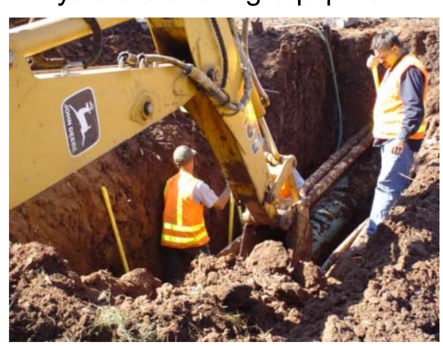
When purchasing a specific type of shoring for the collection system, the operator should consider price and quality of the material. The type of shoring purchased for an agency is governed by soil conditions in the area.

The operator has installed a screw jack between the solid sheeting material for shoring a trench. To ensure safe conditions in the trench the operator needs to perform the following additional task on the screw jacks; driving nails into the base of the jack and timbers. An alternative to screw jacks as a shoring brace is to use air shores.

The operator is installing air shores. The tank is used to fill the cylinders which reinforce the trench walls. The cylinders are pressurized to 300 PSI. The next step in using this type of shoring equipment as well as related shoring equipment is to insert a metal pin behind the collar to form a mechanical lock.

Hydraulic shores are used due to their ease of installation and removal. However, they are usually not used on jobs for a time period greater than five (5) days, because there is a possibility of the hydraulic pressure bleeding off during a time period longer than five (5) days.

Hydraulic shoring fluid is the only fluid recommended for use in hydraulic shoring equipment.



Driving: If the operator is confronted by an unsafe or discourteous driver while driving a treatment plant vehicle, he should swallow his pride and handle the situation with manners.

The advance traffic warning area is located from the first sign to the start of the next sign and should be at least one block for urban streets. The transition area is the area that barricades are utilized to push the traffic over. The safety buffer zone is the area that employees can work safely away from traffic.

LOTO, the lock is a physical restraint and only the person that locked the lock should have the key to open it. The tag is an identification device to identify the person and reason for the lock.

Two unsafe excavation examples; Top--notice the man in a 6 foot deep trench with no ladder or shoring and the placement of spoil. Bottom picture--utilities are marked after the excavation has begun; no hard hats, no ladders, no protective system, incorrect spoil placement.

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"?

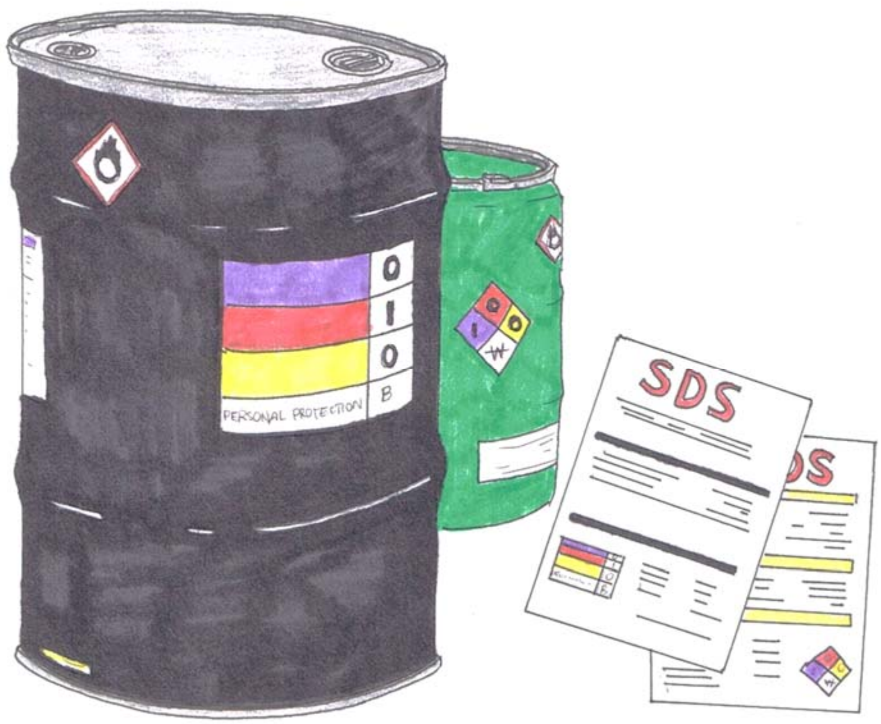
10. What is the classification of material that includes granular soils such as gravel, sand and loamy sand, submerged soil, soil from which water is freely seeping?

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



Memorize these for your exam.

Chemical Name	Common Name	Chemical Formula
Ammonia		NH_3
Ammonium		NH_4
Calcium Hypochlorite	HTH	$Ca(OCl)_2 . 4H_2O$
Calcium hydroxide	Slaked Lime	$Ca(OH)_2$
Carbon	Activated Carbon	C
Carbon dioxide		CO_2
Carbonic acid		$H2CO_3$
Chlorine gas		Cl_2
Chlorine Dioxide		ClO_2
Ferric chloride	Iron chloride	$FeCl_3$
Ferric hydroxide		$Fe(OH)_3$
Ferric sulfate	Iron sulfate	$Fe_2(SO_4)3$
Ferrous hydroxide		$Fe(OH)_3$
Hydrochloric acid	Muriatic acid	HCl
Hydrogen sulfide		$H2_S$
Hypochlorous acid		HOCL
Magnesium hydroxide		$Mg(OH)_2$
Magnesium dioxide		MgO_2
Manganous bicarbonate		$Mn(HCO_3)2$
Sodium hydroxide	Lye	NaOH
Sodium hypochlorite		NaOCl
Sodium sulfate		Na_2SO_4
Sulfuric acid		H_2SO_4

Practice Quiz, identify the following…
Cl
Cl_2

Atomic number of Cl

H_2SO_4
H_2S
Cu
S
Two compounds that contain Sulfur. Mercaptans and Phenols

What does Cl_2 and H_2S have in common?

Wastewater Treatment Glossary

Please memorize these statements to pass your exam.

Acidic Solution: The proper definition of an acidic solution is a solution that contains a significant number of H+ ions.
Activated Sludge: During cold weather operation of an activated sludge plant, biological activity is reduced. This results in a decreasing rate of solids accumulation. Extended aeration activated sludge is necessary for proper luxury uptake of phosphorous. At least 3 or more days before observing a change made for process control in an activated sludge package plant. During cold weather operation of an activated sludge plant, biological activity will be reduced. This results in decreasing rate of solids accumulation. 2.0 mg/l to 4.0 mg/l is the dissolved oxygen concentration needed during start-up of an activated sludge plant. 2 to 3 MCRTs before a change in an activated sludge process is observed. In a rectangular conventional activated sludge tank, the DO concentration is lowest at the beginning of the tank where the air diffusers are all evenly opened. Thiothrix is a type of filament that can grow in the aeration basin of an activated sludge plant. Low DO levels is a possible cause to the growth of this long filament. The dissolved oxygen concentration needed during start-up of an activated sludge plant is 2.0 mg/l to 4.0 mg/l.
Aeration Basin: Operation change that should be employed if a dark brown foam is developing on the aeration basin is to increase the wasting rate.
Aeration Plant: An extended aeration plant designed to operate when the microorganism population is in the endogenous respiration phase. This is the time of the most complete oxidation of organic material.
Aerobic Digester: In an aerobic digester the DO drops to less than 1.0 mg/l but the blowers are operating at full capacity. Reducing the loading to the digester should be done under these conditions. In an anaerobic digester the volatile acid/alkalinity ratio is experiencing a decrease in pH. Soda ash can be added to correct this condition. Decreasing the air intake to reduce turbulence should be done to correct excessive foam in an aerobic digester when the DO is high, pH is 7, and the O2 uptake and temperature are stable. Sufficient air must be used to place all solids in the aeration tank in suspension. Some of the by-products of aerobic digestion are Nitrate, Sulfate and Carbon Dioxide. Not Volatile acids. pH will decrease if the level of carbon dioxide increases in an anaerobic digester. Empting the condensate from the drip traps daily is necessary for maintaining proper operation of a drip trap placed on the gas line of a heated anaerobic digester. Volatile acid concentration will be observed first following an upset of the anaerobic digestion process.
Aerobic Sludge: The pH should be 11.5 to 12.0 when lime is mixed with aerobic sludge for stabilization.
Algae Problem: Sunlight is required in the process of producing oxygen from carbon dioxide from algae.
Alternative Disinfectants: The following chemicals may be used as alternative disinfectants; Ozone, chlorine dioxide or chloramines, O3, ClO2, or NH4CL2.
Ammonium Ion: NH4+.
Anaerobic Digester Annular Space: The purpose of the annular space on a floating cover anaerobic digester is to provide a water seal to prevent air from entering the digester.
Anaerobic Digester Seal: If a water seal on an anaerobic digester breaks and air enters, an explosion could occur.
Anaerobic Sludge vs. Aerobic Sludge: The difference between anaerobic sludge and aerobic sludge; Aerobic sludge has a higher water content.
Belt Filter Press: The ability of a belt filter press to dewater sludge and remove suspended solids is dependent upon sludge type and conditioning, the relationship between hydraulic loading and the belt speed. The purpose of a belt filter press containing a Venturi-type restriction is to provide turbulence during the mixing of polymer with the flow of sludge.
Binding: The clogging of the filtering medium of a microscreen or a vacuum filter when the holes or spaces in the media become sealed off.
Biological Community: It take about 60 days to establish a thriving biological community.
Biological Contactor: A biological contactor uses stages to maximize the effectiveness of a given amount of media surface. As BOD decreases, nitrification begins as the benefit of this design.
Biological Treatment: Removes colloidal solids from wastewater.
Black Foam: An anaerobic digester has a black foam covering about one half of the surface. All of the following are possible causes to the foam problem: The temperature is changing in the digester too fast. High organic loading to the digester. A thick sludge blanket was broken up. If this is not the problem, the settled sludge in the secondary digester is being removed too fast.

Blacktop or Paved Drying Bed: Pavement allows mechanical equipment to mix the sludge; that is why a blacktop or paved drying bed can handle 2 to 3 time more sludge than a normal sand drying bed.
BOD Test: Dilution water is seeded (saturated) with oxygen when conducting a BOD test on an un-chlorinated wastewater sample to compare to an unseeded or blank reservoir of dilution water
Breakpoint Chlorination: Adding chlorine to the water until the chlorine demand is satisfied.
Ca(OCl)2.4H2O: Is the molecular formula of calcium hypochlorite.
Carbon Dioxide: The production of this compound during evening hours causes a pH decrease in a stabilization pond.
Caustic Soda: May be added to raise the pH of a solution.
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. Prime the pump with water before starting a new centrifugal pump for the first time. A key and a tight fit is the common method used to secure an impeller to the shaft on a double-suction pump. A mechanical seal is the best seal to use for a pump operating under high suction head conditions. A possible cause of a scored shaft sleeve is that the packing has broken down or the packing is too tight or over tightened. A reciprocating pump or piston pump should not be operated with the discharge valve in the closed position. An air compressor generates heat during the compression cycle. What is the most common type of damage caused by heat generated during operation? The lubricating oil tends to break down quickly, requiring frequent replacement. Cavitation is caused by a suction line that may be 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 must be provided on the suction piping to hold the prime. Continuous leakage from a mechanical seal on a pump indicates that the mechanical seal needs to be replaced. One disadvantage of a centrifugal pump is that it is not self-priming. 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. The purpose of the foot valve on a pump is that it keeps the air relief opened. The viscosity decreases with most lubricants as the temperature increases. Two pumps of the same size can be operated alternately to equalize wear and distribute lubricant in bearings.
Chemistry: Amperometric titration is used to measure Chlorine residual. A glass burette is read by looking at the bottom of the curved level of the liquid in the burette. A spectrophotometer operates based on the light transmitted or absorbed by the sample at a selected wavelength. A standard solution is a prepared chemical solution in which the exact chemical concentration is known. At 4^{O} C is water the most dense. Hydrogen chloride is a colorless gas with a pungent odor. The aqueous solution of this compound called is Hydrochloric acid. Hypochlorous acid dissociates according to the following reactions? HOCl <-- --> H+ + OCl-. Sulfate is a compound that will readily dissolve in water forming an anion. Shaking or mixing the sample is a pretreatment step needed for the suspended solids test. In VOC water tests it is permissible to use a composite sample. Dry gaseous sulfur dioxide forms H2SO4 in the presence of moisture. When water is added to acid, the mixture will tend to splatter.
Chlorinating In addition to disinfecting a plant's effluent, chlorinating a wastestream may also lower the BOD.
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. Chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air. Atomic number is 17. Monochloramine, dichloramine, and trichloramine are known as combined available chlorine. Acetylene and ether, turpentine and ammonia and hydrogen and finely divided metals are pairs of substances with which chlorine will react explosively or form explosive compounds. The chlorine pressure reducing valve should be located when using an evaporator downstream of the evaporator. Precaution should be taken when applying chlorine in the sewer line near a wastewater treatment plant to control hydrogen sulfide production and anaerobic bacteria because excessive chlorine can kill the aerobic organisms in the secondary treatment plant. Chlorine is added to the effluent before the contact chamber for complete mixing. The reason for not adding it directly to the chamber is that he chamber has very little mixing due to low velocities. High doses of chlorine help the reaction of chlorine with the bacteria in the water being disinfected. Hypochlorous acid is the most germicidal of all chlorine compounds with the possible exception of chlorine dioxide. The two main chemical species formed by chlorine in water and

what name are they known by collectively are HOCl and OCl-; free available chlorine. When chlorine gas is added to water, it rapidly hydrolyzes. The chemical equations that best describes this reaction is Cl2 + H2O --> H+ + Cl- + HOCl. When hypochlorite is brought into contact with an organic material, the organic material decomposes releasing heat very rapidly. Yoke-type connections should be used on a chlorine cylinder's valve assuming the threads on the valve may be worn.

Chlorine Exposure Symptoms: 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.

Chlorine Gas: Causes suffocation, constriction of the chest, tightness in the throat, and edema of the lungs. As little as 2.5 mg per liter(approximately 0.085 percent by volume) in the atmosphere causes death in minutes, but less than 0.0001 percent by volume may be tolerated for several hours. Chlorine gas is highly corrosive in moist conditions. Gold, Platinum, and Tantalum are the only metals totally inert to moist Chlorine gas. 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. Even brief exposure to 1,000 ppm of CL2 can be fatal. Chronic exposure to low concentrations of chlorine gas may cause corrosion of the teeth. Reacts with water producing a strong oxidizing solution causing damage to the moist tissue lining; 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. Where other factors are constant, the disinfection action may be represented by: Kill = C X T.

Chlorine Gas Cylinder: Should be initially opened 1/4 turn to unseat the valve, then open one complete turn.

Chlorine Gas Leak: Is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite.

Chlorine Residual Test: A chlorine residual test during various time periods on a plant's effluent samples indicates the amount of free and/or available chlorine available after a given contact time.

Chlorine Safety: 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. 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. The approved method s for storing a chlorine cylinder; Secure each cylinder in an upright position. Attach the protective bonnet over the valve and Firmly secure each cylinder. The connection from a chlorine cylinder to a chlorinator should be replaced by using a new, approved gasket on the connector. The necessary emergency procedures in the case of a large uncontrolled chlorine leak: 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.

Chlorine Solution Line: A chlorine solution line should be corrosion resistant. PVC pipe material is recommended for this purpose. PVC Schedule 80 should be used for a chlorine solution line.

Cl2 + H2O --> H+ + Cl- + HOCl: When chlorine gas is added to water, it rapidly hydrolyzes. This is the chemical equation that best describes this reaction.

Clarifier Effluent Quality: Sealing of sanitary sewers and/or use of an equalization basin should be done to improve clarifier effluent quality when excessive storm flow infiltration is a frequent problem.

Clarifier: Sludge withdrawal from a clarifier should be conducted slowly to prevent the pumping of too much water. The purpose of an effluent weir is to evenly distribute the influent across a surface of the clarifier. When a primary clarifier is operating properly, The BOD and TSS will decrease through the clarifier.

ClO_2: Is the molecular formula of Chlorine dioxide.

Coliform Bacteria: A grab sample should be collected to analyze for coliform bacteria.

Combined Available Chlorine: Also known as monochloramine, dichloramine, and trichloramine.

Composite Sample: A combination of a group of samples collected at various intervals during the day. A composite sample of the clarifier influent and effluent is a type of process control sample that should be collected to determine the efficiency of treatment.

Confined Space: The definition of a hazardous atmosphere is an atmosphere that is explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful that may cause death, illness, or injury. The detailed plan for emergency response to an injury or other emergency within the confined space should be described in detail in the water system's Confined Space Entry

Program. A 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. Confined space entry Permitted Entry, Hot Work permit type is required. Type 2 confined space or permit required confined space has the characteristic of containing or has the potential to contain a hazardous atmosphere. Atmospheric monitoring in a confined space should be performed continuously from pre-entry to exit. Below 19.5 or .0195 maximum percentage an atmosphere considered oxygen deficient. Entry into a confined space requires a confined space entry permit.
Contact Chamber: The chamber provides for very little mixing due to low flow velocities; this is the reason for having a well-mixed solution of chlorine and wastewater effluent in the contact chamber.
Dark Brown Foam: Increase of the wasting rate should be employed if a dark brown foam is developing on the aeration basin.
Deep Filter Media: A deep filter media provides a slower buildup of head loss on the filter.
Denitrification; An indication of good treatment, providing that the sludge in the settleability test stays on the bottom. When sludge is floating up too early in a test this indicates that the sludge age should be reduced. Denitrification is taking place if sludge rises during the settleability test.
Digested Sludge Problem: Substances inhibiting the organisms may cause the oxygen uptake measurement in aerobically digested sludge to decrease.
Digester: An aeration system in an aerobic digester is shut off to decant the supernatant. The sludge begins to rise to the surface within 60 minutes. The supernatant is now full of the floating sludge. One solution to this problem is to install a below water surface draw off pipe for decanting. If the level of carbon dioxide increases in an anaerobic digester, the pH will decrease. In an aerobic digester the DO drops to less than 1.0 mg/l but the blowers are operating at full capacity. Reduce the loading to the digester should be done under these conditions. In an anaerobic digester, if the volatile acid/alkalinity ratio is experiencing a decrease in plant, you have high F/M.
Digester Methane Production: 8 - 12 ft^3 or cubic feet of methane can be expected to be produced for every pound of volatile material applied to a digester.
Dilution Water: Seeded with BOD to supply bacteria to decompose all organic matter.
Diseases: Giardiasis, hepatitis, or typhoid are common diseases that may be transmitted through the contamination of a water supply, but AIDS is not.
Disinfection: Good contact time and low turbidity are important in providing good disinfection using chlorine. Temperature in which chlorine disinfection will be the most effective is 25 degrees C^o. The primary objective of disinfection is to kill pathogenic microorganisms.
Dissolved Air Flotation Unit: Air to solids ratio is important in process control and may affect a dissolved air flotation unit.
DO Concentration: An operator should try to maintain a DO concentration of 1.0 mg/l to 2.0 mg/l dissolved oxygen in a sludge. Infrequent sludge pumping is the most probable cause if DO drops excessively across a primary clarifier.
DO Measurements: Take DO measurements with a probe in at least 3 to 5 different locations in an aerobic digester.
DPD Procedure: Commonly used to measure chlorine residual.
Electric Problem The overload on a heater element on a motor starter usually rated at to drop the circuit at 0.1 or ten percent. The voltage of the circuit to be tested is unknown, the meter be set on the highest range for voltage and work down. The expected voltage when testing the incoming voltage that is 220 VAC, single phase power is 110 volts. When testing a control circuit with a megger, first turn off circuit breaker before testing. Prior to resetting a tripped circuit breaker, first inspect the electrical equipment for problems.
Electrical Safety: Only allow qualified personnel to service electrical equipment as a general rule of thumb to protect an operator from electrical injury.
Elutriation: The purpose Elutriation is to reduce sludge alkalinity. Elutriation is a process of sludge conditioning whereby the sludge is washed, either with fresh water or plant effluent. The purpose of elutriation is to reduce sludge alkalinity.
Elutriation of Sludge: To reduce the chemical conditioning requirements.
Endogenous Respiration An extended aeration plant was designed to operate when the microorganism population is in the endogenous respiration phase. This is the time of the most complete oxidation of organic material. Endogenous respiration of microorganisms in an extended aeration plant will complete oxidation of organic material.
Exfiltration: Is the term that describes stormwater and groundwater flowing out of a sewer line.

Extended Aeration Plants: They do not produce as much waste sludge as other processes. This sludge type typically takes approximately 20 days to be fully stabilized.
Facultative: The classification of a body of water where the upper portion has dissolved oxygen while the lower portion does not.
Fecal Coliform Count: A higher effluent fecal coliform count may occur if a chlorine solution pump fails.
Filamentous Bacteria: Organisms that grow in thread form commonly cause sludge bulking in an activated sludge process. These bugs are called Filamentous bacteria.
Filter Backwash: A rate control valve which opens slowly is used to control the pressure during filter backwash.
Filter Fly Control: Chlorine residual of 1 mg/L is recommended for filter fly control.
Filters: Rapid head loss buildup is a disadvantage to surface straining versus depth filtration.
Floating Sludge: In a primary clarifier it usually means that the settled sludge has gone septic.
Flow measurement Devices: Are most commonly found at the plant headworks.
Flow Measurement Receiver: Records the friction loss through a conduit or pipeline; not a common function of a flow measurement receiver.
Fusible Plug: The part of a chlorine cylinder designed to melt at 158 to 165*F to prevent the cylinder from exploding in the event of fire.
Gas LEL: An explosive gas that is in a concentration below its Lower Explosive Limit it will not explode.
Geometric Mean: When reporting the monthly averages for fecal coliform limits in effluent, an operator must calculate the averages by the Geometric Mean.
Gold, Platinum, and Tantalum: Chlorine gas is highly corrosive in moist conditions. These are the only metals that are totally inert to moist chlorine gas.
Gravity Sand Filter: In order to calculate head loss through a gravity sand filter, an operator needs to have two pressure readings, one above and one below the media.
Grit Chamber: Grit is removed from wastewater early in the treatment process is to protect pumps and other equipment. Carryover grit from the grit chamber indicates that it is time to clean the grit chamber more frequently.
H_2SO_4: The molecular formula of sulfuric acid. Dry gaseous sulfur dioxide forms in the presence of moisture.
Hazardous Materials: The National Fire Protection Association uses color-coded hazard warning labels for hazardous materials. The color for a reactive material is Yellow.
Head works: Close inlet, close outlet, turn off screen, drain, and hose down is the best procedure for removing a mechanical bar screen from service.
Heated Anaerobic Digester: Emptying the condensate from the drip traps daily is necessary for maintaining proper operation of a drip trap placed on the gas line of a heated anaerobic digester.
Heavy Organic Loading: Excessive sloughing of biological growth on a trickling filter indicates heavy organic loading.
High F/M: An activated sludge plant is experiencing sludge bulking. The effluent from the clarifier is full of mixed liquor. High F/M can cause bulking sludge due to filamentous growth in the plant.
Hyacinth: A biological process which appears to be effective in removing algae from effluent and is fairly easy to operate and maintain if the proper environmental conditions can be developed.
Hydraulic Shores: 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.
Hydrogen Chloride: A colorless gas with a pungent odor. The aqueous solution of this compound called Hydrochloric acid.
Hypochlorous Acid: This is the active agent that is used in the destruction of microorganisms.
IDLH: For chlorine gas, according to the NIOSH manual, it is 10 ppm.
Jar Test: A lab test used to simulate a tertiary plant operation.
Laboratory Tests: BOD and Suspended Solids laboratory tests are typically conducted to monitor and control a primary clarifier.
Lagoon System: Discharge that is restricted to specific periods best describes the batch operation of a lagoon system.
Lantern Ring: When installing new packing, the purpose of the lantern ring to allow cooling liquid to enter along the shaft.
Long Filaments: Undesirable in large numbers because they prevent good settling of the sludge.
Long Term Storage Lagoon: 6 to 12 % solids of sludge is dredged from a long term storage lagoon.

LOTO: When shutting down a pump for a long period, the motor disconnect switch should be Opened, Locked Out, and Tagged.
Luxury Uptake: Extended aeration activated sludge is critical for a phosphorus removal system using the luxury phosphorous. An anaerobic or facultative tank must cause the release of phosphorus which is critical for a phosphorus removal system using the luxury uptake process.
Mechanical Seal: One of the limitations of a mechanical seal is that the pump must be dismantled to repair it. Used in place of packing because mechanical seals eliminate continual adjusting and do not leak.
Methane UEL: 15% is the upper explosive limit for Methane.
Microscopic Examination: Effluent end of the aeration system is the best location for microscopic examination of activated sludge.
Minor Ponding Problem: If a tricking filter process is experiencing a minor ponding problem on parts of the surface of the media; increase the recirculation rate over the surface to ensure that the quality of the effluent is not drastically changed.
Mixed Liquor: Contents of a balanced, good settling mixed liquor: Free-swimming and stalked ciliates and some flagellates and rotifers.
MLSS Determination: What is the significance of the MLSS determination? It is an indication of bacterial population available for utilizing organic waste.
MLSS: The significance of the MLSS determination is it is an indication of bacterial population available for utilizing organic waste.
Monitor Plant Performance: Lab Analysis, Equipment maintenance and Process Control are data that an operator uses to monitor plant performance.
Mosquito Breeding: Can be promoted by weed and scum accumulation along the levee of a stabilization pond.
Motor 3600 rpms: Is the maximum synchronous speed of an electric motor that has a frequency of 60 Hz.
Motor Overload Control: The overload control on a motor has tripped and the motor has stopped running. An operator waits for the overload to cool, then tries to start the motor again. If the motor does not start, the operator should first check the Motor overload control.
Motor: If a motor is rated for 10 amps the overload relays that should be used are 10 to 11 amps. A possible cause for a mechanical noise coming from a motor is that there is an unbalance of a rotating mechanical part. A possible result of over-greasing a bearing is that there will be extreme friction in the bearing chamber.
Motor Problem: Copper is not part of a motor brush composition.
Multi-Stage Pump: The name of a centrifugal pump with two impellers.
NaOCl: The molecular formula of Sodium hypochlorite.
NaOH: The molecular formula of Sodium hydroxide.
Natural Bacteria Sloughing: As the biological film or slime grows on a standard rate tricking filter, the excess slime must be wasted from the media. This is how the process of wasting excess slime is accomplished.
New Stabilization Pond: Fill the pond with at least one foot of clean water before a new stabilization pond is put into service.
NH4+: Is the molecular formula of the ammonium ion.
Nitrification: One common problem with a nitrification treatment process is a decrease in the alkalinity. Soda ash is used to control the alkalinity concentration.
Nitrification Treatment Process: One common problem with a nitrification treatment process is a decrease in the alkalinity. Soda ash is used to control the alkalinity concentration. When there is plenty of DO, available nitrification is most likely to occur in an aeration tank.
Nitrogenous Waste: Removed from the wastewater at a wastewater treatment plant because it exerts an oxygen demand on the receiving waters.
Nocardia: Causes frothing.
Olfactory Fatigue: Hydrogen Sulfide and Chlorine gas are extremely hazardous even at extremely low concentrations. Instrumentation should be used to detect the presence of these gases because of olfactory fatigue.
Osmosis: The spontaneous process by which solvent molecules pass through a semipermeable membrane from a solution of lower concentration into a solution of higher concentration.
Parshall Flume: Measures flow by measuring a rise in head produced by the Parshall Flume.

Pathogens: Disease-causing bacteria.
pH: (*Power of Hydroxyl Ion Activity*). 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. Alkalinity and pH tell an operator with regards to coagulation how to determine the best chemical coagulant to be used. The definition of an acidic solution is a solution that contains a significant number of H+ ions. An operator should calibrate the instrument with a known buffer solution before using a pH meter. Rinse the electrodes with distilled water should be done with the electrodes after measuring the pH of a sample with a pH meter. pH Temperature and Chlorine dosage are the factors that influence the effectiveness of chlorination the most.
Phenols: This chemical does not cause turbidity in wastewater.
Phosphate: Does not react with chlorine before disinfection takes place.
Photosynthesis Process: Produces oxygen as a by-product.
Pneumatic Ejector Problem: If an operator has a pneumatic ejector pumping station that is operating properly but there is no flow being pumped, the inlet check sticking open could be the problem.
Polishing Ponds: Water will flow from one pond to the other when two polishing ponds are operating in a series.
Polyelectrolyte: A high molecular weight substance used as a sludge conditioner that is formed by either a natural or synthetic processes.
Pre-aeration: Will freshen wastewater and separates oil and grease from the waste stream.
Pre-Chlorination: The name of the process whereby chlorine is added to wastewater stream at the headworks.
Pretreatment: Vitally important to the operation of a sludge digester because without pretreatment, the digester could become filled with grit.
Primary Clarifier: During low flow periods, operational change may be necessary to maintain the proper detention time in a primary clarifier and keep the primary effluent fresh. One method is to take one or more of the clarifiers off line. The most probable cause if DO drops excessively across a primary clarifier is infrequent sludge pumping. When a primary clarifier is operating properly, the BOD and TSS will decrease through the clarifier.
Primary Clarifier Efficiency: The efficiency of the primary clarifier affects the efficiency of any other treatment processes that follows.
Primary Sedimentation Process: Settleable solids and floatable material is removed in the primary sedimentation process.
Primary Settling Tank: The wearing shoes on a primary settling tank prevent wear on the scraper cross pieces and metal track.
Primary Sludge: If primary sludge is added to an aerobic digester, more food will be available to the microorganisms and more oxygen will be required.
Progressive Cavity Pump: Is typically used for pumping liquid that contains a high concentration of solids. A progressive cavity pump should never be operated under dry or with a closed discharge valve. In a progressive cavity pump, the rotor is the only part that spins. The size of the cavity in which the rotor turns determines the capacity of a progressive pump.
Proper Detention Time: During low flow periods, taking one or more of the clarifiers off line may be necessary to maintain the proper detention time in a primary clarifier and keep the primary effluent fresh.
Pump 5,000 to 20,000 hours: The typical operating life of a mechanical seal.
Pump Discharge Valve Off: When a reciprocating pump or piston pump is not operated.
Pump: A key and a tight fit is the common method used to secure an impeller to the shaft on double-suction pump. A mechanical seal is the best seal to use for a pump operating under high suction head conditions. A possible cause of a scored shaft sleeve is that the packing has broken down or the packing is too tight or over tightened. A reciprocating pump or piston pump should not be operated with the discharge valve in the closed position. An air compressor generates heat during the compression cycle. What is the most common type of damage caused by heat generated during operation? The lubricating oil tends to break down quickly requiring frequent replacement. Cavitation is caused by a suction line that may be 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 must be provided on the suction piping to hold the prime. Continuous leakage from a mechanical seal on a pump indicates that the mechanical seal needs to be replaced. One disadvantage of a centrifugal pump is that it is not self-priming. The main

purpose of the wear rings in a centrifugal double suction pump is that they maintain a flow restriction between the impeller discharge and suction areas. The purpose of the foot valve on a pump is that it keeps the air relief opened. The viscosity decreases with most lubricants as the temperature increases. Two pumps of the same size can be operated alternately to equalize wear and distribute lubricant in bearings. A dial Indicator is used to check a coupling alignment.

Pump Priming: Venting the excess air is an essential aspect of priming a pump.

Raw sludge: Should be fed to an anaerobic digester when the solids content of sludge is < 3.5 %.

Reciprocating Pump: Intake closed; discharge open are the proper operation positions of check valves on a reciprocating pump during the discharge stroke.

Relative Compaction: Refers to the level of compaction obtained compared to the level possible under ideal conditions.

Safety: 2 Feet is the required distance from the edge of a hole that you must place the spoil from an excavation.

Safety: A supervisor should warn an operator about the presence of a confined space by clearly posting the appropriate signage at all entries to a confined space. Before beginning an excavation, An "Underground Service Alert" center should be contacted to assist in determining the location of all underground utilities in the work area. Corrosive-This type of chemical classification may weaken, burn, or destroy a person's skin or eyes and can be either acidic or basic. Ladders and climbing devices should be inspected by a qualified individual once a year. The correct order for placing shorting equipment in a trench is starting at the top, moving to the bottom of the trench; and reversing to remove it. Stand away from rotating shafts before startup to avoid injury on equipment with rotating parts.

Sand Filter: The purpose of having a continuous readout of turbidity in the effluent of a tertiary sand filter is to indicate the possible breakthrough of solids in the filter.

Saprophytic Bacteria: Produces the most acid in an anaerobic digester.

Scum Pipe: Allows the collected scum to flow from the skimmer box to the scum tank or a pump.

Secondary Treatment: The reason a wastewater treatment plant provides secondary treatment is to remove organic matter from wastewater.

Septic Sludge: A septic sludge in a primary clarifier may result in foul odors, bubbles of gas at the surface, and floating clumps of solids. Low DO is the cause of odor associated with septic sludge.

Septic Solids: When wastewater influent is not fresh but has been in the collection system for some time, septic solids which may produce gas and are difficult to settle may be observed in the primary clarifier.

Sewage: Untreated wastes from toilets, baths, sinks, lavatories, laundries, and other plumbing fixtures in place of human habitation, employment or recreation.

Single Phase Power: The type of power used for lighting systems, small motors, appliances, portable power tools and in homes.

Sludge Age: Denitrification is an indication of good treatment, providing that the sludge in the settleability test stays on the bottom. The sludge age should be reduced if sludge is floating up too early during a test.

Sludge Basins: After cleaning sludge basins and before returning the tanks into service, the tanks should be inspected, repaired if necessary, and disinfected.

Sludge: Decreasing sludge wasting may be necessary to accommodate colder operating temperatures in the winter months. Denitrification is an indication of good treatment, providing that the sludge in the settleability test stays on the bottom. What does sludge floating up too early in a test indicate? The sludge age should be reduced. Gases may be produced causing sludge to rise if sludge is septic and it is put in a gravity sludge thickener. 6 to 12 % percent solids of sludge should be dredged from a long term storage lagoon.

Sludge Conditioning: The preliminary step that is required when using dry chemicals for sludge conditioning is that the dry chemical should be weighed out and mixed with water.

Sludge Dewatering: The pH should be 11.5 to 12.0.when lime is mixed with sludge to improve dewatering.

Sludge for Root Crops: Dried sludge from a sand drying bed may not be used on root crops unless the sludge has been treated by heat drying at 790 degrees C.

Sludge: It might take at least 3 or more days before observing a change made for process control in an activated sludge package plant. If primary sludge is added to an aerobic digester, more food will be available to the microorganisms and more oxygen will be required. An increase in the belt speed will allow for greater volumes of water to drain from the sludge in a press. Sludge withdrawal from a clarifier should be conducted slowly to prevent the pumping of too much water. The complete oxidation of a sludge in sludge incineration depends on the ratio of fuel and air supplied to the incinerator. The dry chemical should be weighed out

and mixed with water when using dry chemicals for sludge conditioning. The pH should be 11.5 to 12.0 when lime is mixed with aerobic sludge for stabilization. The purpose of elutriation of sludge is to reduce the chemical conditioning of the sludge.
Sludge Incineration: The complete oxidation of a sludge in sludge incineration depends on the ratio of fuel and air supplied to the incinerator.
Sludge Press: Increasing the belt speed will allow for greater volumes of water to drain from the sludge in a press.
Sludge Rising: Increase sludge wasting to decrease MCRT; this may prevent sludge from floating to the surface of a secondary clarifier. Sludge that is rising to the top of the clarifier is a good indication that sludge is not being removed from the primary clarifier often enough.
Sludge Settling Problem: Dissolved oxygen levels are too high if, during a settling test the sludge settles in 15 minutes and rises to the surface in 30 minutes.
Sludge Thickener Problem: Gases may be produced causing sludge to rise if sludge is septic and it is put in a gravity sludge thickener.
Sludge to a Sand Drying Bed: An operator should remove sludge from a digester slowly when drawing the sludge to a sand drying bed because it prevents coning in the digester.
Sludge Volume: A thickening or dewatering process used prior to sludge transportation and storage affects the sludge in which way? It reduces the sludge volume to be handled.
Sludge Wasting: Decreasing sludge wasting may be necessary to accommodate colder operating temperatures in the winter months.
Sodium Hydroxide: NaOH.
Sodium Hypochlorite: NaOCL.
Specific Gravity: A vapor with a specific gravity greater than 1 is considered heavier than air.
Spectrophotometer: A spectrophotometer measures a selected wavelength transmitted or absorbed by a sample.
Spring and Fall: The typical periods of discharge from a stabilization pond.
Stabilization Pond: One method of controlling shoreline aquatic vegetation is by fluctuating the water surface in a stabilization pond. Fill the pond with at least one foot of clean water before a new stabilization pond is put into service. Sodium nitrate added to a stabilization pond improves the operation by increasing the dissolved oxygen concentration.
Standard Solution: A standard solution is a prepared chemical solution in which the exact chemical concentration is known.
Suction Bell on a Pump: Guides wastewater into pump's suction pipe and reduces pipe entrance energy losses.
Sulfate: Will dissolve in water to form an anion.
Sulfur Dioxide defer from Chlorine: In that Sulfur Dioxide cylinders are at lower pressures than Chlorine. A physical similarity is that they are both highly corrosive when mixed in water.
Sulfur Dioxide: Most commonly used for dechlorination in a large WWTP. Handle with care similar to that of chlorine.
Sulfuric Acid: H^2SO^4.
Sunrise: The time that the pH and dissolved oxygen concentration are the lowest in a pond.
Supernatant: An aeration system in an aerobic digester is shut off to decant or remove some clear supernatant. The sludge begins to rise to the surface within 60 minutes. The supernatant is now full of the floating sludge which may interfere with the activated sludge process. Install a below water surface draw off pipe for decanting; this is a logical solution to this problem. A single adjustable tube is typically used to read supernatant on a floating cover anaerobic digester.
Surface Loading: To a clarifier it is expressed as gallons per day per unit of surface area.
Surface Straining: Rapid head loss buildup is common to surface straining versus depth filtration.
Suspended Solids Test: Always shake or mix the sample is a necessary pretreatment step for the suspended solids test.
Telemetering: The use of a transmission line with remote signaling to monitor a pumping
Telemetry: Can be used to accomplish accurate and reliable remote monitoring and control over a long distribution system.
Temperature: This test should be performed immediately in the field.
Tertiary Sand Filter: The purpose of having a continuous readout of turbidity in the effluent of a tertiary sand filter is to indicate the possible breakthrough of solids in the filter.

Tertiary Treatment: The advance treatment of wastewater is sometimes used to remove nutrients.
Thermal Overload: Is the primary reason for most motor malfunctions.
Thermal Valve: Shut down of the flow of gas if subjected to a flame is the main purpose of a thermal valve on an anaerobic digester.
Thin Sludge: Will be going to the digester which causes it to perform poorly; could be caused by pumping too long or too often from a primary clarifier.
Thiothrix: Type of filament that can grow in the aeration basin of an activated sludge plant. Low DO levels is a possible cause to the growth of this long filament.
Three-Phase Motor Problem: A three-phase variable speed electric motor is examined during regular maintenance. What should you do if the brushes are coated with fine particles? The brushes should be carefully cleaned to remove these particles because they may cause sparking or flashover.
Total Dissolved Solids: When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried.
Total Solids: Wastewater is primarily composed of dissolved solids and suspended solids.
Trickling Filter Process: The main purpose of recirculation in a trickling filter process to increase the contact time of the BOD and microorganisms. Controls flow to the filter media best describes the purpose of the outlet orifice of a trickling filter.
Turbidity Meter: Can be used to analyze and record the clarity of the filter influent and effluent flows.
Underdrain System: The underdrain system on a blacktop or concrete drying bed is closed while the bed fills with sludge. After the sludge has risen to the top due to gasification, the drainage system should be opened to allow the clear water to be returned to the head. To provide adequate ventilation to the filter media is another function of an underdrain system in a tricking filter.
Vectors: Birds, rodents, and flies may carry disease from sludge.
Venturi Meter: Can be used for measuring the flow of wastewater through a pipe.
Volatile Acid Concentration: Will be observed first following an upset of the anaerobic digestion process.
Volatile Liquids: Should be stored segregated by incompatible chemicals, away from heat sources and clearly labeled and dated.
Volute: Remove the wastewater from the volute if a pump is off for an extended period. Draining the volute is the most important task when isolating a pump from service.
Warm Temperatures: This condition will have the greatest positive effect upon the operation of a stabilization pond.
Wastewater Treatment Efficiency: A composite sample is the preferred method to calculate the efficiency of a wastewater treatment process.

Grade 1 and 2 Wastewater Treatment Practice Exam

***Answers in rear*.**

1. Which of the following is a Composite Sample? SAC-WW-V2 sec. 16.33
A. Samples taken throughout the day at intervals of time
B. A single sample taken at a set time
C. A freebie at the store
D. A sample that the operator deposits
E. None of the above

2. What is the purpose of a Secchi Disc? SAC-WW-V2 sec. 16.4
A. For measuring the clarity of water
B. Marking sludge levels
C. A new disc to replace CD's
D. Analyze solids

3. Which chemical would NOT be used to control Hydrogen Sulfides?
SAC-WW-V2 sec. 16.411
A. Chlorine
B. Oxygen
C. Methane
D. Hydrogen peroxide

4. When preparing to filter TSS, which of the following is a pretreatment step?
SAC-WW-V2 sec. 16.43
A. Shake or mix the sample
B. Acidify the sample
C. Dechlorinate the sample
D. Adjust the pH of the sample

5. When performing a volatile solids test on the sludge, what is the test measuring?
SAC-WW-V2 sec. 16.44
A. The amount of inorganic material
B. The amount of gasoline or oil in the sample
C. The amount of organic material
D. The amount of nitrogen in the sample

6. Grouping measurements and describing the result in a single number is known as:
SAC-WW-V2 sec. 18.3
A. Average and means
B. Gage readings
C. Time intervals
D. None of the above

7. A device that continuously measures and calculates totals are called:
SAC-WW-V2 sec. 18.4
A. Manometer
B. Gage
C. Totalizer
D. Ranger

8. What is MPN? SAC-WW-V2 sec. 18.6
A. Mixed Portion Number
B. Most Probable Number
C. My Personal Number
D. Means Probable Numbers

9. Which analysis requires a grab sample? SAC-WW-V2 sec. 16.33
A. pH, DO,
B. Temperature
C. All of the above
D. None of the above
E. SS

10. How should volatile liquids be stored? SAC-WW-V2 sec. 16.220
A. Segregated by incompatible chemicals
B. Away from heat sources and clearly labeled and dated
C. Both A and B
D. Under an open flame
A. None of the above

11. What is the most common measuring device found at the headworks of a wastewater treatment plant? SAC-WW-V1 sec. 3.4
A. MAG meter
B. Parshall flume
C. Venturi meter
D. Weir

12. _______________ meters are commonly found in untreated wastewater pipelines. SAC-WW-V1 sec. 3.4
B. Venturi
C. Weir
D. Flume
E. Displacement

13. In most treatment plants, the sedimentation and flotation units are found _________ the activated sludge process. SAC-WW-V1 sec. 5.0
A. After
B. Before
C. None of the above

14. Wearing shoes are usually a flat metal plate attached to the end of a wooden flight. Which structure would these shoes be found in? SAC-WW-V1 sec. 5.10
A. Grit chamber
B. Aeration tank
C. Mechanical bar screen
D. Circular clarifier
E. Rectangular clarifier

15. Which of the following would not be an abnormal condition for the performance of a clarifier? SAC-WW-V1 sec. 5.14
A. Sludge blankets
B. Toxic waste
C. Storm flows and hydraulic overloads
D. Septicity from collection system problems

16. Which sampling method is preferred to calculate the efficiency of a wastewater treatment process? SAC-WW-V1-sec. 5.22
A. Composite samples
B. Grab samples
C. DO samples
D. Temperature
E. ORP test

17. When determining the efficiency of a clarifier rate of flow as compared to design flow, this would be called the: SAC-WW-V1 sec. 5.23
A. Hydraulic loading
B. Shock loading
C. Total dynamic flow
D. Normal operating condition

18. Trickling filters provide a media with a large surface area which biological growth develops. This slime growth is sometimes called: SAC-WW-V1 sec. 6.01
A. Shigellosis
B. Cholera film
C. Zoogleal film
D. Prussian Blue

19. Which statement best describes the purpose of the outlet orifice of a trickling filter? SAC-WW-V1 sec. 6.01
A. Controls flow to filter media
B. Provides a large surface area for slim growth
C. Drains distributor arm and controls filter flies along filter retaining wall
D. Regulates speed of distributor arm
E. All of the above

20. What term best represents an aerobic process in which bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen. SAC-WW-V1 sec. 7.0
A. Biodegradable
B. Anaerobic digestion
C. Nitrification
D. None of the above

21. Why would solar heat be used for a RBC unit? SAC-WW-V1 sec. 7.121
A. Solar power is used to keep cost down
B. Solar power increases the DO levels
C. When temperatures are below 55°F, the sun warms the room without drying the bugs out
D. All of the above

22. Organisms that grow in a thread form commonly cause sludge bulking in the activated sludge process. These bugs are called: SAC-WW-V1 sec. 8.02
A. Facultative bacteria
B. Biological sloth
C. Agglomeration
D. Filamentous organism
E. Silk worms

23. ____________ is caused when storm sewers and ground water flow out of the sewer lines. SAC-WW-V1 sec. 3.10
A. Infiltration
B. Allocation
C. Subsidence
D. Exfiltration

24. The principle purpose of wastewater pretreatment is: SAC-WW-V1 sec. 3.3
A. The removal of coarse material from the wastewater
B. The reduction of organic material from the wastewater
C. The reduction of suspended solids from the wastewater
D. The reduction of energy usage in wastewater plants

25. A non-automated bar screen is typically cleaned by: SAC-WW-V1 sec. 3.31
A. Conveyor belt
B. Fluctuations in the daily flow
C. Hand raking
D. Use of a hand grinder

26. Wastewater pretreatment components are typically found: SAC-WW-V1 sec. 3.4
A. In the collection system
B. Immediately before tertiary treatment
C. After primary treatment
D. At the plants headwork

27. Grit is removed from wastewater early in the treatment process to: SAC-WW-V1 sec. 3.33
A. Protect pumps and other equipment
B. Prevent synergistic affects in the plant
C. Trap inorganic solvents before the biological treatment
D. Facilitate the suspension of organic materials

28. The colloidal solids which appear in wastewater are removed by which type of treatment? SAC-WW-V1 sec. 3.2
A. Biological treatment
B. Physical treatment
C. Sedimentation
D. Clarifier skimming devices
E. All of the above

29. Process control samples to determine the efficiency of treatment in the primary clarifier should be: SAC-WW-V1 sec. 5.22
A. Grab samples of the effluent from the clarifier
B. Grab samples of the influent and effluent from the clarifier
C. Composite samples of the clarifier effluent
D. Composite samples of the clarifier influent and effluent

30. Which problem could be caused by pumping too long or too often from a primary clarifier: SAC-WW-V1 sec. 5.3
A. Thin sludge will be going to digester which causes it to perform poorly
B. Short circuiting which results in excess solids loss over the weirs
C. Hydraulics overloading of sludge pumps
D. Proteinaceous

31. When the primary clarifier is operating properly, which of the following will happen? SAC-WW-V1 sec. 5.23
A. The pH will drop or lower through the clarifier
B. The pH will rise through the clarifier
C. The BOD and TSS will be raised through the clarifier
D. The BOD and TSS will be lowered through the clarifier

32. A rectangular clarifier has been empty for a period of time. Before starting the skimming mechanism the operator should: SAC-WW-V1 sec. 5.10
A. Lift each flight off the rail to make sure not rusted and apply proper lubricate
B. Tighten the chain links as tight as possible
C. Start the motor and skimmer under a no load situation
D. Make sure the clarifier is full of water to prevent skimmer damage
E. First call OSHA

33. What is the purpose of an effluent ________? SAC-WW-V1 sec. Table 5.2
A. Flume, To prevent sludge accumulation
B. Weir, Ensures equal flow over all weirs
C. Weir, To direct flow through the scum channel
D. Stilling Well, Transports the wastewater to the clarifier

34. What is the purpose of the scum pipe? SAC-WW-V1 sec. Table 5.2
A. Allows the collected scum to flow from the skimmer box to the scum tank or a pump
B. Scrapes sludge before withdrawal
C. Transports bad people to jail
D. Receives the scum from the skimming arm
E. None of the above

35. A good indication that the sludge is not being removed from the primary clarifier often enough is: SAC-WW-V1 sec. 5.3
A. The sludge blanket is low
B. Sludge rising to the top of the clarifier
C. Pump discharge has excess water
D. Scum collection area becomes full
E. The Supervisor is complaining

36. The purpose of a scum baffle in a rectangular primary settling basin is to: SAC-WW-V1 sec. Table 5.1

A. Deflect the wind across the basin
B. Prevent the floating materials from reaching the effluent trough
C. Hold the side walls of the tank at a fixed distance
D. Maintain proper water levels in the basin

37. A rectangular primary settling basin has many moving components. Which of the following prevents wear on the scraper crosspieces? SAC-WW-V1 sec. Table 5.1

A. Wearing shoes
B. Angle track
C. Rubber gaskets
D. Low sludge blanket

38. Which step could be taken to improve clarifier effluent quality when excessive storm flow infiltration is a frequent problem? SAC-WW-V1 sec. 5.14

A. Seal sanitary sewers and/or the use of a equalization basin
B. Add aeration
C. Add large quantities of chlorine
D. Slow re-circulation

39. Which of the following explains the differences between a primary and secondary clarifier? SAC-WW-V1 sec. 5.0

A. Primary clarifiers do not have surface skimmers
B. Sludge remains in the primary clarifier for months while secondary clarifiers only hours
C. Basically the operations and components are the same
D. The shapes of the clarifiers must be different

40. If the sludge age in a clarifier is too old, what will happen? WW-V1 sec. 5.23

A. Turbidity will decrease in the effluent
B. Sludge may become septic
C. SS from aeration tank will decrease
D. Return activated sludge will have high oxygen demand

41. The underdrain system of a trickling filter supports: SAC-WW-V1 sec. 6.01

A. Distributor arm
B. Media and ventilation
C. Center well
D. Underdrain channel

42. What is the main purpose of re-circulation in a trickling filter process? SAC-WW-V1 sec. 6.02

A. To increase influent TSS concentration
B. To increase the contact time of the BOD and microorganisms
C. To prevent the leakage of water from the shaft seal
D. To increase the filtering period of the wastewater
E. To make precipitate

43. Standard-rate trickling filter growth usually sloughs off at which intervals: SAC-WW-V1 sec. 6.11
A. Summer and winter
B. Spring and fall
C. Morning and night
D. None of the above

44. The trickling filter process is experiencing a minor ponding problem on parts of the surface media. Which of the following corrective actions should be tried to ensure the quality of the effluent is not drastically changed? SAC-WW-V1 sec. 6.410
A. Chlorinate the surface with a 50 mg/L dosage
B. Force a high volume of air through the underdrain system
C. Spray a masking agent over the surface to help with odors
D. Increase the re-circulation rate over the surface

45. ____________ may be used to control the filter fly in trickling filters. What chlorine residual is recommended for filter fly control? SAC-WW-V1 sec. 6.412
A. Chlorine, 1 mg/L
B. Bromine, 200 mg/L
C. Halogen, 0.1 mg/L
D. Chlorine, 500 mg/L

46. What is the main purpose of re-circulation in a trickling filter process? SAC-WW-V1 sec. 6.02
A. To increase the contact time of BOD and microorganisms
B. To increase the filtering period of the wastewater
C. To prevent the leakage of water from the underdrain
D. To increase influent TSS concentration
E. None of the above

47. Biological contactors use stages to maximize the effectiveness of a given amount of media surface. What is the benefit of this design? SAC-WW-V1 sec. 7.0
A. As BOD decreases, Nitrification starts
B. Increases the TSS and increases Nitrification
C. Handles lower BOD
D. None of the above

48. In a rotating biological contactor, what controls flow from one stage to the next stage or from one bay to the next bay? SAC-WW-V1 sec. Table 7.1
A. Rotating media
B. Drive assembly
C. Underdrains
D. Orifice or weir located in the baffle

49. What rotates the media in an air-driven rotating biological contactor (RBC) ? SAC-WW-V1 figure 7.8
A. Air pressure
B. Air cups
C. Air velocity
D. Diffuser head setting

50. Which of the following samples are NOT suggested for monitoring rotating biological contactor treatment? SAC-WW-V1 sec. 7.121
A. NTU
B. BOD
C. DO
D. pH

51. Considering the layout and flow diagram for the complete treatment plant, most oxidation ditch plants would be most similar to which of the following: SAC-WW-V1 sec 8.300
A. Completely mixed activated sludge
B. Extended aeration
C. Conventional activated sludge
D. Contact stabilization

52. Settled activated sludge is generally________ than raw sludge.
SAC-WW-V1 sec. 8.02
A. Thinner
B. Thicker
C. Denser
D. No difference

53. Control of sludge wasting requires a certain concentration of food microorganisms' ratio. Which of the following measurements are needed to determine F/M?
SAC-WW-V1 sec. 8.01
A. SS detention time
B. VSS in the return sludge
C. BOD
D. pH

54. The operator is taking a settling test on a package activated sludge plant and notices that the sludge settles in 15 minutes and rises to the surface in 30 minutes. This indicates:
SAC-WW-V1 sec. 8.26
A. Dissolved oxygen levels are too high
B. Solids levels in the aeration tank are to slow
C. Coliform levels are too high in the aeration tank
D. The plant is in good operation

55. An activated sludge package plant is designed without sludge wasting facilities. Which procedure could be used if it is necessary for the plant to waste excess sludge?
SAC-WW-V1 sec. 8.24
A. Pump from the settled sludge in the clarifier to a sand drying bed
B. Pump excess solids to the receiving stream
C. Allow the sludge to billow over the clarifier weirs during sampling
D. Chlorinate the effluent heavily during periods of bulking or billowing

56. What is the standard DO level needed during start-up of activated sludge in an oxidation ditch? SAC-WW-V1 sec. 8.321
A. At least 2.0 mg/L
B. >.1 to <.5 mg/L
C. >.5 to <1.0 mg/L
D. <.1 mg/L

57. Which of the following is true about extended aeration plants? WW-V1 sec. 8.201
A. They have high organic loading rates
B. They produce no sludge
C. They do not produce as much waste sludge as other process
D. They have short aeration detention time

58. Typically controlled discharge or storage stabilization ponds, periods of discharge are: SAC-WW-V1 sec. 9.2
A. Spring and summer
B. Spring and fall
C. Fall and summer
D. Summer and winter

59. During which time would hydrogen sulfide odor cause problems in a stabilization pond? SAC-WW-V1 sec. 9.3
A. Winter
B. Summer
C. Daylight hours
D. At noon due to high flow rates entering the plant

60. What does algae in a facultative stabilization pond need to convert carbon dioxide to oxygen? SAC-WW-V1 sec. 9.3
A. Methane gas
B. Nitrates
C. Ammonia
D. Sunlight

61. The addition of chlorine, acid, carbon dioxide, or sulfuric acid will________ the pH of the wastewater. SAC-WW-V1 sec. 9.3
A. Neutralize
B. Increase
C. Have no effect on
D. Lower

62. Which of the following is necessary before startup of a stabilization pond? SAC-WW-V1 sec. 9.5
A. Spray the floor with a herbicide to prevent weed growth
B. Allow only wastewater to fill the pond
C. Mix a clay dirt mixture into the influent flow to seal the floor
D. Fill the pond with at least one foot of clean water
E. NPDES permit

63. What is the minimum depth of water needed to control weed growth in a stabilization pond? SAC-WW-V1 sec. 9.62
A. 1 foot
B. 2 feet
C. 3 feet
D. 5 feet
E. 10 feet

64. All of the following methods are effective in algae removal in a stabilization pond <u>except:</u> SAC-WW-V1 sec. 9.65
A. Overturn the pond
B. Air flotation
C. Micro screening
D. Slow sand filtration

65. Which of the following best describe pathogens? SAC-WW-V1 sec.10.00
A. Pathogens obtain their food supply without help
B. Bacteria that are not found in water
C. Bacteria, viruses and parasites that cause disease
D. Pathogens are not harmful to humans

66. Chlorine is added to the effluent before the contact chamber for complete mixing. What is the reason for not adding it directly to the chamber? SAC-WW-V1 sec. 10.232
A. Removes the excess chlorine immediately after the solution enters the chamber
B. It has very little mixing due to low velocities
C. Is designed to have a high flow velocity
D. Is covered and sunlight is needed to activate the chlorine

67. Which of the following materials <u>is not</u> part of the motor brush composition? SAC-WW-V2 sec. 15.170
A. Carbon graphite
B. Copper
C. Metal graphite
D. Graphite
E. None of the above

68. Chloramines are? SAC-WW-V1 sec. 10.031
A. Enzymes
B. Combined chlorine and ammonia
C. Found in polluted air
D. Free chlorine

69. Which one of the following does not react with chlorine before disinfection takes place? SAC-WW-V1 sec. 10.02
A. Phosphate
B. Phenols
C. Hydrogen sulfide
D. Organic matter

70. Which of the following is a recommended type of pipe used for chlorine solution lines? SAC-WW-V1 sec. 10.230
A. Iron or galvanized
B. PVC schedule 40
C. PVC schedule 80
D. Copper
E. Pre-coat

71. Which one of the following are NOT normal conditions for a gas chlorination Start-up? SAC-WW-VI sec. 10.250

A. Open chlorine metering orifice slightly
B. Inspect vacuum lines
C. Start injector water supply
D. Chlorine gas valve open at the chlorinator

72. The part of the chlorine cylinder designed to melt at 158 to 165°F to prevent the cylinder from exploding in the event of fire is the? SAC-WW-V1 sec. 10.400

A. Fusible plug
B. Needle valve seat
C. Tank
D. Injector

73. A chlorine leak can be detected by: SAC-WW-V1 sec. 10.42

A. Ammonia solution vapor
B. By smell
C. Checking the leak gauge
D. Spraying water on suspected leak

74. Failure of the chlorine solution pumps would result in: SAC-WW-V1 sec. 10.06

A. Higher effluent fecal coliform count
B. A decrease in digester gas production
C. No change in effluent fecal coliform count
D. Lower effluent fecal coliform count

75. An amperometric titration is used to measure: SAC-WW-V1 sec. 10.205

A. Chlorine residual
B. Alkalinity
C. Conductivity
D. COD

76. When shutting down a gas chlorinator system, which valve should be closed first on the system? SAC-WW-V1 sec. 10.270

A. The chlorine container gas outlet valve
B. The pressure regulator valve
C. The pressure relief/vacuum valve
D. The rotameter or needle valve
E. The water line

77. Estimate the velocity of wastewater flowing through a grit channel if a stick travels 32 feet in 36 seconds. SAC-WW-V1 sec. A.131 Example 2

A. 1.125 ft/sec
B. 1152 ft/sec
C. .89 ft/sec
D. 15 ft/sec

78. A circular secondary clarifier handles a flow of o.9 MGD and suspended solids of 3600 mg/L. The clarifier is 50 feet in diameter and 8 feet deep. Find the surface-loading rate. SAC-WW-V1 sec. A. 132 Example 5

A. 500 gpd/sq. ft
B. 400 gpd/sq. ft
C. 459 gpd/sq. ft
D. 363 gpd/sq. ft

79. A flow of 1.1 MGD is applied to a 50 feet in diameter and 4 feet deep trickling filter. The BOD of the wastewater is 120 mg/L. Calculate the hydraulic loading on the filter. SAC-WW-V1 sec. A. 133 Example 8

A. 561 gpd/sq. ft
B. 542 gpd/sq. ft
C. 571 gpd/sq. ft
D. 556 gpd/sq. ft

80. Determine the chlorine demand of an effluent if the chlorine residual is 1.1 mg/L and the chlorine dose is 10.0 mg/L. SAC-WW-V1 sec. A. 137 Example 21

A. 8.9 mg/L
B. 9.1 mg/L
C. 9.4 mg/L
D. 9.6 mg/L

81. Operators perform jobs that require specialized safety equipment and procedures in case of an emergency. How can a facility insure proper use? SAC-WW-V2 sec. 14.84

A. Give each operator a training manual to study
B. Perform hands-on training courses with the safety equipment used during emergencies
C. Demonstrate an emergency through pictures and slides
D. Fire any operator who performs tasks in a dangerous manner
E. Supervisor keeps a chart

82. When working around anaerobic digesters the operators must be aware of hydrogen sulfide gas. Why must the air be tested for hydrogen sulfide gas rather than relying on the sense of smell? SAC-WW-V2 sec. 14.223

A. Hydrogen sulfide gas will dull the sense of smell at low concentrations
B. Hydrogen sulfide can sensed only at high concentrations
C. Hydrogen sulfide cannot be detected by the sense of smell
D. Hydrogen sulfide is lighter than air and is near the ceiling
E. None of the above

83. What is the maximum noise level (decibels dBA) operators can be exposed to for an eight-hour period? SAC-WW-V2 sec. 14.191

A. 25 dBA
B. 85 dBA
C. 95 dBA
D. 105 dBA

84. When painting inside of a steel tank with a new bitumastic or asphaltic coating for corrosion, besides air what would another safety concern be? SAC-WW-V2 sec. 14.228

A. Vapors will react with skin to produce burns
B. Production of high oxygen atmosphere
C. Coating will react with steel and produce methane gas
D. Carbon monoxide is a by-product of the coating

85. Laboratory chemicals can be deadly and should have markings to show it. What other information should clearly printed on the containers? SAC-WW-V2 sec. 14.31

A. Approved warning labels
B. Return address of the manufacture
C. Telephone number of the local poison control center
D. The date of purchase

86. Which of the following pumps are known as propeller pumps? WW-V2 sec. 15.111

A. Incline screw pump
B. Axial-flow
C. Centrifugal pump
D. Reciprocating

87. Why would it be more of an advantage to use pneumatic ejectors in place of centrifugal pumps when handling limited flows? SAC-WW-V2 sec. 15.111

A. Pneumatic ejectors are highly efficient for pumping large flows
B. Centrifugal pumps need more attention
C. Because of Y2K concerns
D. At lower flows centrifugal pumps tend to plug easily do to small impellers

88. In a progressive cavity pump, which of the following parts spin?
SAC-WW-V2 sec. Figure 15.12

A. The stator
B. The rotor
C. The mounting
D. The inlet

89. When properly maintained bearings can last for years. What can cause a bearing to fail? SAC-WW-V2 sec. 15.122
A. Lubricating properly
B. Fatigue failure
C. Too much rotation
D. Too large of bearings
E. Operator 2

90. What is the purpose of a suction gauge for a wet well? SAC-WW-V2 table 15.3
A. Indicates discharge head
B. Directs flow
C. Indicates trapped gases in the line
D. Indicates suction head or lift

91. A _________ culture is a biological process which appears to be effective in removing algae from effluents and fairly easy to operate and maintain if the proper environmental conditions can be developed. SAC-WW-V1 sec. 9.11
A. Fecal
B. Hyacinth
C. Protozoa
D. Liquefaction

92. Why are shear pins used? SAC-WW-V2 Chapter 15 paragraph 12
A. To help operator record work completed
B. To prevent damage under sudden overload
C. To make sure equipment runs when overloaded
D. To hold flanges in place
E. Because hair pins are hard to find at the sewer plant

93. When sludge lines become plugged, which of the following would NOT be used to remove scum? SAC-WW-V2 sec. 15.32
A. A pig
B. Rod or high pressure
C. Pumped grit
D. Warm digested sludge

94. Mechanical seals are used in place of packing for what reason?
SAC-WW-V2 sec. 15.121
A. Mechanical seals eliminates undesirable leakage
B. Mechanical seals handles all shaft misalignment
C. Packing can be more expensive
D. Packing causes direct damage to shaft
E. All of the above

95. A progressive cavity pump is typically used for: SAC-WW-V2 sec. 15.115
A. Pumping chemical feeds
B. Very small applications such as lab equipment
C. Moving large volumes of wastewater
D. Pumping liquids high in solids

96. What is the proper operating positions of check valves on a reciprocating pump when in discharge stroke? SAC-WW-V2 sec. 15.113

A. Intake closed; discharge open
B. Intake open; discharge closed
C. Intake open; discharge open
D. Intake closed; discharge closed
E. In through the out door

97. An imaginary line running along the center of the shaft is called:
SAC-WW-V2 sec. 15.111

A. Axial to Impeller
B. Axis to Impeller
C. Radial to Impeller
D. Stator

98. A vertical centrifugal pump with two impellers are known as:
SAC-WW-V2 sec. 15.112

A. Multi-stage pumps
B. Compound pumps
C. Auxiliary pumps
D. Double suction pumps

99. Liquids that vaporize or evaporate at room temperature are known as:
SAC-WW-V2 sec. 16.220

A. Volatile liquids
B. Volatile odors
C. Volatile acids
D. Volatile solids

100. When reading a liquid measurement in a glass burette, the operator should:
SAC-WW-V2 sec. 16.43

A. Read the liquid at the top of the curve line in the burette
B. Read the liquid at the middle of the curve line in the burette
C. Ask somebody to read it for you
D. Read the liquid at the bottom level of the curve line in the burette

Grade 3 and 4 Practice Exam *Answers in rear.*

1. To control the pressure during filter backwash, most system have:
SAC-WW-V3 sec. 4.21
A. Rate control valve which slowly opens
B. Pressure regulator on backwash pump
C. By-pass valving
D. Variable frequency drives (VFD's) on pumps
E. None of the above

2. Solids breakthrough in a tertiary filter happens when:
SAC-WW-V3 sec. 4.23
A. Solids pass through the media into the clearwell
B. Solids blind the sand bed of the filter
C. When mud balls float
D. Excessive backwashing

3. Which of the following disadvantages is common to surface straining versus depth filtration?
SAC-WW-V3 sec. 4.241
A. Media contamination
B. Breakthrough of TSS
C. Rapid head loss buildup
D. Fecal coliform buildup

4. A depth filter media provides a slower buildup of head loss in the filter but this does allow for quicker: SAC-WW-V3 sec. 4.242
A. Breakthrough of the solids
B. Anaerobic conditions to be produced
C. Lowering of the pH in the effluent
D. Backwash cycles
E. All of the above

5. A typical set point to start backwashing is at_____ of head loss.
SAC-WW-V3 sec. 4.2811
A. 4 feet
B. 5 feet
C. 7 feet
D. 10 feet

6. What lab test is used to simulate a tertiary plant operation?
SAC-WW-V3 sec. 4.282
A. Jar test
B. COD
C. TOC
D. NTU

7. Which of the following metering devices can be used to analyze and record the clarity of the filter influent and effluent flows? SAC-WW-V3 sec. 4.411
A. DO
B. TSS
C. NTU Meter
D. Parshall flume
E. None of the above

8. Complete oxidation of the sludge in sludge incineration depends on:
SAC-WW-V3 sec. 3.5315
A. The sludge feed rate
B. The ratio of fuel and air supplied to the incinerator
C. Detention time in the incinerator
D. Complete mixing
E. None of the above

9. Ponding can occur at sites where wastewater effluent is being irrigated. Which of the following is NOT a reason that ponding occurs? SAC-WW-V3 sec. 8.11
A. Excessive application rate
B. A broken pipe in the irrigation line
C. Clogging of distribution line with solids
D. Inadequate drainage
E. None of the above

10. Land treatment systems which have a point source effluent are known as:
SAC-WW-V3 sec. 8.60
A. Irrigation systems
B. Water recycling systems
C. Overland flow systems
D. Infiltration / percolation
E. None of the above

11. The pH of wastewater is an important condition. Hydrogen sulfide is extremely pH dependent. Which state is sulfide in at an ionic form? SAC-WW-V3 sec. 1.12
A. Gaseous
B. Solution
C. Solid
D. Pure form

12. Sulfide can exist in wastewater in three forms depending on the pH: S^{2-} ion, HS^- ion, or H2S gas. At the ideal temperature, what sulfide would form at a pH of 14?
SAC-WW-V3 sec. 1.12
A. S^{2-} ion, 90%
B. HS^- ion, 100%
C. H2S gas, 100%
D. H2S, 50% and HS^-, 50%

13. The presence or absence of oxygen establishes whether hydrogen sulfide will exist. If more than 1.0 mg/l of oxygen is present what will happen to anaerobic bacteria?
SAC-WW-V3 sec. 1.12
A. It will become soluble BOD
B. It will oxidize to thiosulfate
C. It will produce higher levels of sulfide
D. Hydrogen sulfide will not exist

14. The reaction of ammonia with chlorine is which of the following?
SAC-WW-V3 sec. 1.40
A. $NH_3 + Cl_2 = NH_2Cl + CHl$
B. $NH_2Cl + Cl_2 = NHCl_2 + HCl$
C. $NHCl_2 + Cl_2 = NCl_3 + HCl$
D. Monochloramine, NH_2Cl
E. All of the above

15. For a number of years, hydrogen peroxide has been used as an oxidant to control odors. What are the disadvantages of using hydrogen peroxide? SAC-WW-V3 sec. 1.401
A. Inability to treat ammonia
B. BOD
C. Inhibits the regeneration of sulfate reducing microorganisms
D. Lack of toxic by-products
E. None of the above

16. The pH of a production facility's wastewater may vary from 2.5 to 13.0 depending on the product being processed. It may be necessary to neutralize the pH to achieve a neutral. What chemical could be added if the pH is at a 2.5 to make it neutral?
SAC-WW-V3 sec. 2.52
A. Caustic
B. Sulfide
C. DO
D. Sodium bicarbonate

17. COD is an alternative to BOD for measuring the pollution strength of wastewater. Bearing in mind that the BOD and COD tests involve separate and distinct reactions, what is the primary disadvantage of the COD test? SAC-WW-V3 sec. 2.52
A. Chloride may interfere with the chemical reaction
B. It measures the presence of carbon and hydrogen
C. It takes 5 days to get results
D. None of the above

18. This chemical has been used like chlorine to control odors. This chemical reacts with other substances very similar to chlorine. SAC-WW-V3 sec. 1.40
A. Phenol
B. Hydrogen Peroxide
C. Sodium hypochlorite
D. Chromate
E. Nitrate

19. Gravity thickening of wastewater sludges uses gravity forces to separate solids from the sludge being treated. Secondary sludges are not well suited for gravity thickening because it contains: SAC-WW-V3 sec. 3.110
A. Bound water
B. High alkalinity
C. Low pH
D. Dissolved oxygen

20. If a primary sludge is allowed to go septic, which of the following gases are produced? SAC-WW-V3 sec. 3.110
A. H_2S and CO_2
B. CH_4
C. A & B
D. Ozone
E. Gasoline type flumes

21. Which of the following is NOT a recommendation to prevent odors in a trickling filter? SAC-WW-V1 sec. 6.411
A. Maintain aerobic conditions in the sewer system
B. Use of masking agents
C. Increase of BOD loading
D. Check and clear filter ventilation
E. All of the above

22. Which of the following solutions will help prevent trickling filters from freezing? SAC-WW-V1 sec. Table 6.2
A. Decrease recirculation
B. Parallel operations
C. Reduce nozzles spray
D. All of the above

23. Excessive sloughing or biological growth on a trickling filter is an indication of: SAC-WW-V1 sec. 6 troubleshooting guide
A. Ice buildup on filter media
B. Increase in secondary clarifier effluent suspended solids
C. Uneven distribution of flow
D. Filter ponding
E. All of the above

24. The high-rate trickling filter is fed at 2,100 GPM and the filter diameter is 100 feet. What is the hydraulic loading of this filter per day? SAC-WW-V1 sec. 6.71
A. 385 GPD/sq. ft
B. 385 GDP/cu ft
C. 7850 GPD/sq. ft
D. 3 MGD/cu ft
*Show math work and learn to convert answer in to metric terms***.**

25. Development of white biomass over most of a Rotating Biological Contactor (RBC) disc area could be resolved by: SAC-WW-V1 table 7.2
A. Decrease the treatment influent flow
B. Increase the chlorination in the first stage
C. Adjust baffles between first and second stages to increase total surface area in first stage
D. None of the above

26. If the motor bearings on a RBC are running above 200°F, which of the following corrective action could be taken.SAC-WW-V1 table 7.232
A. Lubricate bearings per manufacturer's instruction
B. Check torque and alignment of bearings
C. Make sure shaft is properly aligned.
D. All of the above
E. None of the above

27. When making changes to correct a problem in an activated sludge package plant, how long might it take before the correction shows? SAC-WW-V1 sec. 8.252
A. At least 3 or more days
B. 24 hours
C. 3 hours
D. Depends on the basin detention time

28. Changing conditions or abnormal conditions can upset the microorganisms in the activated sludge process. If the sludge is not settling in the clarifier **(sludge bulking)** what could the possible reason be? SAC-WW-V1 sec. 8.252
A. Low DO concentration
B. High rate of aeration
C. Clarifier flow to high
D. Hydraulic overload is too high
E. All of the above

29. Some aeration tubing systems require cleaning on a weekly basis with:
SAC-WW-V1 sec. 9.7
A. Chlorine
B. Sodium hydroxide
C. Anhydrous ammonia
D. Anhydrous hydrogen chloride
E. All of the above

30. Which of the following lab samples is taken daily from the effluent of a pond?
SAC-WW-V1 table 9.3
A. Chlorine residual
B. Coliform group
C. Dissolved oxygen
D. pH

31. WWTP's may be required to provide chlorination services for: WW-V1 sec. 10.28
A. Disinfection of effluent
B. Process control of activated sludge
C. Season odor control
D. All of the above

32. According to the Sacramento Manual, what is the required chlorine residual of the outlet chlorine contact basin? SAC-WW-V1 sec. 10.28
A. 4.5 mg/L
B. 3 mg/L
C. 2.5 mg/L
D. 1 mg/L

33. During the night shift, the operator notes that the chlorine residual analyzer recorder controller does not maintain the chlorine residual properly. What recommendation would you give to correct this problem? SAC-WW-V1 Table 10.1
A. Explain that flow fluctuations is the cause
B. Assign the operator to inspect electrodes and if fouled, clean them
C. The operator should know that increased DO oxidizes the residual
D. Ammonia is interfering and this is a common problem

34. A regular program of scheduled preventive maintenance is essential to keep the chlorinator functioning properly. If the operator notices that the chlorinator will not feed chlorine, the operator should: SAC-WW-V1 Table 10.1
A. Check the chlorine supply gages
B. Check the evaporation unit
C. Check the injector line
D. None of the above

35. During your inspection of the chlorine feed system, you find that there is no chlorine gas pressure at the chlorinator. The chlorine cylinder is full but you find that the chlorine pressure is high up stream. What is the probable cause? SAC-WW-V1 table 10.1
A. Inadequate injector vacuum
B. Plugged or damaged pressure-reducing valve
C. Supply valve is closed
D. Injector diaphragm ruptured

36. The operator determines that the Coliform count fails to meet required standards for Disinfection. The operator checks the contact time and finds that short-circuiting has occurred in the contact chamber. What measures should be taken to correct this problem?
SAC-WW-V1 table 10.1
A. Adjust injector flow
B. Install baffling in the contact chamber
C. Reduce the chlorine feed rate
D. This is normal and will correct in time
E. All of the above

37. Procedures and equipment for operating and maintaining chlorination and sulfonation systems are very similar. However, there is a difference. Which of the following statements is true how sulfur dioxide differs from chlorine? SAC-WW-V1 sec. 10.875
A. Sulfur dioxide containers are a lower pressure than chlorine gas pressure
B. Chlorinator control valve diaphragms can be used for sulfur dioxide
C. Sulfur dioxide has no health effects and is not dangerous
D. Sulfur dioxide vaporizes at the same rate as chlorine
E. All of the above

38. Maintenance of the sulfur dioxide system should be part of a preventive maintenance program. It is recommended that the sulfonators be cleaned: SAC-WW-V1 sec. 10.883
A. Every year or more frequently if necessary
B. Never, they are self-cleaning units
C. Every six months
D. Monthly

39. A chlorinator is set to feed 50 pounds of chlorine per 24 hours; the wastewater flow is at a rate of 0.85 MGD; and the chlorine as measured by the chlorine residual test is 0.5 mg/L. What is the chlorine dose? SAC-WW-V1 sec. 10.06 Example
A. 3.5 mg/L
B. 2956 lbs
C. 7.1 mg/L
D. None of the above

40. A plant with a 2 MGD flow has an effluent chlorine residual of 4.5 mg/L. Sulfur dioxide dose is being applied at 1.0 mg/L more than the chlorine residual. Determine the sulfonator feed rate in pounds of sulfur dioxide per day. SAC-WW-V1 sec. 10.851 Example

A. 75.06 lbs/day
B. 92 lbs/day
C. 58.3 lbs/day
D. None of the above

41. Sludge floating to the surface of a secondary clarifier could be resolved by which of the following? SAC-WW-V2 sec. 11.67

A. Increase sludge wasting to decrease MCRT
B. Increase MCRT to greater than 6 days
C. Add NaOH to drop the pH
D. Sludge floating is typical in this process
E. All of the above

42. Which of the following is a probable cause of dead spots in aeration tanks? SAC-WW-V2 sec. 11.67

A. Sludge return rate to high
B. Air supply valve improperly adjuster
C. Predominate actinomycetes
D. Inadequate flow distribution
E. All of the above

43. Denitrification is an indication of good treatment, providing that the sludge in the settleability test stays on the bottom. If it floats up too early in the test this would indicate: SAC-WW-V2 sec. 11.314

A. The operator should re-take the sample and test again
B. The sludge age should be reduced
C. The food-to-microorganism (FM) ratio is way too low and needs to be increased
D. None of the above

44. Which of the following are typical loading guidelines for activated sludge? SAC-WW-V2 sec. 11.71

A. High-rate: COD >1 LB , BOD >.5 LB (MLVSS under aeration)
B. Conventional: COD 0.5 to 1.0 LB, BOD 0.25 to 0.5 LB (MLVSS under aeration)
C. Extended aeration: COD <0.2 LB, BOD <.10 LB (MLVSS under aeration)
D. All of the above

45. In which of the following activated sludge processes should the micro sample be taken at the end of the stabilization zone? SAC-WW-V2 sec. 11.911 and Fig. 11.29

A. Contact stabilization mode
B. Extended aeration mode
C. Step feed mode
D. Conventional mode

46. All microorganisms are classified in kingdoms such as plant, animal, protists and monera. Which of the following organisms belong to the protists kingdom?
SAC-WW-V2 sec. 11.931

A. Fungi
B. Bacteria
C. Rotifers
D. Worms

47. Protozoa can be called "indicator organisms." Their presence or absence indicates the amount of bacteria in the activated sludge and the degree of treatment. Which of the following is <u>NOT</u> part of the protozoa family? SAC-WW-V2 sec. 11.931

A. Thiothrix
B. Mastiogophora
C. Amoeba
D. Suctoria

48. What is the generation time of E. coli bacteria in a broth media?
SAC-WW-V2 sec. 11.931

A. 24 hours
B. 8 hours
C. 1 hour
D. 17 minutes

49. The Sacramento book gives an illustration of an operation and maintenance checklist for digesters. What is the suggested schedule for lubricating valves stems along with inspecting and greasing motor bearings? SAC-WW-V2 sec. 12.40

A. Never
B. Semi-annually
C. Weekly
D. Daily

50. Which of the following is not beneficial for the digestion process?
SAC-WW-V2 Table 12.3

A. Sodium Hydroxide
B. Ammonia Nitrogen
C. Magnesium
D. Sodium
E. All of the above

51. Feeding of raw sludge to an anaerobic digester should be:
SAC-WW-V2 sec. 12.22

A. Done every 6 hours to prevent upsets
B. Done when the solids content of the sludge is <3.5%
C. Spread over a period of time
D. Done only when the volatile acids/alkalinity ratio in below 0.2

52. The efficient cleaning of a digester demands that operators follow appropriate safety rules. Which of the following are more important safety precautions?
SAC-WW-V2 sec. 12.53

A. When a digester is taken out of service the operator should provide adequate ventilation through the access holes with the use of explosion proof vents.
B. Make sure everyone working has had proper vaccination in case they come in contact with airborne viruses
C. Train the operator in proper use of personal protective equipment
D. Make sure that processes will not be interrupted when digester is off line
E. All of the above

53. Which of the following describes aerobic sludge digestion? SAC-WW-V2 sec.12.60

A. Does not require air
B. Generates sludge that needs additional stabilization before ultimate disposal
C. Produces a sludge that has higher water content.
D. None of the above

54. Which of the following describes anaerobic sludge digestion?
SAC-WW-V2 sec. 12.60

A. Produces liquids that may be difficult to treat when returned to the plant
B. Produces liquids that usually are easier to treat when returned to the plant
C. Works by aerobic decay which produces fewer odors
D. Has low equipment cost
E. All of the above

55. Laboratory results indicate that a total digested sludge solids sample was 9.6% solids and 42.8% volatile content. The raw sludge solids volatile content was 68%. What is the overall % reduction? SAC-WW-V2 sec. 12.3 Example 6 I

A. 64%
B. 36%
C. 50%
D. None of the above

56. How many two cubic yard dump trucks would it take to haul dry sludge in a bed 100 feet long and 25 feet wide if the dried sludge is six inches thick?
SAC-WW-V2 sec. 12.70 Question G

A. 24 truck loads
B. 46 truck loads
C. 83 truck loads
D. 28 truck loads

57. According to the Water Quality Criteria for effluent, what is the suggested limit of Nitrite and Nitrate as N for livestock and wildlife? SAC-WW-V2 Table 13.1
A. 1000 mg/L
B. 100 mg/L
C. 10 mg/L
D. 1 mg/L

58. What would cause excessive algae in the effluent? SAC-WW-V2 Table 13.2
A. Outlet baffle not at proper location
B. Temperature or weather conditions favoring a specific species of algae
C. The weirs on the secondary basins are the improper design
D. Skimmers not working properly
E. All of the above

59. Your plant is designed with series ponds. The operator notifies you that there is excessive BOD in the effluent that has the potential to cause your plant to be out of compliance. You calculated the organic loading and it indicates an overload. How would you have the operator correct this? SAC-WW-V2 sec. 13.25
A. Use pumps to recirculate the pond contents
B. Have the operate wait for 24 hours and see if the pond corrects the problem
C. Notify EPA immediately of the problem
D. Tell the operator to add chlorine to kill the excess organisms
E. All of the above

60. When an atmosphere for a confined space cannot be considered free of hazard, which procedure should be followed:SAC-WW-V2 sec. 14.12
A. Wear approved safety belt and attached life line
B. Station at least one person to stand by on the outside and another within sight to call for help
C. Wear appropriate, approved respiratory protective equipment
D. All of the above

61. What is the Upper Explosive Limit level for Methane?
SAC-WW-V2 Table 14.1
A. 100%
B. 75%
C. 50%
D. 15%

62. Which type of fire extinguisher should be provided at a pumping station?
SAC-WW-V2 sec. 14.21
A. Water filled
B. Type A
C. Halogen
D. Type ABC
E. None of the above

63. Which of the following statements are True about covered Wet Pits? SAC-WW-V2 sec. 14.220
A. Work is never done inside one
B. Because of the cover moisture does not enter
C. Only explosion-proof equipment should be used
D. It would not be considered confined space
E. All of the above

64. Highly acidic or alkaline wastes can be very hazardous and dangerous to personnel, treatment processes, and equipment. By adding H2SO4, at the headworks, what effect would it have on the pH? SAC-WW-V2 sec. 14.235
A. It would lower the pH
B. It would higher the pH
C. It would have no effect and is used to increase DO
D. All of the above
E. None of the above

65. The National Fire Protection Association uses color-coded hazard warning labels for hazardous materials. What is the color for Reactive? SAC-WW-V2 Fig. 14.7
A. Blue
B. White
C. Yellow
D. Red
E. None of the above

66. Which statement describes "Brinelling"? SAC-WW-V2 sec. 15.122
A. When a pump and motor is in misalignment
B. Tiny indentations high on the shoulder of the bearing race
C. Lubrication failure
D. Motor bushing overheats
E. Excessive heat to the stator

67. Which of the following materials is NOT part of the motor brush composition? SAC-WW-V2 sec. 15.170
A. Carbon graphite
B. Copper
C. Metal graphite
D. Graphite

68. To properly maintain a standard three-phase variable speed synchronous AC motor you must have some idea of what to look for when examining the slip rings and brushes. Which of the following components should be examined before startup? SAC-WW-V2 sec. 15.170
A. The coil inductor
B. Film which forms on the slip ring
C. The disconnect switch
D. The piston rings

69. What is the purpose of a suction bell for a pump? SAC-WW-V2 Table 15.3
A. Guide wastewater into pumps suction pipe and reduces pipe entrance energy losses
B. Keeps pump primed for automatic operation by allowing entrapped gases to escape
C. Collects the waste discharged by pump impeller
D. Isolates pump from discharge system

70. What is the purpose of a shear pin in a reciprocating pump?
SAC-WW-V2 sec. 15.2 Paragraph 2
A. To insure alignment of piston
B. To indicate clogged suction line
C. To prevent damage by allowing eccentric to move in neutral position
D. Only mechanical rakes have shear pins
E. All of the above

71. When installing new packing, what is the purpose of the lantern ring?
SAC-WW-V2 figure 15.21
A. To allow clearance for the gland
B. To keep the packing spaced in the stuffing box
C. To keep the shaft from detaching
D. To allow cooling liquid to enter along the shaft

72. Motor failure can be very costly and cause process shut downs if backup equipment is not available. Understanding insulation could help prevent problems to occur. How is the limitation of insulation defined? SAC-WW-V2 sec. 15.340
A. Ambient temperature
B. Motor winding
C. Phasing of motor
D. Induction of motor

73. Work needs to be done on the motor. Recommended safety procedures includes lockout / tagout and suggest that the following component be discharged.
SAC-WW-V2 sec. 15.45
A. The capacitor
B. The inductor
C. The diode
D. The thermal switch

74. Research has shown that there are several types of motor failures. Some can occur more frequent than others can. Which of the following causes the greatest motor malfunction?
SAC-WW-V2 sec. 15.42
A. Overload
B. Single phasing
C. Bearing failure
D. Old age
E. All of the above

75. Horizontal motors should be mounted so that all four mounting feet are aligned. When connecting a pump and motor there are several types of misalignment. The following are terms used EXCEPT: SAC-WW-V2 sec. 15.46

A. Linear misalignment
B. Angular misalignment
C. Parallel misalignment
D. Shaft end float
E. All of the above

76. The electrical potential required to transfer electrons from one compound or element to another is: SAC-WW-V2 Chapter 16 Definitions

A. Oxidation reduction potential
B. Reverse osmosis
C. Ion exchange
D. Oxidation
E. None of above

77. Solutions used in laboratory procedures are generally described in what standard concentrations? SAC-WW-V2 sec. 16.15

A. Grams
B. Moles
C. Normality
D. Liters
E. All of the above

78. In units of absorbency a logarithmic scale of non-equal division graduates from: SAC-WW-V2 sec. 16.17

A. 10.0 - 20.0
B. 5.0 - 10.0
C. 0.0 - 2.0
D. None of the above

79. Which of the following chemicals are explosive or flammable? SAC-WW-V2 sec. 16.203

A. Carbon disulfide
B. Sulfuric
C. Nitric
D. Chromic

80. What is the method for preserving a Sulfide sample? SAC-WW-V2 Table 16.4

A. Add 2 mL 1 M zinc acetate & 1 N NaOH to pH >9 and store at 4°C
B. Add sodium sulfide and store at room temperature
C. Add H_2SO_4 to pH <2 and store at 4°C
D. Store at 4°C

81. The Secchi disc is used to determine: SAC-WW-V2 sec. 16.40

A. The weight of dry solids
B. The clarity of a clarifier
C. The depth of water
D. None of the above

82. Calculate the % removal of a clarifier when the influent suspended solids is 12.0 mL/L and the effluent is 0.2 mL/L. SAC-WW-V2 sec. 16.42 Example E
A. 98%
B. 16%
C. 50%
D. 2.4%

83. $Ca(OH)2$ has been used in wastewater treatment for many years. Typically it was used as a coagulant, especially treating industrial waste. What is the correct name for $Ca(OH)2$?
SAC-WW-V2 sec. 16.47
A. Lime
B. Hydrated lime
C. Quicklime
D. Soda ash
E. None of the above

84. Most probable numbers of coliform bacteria are estimated to indicate the presence of bacteria originating from the intestines of warm-blooded animals. Which method does NPDES approve for the test? SAC-WW-V2 sec. 16.51 #6
A. Membrane filter method
B. Nonstandard titration method
C. Acetate solution method
D. Gauche crucible method

85. Wastewater is relatively rich in phosphorus compounds. The forms of phosphorus found in wastewater are commonly classified into three categories. Which category term is the amount of inorganic phosphorus in the sample of wastewater that is measured by the direct colormetric analysis procedure? SAC-WW-V2 sec. 16.51 #12
A. Orthophosphate
B. Condensed phosphate
C. Organically bound phosphate
D. Total phosphate
E. None of the above

86. The most important use of chlorine in the treatment of wastewater is for disinfection. When chlorine reacts quickly and completely with ammonia in wastewater it will produce which compound? SAC-WW-V2 sec. 16.51 #5
A. Disinfection by-products
B. Monochloramines
C. Hypochlorite
D. Chlorine dioxide
E. None of the above

87. What is the volatile solids test measuring when it is performed on solids?
SAC-WW-V2 sec. 16.44
A. The amount of inorganic material
B. The amount of grease in the sample
C. The amount of nitrogen in the sample
D. The amount of organic material
E. None of the above

88. Hydrogen sulfide generation is greatest when conditions are:
SAC-WW-V3 sec. 1.12
A. pH above 9.0
B. Temperatures above 30°C
C. High alkalinity concentrations
D. High oxygen concentrations

89. Aeration or high turbulence of wastewater will cause hydrogen sulfides to:
SAC-WW-V3 sec. 1.40
A. Be produced in higher concentrations
B. Stripped or carries out by the air
C. Bind with the nitrogen in the water
D. All the above

90. What will the result be if septic sludge is put into a gravity sludge thickener?
SAC-WW-V3 sec. 3.110
A. The septic sludge will produce a more compact sludge blanket
B. The rate of settling will increase
C. The pH will decrease and the sludge will thicken more readily
D. Gases may be produced which cause rising sludge

91. Which of the following is important in process control and would affect a dissolved air flotation unit? SAC-WW-V3 sec. 3.120
A. Temperature
B. Air to solids ratio
C. Alkalinity
D. pH

92. How is the organic loading on a digester determined?
SAC-WW-V3 sec. 3.2212

A. By determining the air flow in cfs per 1000 pounds of digester
B. By measuring the volatile solids loading per cubic foot per day
C. By measuring the rate of gas destruction in pounds per cubic foot per day
D. By determining the digestion time in days and hydraulic loading
E. None of the above

93. What should an operator do to correct excessive foam in an aerobic digester when the DO is high, pH is 7, and the O_2 uptake and temperature are stable?
SAC-WW-V3 sec. 3.2241

A. Increase the digester temperature
B. Raise the pH by adding Lime
C. Lower the air intake to reduce turbulence
D. All of the above

94. When Lime is mixed with sludge to improve dewatering the pH should be:
SAC-WW-V3 sec. 3.230

A. 11.5 to 12.0
B. 9 to 10.0
C. 5 or higher
D. None of the above

95. What type of sludge conditioning does the Elutriation process mean?
SAC-WW-V3 sec. 3.340

A. Reduce sludge alkalinity
B. Reduce sludge acidity
C. Reduce quantity of anions in the sludge
D. Increase the sludge's affinity for water

96. A belt filter press may contain a Venturi-type restriction whose purpose is:
SAC-WW-V3 sec. 3.411

A. To provide turbulence to mix polymer with the flow
B. Reduce sludge acidity
C. Increase sludge belt
D. Control belt tension

97. What will allow for greater volumes of water to drain from the sludge in a press?
SAC-WW-V3 sec. 3.4110

A. Mixing of polymer with sludge
B. Increase of belt speed
C. Too much wash water being used
D. Inadequate belt tension
E. None of the above

98. What information should be used by operators to determine the optimum depth to apply sludge on a sand drying bed? SAC-WW-V3 sec. 3.431

A. The drying time and the time required to remove sludge
B. The depth of sand in the drying bed
C. The capacity of the underdrain
D. All of the above

99. The application of a free draining, non-cohesive material such as diatomaceous earth to a filtering media is known as: SAC-WW-V3 sec. 3.4101
A. Blinding
B. Filter break through
C. Wash out
D. Plate overrun
E. All of the above

100. Advance or tertiary treatment may include which of the following processes:
SAC-WW-V3 sec. 3.9
A. Settling and centrifugation
B. Facultative decomposition and aeration
C. Aeration followed by sedimentation
D. Coagulation-sedimentation and filters
E. All of the above

Please memorize these statements.

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.

ANSWER KEY for Grades 1, 2 and 3,4 Practice Exams

1. A
2. A
3. C
4. A
5. C
6. A
7. C
8. B
9. C
10. C
11. B
12. A
13. B
14. E
15. A
16. A
17. A
18. C
19. A
20. C
21. C
22. D
23. D
24. A
25. C
26. D
27. A
28. A
29. D
30. A
31. D
32. A
33. B
34. A
35. B
36. B
37. A
38. A
39. C
40. B
41. B
42. B
43. B
44. D
45. A
46. A
47. A
48. D
49. B
50. A
51. B
52. A
53. C
54. A
55. A
56. A
57. C
58. B
59. A
60. D
61. D
62. D
63. C
64. A
65. C
66. B
67. B
68. B
69. A
70. C
71. D
72. A
73. A
74. A
75. A
76. A
77. C
78. C
79. A
80. A
81. B
82. A
83. B
84. A
85. A
86. B
87. D
88. B
89. B
90. D
91. B
92. B
93. C
94. A
95. A
96. A
97. B
98. A
99. A
100. D

Wastewater Treatment Practice #1 Examination

Here is an excellent practice exam for your review. No answers are provided, but you can find all of the answers in the glossary.

1. Sulfide can exist in wastewater in three forms depending on the pH: S^{2-} ion, HS^- ion, or H^2S gas. At the ideal temperature, what sulfide would form at a pH of 14?
A. S^{2-} ion, 90%
B. HS^- ion, 100%
C. H2S gas, 100%
D. H2S, 50% and HS^-, 50%

2. The presence or absence of oxygen establishes whether hydrogen sulfide will exist. If more than 1.0 mg/L of oxygen is present, what will happen to anaerobic bacteria?
A. It will become soluble BOD
B. It will oxidize to thiosulfate
C. It will produce higher levels of sulfide
D. Hydrogen sulfide will not exist

3. Which of the following represents the reaction of ammonia with chlorine?
A. $NH_3 + Cl_2 = NH_2Cl + CHI$
B. $NH_2Cl + Cl_2 = NHCl_2 + HCl$
C. $NHCl_2 + Cl_2 = NCl_3 + HCl$
D. Monochloramine, NH_2Cl
E. All of the above

4. Hydrogen peroxide has been used as an oxidant to control odors. What are the disadvantages of using hydrogen peroxide?
A. Inability to treat ammonia
B. It's an oxidant
C. Inhibits the regeneration of sulfate reducing microorganisms
D. Lack of toxic by-products

5. The pH of a production facility's wastewater may vary from 2.5 to 13.0 depending on the product being processed. It may be necessary to neutralize the wastewater to achieve a neutral pH. What chemical could be added to make a wastewater with a pH of 2.5 neutral?
A. Caustic
B. Sulfide
C. DO
D. Sodium bicarbonate

6. COD is an alternative to BOD for measuring the pollutional strength of wastewater. Bearing in mind that the BOD and COD tests involve separate and distinct reactions, what is the primary disadvantage of the COD test?
A. Chloride may interfere with the chemical reaction
B. It measures the presence of carbon and hydrogen
C. It takes 5 days to get results
D. None of the above

7. This chemical has been used like chlorine to control odors. This chemical reacts with other substances very similar to chlorine.
A. Phenol
B. Hydrogen Peroxide
C. Sodium hypochlorite

8. In gravity thickening of wastewater sludge, gravity forces are used to separate solids from the sludge being treated. Secondary sludge is not well suited for gravity thickening because it contains:
A. Bound water
B. High alkalinity
C. Low pH
D. Dissolved oxygen

9. If a primary sludge is allowed to go septic, which of the following gases are produced?
A. H_2S and CO_2
B. CH_4
C. A & B
D. Ozone
E. All of the above

10. Which of the following is not a recommendation for preventing odors in a trickling filter?
A. Maintain aerobic conditions in the sewer system
B. Use of masking agents
C. Increase of BOD loading
D. Check and clear filter ventilation

11. Which of the following solutions helps prevent trickling filters from freezing?
A. Decrease the recirculation
B. Parallel operations
C. Reduce nozzles spray
D. All of the above

12. Excessive sloughing or biological growth on a trickling filter is an indication of:
A. Ice buildup on filter media
B. Increase in secondary clarifier effluent suspended solids
C. Uneven distribution of flow
D. Filter ponding

13. The high-rate trickling filter is fed at 2,100 GPM and the filter diameter is 100 feet. What is the surface area flow rate in gallons per day?
A. 385 GPD/sq. ft
B. 385 GDP
C. 7850 GPD/Sq. ft
D. 3 MGD

14. Development of a white biomass over most of a Rotating Biological Contactor (**RBC**) disc area could be resolved by:
A. Decreasing the treatment influent flow
B. Increasing the chlorination in the first stage
C. Adjusting baffles between first and second stages to increase total surface area in first stage
D. None of the above

15. If the motor bearings on a RBC are running above 200°F, which of the following corrective actions could be taken?
A. Lubricate bearings per manufacturer's instruction
B. Check torque and alignment of bearings
C. Make sure the shaft is properly aligned.
D. All of the above

16. When making changes to correct a problem in an activated sludge package plant, how long might it take before the correction shows?
A. At least 3 or more days
B. 24 hours
C. 3 hours
D. Depends on the basin detention time

17. Changing conditions or abnormal conditions can upset the microorganisms in the activated sludge process. If the sludge is bulking in the clarifier, what could one possible factor be?
A. Low DO concentration
B. High rate of aeration
C. Clarifier flow to high
D. Hydraulic overload is too high

18. Some aeration tubing systems require cleaning on a weekly basis. Which of the following can be used to remove deposits of carbonate on the tubing slits and biological slime from inside the tubing?
A. Chlorine
B. Sodium hydroxide
C. Anhydrous ammonia
D. Anhydrous hydrogen chloride

19. Which of the following lab sample is taken daily from the effluent of a pond?
A. Chlorine residual
B. Coliform group
C. Dissolved oxygen
D. pH

20. Wastewater facilities may be required to provide chlorination services for which of the following activities?
A. Disinfection of effluent
B. Process control of activated sludge
C. Season odor control
D. All of the above

21. In order to meet NPDES permit coliform requirements what is the required chlorine residual at the outlet of the chlorine contact basin?
A. 4.5 mg/L
B. 3 mg/L
C. 2.5 mg/L
D. 1 mg/L

22. During the night shift, the operator notes that the chlorine residual analyzer recorder controller is not maintaining the chlorine residual properly. Which of the following could be a probable cause of the problem?
A. That flow fluctuations is the probable cause
B. That electrodes are fouled and should be cleaned
C. An increase in DO oxidized the residual
D. Ammonia is interfering and this is a common occurrence

23. A regular program of scheduled preventive maintenance is essential to keep a chlorinator functioning properly. If the operator notices that the chlorinator will not feed chlorine, the first thing an operator should check is:
A. The chlorine supply gauges
B. The evaporation unit
C. The injector line
D. None of the above

24. During your inspection of the chlorine feed system; you find that there is no chlorine gas pressure at the chlorinator. You check and find the chlorine cylinder is full and the valve is open. What is the probable cause?
A. Inadequate injector vacuum
B. Plugged or damaged pressure-reducing valve
C. Chlorinator discharge valve is closed
D. Injector diaphragm ruptured

25. The operator determines that the Coliform count fails to meet required standards for Disinfection. The operator checks the contact time and finds that short-circuiting has occurred in the contact chamber. What measures should be taken to correct this problem?
A. Adjust the injector flow
B. Install baffling in the contact chamber
C. Reduce the chlorine feed rate
D. This is normal, it will correct with an increase in flow

26. Procedures and equipment for operating and maintaining chlorination and sulfonation systems are very similar but you should be aware of the differences. Which of the following is a true statement regarding sulfur dioxide and chlorine?
A. Sulfur dioxide gas pressures are lower than chlorine gas pressure at the same temperature
B. Chlorinator control valve diaphragms can be used for sulfur dioxide
C. Sulfur dioxide has no health effects and is not dangerous
D. Sulfur dioxide vaporizes at the same rate as chlorine at the same temperature

27. Maintenance of the sulfur dioxide system should be part of a preventive maintenance program. It is recommended that the sulfonators be cleaned:
A. Every year or more frequently if necessary
B. Never, they have self-cleaning units
C. Every six months
D. Monthly

28. A chlorinator is set to feed 50 pounds of chlorine per 24 hours; the wastewater flow is at a rate of 0.85 MGD; and the chlorine as measured by the chlorine residual test is 0.5 mg/L. What is the chlorine dose?
A. 3.5 mg/L
B. 2956 lbs
C. 7.1 mg/L
D. None of the above

29. A plant with a 2-MGD flow has an effluent chlorine residual of 4.5 mg/L. Sulfur dioxide dose is being applied at 1.0 mg/L more than the chlorine residual. Determine the sulfonator feed rate in pounds of sulfur dioxide per day.
A. 75.06 lbs/day
B. 92 lbs/day
C. 58.3 lbs/day
D. None of the above

30. Sludge floating to the surface of a secondary clarifier could be resolved by which of the following?
A. Increase sludge wasting to decrease MCRT
B. Increase MCRT to greater than 6 days
C. Add NaOH to drop the pH
D. Sludge floating is no problem

31. Which of the following would be a cause of dead spots in aeration tanks?
A. Sludge return rate to high
B. Air supply valve improperly adjusted
C. Predominate actinomycetes
D. Inadequate flow distribution

32. Denitrification is an indication of good treatment, providing that the sludge in the settleability test stays on the bottom. If it floats up too early in the test this would indicate:
A. The operator should re-take the sample and test again
B. The sludge age should be reduced
C. The food-to-microorganism ratio is way too low and needs to be increased
D. None of the above

33. Which of the following are typical loading guidelines for activated sludge?
A. High-rate: COD >1, BOD >.5
B. Conventional: COD 0.5 to 1.0, BOD 0.25 to 0.5
C. Extended aeration: COD <0.2 lbs, BOD <.10 lbs
D. All of the above

34. In which of the following activated sludge processes is it recommended that the sample used for microscopic observations be taken at the end of the zone?
A. Contact stabilization
B. Extended aeration
C. Step feed
D. Conventional

35. All microorganisms are classified in kingdoms such as plant, animal, protista and monera. Which of the following organisms belong to the protista kingdom?
A. Fungi
B. Bacteria
C. Rotifers
D. Worms

36. Protozoa can be called "*indicator organisms*." Their presence or absence indicates the amount of bacteria in the activated sludge and the degree of treatment. Which of the following is NOT part of the protozoa family?
A. Thiothrix
B. Mastigophora
C. Amoeba
D. Suctoria

37. Bacteria is produced by binary fission which is called the generation time. The ***E. coli*** bacteria is found in the intestinal tract of humans and warm-blooded animals. What is the generation time of this bacterium in a broth medium?
A. 24 hours
B. 8 hours
C. 1 hour
D. 17 minutes

38. What is the suggested schedule for lubricating all valves and stems, and inspecting and greasing motor bearings?
A. Never
B. Semi-annually
C. Weekly
D. Daily

39. Which of the following is not beneficial to the digestion process?
A. Sodium Hydroxide
B. Ammonia Nitrogen
C. Magnesium
D. Sodium

40. Feeding of raw sludge to an anaerobic digester should be done:
A. At night, during the period of low flow
B. When the solids content of the sludge is <3.5%
C. Spread over a period of time
D. Only when the volatile acids/alkalinity ratio in below 0.2

41. The efficient cleaning of a digester demands that operators follow appropriate safety rules. Which of the following is the more important safety precaution to institute?
A. Isolate the gas collection and sludge system and provide adequate ventilation through the access holes with the use of explosion proof fans.
B. Make sure everyone working has had proper immunization in case they come in contact with airborne viruses
C. Train the back-up operator in proper use of rescue equipment
D. Make sure that processes will not be interrupted when digester is off line
E. None of the above

42. Which of the following describes aerobic sludge digestion?
A. Does not require air
B. Generates sludge that needs additional stabilization before ultimate disposal
C. Produces a sludge that has higher water content.
D. None of the above

43. Which of the following describes anaerobic sludge digestion?
A. Produces liquids that may be difficult to treat when returned to the plant
B. Produces liquids that usually are easier to treat when returned to the plant
C. Works by aerobic decay which produces fewer odors
D. Has low equipment cost

44. Laboratory results indicate that a total digested sludge solids sample was 9.6% solids and 42.8% volatile content. The raw sludge solids volatile content was 68%. What is the overall % reduction?
A. 64%
B. 36%
C. 50%
D. None of the above

45. How many two cubic yard dump trucks would it take to haul dry sludge to a bed 100 feet long and 25 feet wide if the dried sludge were spread six inches thick?
A. 24 truck loads
B. 46 truck loads
C. 83 truck loads
D. 36 truck loads

46. According to the Water Quality Criteria for effluent, what is the suggested limit of Nitrite and Nitrate as N for livestock and wildlife?
A. 1000 mg/L
B. 100 mg/L
C. 10 mg/L
D. 1 mg/L

47. What would cause excessive algae in the effluent of a pond?
A. Outlet baffle not at proper location
B. Temperature or weather conditions promoting growth
C. The secondary clarifier is hydraulically overloaded
D. Skimmers not working properly

48. Your plant is designed with series ponds. The operator notifies you that there is excessive BOD in the effluent that has the potential to cause your plant to be out of compliance. You calculated the organic loading and it indicates an overload. How would you have the operator correct this?
A. Use pumps to recirculate the pond contents
B. Wait 24 hours and see if the pond corrects itself
C. Notify EPA or local authority immediately of the problem
D. Tell the operator to add chlorine to kill the excess organisms

49. When an atmosphere for a confined space cannot be considered free of hazards which procedure should be followed?
A. Wear approved safety belt and attached life line
B. Station at least one person to stand by on the outside and another within site to call for help
C. At least one stand by person with first aid and CPR skills
D. All of the above

50. What is the Upper Explosive Limit **(UEL)** for Methane?
A. 100%
B. 75%
C. 50%
D. 15%

51. Which type of fire extinguisher should be provided at a pumping station?
A. Water filled
B. Class A
C. Carbon Monoxide
D. Class ABC

52. Which of the following statements is **true** about covered Wet Pits (Lift Station)?
A. Work is never done inside one
B. Because of the cover moisture does not enter
C. Only explosion-proof equipment should be used
D. It would not be considered confined space

53. Highly acidic or alkaline wastes can be very hazardous and dangerous to personnel, treatment processes, and equipment. By adding $H2SO^4$, at the headworks, what effect would it have on the pH?
A. It would lower the pH
B. It would raise the pH
C. It would make the influent pH neutral
D. All of the above
E. None of the above

54. The National Fire Protection Association uses color-coded hazard warning labels for hazardous materials. What is the color designated for Reactive materials?
A. Blue
B. White
C. Yellow
D. Red

55. Which statement describes "*Brinelling*"?
A. When a pump and motor is in misalignment
B. Tiny indentations high on the shoulder of the bearing race
C. Lubrication failure
D. Motor bushing overheats

56. Which of the following materials is not part of the motor brush composition?
A. Carbon graphite
B. Copper
C. Metal graphite
D. Graphite

57. To properly maintain a standard three-phase variable speed synchronous AC motor, you must have some idea of what to look for when examining the slip rings and brushes. Which of the following components should be examined before startup?
A. The coil inductor
B. The slip ring for a film
C. The disconnect switch
D. The piston rings
E. None of the above

58. What is the designed purpose of a suction bell on a pump?
A. Guide waste into pump suction pipe and reduces pipe entrance energy losses
B. Keeps pump primed for automatic operation by allowing entrapped gases to escape
C. Collects the waste discharged by pump impeller
D. Isolates pump from discharge system

59. What is the purpose of a shear pin in a reciprocating pump?
A. To insure alignment of piston
B. To indicate clogged suction line
C. To prevent damage by allowing eccentric to move to the neutral position

60. When installing new packing, what is the purpose of the lantern ring?
A. To allow clearance for the gland
B. To keep the packing spaced in the stuffing box
C. To keep the shaft from detaching
D. To allow cooling liquid to enter along the shaft

61. Motor failure can be very costly and cause process shut downs if backup equipment is not available. Understanding insulation could help prevent problems to occur. How is the limitation of insulation defined?
A. Ambient temperature
B. Motor winding
C. Phasing of motor
D. Induction of motor
E. None of the above

62. Work needs to be done on a motor. Recommended safety procedures include lockout/tagout and suggest that the following component be discharged.
A. The capacitor
B. The inductor
C. The diode
D. The thermal switch

63. Research has shown that there are several types of motor failures. Some can occur more frequently than others can. Which of the following causes the greatest number of motor malfunctions?
A. Overloads
B. Single phasing
C. Bearing failures

64. Horizontal motors should be mounted so that all four mounting feet are aligned. When connecting a pump and motor there are several types of misalignment. The following terms define types of misalignment ***EXCEPT:***
A. Linear misalignment
B. Angular misalignment
C. Parallel misalignment
D. Shaft end float

65. The electrical potential required to transfer electrons from one compound or element to another is called:
A. Oxidation reduction potential
B. Reverse osmosis
C. Ion exchange
D. Oxidation

66. Solutions generally used in the laboratory are expressed in what concentration?
A. Grams
B. Moles
C. Normality
D. Liters

67. The scale of a spectrophotometer is generally graduated two ways. If Units of Absorbance are used a logarithmic scale of non-equal divisions is graduated from:
A. 10.0 - 20.0
B. 5.0 - 10.0
C. 0.0 - 2.0
D. None of the above

68. Which of the following chemicals are classified as explosive or flammable?
A. Carbon disulfide
B. Sulfuric
C. Nitric
D. Chromic
E. All of the above

69. What is the method for preserving a Sulfide sample?
A. Add 2 mL 1 M zinc acetate & 1 N NaOH to pH >9 and store at 4°C
B. Add sodium sulfide and store at room temperature
C. Add H2SO4 to pH <2 and store at 4°C
D. Store at 4°C

70. The Secchi disc is used to determine:
A. The weight of dry solids
B. The clarity of a clarifier
C. The depth of water
D. None of the above

71. Calculate the % removal of settleable solids of a clarifier when the influent set. solution is 12.0 mL/L and the effluent set. solution is 0.2 mL/L.
A. 98%
B. 16%
C. 50%
D. 2.4%

72. $Ca(OH)^2$ has been used in wastewater treatment for many years. Usually it is used as a coagulant, especially treating industrial waste. What is the correct name for $Ca(OH)^2$?
A. Lime
B. Hydrated lime
C. Quicklime
D. Soda ash

73. Coliform bacteria, originating from the intestines of warm-blooded animals, are tested for in wastewater because they can be an indication of the presence of disease-producing organisms that can be associated with them. Which test method is approved by NPDES to determine Total Coliform analysis?
A. Membrane filter method
B. Nonstandard titration method
C. Col-alert

74. Wastewater is relatively rich in phosphorus compounds. The forms of phosphorus found in wastewater are commonly classified into three categories. Which category term measures the amount of inorganic phosphorus in the sample of wastewater as measured by the direct colormetric analysis procedure?
A. Orthophosphate
B. Condensed phosphate
C. Organically bound phosphate
D. Total phosphate

75. The most important use of chlorine in the treatment of wastewater is for disinfection. When chlorine reacts quickly and completely with ammonia in wastewater, which compound is produced?
A. Disinfection by-products
B. Monochloramines
C. Hypochlorite

76. What is the volatile solids test measuring when it is performed on solids?
A. The amount of inorganic material
B. The amount of grease in the sample
C. The amount of nitrogen in the sample
D. The amount of organic material

77. Hydrogen sulfide generation is greatest when which of the following conditions occur?
A. pH above 9.0
B. Temperatures above 30°C
C. High alkalinity concentrations
D. High oxygen concentrations
E. All of the above

78. Aeration or high turbulence of wastewater will cause hydrogen sulfide to be:
A. Produced in higher concentrations
B. Stripped or carried out by the air
C. Bind with the nitrogen in the water
D. All the above

79. What will the result be if septic sludge is put into a gravity sludge thickener?
A. The septic sludge will produce a more compact sludge blanket
B. The rate of settling will increase
C. The pH will decrease and the sludge will thicken more readily
D. Reduced efficiency and lower solids concentration

80. Which of the following is important in process control and would affect a dissolved air flotation (DAF) unit?
A. Temperature
B. Air to solids (A/S)ratio
C. Alkalinity
D. pH

81. How would you determine the organic loading on a digester?
A. By determining the air flow in CFS per 1000 pounds of digester
B. By measuring the volatile solids loading per cubic foot per day
C. By measuring the rate of gas destruction in pounds per cubic foot per day
D. By determining the digestion time in days and hydraulic loading

82. What should an operator do to correct excessive foam in an aerobic digester when the DO is high, pH is 7, and the O_2 uptake is stable?
A. Increase the digester temperature
B. Raise the pH by adding Lime
C. Lower the air intake to reduce turbulence
D. All of the above

83. When lime is mixed with sludge to improve dewatering the pH should be:
A. 11.5 to 12.0
B. 9.0 to 10.0
C. 5.0 to 8.0
D. None of the above

84. When the Elutriation process is used, what type of sludge conditioning is occurring?
A. Reduce the sludge alkalinity
B. Reduce the sludge acidity
C. Reduce quantity of anions in the sludge
D. Increase the sludge's affinity for water
E. All of the above

85. The purpose of a Venturi-type restriction on a belt filter press would be to:
A. Provide turbulence to mix polymer with the flow
B. Reduce sludge acidity
C. Increase sludge application speed
D. Control belt tension and pressure
E. All of the above

86. One factor that would allow for greater volumes of water to drain from the sludge in a belt filter press is to:
A. Mix more polymer with the sludge
B. Increase the belt speed
C. Increase the wash water being used
D. Decrease the belt tension

87. What information should be used by operators to determine the optimum depth to apply sludge on a sand drying bed?
A. The drying time and the time required to remove sludge
B. The depth of sand in the drying bed
C. The capacity of the underdrain
D. All of the above

88. The application of a free draining, non-cohesive material such as diatomaceous earth to a filtering media is known as:
A. Binding
B. Filter break through
C. Wash out
D. Plate overrun

89. A typical set point to start backwashing a rapid-sand filter is at_____ of head loss.
A. 4 feet
B. 5 feet
C. 6 feet
D. 7 feet

90. What lab test is used to simulate a tertiary plant operation?
A. Jar test
B. COD
C. TOC
D. NTU

91. Which of the following meters can be used to analyze and record the clarity of the filter influent and effluent flows?
A. NTU or Turbidity Meter
B. TSS meter
C. DO meter
D. Parshall flume

92. In sludge incineration a complete oxidation of the sludge depends on:
A. The sludge feed rate
B. Detention time in the incinerator
C. The ratio of fuel/air supplied to the incinerator
D. Complete mixing

93. Ponding can occur at sites where wastewater effluent is being irrigated. Which of the following is not a reason that ponding occurs?
A. Distribution line clogged with solids
B. A broken pipe in the irrigation line
C. Excessive application rate
D. Inadequate drainage

94. Land treatment systems, which have a point source effluent, are known as:
A. Irrigation systems
B. Water recycling systems
C. Overland flow systems
D. Infiltration / percolation

95. Advance or tertiary treatment may include which of the following processes:
A. Coagulation-sedimentation
B. Facultative decomposition and aeration
C. Aeration followed by sedimentation
D. Settling and centrifugation

96. To control the pressure during filter backwash, most systems have a:
A. By-pass valve
B. Pressure regulator on backwash pump
C. Rate control valve which slowly opens
D. VFD's on pumps

97. Solids break-through in a tertiary filter can happen when the:
A. Solids bind the sand bed of the filter
B. Solids pass through the media into the clearwell
C. Mud balls begin to float
D. Filter is backwashed excessively

98. Which of the following disadvantages is common to surface straining as contrasted to depth filtration?
A. Media contamination
B. Breakthrough of TSS
C. Rapid head loss buildup
D. Fecal coliform buildup
E. None of the above

99. A depth filter media provides a slower buildup of head loss in the filter, but this does allow for a quicker:
A. Lowering of the pH in the effluent
B. Anaerobic condition to be produced
C. Breakthrough of the solids
D. Backwash cycle
E. None of the above

100. Wastewater discharge in streams could be put in four pollution categories. Which of the following would not be included in a category?
A. Organic
B. Dissolved Oxygen
C. Inorganic
D. Thermal
E. Radioactive

101. In most cases, wastewater flowing into plant will contain pieces of wood, rags, trash, and other debris. To protect equipment and the process downstream preliminary treatment is performed. What is the name of the piece of equipment used to remove these items?
A. Bar screen
B. Trash compactor
C. Vacuum press
D. Solid waste screen

102. Grit should be removed early in treatment because it is abrasive and will rapidly wear out pumps. A grit channel is designed to flow at a velocity of ______?
A. 4 ft/sec
B. 1 foot per second
C. 5 ft^3/hr.
D. The velocity does not matter, only the detention time

103. One way to freshen the wastewater and separate oils and grease is to add which of the following:
A. BOD
B. Chlorine
C. Bar screens
D. Grit removal
E. Pre-aeration

104. Manual bar screens require frequent attention. What would happen to the flow if debris collected on the bars?
A. Head loss
B. Flow would remain the same
C. Increase of raking
D. Flow would decrease

105. On a mechanical bar screen, which device regulates or controls the travel distance of a chain or cable?
A. Limit Switch
B. Shear pin
C. Gear housing
D. Manually regulated by an operator
E. All of the above

106. The upper portion of a pond has air while the lower portion has no air. This pond would be classified as:
A. Facultative
B. Anaerobic
C. Aerobic
D. Activated sludge

107. Some ponds located in hot, arid areas, have been designed to take advantage of this condition:
A. Percolation
B. Condensation
C. Evaporation
D. Exfiltration
E. Sludge drying

108. A biological decomposition of organic matter with the production of ill-smelling products associated with anaerobic conditions is called?
A. Putrefaction
B. Septic
C. Slurry

109. Operators should be familiar with a pond's characteristics at various times of the day. When is the pH and the dissolved oxygen the lowest?
A. Middle of the day
B. Early evening
C. At sunrise
D. It stays the same

110. The process of adding a chemical compound drop by drop until a desired change occurs is known as?
A. Precipitation
B. Known addition
C. Titration
D. None of the above

111. The more familiar an operator becomes with the operation of a pond, the more accurate they become with visual observations. What does a deep green sparkling color indicate?
A. Hospitality operations
B. Commercial facilities
C. Restaurants
D. Industrial facilities or operations

112. Total solids in wastewater are composed of:
A. Dissolved solids and filterable residue
B. Suspended solids and settable solids
C. Colloidal solids and non-settable solids
D. Dissolved solids and suspended solids

113. The sludge volume index (**SVI**) is a procedure typically used at:
A. Activated sludge facilities
B. Stabilization ponds
C. Trickling filters
D. Sludge thickening facilities

114. Why must operators take representative samples?
A. To maximize the sample holding time
B. Grab samples should not be taken
C. Because the composition of the waste stream changes throughout the day
D. To insure analytical precision

115. A thirty-minute settleability test is used to determine:
A. The TSS concentration
B. The BOD concentration
C. The F/M ratio
D. The SVI

116. What is the maximum holding time of a sample that will be analyzed for pH?
A. None-analyze immediately
B. Six hours maximum
C. One day
D. Six days
E. None of the above

117. Which of the following procedures is commonly used to measure chlorine residual?
A. DPD
B. Scratch test
C. Presence
D. Toluidine method

118. Advance treatment of wastewater is sometimes used to remove nutrients. This type of treatment is generally known as:
A. Phosphoionization
B. Chelation
C. Anaerobic treatment
D. Tertiary treatment

119. A pneumatic ejector is a type of:
A. Pump
B. Chlorinator
C. Laboratory equipment
D. Aerator
E. None of the above

120. A progressive cavity pump is typically used for:
A. Moving large volumes of wastewater
B. Very small applications such as lab equipment
C. Pumping corrosives like ferric chloride
D. Pumping liquids high in solids

121. In a centrifugal pump, the water that is to be pumped moves through the:
A. The eye of the impeller
B. The lantern rings
C. Pulsation dampener
D. The intake grinder
E. None of the above

122. Before starting a centrifugal pump for the first time, the pump should be:
A. Under warranty
B. Primed with water
C. Inspected by a manufacturing representative
D. Filled with a startup lubricant
E. All of the above

123. An imaginary line running along the center of a shaft is called:
A. Axis to impeller
B. Axial to impeller
C. Pump centerline
D. Hemisphere

124. What is the proper operating position of the inlet and outlet check valves of a reciprocating pump on the discharge stroke?
A. Intake open; discharge closed
B. Intake closed; discharge open
C. Intake open; discharge open
D. Intake and bake

125. Which of the following statements describes the proper operation of a progressive cavity pump?
A. Shut off intake valve near the end of the pumping cycle and run pump to clear solids
B. Never run the pump without liquid
C. Control the pump discharge by throttling discharge valves

126. Centrifugal pumps with two impellers are known as:
A. Multi-stage pumps
B. Compound pumps
C. Auxiliary pumps
D. Double pumps

127. The average velocity through a properly designed channel type grit chamber should be approximately:
A. 1 foot per second
B. 0.4 feet per second
C. 2 feet per second
D. 3 feet per second

128. An essential aspect of priming a pump is:
A. Closing the intake and discharge valves
B. Turning off seal water valves
C. Venting excess air
D. Briefly operating pump before priming

129. Weeds and scum accumulation along levees of stabilization ponds can lead to:
A. Increase in DO
B. Mosquito breeding
C. Decrease in DO
D. Increase in COD

130. Head loss on the downstream side of a bar screen indicates:
A. A decrease in pumping efficiency
B. Debris on the bar screen
C. The barminutor is not functioning
D. A short detention time in the primary clarifier

131. Why is pretreatment vitally important to the operation of a sludge digester?
A. Without pretreatment, hydrogen sulfide and other gasses would be upset
B. Without pretreatment, the digester could become filled with grit
C. Without pretreatment, there would be insufficient microbes present
D. None of the above

132. If a mechanical bar screen ceases to operate, the most likely problem would be attributed to:
A. An overload motor circuit
B. Something jammed in the rake mechanism
C. A defective limit switch
D. An overcrowded telephone booth

133. When shutting down a pump for a long period, the motor disconnect switch should be:
A. Opened
B. Locked out
C. Tagged
D. All of the above

134. Pre-aeration can do all of the following except:
A. Disinfect
B. Remove gases
C. Add oxygen
D. Promote flotation
E. All of the above

135. Grit channel shutdowns are best scheduled for:
A. Periods of low flow
B. Mornings
C. Weekdays
D. Weekends

136. Before raking a manually-cleaned bar screen, the operator should be certain that:
A. There is nothing in the area that would cause you to lose balance and fall
B. The chain drive sprockets are disengaged
C. All power to the bar screen is locked and tagged
D. The cutting blade drive is disengaged

137. Select the best procedure for removing a mechanical bar screen from service.
A. Close inlet, turn off screen, close outlet, hose down
B. Turn off screen, close outlet, close inlet
C. Close outlet, close inlet, turn off screen, hose down
D. Close inlet, close outlet, turn off screen, drain, hose down

138. Sodium nitrate has been used in stabilization ponds to improve the operation. When the operator adds sodium nitrate, what condition will be improved?
A. Turbidity
B. Dissolved oxygen level
C. Fertilizer content
D. Hangover

139. If two polishing ponds are to be operated in series, this means:
A. Water will flow from one pond to another
B. The ponds will receive equal flows simultaneously
C. The ponds will be aerated intermittently throughout the day
D. There will be intermittent discharge from storage cell

140. Which of the following is not a good method of controlling odors in lagoons?
A. Recirculation from aerobic units
B. Pond needs more overloading
C. Floating aeration
D. Chlorination

141. Aerobic ponds are characterized by having dissolved:
A. Oxygen
B. Methane
C. Carbon monoxide
D. Sulfate

142. The biological formation of scum on a stabilization pond will most likely occur:
A. In the afternoon
B. Shortly after a heavy rain
C. During warmer weather
D. When the pH is below 4

143. The minimum depth for a stabilization pond is usually considered to be:
A. 3 feet
B. 2 feet
C. 5 feet
D. 4 feet

144. The proper operation of a stabilization pond with surface aeration includes:
A. Frequent cycling of aerators
B. Continuous operation of all aerators
C. Summer operations only
D. Addition of sodium nitrate

145. Allowing the water surface to fluctuate in stabilization ponds will help to:
A. Control shoreline aquatic vegetation
B. Control copepods
C. Control grit
D. Keep the pond aerobic

146. Which of the following conditions will have the greatest positive effect on the operation of a stabilization pond?
A. Normal rainfall amounts
B. pH range of 5.0 to 6.0
C. pH range between 10-11
D. Frequent wind for mixing and warm temperatures

147. Algae can frequently cause excessive solids in stabilization pond effluent. Which of the following offers the best the best solution to this problem?
A. Chlorinate the effluent
B. Draw the effluent off from under the surface
C. Fluctuate the water levels in the pond
D. Kill the algae with radioactive waste

148. Black and brown scum on a stabilization pond is most likely caused by:
A. Organic overloading
B. Frequent level fluctuations
C. Inadequate chemical treatment
D. Low pH

149. If a water hyacinth culture is used in a stabilization pond, it may immediately result in:
A. Sludge contamination
B. Excessive growth of undesirable organisms
C. Foul odors
D. The removal of algae

150. Organic loading in a stabilization pond is defined as:
A. Pounds of BOD/person/day
B. Pounds of BOD/day
C. Pounds of BOD/gallon/day
D. Pounds of BOD/acre/day

151. If seepage is noted on the outside surface of a levee, the operator should:
A. Closely watch the situation
B. Repair the leakage with Bentonite
C. Place rip-rap on both sides of the dike
D. Notify an engineer of the problem

152. Stabilization ponds will most likely have problems with mosquitoes:
A. If kept at maximum water levels
B. If offensive odors are present
C. If emergent weeds are allowed to grow near the shore
D. If algaecides are not used routinely
E. All of the above

153. Which would be the best method to prevent erosion by surface runoff to a pond or dike not exposed to wave action?
A. Planting low-growing spreading grass
B. Using rip-rap
C. Using a shredded plastic mat
D. Covering the dike with pea gravel

154. Which of the following statements best describes the batch operation of a lagoon system?
A. Water moves in a plug flow from one cell to another
B. Permeable dikes are placed to slow the distribution of water to different areas of the stabilization pond
C. Discharge is restricted to specific periods
D. Each cell is operated independently of the other

155. A chlorine gas leak should be detected by:
A. A DPD procedure
B. Using an ammonia solution spray bottle and watching for a white vapor
C. Holding an open bottle of "*Leak*" finder
D. The RUN procedure

156. The object of disinfection is to:
A. Kill most microorganisms except Fecal
B. Kill pathogenic microorganisms
C. Kill only coliform microorganisms
D. Kill bacterial spores

157. When chlorine is used in disinfection, the term 'free chlorine' refers to:
A. The loss of chlorine to the air
B. The amount of chlorine found in the water
C. Chlorine produced as a by-product
D. HTH in available form

158. Which of the following types of treatment would be expected to result in the greatest reduction of pathogenic microorganisms?
A. Activated sludge
B. Pretreatment
C. Primary sedimentation
D. Stabilization ponds

159. The addition of chlorine to wastewater at the entrance to the treatment plant, ahead of the settling units and before the addition of other chemicals is known as:
A. Post-chlorination
B. Breakpoint chlorination
C. Prechlorination
D. Hypochlorination

160. What is the purpose of a rotameter on a chlorinator?
A. It injects the chlorine gas into the water stream
B. It volatizes the gas to allow it to go into solution
C. It indicates the concentration of break-point chlorine
D. It measures gas flow

161. At which of the following temperatures will chlorine disinfection be most effective?
A. 25 degrees Celsius
B. 15 degrees Celsius
C. 20 degrees Celsius
D. 10 degrees Celsius

162. Which of the following chemicals is NOT used for dechlorination?
A. Sodium trioxide
B. Sodium sulfite
C. Sodium metabisulfite

163. Chlorine can be accurately described as a:
A. Strong oxidizer
B. Solvent
C. Strong acid
D. Strong base

164. Impurities in water that bind with chlorine result in a condition known as:
A. Chlorine demand
B. Chlorine degradation
C. Chlorine residual
D. Chlorine isolation

165. Hydrogen sulfide is extremely hazardous even at extremely low concentrations, due to its ability:
A. To impair the sense of smell
B. To bind with oxygen
C. To bind with fat tissue
D. To explode

166. An explosive gas that is in a concentration below its LEL will:
A. Explode upon ignition
B. Create and evolve into a complex life form just like human have evolved
C. Not explode
D. Extinguish any ignition source

167. The minimum concentration of oxygen allowable before entry into a confined space is:
A. 21.0% oxygen
B. 16.0% oxygen
C. 19.5% oxygen
D. 23.2% oxygen

168. A general rule to protect operators from electrical injuries is:
A. Allow only qualified personnel to service electrical equipment
B. Never work on equipment with a voltage higher than 120 volts
C. Always stand on a rubber mat when servicing electrical equipment
D. Try not to ground yourself when servicing electrical equipment

169. The proper fire extinguisher to have available near flammable liquids such as grease and oils is which type?
A. Class B
B. Class A
C. Class C
D. Classless

170. The best way to learn about the harmful effects of a material you are working with is to:
A. Ask your supervisor
B. Read the Material Safety Data Sheet (MSDS) for the product (Now SDS)
C. Check with a coworker
D. Check the safety chart
E. All of the above

171. Before entering an excavated trench, the operator should be sure:
A. That adequate shoring has been provided
B. That adequate personal protection equipment is worn
C. That there is no water present

172. Safety in the wastewater plant includes protection from infectious disease. Which of the following disease is not contracted through wastewater?
A. Typhoid fever
B. HIV Virus (AIDS)
C. Cholera

173. When entering a manhole, how many other people shall be present above ground?
A. 2
B. 3,
C. 1
D. 0, as long as radio contact is maintained with the Fire Department

174. The greatest danger posed by the accumulation of nitrogen gas in confined areas is:
A. Displacement of oxygen
B. Toxicity
C. Synergism with hydrogen sulfate
D. Flammability

175. Adequate protection from traffic hazards would include traffic warning signs. How far ahead of the work should the signs be placed?
A. 250 feet
B. 500 feet
C. 100 feet
D. 1,000 feet

176 After working on equipment with rotating parts, operators should avoid injury during start-up by:
A. Energizing the equipment from a remote location
B. Standing close to equipment to observe or hear potential problems
C. Starting and stopping equipment rapidly to prevent full operating speed from being achieved
D. Standing away from rotating shafts

177. A Venturi meter is used to:
A. Monitor dissolved oxygen concentrations
B. Measure flows in pipes
C. Measure the rate of discharge through air blowers
D. Measure pressure differentials between head loss on centrifugal pumps

178. Flow measuring is very important to wastewater operators for all of the following reasons except:
A. It is useful for determining pumping rates
B. It is useful for freshening water before treatment, especially Parshall flumes
C. It is useful for determining chlorination loading
D. It is useful for determining organic loading on the plant

179. Which of the following statements concerning flow measurements is true?
A. Flow measurement devices remove an appreciable amount of BOD
B. Most process control decisions can be made without flow data
C. In actual practice, flow-measuring devices are rarely used
D. Flow measurement devices are most commonly at the plant headworks

180. Which of the following flow measurement methods is most commonly used in wastewater treatment?
A. Totalizer
B. Parshall flume
C. Rotameter
D. Venturi meter

181. The main purpose of completing an NPDES report is to:
A. Report operation and maintenance expenditures
B. Report effluent values to DEQ
C. Maintain a quality control program on laboratory equipment
D. Report pretreatment violations to DEQ

182. Public relations is an important aspect of wastewater management. What must be done to insure a positive image?
A. Give to the United Way
B. Disclose the NPDES reports
C. Keep the plant clean and neat
D. Send out a monthly newsletter
E. All of the above

183. Even though your treatment facility may be operating like a model plant, the operator may be asked to prove its performance. The best way to accomplish this is to:
A. Keep good operating records
B. Hire a consultant to provide an unbiased view of the plant operation
C. Use a check list for maintenance activities
D. Retain samples of your effluent

184. A positive public image of wastewater operations and treatment facilities is important for continued public support. Which of the following is most likely to give the public a negative image of your operations?
A. Odors and unsightly appearances
B. Higher than average utility expenses
C. Exceeding your discharge limits once a month
D. Amount of over-time worked

185. As the manager of a small wastewater utility, you are responsible for many duties except:
A. Making recommendations on regulatory standards
B. Planning for equipment replacement
C. Giving interviews with the media
D. Providing tours for schools or civic organizations

186. Convert a flow of 600 gallons per minute to million gallons per day. You can find these in the Sacramento Manuals as well.
A. 0.94 MGD
B. 0.86 MGD
C. 0.67 MGD
D. 0.77 MGD

187. Estimate the velocity of wastewater flowing through a grit channel if a stick travels 32 feet in 36 seconds.
A. 0.89 ft/sec
B. 0.97 ft/sec
C. 0.64 ft/sec
D. .52 ft/sec

188. 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.
A. 50 lbs./day
B. 42 lbs./day
C. 56 lbs./day
D. 61 lbs./day

189. To maintain satisfactory chlorine residual in a plant, the chlorine dose must be 10 mg/L when the flow is 0.37 MGD. Determine the chlorinator setting (feed rate) in pounds per day.
A. 26 lbs./day
B. 28 lbs./day
C. 36 lbs./day
D. 31 lbs./day

190. Convert 20 degrees Celsius to degrees Fahrenheit.
A. 68 F
B. 72 F
C. 63 F
D. 75 F

191. A rectangular channel 3 feet wide contains water 2 feet deep and flowing at a velocity of 1.5 feet per second. What is the flow rate in CFS?
A. 9 cubic feet per second
B. 8 cubic feet per second
C. 13 cubic feet per second

192. Change 10 cubic feet of water to gallons.
A. 87.3 gallons
B. 99.2 gallons
C. 74.8 gallons

193. A circular secondary clarifier handles flow of 0.9 MGD and suspended solids of 3600 mg/L. The clarifier is 50 feet in diameter and 8 feet deep. What will the detention time be?
A. 3.1 hr.
B. 5.2 hr.
C. 4.4 hr.
D. 2.8 hr.

194. Waste material which comes from animal or vegetable sources is called:
A. Coliform
B. Inorganic waste
C. Organic waste
D. Nutrients

195. If an operator refers to the retention time of a process, they are probably meaning:
A. The amount of time that water or solids are held
B. The ability of the process to bind with impurities
C. The ability of water or solids to retain oxygen
D. The ability of water to hold solids
E. The time that was spent in the safety meeting

196. Aerobic bacteria are those which:
A. Must have no oxygen present in order to function
B. Can function either with or without oxygen
C. Must have oxygen to function

197. Very small un-dissolved particles that resist settling are known as:
A. Stragglers
B. Colloids
C. Sludge
D. Ghost Particles
E. TDS

198. Chlorination can help eliminate odors in stabilization ponds and will also:
A. Increase the BOD loading
B. Increase the alkalinity
C. Interfere with the treatment process
D. Increase dissolved oxygen concentrations
E. All of the above

199. During the evening hours the pH will decrease in a stabilization pond. The lowering of the pH is caused by production of:
A. Sodium sulfide
B. Hydrochloric acid
C. Carbon dioxide
D. Sodium bicarbonate
E. All of the above

200. What is the definition of '*sewage*'?
A. Nonpotable water.
B. Reclaimed water.
C. Untreated wastes from toilets, baths, sinks, lavatories, laundries, and other plumbing fixtures in places of human habitation, employment, or recreation.
D. Human fecal matter.

Wastewater Treatment Practice Exam Section #2 **Answers in rear**

1. Why are hydraulic shores usually not used on jobs exceeding five (5) days in length?

2. What does the term "relative compaction" refer to?

3. What chemical does not react with chlorine before disinfection takes place?

4. What is the IDLH for chlorine gas according to the NIOSH manual?

5. What is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite?

6. What is the reason for having a well-mixed solution of chlorine and wastewater effluent in the contact chamber?

7. What may occur due to chronic exposure to low concentrations of chlorine gas?

8. What physically happens when chlorine is inhaled in high concentrations?

9. When chlorine gas is added to water, it rapidly hydrolyzes. Which chemical equations best describes this reaction?

10. When opening the top valve on a one ton chlorine cylinder, what will be discharged?

11. Where should the chlorine pressure reducing valve be located when using an evaporator?

12. Which of the following types of connections should be used on a chlorine cylinder's valve?

13. With long contact times, a low concentration of disinfectant suffices, whereas short contact times require high concentrations to accomplish equivalent kills.
A. TRUE
B. FALSE

14. Name several health hazards associated with exposure to chlorine gas.

15. Name several safety precautions when using chlorine gas.

16. Name several symptoms of chlorine exposure.

17. What are monochloramine, dichloramine, and trichloramine known as:

18. What are the necessary emergency procedures in the case of a large uncontrolled chlorine leak?

19. What are the physical and chemical properties of chlorine?

20. What are the two main chemical species formed by chlorine in water and what name are they known by collectively?

21. What compounds are formed in water when chlorine gas is introduced?

22. What does the term 'free chlorine' refer to?

23. Chlorine gas is highly corrosive in moist conditions. What are the only metals that are TOTALLY inert to moist chlorine gas?

24. Chlorine is added to the effluent before the contact chamber for complete mixing. What is the reason for not adding it directly to the chamber?

25. Chlorine is soluble in chlorides, alkali, and alcohols.
A. TRUE
B. FALSE

26. Chlorine reacts explosively or forms explosive compounds with many common substances such as:

27. Chlorine's strong odor gives warning of its presence at much lower concentrations than are dangerous.
A. TRUE
B. FALSE

28. 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

29. Name the most common exposure routes of chlorine.

30. Hydrogen chloride is a colorless gas with a pungent odor. What is an aqueous solution of this compound called?

31. How is chlorine transported commercially?

32. Even brief exposure to 1,000 ppm of Cl^2 can be fatal.
A. TRUE
B. FALSE

33. How do you replace the connection from a chlorine cylinder to the chlorinator?

34. How many turns should a chlorine gas cylinder be initially opened?

35. Hypochlorous acid dissociates according to which of the following reactions?

36. If the temperature of a full chlorine cylinder is increased by 50 F or 30 C, what is the most likely result?

37. As soon as Cl2 gas enters the throat area, a victim will sense a sudden stricture in this area - 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.

38. An aeration system in an aerobic digester is shut off to decant or remove some clear supernatant. The sludge begins to rise to the surface within 60 minutes. The supernatant is now full of the floating sludge which may interfere with the activated sludge process. What is a logical solution to this problem?

39. An anaerobic digester has black foam covering about one half of the surface. All of the following are possible causes to the foam problem:

40. When should raw sludge be fed to an anaerobic digester?

41. Which of the following tasks is necessary for maintaining proper operation of a drip trap placed on the gas line of a heated anaerobic digester?

42. What will be observed first following an upset of the anaerobic digestion process?

43. Which bacteria produces the most acid in an anaerobic digester?

44. What should be done to correct excessive foam in an aerobic digester when the DO is high, pH is 7, and the O2 uptake and temperature are stable?

45. How much methane can be expected to be produced for every pound of volatile material applied to a digester?

46. If the level of carbon dioxide increases in an anaerobic digester what effect would occur?

47. How long might it take before observing a change made for process control in an activated sludge package plant?

48. During cold weather operation of an activated sludge plant, biological activity will be reduced. What does this result in?

49. In an aerobic digester the DO drops to less than 1.0 mg/l but the blowers are operating at full capacity. What should be done under these conditions?

50. In an anaerobic digester the volatile acid/alkalinity ratio is experiencing a decrease in pH. Which chemical can be added to correct this condition?

51. What is the dissolved oxygen concentration needed during start-up of an activated sludge plant?

52. What state of the activated sludge process is necessary for proper luxury uptake of phosphorous?

53. An activated sludge plant is experiencing sludge bulking. The effluent from the clarifier is full of mixed liquor. Which of the following can cause bulking sludge due to filamentous growth in the plant?

54. What does it mean if during a settling test the sludge settles in 15 minutes and rises to the surface in 30 minutes?

55. What does the complete oxidation of sludge in sludge incineration depends upon?

56. What happens if sludge is septic and it is put in a gravity sludge thickener?

57. What is the purpose of elutriation of sludge?

58. What percent solids of sludge is dredged from a long term storage lagoon?

59. What may cause the oxygen uptake measurement in aerobically digested sludge to decrease?

60. What preliminary steps are required when using dry chemicals for sludge conditioning?

61. What should the pH be when lime is mixed with sludge to improve dewatering?

62. What will allow for greater volumes of water to drain from the sludge in a press?

63. What will happen if primary sludge is added to an aerobic digester?

64. At what temperature is water the most dense?

65. Denitrification is an indication of good treatment, providing that the sludge in the settleability test stays on the bottom. What does sludge floating up too early in a test indicate?

66. Detention time can be described as the amount of time required to fill a tank at a given flow.
A. TRUE
B. FALSE

67. During low flow periods, what operational change may be necessary to maintain the proper detention time in a primary clarifier and keep the primary effluent fresh?

68. How does sodium nitrate added to a stabilization pond improve the operation?

69. Osmosis is the spontaneous process by which solvent molecules pass through a semipermeable membrane from a solution of lower concentration into a solution of higher concentration.
A. TRUE
B. FALSE

70. The atomic number is the number of protons plus neutrons in the nucleus of an atom.
A. TRUE
B. FALSE

71. What does dry gaseous sulfur dioxide form in the presence of moisture?

72. What is the main purpose of recirculation in a trickling filter process?

73. What is the purpose of having a continuous readout of turbidity in the effluent of a tertiary sand filter?

74. What operation change should be employed if a dark brown foam is developing on the aeration basin?

75. What operational change may be necessary to accommodate colder operating temperatures in the winter months?

76. When a primary clarifier is operating properly, which of the following will happen?

77. Which of the following disadvantages is common to surface straining versus depth filtration?

78. What applies to the aerobic digestion process?

79. What is important in process control and may affect a dissolved air flotation unit?

80. What is necessary before a new stabilization pond is put into service?

81. What are not by-products of aerobic digestion?

82. What is true about extended aeration plants?

83. What may affect the performance of a dissolved air flotation unit?

84. What sludge types typically takes approximately 20 days to be fully stabilized?

85. Why should sludge withdrawal from a clarifier be conducted slowly?

86. What will dissolve in water to form an anion?

87. Which chemical may be added to raise the pH of a solution?

88. Why is an extended aeration plant designed to operate when the microorganism population is in the endogenous respiration phase?

89. Why is dilution water seeded with BOD?

90. A spectrophotometer operates based on the light transmitted or absorbed by the sample at:

91. Elutriation is a process of sludge conditioning whereby the sludge is washed, either with fresh water or plant effluent. The purpose of elutriation is to:

92. Endogenous respiration of microorganisms in an extended aeration plant will:

93. A standard solution is a prepared chemical solution in which ….

94. For which water tests is it permissible to use a composite sample?

95. What is the definition of an acidic solution?

96. One common problem with a nitrification treatment process is a decrease in the alkalinity. Which chemical is used to control the alkalinity concentration?

97. Thiothrix is type of filament that can grow in the aeration basin of an activated sludge plant. What is a possible cause to the growth of this long filament?

98. What is the molecular formula of Calcium hypochlorite?

99. What is the molecular formula of Chlorine dioxide?

100. What is the molecular formula of Sodium hydroxide?

101. What is the molecular formula of Sodium hypochlorite?

102. What is the molecular formula of Sulfuric acid?

103. What is the molecular formula of the Ammonium ion?

104. What is the most probable cause if DO drops excessively across a primary clarifier?

105. What is the significance of the MLSS determination?

106. What likely happens if sludge rises during the settleability test?

107. Which microorganism causes frothing?

108. What describes the contents of a balanced, good settling mixed liquor?

109. Which condition is critical for a phosphorus removal system using the luxury uptake process?

110. Which is a pretreatment step needed for the suspended solids test?

Math Section

111. What is the moisture content of a 120 gram sludge sample that was evaporated to a dry weight of 7.3 grams?

112. How many pounds of dry solids would be contained in 19,000 gallons of liquid sludge at 4% concentration?

113. If the desired DO depletion is 4.0 mg/l in the BOD test and the expected BOD strength of the wastewater sample is 200 mg/l, how much of the sample should be added to the 300 ml BOD bottle?

114. The density of chlorine gas is 0.187 lb/ft3 and the density of air is 0.075 lb/ft3. What is the specific gravity of chlorine gas at Standard Temperature and Pressure?

115. To maintain a satisfactory chlorine residual in a plant's effluent, the chlorine dose must be 10 mg/l when the flow is 1,400 m3/day. Determine the feed rate in kilograms per day.

116. To maintain satisfactory chlorine residual in a plant, the chlorine dose must be 10 mg/l when the flow is 0.37 MGD. Determine the feed rate in pounds per day.

117. Water weighs approximately 62.4 lb/ft^3. If the specific gravity of a load of copper sulfate crystals is 1.41, what is the density in lb/ft^3 of the copper sulfate crystals?

118. Water weighs approximately 62.4 lb/ft^3. Specific gravity = density of substance / density of water. The weight of 3 ft^3 of Hg is 2,546 lb. What is the specific gravity of Hg.

119. How much of a 0.250 N stock sodium thiosulfate solution is required to prepare 1 liter of 0.025 N sodium thiosulfate for titrating dissolved oxygen samples?

120. Calculate the percent removal of a clarifier when the influent suspended solids is 12.4 ml/liter and the effluent is 0.5 ml/liter.

121. Calculate the SVI in a 0.5 MG aeration tank. The settable solids is 7% and the mixed liquor is 1,900 mg/l.

122. Determine the actual chemical feed in pounds per day from a dry chemical feeder. A bucket placed under the chemical feeder weighs 0.32 pounds empty and 2.15 pounds after 30 minutes.

123. Determine the chemical feed in pounds of polymer per day from a chemical feed pump. The polymer solution is 1.5 percent or 15,000 mg polymer per liter. Assume a specific gravity of the polymer solution of 1.0. During a test run the chemical feed pump delivered 800 ml of polymer solution during five minutes.

124. Determine the return activated sludge (RAS) flow in MGD when the influent flow is 7.5 MG (28,390 m^3/day), the mixed liquor suspended solids (MLSS) are 2,000 mg/l and the SVI is 120.

125. A flow rate of 4,300 m^3 per day is applied to a trickling filter. The filter is 15 meters in diameter and 1.2 meters deep. The BOD of the wastewater applied to the filter is 120 mg/l. Calculate the hydraulic loading on the filter.

Answers Practice Exam# 2

1. There is a possibility of the hydraulic pressure bleeding off during this length of time.
2. The level of compaction obtained compared to the level possible under ideal conditions
3. Phosphate
4. 10 ppm
5. The potential for a gas leak in a poorly designed system.
6. The chamber provides for very little mixing due to low flow velocities.
7. Chronic exposure may cause corrosion of the teeth.
8. It causes emphysema and damage to the pulmonary blood vessels.
9. $Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$
10. Gas chlorine
11. Downstream of the evaporator
12. Yoke-type connectors
13. True
14. Irritation to the mucous membranes and eyes; contact with the skin causes severe burns; inhalation causes lung damage.
15. 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.
16. 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.
17. Combined available chlorine
18. 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.
19. 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. Gaseous chlorine is about 2.5 times heavier than air.
20. HOCl and OCl^-; free available chlorine.
21. Chlorine gas forms a mixture of hydrochloric and hypochlorous acids.
22. The amount of chlorine found in the water.
23. Gold, Platinum, and Tantalum.
24. The chamber has very little mixing due to low velocities.
25. True
26. Acetylene and ether
27. True
28. True
29. Inhalation, dermal, and eye contact.
30. Hydrochloric acid
31. In commerce, chlorine is always packaged as a liquefied gas under pressure in steel containers. Liquid chlorine in the absence of moisture will not attack ferrous metals; hence the use of steel containers.
32. True
33. Use a new, approved gasket on the connector.
34. 1/4 turn to unseat the valve, then open one complete turn.
35. $HOCl \leftrightarrow H^+ + OCl^-$
36. The cylinder may rupture
37. 1) Get out of the area of the leak, proceeding upwind, and 2) take only very short breaths

through the mouth.
38. Install a below water surface draw off pipe for decanting.
39. The temperature is changing in the digester too fast. High organic loading to the digester A thick sludge blanket was broken up. This is not the problem the settled sludge in the secondary digester is removed too fast.
40. When the solids content of sludge is < 3.5 %.
41. Empty the condensate from the drip traps daily.
42. Volatile acid concentration.
43. Saprophytic bacteria.
44. Decrease the air intake to reduce turbulence.
45. 8 - 12 ft3.
46. pH will decrease.
47. At least 3 or more days.
48. Decreasing rate of solids accumulation.
49. Reduce the loading to the digester.
50. Soda Ash.
51. 2.0 mg/l to 4.0 mg/l.
52. Extended aeration activated sludge.
53. High F/M.
54. Dissolved oxygen levels are too high.
55. The ratio of fuel and air supplied to the incinerator.
56. Gases may be produced causing sludge to rise.
57. To reduce the chemical conditioning requirements.
58. 6 to 12 % solids.
59. Substance inhibiting the organisms.
60. The dry chemical should be weighed out and mixed with water.
61. 11.5 to 12.0.
62. Increase the belt speed.
63. More food will be available to the microorganisms and more oxygen will be required.
64. 4 C.
65. The sludge age should be reduced
66. False
67. Take one or more of the clarifiers off line
68. Dissolved oxygen concentration.
69. True
70. False
71. H_2SO_4
72. To increase the contact time of the BOD and microorganisms.
73. To indicate the possible breakthrough of solids in the filter.
74. Increase the wasting rate.
75. Decrease sludge wasting.
76. The BOD and TSS will decrease through the clarifier.
77. Rapid head loss buildup
78. Sufficient air must be used to place all solids in the aeration tank in suspension
79. Air to solids ratio
80. Fill the pond with at least one foot of clean water
81. Volatile acids
82. They do not produce as much waste sludge as other process
83. Air to solids ratio
84. Extended aeration sludge
85. Prevent the pumping of too much water

86. Sulfate
87. Caustic soda
88. This is the time of the most complete oxidation of organic material
89. Supply bacteria to decompose all organic matter
90. A selected wavelength
91. Reduce sludge alkalinity
92. Complete oxidation of organic material
93. The exact chemical concentration is known
94. VOCs
95. A solution that contains a significant number of H+ ions
96. Soda ash
97. Low DO levels
98. $CaCl^2 0^2$
99. ClO^2
100. NaOH
101. NaOCl
102. H2SO4
103. NH4+
104. Infrequent sludge pumping
105. It is an indication of bacterial population available for utilizing organic waste.
106. Denitrification is taking place
107. Nocardia
108. Free-swimming and stalked ciliates and some flagellates and rotifers.
109. Anaerobic or facultative tank must cause the release of phosphorus
110. Shake or mix the sample
111. 6.1 %
112. 6,338 lbs
113. 6.0 ml
114. 2.49
115. 14 kg/day
116. 31 lbs/day
117. 87.98
118. 13.6
119. 100 ml
120. 96%
121. 37
122. 88 lbs./day
123. 7.6 lbs polymer/day
124. 2.4 MGD
125. 24 m3/day/m2

Key Areas to Study

1. How does a proportional valve operate?

2. Many questions on BOD removal percentages. What is the BOD removal percentage in the primary clarifier?

3. BOD 5 Averages

4. The hard security questions… Preparedness's

5. Everything on Methane CH_4, color, toxic, specific gravity 0.5545.

6. Hydrogen Sulfide, is it inorganic or organic.

7. Chlorination shut down procedures

8. Grit chamber, Vortex, increase the flow…

9. Commutator making ropes.

10. Discharge Report information, who and what is on it

11. Several compose sample questions. How many samples are taken in 24 hours?

12. Pressure and head calculations 2.31 and 1 PSI.

13. Measurement of electrical draw…. Amps or Watts or ?

14. Several PPD per day math questions.

15. Couple of averaging math questions.

16. One pressure math question which wasn’t really a math question, two different size containers with the same level of water in them.

17. Positive Displacement pumps. Couple of the closed discharge

18. Which type of pump can run with a closed discharge

19. Speed and constancy of a piston pump.

20. Which pump will not run a 5 percent solids solution?

21. What samples are done every day or what samples are required each day?

22. Convert 85 degrees F to C.

23. How much water does a piston pump produce with a 7-inch diameter and 7-inch stroke at 16 strokes per hour?

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 Ft 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: (3.14) (Diameter)3
(6)

Circumference = 3.14 X Diameter

General Conversions
Flowrate

Multiply	—>	to get
to get	<—	Divide
cc/min	1	mL/min
cfm (ft3/min)	28.31	L/min
cfm (ft3/min)	1.699	m3/hr.
cfh (ft3/hr.)	472	mL/min
cfh (ft3/hr.)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m3/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

PERCENT EFFICIENCY = In – Out X 100
In

TEMPERATURE: 0F = (0C X 9/5) + 32 9/5 =1.8
0C = (0F - 32) X 5/9 5/9 = .555

CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)

FLOW RATE (Q): Q = A X V (Quantity = Area X Velocity)

FLOW RATE (gpm): Flow Rate (gpm) = 2.83 (Diameter, in)2 (Distance, in)
Height, in

% SLOPE = Rise (feet) X 100
Run (feet)

ACTUAL LEAKAGE = Leak Rate (GPD)
Length (mi.) X Diameter (in)

VELOCITY = Distance (ft)
Time (Sec)

N = Manning's Coefficient of Roughness
R = Hydraulic Radius (ft.)
S = Slope of Sewer (ft/ft.)

HYDRAULIC RADIUS (ft) = Cross Sectional Area of Flow (ft)
Wetted pipe Perimeter (ft)

WATER HORSEPOWER = Flow (gpm) X Head (ft)
3960

BRAKE HORSEPOWER = Flow (gpm) X Head (ft)
X Pump Efficiency

MOTOR HORSEPOWER = Flow (gpm) X Head (ft)
X Pump Eff. X Motor Eff.

MEAN OR AVERAGE = Sum of the Values
Number of Values

TOTAL HEAD (ft) = Suction Lift (ft) X Discharge Head (ft)

SURFACE LOADING RATE = $\frac{\text{Flow Rate (gpm)}}{\text{Surface Area (sq. ft)}}$
(gal/min/sq.ft)

MIXTURE = (Volume 1, gal) (Strength 1, %) + (Volume 2, gal) (Strength 2,%)

STRENGTH (%) (Volume 1, gal) + (Volume 2, gal)

INJURY FREQUENCY RATE = $\frac{\text{(Number of Injuries) 1,000,000}}{\text{Number of hours worked per year}}$

DETENTION TIME (hrs) = $\frac{\text{Volume of Basin (gals) X 24 hrs}}{\text{Flow (GPD)}}$

SLOPE = $\frac{\text{Rise (ft)}}{\text{Run (ft)}}$ SLOPE (%) = $\frac{\text{Rise (ft) X 100}}{\text{Run (ft)}}$

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

LEAKAGE (GPD/inch) = $\frac{\text{Leakage of Water per Day (GPD)}}{\text{Sewer Diameter (inch)}}$

CHLORINE DEMAND (mg/L) = Chlorine Dose (mg/L) – Chlorine Residual (mg/L)

τQ = Allowable time for decrease in pressure from 3.5 PSU to 2.5 PSI
τq = As below

τQ = (0.022) (d12L1)/Q τq = $\frac{\text{[0.085] [(d12L1)/(d1L1)]}}{\text{q}}$

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 = $\frac{\text{1.486 R 2/3 S 1/2}}{\nu}$

V = Velocity (ft./sec.)
ν = Pipe Roughness
R = Hydraulic Radius (ft)
S= Slope (ft/ft)

HYDRAULIC RADIUS (ft) = $\frac{\text{Flow Area (ft. 2)}}{\text{Wetted Perimeter (ft.)}}$

Formula/Conversion Table

Acid Feed Rate = $\frac{\text{(Waste Flow) (Waste Normality)}}{\text{Acid Normality}}$

Alkalinity = $\frac{\text{(mL of Titrant) (Acid Normality) (50,000)}}{\text{mL of Sample}}$

Amperage = Voltage ÷ Ohms

Area of Circle = (0.785)(Diameter2) OR (π)(Radius2)

Area of Rectangle = (Length)(Width)

Area of Triangle = $\frac{\text{(Base) (Height)}}{2}$

C Factor Slope = Energy loss, ft. ÷ Distance, ft.

C Factor Calculation = Flow, GPM ÷ [193.75 (Diameter, ft.)2.63(Slope)0.54]

Chemical Feed Pump Setting, % Stroke = $\frac{\text{(Desired Flow) (100\%)}}{\text{Maximum Flow}}$

Chemical Feed Pump Setting, mL/min =

$\frac{\text{(Flow, MGD) Dose, mg/L) (3.785L/gal) (1,000,000 gal/MG)}}{\text{(Liquid, mg/mL) (24 hr. / day) (60 min/hr.)}}$

Chlorine Demand (mg/L) = Chlorine dose (mg/L) – Chlorine residual (mg/L)

Circumference of Circle = (3.141)(Diameter)

Composite Sample Single Portion = $\frac{\text{(Instantaneous Flow) (Total Sample Volume)}}{\text{(Number of Portions) (Average Flow)}}$

Detention Time = $\frac{\text{Volume}}{\text{Flow}}$

Digested Sludge Remaining, % = $\frac{\text{(Raw Dry Solids) (Ash Solids) (100\%)}}{\text{(Digested Dry Solids) (Digested Ash Solids)}}$

Discharge = $\frac{\text{Volume}}{\text{Time}}$

Dosage, lbs/day = (mg/L)(8.34)(MGD)

Dry Polymer (lbs.) = (gal. of solution)(8.34 lbs/gal)(% polymer solution)

$$\text{Efficiency, \%} = \frac{(\text{In} - \text{Out})(100\%)}{\text{In}}$$

$$\text{Feed rate, lbs/day} = \frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34\text{ lbs/gals})}{(\text{Available fluoride ion})(\text{Purity})}$$

$$\text{Feed rate, gal/min (Saturator)} = \frac{(\text{Plant capacity, gal/min.})(\text{Dosage, mg /L})}{18{,}000\text{ mg/L}}$$

$$\text{Filter Backwash Rate} = \frac{\text{Flow}}{\text{Filter Area}}$$

$$\text{Filter Yield, lbs/hr./sq. ft} = \frac{(\text{Solids Loading, lbs/day})(\text{Recovery, \% / 100\%})}{(\text{Filter operation, hr./day})(\text{ Area, ft2})}$$

Flow, cu. ft./sec. = (Area, Sq. Ft.)(Velocity, ft./sec.)

$$\text{Gallons/Capita/Day} = \frac{\text{Gallons / day}}{\text{Population}}$$

$$\text{Hardness} = \frac{(\text{mL of Titrant})(1{,}000)}{\text{mL of Sample}}$$

$$\text{Horsepower (brake)} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3{,}960)(\text{Efficiency})}$$

$$\text{Horsepower (motor)} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3960)(\text{Pump, Eff})(\text{Motor, Eff})}$$

$$\text{Horsepower (water)} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3960)}$$

$$\text{Hydraulic Loading Rate} = \frac{\text{Flow}}{\text{Area}}$$

Leakage (actual) = Leak rate (GPD) ÷ [Length (mi.) x Diameter (in.)]

Mean = Sum of values ÷ total number of values

$$\text{Mean Cell Residence Time (MCRT)} = \frac{\text{Suspended Solids in Aeration System, lbs}}{\text{SS Wasted, lbs / day + SS lost, lbs / day}}$$

$$\text{Organic Loading Rate} = \frac{\text{Organic Load, lbs BOD / day}}{\text{Volume}}$$

$$\text{Oxygen Uptake} = \frac{\text{Oxygen Usage}}{\text{Time}}$$

Pounds per day = (Flow, MGD) (Dose, mg/L) (8.34)

$$\text{Population Equivalent} = \frac{(\text{Flow MGD})\ (\text{BOD, mg/L})\ (8.34\ \text{lbs / gal})}{\text{Lbs BOD / day / person}}$$

$$\text{RAS Suspended Solids, mg/l} = \frac{1{,}000{,}000}{\text{SVI}}$$

$$\text{RAS Flow, MGD} = \frac{(\text{Infl. Flow, MGD})\ (\text{MLSS, mg/l})}{\text{RAS Susp. Sol., mg/l} - \text{MLSS, mg/l}}$$

$$\text{RAS Flow \%} = \frac{(\text{RAS Flow, MGD})\ (100\ \%)}{\text{Infl. Flow, MGD}}$$

$$\text{Reduction in Flow, \%} = \frac{(\text{Original Flow} - \text{Reduced Flow})\ (100\%)}{\text{Original Flow}}$$

$$\text{Slope} = \frac{\text{Drop or Rise}}{\text{Run or Distance}}$$

$$\text{Sludge Age} = \frac{\text{Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs / day}}$$

$$\text{Sludge Index} = \frac{\text{\% Settleable Solids}}{\text{\% Suspended Solids}}$$

$$\text{Sludge Volume Index} = \frac{(\text{Settleable Solids, \%})\ (10{,}000)}{\text{MLSS, mg/L}}$$

$$\text{Solids, mg/L} = \frac{(\text{Dry Solids, grams})\ (1{,}000{,}000)}{\text{mL of Sample}}$$

Solids Applied, lbs/day = (Flow, MGD)(Concentration, mg/L)(8.34 lbs/gal)

$$\text{Solids Concentration} = \frac{\text{Weight}}{\text{Volume}}$$

$$\text{Solids Loading, lbs/day/sq. ft} = \frac{\text{Solids Applied, lbs / day}}{\text{Surface Area, sq. ft}}$$

$$\text{Surface Loading Rate} = \frac{\text{Flow}}{\text{Rate}}$$

Total suspended solids (TSS), mg/L =
(Dry weight, mg)(1,000 mL/L) ÷ (Sample vol., mL)

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}} \quad \text{O R} \quad \frac{\text{Distance}}{\text{Time}}$$

$$\text{Volatile Solids, \%} = \frac{(\text{Dry Solids} - \text{Ash Solids})(100\%)}{\text{Dry Solids}}$$

Volume of Cone = (1/3)(0.785)(Diameter2)(Height)

Volume of Cylinder = (0.785)(Diameter2)(Height) OR (π)(r2)(h)

Volume of Rectangle = (Length)(Width)(Height)

Volume of Sphere = [(π)(diameter3)] ÷ 6

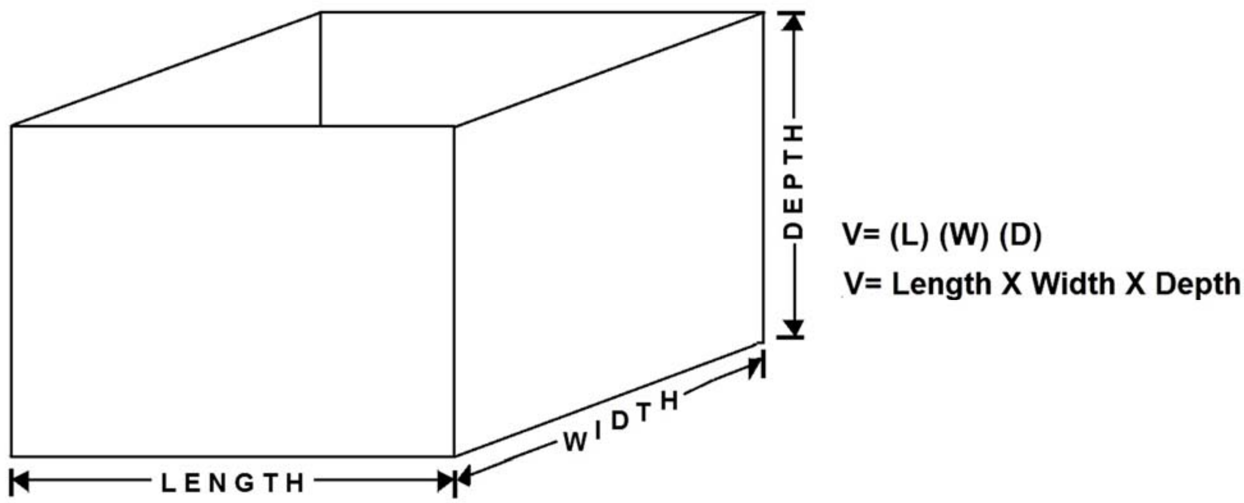
Waste Milliequivalent = (mL) (Normality)

$$\text{Waste Normality} = \frac{(\text{Titrant Volume})(\text{Titrant Normality})}{\text{Sample Volume}}$$

$$\text{Weir Overflow Rate} = \frac{\text{Flow}}{\text{Weir Length}}$$

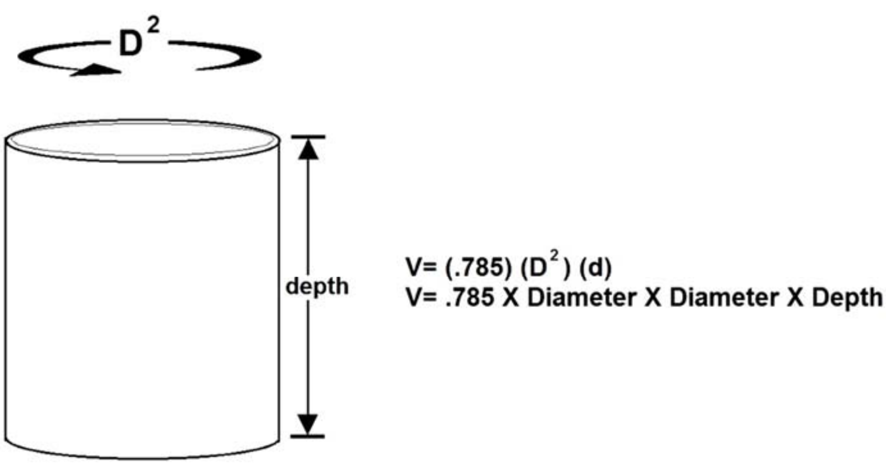
Conversion Factors
1 acre = 43,560 square feet
1 cubic foot = 7.48 gallons
1 foot = 0.305 meters
1 gallon = 3.785 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
1 horsepower = 0.746 kilowatts
1 million gallons per day = 694.45 gallons per minute
1 pound = 0.454 kilograms
1 pound per square 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

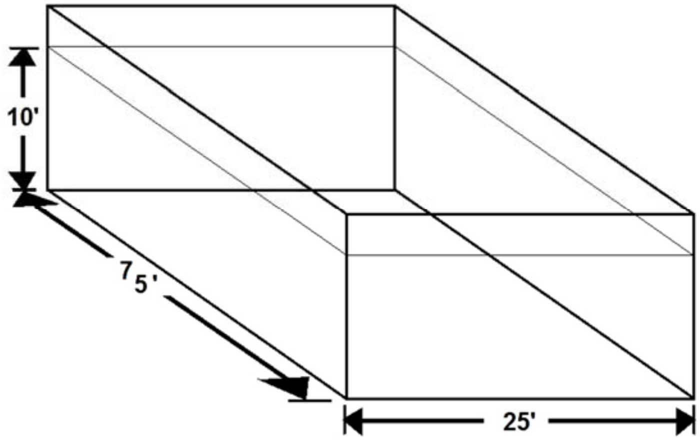
Cube Formula
V= (L) (W) (D)
Volume= Length X Width X Depth



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

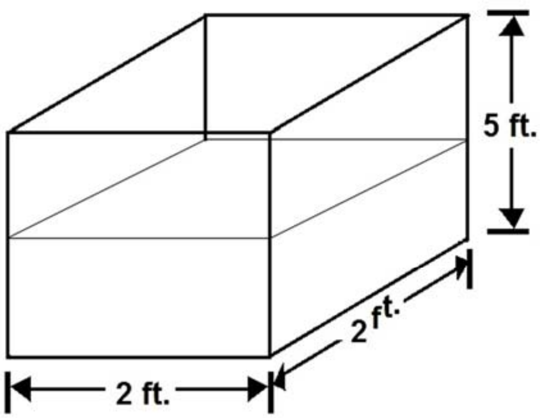
V= (L) (W) (D)

(25) (75) (10)(7.48)

25' x 75' x 10' x 7.48 = 46750 gallons

1. Convert 10 cubic feet to gallons of water.

There is 7.48 gallons in one cubic foot.



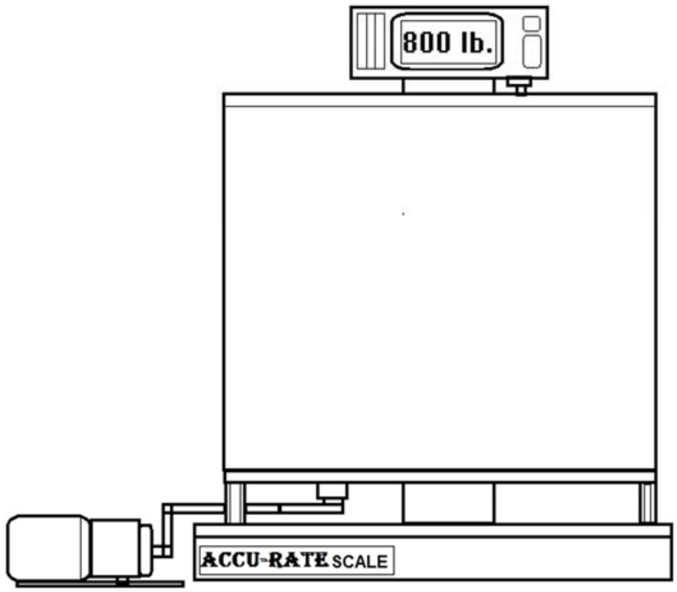
Convert 10 cu.ft. to gallons of water :

$(10\ ft.^3)\ (7.48)$

Multiply $10\ ft.^3$ X 7.48 = 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.

$$\frac{800\text{lbs.}}{8.34\text{ lbs./gal.}} =$$

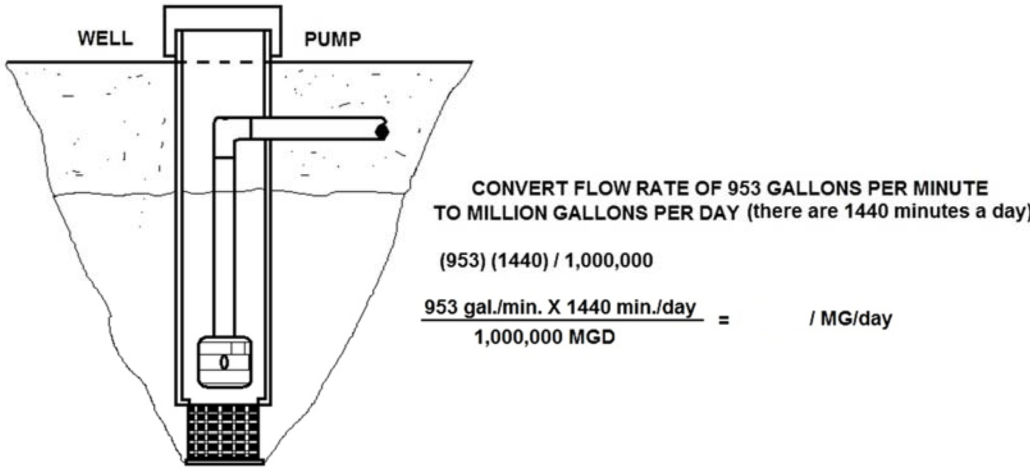
CONVERTING POUNDS TO GALLONS

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?

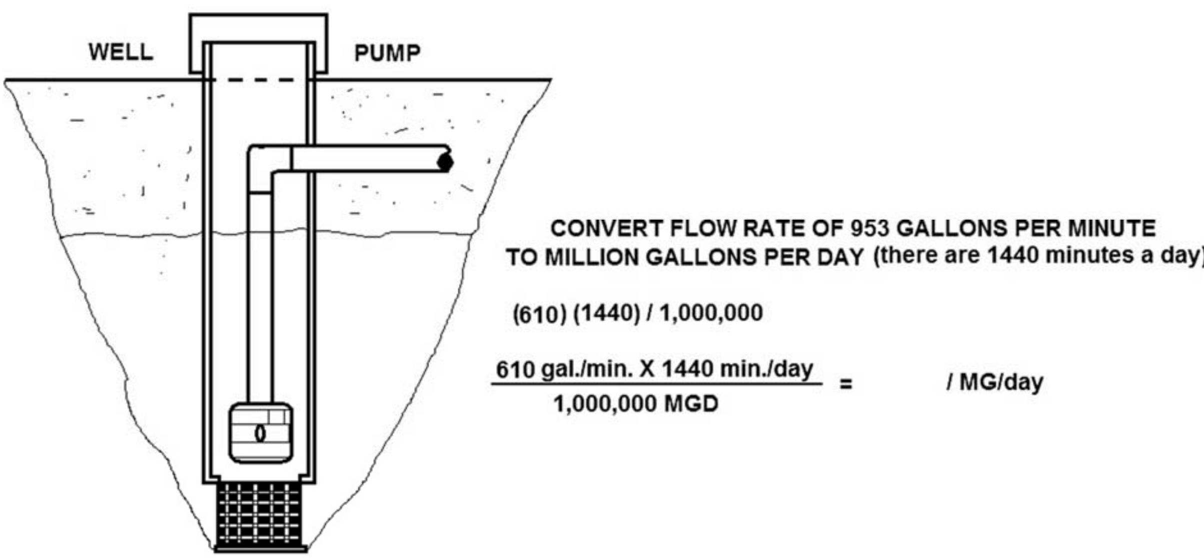
3. Convert a flow rate of 953 gallons per minute to million gallons per day.
There is 1440 minutes in a day.



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.

$$1\ \mathrm{MG} = \frac{100{,}000\ \text{Gallons}}{24\ \text{Hours (fill time)}}$$



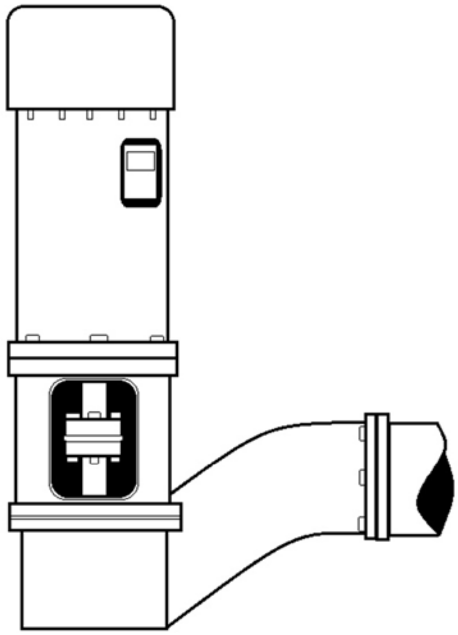
CONVERTING GALLONS PER MINUTE TO MILLION GALLONS PER DAY

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

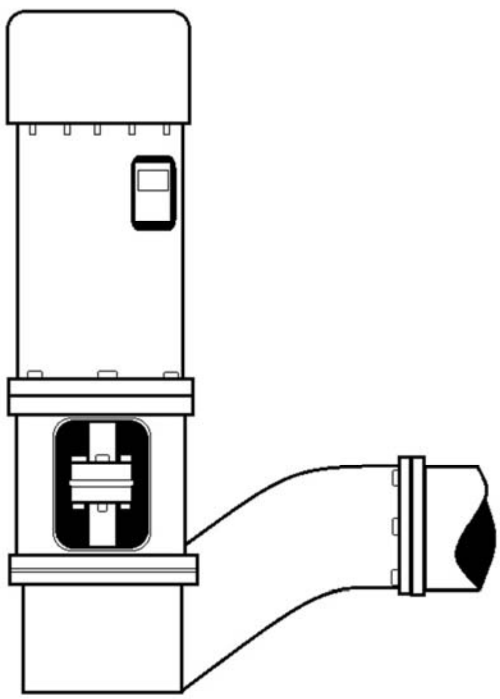
(550) / (60)

550 divided by 60

$$\frac{550 \text{ gal./ min.}}{60 \text{ sec./ min.}} = \qquad \text{gal./sec.}$$

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

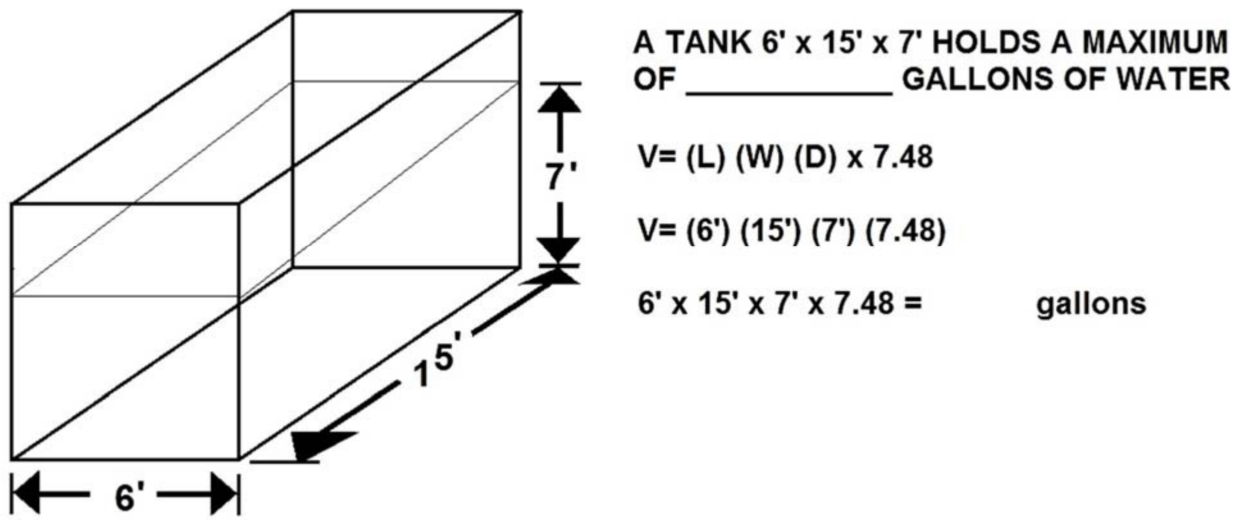
(9.167) X (3.79)

9.167 X 3.79

9.167 gal./sec. X 3.79 liters/gal. = liters/sec.

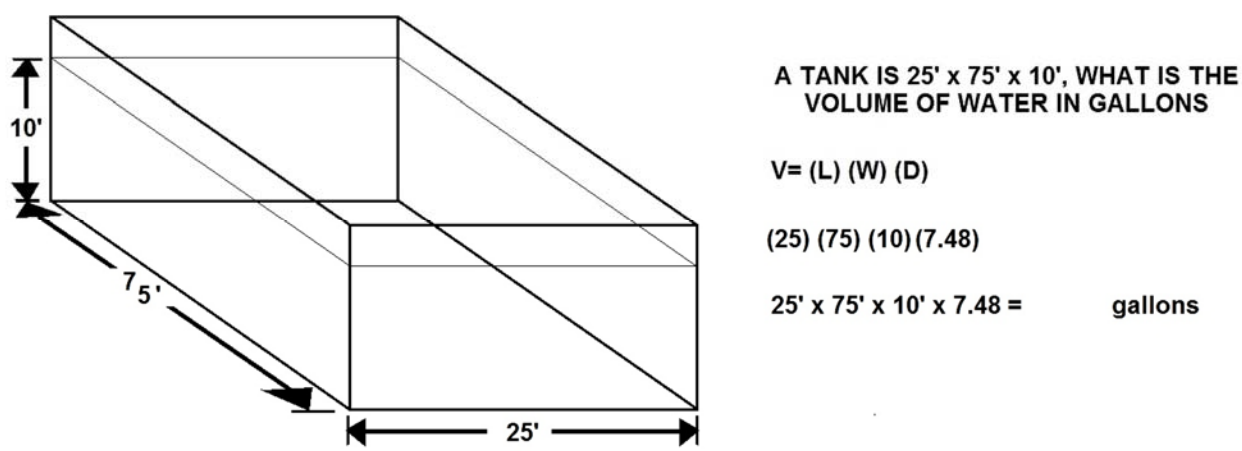
7. A tank is 6’ X 15’ x 7’ and can hold a maximum of ____________ gallons of water.

V= (L) (W) (D) X 7.48 =



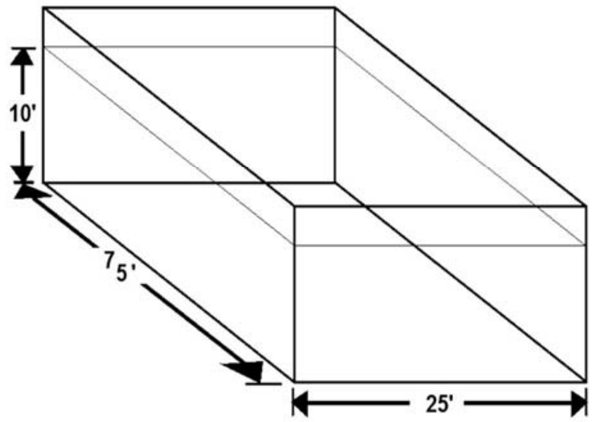
8. A tank is 25’ X 75’ X 10’ what is the volume of water in gallons?

V= (L) (W) (D) X 7.48 =



9. In Liters?

V= (L) (W) (D) X 7.48 =_________ X 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' x 75' x 10' x 7.48 = 46750 gallons

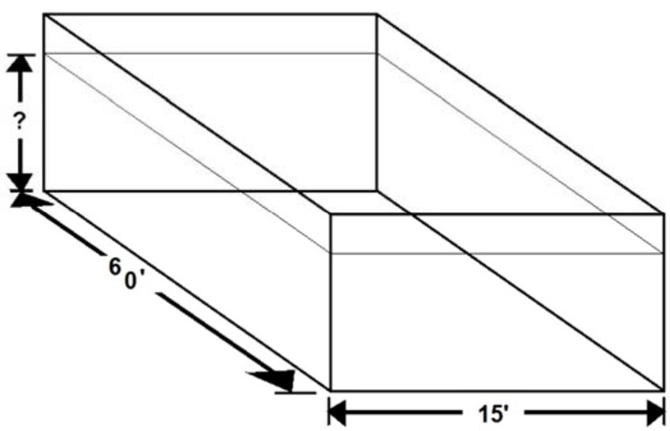
1 GALLON = 3.79 LITERS

V= (L) (W) (D) X 7.48= 46750 gallons X 3.79

V= Liters

10. A tank holds 67,320 gallons of water. The length is 60' and the width is 15'. How deep is the tank?

Gallons______ ÷ 7.48 = _______ 60 X 15 =



A TANK HOLDS 67,320 GALLONS OF WATER. THE LENGTH IS 60' AND THE WIDTH IS 15'. HOW DEEP IS THE TANK?

Gallons 67,320 / 7.48 = 9000 gal.

60' X 15' = 900 ft.

$\frac{9000 \text{ gal.}}{900 \text{ ft.}}$ = 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?

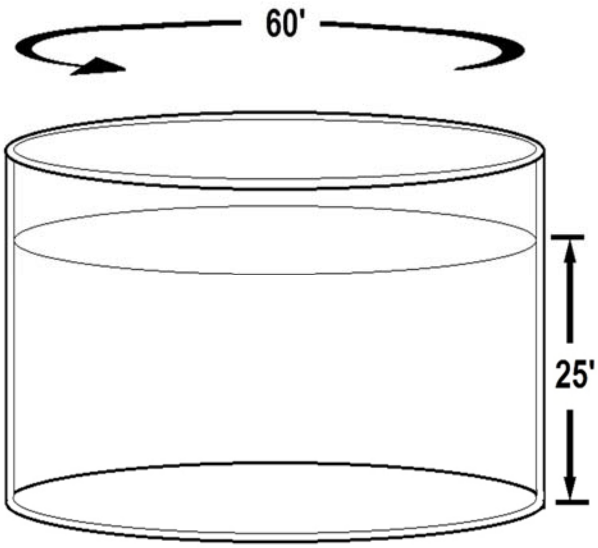
V= (L) (W) (D) X 7.48 =_________ X 3.785

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 X 60’ X 60’ X 25’ X 7.48 =



THE DIAMETER OF A TANK IS 60' AND A DEPTH OF 25'. HOW MANY GALLONS DOES IT HOLD.

V = (.785) (D2) (d)

.785 X 60 X 60 X 25 X 7.48 = 528,462 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
ft_3, feet 3, foot 3
feet3, foot3, ft_3
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.

$$\text{1 MG} = \frac{\text{100,000 Gallons}}{\text{24 Hours (fill time)}}$$

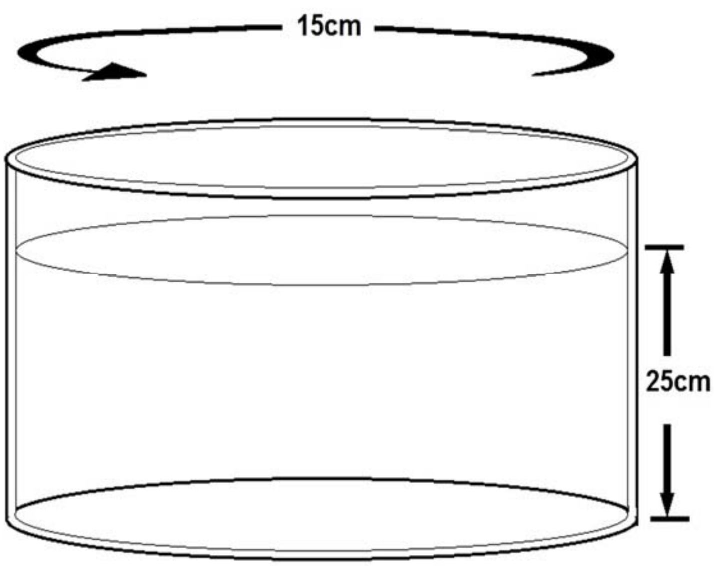
FILL TIME= 2.4 Hours

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?

2.54cm = 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 =



THE DIAMETER OF A TANK IS 15 Centimeters OR cm, WHAT IS THE VOLUME IN Liters.

2.54cm = 1 inch , 12 inches = 1 foot

15cm / 2.54cm / 12 inches = .492 feet

25cm / 2.54 / 12 inches = .82 feet

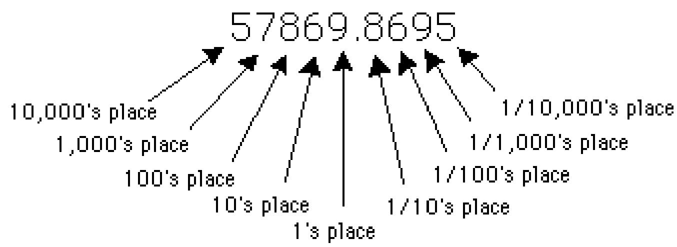
.785 X .492' X .492' X .82 X 7.48 = 1.17

1.17 X 3.785 Liters = 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:

.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 ÷ 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:

```
      .5
    -----
 10 ) 5.0
      5 0
    ----
```
So 5/10 (five tenths) = .5 (five tenths).

B. How about 1/2 (one half) or 1 divided by 2 ?
```
     .5
    -----
  2 ) 1.0
      1 0
      ----
```
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 ÷ 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:

$$Q(m^3/s) = A(m^2) \times V(m/s)$$

Or

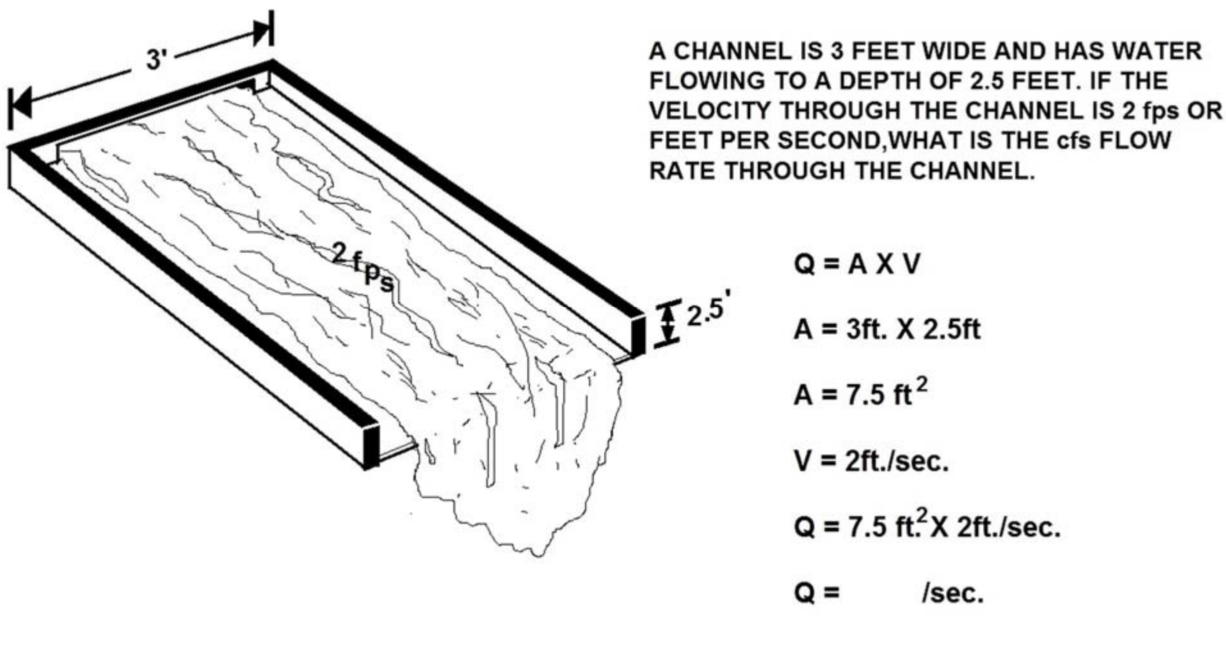
$$Q = A \times V$$

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 X V

Q = 7.5 sq. ft. X 2 fps *What is Q?*

A= 3' X 2.5' = 7.5
V= 2 fps

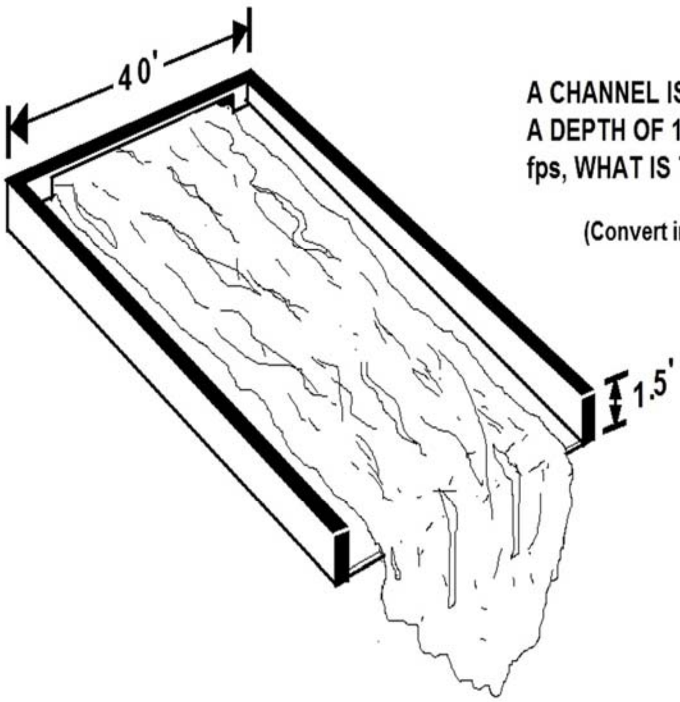


14. A channel is 40 inches wide and has water flowing to a depth of 1.5 ft. If the velocity of the water is 2.3 fps, what is the cfs flow in the channel? Q = A X V
First we must convert 40 inches to feet.

40 ÷ 12" = 3.333 feet

A = 3.333' X 1.5' = 4.999 or round up to 5
V = 2.3 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 X V

A = (40/12 = 3.33ft.) X (1.5ft)

A = 4.995 (Round to 5)

V = 2.3 ft/sec.

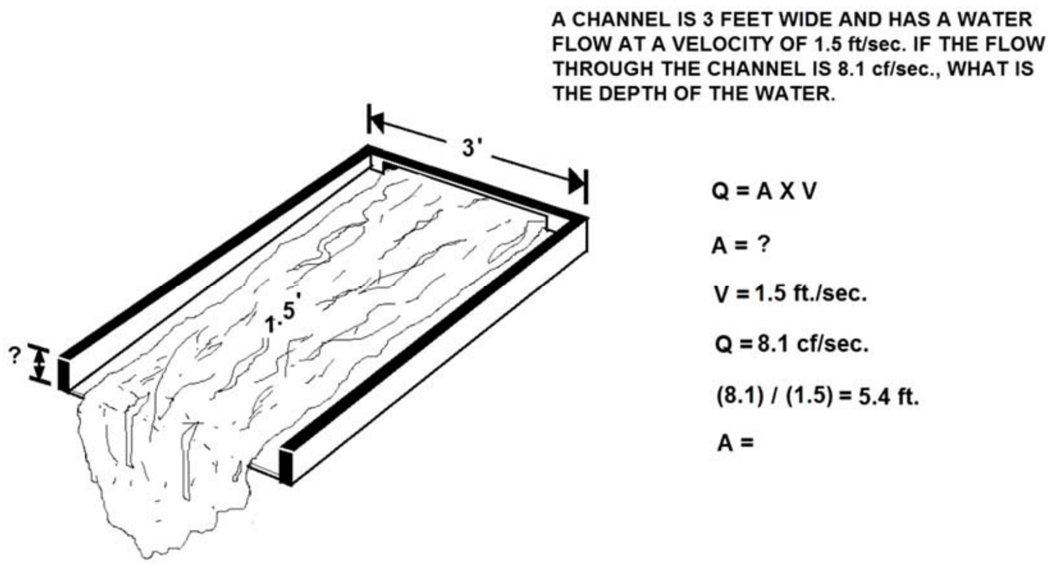
Q = 2.3 ft/sec. X 5ft

Q = 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?

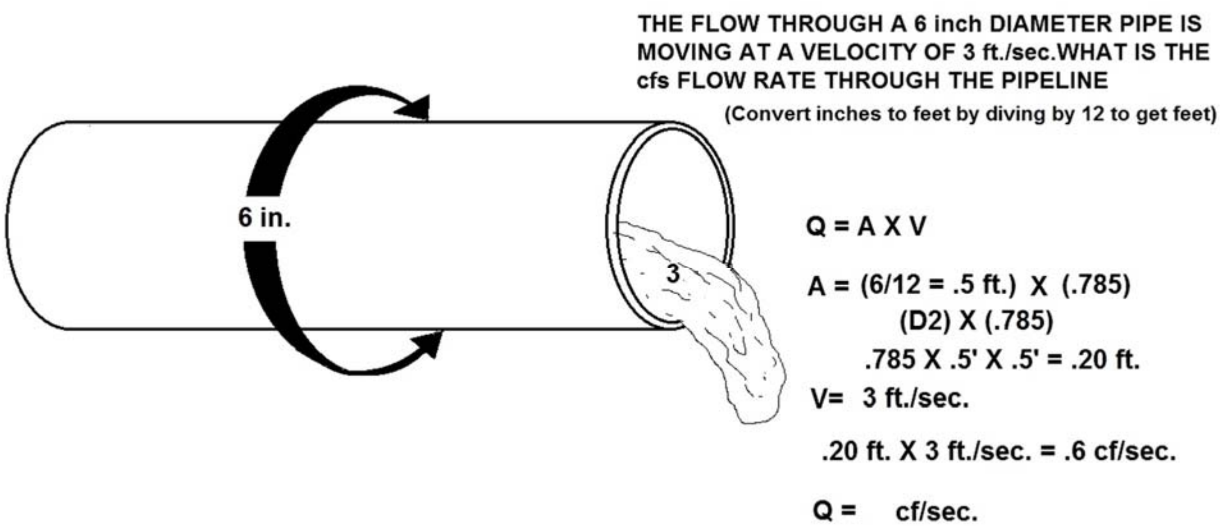
Q = 8.1 cfs
V = 1.5 fps
A = ?

8.1 ÷1.5 = _______ Total Area

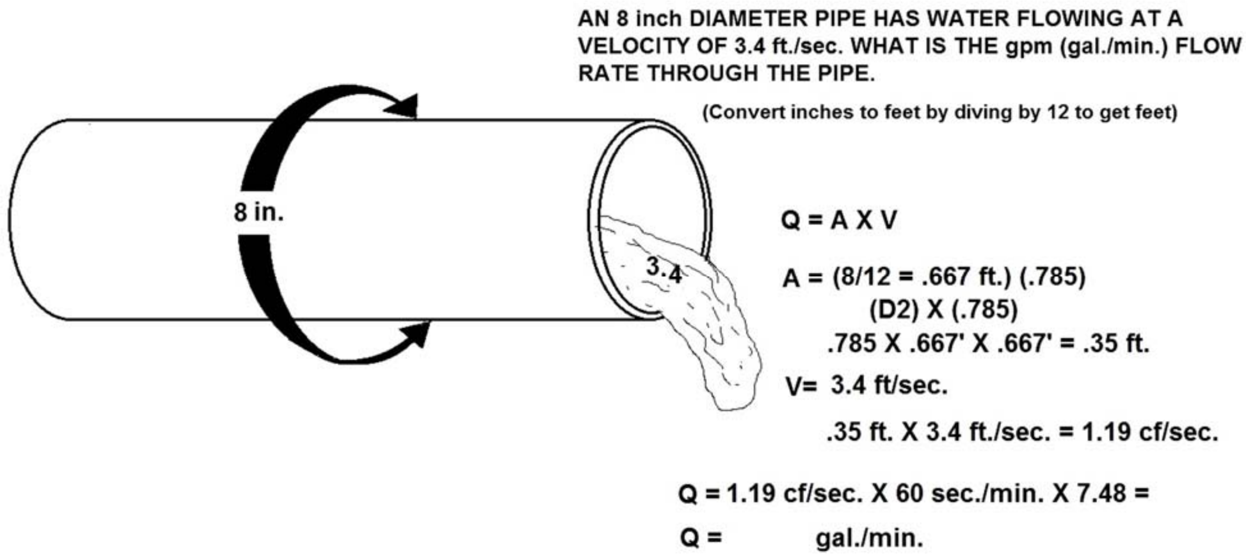


16. The flow through a 6 inch diameter pipe is moving at a velocity of 3 ft/sec. What is the cfs flow rate through the pipeline?

Q =
A = .785 X .5' X .5' =
V = 3 fps



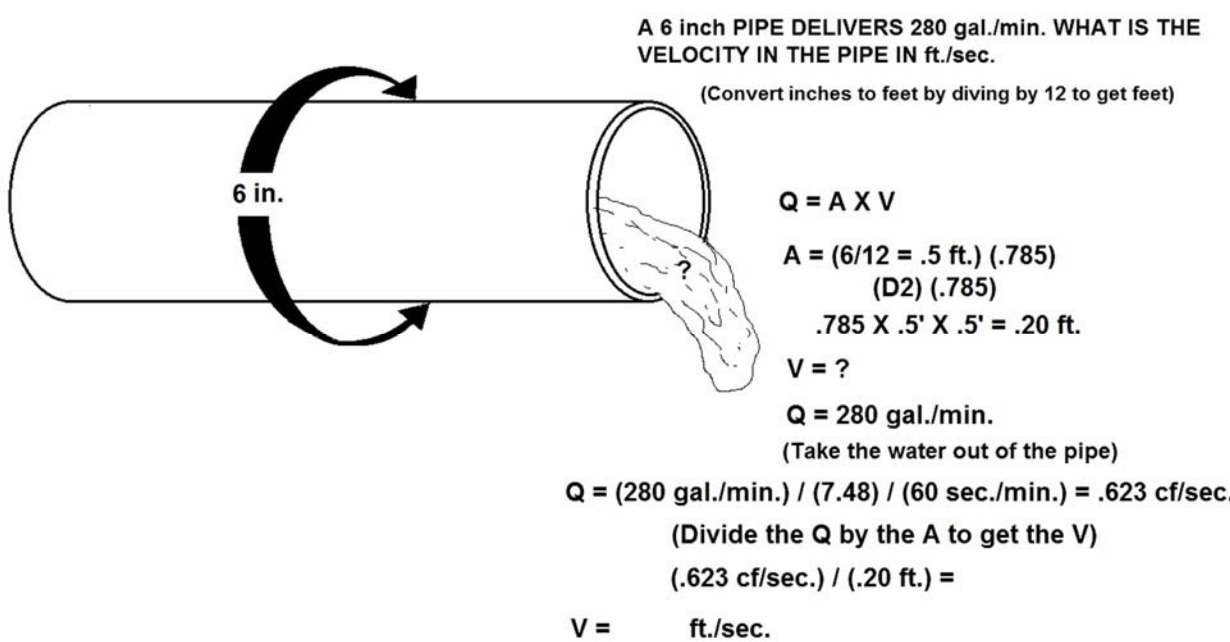
17. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?
Q = ______ cfs X 60 sec/min X 7.48 = ___________ gpm
A = .785 X .667' X .667'
V = 3.4 fps



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 gpm ÷ 7.48 ÷ 60 sec/min = ________ cfs

Q =
A = .785 X .5' X .5' =
V =



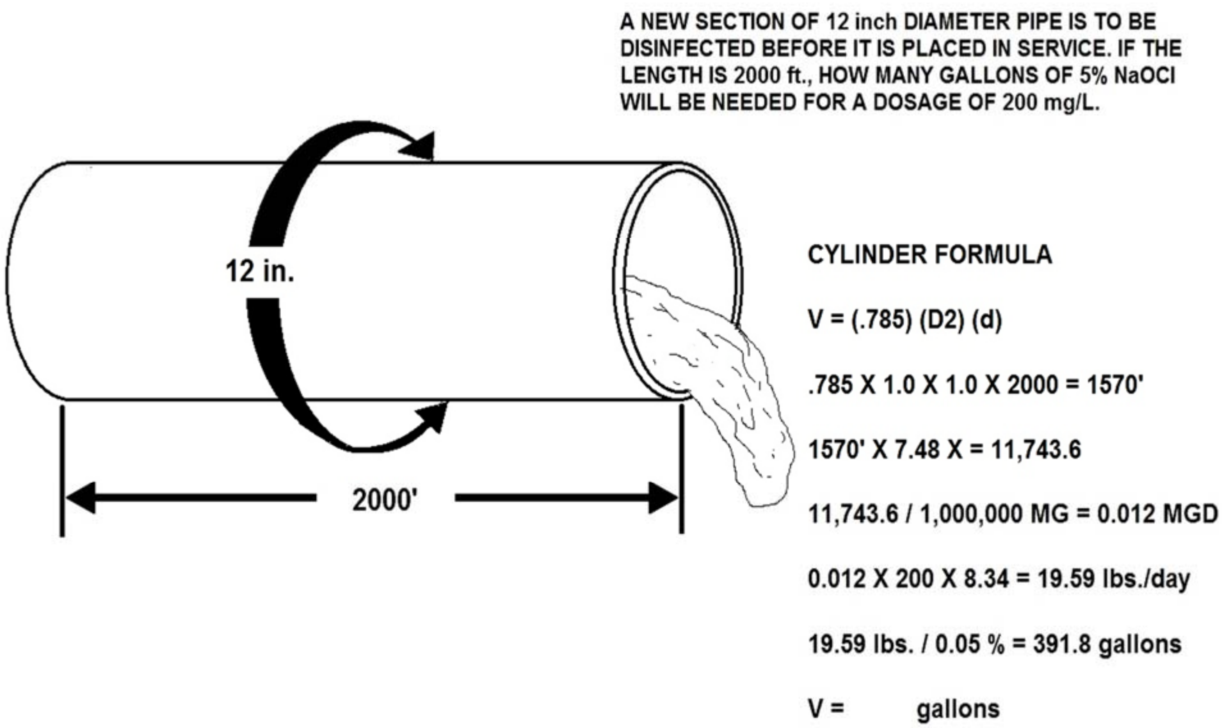
19. A new section of 12 inch diameter pipe is to be disinfected before it is placed in service. If the length is 2000 feet, how many gallons of 5% NaOCl will be needed for a dosage of 200 mg/L?

Cylinder Formula
V= (.785) (D^2) (d)

.785 X 1' X 1' X 2000' = ________ cu.ft. X 7.48 = _______ ÷ 1,000,000 = ____________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 MG X 200 mg/L X 8.34 =__________ lbs/day ÷ .05 =

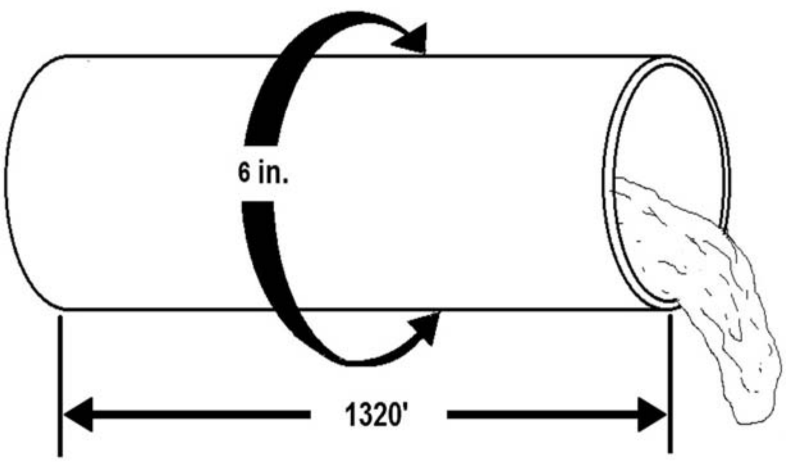


20. A section of 6 inch diameter pipe is to be filled with water. The length of the pipe is 1320 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 3 mg/L?

.785 X .5' X .5' X 1320' X 7.48 =_____________ 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) (D2) (d)

.785 X .5 X .5 X 1320 = 259.05

259.05 X 7.48 X = 1937.694

1937.694 / 1,000,000 MG = 0.002

0.002 X 3mg/L X 8.34 = 0.050 lbs/day

0.050 lbs. X .454 gram = 0.023 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?

Pounds per day formula = Flow X Dose X 8.34 X .454 Grams per pound

Chlorine Dose Example

$$\text{DOSE , mg/L} = \frac{(332)\quad \text{lbs. / day}}{(5.27)\quad \text{MGD x 8.34 lbs./mg/L/MG}}$$

$$\text{DOSE , mg/L} = (7.6)\ \text{mg/L}$$

DOSE CALCULATION EXAMPLE

Chlorine Residual Formula

$$\text{Dose, mg / L} = \text{Demand, mg / L} + \text{Residual, mg / L}$$

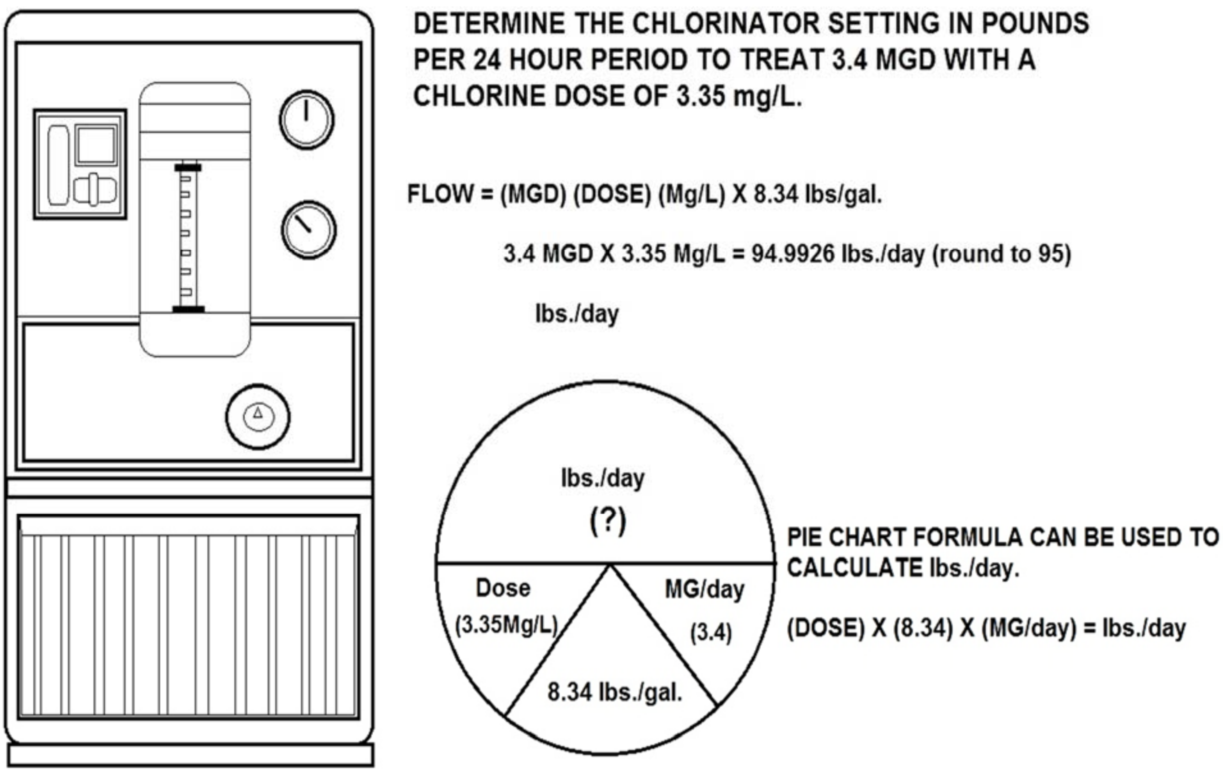
How To Calculate Chlorine Dose

$$(\text{mg / L } Cl_2)\ (\text{MGD flow})\ (8.34 \text{ lbs. / gal.}) = \text{lbs. / day } Cl_2$$

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.

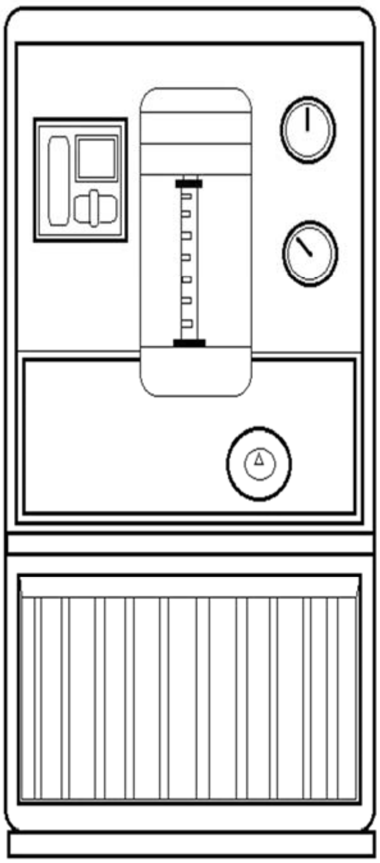
Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal



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.

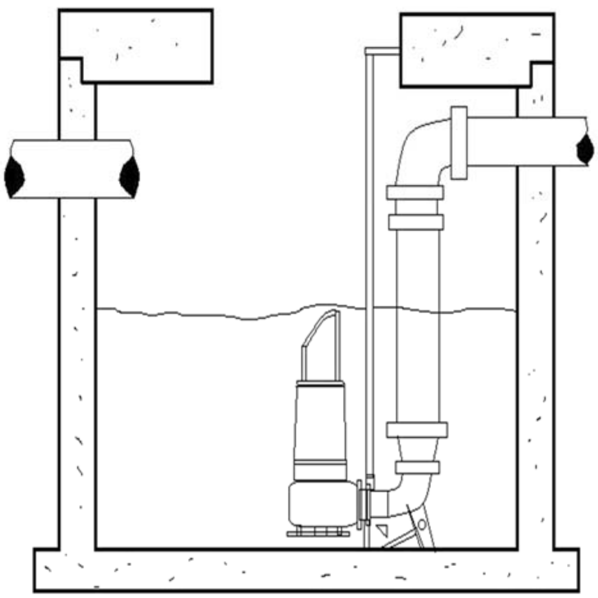
NOW CONVERT TO MGD: 122,400 divided by 1,000,000 = .1224 MGD.

.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) X (10) X (3) = 240 ft3
(CONVERT TO GALLONS: X 7.48)

240 ft3 X 7.48 = 1795.2 gals.

DETERMINE HOW MANY CYCLES IN 24 hrs.:
9 times hour X 24 hrs./day = 216 times/day.

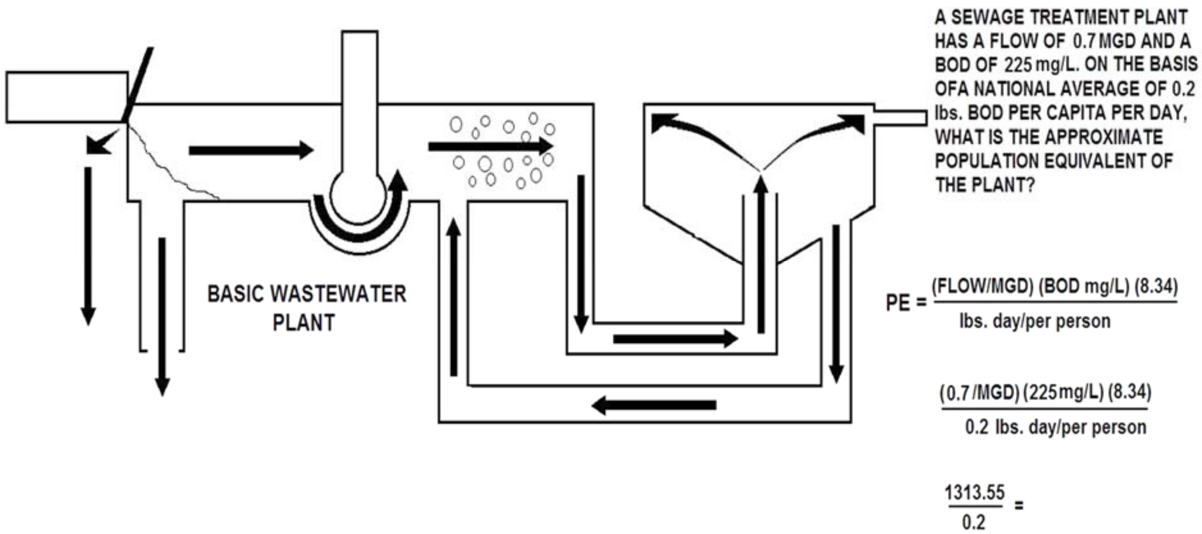
1795.2 gals. X 216 times/day = 387763.2 gals./day

CONVERT THIS TO MGD BY DIVIDING BY 1,000,000.

387763.2 gals./day / 1,000,000 = .388 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?

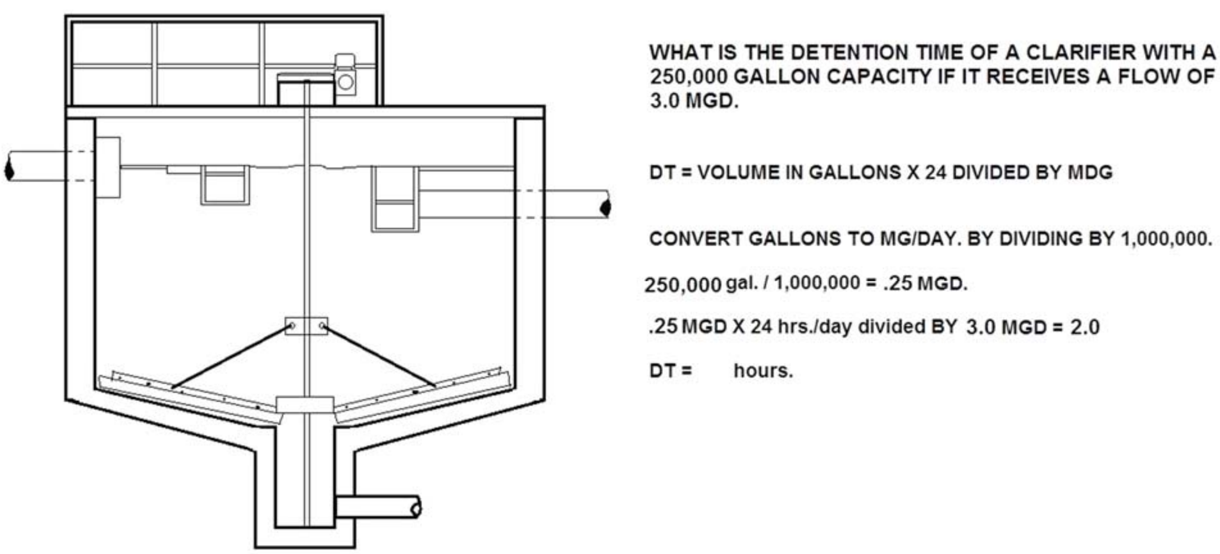


25. What is the detention time of a clarifier with a 250,000 gallon capacity if it receives a flow of 3.0 MGD?

DT= Volume in Gallons X 24 Divided by MGD

.25 MG X 24 hrs ÷ 3.0 MGD =________ Hours of DT

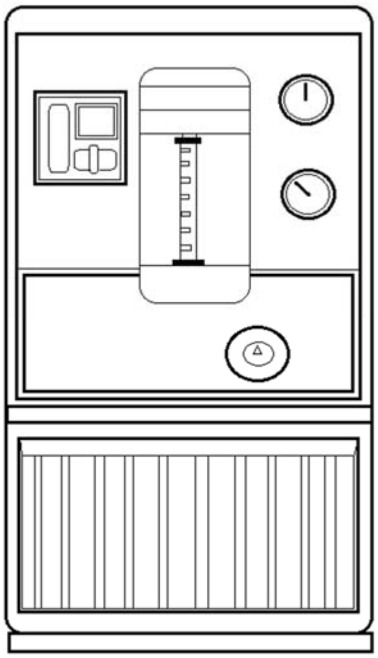
Always convert gallons to MG



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

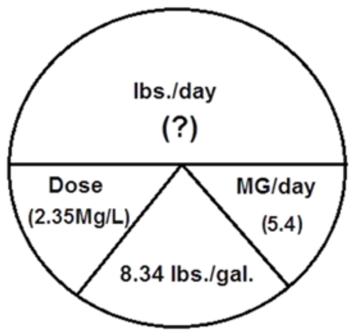


DETERMINE THE CHLORINATOR SETTING IN POUNDS PER 24 HOUR PERIOD TO TREAT 5.4 MGD WITH A CHLORINE DOSE OF 2.35 mg/L.

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)

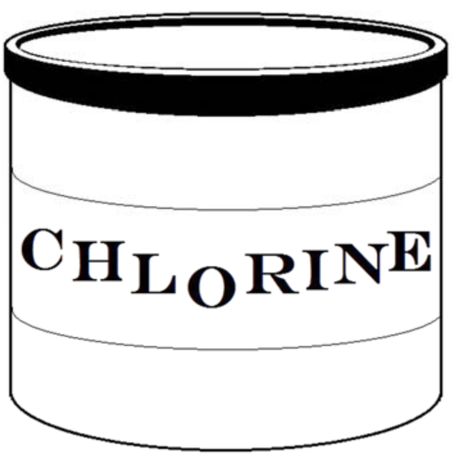
106 lbs./day



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

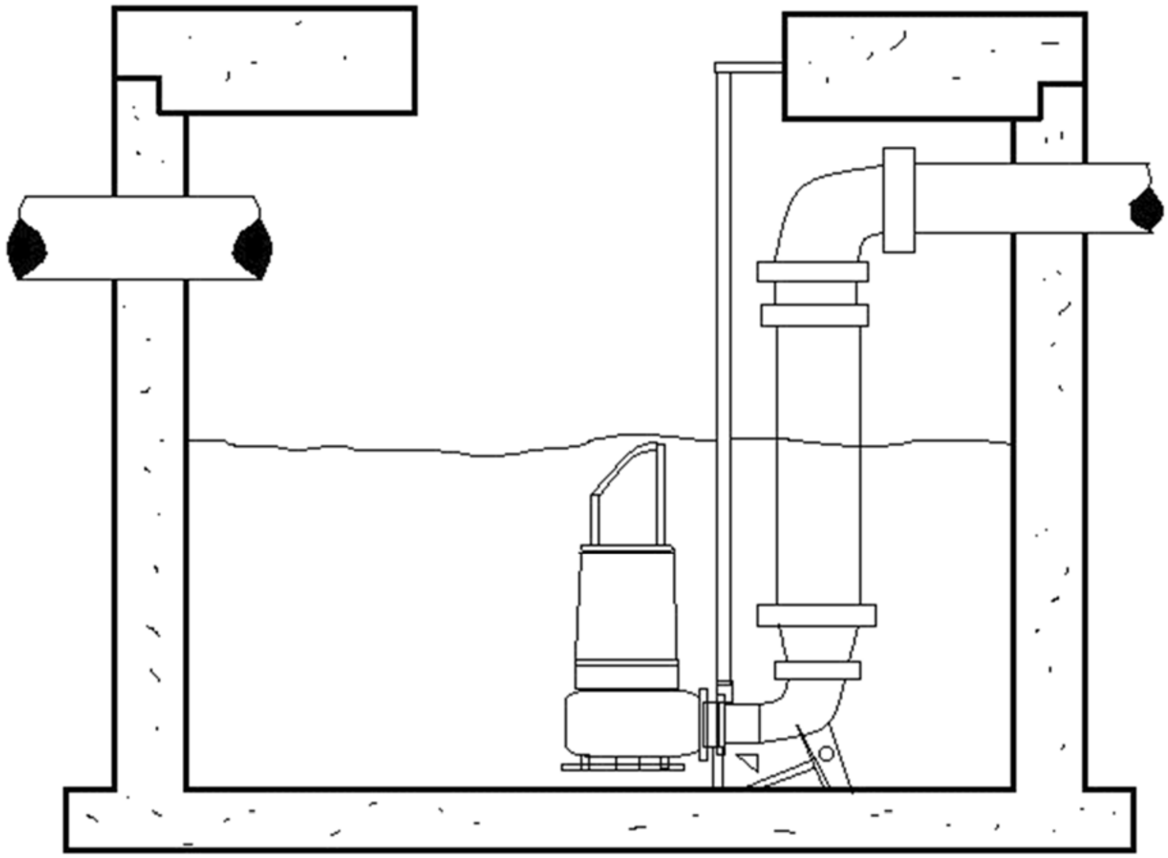
DIVIDE gal./day BY 1,000,000 TO GET MGD

10,080 / 1,000,000 = 0.010 MGD

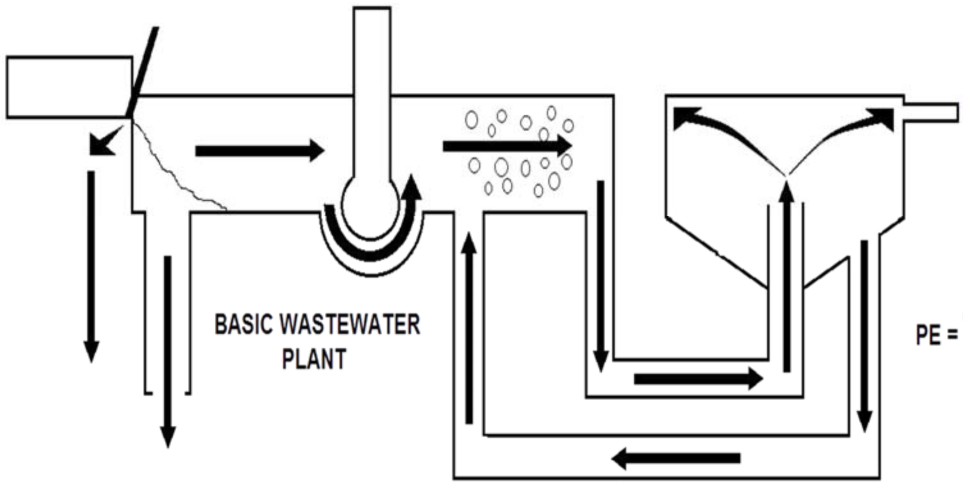
(0.010 MGD) (15 mg/L) (8.34 lbs./gal.) ($0.15/lb.) (365 days/year)= $68.49

$ 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 OFA NATIONAL AVERAGE OF 0.2 lbs. BOD PER CAPITA PER DAY, WHAT IS THE APPROXIMATE POPULATION EQUIVALENT OF THE PLANT?

$$PE = \frac{\text{(FLOW/MGD) (BOD mg/L) (8.34)}}{\text{lbs. day/per person}}$$

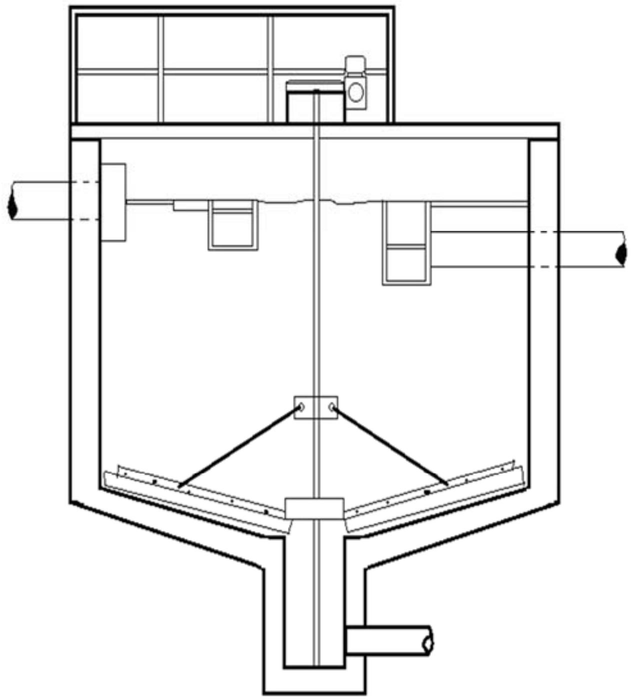
$$\frac{\text{(1.3 /MGD) (25 mg/L) (8.34)}}{\text{0.2 lbs. day/per person}}$$

$$\frac{271.5}{0.2} = 1355.25$$

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= Volume in Gallons X 24 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 = VOLUME IN GALLONS X 24 DIVIDED BY MDG

CONVERT GALLONS TO MG/DAY. BY DIVIDING BY 1,000,000.

750,000 gal. / 1,000,000 = .75 MGD.

.75 MGD X 24 hrs./day divided BY 10.0 MGD = 1.8

DT = 1.8 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)

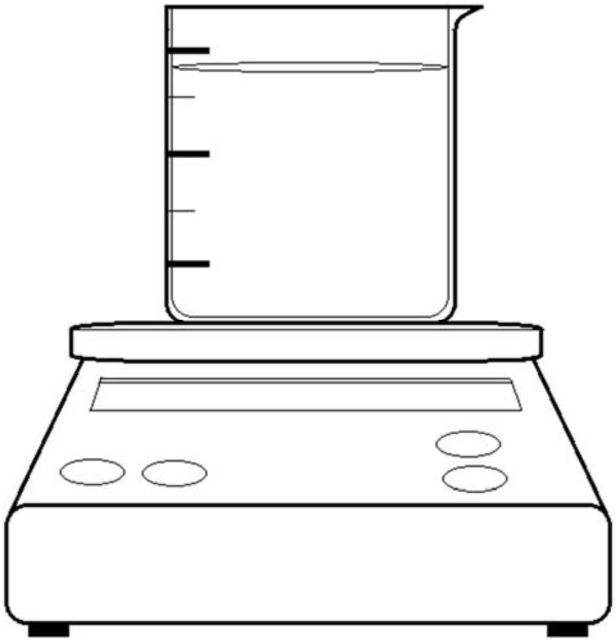
1 Liter of Water = 1,000,000 milligrams (1,000 X 1,000) (so)

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.



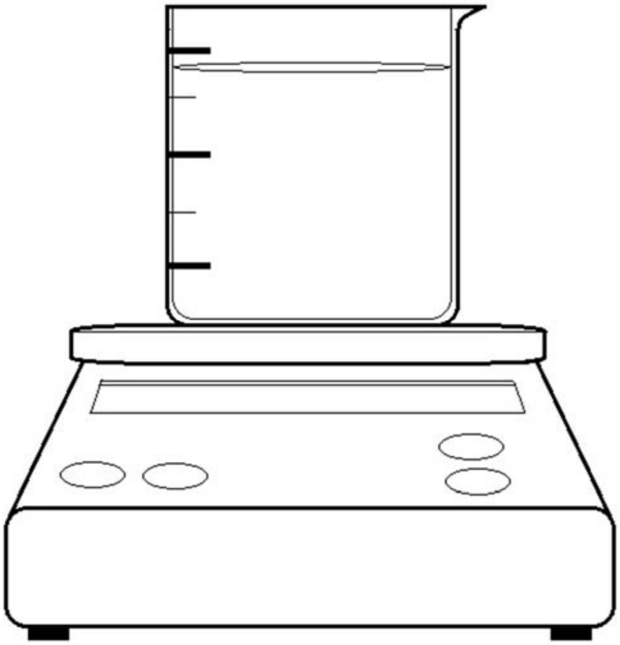
HOW MANY GRAM EQUAL 4,500mg.

Just divide by 1,000
(there are 1,000 mg in a gram)

$$\frac{4500}{1000} = \quad \textbf{Grams}$$

Practice Questions

A7. How many grams equal 7,500 mg?

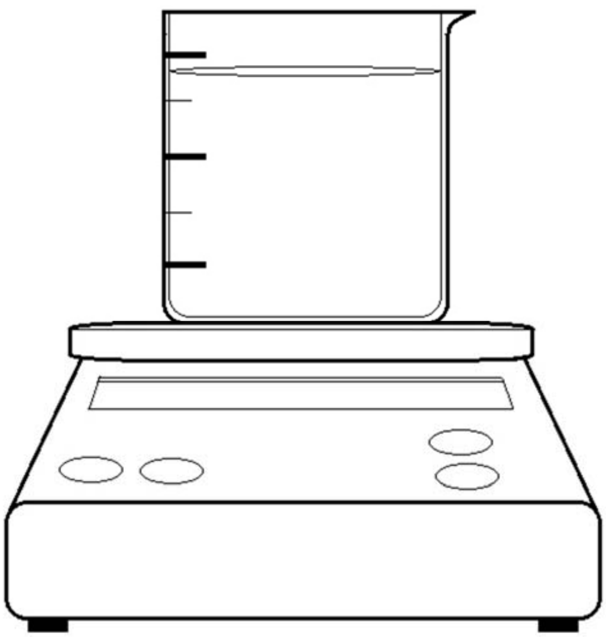


HOW MANY GRAM EQUAL 7,500mg.

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)

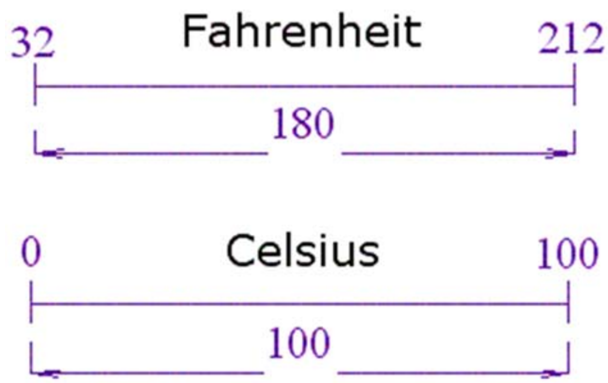
$$\frac{12500}{1000} = 12.5 \text{ Grams}$$

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

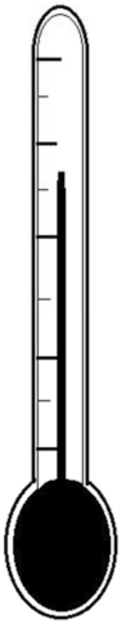
Note: 180/100 can be simplified to 9/5, and likewise 100/180=5/9.

$^{0}F = (0C \ X \ 9/5) + 32$ 9/5 =1.8

$^{0}C = (0F - 32) \ X \ 5/9$ 5/9 = .555

27. Convert 20 degrees Celsius to degrees Fahrenheit.

$$20^{o} \times 1.8 + 32 = F$$



CONVERT 20 degrees CELSIUS TO degrees FAHRENHEIT

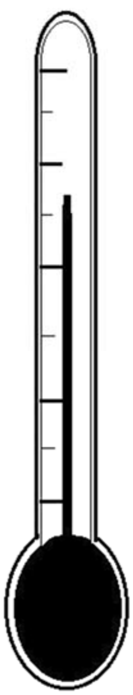
To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

(20) (1.8) + 32 = 68

20°C =

28. Convert 4 degrees Celsius to degrees Fahrenheit.

$$4^{o} \times 1.8 + 32 = F$$



CONVERT 4 degrees CELSIUS TO degrees FAHRENHEIT

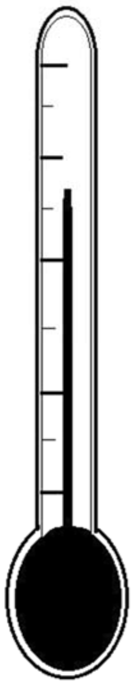
To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

(4) (1.8) + 32 = 39.2

4°C =

Practice Questions

A8. Convert 22 degrees Celsius to degrees Fahrenheit.



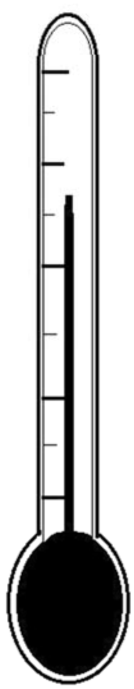
CONVERT 22 degrees CELSIUS TO degrees FAHRENHEIT

To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

$(22)\ (1.8) + 32 = 71.6$

$22^{\circ}C = 71.6^{\circ}F$

B8. Convert 2 degrees Celsius to degrees Fahrenheit.



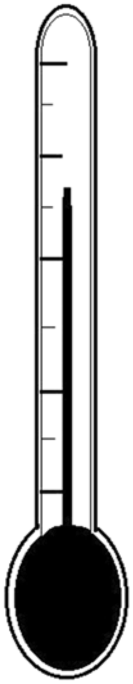
CONVERT 2 degrees CELSIUS TO degrees FAHRENHEIT

To convert Celsius to Fahrenheit:
Multiply degree Celsius by 1.8. Then add 32.

$(2)\ (1.8) + 32 = 35.6$

$2^{\circ}C = 35.6^{\circ}F$

C8. Convert 82 degrees Fahrenheit to degrees Celsius.



CONVERT 82 degrees FAHRENHEIT TO degrees CELSIUS

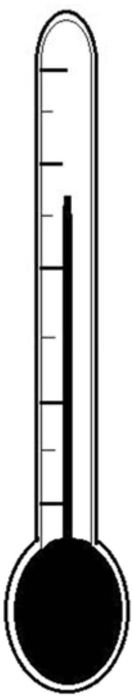
To convert Fahrenheit to Celsius :

First subtract by 32 then multiply by .555

$82 - 32 (.555) = 27.75$

$82^\circ F = 27.75^\circ C$

D8. Convert 33 degrees Fahrenheit to degrees Celsius.



CONVERT 33 degrees FAHRENHEIT TO degrees CELSIUS

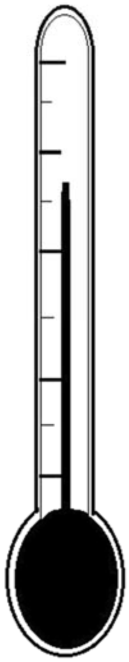
To convert Fahrenheit to Calsius :

First subtract by 32 then multiply by .555

$33 - 32 (.555) = .555$

$33^\circ F = .555^\circ C$

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

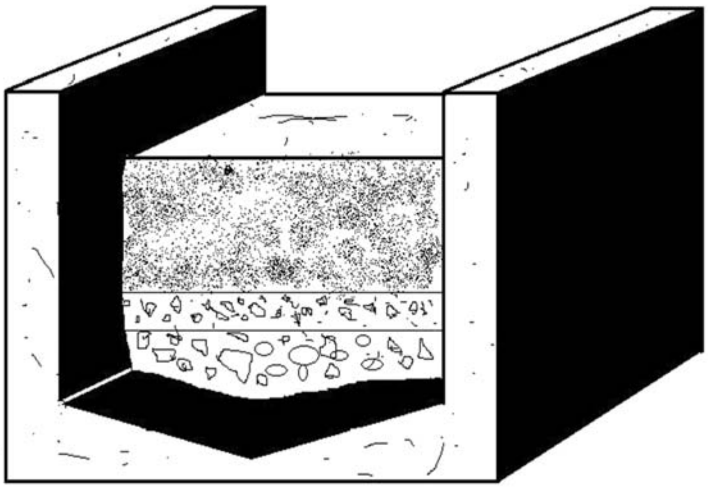
$$72 - 32\ (.555) = 22.2$$

$$72^{\circ}F = 22.2^{\circ}C$$

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



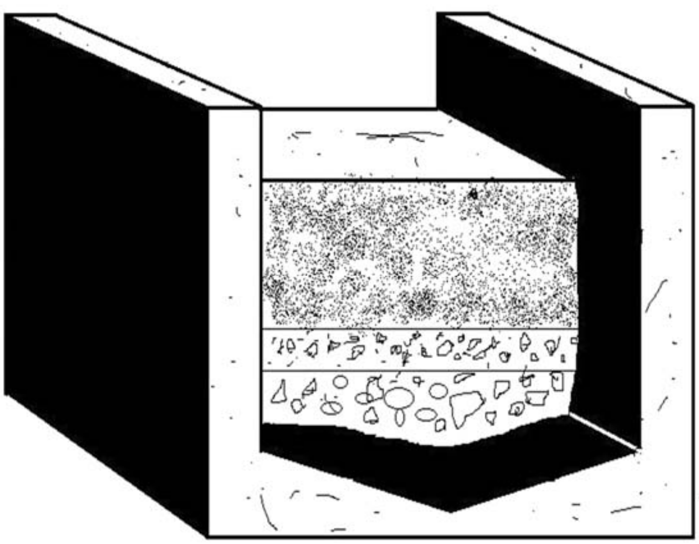
A 19 FOOT WIDE BY 31 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 2,050 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:
(W) (H)
(19) (31) = 598 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 INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

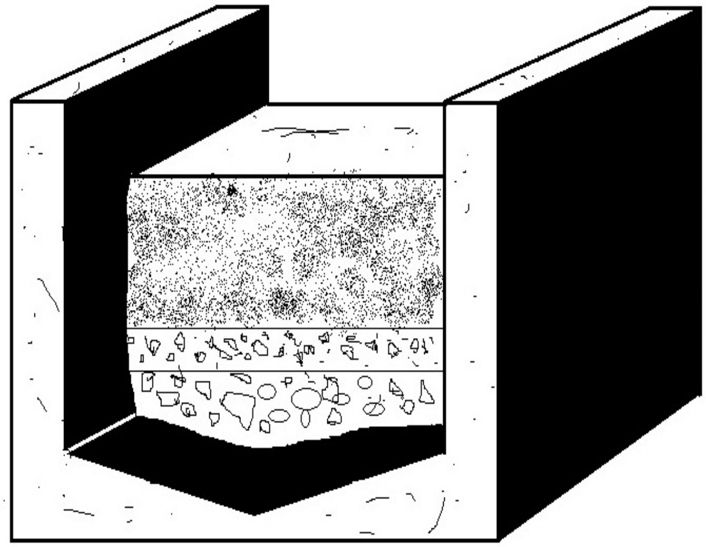
GPM divided by Square Feet

Determine Square Feet:
(W) (H)
(26) (36) = 936 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.



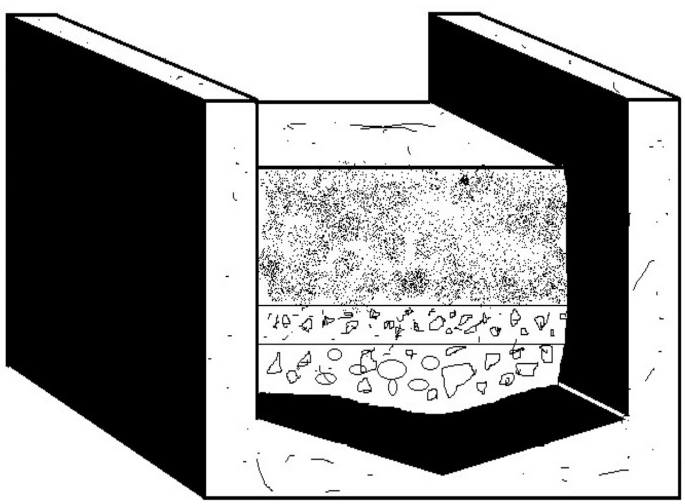
A 25 FOOT WIDE BY 25 FOOT LONG RAPID SAND FILTER TREATS A FLOW OF 300 gal/min. CALCULATE THE FILTRATION RATE INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:
(W) (H)
(25) (25) = 625 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 INGALLONS PER MINUTE PER SQUARE FOOT OF FILTER AREA.

GPM divided by Square Feet

Determine Square Feet:
(W) (H)
(30) (30) = 900 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

$51{,}500 \div 43{,}560 =$ _______ X 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

$$\text{GPD} = \frac{\text{GALLONS}}{\text{MINUTE}} \times \frac{\text{60 MINUTES}}{\text{HOUR}} \times \frac{\text{24 HOURS}}{\text{DAY}}$$

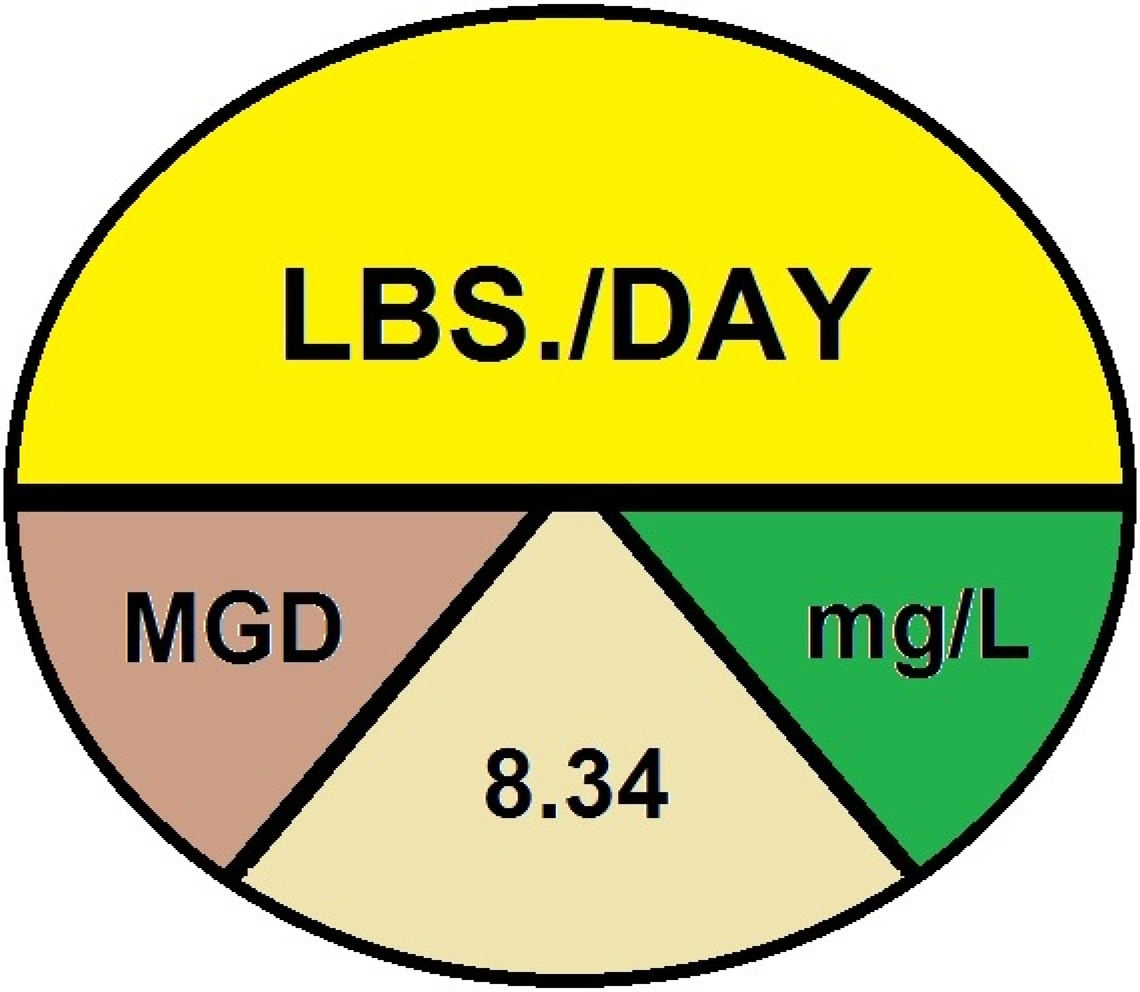
$$\text{GT} = \frac{\text{CHLORINE \% X 10,000}}{\text{1 PPM}}$$

$$\frac{\text{GPD}}{\text{GT}} = \text{GALLONS OF CHLORINE PER 24 HOURS}$$

GPD= Gallon Per Day
GT= Gallons Treated

$$(\text{mg / L } Cl_2)\ (\text{MGD flow})\ (8.34 \text{ lbs. / gal.}) = \text{lbs. / day } Cl_2$$

Formula To Convert : mg/L TO lbs./day



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 CFS x 60 Seconds x 7.48 GAL/CU.FT = 532 GPM
A = .785 X .667 X .667 X 1 = .349 Sq. Ft.
V= 3.4 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 GPM ÷ 60 seconds in a minute ÷ 7.48 gallons in a cu.ft. = .623 CFS

Q = .623
A = .785 X.5 X .5 =.196 Sq. Ft.
V = 3.17 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 ÷ 8.34 = 95.92 gallons
3. 1372320 or 1.3 MGD
4. 610 X 1441 = 878400 or 0.87 MGD
5. 550 ÷ 60 = 9.167 gpm
6. 9.167 X 3.785 = 34.697 Liters
7. 630 Area 4712.4 gallons
8. 18,750 cu. ft. X 7.48 = 140250 gallons
9. 177182.5
10. 10 feet deep
11. 528462 or .5 MG
12. 1.166 Gallons X 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

Math Exercise #1 **Answers in rear section.**

1. Calculate the SVI in a 0.5 MG aeration tank. The settable solids is 7% and the mixed liquor is 1,900 mg/l.

2. Determine the actual chemical feed in pounds per day from a dry chemical feeder. A bucket placed under the chemical feeder weighs 0.32 pounds empty and 2.15 pounds after 30 minutes.

3. To maintain satisfactory chlorine residual in a plant, the chlorine dose must be 10 mg/l when the flow is 0.37 MGD. Determine the feed rate in pounds per day.

4. Calculate the percent removal of a clarifier when the influent suspended solids is 12.4 ml/liter and the effluent is 0.5 ml/liter.

5. If the desired DO depletion is 4.0 mg/l in the BOD test and the expected BOD strength of the wastewater sample is 200 mg/l, how much of the sample should be added to the 300 ml BOD bottle?

6. The density of chlorine gas is 0.187 lb/ft3 and the density of air is 0.075 lb/ft3. What is the specific gravity of chlorine gas at Standard Temperature and Pressure?

7. To maintain a satisfactory chlorine residual in a plant's effluent, the chlorine dose must be 10 mg/l when the flow is 1,400 m^3/day. Determine the feed rate in kilograms per day.

8. Water weighs approximately 62.4 lb/ft^3. If the specific gravity of a load of copper sulfate crystals is 1.41, what is the density in lb/ft^3 of the copper sulfate crystals?

9. A chemical feed pump delivers 800 ml of a 1.5 percent polymer solution in five minutes. Calculate the amount delivered in pounds per day. Assume a specific gravity of the polymer solution of 1.0.

10. A flow rate of 4,300 m^3 per day is applied to a trickling filter. The filter is 15 meters in diameter and 1.2 meters deep. The BOD of the wastewater applied to the filter is 120 mg/l. Calculate the hydraulic loading on the filter.

11. A trickling filter is 100 ft. in diameter and 6 ft. deep. The raw sewage has a BOD of 230 mg/l and a flow rate of 0.5 MGD. The primary clarifier removes 35% of the BOD. Calculate the number of lbs. of BOD applied per yd^3 of filter media.

12. Determine the return activated sludge (RAS) flow in MGD when the influent flow is 7.5 MG (28,390 m3/day), the mixed liquor suspended solids (MLSS) are 2,000 mg/l and the SVI is 120.

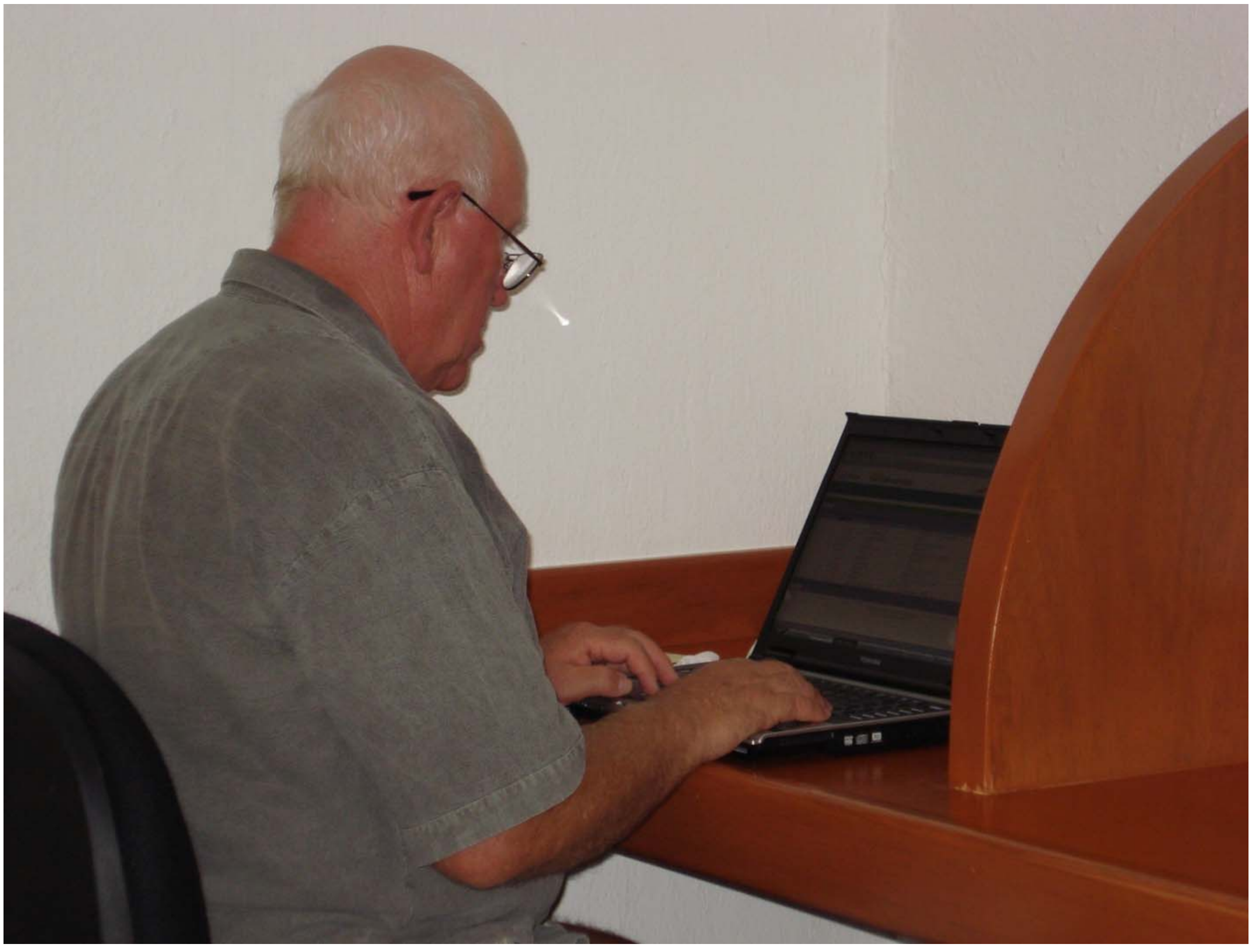
13. How many pounds of dry solids would be contained in 19,000 gallons of liquid sludge at 4% concentration?

14. How much of a 0.250 N stock sodium thiosulfate solution is required to prepare 1 liter of 0.025 N sodium thiosulfate for titrating dissolved oxygen samples?

15. Water weighs approximately 62.4 lb/ft^3. Specific gravity = density of substance / density of water. The weight of 3 ft^3 of Hg is 2,546 lb. What is the specific gravity of Hg.

Math Exercise #1 Answers

1. 37
2. 88 lbs./day
3. 31 lbs/day
4. 96%
5. 6.0 ml
6. 2.49
7. 14 kg/day
8. 87.98
9. 7.6 lbs polymer/day
10. 24 m^3/day/m^2
11. 0.36 lbs.
12. 2.4 MGD
13. 6,338 lbs
14. 100 ml
15. 13.6



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