

POINT-OF-USE WATER TREATMENT

PROFESSIONAL DEVELOPMENT COURSE

1st Edition



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Important Information about this Manual

This manual has been prepared to educate operators in the general education of valves, valve system design, valve operation, and hydraulic principles including basic mechanical training and different valve related applications. For most students, the study of valving and hydraulics is quite large, requiring a major effort to bring it under control.

This manual should not be used as a guidance document for employees who are involved with cross-connection control. It is not designed to meet the requirements of the United States Environmental Protection Agency (EPA) or the Department of Labor-Occupational Safety and Health Administration (OSHA) or your state environmental or health agency. Technical Learning College or Technical Learning Consultants, Inc. make no warranty, guarantee or representation as to the absolute correctness or appropriateness of the information in this manual and assumes no responsibility in connection with the implementation of this information.

It cannot be assumed that this manual contains all measures and concepts required for specific conditions or circumstances. This document should be used for educational purposes and is not considered a legal document. Individuals who are responsible for hydraulic equipment, cross-connection control, backflow prevention or water distribution should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, the EPA and other appropriate federal, state and local agencies.

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

Do not solely depend on TLC's Approval list for it may be outdated.

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

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

Responsibility

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

Technical Learning College's Scope and Function

Welcome to the Program,

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

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. TLC's distance based or independent study courses are offered in a print- based format and you are welcome to examine this material on your computer with no obligation. We will beat any other training competitor's price for the same CEU material or classroom training.

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

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

Flexible Learning

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

Course Structure

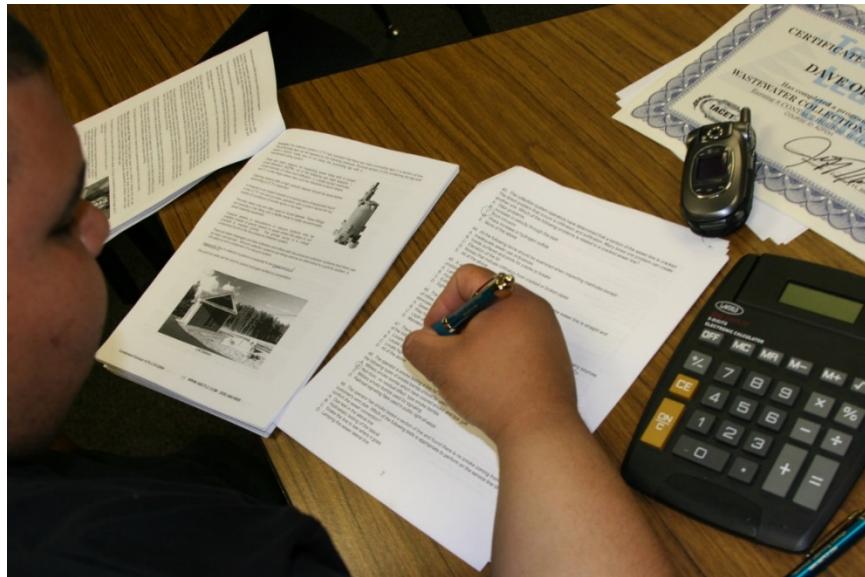
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student friendly course design allows you the most flexibility in choosing when and where you will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

Classroom of One

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

Satisfaction Guaranteed

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



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail.

If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of \$50.

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

CEU Course Description

Point-of-Use Water Treatment CEU Training Course

This course will review various point-of-use water treatment devices and methods including Ozone and Reverse Osmosis. This course will also cover water fundamentals/principles including chemistry and math. This course is general in nature and not state specific. 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).

CEU Course Goals

I. Water Familiarization

- A. Definitions
- B. Physical Description/Characteristics
- C. Hard Water Characteristics
- D. Alkalinity
- E. Chlorine and Halogens
- F. Arsenic Removal Technology



II. Types of Point-of-Use Treatment Methods

- A. Define Ozone
- B. Define Reverse Osmosis
- C. Define Distilled Water

III. Types of Filtration Methods

- A. Define Carbon Filtration
- B. Define Nanofiltration
- C. Define Hyperfiltration

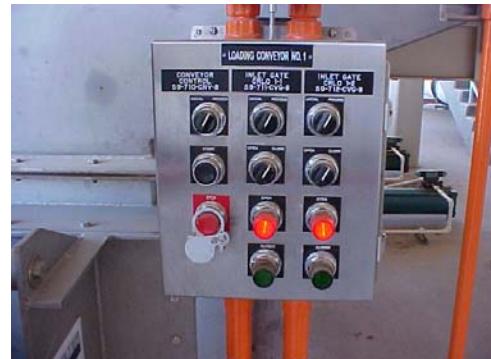
IV. Environmental Protection Agency

- A. Definitions
- B. Rules and Regulations
- C. Maximum Containment Levels (MCLs)

V. Program Review

- A. References
- B. Glossary

VI. Advanced water treatment application and competency



Prerequisites: None

Course Procedures for Registration and Support:

All of Technical Learning College 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 their social security number or a unique number will be assigned to the student.

Instructions for Written Assignments

The Point-Of-Use Water Treatment distance learning course uses a fill-in-the-blank and an essay style answer key.

You can write your answers in this manual or type out your own answer key. TLC would prefer that you type out and e-mail each of the chapter examinations to TLC, but it is not required.

Feedback Mechanism (examination procedures)

Each student will receive a feedback form as part of his or her study packet. You will be able to find this form in the rear of the course or lesson.

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 the 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 course will not require any other materials. This course comes complete. No other materials are needed.

Environmental Terms, Abbreviations, and Acronyms

TLC provides a glossary that defines in non-technical language commonly used environmental terms appearing in publications and materials. It also explains abbreviations and acronyms used throughout the EPA and other agencies. You can find the glossary this in the rear of the manual.

Recordkeeping and Reporting Practices

TLC will keep all student records for a minimum of seven years. It is your responsibility to give the completion certificate to the appropriate agencies. We will send the required information to Texas, Indiana and Pennsylvania 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.

You will have 90 days from receipt of this manual to complete the course in order to receive your Continuing Education Units (**CEUs**) or Professional Development Hours (**PDHs**). A score of 70 % is necessary to pass this course. If you should need any assistance, please email all concerns and the final test to info@tlch2o.com.

There are 100 total points possible for the course. This course will be graded on a "P" (credit) or "Z" (no credit) basis. If you desire a letter grade for this course, you must inform the instructor prior to submitting any of the assignments.

Credit/no credit option (**P/Z**) - None Available

Note to students: Keep a copy of everything that you submit. That way if your work is lost you can submit your copy for grading. If you do not receive your graded assignment or quiz results within two or three weeks after submitting it, please contact your instructor.

We expect every student to produce his/her original, independent work. Any student whose work indicates a violation of the Academic Misconduct Policy (cheating, plagiarism) can expect penalties as specified in the Student Handbook, which is available through Student Services; contact them at (928) 468-0665.

A student who registers for a Distance Learning course is assigned a "**start date**" and an "**end date**." It is the student's responsibility to note due dates for assignments and to keep up with the course work.

If a student falls behind, she/he must contact the instructor and request an extension of her/his **end date** in order to complete the course.

It is the prerogative of the instructor to decide whether to grant the request.

You will have 90 days from receipt of this manual to complete in order to receive your Continuing Education Units (**CEUs**) or Professional Development Hours (**PDHs**). A score of 70 % is necessary to pass this course.

If you should need any assistance, please email all concerns and the final test to info@tlch2o.com.

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 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.

Course Objective: To provide education in effective and efficient **Point-of-Use Water Treatment** methods and related procedures.



Reverse Osmosis and Nano filtration processes work in a similar way to an extremely fine filter but use a "**membrane**" to remove atoms which are larger than water molecules. The mechanism requires sophisticated pumping and control. RO is therefore used to remove a wide range of contaminants, typically salts, hardness and large organic molecules where a very high level of purity is required. It is, of course, more expensive than conventional filtration and is used only where high purity is essential.

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Important Information about this Manual

This manual has been prepared to educate operators in the general awareness of dealing with the often-complex and various water treatment devices and methods.

This manual will cover general laws, regulations, required procedures and accepted policies relating to point-of-use water treatment devices. It should be noted, however, that the regulation of water treatment and hazardous materials is an on going process and subject to change over time. For this reason, a list of resources is provided to assist in obtaining the most up-to-date information on various subjects.

This manual is not a guidance document for operators who are involved with water treatment. It is not designed to meet the requirements of the United States Environmental Protection Agency or your local State environmental protection agency or health department.

This course manual will provide general Point-of-Use Water Treatment awareness and should not be used as a basis for water treatment methods/devices guidance. This document is not a detailed plumbing code or a source or remedy for water treatment or water quality improvement.

Technical Learning College or Technical Learning Consultants, Inc. make no warranty, guarantee or representation as to the absolute correctness or appropriateness of the information in this manual and assumes no responsibility in connection with the implementation of this information. It cannot be assumed that this manual contains all measures and concepts required for specific conditions or circumstances.

This document should be used for educational purposes only and is not considered a legal document. Individuals who are responsible for water treatment, water quality and water distribution should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with the EPA and other appropriate federal, state and local agencies.

Point-of-Use Water Treatment Introduction

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

The treatment needs of a water system are likely to differ depending on whether the system uses a groundwater or surface water source. Common surface water contaminants include turbidity, microbiological contaminants (**Giardia**, viruses and bacteria) and low levels of a large number of organic chemicals.

Groundwater contaminants include naturally occurring inorganic chemicals (such as arsenic, fluoride, radium, radon and nitrate) and a number of volatile organic chemicals (**VOCs**) that have recently been detected in localized areas. When selecting among the different treatment options, the water supplier must consider a number of factors. These include regulatory requirements, characteristics of the raw water, configuration of the existing system, cost, operating requirements and future needs of the service area. In recent years, the public has shown increasing interest in installing special devices on their water service to further treat water supplied to them by a public water system. One reason is that they are not satisfied with the aesthetic qualities of the water, such as hardness, taste, and odor, and wish to improve the quality for their own use.

Another major reason is fear that the water is harmfully contaminated. This idea is fostered primarily by media stories of water contamination at specific locations and advertising by some bottled water and point-of-use device companies. Home treatment devices are also widely used by owners of private wells to improve water quality. All of this public interest in improving water quality has led to many new companies entering the field of providing small treatment units.

Aesthetic Objectives

Certain contaminants, such as iron and manganese, impart undesirable qualities to drinking water but do not represent a health threat. These are classified as secondary contaminants and do not have enforceable maximum contaminant levels.



Using titration to check the chlorine level, you can also use the DPD method which will be discussed later.

POU Terminology

It is necessary to define the terms associated with these treatment devices. The term home drinking water treatment is fairly descriptive of the field. It covers the vast majority of uses, but many individual treatment devices are also installed in factories, offices, and other buildings. There is a need to differentiate between units installed to treat all of the water at a building and those at just one water tap, so the following definitions have come into general use.

Point-of-Entry (POE) devices are treatment units that are connected so they treat all of the water entering a building. A common example is a water softener installed to treat all of the water used in a building.

Point-of-Use (POU) devices are units connected to treat water at a single location in a building. POU devices can be further subdivided into the following categories:

- **Stationary.** An example is a treatment unit mounted under a kitchen sink to treat all water to the cold-water faucet.
- **Line bypass.** An example is a treatment unit, mounted under a kitchen sink, that takes water from the cold-water pipe but delivers into a separate, third faucet.
- **Countertop.** This generally refers to a small treatment unit that rests on the counter near the sink and is connected to the regular faucet by a hose when it is needed.
- **Faucet mounted.** This refers to a small treatment units that are clamped on the spout of the regular faucet. These units usually have a bypass valve to select either treated or untreated water.
- **Pour-through.** These are portable, self-contained units, similar to a coffee maker. Water is poured through the unit for treatment.

Before we go in to detail about treatment let's examine water quality including pathogens and disinfection.



Small RO commercial unit

POU Definitions Larger Glossary in the rear.

As used in EPA's 40 CFR 141, the term:

Best available technology or BAT means the best technology, treatment techniques, or other means which the Administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking cost into consideration). For the purposes of setting MCLs for synthetic organic chemicals, any BAT must be at least as effective as granular activated carbon.

Community water system is a public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

Compliance cycle is the nine-year calendar year cycle during which public water systems must monitor. Each compliance cycle consists of three three-year compliance periods. The first calendar year cycle begins January 1, 1993 and ends December 31, 2001; the second begins January 1, 2002 and ends December 31, 2010; the third begins January 1, 2011 and ends December 31, 2019.

Compliance period is a three-year calendar year period within a compliance cycle. Each compliance cycle has three three-year compliance periods. Within the first compliance cycle, the first compliance period runs from January 1, 1993 to December 31, 1995; the second from January 1, 1996 to December 31, 1998; the third from January 1, 1999 to December 31, 2001.

Contaminant is any physical, chemical, biological, or radiological substance or matter in water.

Maximum contaminant level is the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

Maximum contaminant level goal or MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. Maximum contaminant level goals are non-enforceable health goals.

Non-transient non-community water system or NTNCWS is a public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year.

Point-of-entry treatment device (POE) is a treatment device applied to the drinking water entering a house or building for the purpose of reducing contaminants in the drinking water distributed throughout the house or building.

Point-of-use treatment device (POU) is a treatment device applied to a single tap used for the purpose of reducing contaminants in drinking water at that one tap.

Public water system is a system for the provision to the public of water for human consumption through pipes or, after August 5, 1998, other constructed conveyances, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. Such term includes: any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system; and any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. Such term does not include any "**special irrigation district**."

A public water system is either a "**community water system**" or a "**noncommunity water system**."

State means the agency of the State or Tribal government which has jurisdiction over public water systems. During any period when a State or Tribal government does not have primary enforcement responsibility pursuant to section 1413 of the Act, the term "**State**" means the Regional Administrator, of the U.S. Environmental Protection Agency.

Surface water means all water which is open to the atmosphere and subject to surface runoff.



Ion Exchange Units

New EPA Rules

Arsenic

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

To protect human health, an EPA standard limits the amount of arsenic in drinking water. In January 2001, EPA revised the standard from 50 parts per billion (**ppb**), ordering that it fall to 10 ppb by 2006. After adopting 10ppb as the new standard for arsenic in drinking water, EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits. In October 2001, the EPA decided to move forward with implementing the 10ppb standard for arsenic in drinking water. More information on the rulemaking process and the costs and benefits of setting the arsenic limit in drinking water at 10ppb can be found at www.epa.gov/safewater/arsenic.html.



ICR

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



Gathering a water sample in the distribution system

Microbes



Bac-T bottles, once the laboratory obtains the sample, they will use colilert to find the presence of bacteria. The yellow color indicates Coliform bacteria is present. If the sample fluoresces under a black light, this will indicate that the sample will contain fecal or E. Coli bacteria.

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

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

Turbidity has no health effects. However, turbidity can interfere with disinfection and provide a medium for microbial growth. Turbidity may indicate the presence of disease causing organisms. These organisms include bacteria, viruses, and parasites that can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.

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

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

Radionuclides

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

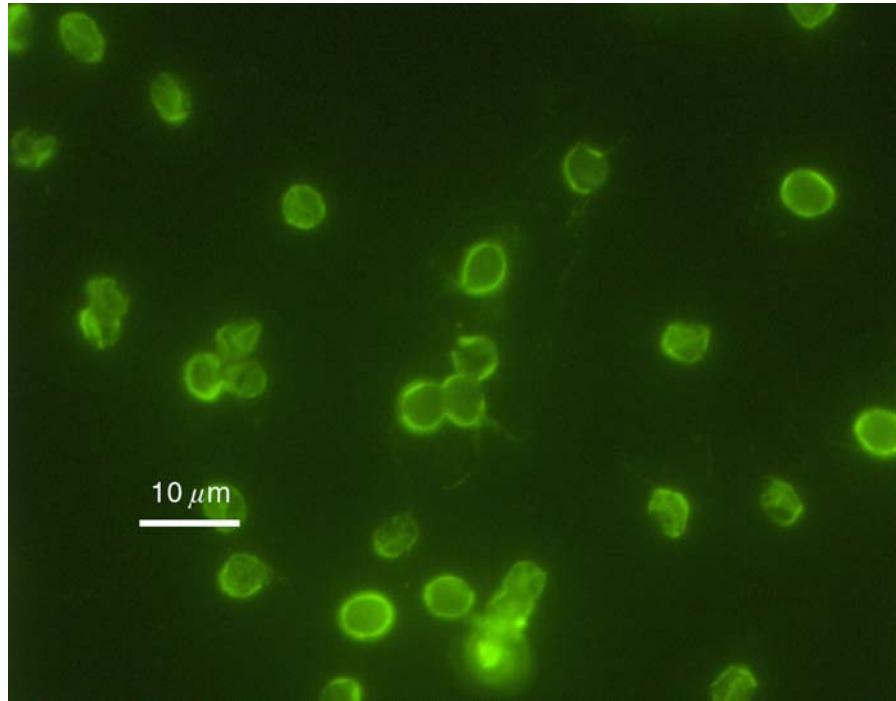
Beta/photon Emitters. Certain minerals are radioactive and may emit forms of radiation known as photons and beta radiation. Some people who drink water containing beta and photon emitters in excess of the EPA's standard over many years may have an increased risk of getting cancer.

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

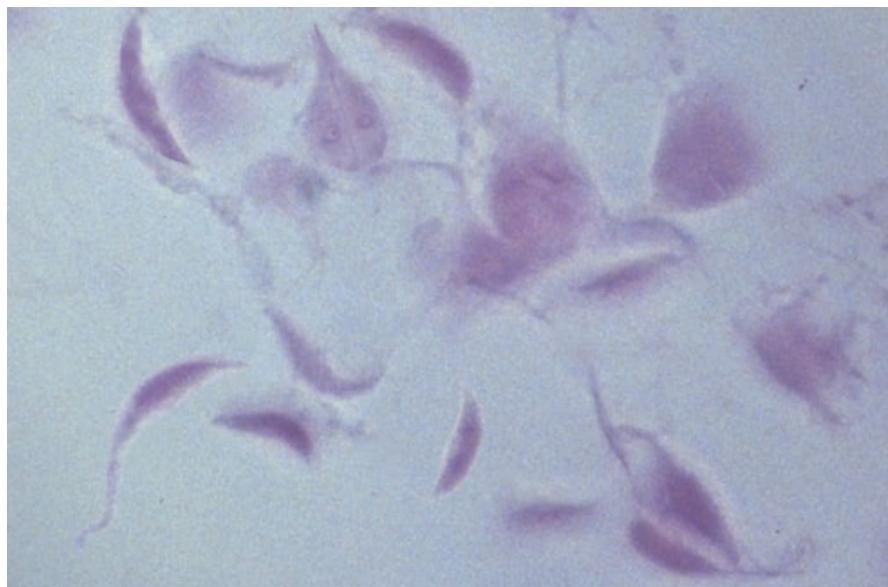
Radon gas can dissolve and accumulate in underground water sources, such as wells, and in the air in your home. Breathing radon can cause lung cancer. Drinking water containing radon presents a risk of developing cancer. Radon in air is more dangerous than radon in water.



Legionella



Cryptosporidium



Giardia

Disinfection Byproduct Regulations

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

Total trihalomethanes (TTHM)	80 parts per billion (ppb)
Haloacetic acids (HAA5)	60 ppb
Bromate	10 ppb
Chlorite	1.0 parts per million (ppm)

Currently trihalomethanes are regulated at a maximum allowable annual average level of 100 parts per billion for water systems serving over 10,000 people under the Total Trihalomethane Rule finalized by the EPA in 1979. The **Stage 1 Disinfectant/Disinfection Byproduct Rule** standards became effective for trihalomethanes and other disinfection byproducts listed above in December 2001 for large surface water public water systems. Those standards will become effective in December 2003 for small surface water and all ground water public water systems.

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

Trihalomethanes (THM) are a group of four chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The trihalomethanes are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate total trihalomethanes (**TTHM**) at a maximum allowable annual average level of **80 parts per billion**. This standard did replace the current standard of a maximum allowable annual average level of 100 parts per billion in December 2001 for large surface water **public water systems**. The standard will become effective for the first time in December 2003 for small surface water and all ground water systems.

Haloacetic Acids (HAA5) are a group of chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The regulated haloacetic acids, known as HAA5, are: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate HAA5 at **60 parts per billion** annual average.

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

Bromate

Bromate is a chemical that is formed when ozone used to disinfect drinking water reacts with naturally occurring bromide found in source water. The EPA has established the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate bromate at an annual average of **10 parts per billion** in drinking water. This standard became effective for large **public water systems** December 2001 and for small surface water and all ground public water systems in December 2003.

Chlorite is a byproduct formed when chlorine dioxide is used to disinfect water. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate chlorite at a monthly average level of 1 part per million in drinking water. This standard became effective for large surface water **public water systems** in December 2001 and small surface water and all ground water public water systems in December 2003.

Microbial Regulations

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

The **Interim Enhanced Surface Water Treatment Rule** was established in December 1998 to control **Cryptosporidium**, and to maintain control of pathogens while systems lower disinfection byproduct levels to comply with the **Stage 1 Disinfectants/Disinfection Byproducts Rule**. EPA established a Maximum Contaminant Level Goal (**MCLG**) of zero for all public water systems and a 99% removal requirement for Cryptosporidium in filtered public water systems that serve at least 10,000 people. The new rule tightened turbidity standards in December 2001. Turbidity is an indicator of the physical removal of particulates, including pathogens.

The EPA is also planning to develop other rules to further control pathogens. The EPA promulgated a Long Term 1 Enhanced Surface Water Treatment Rule, for systems serving fewer than 10,000 people, in November 2000 to improve physical removal of **Cryptosporidium**, and to maintain control of pathogens while systems comply with **Stage 1 Disinfectants/Disinfection Byproducts Rule**.

Inorganic Contaminants

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

Inorganic Contaminants

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

Fluoride Many communities add fluoride to their drinking water to promote dental health. Each community makes its own decision about whether or not to add fluoride. The EPA has set an enforceable drinking water standard for fluoride of 4 mg/L (some people who drink water containing fluoride in excess of this level over many years could get bone disease, including pain and tenderness of the bones).

The EPA has also set a secondary fluoride standard of 2 mg/L to protect against dental fluorosis. Dental fluorosis, in its moderate or severe forms, may result in a brown staining and/or pitting of the permanent teeth. This problem occurs only in developing teeth, before they erupt from the gums. Children under nine should not drink water that has more than 2 mg/L of fluoride.

Lead typically leaches into water from plumbing in older buildings. Lead pipes and plumbing fittings have been banned since August 1998. Children and pregnant women are most susceptible to lead health risks. For advice on avoiding lead, see EPA's "**Lead in your drinking water**" fact sheet.

Synthetic Organic Contaminants

Including pesticides & herbicides

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

Volatile Organic Contaminants or VOCs

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



Common water sampling bottles, VOC and THM are in the front. Bacteria sample bottles are not shown.

Water Disinfectants

Many water suppliers add a disinfectant to drinking water to kill germs such as giardia and e coli. Especially after heavy rainstorms, 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 the 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 the 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 the 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 the EPA's standard. Some people may experience anemia.

Disinfection Byproducts

Disinfection byproducts form when disinfectants added to drinking water to kill germs react with naturally-occurring organic matter in water.

Total Trihalomethanes Some people who drink water containing trihalomethanes in excess of EPA's standard over many years may experience problems with their liver, kidneys, or central nervous systems, and may have an increased risk of getting cancer.

Haloacetic Acids Some people who drink water containing haloacetic acids in excess of the EPA's standard over many years may have an increased risk of getting cancer.

Bromate Some people who drink water containing bromate in excess of the EPA's standard over many years may have an increased risk of getting cancer.

Chlorite Some infants and young children who drink water containing chlorite in excess of the EPA's standard could experience nervous system effects. Similar effects may occur in fetuses of pregnant women who drink water containing chlorite in excess of the EPA's standard. Some people may experience anemia.



Chlorine Rotometer

What is Ozone?

Ozone (O_3) is probably the strongest oxidizing agent available for water treatment. Although it is widely used throughout the world, it has not found much application in the United States. Ozone is obtained by passing a flow of air or oxygen between two electrodes that are subjected to an alternating current in the order of 10,000 to 20,000 volts.



Liquid ozone is very unstable and can readily explode. As a result, it is not shipped and must be manufactured on-site. Ozone is a light blue gas at room temperature. It has a self-policing pungent odor similar to that sometimes noticed during and after heavy electrical storms. In use, ozone breaks down into oxygen and nascent oxygen.



It is the nascent oxygen that produces the high oxidation and disinfections, and even sterilization. Each water has its own ozone demand, in the order of 0.5 ppm to 5.0 ppm. Contact time, temperature, and pH of the water are factors to be determined.

Ozone acts as a complete disinfectant. It is an excellent aid to the flocculation and coagulation process, and will remove practically all color, taste, odor, iron, and manganese. It does not form chloramines or THMs, and while it may destroy some THMs, it may produce others when followed by chlorination. Ozone is not practical for complete removal of chlorine or chloramines, or of THM and other inorganics. Further, because of the possibility of formation of other carcinogens (such as aldehydes or phthalates) it falls into the same category as other disinfectants in that it can produce DBPs.



Large Ozone generator

Customer Service

What's That Stuff in the Tap Water?

by Jameel Rahman and Gary A. Burlingame

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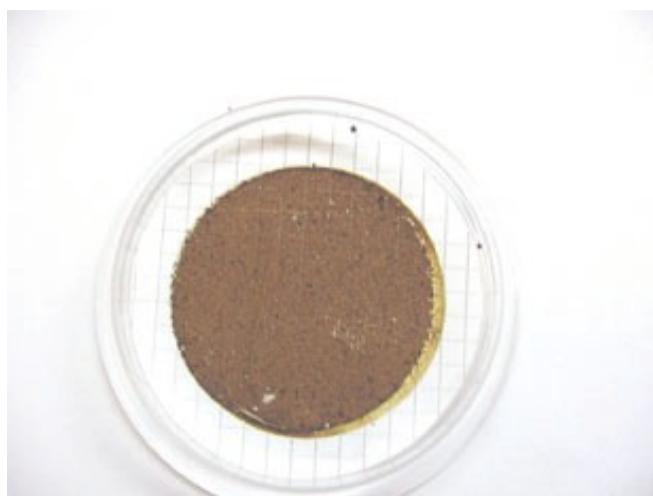
Almost every water utility employee responsible for solving customer problems has fielded a complaint about particles in a bathtub or faucet aerator. Although particles can come from cold or hot water systems, household plumbing, water distribution systems, and water treatment, the water supplier—at least in customers' eyes—is usually “*guilty until proven innocent*.”

The Philadelphia Water Department has standardized procedures in place that can identify offending materials and help pinpoint their source.

Collecting and Identifying Particulates

Typically, the suspended matter customers complain about is particulate in form. The most important step in solving a particulate complaint is to collect as much suspect material as possible, making sure it represents the customer's actual concern. Sometimes enough material for analysis can be collected from faucet aerators. A container may be left with the customer for sample collection during normal tap use.

Particulates can also accumulate in the toilet tank.



Particulate matter can be extracted from water samples by using nitrocellulose membrane filters. A 0.45 µm filter can be used if the water's colloidal matter doesn't clog the filter before enough particulate material is collected for analysis. Enough particulate matter can usually be captured with a water sample of approximately 250 mL. When samples have low turbidity, larger volumes will need to be filtered.

Granular Rust

Under a microscope, examine the particulate matter captured on a filter. Use a zoom microscope with at least 40×, preferably 75×, magnification to identify matter on the membrane filter disk, which can be stored in a Plexiglas Petri dish. For optimum observation, illuminate the particulates from above with a fiber-optic light.

Some particulates can be identified by their appearance and, sometimes, by touching them with a sharp needle and observing their physical properties, such as softness, stickiness, or solubility in a solvent. Particulates can be quantified as few, several, or numerous. If particulates cannot be identified by their appearance, perform simple chemical tests on the filter. A characteristic evolution of a gas, such as carbon dioxide from scale particulates or marble, can be observed under the microscope. Color formed by chemical reactions can be seen by the unaided eye. If these tests still fail to identify the debris, or further delineation is required, use infrared spectroscopy (**IR**).

Visual Identification

Sand particulates have a characteristic vitreous appearance and irregular shape with smooth facets. They can be colorful but usually appear translucent to whitish.

Mica particulates have a characteristic platelet shape and shine under reflected light. You will need to understand the common soil minerals in your area to identify them.

Man-made fibers, found in all colors and with a characteristic wrinkled strip shape, are present in single strands, have significant length, and often are visible to the unaided eye. Usually, fibers are not present in large numbers — at most, 10 per filter. Fibers used in apparel are round, but fibers found in water typically have a strip shape, indicating a common source, such as pump packing.

Glass chips are transparent, may have smooth facets with sharp edges, and may be colorful.

Relatively large amounts of similar particulates often indicate a problem within a plumbing system. Usually the source of such particulates is disintegrating plastic, a rubber gasket, or a corroding component of the plumbing system.

Heat Identification

Activated carbon particulates are black and usually coated with debris. They can show porosity but appear dull compared to anthracite particulates, which display a shiny luster under reflected light. Pick up a few particulates on the tip of a wetted platinum wire and burn them in the blue part of a Bunsen burner flame. AC particulates will burn instantaneously with a glitter and no visible smoke or residue.

Disintegrated plastic particulates are usually white, large, and may be present in large numbers. Pick up a few particulates and burn them in a Bunsen burner flame. Plastic burns with a smoke. With fine-tipped tweezers, remove sufficient particulates from the disk and further identify them by IR. Most often they are polypropylene plastic.

Disintegrated rubber gasket particulates are usually black, relatively large, and do not smear the filter disk with black when a drop of toluene is applied. If pressed with a needle, they flex. Remove a few particulates and burn them; rubber burns with a black smoke. Identify them further by IR.

Often these particulates are ethylene-propylene-diene monomer, used in gaskets.

Acid Identification

Rust particulates are usually abundant and are easy to identify with their typically brown and rough irregular shapes. Large particulates may have yellow and black streaks or inclusions, while fine rust particulates form a uniform brown film on the filter disk. To confirm rust, add a drop of (1+1) hydrochloric acid (500 mL of 11.5N hydrochloric acid [HCl] solution plus 500 mL of distilled water) to the filter. Yellow staining indicates the presence of ferric chloride. Add a drop of 2 percent solution of potassium thiocyanate on the yellow area where HCl was added. Brick-red staining confirms the presence of potassium ferrithiocyanate.



Large Rust Particles

Lead solder particulates are gray and may have a whitish coating, are usually brittle, and can be easily pulverized. Often, they are relatively large in size compared to most other particulates on the filter disk. If lead particulates are suspected, add a drop of pH 2.8 tartrate-buffer solution followed by a drop of 0.2 percent solution of freshly prepared sodium rhodizonate. If the particulates turn scarlet red, lead solder is present.

Prepare a pH 2.8 buffer solution by dissolving 1.9 g of sodium bitartrate and 1.5 g of tartaric acid in 100 mL of distilled water. To prepare the sodium rhodizonate reagent, dissolve 0.2 g of rhodizonic acid disodium salt in 100 mL of distilled water.

Patina is hydrated basic copper carbonate and has a greenish color. These irregularly shaped particulates result from corrosion of copper and copper alloys. To confirm their presence, add a drop of (1+1) HCl from a Pasture pipette. If tiny bubbles of carbon dioxide form under the microscope, the presence of patina is indicated. Remove a few particulates and place them in the cavity of a spot-test plate. Add a drop of (1+1) HCl followed by a drop of ammonia. Appearance of a blue precipitate or blue color confirms the presence of patina particulates. Rust particulates will interfere with this test if it is performed on the rust-coated filter.

Calcium carbonate can develop as a white scale through evaporation of hard water or can occur as a particulate of limestone or calcite. Scales can form in water heaters. Limestone can come from water treatment processes. Add a drop of HCl (1+1) on the particulates and observe the evolution of carbon dioxide under the microscope. The brisk evolution of gas confirms the presence of carbonates.

Solvent Identification

Asphalt pipe-coating compounds are black. To differentiate between various black particulates, add a drop of toluene or chloroform to the filter disk under the microscope. If the disk becomes smeared with black around the particulates, the particulates are classified as pipe-coating of an asphaltic nature. Anthracite, activated carbon, and rubber particulates are insoluble in the solvents used.

Anthracite particulates appear shiny compared with other black particulates and do not smear the filter disk if a drop of toluene is applied. These particulates can be removed from the filter disk and burned in a crucible; they will leave a solid residue.

Grease particulates are black and may be shiny. They are usually present as tiny heaps on the filter disk because of their softness and hydrophobic nature. They are soft and sticky when touched with a needle and can be smeared easily on the disk. Add a drop of toluene; grease will dissolve and a black color will spread around the particulates.

Let the toluene evaporate or use an oven to expedite drying. Touch the particulates with a needle in the area where toluene was added; they should no longer be sticky and may behave like a black powder. All greases may not behave this way, but their stickiness and extreme softness differentiates them from other black particulates.

Infrared Spectroscopy

When particulates cannot be completely identified by the above means, use IR to identify organic and inorganic materials. Inorganic compounds include calcium carbonate, calcium sulfate, barium sulfate, lead carbonate, metal oxides, silicates, or phosphates. Visually, and with the aid of heat, you might suspect a particulate is plastic in nature, but various types of plastics can occur in water systems, including polypropylene, polyvinyl chloride, and polyethylene. IR can differentiate between plastic materials.

Atoms in a molecule are in constant motion, changing bond angles by bending and bond lengths by stretching. Among these motions only certain vibrations absorb infrared radiation of specific energy. When portions of electromagnetic radiation are absorbed by such vibrations, an IR absorption band spectrum appears, which an infrared spectrometer records.

Each compound has a unique infrared absorption spectrum, and various compounds can be identified by comparing absorption band positions in the IR spectrum of an unknown compound to band positions of known compounds.

Particulates are removed with fine-tipped tweezers one by one from the filter disk and transferred to a small vial for dissolving in a solvent or to a small agate mortar for grinding and mixing with KBr for making a potassium bromide (KBr) pellet.

The usually brittle plastic fragments can be powdered easily, and 10 mg of sample is all that is commonly needed to produce a good infrared absorption spectrum. Inorganic materials are identified by IR scanning of the KBr pellet of the sample alone; organic materials are identified by scanning a pellet or a film of the sample cast on a KBr plate.



Zeolite Particles from a Water Softener

Most plastics are readily soluble in hot o-dichlorobenzene; try dissolving the sample in this solvent first. If soluble, cast a film of the sample on a KBr plate and scan it. If the sample is insoluble, evaporate the solvent completely and transfer the particulates to an agate mortar, make a KBr pellet, and scan the pellet. After obtaining a reasonably strong infrared spectrogram, the sample is identified by manual means or a computer search of a commercially available online IR library.

Standard Chemical Analyses

Chemical analyses available in most full-service water testing laboratories can be used to identify particulates when sufficient material is available. For example, hydrated aluminum oxide can occur as white slurry and be analyzed by inductively coupled plasma emission spectrometry after dissolving in mineral acids.

Similarly, granules of lead solder can also be analyzed by wet chemical or instrumental methods. After a sample is dissolved in a mineral acid, it can be analyzed for various elements by atomic absorption spectrophotometry. A variety of materials, including iron oxides, manganese dioxides, aluminum oxides, calcium carbonates, and copper and silicate particulates, can be identified by common chemical analyses.

During the late 1990s, customers in Philadelphia and across the country complained about white particulates clogging faucet aerators. Infrared spectroscopy revealed the particulates to be polypropylene, a plastic not used in the distribution system. The only common source for this plastic was found to be the dip tubes in residential gas hot-water heaters (see *Opflow*, December 1998).

Eventually, the dip-tube manufacturer admitted to changing materials to a less-durable plastic, prompting water heater manufacturers to give rebates to customers for dip-tube replacements. When this issue made the TV news, Philadelphia was in a good position to explain the situation to customers because our procedure was already in place for testing and characterizing particulates.



Dip Tube Particles

Table 1. Potential sources for particulate matter found in tap water

Particulate	From Customer Plumbing	From Water Supplier Piping
Activated carbon fines		X
Asphaltic lining fragments		X
Backfill sand		X
Calcium carbonate scale	X	X
Cast iron rust		X
Cement lining fragments		X
Copper fragments	X	
Glass chips		X
Greases and lubricants	X	X
Lead fragments	X	
Manganese dioxide deposits		X
Man-made fibers		X
On-site treatment device media		X
Plastic fragments	X	
Rubber gasket fragments	X	X
Soil minerals, mica		X

Table 2. Suspended matter classified by size

Soluble	< 0.45 µm
Colloidal	< 1.0 µm but > 0.45 µm
Particulate	> 1.0 µm

End of Article by Jameel Rahman and Gary A. Burlingame

Waterborne Pathogen Introduction

Bacteria, viruses and protozoans that cause disease are known as pathogens. Most pathogens are generally associated with diseases that cause intestinal illness and affect people in a relatively short amount of time, generally a few days to two weeks. They can cause illness through exposure to small quantities of contaminated water or food or from direct contact with infected people or animals. Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral or feces-to-mouth route.

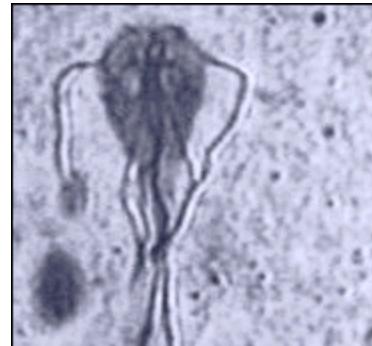
Pathogens may get into water and spread when infected humans or animals pass the bacteria, viruses and protozoa in their stool. For another person to become infected, he or she must take that pathogen in through the mouth. Waterborne pathogens are different from other types of pathogens such as the viruses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

Human or animal wastes in watersheds, failing septic systems, failing sewage treatment plants or cross-connections of water lines with sewage lines provide the potential for contaminating water with pathogens. The water may not appear to be contaminated because feces has been broken up, dispersed and diluted into microscopic particles. These particles, containing pathogens, may remain in the water and be passed to humans or animals unless adequately treated.

Only proper treatment will ensure eliminating the spread of disease. In addition to water, other methods exist for spreading pathogens by the fecal-oral route. The foodborne route is one of the more common methods. A frequent source is a food handler who does not wash his hands after a bowel movement and then handles food with "**unclean**" hands. The individual who eats feces-contaminated food may become infected and ill. It is interesting to note the majority of foodborne diseases occur in the home, not restaurants. Day care centers are another common source for spreading pathogens by the fecal-oral route. Here, infected children in diapers may get feces on their fingers, then put their fingers in a friend's mouth or handle toys that other children put into their mouths. You will usually be asked to sample at these facilities for Giardia. The general public and some of the medical community usually refer to diarrhea symptoms as "**stomach flu**".

Technically, influenza is an upper respiratory illness and rarely has diarrhea associated with it; therefore, stomach flu is a misleading description for foodborne or waterborne illnesses, yet is accepted by the general public. So the next time you get the stomach flu, you may want to think twice about what you've digested within the past few days.

Giardia



Chain of Transmission

When water is contaminated with feces, this contamination may be of human or animal origin. The feces must contain pathogens. If the human or animal source is not infected with a pathogen disease-causing bacteria, viruses or protozoa, no disease will result.

The pathogens must survive in the water. This depends on the temperature of the water and the length of time the pathogens are in the water. Some pathogens will survive for only a short time in water, others, such as Giardia or Cryptosporidium, may survive for months.

The pathogens in the water must enter the water system's intake and in numbers sufficient to infect people. The water is either not treated or inadequately treated for the pathogens present. A susceptible person must drink the water that contains the pathogen. In order for illness (disease) to occur.

This chain lists the events that must occur for the transmission of disease via drinking water. By breaking the chain at any point, the transmission of disease will be prevented.

Bacterial Diseases

Campylobacteriosis is the most common diarrheal illness caused by bacteria. Other symptoms include abdominal pain, malaise, fever, nausea and vomiting. Symptoms begin three to five days after exposure. The illness is frequently over within two to five days and usually lasts no more than 10 days. Campylobacteriosis outbreaks have most often been associated with food, especially chicken and unpasteurized milk as well as unchlorinated water. These organisms are also an important cause of "**travelers' diarrhea**." Medical treatment generally is not prescribed for campylobacteriosis because recovery is usually rapid.

Cholera, Legionellosis, salmonellosis, shigellosis, yersiniosis, are other bacterial diseases that can be transmitted through water. All bacteria in water are readily killed or inactivated with chlorine or other disinfectants.

Viral Diseases

Hepatitis A is an example of a common viral disease that may be transmitted through water. The onset is usually abrupt with fever, malaise, loss of appetite, nausea and abdominal discomfort, followed within a few days by jaundice. The disease varies in severity from a mild illness lasting one to two weeks, to a severely disabling disease lasting several months (rare). The incubation period is 15-50 days and averages 28-30 days. Hepatitis A

outbreaks have been related to fecally contaminated water; food contaminated by infected food handlers, including sandwiches and salads that are not cooked or are handled after cooking and raw or undercooked mollusks harvested from contaminated waters.

Aseptic meningitis, polio and viral gastroenteritis (Norwalk agent) are other viral diseases that can be transmitted through water. Most viruses in drinking water can be inactivated by chlorine or other disinfectants.

Protozoan Diseases

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

Giardiasis is a commonly reported protozoan-caused disease. It has also been referred to as “**backpacker’s disease**” and “**beaver fever**” because of the many cases reported among hikers and others who consume untreated surface water. Symptoms include chronic diarrhea, abdominal cramps, bloating, frequent loose and pale greasy stools, fatigue and weight loss. The incubation period is 5-25 days or longer, with an average of 7-10 days. Many infections are asymptomatic (no symptoms). Giardiasis occurs worldwide. Waterborne outbreaks in the United States occur most often in communities receiving their drinking water from streams or rivers without adequate disinfection or a filtration system. The organism, ***Giardia lamblia***, has been responsible for more community-wide outbreaks of disease in the U.S. than any other pathogen. Drugs are available for treatment but are not 100% effective.



Cryptosporidiosis

Cryptosporidiosis is an example of a protozoan disease that is common worldwide but was only recently recognized as causing human disease. The major symptom in humans is diarrhea, which may be profuse and watery. The diarrhea is associated with cramping abdominal pain. General malaise, fever, anorexia, nausea and vomiting occur less often.

Symptoms usually come and go, and end in fewer than 30 days in most cases. The incubation period is 1-12 days, with an average of about seven days. ***Cryptosporidium*** organisms have been identified in human fecal specimens from more than 50 countries on six continents. The mode of transmission is fecal-oral, either by person-to-person or animal-to-person. There is no specific treatment for ***Cryptosporidium*** infections.

All these diseases, with the exception of hepatitis A, have one symptom in common: diarrhea. They also have the same mode of transmission, fecal-oral, whether through person-to-person or animal-to-person contact, and the same routes of transmission, being either foodborne or waterborne. Although most pathogens cause mild, self-limiting disease, on occasion, they can cause serious, even life threatening illness. Particularly vulnerable are persons with weak immune systems such as those with HIV infections or cancer. By understanding the nature of waterborne diseases, the importance of properly constructed, operated and maintained public water systems becomes obvious. While water treatment cannot achieve sterile water (no microorganisms), the goal of treatment must clearly be to produce drinking water that is as pathogen-free as possible at all times. For those who operate water systems with inadequate source protection or treatment facilities, the potential risk of a waterborne disease outbreak is real. For those operating systems that currently provide adequate source protection and treatment, operating and maintaining the system at a high level on a continuing basis is critical to prevent disease.

Waterborne Diseases

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

Source: Adapted from American Water Works Association, *Introduction to Water Treatment: Principles and Practices of Water Supply Operations*, Denver CO, 1984.

Killing Microorganisms

Disinfection is usually synonymous with chlorination. That is because chlorine addition is by far the most common form of disinfection used today. In this section, the main emphasis will be on chlorination: how it works, safety, types of chlorine, basic chemistry of chlorine and an introduction to CT values. Disinfection is the process of killing microorganisms in water that might cause disease (**pathogens**). Disinfection, however, should not be confused with sterilization, which is the destruction of all microorganisms. Disinfection is concerned only with killing pathogens.

Bacteriological Monitoring

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

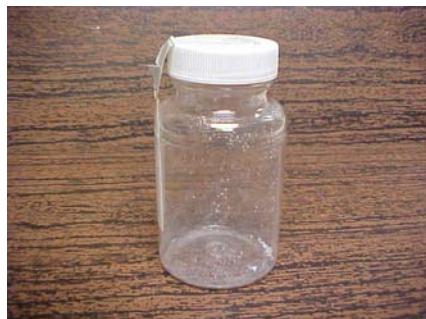
The presence of an indicator or pathogenic bacteria in your drinking water is an important health concern. Indicator bacteria signal possible fecal contamination and therefore, the potential presence of pathogens. They are used to monitor for pathogens because of the difficulties in determining the presence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

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

Bacteria Sampling

Water samples for bacteria tests must always be collected in a sterile container. Take the sample from an inside faucet with the aerator removed. Sterilize by spraying a 5% Clorox or alcohol solution or flaming the end of the tap with disposable butane lighter. Run the water for five minutes to clear the water lines and bring in fresh water. Do not touch or contaminate the inside of the bottle or cap. Carefully open the sample container and hold the outside of the cap. Fill the container and replace the top.

Refrigerate the sample and transport it to the testing laboratory within six hours (in an ice chest). Many labs will not accept bacteria samples on Friday so check the lab's schedule. Mailing bacteria samples is not recommended because laboratory analysis results are not as reliable. Iron bacteria forms an obvious slime on the inside of pipes and fixtures. A water test is not needed for identification. Check for a reddish-brown slime inside a toilet tank or where water stands for several days.



Standard Sample Coliform Bacteria Bac-T

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

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

Laboratory Procedures

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

Methods

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



The above picture is of IDEXX Colilert Quanti-Tray method for coliform and E. Coli tests. These tests can take 24 to 18 hours depending upon the feature of the product that you have purchased. You can also choose between a yellow or magenta positive endpoint for positive samples. Above picture, we have yellow has our indicator color.

Types of Water Samples

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

The three (3) types of samples are:

1. **Routine:** Samples collected on a routine basis to monitor for contamination. Collection should be in accordance with an approved sampling plan.
2. **Repeat:** Samples collected following a '**coliform present**' routine sample. The number of repeat samples to be collected is based on the number of routine samples you normally collect.
3. **Special:** Samples collected for other reasons. Examples would be a sample collected after repairs to the system and before it is placed back into operation or a sample collected at a wellhead prior to a disinfection injection point.

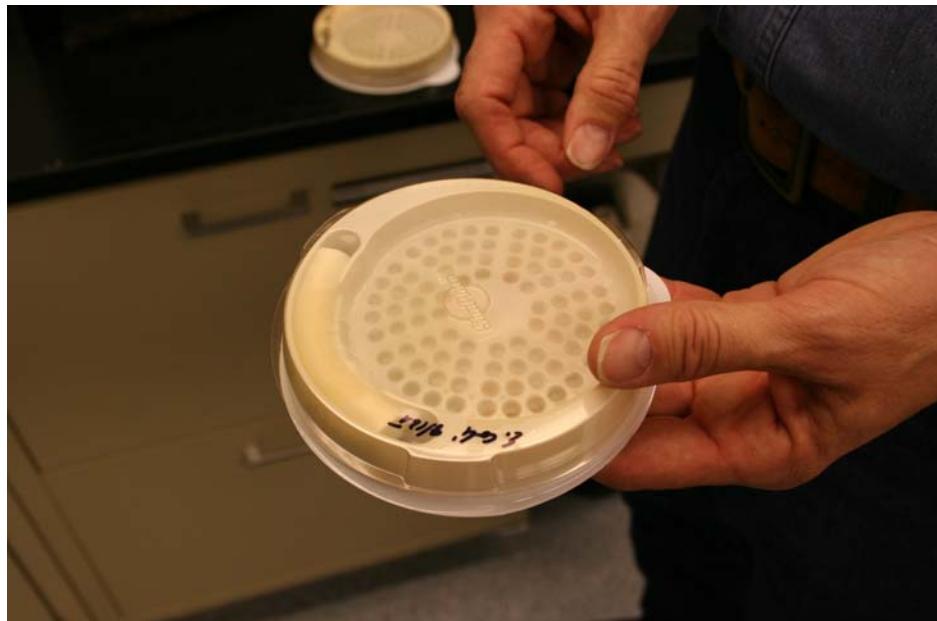
Routine Coliform Sampling

The number of routine samples and frequency of collection for community public water systems is shown in Table 3-1 next page.

Noncommunity and nontransient noncommunity public water systems will sample at the same frequency as a like sized community public water system if:

1. it has more than 1,000 daily population and has ground water as a source, or
2. it serves 25 or more daily population and utilizes surface water as a source or ground water under the direct influence of surface water as its source.

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



Here is a picture of IDEXX SimPlate for HPC. This is used for the quantification of heterotrophic plate counts in water. The number of fluorescing wells corresponds to a Most Probable Number or MPN of total bacteria in the original sample. The MPN values generated by the SimPlate for HPC method correlate with the Pour Plate method using Total Plate Count Agar at 35°C for 48 hours as described in Standard Methods for the Examination of Water and Wastewater, 19th Edition.

Table 3-1. No. of Samples per System Population

Persons served - Samples per month

up to 1,000	1
1,001-2,500	2
2,501-3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 12,900	10
12,901 to 17,200	15
17,201 to 21,500	20
21,501 to 25,000	25
25,001 to 33,000	30
33,001 to 41,000	40
41,001 to 50,000	50
50,001 to 59,000	60
59,001 to 70,000	70
70,001 to 83,000	80
83,001 to 96,000	90
96,001 to 130,000	100
130,001 to 220,000	120
220,001 to 320,000	150
320,001 to 450,000	180
450,001 to 600,000	210
600,001 to 780,000	240



Quebec Colony Counter

Repeat Sampling

Repeat sampling replaces the old check sampling with a more comprehensive procedure to try to identify problem areas in the system. Whenever a routine sample is total coliform or fecal coliform present a set of repeat samples must be collected within 24 hours after being notified by the laboratory. The follow-up for repeat sampling is:

1. If only one routine sample per month or quarter is required, four (4) repeat samples must be collected.
2. For systems collecting two (2) or more routine samples per month, three (3) repeat samples must be collected.
3. Repeat samples must be collected from:
 - a. The original sampling location of the coliform present sample.
 - b. Within five (5) service connections upstream from the original sampling location.
 - c. Within five (5) service connections downstream from the original sampling location.
 - d. Elsewhere in the distribution system or at the wellhead, if necessary.
4. If the system has only one service connection, the repeat samples must be collected from the same sampling location over a four-day period or on the same day.
5. All repeat samples are included in the MCL compliance calculation.

6. If a system which normally collects fewer than five (5) routine samples per month has a coliform present sample, it must collect five (5) routine samples the following month or quarter regardless of whether an MCL violation occurred or if repeat sampling was coliform absent.

Positive or Coliform Present Results

What do you do when your sample is positive or coliform present?

When you are notified of a positive test result you need to contact either the Drinking Water Program or your local county health department within 24 hours or by the next business day after the results are reported to you. The Drinking Water Program contracts with many of the local health departments to provide assistance to water systems. After you have contacted an agency for assistance you will be



instructed as to the proper repeat sampling procedures and possible corrective measures for solving the problem. It is very important to initiate the repeat sampling immediately as the corrective measures will be based on those results.

Some examples of typical corrective measures to coliform problems are:

1. Shock chlorination of a ground water well. The recommended dose of 5% household bleach is 2 cups per 100 gallons of water in the well. This should be done anytime the bell is opened for repair (pump replacement, etc.). If you plan to shock the entire system, calculate the total gallonage of storage and distribution.
2. Conduct routine distribution line flushing. Install blowoffs on all dead end lines.
3. Conduct a cross connection program to identify all connections with non-potable water sources. Eliminate all of these connections or provide approved backflow prevention devices.
4. Upgrade the wellhead area to meet current construction standards as set by your state environmental or health agency.
5. If you continuously chlorinate, review your operation and be sure to maintain a detectable residual (0.2 mg/l free chlorine) at all times in the distribution system.
6. Perform routine cleaning of the storage system.

This list provides some basic operation and maintenance procedures that could help eliminate potential bacteriological problems, check with your state drinking water section or health department for further instructions.

Maximum Contaminant Levels (MCLs)

State and federal laws establish standards for drinking water quality. Under normal circumstances when these standards are being met, the water is safe to drink with no threat to human health. These standards are known as maximum contaminant levels (**MCL**). When a particular contaminant exceeds its MCL a potential health threat may occur.

The MCLs are based on extensive research of the toxicological properties of the contaminants, risk assessments and factors, short term (**acute**) exposure and long term (**chronic**) exposure. The water provider must conduct the monitoring to make sure your water is in compliance with the MCL.

There are two types of MCL violations for coliform bacteria. The first is for total coliform; the second is an acute risk to health violation characterized by the confirmed presence of fecal coliform or E.coli.

Total Coliforms

This MCL is based on the presence of total coliforms and compliance is on a monthly or quarterly basis, depending on your water system type and state rule. For systems which collect fewer than 40 samples per month, no more than one sample per month may be positive. In other words, the second positive result (repeat or routine) in a month or quarter results in an MCL violation. For systems which collect 40 or more samples per month, no more than five (5) percent may be positive, check with your state drinking water section or health department for further instructions.

Acute Risk to Health (Fecal coliforms and E.coli)

An acute risk to human health violation occurs if either one of the following happen:

1. A routine analysis shows total coliform present and is followed by a repeat analysis which indicates fecal coliform or E. coli present.
2. A routine analysis shows total and fecal coliform or E. coli present and is followed by a repeat analysis which indicates total coliform present. An acute health risk violation requires the water system to provide public notice via radio and television stations in the area. This type of contamination can pose an immediate threat to human health and notice must be given as soon as possible but no later than 72 hours after notification from your laboratory of the test results.

Certain language maybe mandatory for both these violations and is included in your state drinking water rule.

Public Notice

A public notice is required to be issued by a water system whenever it fails to comply with an applicable MCL or treatment technique or fails to comply with the requirements of any scheduled variance or permit. This will inform users when there is a problem with the system and give them information. A public notice is also required whenever a water system fails to comply with its monitoring and/or reporting requirements or testing procedure. Each public notice must contain certain information, be issued properly and in a timely manner and contain certain mandatory language. The timing and place of posting of the public notice depends on whether an acute risk is present to users. Check with your state drinking water section or health department for further instructions.

The following are acute violations:

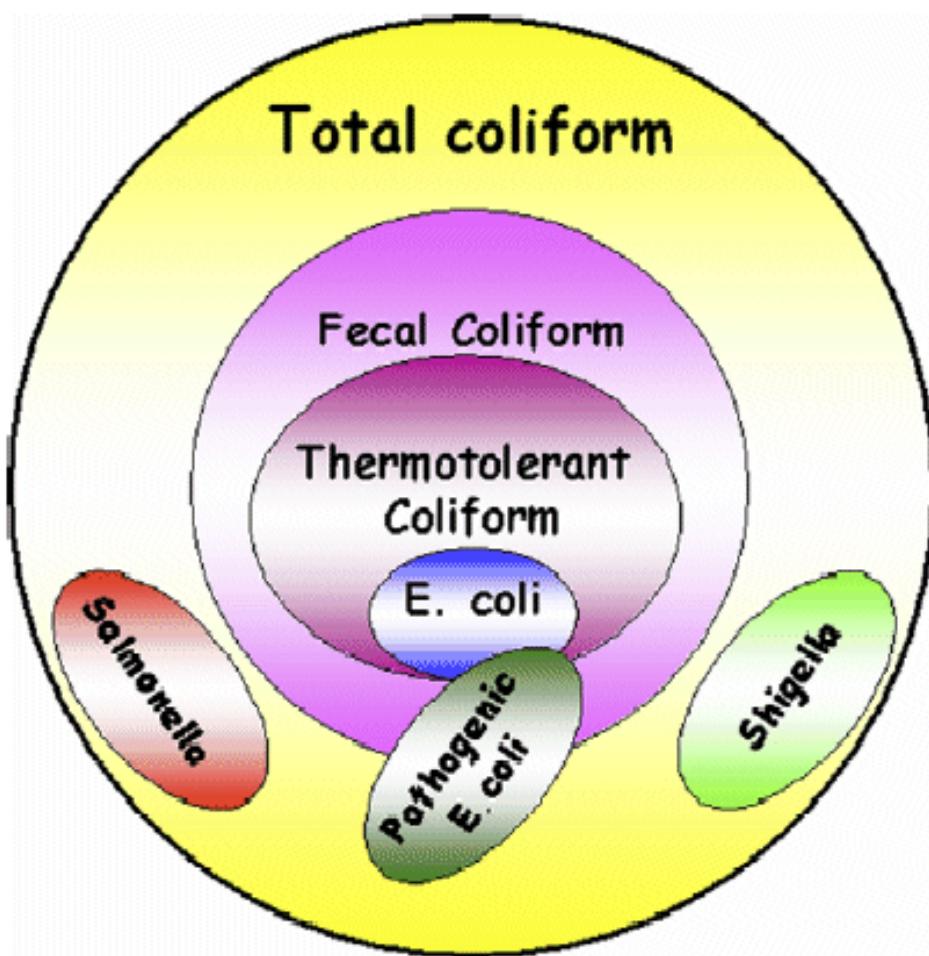
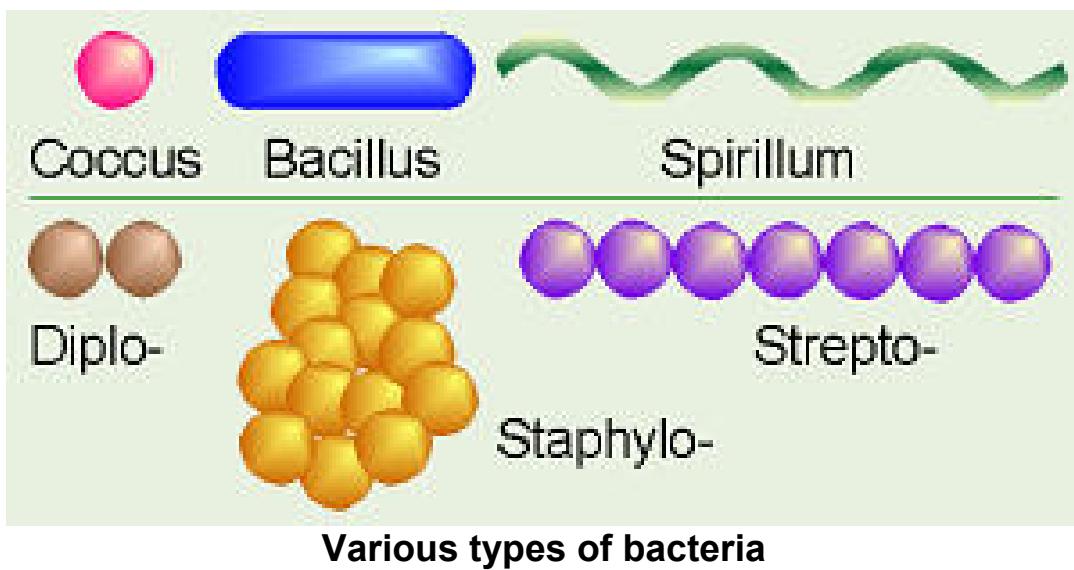
1. Violation of the MCL for nitrate.
2. Any violation of the MCL for total coliforms, when fecal coliforms or E. coli are present in the distribution system.
3. Any outbreak of waterborne disease, as defined by the rules.



HPC Pour Plate



Using a black light to see fecal coliform bacteria



Using DPD Method for Chlorine Residuals

N, N – diethyl-p-phenylenediamine



Small portable chlorine measuring kit. The redder the mixture the “hotter” or stronger the chlorine in solution.

Chlorine Field Tests

Sampling Techniques for Free and Total Chlorine (Hach Kit)

Procedures for determining free chlorine are as follows.

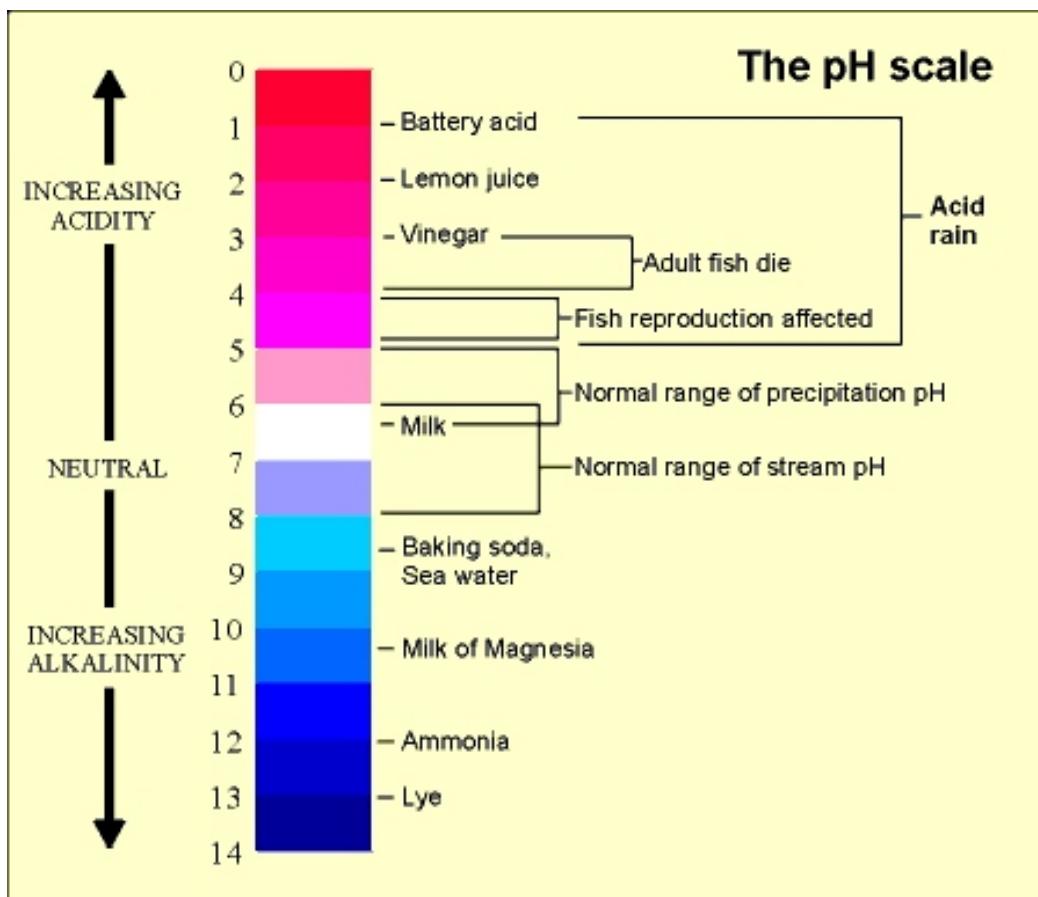
- (1) Rinse out the two sample vials with water. Place one inside the tester for calibration. Allow the tester to calibrate to zero. If there seems to be a calibration problem, re-calibrate using the factory colored vials as your standard.
- (2) Refill one of the vials to the 5 ml mark with a sample (this is the test sample). Tear open the one DPD free chlorine reagent powder pillow. Add the contents of the pillow to the sample. Stopper and shake to mix and put the tube in the color comparator. All of the powder does not have to dissolve to obtain correct readings.
- (3) Let the vial sit in the tester for approximately 1 minute. The samples should not be exposed to direct sunlight.
- (4) Take your reading. Record the results from the indicator (which is read in mg/l free chlorine) onto the chain of custody form.

Procedures for determining total chlorine are as follows.

Procedures for determining free chlorine are as follows.

- (1) Rinse out the two sample vials with water. Place one inside the tester for calibration. Allow the tester to calibrate to zero. If there seems to be a calibration problem, re-calibrate using the factory colored vials as your standard.
- (2) Refill one of the vials to the 5 ml mark with a sample (this is the test sample). Tear open the one DPD total chlorine reagent powder pillow. Add the contents of the pillow to the sample. Stopper and shake to mix and put the tube in the color comparator. All of the powder does not have to dissolve to obtain correct readings.
- (3) Let the vial sit in the tester for approximately 3 minutes. The samples should not be exposed to direct sunlight.
- (4) Take your reading. Record the results from the indicator (which is read in mg/l total chlorine) onto the chain of custody form.

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**.

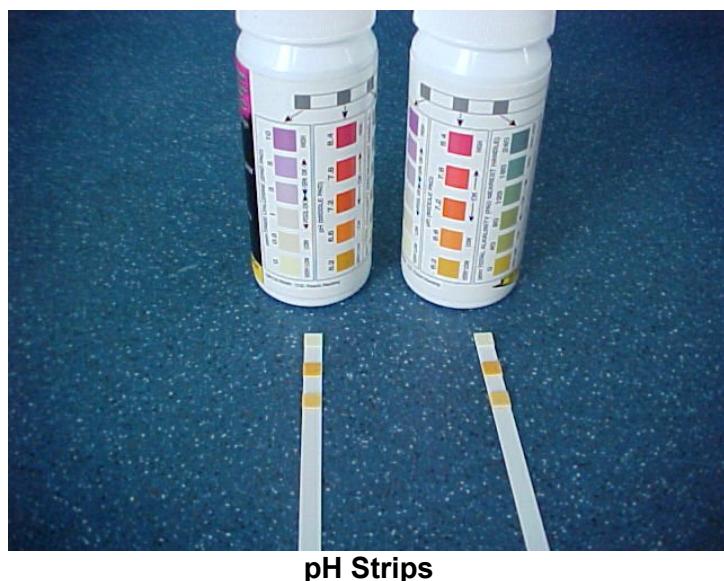
Because the scale is logarithmic, a difference of one pH unit represents a tenfold change. For example, the acidity of a sample with a pH of **5** is ten times greater than that of a sample with a pH of **6**. A difference of 2 units, from **6** to **4**, would mean that the acidity is one hundred times 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.



pH Meter pH scale is between 0-14 0 being Acidic and 14 being Base.

For fun, we measured Orange Juice and that is pH 3.5 or so - acid! We also measured Welch's Grape Juice and the meter showed 3.4 - also an acid (and slightly stronger). Here is a close-up of the pH41 meter we use and its pH 7.0 buffer solution (used for calibration and storage - there are a few drops of the buffer solution in the cap of the pH41 to keep it properly moist when not in use).



Chemical Equations, Oxidation States and Balancing of Equations

Before we breakdown Chlorine and other chemicals, let's start with this review of basic chemical equations.

Beginning

The common chemical equation could be A + B \rightarrow 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⁺⁺ \rightarrow 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's. Reaction of a hydrocarbon with a halogen, for example, CH₄ + 2 Cl \rightarrow 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's to aldehyde's.

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 is the table of common ions, both positive ions and negative ions.

Table of Common Ions

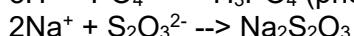
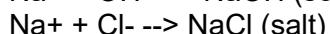
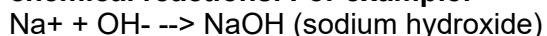
Positive Ions

Valency 1		Valency 2		Valency 3	
lithium	Li^+	magnesium	Mg^{2+}	aluminum	Al^{3+}
sodium	Na^+	calcium	Ca^{2+}	iron III	Fe^{3+}
potassium	K^+	strontium	Sr^{2+}	chromium	Cr^{3+}
silver	Ag^+	barium	Ba^{2+}		
hydronium	H_3O^+	copper II	Cu^{2+}		
(or hydrogen)	H^+	lead II	Pb^{2+}		
ammonium	NH_4^+	zinc	Zn^{2+}		
copper I	Cu^+	manganese II	Mn^{2+}		
mercury I	Hg^+	iron II	Fe^{2+}		
		tin II	Sn^{2+}		

Negative Ions

Valency 1		Valency 2		Valency 3	
fluoride	F^-	oxide	O^{2-}	phosphate	PO_4^{3-}
chloride	Cl^-	sulfide	S^{2-}		
bromide	Br^-	carbonate	CO_3^{2-}		
iodide	I^-	sulfate	SO_4^{2-}		
hydroxide	OH^-	sulfite	SO_3^{2-}		
nitrate	NO_3^-	dichromate	Cr_2O_7^-		
bicarbonate	HCO_3^-	chromate	CrO_4^{2-}		
bisulphate	HSO_4^-	oxalate	$\text{C}_2\text{O}_4^{2-}$		
nitrite	NO_2^-	thiosulfate	$\text{S}_2\text{O}_3^{2-}$		
chlorate	ClO_3^-	tetrathionate	$\text{S}_4\text{O}_6^{2-}$		
permanganate	MnO_4^-	monohydrogen phosphate	HPO_4^{2-}		
hypochlorite	OCl^-				
dihydrogen phosphate	H_2PO_4^-				

Positive ions will react with negative ions, and vice versa. This is the start of our chemical reactions. For example:



You will see from these examples, that if an ion of one (+), reacts with an ion of one (-) then the equation is balanced. However, an ion like PO_4^{3-} (phosphate) will require an ion of 3+ or an ion of one (+) (but needs three of these) to neutralize the 3- charge on the phosphate. So, what you are doing is balancing the charges (+) or (-) to make them zero, or cancel each other out.

For example, aluminum exists in its ionic state as Al^{3+} , it will react with many negatively charged ions, examples: Cl^- , OH^- , SO_4^{2-} , PO_4^{3-} .

Let us do these examples and balance them.



How did we work this out?

Al^{3+} has three positives (3+)

Cl^- has one negative (-)

It will require **3 negative charges** to cancel out the **3 positive charges** on the aluminum (Al^{3+}).

When the **left hand side** of the equation is written, to balance the number of chlorine's (Cl^-) required, the number 3 is placed in front of the ion concerned, in this case Cl^- , becomes 3Cl^- .

On the **right hand side** of the equation, where the ions have become a compound (a chemical compound), the number is transferred to after the relevant ion, Cl_3 .

Another example:



Let me give you an easy way of balancing:

Al is 3+

SO_4 is 2-

Simply transpose the number of positives (or negatives) for each ion, to the other ion, by placing this value of one ion, in front of the other ion. That is, Al^{3+} the 3 goes in front of the SO_4^{2-} as 3SO_4^{2-} , and SO_4^{2-} , the 2 goes in front of the Al^{3+} to become 2Al^{3+} . Then on the **right hand side** of the equation, this same number (now in front of each ion on the **left side** of the equation), is placed after each "ion" entity.

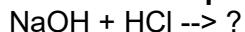
Let us again look at:



Put the three from the Al in front of the SO_4^{2-} and the 2 from the SO_4^{2-} in front of the Al^{3+} .

Equation becomes:

$2\text{Al}^{3+} + 3\text{SO}_4^{2-} \rightarrow \text{Al}_2(\text{SO}_4)_3$. You simply place the valency of one ion, as a whole number, in front of the other ion, and vice versa. **Remember** to encase the SO_4 in brackets. **Why?** Because we are dealing with the sulfate ion, SO_4^{2-} , and it is this ion that is 2- charged (not just the O_4), so we have to ensure that the "ion" is bracketed. Now to check, the 2 times $3^+ = 6^+$, and 3 times $2^- = 6^-$. We have equal amounts of positive ions, and equal amounts of negative ions.

Another example:

Na is Na^+ , OH is OH^- , so this gave us NaOH. Originally the one positive canceled the one negative.

HCl is $\text{H}^+ + \text{Cl}^-$, this gave us HCl.

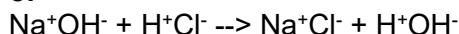
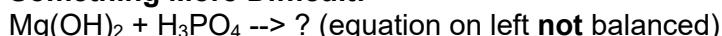
Reaction is going to be the Na^+ reacting with a negatively charged ion. This will have to be the chlorine, Cl^- , because at the moment the Na^+ is tied to the OH^- . **So:** $\text{Na}^+ + \text{Cl}^- \rightarrow \text{NaCl}$

The H^+ from the HCl will react with a negative (-) ion this will be the OH^- from the NaOH. **So:** $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ (water).

The complete reaction can be written:

$\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$. We have **equal amounts** of all atoms **each side** of the equation, so the equation is **balanced**.

or

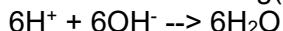
**Something More Difficult:**

$\text{Mg}^{2+} 2\text{OH}^- + 3\text{H}^+\text{PO}_4^{3-} \rightarrow ?$ (equation on left **not** balanced), so let us rewrite the equation in **ionic form**.

The Mg^{2+} **needs to react with a negatively charged ion**, this will be the PO_4^{3-} , **so:** $3\text{Mg}^{2+} + 2\text{PO}_4^{3-} \rightarrow \text{Mg}_3(\text{PO}_4)_2$

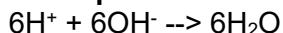
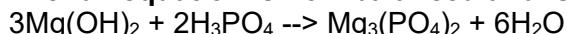
(**Remember** the **swapping** of the positive or negative charges on the ions in the **left side** of the equation, and placing it in front of each ion, and then placing this number after each ion on the **right side** of the equation)

What is left is the H^+ from the H_3PO_4 and this will react with a negative ion, we only have the OH^- from the $\text{Mg}(\text{OH})_2$ left for it to react with.



Where did I get the 6 from? When I balanced the Mg^{2+} with the PO_4^{3-} , the equation became $3\text{Mg}^{2+} + 2\text{PO}_4^{3-} \rightarrow \text{Mg}_3(\text{PO}_4)_2$

Therefore, I must have required $3\text{Mg}(\text{OH})_2$ to begin with, and $2\text{H}_3\text{PO}_4$, (because we originally had $(\text{OH})_2$ attached to the Mg, and H_3 attached to the PO_4 . I therefore have 2H_3 reacting with $3(\text{OH})_2$. We have to write this, on the **left side** of the equation, as $6\text{H}^+ + 6\text{OH}^-$ because we need it in ionic form.

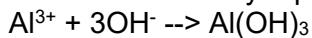
The equation becomes:**The full equation is now balanced and is:**

I have purposely split the equation into segments of reactions. This is showing you which ions are reacting with each other. Once you get the idea of equations you will not need this step.

The balancing of equations is simple. You need to learn the valency of the common ions (see tables). The rest is pure mathematics, you are balancing valency charges, positives versus negatives. You have to have the **same number of negatives**, or **positives**, each side of the equation, and the **same number of ions or atoms** each side of the equation.

If one ion, example Al^{3+} , (3 positive charges) reacts with another ion, example OH^- (one negative ion) then we require 2 more negatively charged ions (in this case OH^-) to counteract the 3 positive charges the Al^{3+} contains.

Take my earlier hint, place the 3 from the Al^{3+} in front of the OH^- , now reads 3OH^- , place the 1 from the hydroxyl OH^- in front of the Al^{3+} , now stays the same, Al^{3+} (the 1 is **never** written in chemistry equations).



The 3 is simply written in front of the OH^- , a recognized ion, there are no brackets placed around the OH^- . On the right hand side of the equation, all numbers in front of each ion on the left hand side of the equation are placed after each same ion on the right side of the equation. Brackets are used in the right side of the equation because the result is a compound. Brackets are also used for compounds (reactants) in the left side of equations, as in $3\text{Mg}(\text{OH})_2 + 2\text{H}_3\text{PO}_4 \rightarrow ?$



Conductivity, temperature and pH measuring equipment.



Hard to tell, but these are one ton cylinders. Notice the five gallon bucket of motor oil in the bottom picture. Also notice that this picture is the only eye wash station that we found during our inspection of 10 different facilities. Do you have an eye wash and emergency shower?

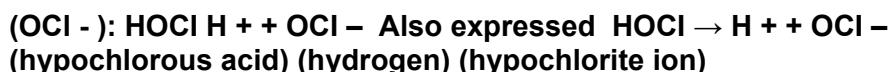


Chemistry of Chlorination

Chlorine can be added as sodium hypochlorite, calcium hypochlorite or chlorine gas. When any of these is added to water, chemical reactions occur as these equations show:



All three forms of chlorine produce hypochlorous acid (HOCl) when added to water. Hypochlorous acid is a weak acid but a strong disinfecting agent. The amount of hypochlorous acid depends on the pH and temperature of the water. Under normal water conditions, hypochlorous acid will also chemically react and break down into a hypochlorite ion.



The hypochlorite ion is a much weaker disinfecting agent than hypochlorous acid, about 100 times less effective.

Let's now look at how pH and temperature affect the ratio of hypochlorous acid to hypochlorite ions. As the temperature is decreased, the ratio of hypochlorous acid increases. Temperature plays a small part in the acid ratio. Although the ratio of hypochlorous acid is greater at lower temperatures, pathogenic organisms are actually harder to kill. All other things being equal, higher water temperatures and a lower pH are more conducive to chlorine disinfection.

Types of Residual

If water were pure, the measured amount of chlorine in the water should be the same as the amount added. But water is not 100% pure. There are always other substances (interfering agents) such as iron, manganese, turbidity, etc., which will combine chemically with the chlorine.

This is called the **chlorine demand**. Naturally, once chlorine molecules are combined with these interfering agents they are not capable of disinfection. It is free chlorine that is much more effective as a disinfecting agent.

So let's look now at how free, total and combined chlorine are related. When a chlorine residual test is taken, either a total or a free chlorine residual can be read.

Total residual is all chlorine that is available for disinfection.

Total chlorine residual = free + combined chlorine residual.

Free chlorine residual is a much stronger disinfecting agent. Therefore, most water regulating agencies will require that your daily chlorine residual readings be of free chlorine residual.

Break-point chlorination is where the chlorine demand has been satisfied, any additional chlorine will be considered **free chlorine**.

Residual Concentration/Contact Time (CT) Requirements

Disinfection to eliminate fecal and coliform bacteria may not be sufficient to adequately reduce pathogens such as Giardia or viruses to desired levels. Use of the "**CT**" disinfection concept is recommended to demonstrate satisfactory treatment, since monitoring for very low levels of pathogens in treated water is analytically very difficult.

The CT concept, as developed by the United States Environmental Protection Agency (Federal Register, 40 CFR, Parts 141 and 142, June 29, 1989), uses the combination of disinfectant residual concentration (mg/L) and the effective disinfection contact time (in minutes) to measure effective pathogen reduction. The residual is measured at the end of the process, and the contact time used is the T10 of the process unit (time for 10% of the water to pass).

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 container and 150 pound cylinders. The 1/2 ton is on a scale.
Cylinders stand up right and containers on their sides.**

Proposed Stage 2 DBP Rule – Compliance

*Written by Sarah C. Clark, P.E.
Senior Project Manager HDR*

The proposed Stage 2 Disinfection Byproduct Rule (DBPR) is expected to minimize exposure to disinfection byproducts (DBPs) at individual locations in the distribution system and to shave the peak values of DBPs in the system. The Initial Distribution System Evaluation was discussed in the last issued of the Newsletter. In the IDSE process, utilities are required to complete a study that locates new permanent DBP monitoring sites.

When the IDSE is complete, an IDSE Report is submitted to the State which includes the proposed new permanent DBP monitoring sites for the utility. Each State may handle the approval of the monitoring sites in a slightly different manner, but the basic process is that the State can approve the monitoring sites as recommended in the IDSE report, the State can suggest alternative sites, or the State may request additional information.

Stage 2A

Compliance under the Stage 2 DBPR is divided into two phases, Stage 2A and Stage 2B. During the time when utilities are monitoring for the IDSE, compliance continues to be based on the current Stage 1 DBPR requirements. Recall that Stage 1 DBPR requires utilities to meet MCLs of 80 µg/L and 60 µg/L for TTHMs and HAA5s, respectively, based on a running annual average calculation across the whole system. During that same period, utilities should be preparing themselves to meet the locational running annual average (LRAA) requirements of the Stage 2A portion of the rule. The relative timing of the parts of the rule are shown in Figure 1.

Stage 2A requires all utilities to calculate the locational running annual average (LRAA) of quarterly sample results for TTHMs and HAA5s at each Stage 1 DBPR sampling site. The LRAA is the running annual average at a specific location in the distribution system. All utilities must meet the MCL of 120 µg/L for TTHMs and 100 µg/L for HAA5s on this LRAA basis. Preparation for meeting these LRAA levels should include evaluating the LRAA at each Stage 1 compliance monitoring site. For any sites that cannot meet the MCLs, development and implementation of a plan to bring them into compliance would be wise. The Stage 2A compliance date is three years from the date when the rule is finalized. At that time, all Stage 1 compliance sites must meet the Stage 2A MCLs based on the LRAA calculation method, in addition to maintaining compliance with the running annual average requirements across the system as required by the Stage 1 rule.

Stage 2B

As soon as the IDSE is complete, utilities can begin to prepare for meeting Stage 2B by monitoring at the newly selected compliance sites identified in the IDSE. Obtaining this data prior to the Stage 2B compliance date will provide information to the utility regarding areas in the system that need changes made that will reduce DBPs. Compliance with Stage 2B is based on meeting the MCLs of 80 µg/L and 60 µg/L for TTHMs and HAA5s, respectively, using the locational running annual average of quarterly sample results at each new monitoring site. Once the utility has some data from the new sites, plans can be made for alterations in treatment or operations to meet MCLs, if needed.

Sufficient time is allowed in the rule for systems to make changes in their system to meet the compliance date for Stage 2B. The Stage 2B compliance date is six years after the rule is finalized for systems serving 10,000 people or more. For small systems the compliance date for Stage 2B is 7.5 or 8.5 years after the rule is finalized, depending on whether the system is required to sample for *Cryptosporidium* under the LT2ESWTR monitoring. Compliance dates for all system sizes for both stages of the rule are shown in Table 1.

**TABLE 1
PROPOSED COMPLIANCE SCHEDULE FOR
STAGE 2A AND STAGE 2B DBPR**

System Size	IDSE Report Due	Comply with Stage 2A	Comply with Stage 2B
≥ 10,000	2 years after publication	3 years after publication	6 years after publication
< 10,000 in combined distribution system	2 years after publication	3 years after publication	6 years after publication
< 10,000	4 years after publication	3 years after publication	7.5/8.5 years after publication

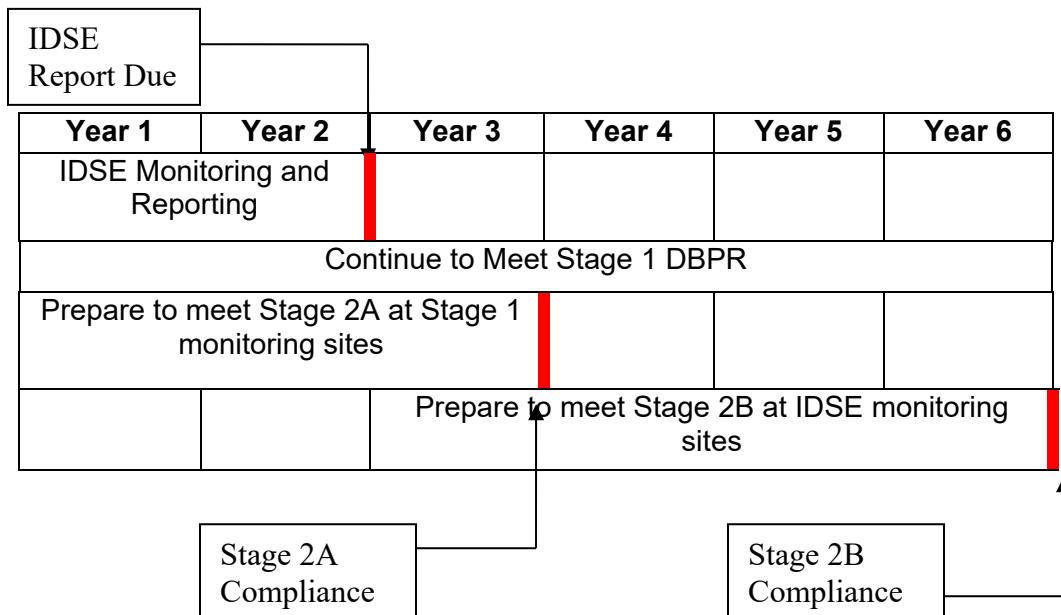
Summary

Utilities should keep in mind that the requirements of the Stage 1 DBPR continue to remain in force. This means that the percent removal requirements for total organic carbon (TOC) continue, as do the alternative compliance criteria for TOC removal. A summary of the Stage 2 DBPR phased compliance requirements is shown in Table 2. Ground water serving 10,000 people or more and surface water systems serving 500 or more people must monitor quarterly, taking at least one sample during the peak historical month for DBP concentration. Very small surface water plants and small ground water plants are on a yearly sampling schedule.

**TABLE 2
PROPOSED STAGE 2 DBPR PHASED COMPLIANCE WITH MCLs**

	Compliance Monitoring Sites	Compliance Calculation Basis	TTHM MCL µg/L	HAA5 MCL µg/L
Stage 2A	Stage 1	LRAA	120	100
	Stage 1	RAA	80	60
Stage 2B	Stage 2	LRAA	80	60

Figure 1
Schedule For DBP Compliance Monitoring



Notes:

- Applies to Large and Medium Systems and Small Systems in Larger Combined Distribution Systems
- Based on years after Stage 2 DBPR is promulgated.

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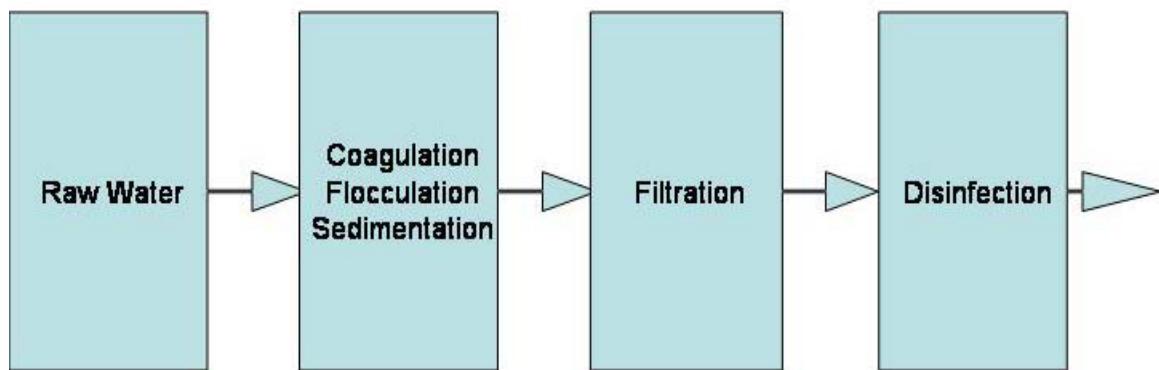
Backwashing Filters



Water Treatment Section

Conventional Filtration

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



Suspended particles carry an electrical charge which causes them to repel one another. The conventional process uses alum (aluminum sulfate) and cationic polymer to neutralize the charge. That allows suspended particles to clump together to form more easily filtered particles. Alum combines with alkalinity in the raw water to form a white precipitate that neutralizes suspended particles' electrical charge and forms a base for coagulating those particles. Conventional technology uses a 30 to 50 mg/L alum dosage to form a large floc that requires extensive retention time to permit settling.

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

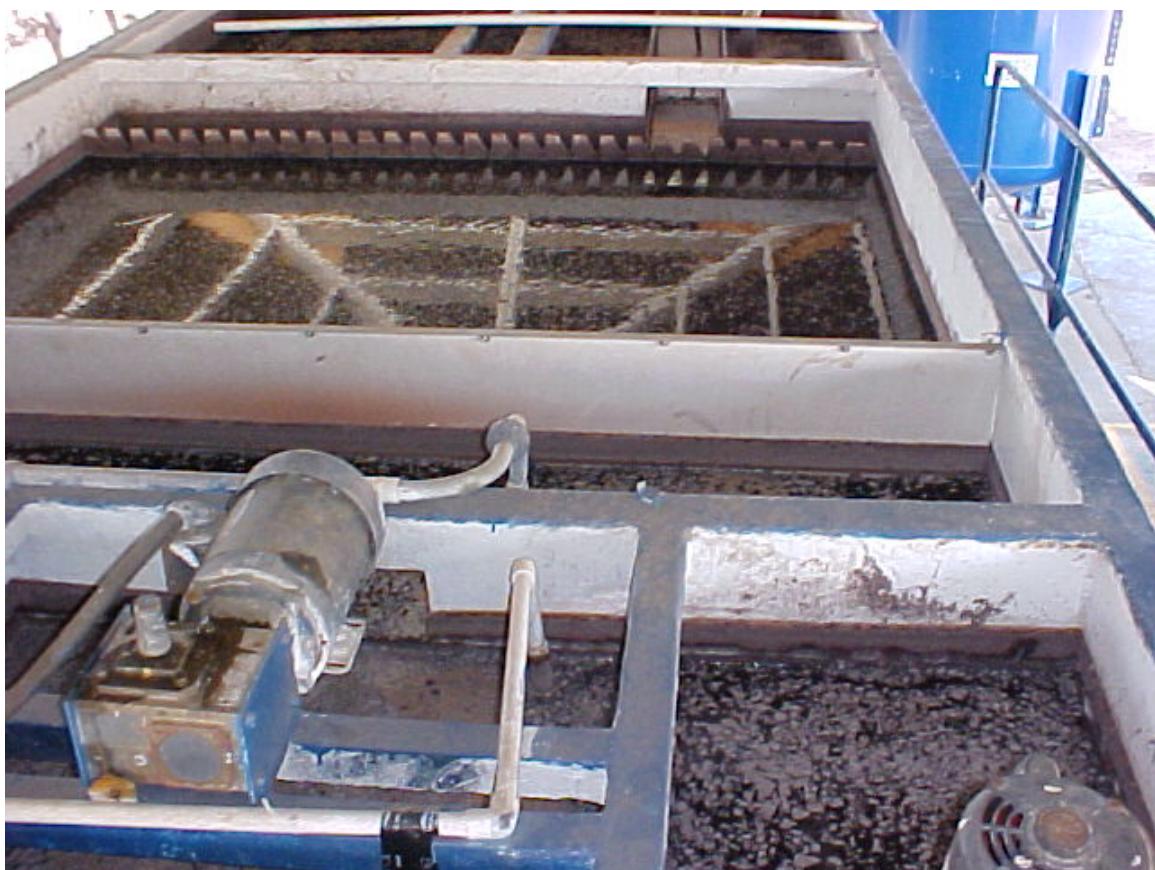
A depth filter has four layers of filtration media, each of different size and density. Light, coarse material lays at the top of the filter bed. The media become progressively finer and denser in the lower layers. Larger suspended particles are removed by the upper layers while smaller particles are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

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

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

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

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



Top of a small water treatment package plant, can you see the floc on the top of the water? Notice the confirmation of the settling zone.

Hard Water

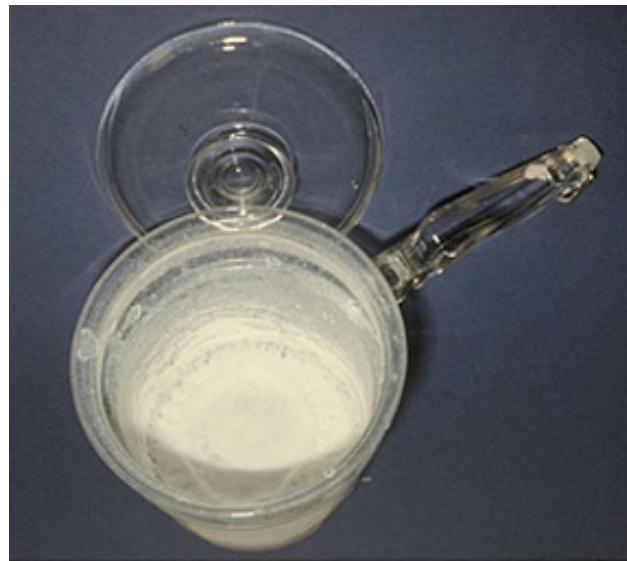
Water contains various amounts of dissolved minerals, some of which impart a quality known as hardness. Consumers frequently complain about problems attributed to hard water, such as the formation of scale in cooking utensils and hot water heaters.

In this document we will discuss the occurrence and effects of hard water and the hard water treatment or softening process that remove the hardness-causing minerals.

The precipitation process most frequently used is generally known as the lime process or lime soda process. Because of the special facilities required and the complexity of the process, it is generally applicable only to medium- or large-size water systems where all treatment can be accomplished at a central location. This process will provide softened water at the lowest cost. Lime softening can be used for treatment of either groundwater or surface water sources.

The other commonly used method of softening involves the ion exchange process. This process has the advantages of a considerably lower initial cost and ease of use by small systems or by large systems at multiple locations. The principal disadvantage is that operating costs are considerably higher. Ion exchange processes can typically be used for direct treatment of groundwater, so long as turbidity and iron levels are not excessive. For treatment of surface water, the process normally must be preceded by conventional treatment.

Softening can also be accomplished using membrane technology, electrodialysis, distillation, and freezing. Of these, the membrane methods seem to have the greatest use potential.



Occurrence of Hard Water

Hard water is caused by soluble, divalent, metallic cations, (positive ions having valence of 2). The principal chemicals that cause water hardness are calcium (**Ca**) and magnesium (Mg). Strontium, aluminum, barium, iron, are or are not usually present in large enough concentrations to contribute significantly to the total hardness.

Water hardness varies considerably in different geographic areas of the contiguous 48 states. This is due to different geologic formations, and is also a function of the contact time between water and limestone deposits. Magnesium is dissolved as water passes over and through dolomite and other magnesium-bearing minerals. Because ground-water is in contact with these formations for a longer period of time than surface water, groundwater is normally harder than surface water.

Expressing Hardness Concentration

Water hardness is generally expressed as a concentration of calcium carbonate, in terms of milligrams per liter as CaCO₃. The degree of hardness that consumer consider objectionable will vary, depending on other qualities of the water and on the hardness to which they have become accustomed. We will show two different classifications of the relative hardness of water:

Comparative classifications of water for softness and hardness

Classification	mg/L as CaCO ₃ [*]	mg/L as CaCO ₃ ⁺
Soft	0 – 75	0 – 60
Moderately hard	75 – 150	61 – 120
Hard	150 – 300	121 – 180
Very hard	Over 300	Over 180

Source: Adapted from Sawyer 1960 and Briggs and Ficke 1977.

* Per Sawyer (1960)

+ Per Briggs and Ficke (1977)

Types of Hardness

Hardness can be categorized by either of two methods: calcium versus magnesium hardness and carbonate versus non-carbonate hardness.

The calcium-magnesium distinction is based on the minerals involved. Hardness caused by calcium is called calcium hardness, regardless of the salts associated with it, which include calcium sulfate (CaSO₄), calcium chloride (CaCl₂), and others. Likewise, hardness caused by magnesium is called magnesium hardness. Calcium and magnesium are normally the only significant minerals that cause hardness, so it is generally assumed that

$$\text{Total hardness} = \text{calcium hardness} + \text{magnesium hardness}$$

Carbonate-Noncarbonate Distinction

The carbonate-noncarbonate distinction, however, is based on hardness from either the bicarbonate salts of calcium or the normal salts of calcium and magnesium involved in causing water hardness. Carbonate hardness is caused primarily by the bicarbonate salts of calcium and magnesium, which are calcium bicarbonate, $\text{Ca}(\text{HCO}_3)_2$, and magnesium bicarbonate $\text{Mg}(\text{HCO}_3)_2$. Calcium and magnesium combined with carbonate (CO_3) also contribute to carbonate hardness. Noncarbonate hardness is a measure of calcium and magnesium salts other than carbonate and bicarbonate salts. These salts are calcium sulfate, calcium chloride, magnesium sulfate (MgSO_4), and magnesium chloride (MgCl_2). Calcium and magnesium combined with nitrate may also contribute to noncarbonate hardness, although it is a very rare condition. For carbonate and noncarbonate hardness;

$$\text{Total hardness} = \text{carbonate hardness} + \text{noncarbonate hardness}$$

When hard water is boiled, carbon dioxide (CO_2) is driven off, bicarbonate salts of calcium and magnesium then settle out of the water to form calcium and magnesium carbonate precipitates. These precipitates form the familiar chalky deposits on teapots. Because it can be removed by heating, carbonate hardness is sometimes called "**Temporary hardness.**" Because noncarbonated hardness cannot be removed or precipitated by prolonged boiling, it is sometimes called "**permanent hardness.**"

Objections to Hard Water

Scale Formation: Hard water forms scale, usually calcium carbonate, which causes a variety of problems. Left to dry on the surface of glassware and plumbing fixtures, including showers doors, faucets, and sink tops, hard water leaves unsightly white scale known as water spots. Scale that forms on the inside of water pipes will eventually reduce the flow capacity or possibly block it entirely. Scale that forms within appliances and water meters causes wear on moving parts.

When hard water is heated, scale forms much faster. In particular, when the magnesium hardness is more than about 40 mg/l (as CaCO_3), magnesium hydroxide scale will deposit in hot water heaters that are operated at normal temperature of 140-150°F (60-66°C). A coating of only 0.04 in. (1 mm) of scale on the heating surfaces of a hot water heater creates an insulation effect that will increase heating costs by about 10 percent.

Effect on Soap: The historical objection to hardness has been its effect on soap. Hardness ions form precipitates with soap. Causing unsightly "curd," such as the familiar bathtub ring, as well as reduced efficiency in washing and laundering. To counteract these problems, synthetic detergents have been developed and are now used almost exclusively for washing clothes and dishes.

These detergents have additives known as sequestering agents that "**tie up**" the hardness ions so that they cannot form the troublesome precipitates. Although modern detergents counteract many of the problems of hard water, many customers prefer softer water. These customers can install individual softening units or use water from another source, such as a cistern, for washing.

Hard Water Treatment Methods

There are many commercial ways of treating hard water including water filters, water softeners, electromagnetic water conditioners and reverse osmosis. In this section we will look at the pros and cons of several of the available methods to treat hard water.

Method	Chemical Water Softeners	Water Filters	Mechanical Water Treatment Softeners	Magnetic Water Conditioners
Description	Chemicals added in laundering process	Drinking water from the tap is filtered with a portable unit	Permanently installed in plumbing system to replace calcium and magnesium with sodium	Permanently installed in plumbing system to alter calcium ions so they cannot cause lime scale
Advantages	Removes Calcium and Magnesium and lengthens lifespan of clothes	Output water is fit for drinking Chlorine removed Water Softened	Prevents Lime scale Increases heating efficiency Lengthens lifespan of clothes	Output water is fit for drinking Prevents Lime scale Increases heating efficiency Lengthens lifespan of clothes Calcium retained, good for diet Low running cost
Disadvantages	Output water is not fit for drinking	Does not prevent lime scale deposits in pipes and heating system	Output water may not be suitable for drinking Expensive	
Approximate Cost		(\$0.09) / gallon	(\$1400) Unit + Installation (\$140) / Year - Salt + Electricity	(\$90) Unit + Installation (\$7) / Year - electricity

Water Softening Section

Water softening is a method of removing from water the minerals that make it hard. Hard water does not dissolve soap readily. It forms scale in pipes, boilers, and other equipment in which it is used. The principal methods of softening water are the lime soda process and the ion exchange process.

In the **lime soda process**, soda ash and lime are added to the water in amounts determined by chemical tests. These chemicals combine with the calcium and magnesium in the water to make insoluble compounds that settle to the bottom of the water tank.

In the **ion exchange process**, the water filters through minerals called zeolites. As the water passes through the filter, the sodium ions in the zeolite are exchanged for the calcium and magnesium ions in the water, and the water is softened. After household softeners become exhausted, a strong solution of *sodium chloride* (salt) is passed through the filter to replace the sodium that has been lost. The use of two exchange materials makes it possible to remove both metal and acid ions from water. Some cities and towns, however, prohibit or restrict the use of ion exchange equipment on drinking water, pending the results of studies on how people are affected by the consumption of the added sodium in softened water.



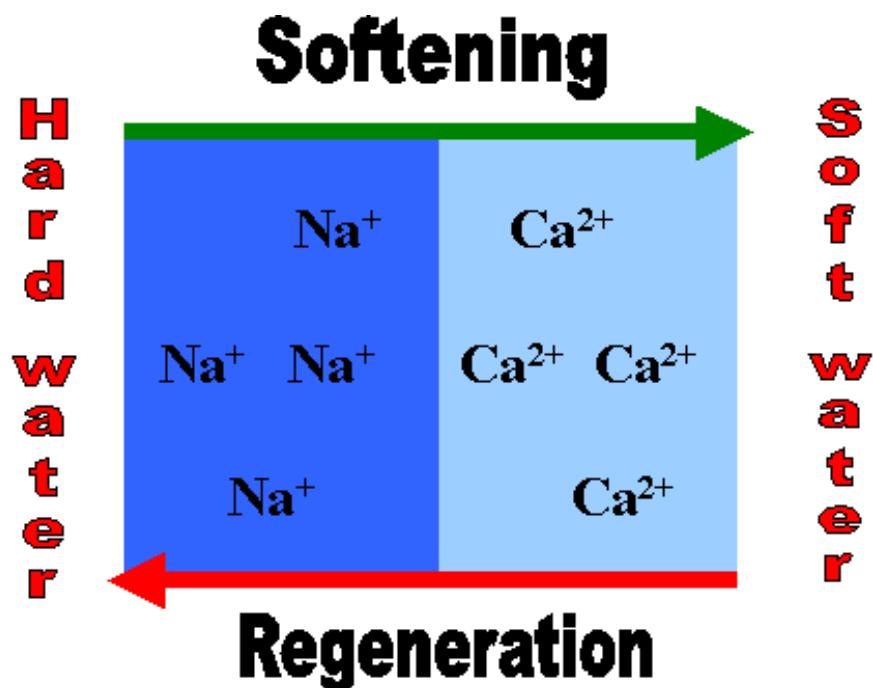
These containers hold the resin for the deionization

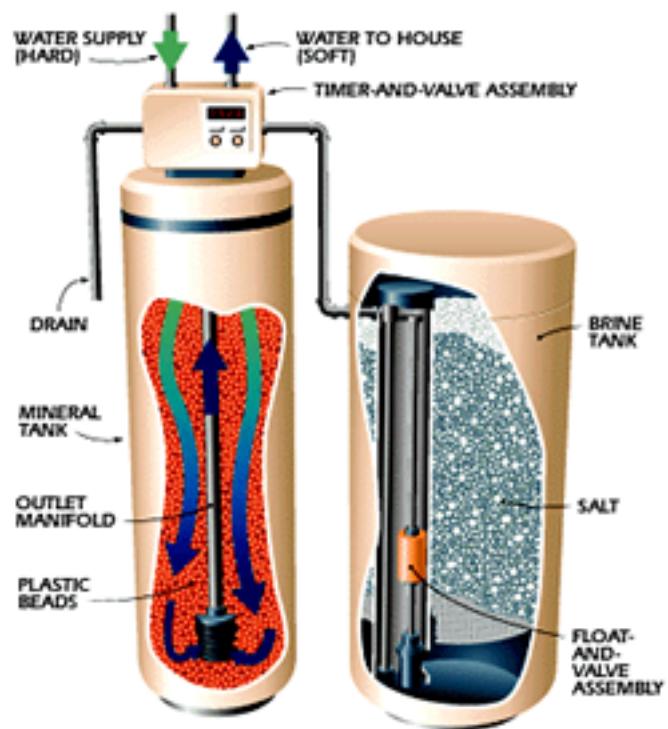
Calcium and magnesium in water create hard water, and at high levels can clog pipes. The best way to soften water is to use a water softener unit connected into the water supply line. You may want to consider installing a separate faucet for unsoftened water used for drinking and cooking. Water softening units also remove iron.

The most common way to soften household water is to use a water softener. Softeners may also be safely used to remove up to about 5 milligrams per liter of dissolved iron if the water softener is rated for that amount of iron removal. Softeners are automatic, semi-automatic, or manual. Each type is available in several sizes and is rated on the amount of hardness it can remove before regeneration is necessary. Using a softener to remove iron in naturally soft water is not advised. A green-sand filter is a better method. When the resin is filled to capacity, it must be recharged. Fully automatic softeners regenerate on a preset schedule and return to service automatically. Regeneration is usually started by a preset time clock, some units are started by water use meters or hardness detectors. Semi automatic softeners have automatic controls for everything except for the start of regeneration. Manual units require manual operation of one or more valves to control back washing, brining and rinsing. In many areas, there are companies that provide a water softening service. For a monthly fee the company installs a softener unit and replaces it periodically with a freshly charged unit.

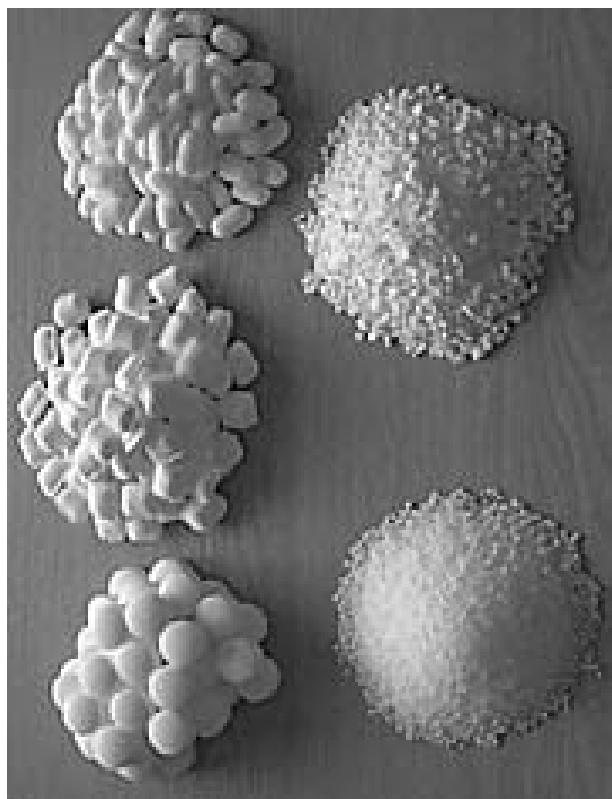
The principle behind water softening is really just simple chemistry. A water softener contains resin beads which hold electrically charged ions. When hard water passes through the softener, calcium and magnesium ions are attracted to the charged resin beads. It's the resulting removal of calcium and magnesium ions that produces "**soft water**." The diagram shows the exchange that takes place during the water softening process.

When the resin beads in your softener become saturated with calcium and magnesium ions, they need to be recharged. Sodium ions from the water softening salt reactivate the resin beads so they can continue to do their job. Without sufficient softening salt, your water softener is less efficient. As a rule, you should check your water softener once a week to be sure the salt level is always at least one quarter full.

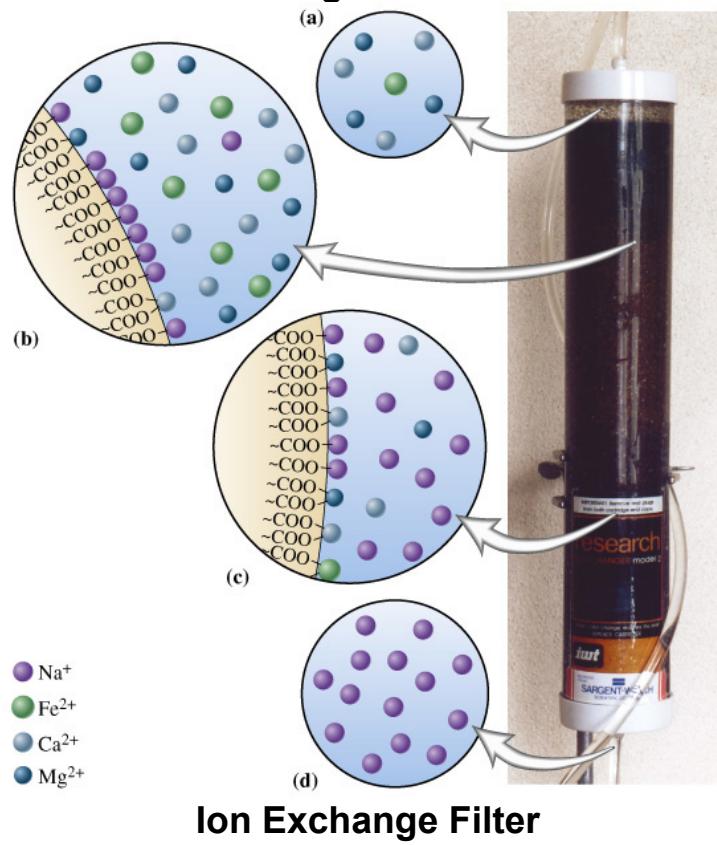




Operation of a household water softener



Various grades of salt



Mechanical Water Treatment Softeners

Mechanical water treatment softening units can be permanently installed into the plumbing system to continuously remove calcium and magnesium.

Water treatment softeners operate on the ion exchange process. In this process, water passes through a media bed, usually sulfonated polystyrene beads. The beads are supersaturated with sodium. The ion exchange process takes place as hard water passes through the softening material. The hardness minerals attach themselves to the resin beads while sodium on the resin beads is released simultaneously into the water.

When the resin becomes saturated with calcium and magnesium, it must be recharged. The recharging is done by passing a salt (**brine**) solution through the resin. The sodium replaces the calcium and magnesium which are discharged in the waste water.

Hard water treated with an ion exchange water softener has sodium added. According to the Water Quality Association (**WQA**), the ion exchange softening process adds sodium at the rate of about 8 mg/liter for each grain of hardness removed per gallon of water.

For example, if the water has a hardness of 10 grains per gallon, it will contain about 80 mg/liter of sodium after being softened in an ion exchange water softener if all hardness minerals are removed.

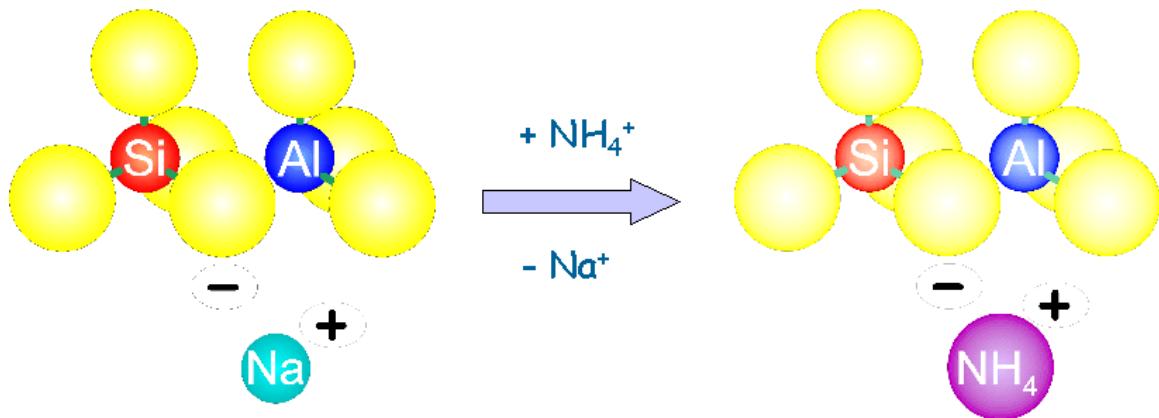
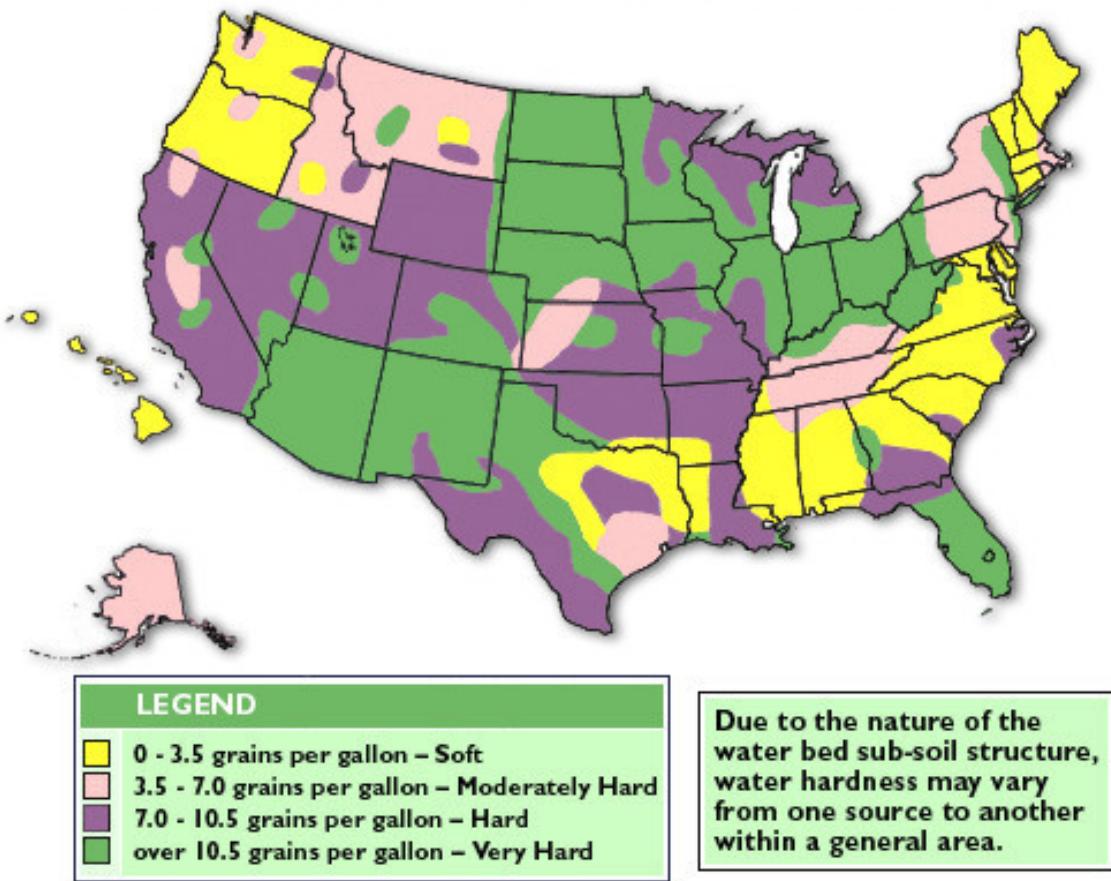
Because of the sodium content of softened water, some individuals may be advised by their physician, not to install water softeners, to soften only hot water or to bypass the water softener with a cold water line to provide unsoftened water for drinking and cooking, usually to a separate faucet at the kitchen sink.

Mechanically softened water is not recommended for watering plants, lawns, and gardens due to its sodium content.



The container behind the salt pallet is a high concentration of salt and water. (Brine)

HARD WATER LEVELS THROUGHOUT THE U.S.



Small Water Filters

Water filters generally come in two forms. Portable ion exchange water filters, and reverse osmosis water filters. Both are used for "**point of use**" drinking water, that is, to filter out harmful or unwanted particles before the water is used for human consumption.

Reverse Osmosis works by forcing the water through a semi-permeable membrane that stops certain particles from passing through.

Portable water filters work using a cartridge containing activated carbon and ion exchange resin. The carbon absorbs and helps reduce the levels of chlorine and chlorine compounds, as well as pesticides, color and other organic substances. This improves taste and appearance. The ion exchange resin works to reduce temporary hardness.

Activated Carbon Filtration

Activated carbon has been used for many years to solve water problems. In the beginning, its use was more art than science. Today, however, we understand more about what activated carbon can remove and how it removes impurities.

Activated carbon quickly and effectively removes chlorine from water.

The presence of organic matter in water can cause color, taste and odor complaints. Activated carbon adsorbs organic matter in its extensive network of pores. The adsorption process takes time, so service rates should be limited to 5 gpm/ft (12m/hr) or less for these applications.



A handful of GAC

Synthetic Organic Chemicals

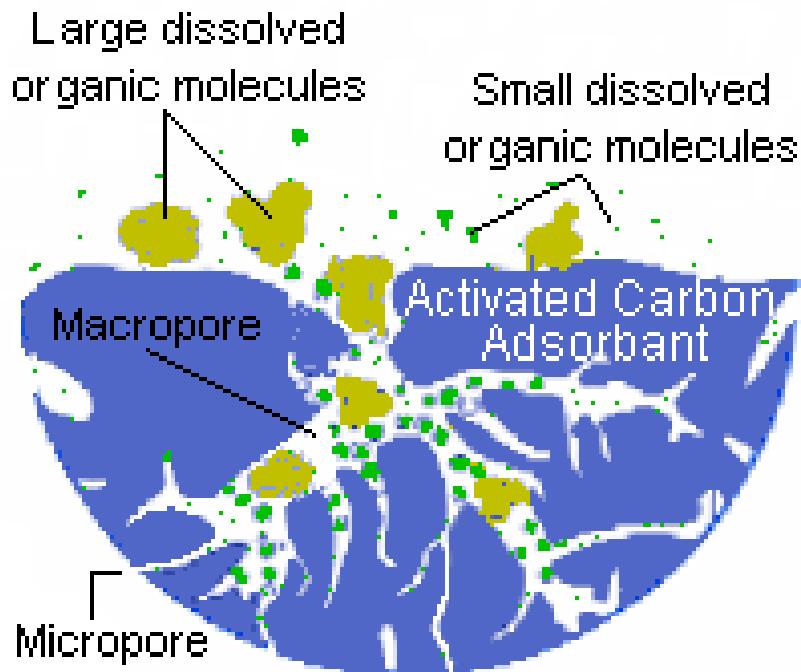
Synthetic organic chemicals (**SOC**) include all man-made organics, some of which are volatile organic compounds (**VOC**). Activated carbon can substantially reduce many VOCs such as benzene, trichlorethane and carbon tetrachloride. Activated carbon also removes SOCs such as Alachlor, EDB and toluene. The EPA is establishing limits for these chemicals in public drinking water supplies.

Before recommending treatment, water suspected of containing any of these and other substances must be analyzed to determine their concentrations and whether they exceed the EPA standards.

Activated carbon beds compact with use so they may need occasional backwashing, however, backwash carbon as little as possible to prevent loss of the fragile material. Also, contaminant-laden carbon may migrate toward the bottom of the bed during backwash and reduce filter performance. When operating a carbon filter or system on turbid water supplies, remove suspended particles with a depth filter before treating it with activated carbon. A carbon filter typically backwashes at 10 gpm/ft (25 m/hr) for about 10 minutes, followed by a 5 minute downflow rinse.

Over a period of several months to two years, the carbon's adsorption capacity diminishes. The exhausted carbon bed should be replaced with fresh carbon. The old carbon should be hauled to an approved disposal facility.

How Activated Carbon Works



Membrane Filtration Processes

In 1748, the French physicist Nollet first noted that water would diffuse through a pig bladder membrane into alcohol. This was the discovery of osmosis, a process in which water from a dilute solution will naturally pass through a porous membrane into a concentrate solution. Over the years, scientists have attempted to develop membranes that would be useful in industrial processes, but it wasn't until the late 1950s that membranes were produced that could be used for what is known as reverse osmosis. In reverse osmosis, water is forced to move through a membrane from a concentrate solution to a dilute solution.

Since that time, continual improvements and new developments have been made in membrane technology, resulting in ever-increasing uses in many industries. In potable water treatment, membranes have been used for desalination, removal of dissolved inorganic and organic chemicals, water softening, and removal of the fine solids.

In particular, membrane technology enables some water systems having contaminated water sources to meet new, more stringent regulations. In some cases, it can also allow secondary sources, such as brackish groundwater, to be used. There is great potential for the continuing wide use of membrane filtration processes in potable water treatment, especially as technology improves and costs are reduced.

Description of Membrane Filtration Processes

In the simplest membrane processes, water is forced through a porous membrane under pressure while suspended solid, large molecules or ions are held back or rejected.

Types of Membrane Filtration Processes

The two general classes of membrane processes, based on the driving force used to make the process work, are:

- Pressure-driven processes
- Electric-driven processes

Pressure-Driven Processes

The four general membrane processes that operate by applying pressure to the raw water are:

- Microfiltration
- Ultrafiltration
- Nanofiltration
- Reverse Osmosis



Microfiltration

Microfiltration (**MF**) is a process in which water is forced under pressure through a porous membrane. Membranes with a pore size of 0.45 µm are normally used; this size is relatively large compared with the other membrane filtration processes. This process has not been generally applicable to drinking water treatment because it either does not remove substances that require removal from potable water, or the problem substances can be removed more economically using other processes. The current primary use of MF is by industries to remove very fine particles from process water, such as in electronic manufacturing. In addition, the process has also been used as a pretreatment for other membrane processes. In particular, RO membranes are susceptible to clogging or filter binding unless the water being processed is already quite clean.

However, in recent years, microfiltration has been proposed as a filtering method for particles resulting from the direct filtration process. Traditionally, this direct filtration process has used the injection of coagulants such as alum or polymers into the raw water stream to remove turbidity such as clay or silts. The formed particles were then removed by rapid sand filters. The use of filter aids to improve filtering efficiency, especially for small particles that could contain bacterial and protozoan life are recommended.

Ultrafiltration

Ultrafiltration (**UF**) is a process that uses a membrane with a pore size generally below 0.1 µm. The smaller pore size is designed to remove colloids and substances that have larger molecules, which are called high-molecular-weight materials. UF membranes can be designed to pass material that weigh less than or equal to a certain molecular weight. This weight is called the molecular weight cutoff (**MWC**) of the membrane. Although UF does not generally work well for removal of salt or dissolved solids, it can be used effectively for removal of most organic chemicals.

Nanofiltration

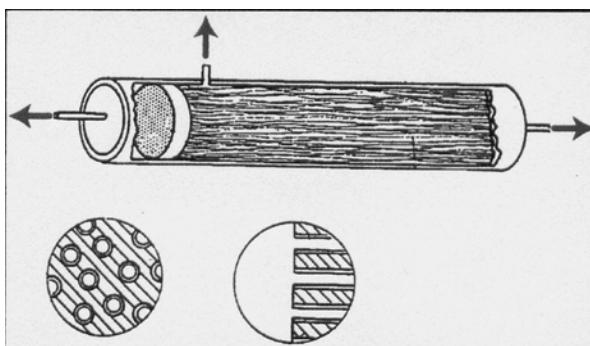
Nanofiltration (**NF**) is a process using membranes that will reject even smaller molecules than UF. The process has been used primarily for water softening and reduction of total dissolved solids (**TDS**). NF operates with less pressure than reverse osmosis and is still able to remove a significant proportion of inorganic and organic molecules. This capability will undoubtedly increase the use of NF for potable water treatment.

Reverse Osmosis

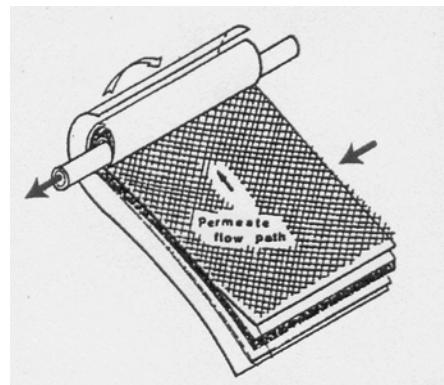
Reverse Osmosis (**RO**) is a membrane process that has the highest rejection capability of all the membrane processes. These RO membranes have very low MWC pore size that can reject ions at very high rates, including chloride and sodium. Water from this process is very pure due to the high reject rates. The process has been used primarily in the water industry for desalination of seawater because the capital and operating costs are competitive with other processes for this service. The RO also works most organic chemicals, and radionuclides and microorganisms. Industrial water uses such as semiconductor manufacturing is also an important RO process.

RO is discussed in more detail later.

Membrane Configurations



Hollow Fiber



Spiral Wound

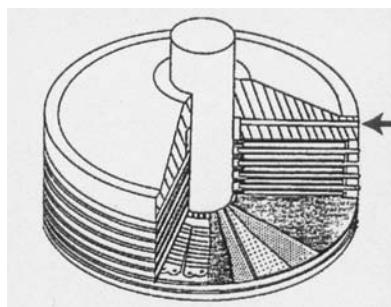
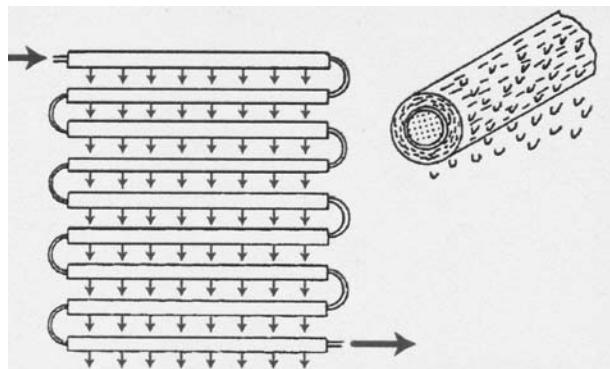


Plate and Frame



Tubular

Electric-Driven Processes

There are two membrane processes that purify a water stream by using an electric current to move ions across a membrane. These processes are:

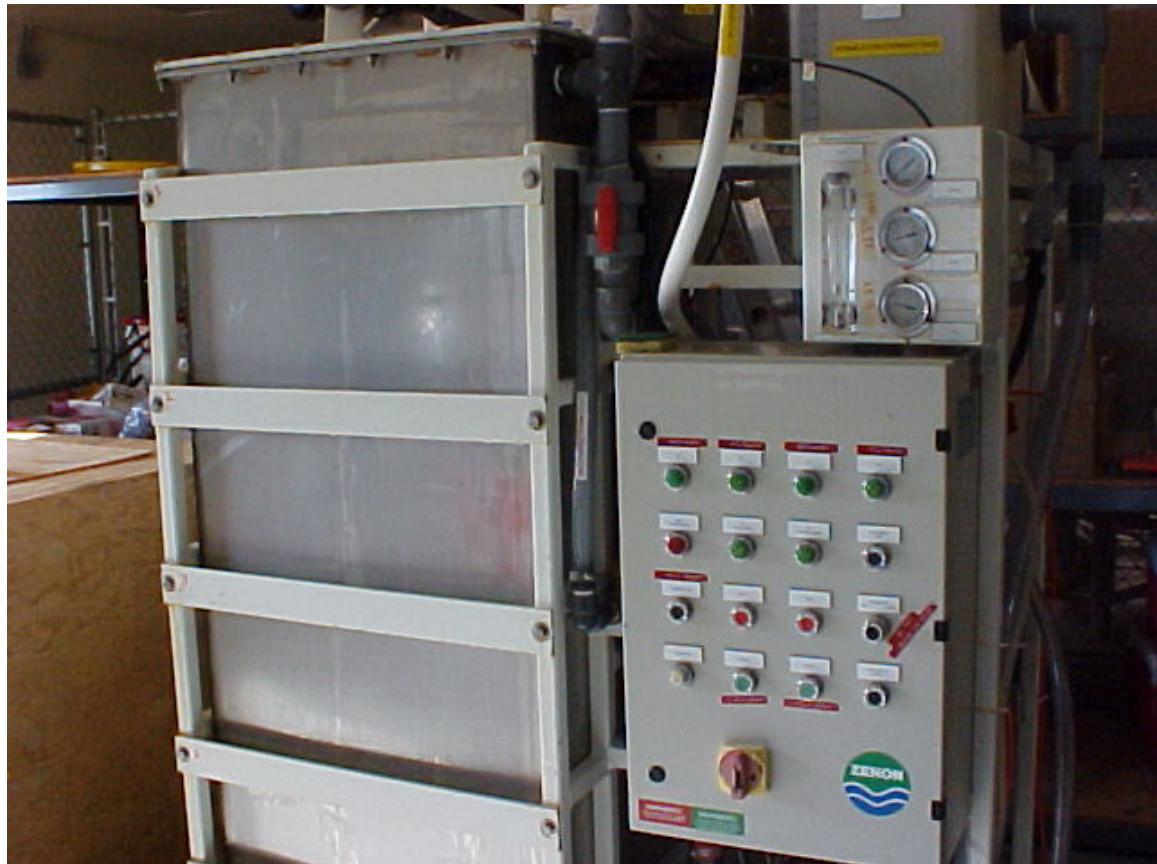
- Electrodialysis
- Electrodialysis reversal

Electrodialysis

Electrodialysis (**ED**) is a process in which ions are transferred through a membrane as a result of direct electric current applied to the solution. The current carries the ions through a membrane from the less concentrated solution to the more concentrated one.

Electrodialysis Reversal

Electrodialysis Reversal (**EDR**) is a process similar to ED, except that the polarity of the direct current is periodically reversed. The reversal in polarity reverses the flow of ions between demineralizing compartments, which provides automatic flushing of scale-forming materials from the membrane surface. As a result, EDR can often be used with little or no pretreatment of feedwater to prevent fouling. So far, ED and EDR have been used at only a few locations for drinking water treatment.



Nanofiltration Unit

Primary Water Treatment Alternatives

Ballasted Flocculation



In an effort to enhance the effectiveness of primary treatment, a ballasted flocculation unit uses many minute particles, which attract and hold materials together. Coagulating chemicals are also added to further clump particles together. The larger, heavier particles settle out of the wastewater rapidly.

This unit may significantly improve solids and organic material removal compared to conventional primary treatments.

Fuzzy Filter



Wastewater flows from the bottom of this machine to the top through lots of fuzzy pink balls that pick up most of the solid particles. This technology is typically used as an advanced treatment and has not been adapted to primary treatment elsewhere. If it is successful, it could dramatically reduce the size, or footprint, of the primary treatment process.

Secondary Treatment Alternative

Biological Aerated Filtration



Primary treated wastewater and air are injected at the bottom of this unit. It moves to the top through lots of granules. The granules both separate solids and provide a surface for biological activity to take place. Biological Aerated Filtration can provide secondary treatment quality without taking up as much space. In addition, this technology can be adapted to function as a nitrogen removal process (nitrification-denitrification) which may be important if reclaimed water is used in the future to augment stream flow.

This information was provided by King County Water Reuse Program
201 South Jackson Street, Suite 505, Seattle, WA 98104-3855 For more information about
King County's Water Reuse Program and water reclamation efforts, contact Jo Sullivan at
206-296-8361

Advanced Secondary Treatment Alternative

Membrane Bioreactors



This unit combines an activated sludge secondary treatment bioreactor and a microfiltration membrane. Membranes are submerged in the aeration tank and water is drawn through the membrane with a low-pressure vacuum, leaving the solids in the aeration tank. The Membrane Bioreactor can convert screened sewage to clean effluent in a single process - eliminating the need for separate primary, secondary and advanced treatment. It produces a very high quality effluent meeting Class A criteria (after disinfection). This technology has the potential to significantly reduce plant footprint while producing improved effluent quality.

Advanced Treatment Alternatives

Fuzzy Filter

This upflow filtration process was described above as a primary treatment alternative. The porosity of the filter bed can be altered by how compressed the fuzzy pink balls (media) are. In an advanced treatment application the loading rate on a fuzzy filter can be 5 times higher than typical sand filtration. This would result in a substantially smaller footprint.

Microfiltration



Microfiltration membranes (such as MEMBRANE BIOREACTORS) are used for physical separation of small particles from liquids. Membranes can be classified according to their pore size. There are four main types of membranes (listed from largest pore size to smallest): microfiltration, ultrafiltration, nanofiltration and reverse osmosis. Membranes are designed to operate in a pressure or vacuum mode.

In pressure membranes, the wastewater to be treated is forced down the center of the spaghetti-like membrane and is pushed through the walls in an 'inside-out' direction. For vacuum membranes, wastewater is drawn from the outside of the membrane into the hollow core where it is collected. Microfiltration membranes can be designed as strands, sheets or plates depending on the manufacturer and application.

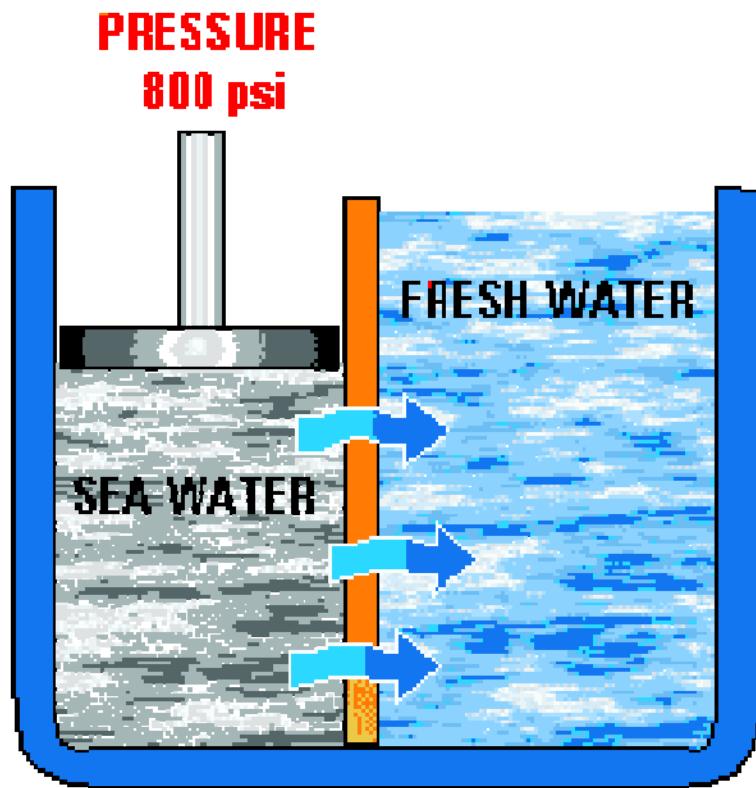
Microfiltration membranes can be used for direct filtration of secondary effluent or as pretreatment for reverse osmosis membranes (see next page). Microfiltration has the potential to produce better effluent quality when compared to standard sand filtration technologies.



Reverse Osmosis Process

Osmosis is a natural phenomenon in which a liquid - water, in this case - passes through a semi-permeable membrane from a relatively dilute solution toward a more concentrated solution. This flow produces a measurable pressure, called osmotic pressure. If pressure is applied to the more concentrated solution, and if that pressure exceeds the osmotic pressure, water flows through the membrane from the more concentrated solution toward the dilute solution.

This process, called reverse osmosis, or RO, removes up to 98% of dissolved minerals, and virtually 100% of colloidal and suspended matter. RO produces high quality water at low cost compared to other purifications processes.

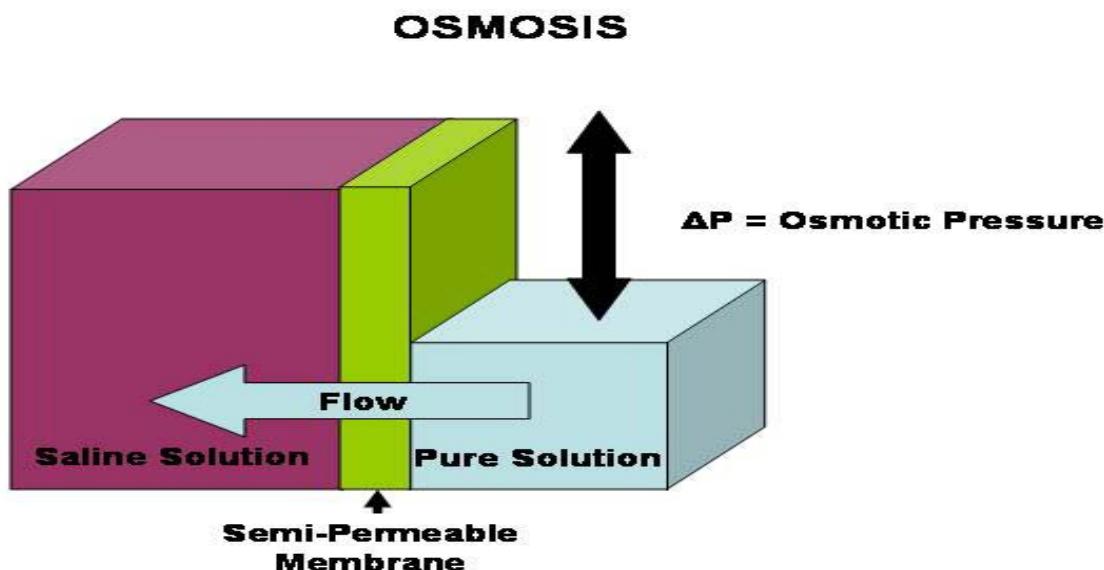


The membrane must be physically strong to stand up to high osmotic pressure - in the case of sea water, 2500 kg/m. Most membranes are made of cellulose acetate or polyamide composites cast into a thin film, either as a sheet or fine hollow fibers. The membrane is constructed into a cartridge called a reverse osmosis module.

After filtration to remove suspended particles, incoming water is pressurized with a pump to 200 - 400 psi (1380 - 2760 kPa) depending on the RO system model. This exceeds the water's osmotic pressure. A portion of the water (**permeate**) diffuses through the membrane leaving dissolved salts and other contaminants behind with the remaining water where they are sent to drain as waste (**concentrate**).

Pretreatment is important because it influences permeate quality and quantity. It also affects the module's life because many water-borne contaminants can deposit on the membrane and foul it. Generally, the need for pretreatment increases as systems become larger and operate at higher pressures, and as permeate quality requirements become more demanding. Because reverse osmosis is the principal membrane filtration process used in water treatment, it is described here in greater detail.

To understand Reverse Osmosis, one must begin by understanding the process of osmosis, which occurs in nature. In living things, osmosis is frequently seen. The component parts include a pure or relatively pure water solution and a saline or contaminated water solution, separated by a semi-permeable membrane, and a container or transport mechanism of some type.



The semi-permeable membrane is so designated because it permits certain elements to pass through, while blocking others. The elements that pass through include water, usually smaller molecules of dissolved solids, and most gases. The dissolved solids are usually further restricted based on their respective electrical charge.

In osmosis, naturally occurring in living things, the pure solution passes through the membrane until the osmotic pressure becomes equalized, at which point osmosis ceases. The osmotic pressure is defined as the pressure differential required to stop osmosis from occurring. This pressure differential is determined by the total dissolved solids content of the saline solution or contaminated solution on one side of the membrane. The higher the content of dissolved solids, the higher the osmotic pressure. Each element that may be dissolved in the solution contributes to the osmotic pressure, in that the molecular weight of the element affects the osmotic pressure.

Generally, higher molecular weights result in higher osmotic pressures. Hence the formula for calculating osmotic pressure is very complex. However, approximate osmotic pressures are usually sufficient to design a system.

Common tap water as found in most areas may have an osmotic pressure of about 10 PSI (Pounds per Square Inch), or about 1.68 Bar. Seawater at 36,000 PPM typically has an osmotic pressure of about 376 PSI (26.75 Bar).

Thus, to reach the point at which osmosis stops for tap water, a pressure of 10 PSI would have to be applied to the saline solution, and to stop osmosis in seawater, a pressure of 376 PSI would have to be applied to the seawater side of the membrane.

Several decades ago, U.S. Government scientists had the idea that the principles of osmosis could be harnessed to purify water from various sources, including brackish water and seawater. In order to transform this process into one that purifies water, osmosis would have to be reversed, and suitable synthetic membrane materials would have to be developed. Additionally, ways of configuring the membranes would have to be engineered to handle a continuous flow of raw and processed water without clogging or scaling the membrane material.

These ideas were crystallized, and fueled by U.S. Government funding, usable membrane materials and designs resulted. One of the membrane designs was the spiral wound membrane element. This design enabled the engineers to construct a membrane element that could contain a generous amount of membrane area in a small package, and to permit the flow of raw water to pass along the length of the membrane. This permits flows and pressures to be developed to the point that ample processed or purified water is produced, while keeping the membrane surface relatively free from particulate, colloidal, bacteriological or mineralogical fouling.

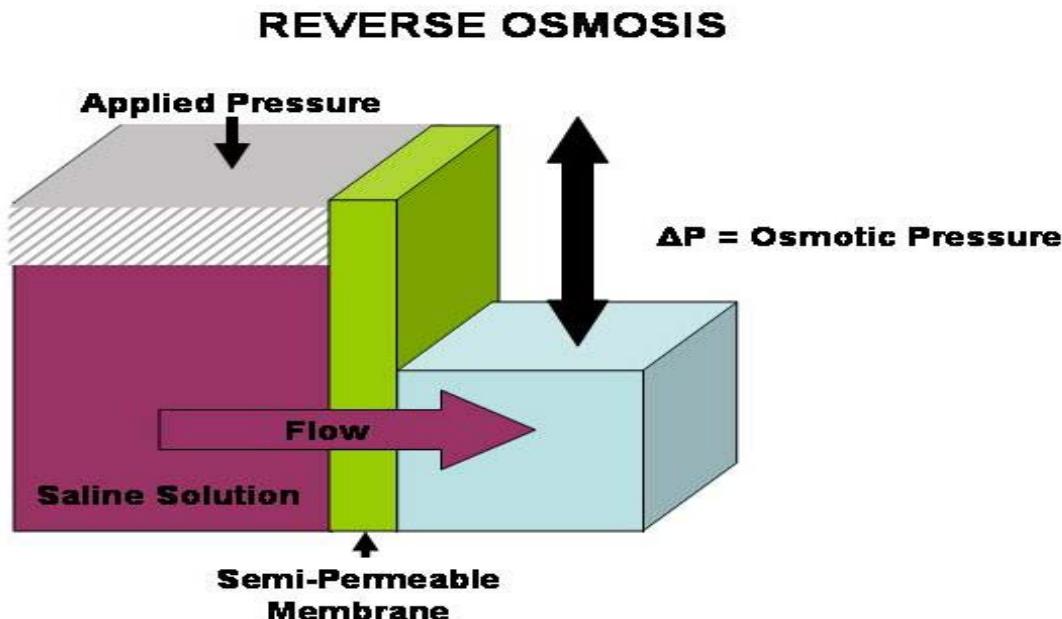
The design features a perforated tube in the center of the element, called the product or permeate tube, and wound around this tube are one or more "**envelopes**" of membrane material, opening at the permeate tube. Each envelope is sealed at the incoming and exiting edge. Thus when water penetrates or permeates through the membrane, it travels, aided by a fine mesh called the permeate channel, around the spiral and collects in the permeate tube. The permeate or product water is collected from the end of each membrane element, and becomes the product or result of the purification process.

Meanwhile, as the raw water flows along the "**brine channel**" or coarse medium provided to facilitate good flow characteristics, it gets more and more concentrated. This concentrated raw water is called the reject stream or concentrate stream. It may also be called brine if it is coming from a salt water source. The concentrate, when sufficient flows are maintained, serves to carry away the impurities removed by the membrane, thus keeping the membrane surface clean and functional. This is important, as buildup on the membrane surface, called fouling, impedes or even prevents the purification process.

The membrane material itself is a special thin film composite (**TFC**) polyamide material, cast in a microscopically thin layer on another, thicker cast layer of Polysulfone, called the microporous support layer. The microporous support layer is cast on sheets of paper-like material that are made from synthetic fibers such as polyester, and manufactured to the required tolerances.

Each sheet of membrane material is inspected at special light tables to ensure the quality of the membrane coating, before being assembled into the spiral wound element design.

To achieve Reverse Osmosis, the osmotic pressure must be exceeded, and to produce a reasonable amount of purified water, the osmotic pressure is generally doubled. Thus with seawater osmotic pressure of 376 PSI, a typical system operating pressure is about 800 PSI. Factors that affect the pressure required include raw water temperature, raw water TDS (Total Dissolved Solids), membrane age, and membrane fouling.



The effect of temperature is that with higher temperatures, the salt passage increases, flux (permeate flow) increases, and operating pressure required is lower. With lower temperatures, the inverse occurs, in that salt passage decreases (reducing the TDS in the permeate or product water), while operating pressures increase. Or if operating pressures do not increase, then the amount of permeate or product water is reduced. In general, Reverse Osmosis (R/O) systems are designed for raw water temperatures of 25° C (77° F). Higher temperatures or lower temperatures can be accommodated with appropriate adjustments in the system design.

Membranes are available in "**standard rejection**" or "**high rejection**" models for seawater and brackish water. The rejection rate is the percentage of dissolved solids rejected, or prevented from passing through the membrane. For example, a membrane with a rejection rate of 99% (usually based on Na (Sodium)) will allow only 1% of the concentration of dissolved solids to pass through into the permeate. Hence product water from a source containing 10,000 PPM would have 100 PPM remaining.

Of course, as the raw water is processed, the concentrations of TDS increase as it passes along the membrane's length, and usually multiple membranes are employed, with each membrane in series seeing progressively higher dissolved solids levels.

Typically, starting with seawater of 36,000 PPM, standard rejection membranes produce permeate below 500 PPM, while high rejection membranes under the same conditions produce drinking water TDS of below 300 PPM.

There are many considerations when designing R/O systems that competent engineers are aware of. These include optimum flows and pressures, optimum recovery rates (the percentage of permeate from a given stream of raw water), prefiltration and other pretreatment considerations, and so forth.

Membrane systems in general cannot handle the typical load of particulate contaminants without prefiltration. Often, well designed systems employ multiple stages of prefiltration, tailored to the application, including multi-media filtration and one or more stages of cartridge filtration. Usually the last stage would be 5m or smaller, to provide sufficient protection for the membranes.

R/O systems typically have the following components: A supply pump or pressurized raw water supply, prefiltration in one or more stages, chemical injection of one or more pretreatment agents may be added, a pressure pump suited to the application, sized and driven appropriately for the flow and pressure required, a membrane array including one or more membranes installed in one or more pressure tubes (also called pressure vessels, R/O pressure vessels, or similar), various gauges and flow meters, a pressure regulating valve, relief valve(s) and/or safety pressure switches, and possibly some form of post treatment.

Post treatment should usually include a form of sterilization such as Chlorine, Bromine, Ultra-Violet (**U-V**), or Ozone. Other types of post treatment may include carbon filters, pH adjustment, or mineral injection for some applications.



Packaged skid with instrumentation, UV, and softening.

Some very low cost R/O systems may dispense with most of the controls and instruments. However, systems installed in critical applications should be equipped with a permeate or product flow meter, a reject, concentrate or brine flow meter, multiple pressure gauges to indicate the pressure before and after each filtration device and the system operation pressure in the membrane loop, preferably both before and after the membrane array. Another feature found in better systems is a provision to clean the membranes in place, commonly known as a "**Clean In Place**" (CIP) system. Such a system may be built right into the R/O system or may be provided as an attachment for use as required.

Reverse Osmosis has proved to be the most reliable and cost effective method of desalinating water, and hence its use has become more and more widespread. Energy consumption is usually some 70% less than for comparable evaporation technologies. Advancements have been made in membrane technology, resulting in stable, long lived membrane elements.

Component parts have been improved as well, reducing maintenance and down time. Additional advancements in pretreatment have been made in recent years, further extending membrane life and improving performance. Reverse Osmosis delivers product water or permeate having essentially the same temperature as the raw water source (an increase of 1° C or 1.8° F may occur due to pumping and friction in the piping). This is more desirable than the hot water produced by evaporation technologies. R/O Systems can be designed to deliver virtually any required product water quality. For these and other reasons, R/O is usually the preferred method of desalination today.

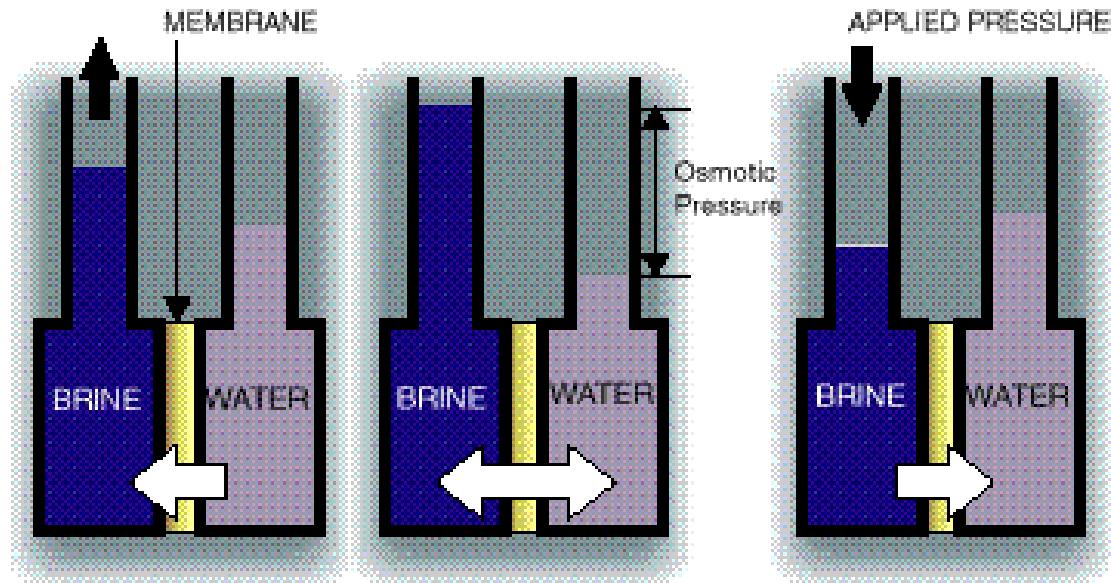
Reverse osmosis, also known as hyperfiltration, is the finest filtration known. This process will allow the removal of particles as small as ions from a solution. Reverse osmosis is used to purify water and remove salts and other impurities in order to improve the color, taste or properties of the fluid. It can be used to purify fluids such as ethanol and glycol, which will pass through the reverse osmosis membrane, while rejecting other ions and contaminants from passing. The most common use for reverse osmosis is in purifying water. It is used to produce water that meets the most demanding specifications that are currently in place.

Reverse osmosis uses a membrane that is semi-permeable, allowing the fluid that is being purified to pass through it, while rejecting the contaminants that remain. Most reverse osmosis technology uses a process known as cross-flow to allow the membrane to continually clean itself. As some of the fluid passes through the membrane the rest continues downstream, sweeping the rejected species away from the membrane. The process of reverse osmosis requires a driving force to push the fluid through the membrane, and the most common force is pressure from a pump. The higher the pressure, the larger the driving force. As the concentration of the fluid being rejected increases, the driving force required to continue concentrating the fluid increases.

Reverse osmosis is capable of rejecting bacteria, salts, sugars, proteins, particles, dyes, and other constituents that have a molecular weight of greater than 150-250 daltons. The separation of ions with reverse osmosis is aided by charged particles. This means that dissolved ions that carry a charge, such as salts, are more likely to be rejected by the membrane than those that are not charged, such as organics. The larger the charge and the larger the particle, the more likely it will be rejected.

Reverse Osmosis, when properly configured with sediment, carbon and/or carbon block technology, produces pure water that is clearly the body's choice for optimal health. It is the best tasting because it is oxygen-rich.

A Reverse Osmosis System removes virtually all: bad taste, odor, turbidity, organic compounds, herbicides, insecticides, pesticides, chlorine and THM's, bacteria, virus, cysts, parasites, arsenic, heavy metals, lead, cadmium, aluminum, dissolved solids, sodium, calcium, magnesium, inorganic dead dirt minerals, fluoride, sulfates, nitrates, phosphates, detergents, radioactivity and asbestos.



OSMOSIS

Water flows from low concentration of salts to higher concentration.

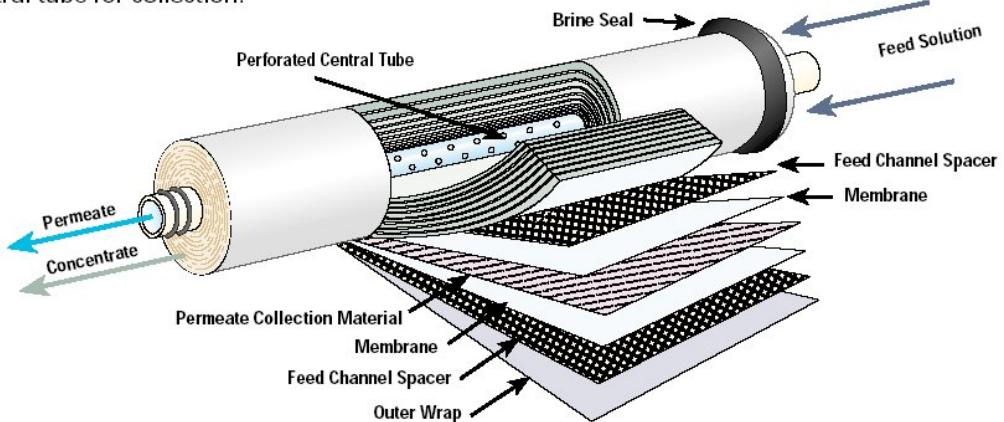
EQUILIBRIUM

Osmotic Pressure is the pressure required to stop water flow and reach equilibrium.

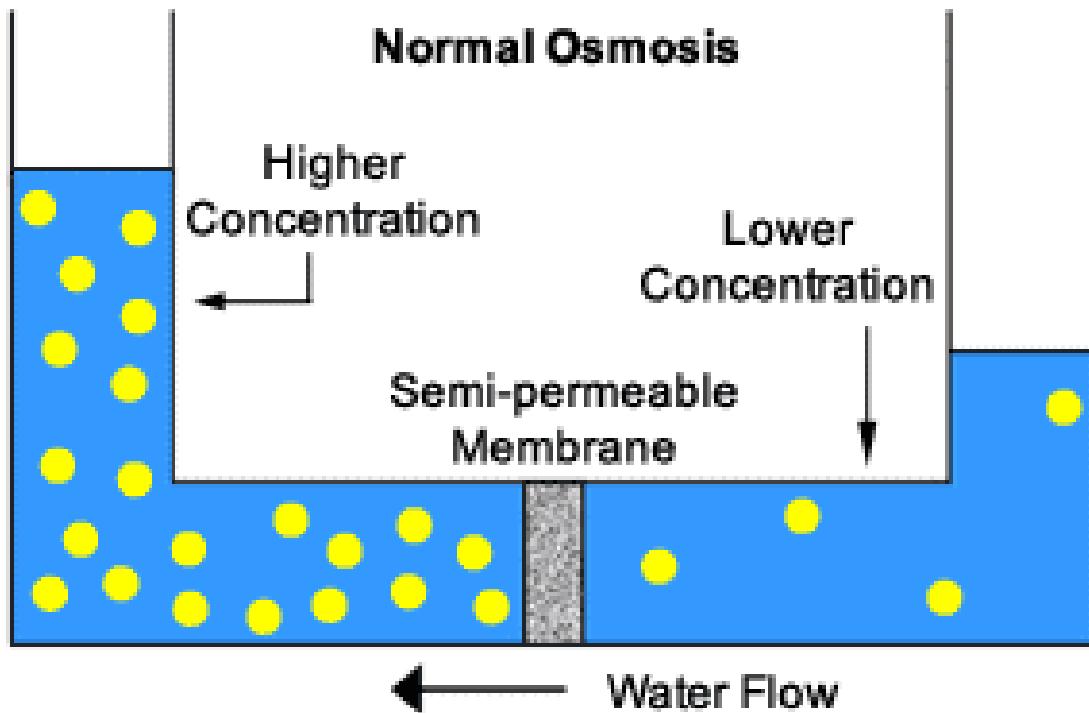
REVERSE OSMOSIS

By applying pressure greater than Osmotic Pressure, flow of water is reversed; water flows from higher concentration solution to lower.

The spiral membrane is constructed of one or more membrane envelopes wound around a perforated central tube. The permeate passes through the membrane into the envelope and spirals inward to the central tube for collection.



The illustration above represents a simplified spiral-wound membrane element. Recovery can be as high as 90% and systems may be capable of chemical cleaning in place (CIP).



Ozone in Cooling Water Treatment

Learn how to use the strong points of ozone to your advantage and avoid the pitfalls.

By Mario C. Uy

When commercial ozone generators were first introduced for cooling water treatment, they were marketed as a stand-alone treatment, a cure-all, a panacea. We now know this isn't true. Because there have been many misconceptions regarding ozone, this article is intended to review the basics of ozone, its true capabilities and limitations and its potential benefits in cooling water treatment applications.

What is Ozone?

Ozone (O₃) is formed by combining three atoms of oxygen. The air we breathe contains two atoms of oxygen (O) in the molecular form of O₂. When sufficient energy is applied to the molecular O₂, such as the discharge of electricity during a thunderstorm or strong UV radiation from the sun, some of the molecular O₂ will split into two individual oxygen atoms.



When the individual oxygen atoms merge with other oxygen molecules (O₂), they form O₃. Ozone is a very unstable molecule and will revert back to O₂ quickly.

Capabilities

Ozone is a very powerful oxidizing biocide, viricide, fungicide, sporicide, disinfectant and sterilizer. It kills microorganisms on contact by cellular lysis and cytoplasmic dispersion – it directly ruptures the cell walls of the microorganisms, which results in an instantaneous death. By comparison, chlorine kills bacteria by diffusing through the cell wall and then oxidizing the enzymes within the cell. Ozone kills microorganisms including *E. Coli*, *Legionella*, *Pneumophilia*, *Streptococcus Facalis*, *Bacillus*, *Clostridium*, amoebae cysts, *Giardia*, *Cryptosporidium*, *Pseudomonas*, etc. It also eradicates fungi, mold and yeast.

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What is the Significance of Ozone?

Ozone is a very powerful oxidant, even more powerful than chlorine. Below is a table comparing the oxidizing potential of ozone to other oxidizing agents.

Oxidizing agent	Oxidation potential (volts)	Power relative to chlorine
Fluorine (F_2)	3.06	2.25
Ozone (O_3)	2.07	1.52
Hydrogen Peroxide (H_2O_2)	1.77	1.30
Potassium Permanganate ($KMnO_4$)	1.67	1.23
Chlorine (Cl_2)	1.36	1.00
Chlorine Dioxide(ClO_2)	1.27	0.93
Bromine (Br_2)	1.09	0.80

This table is courtesy of CEC the Ozone Company.

In Addition, Ozone:

- Oxidizes and mitigates pollutants from water and wastewater.
- Breaks down volatile organic compounds (VOC) such as, phenols, benzene, pesticides and other aromatic hydrocarbons.
- Breaks down inorganic compounds such as cyanides, sulfides, nitrites.
- Removes color.
- Bleaches.
- Removes taste and odor.
- Removes soluble iron and manganese indirectly by converting them to filterable insoluble solids.

Ozone is very friendly to the environment. The extra atom of oxygen makes ozone very unstable.

While it has a half-life of about 20 minutes in clean water, its half-life in dirty water is even shorter as it is consumed by the microorganisms, VOCs and other compounds.

Because it breaks down to oxygen, ozone does not leave any toxic or carcinogenic by-products. It does not impart any taste, odor, color or solids.

By comparison, chlorine forms carcinogenic by-products, such as trihalomethanes (THM) and other halogenated compounds. When added to water, chlorine hydrolyzes to hypochlorous acid and then to hypochlorite ion, both of which can linger on and adversely affect our hydrological system.

Since ozone reverts to oxygen very quickly it cannot be packaged and stored. Thus it must be generated on-site. In turn, this on-site generation eliminates any hazards associated with transportation, storing and handling.

Commercial Production

Ozone is produced commercially in the same way it is formed naturally by lightning or UV radiation from the sun. The commercial lightning method is called corona discharge. Dried air or oxygen is passed through an electrified field (corona) generated by a high voltage between positive and negative grids.

The high voltage splits the molecular oxygen into atomic oxygen. Some of the atomic oxygen merge with molecular oxygen to form ozone, while other oxygen atoms simply recombine to form O₂. A fraction of oxygen in the air is transformed into ozone. When ambient air is used as a feed gas, you can get ozone between 1 and 2 percent by weight in air. When oxygen is used as a feed gas, you can get ozone between 6 and 12 percent by weight.



Natural UV radiation is simulated commercially by UV lamps. Air is passed through a chamber between the UV lamp and a shield. UV light can create or destroy ozone depending on the UV wavelength. Wavelengths of 185 nanometers (nm) are required for the generation of ozone and 254 nm for the destruction of ozone. This method produces a very low level of ozone and is usually suitable for small applications. In addition to these methods, ozone may also be made through electrolytic and chemical reactions.

Potential Health Hazards

According to the EPA, “the same chemical properties that allow high concentrations of ozone to react with organic material outside the body give it the ability to react with similar organic material that makes up the body.

“When inhaled, ozone can damage the lungs. Relatively low amounts can cause chest pain, coughing, shortness of breath, and throat irritation. Ozone may worsen chronic respiratory diseases such as asthma and compromise the ability of the body to fight respiratory infections.”

The EPA makes a distinction between ozone in the upper and lower atmosphere. Ozone in the upper atmosphere, referred to as stratospheric ozone, helps filter out damaging ultraviolet radiation from the sun. Conversely, ozone in the lower atmosphere, – the air we breathe – can be harmful to the respiratory system.

OSHA has issued a threshold limit value (**TLV**) on ozone exposure to 0.1 ppm over eight hours per day and five days per week, or 0.3 ppm for a 15-minute continuous exposure.

Because of the potential health hazards, it is crucial to destroy any excess ozone in a safe way.

How is Ozone Injected?

Ozone is typically injected into water via a venturi. A side stream water pump is typically used to create the vacuum on the venturi with a static mixer installed after it to ensure adequate mixing, distribution and proper contact between the ozone and water.

Another less popular alternative is the diffuser method, where ozone is injected under pressure through diffusers creating bubble columns – much like air diffusers in aquariums.

Destroying Ozone

Ozone can be destroyed by catalytic conversion units, activated carbon filters, thermal destructors or by ultraviolet radiation.

Catalytic conversion is the most popular method of ozone destruction. Activated carbon filtration decomposes ozone but carbon is also consumed in the process. There's also a risk of fire as carbon could ignite under high exothermic conditions.

In thermal destruction, ozone is destroyed by heating it in excess of 300 degrees Celsius. Ultraviolet radiation decomposes ozone at the wavelength of 254 nanometers.

Early Misconceptions

In cooling water applications, the most common problems encountered are scale deposition, corrosion, fouling and microbiological (bacteria, algae, fungi, etc) growth. Today, there's an even greater threat - the emergence of pathogenic bacteria like *Legionella*

Pneumophilia.

Microbial is a concern because it contributes to and amplifies deposition, corrosion and fouling by acting as a nucleation point or catalyst for these problems. The effect of microbial on scale deposition and fouling is one of the early misconceptions of ozone.

Early applications showed that ozone also removed mineral deposits. Later, it was found that this removal was only true where the deposits were held in a bio-matrix. It is like the steel structure of a building that holds up all the bricks. By destroying the steel structure at strategic points, the whole building implodes.

Comparing this to the bio-induced deposits, the bio-matrix held the deposits together, acting like glue. When the ozone destroyed the bio-matrix, the attached crystals became dispersed.

Not understanding this phenomenon fully, some ozone manufacturers began marketing them as scale inhibitor. Needless to say, ozone failed to prevent mineral deposits under other conditions, such as super saturation, excessive hardness, and alkalinity.

Because microorganisms also induce other problems such as corrosion and fouling, ozone was also marketed early on as a corrosion and fouling inhibitor, under similar biological pretext. Likewise, ozone failed to prevent these problems under non-biological conditions.

Traditionally, non-oxidizing biocides and oxidizing biocides are used to control microbial. Typical non-oxidizing biocides are organo-sulfur compounds (carbamate based, thiocyanate), organotin, isothiazolone, organobromine (dibromonitrilopropionamide), organic thiocyano-azole (benzothiazole) glutaraldehyde and quaternary ammonia.

Typical oxidizing biocides are chlorine, bromine and chlorine dioxide. Most of these biocides have a long-term negative impact on the environment. As such, there is a growing pressure to reduce or restrict these biocides in the blowdown water, especially if the water is being discharged to a waterway.

In addition to the discharge burden, these biocides have to be stored, transported and handled, which increases potential health and injury risks to personnel.

Limitations

Because of its short life, ozone levels drop off rapidly as time progresses and as it moves away from the injection point, decreasing its disinfecting efficacy. In systems with long piping runs, ozone may not get far enough, leaving the farthest areas vulnerable to microbiological growth.

This situation may be remedied by injecting ozone at various strategic points throughout the water system. A bio-dispersant can be added to penetrate and disperse the sessile bacteria (growing on surfaces) so that they can become planktonic (floating in water), thus enabling the bacteria to be transported to the ozone injection point for destruction.

Increasing the ozone level at the injection point to raise residual levels downstream is not a good solution. The higher ozone concentration may destroy the water treatment chemicals, increase corrosion near the injection area and destroy seals, gaskets, etc.

Ozone does not do a good job penetrating biofilm. It may burn the surface of the biofilm, protecting the microorganisms underneath from further destruction. Therefore, they will survive and will likely continue to cause localized corrosion.

This situation may be remedied by adding a good bio-dispersant to penetrate and disperse the biofilm, including the bacteria living under the biofilm.

Ozone does not discriminate in terms of what it oxidizes. If ozone is used as a disinfectant in water loaded with other non-biological organic matters, they will also consume ozone. As such, there may not be enough ozone left to accomplish the intended disinfection.

The remedy is to generate more ozone to supply the total ozone demand. However, this increases costs in both operating and capital. As such, ozone may not be cost effective for these types of applications.

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Ozone Generator and control panel



Ultraviolet Radiation

The enormous temperatures on the sun create ultraviolet (**UV**) rays in great amounts, and this radiation is so powerful that all life on earth would be destroyed if these rays were not scattered by the atmosphere and filtered out by the layers of ozone gas that float some 20 miles above the earth.



This radiation can be artificially produced by sending strong electric currents through various substances. A sun lamp, for example, sends out UV rays that when properly controlled result in a suntan. Of course, too much will cause sunburn.

Open contact chamber, beautiful green light that can burn your eyes.

The UV lamp that can be used for the disinfection of water depends upon the low-pressure mercury vapor lamp to produce the ultraviolet energy. A mercury vapor lamp is one in which an electric arc is passed through an inert gas. This in turn will vaporize the mercury contained in the lamp; and it is a result of this vaporization that UV rays are produced.



Enclosed lamp system, this one is on wastewater effluent

The lamp itself does not come into contact with the water, the lamp is placed inside a quartz tube, and the water is in contact with the outside of the quartz tube. Quartz is used in this case since practically none of the UV rays are absorbed by the quartz, allowing all of the rays to reach the water. Ordinary glass cannot be used since it will absorb the UV rays, leaving little for disinfection.

The water flows around the quartz tube. The UV sterilizer will consist of a various number of lamps and tubes, depending upon the quantity of water to be treated. As water enters the sterilizer, it is given a tangential flow pattern so that the water spins over and around the quartz sleeves. In this way the microorganisms spend maximum time and contact with the outside of the quartz tube and the source of the UV rays.

The basic design flow of water of certain UV units is in the order of 2.0 gpm for each inch of the lamp. Further, the units are designed so that the contact or retention time of the water in the unit is not less than 15 seconds.

Most manufacturers claim that the UV lamps have a life of about 7,500 hours, which is about 1 year's time. The lamp must be replaced when it loses about 40% to 50% of its UV output; in any installation this is determined by means of a photoelectric cell and a meter that shows the output of the lamp. Each lamp is outfitted with its own photoelectric cell, and with its own alarm that will be activated when the penetration drops to a present level.

Ultraviolet radiation is an excellent disinfectant that is highly effective against viruses, molds, and yeasts and it is safe to use. It adds no chemicals to the water, it leaves no residual, and it does not form THMs. It is used to remove traces of ozone and chloramines from the finished water. Alone, UV radiation will not remove precursors, but in combination with ozone, it is said to be effective in the removal of THM precursors and THMs.



UV Trains and SCADA display

The germicidal effect of UV is thought to be associated with its absorption by various organic components essential to the cell's functioning.

For effective use of ultraviolet, the water to be disinfected must be clean, and free of any suspended solids. The water must also be colorless and must be free of any colloids, iron, manganese, taste, and odor.

These are conditions that must be met. Also, although a water may appear to be clear, such substances as excesses of chlorides, bicarbonates, and sulfates affect absorption of the ultraviolet ray.

These parameters will probably require at least filtration of one type or another. The UV manufacturer will of course stipulate which pretreatment may be necessary.

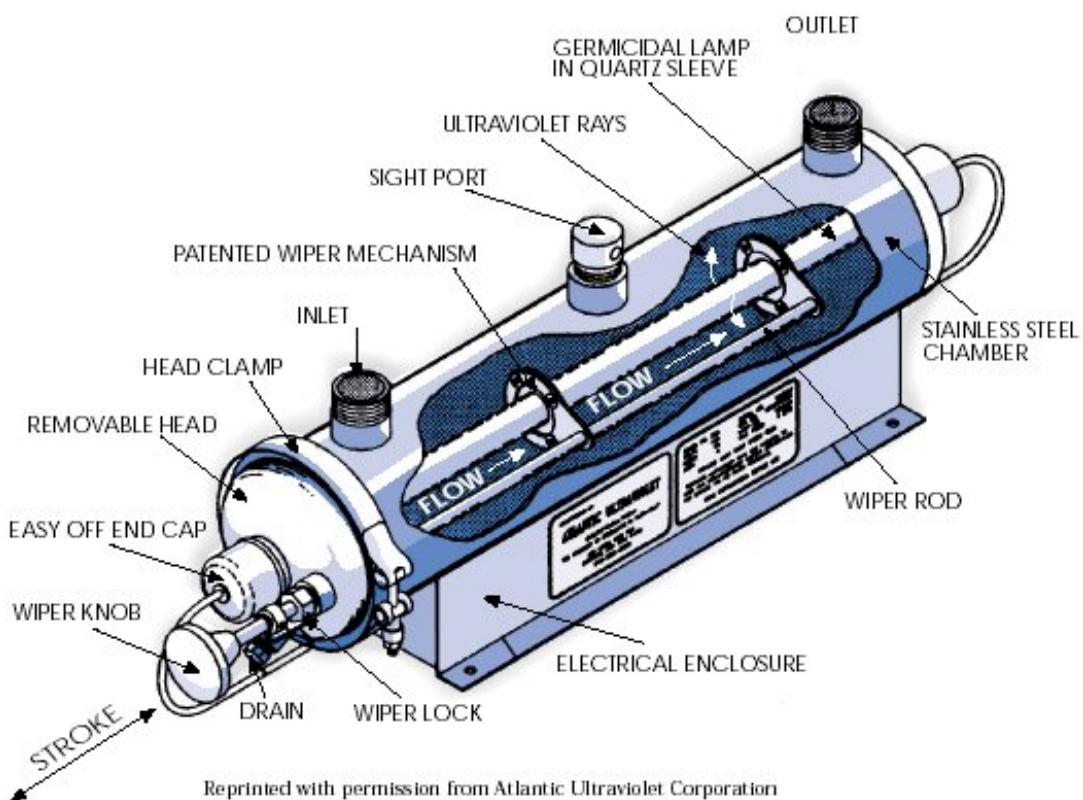
Removal of Disinfection By-products		
<i>Disinfectant</i>	<i>Disinfectant By-product</i>	<i>Disinfectant By-product Removal</i>
Chlorine (HOCl)	Trialomethane (THM)	Granular Activated Carbon (GAC), resins, controlled coagulation, aeration.
	Chloramine	GAC-UV
	Chlorophenol	GAC
Chloramine (NH_xCl_y)	Probably no THM	GAC
	Others?	UV?
Chlorine dioxide (ClO_2)	Chlorites Chlorates	Use of Fe^{2+} in coagulation, RO, ion-exchange
Permanganate (KMnO_4)	No THMs	
Ozone (O_3)	Aldehydes, Carboxylics, Phthalates	GAC
Ultraviolet (UV)	None known	GAC

The table indicates that most of the disinfectants will leave a by-product that is or would possibly be inimical to health. This may aid with a decision as to whether or not precursors should be removed before these disinfectants are added to water.

If it is decided that removal of precursors is needed, research to date indicates that this removal can be attained through the application of controlled chlorination plus coagulation and filtration, aeration, reverse osmosis, nanofiltration, GAC or combinations of others processes.

In conclusion, the literature is replete with the pursuit of newer processes, or combination of known processes, or the search for new methods for removal of the DBPs. These will all require laboratory, pilot plant, and field experience research will be more than a “***labor of love***.”

Ultraviolet Water Purifier



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Types of POU Home Treatment Methods

This section discusses the principal types of **POE** and **POU** home treatment devices.

Water Softeners



Home-type water softeners generally use the ion exchange process. In addition to reducing hardness, they remove some other impurities. But at the same time, they increase the salt level in the treated water.

Coarse salt is typically used for regeneration, and most units are furnished with a time clock to operate the regeneration cycle automatically in the middle of the night on set days of the week.

Softeners are normally classified as **POE** devices because they are often installed to treat all water to the building. In other instances, softeners are connected to treat only the hot-water supply to a building.

Softener with brine tank on left

Physical Filters

Physical filters are rather like strainers in that they are intended to remove suspended matter from the water. Some can remove material as small as cysts, large bacteria, and asbestos fibers. Most units are designed to remove only larger particles such as grit, dirt, and rust.

The filter unit may be made of fabric, fiber, ceramic, screening, diatomaceous earth, or other materials. Physical filters are most often used as a prefilter ahead of other treatment devices.

Activated Carbon Filters

As detailed before, activated carbon can remove many organic chemical contaminants from water – provided there is sufficient contact time with the water. Carbon filters can remove most taste, odors, and color as well as synthetic organic chemicals such as pesticides and volatile organic chemicals (**VOCs**). Carbon also effectively removes radon and chlorine from water. It does not effectively remove microorganisms. As a matter of fact, if there are any microorganisms in the source of water, they can actually thrive by feeding on the organic material that has previously been retained on the carbon particles.

The carbon in filters will eventually become loaded with contaminants so that the unit will no longer function. If a carbon unit is used after this point, it will periodically start to discharge quantities of organics into the effluent. As a result, the water being used from the unit may, at times, have a higher level of organics than the influent.

Unfortunately, there is no definite way of determining when carbon is exhausted. The life of the carbon in a unit depends on such factors as the concentration and types of contaminants in the water, the quantity of granular activated carbon (**GAC**) in the treatment unit, and the amount of water put through the unit. It is strongly recommended that when a GAC treatment unit is used, the carbon be changed frequently.

Reverse Osmosis

A reverse osmosis (**RO**) unit cannot be used by itself for water treatment. Some membranes will be destroyed by exposure to chlorine, and the efficiency of a membrane can be fouled by suspended matter in the influent water. For this reason, an RO module is always preceded by pre-filters.

As discussed before, RO units must be operated under pressure. Home-type RO units do not work very efficiently because they must operate on water system pressure, so about 75 percent of the water introduced to the unit is usually piped to waste.

Small RO units produce a very small flow, so the treated water is piped to a diaphragm pressure tank, which supplies water to a separate faucet. RO is effective in removing most inorganics, salts, metals, and organics having larger molecules. Although RO is known to effectively remove *Giardia lamblia* cysts, bacteria, and viruses, it is not recommended for use on microbiologically unsafe water.

Ultraviolet Disinfection

Although the use of ultraviolet (**UV**) light is not cost effective for the treatment of any sizable quantities of water, it can be practically applied for home treatment use. Units consist of a UV light source enclosed in a protective transparent sleeve, mounted so that water can flow past the light. UV light destroys bacteria and inactivates viruses. However, its effectiveness against spores and cysts is questionable.

Both dissolved solids and turbidity adversely affect the performance of UV disinfection. The most common operation problem is a buildup of dirt on the transparent shield, so units should frequently be inspected and cleaned.



Distillers

Various sizes of distillers are available for home use. They all work on the principle of vaporizing water and then condensing the vapor. In the process, dissolved solids such as salt, metals, minerals, asbestos fibers, and other particles are removed. Some organic chemicals are also removed, but those that are more volatile are often vaporized and condensed with the product water. Distillers are effective in killing all microorganisms.

The principal problem with a distiller is that a small unit can produce only 2-3 gal (7.5 -11 Lt) a day, and that the power cost for operation will be substantially higher than the operating cost of other types of treatment devices.

Water Distillers have a high energy cost (approximately 20-30 cents per gallon). They must be carbon filtered before and/or after to remove volatile chemicals. It is considered "dead" water because the process removes all extra oxygen and energy. It has no taste. It is still second only to reverse osmosis water for health. Diets should be rich in electrolytes as the aggressive nature of distilled water can "leech" electrolytes from the body.

Special Treatment

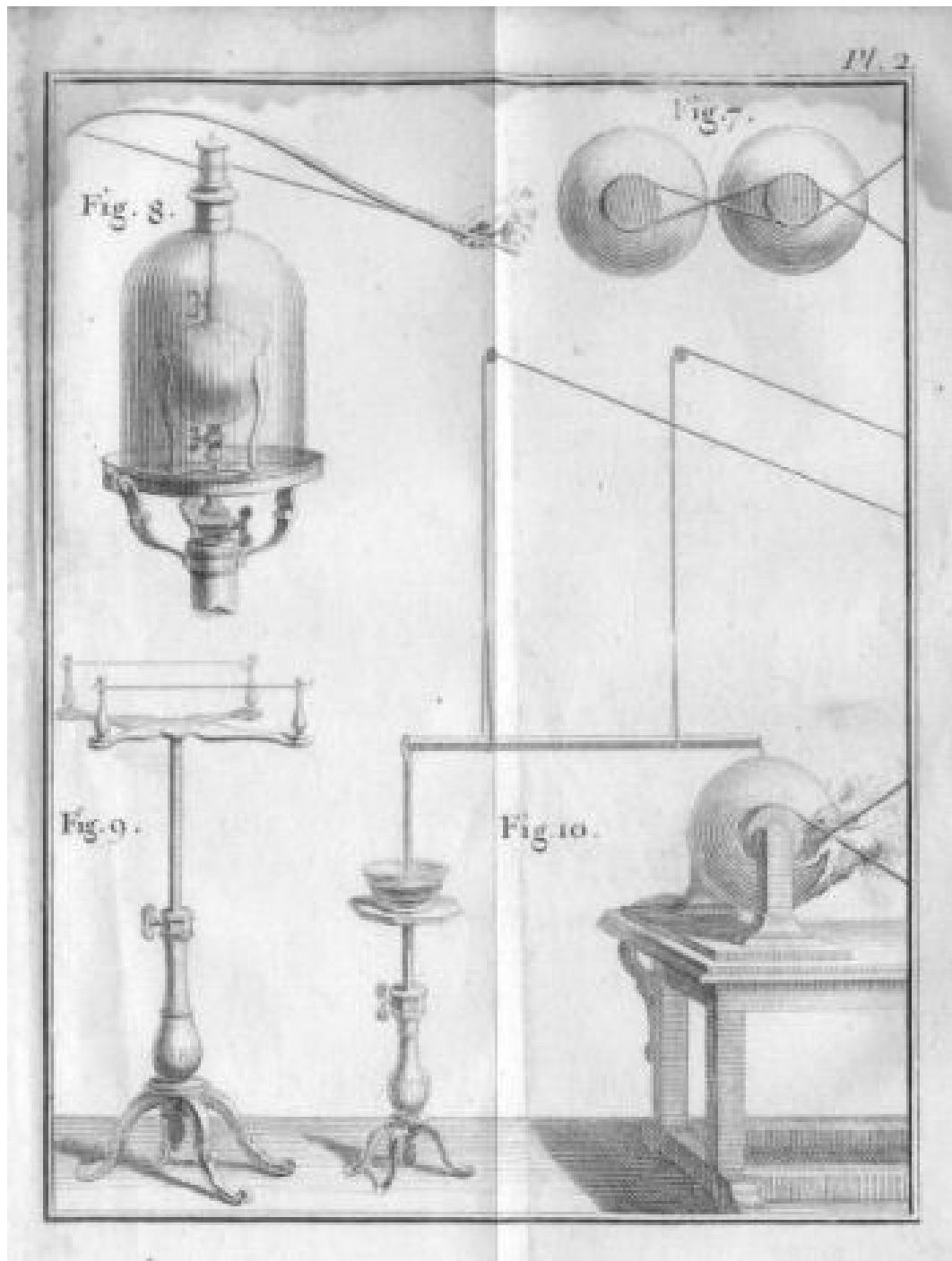
Special treatment units for home use are also available for removal of methane, hydrogen sulfide, nitrate, fluoride, radon, and other objectionable contaminants. Most often, this type of treatment is used on private wells.

The Use of Point-of-Entry (POE) Treatment Instead of Central Treatment

Under recent US Environmental Protection Agency (**USEPA**) regulations, water systems with a source water exceeding a maximum contaminant level (**MCL**) can install **POE** devices on all water services (instead of providing central treatment) to satisfy the requirement of providing water to the public below the MCL. An example of where this might be a viable alternative is a system having water so hard that a large proportion of the customers have already installed home softeners. If the contaminant exceeding the MCL in the source water can be removed by ion exchange softening, the system might meet the federal requirements by ensuring that every customer has a softener installed.

At the same time, a number of problems must be overcome. It is difficult for the system to ensure that all drinking water furnished to the public is treated. Another problem is that the water system must have a plan for checking and maintaining all the units to ensure that they are always properly operated. It is expected that some very small systems may find this option workable under certain circumstances.

The American Water Works Association has recommended that all treatment required for a public water supply be in the form of central treatment.



Nollet's first RO unit

Reverse Osmosis Home Filtration Devices

Reverse Osmosis home filtration devices are designed to fit neatly under almost any sink. The filter pack typically will slide to the back of the sink next to the garbage disposal. The tank tucks behind the plumbing and garbage disposal to the back of the sink. It uses very little of the sink's practical space.

The R/O connects to the cold water supply under the sink. First, water first passes through at a 1 micron sediment filter, which removes large particles that float in the water like silt, sand, rust, dirt, etc. We can see down to 40 microns (a human hair is about 80 microns and most bacteria is around 1 micron). This filter should be changed as needed by visually looking at it. (typically 6 months to 1 year).



Small under the sink home use unit

Second, the water passes through a Bituminous granulated coal filter that removes chlorine, some pesticides, herbicides and toxic chemicals. This filter should be changed every 6 months religiously.

Both of the first two filters' main purpose is to protect the R/O membrane from chlorine and particles that can prematurely ruin the membrane. The R/O membrane is the heart of the system. It filters down to a molecular level (1/10,000/micron).

Water is basically forced through the membrane. The water that makes it through is the purified water and the water that doesn't make it is impure water and it is dumped down the drain. The water slows down to a drop at a time and is accumulated in a 3 gallon pressurized storage tank.

The water is then pushed out of the tank at about 40-60 psi through a 10 inch post coconut shell carbon filter designed to pick up anything missed by the previous filters insuring great taste on the way to the faucet. The faucet is an air gap faucet and meets all plumbing codes.

1 micron sediment filter

A micron is a unit of measure. People can see down to 40 microns. Most Bacteria is between 1-5 microns. The sediment filter consists of a poly spun fiber and removes sediment down to 1 micron.

Bituminous granulated coal filter

This carbon filter has 56 cubic inches of carbon, which is more than any other filter made with similar dimensions on the market. We use two different types of carbon in our system (post carbon filter is a coconut shell carbon). Different types of carbon have different adsorption rates and different removal rates of toxic chemicals, so by using two types of carbon, we get the highest adsorption rates possible.

R/O Membrane

R/O membranes are generally made of Thin Film Composite. (**TFC for short**). There are basically two types of membranes on the market -TFC and CTA (**Cellulose Triacetate**).

TFC membranes are simply more durable because they are made out of a plastic type of material. CTA's are made with a paper type of material.

Any one who knows the R/O business in areas of hard water will only use TFC membranes because CTA customers will be buying membranes typically every 1 to 3 years (that gets expensive), whereas TFC membranes will typically last 3 to 5 years.



Small Three-Pass CTA Membrane Unit

Homeowner's Water Filtration Devices

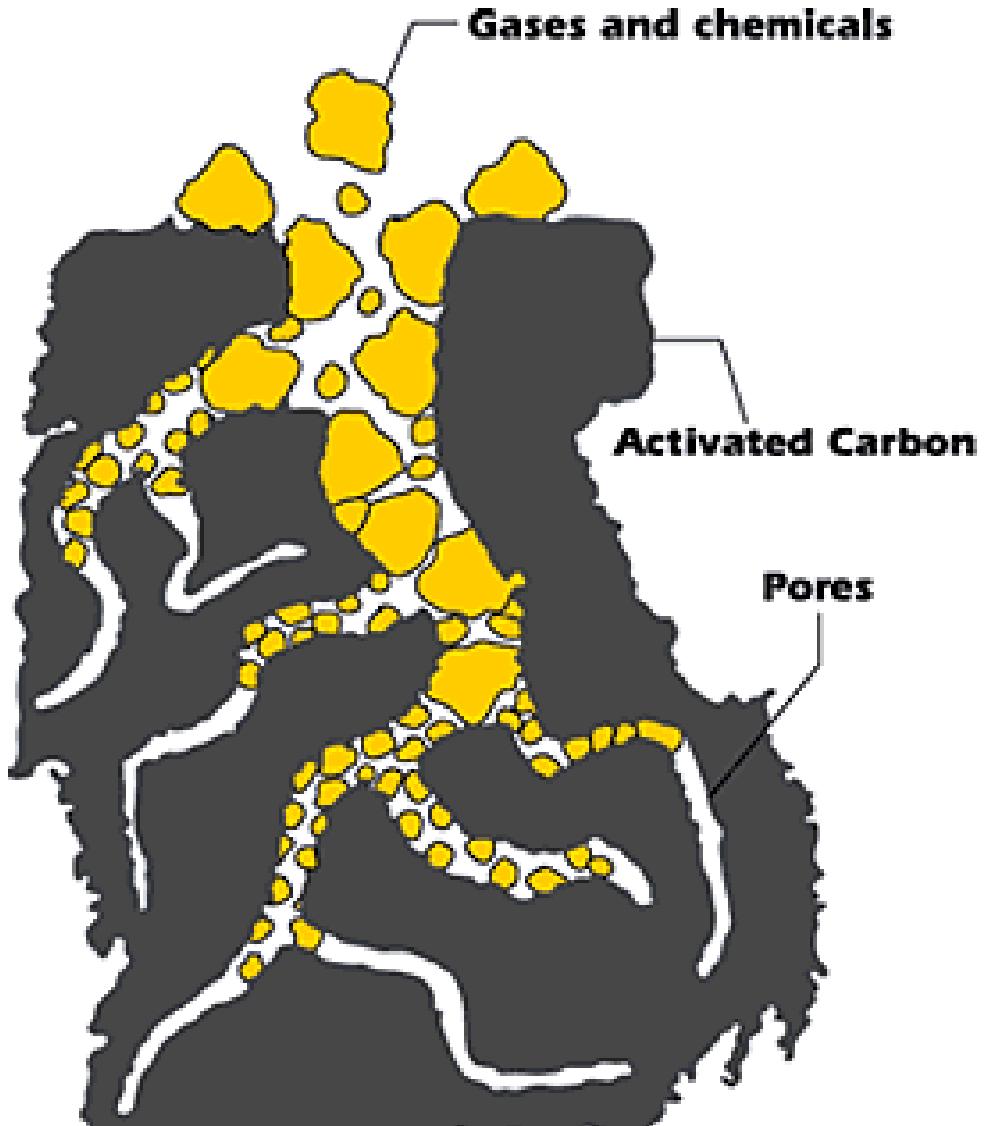
Carbon Block Filters improve taste and odor, reduce turbidity, remove chlorine and THM's, remove organic chemicals, pesticides, herbicides, and insecticides, and may remove some bacteria, cysts and parasites, radioactivity and asbestos fibers. A carbon-block filter can also remove some heavy metals. They do not remove fluorides, viruses, dissolved solids such as salt, sodium, calcium/magnesium and inorganic minerals as well as phosphates and detergents. Manganese, iron, metallic dead dirt minerals, hydrogen sulfide/sulfates, arsenic, aluminum, dissolved lead, nitrates and heavy metals also remain in the water. (Some specially treated carbon block units have excellent lead removal.)

Granular Activated Carbon Filters improve taste and odor, reduce turbidity, remove chlorine and THM's, organic chemicals, pesticides, herbicides, and insecticides. They may control bacteria growth when silver-impregnated. Mercury and radioactivity may also be reduced by this type of filter. Granular Activated Carbon Filters do not remove fluorides, sulfates, nitrates, arsenic, aluminum, metallic dead dirt minerals, salts, sodium, heavy metals, lead, calcium, iron, magnesium, virus, bacteria, parasites, cysts, manganese, hydrogen sulfide or asbestos. Back flushing is often recommended for this type of filter. Bacteria may become a problem.



KDF/Carbon Combination is similar to a Granular Activated Carbon Filter with additional metal removal capabilities, including lead. Chlorine is converted to chloride by KDF (zinc/copper composite), extending the life of a carbon media bed.

This type of filtration helps to minimize biological activity. KDF/Carbon Filters do not remove salts, fluorides, sulfates, nitrates, arsenic, aluminum, dead dirt minerals, phosphates or detergents. They may or may not be effective at removing parasites, cysts, and asbestos.



**Activated Carbon adsorbs
gases and chemicals**

KDF Process Media Section

KDF Process Media

As good as existing water treatment technologies are, most have limitations. They're short-lived, expensive, difficult to maintain, easily fouled by microorganisms, or just plain unable to perform up to anticipated stricter regulations.



Courtesy of KDF Fluid Treatment, Inc. All Rights Reserved.

Improve your system's economy while improving performance

KDF® process media, however, improve water treatment performance by protecting, and in some cases replacing, existing filtration/purification technologies. The exceptional filtration/purification performance and versatility of KDF media make them an economical and easy-to-use water treatment technology in both new systems and retrofit applications.

Manufacturers, hospitals, beverage manufacturers, restaurants, municipal water treatment facilities, consumers, and others rely on KDF process media to safely reduce or remove chlorine, hydrogen sulfide, heavy metals, and bacteria from water.

When Used Alone, KDF media can remove more than 95% of chlorine, iron, heavy metals, hydrogen sulfide, and other contaminants from water.

- When used in combination with granular activated carbon (**GAC**), KDF media can significantly extend the life of the carbon.
- Used ahead of reverse osmosis (**RO**) and ion exchange systems, KDF process media also safeguard expensive membranes, resins and system components.
- Compared to other water treatment technologies, KDF process media offer reduced material requirements resulting in more compact and more economical systems. KDF process media also last longer than GAC, which means material replacement requirements are lower.
- Because KDF process media contain no chemical additives and are 100% recyclable, costly disposal requirements are eliminated. What's more, KDF process media are safer for the environment.

All Forms of KDF Media are guaranteed for product purity and a certified analysis sheet is provided with each manufacturing run.

Improve Water Treatment Performance and Reduce Expense

KDF® process media are available in several different forms to meet the requirements of specific applications.

- KDF 55 granules are designed for removing or reducing chlorine and soluble heavy metals. They are also used for controlling scale, bacteria, and algae.
- KDF 85 granules are used to remove or reduce iron and hydrogen sulfide from water supplies. They are also used for controlling scale, bacteria, and algae.
- KDF-F fine mesh granules can be incorporated into carbon blocks and other matrixes.
- KDF-C coarse mesh granules are used for removal or reduction of soluble heavy metals and chlorine. For use when less pressure drop is required.

Redox Action is the Science Behind KDF Process Media

KDF® process media are high-purity, copper-zinc formulations that reduce contaminants in water using an oxidation/reduction (redox) reaction.

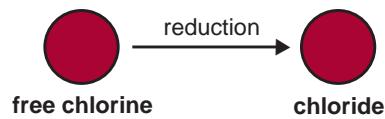
In other words, KDF media exchange electrons with contaminants, changing them into harmless components. For example, chlorine is changed into soluble chloride, soluble ferrous cations are changed into insoluble ferric hydroxide, and hydrogen sulfide is changed into insoluble copper sulfide. Insoluble reaction by-products are easily removed by periodic backwashing.

Other heavy metals such as mercury, copper, and nickel are removed simply by bonding to the KDF media. Microorganisms, however, are controlled two ways: First, the exchange of electrons in the redox reaction creates an electrolytic field that most microorganisms can't survive. Second, KDF process media may catalyze the formation of radicals and peroxides in certain circumstances. The radicals can interfere with microorganisms' ability to function.

Typical Redox Reactions

Harmful chlorine is removed by changing free chlorine into chloride ions.

KDF process media act as catalysts to change soluble ferrous cations into insoluble ferric hydroxide, which is easily removed by regular backwashing. KDF process media converts hydrogen sulfide to insoluble sulfide, which can be removed by backwashing.



Contaminants Removed by KDF Process Media

KDF® process media remove many of the most common impurities found in water supplies.

Chlorine Removal

KDF 55 medium can remove over 99% of free chlorine. This frees up granular activated carbon for more effective removal of organic contaminants, which affect water quality and foul downstream ion exchange resins and membranes.

KDF 55 medium can also be used to replace GAC entirely. Because KDF 55 medium provides more efficient chlorine removal, you'll benefit from a more cost effective water treatment system. Chlorine removal costs can be reduced 50% or more with KDF 55 medium.

Household Water Treatment

Both point-of-entry and point-of-use applications use KDF media to remove chlorine, lead, bacteria, iron, other heavy metals, and a variety of other impurities. For whole-house water systems, KDF media remove chlorine and other impurities from the water supply at the point-of-entry. KDF 55 medium delivers 10 times greater filter life than GAC.

Point-of-Use Applications

For chlorine removal in point-of-use applications, KDF media is incorporated into shower filters and into cartridges at the tap. KDF media are also used in water treatment systems in recreational vehicles.

In a controlled test under normal operating conditions, KDF process media delivered a filter life 10 times longer than GAC in chlorine removal service.

Water Treatment Costs with KDF 55 Medium

are less than half that of GAC

In the same test, after treating two million gallons of water, chlorine removal cost is 50% lower with KDF process media.

A Kalamazoo, Michigan producer of bottled drinking water uses KDF media as a non-chemical method of removing chlorine and sequestered iron from 7,500 gallons of municipal water daily, extending the operating life of downstream RO membranes by as much as 10 years.

Iron Removal

Iron (Fe^{+2}) or ferrous iron in groundwater can impart objectionable taste and color to potable water and can severely stain household fixtures. KDF® process media remove iron from water, either alone or in combination with other treatment technologies used at the point-of-entry.

KDF 85 medium removes more than 90% of iron from groundwater supplies.

Hydrogen Sulfide Removal

Hydrogen sulfide (H_2S) is a highly corrosive gas formed in groundwater when bacteria decompose vegetation and other organic matter. H_2S removal with KDF process media is both safe and economical.

KDF 85 medium eliminates H_2S by converting the hydrogen sulfide gas to insoluble sulfide, an inert, harmless precipitant. KDF medium then filters the precipitant from the water. Periodic backwashing eliminates accumulations of the precipitant from the media bed.

In contrast, aeration towers and degasification systems are expensive and bulky H_2S removal options. Using chlorine to oxidize H_2S can leave trihalomethane levels exceeding U.S. Environmental Protection Agency (EPA) limits.

Heavy Metals Removal

Heavy metals in drinking water are a significant health threat.

KDF® 55, KDF 85 and KDF-C media can remove up to 98% of soluble lead, mercury, and other dissolved metals. KDF media can be used alone, or to protect existing water purification technologies to treat groundwater supplies containing soluble heavy metals or to remove heavy metals from process water before it is discharged.

Controlling Microorganisms

KDF media control the build-up of bacteria, algae and fungi in organic based media such as GAC beds, carbon block filters, and in-line carbon filters.

By controlling these microorganisms, KDF media significantly extend the life of the carbon, as well as protect downstream RO membranes and ion exchange resins from fouling.

KDF media also control scale, algae, and bacteria in cooling tower water and swamp coolers. Using KDF media to reduce the build-up of bacteria and other microorganisms eliminates the need for chemical treatment methods which are both costly and harmful to the environment.

Municipal Water Treatment

Many municipalities rely on the exceptional performance of KDF media to remove chlorine and other impurities from feedwater entering public utilities, schools, and businesses. KDF media are also cost-effective alternatives to greensand and other filtration methods traditionally used to remove iron from municipal water supplies.

Commercial Water Treatment

Water treatment systems serving commercial facilities such as hotels and restaurants use KDF process media to remove chlorine. These facilities benefit from better tasting water with less odor, as well as less wear on towels, bedding, napkins and other items that are laundered frequently on-site.

Process Water Treatment

KDF media remove chlorine and help control bacteria and scale build-up in large-scale industrial water treatment facilities serving cooling towers, food and beverage plants, and industrial laundry facilities. KDF media can be used alone, or in combination with existing water treatment technologies to extend the life of granular activated carbon, and to protect downstream reverse osmosis membranes and ion exchange resins.

Medical Water Treatment

For medical labs and dialysis centers where water purity is crucial, KDF media provide exceptional water purification. KDF media also remove mercury and other soluble heavy metals from feedwater entering hospitals and from wastewater prior to discharge to public water treatment systems.

KDF Process Media Product Specifications

KDF 55 Process Medium

Applications: Chlorine, Heavy Metal Removal and Bacteria

KDF 85 Process Medium

Applications: Iron and Hydrogen Sulfide

The data included herein are based on outside laboratory tests. We believe the data are reliable, but recommend that users test performance on their own equipment. When using KDF media, proper backwash procedures should be applied.

Medium composition atomized high purity copper/zinc alloy

Color golden(55), reddish brown (85)

Physical form granular

Screen size (U.S. mesh) -10 + 100

Particle size range 0.149 mm to 2.00 mm

Apparent density 2.2-2.9 g/cc (171 lbs./cu.ft.)

Turbidity <20 ntu

Skid 48-1/3 cu. ft. drums (2,736 lbs.)

Odor and tastes none

Recommended Operating Conditions (use 3-cycle valve):

Service flow 15 gpm/sq. ft.

Backwash for 10 min. @ 30 gpm/sq. ft.

Purge/rinse for 3 min. @ maximum

Bed expansion, backwash 10 to 15%

Free board 20%

Minimum bed depth (6"dia.) 10 inches

pH range: drinking water 6.5 to 8.5

Water temperature, influent 35° to 212°F.

To learn more...

To learn more about KDF process media and the results they can provide in your water treatment system, call 1-800-437-2745.

1500 KDF Drive

Three Rivers, MI 49093-9287

1-800-437-2745 • 269-273-3300

Fax: 1-800-533-3584 • 269-273-4400

E-mail: info@kdfft.com

Web address: www.kdfft.com

About KDF Fluid Treatment, Inc.

Founded in 1984 in Three Rivers, Michigan, KDF Fluid Treatment is a technological leader in the fluid treatment industry. KDF has obtained 15 patents, with other U.S. and foreign patents pending. KDF process media have earned NSF certification (ANSI/NSF Standard 61 for drinking water system components—health effects and Standard 42). Furthermore, KDF Fluid Treatment's process media have been ruled by the U.S. EPA as a "**Pesticidal Device**."

KDF Fluid Treatment offers superior customer service through an extensive distributor network. With distributors across North America, South America, Europe, and in Japan and China, KDF process media can meet your water filtration/purification needs globally.

NOTICE: As of April 2003, KDF Fluid Treatment believes the data herein are reliable and accurate.

The data are based on outside and internal laboratory tests. Due to varying water chemistry, it is recommended that users test performance on their own equipment. As technical assistance is furnished by KDF Fluid Treatment at no charge to the user and since KDF Fluid Treatment has no control over engineering of hardware incorporating the KDF® media, KDF Fluid Treatment assumes no liability or responsibility for such assistance.

Due to synthetic procedures used by outside laboratories, KDF Fluid Treatment is not responsible for differing results in the field. KDF Fluid Treatment assumes no responsibility for user claims on the pesticidal abilities of KDF media because of varying water chemistry and users' applications. Since governmental regulations may differ from one location to another and may change from time to time, KDF Fluid Treatment is not responsible for users' manufacturing procedures, disposal practices, selection of media, or claims or advertising by the user. No warranty, express or implied is given nor is freedom from any patent owned by KDF Fluid Treatment or others to be inferred.

Glossary

ACTIVATED CARBON FILTRATION: Can remove organic chemicals that produce off-taste and odor. These compounds are not dangerous to health but can make the water unpleasant to drink. Carbon filtration comes in several forms, from small filters that attach to sink faucets to large tanks that contain removable cartridges. Activated carbon filters require regular maintenance or they can become a health hazard.

AIR GAP SEPARATION: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet.

ALTERNATIVE DISINFECTANTS: Disinfectants - other than chlorination (halogens) - used to treat water, e.g. ozone, ultraviolet radiation, chlorine dioxide, and chloramines. There is limited experience and scientific knowledge about the by-products and risks associated with the use of alternatives.

ALGAE: Are microscopic plants that are free-living and usually live in water. They occur as single cells floating in water, or as multicellular plants like seaweed or strands of algae that attach to rocks.

ALPHA AND BETA RADIOACTIVITY: Represent two common forms of radioactive decay. Radioactive elements have atomic nuclei so heavy that the nucleus will break apart, or disintegrate, spontaneously. When decay occurs, high-energy particles are released. These high-energy particles are called radioactivity. Although radioactivity from refined radioactive elements can be dangerous, it is rare to find dangerous levels of radioactivity in natural waters.

An alpha particle is a doubly-charged helium nucleus comprised of two protons, two neutrons, and no electrons. A beta particle is a high-speed electron. Alpha particles do not penetrate matter easily, and are stopped by a piece of paper. Beta particles are much more penetrating and can pass through a millimeter of lead.

AMMONIA: A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water.

APPROVAL AUTHORITY [40 CFR §403.3(c)]: The Director in an NPDES State with an approved State Pretreatment Program and the appropriate EPA Regional Administrator in a non-NPDES State or State without an approved pretreatment program.

APPROVED POTW PRETREATMENT PROGRAM[40 CFR §403.3(d)]: A program administered by a POTW that meets the criteria established in 40 CFR Part 403 and which has been approved by a Regional Administrator or State Director.

APPROVED STATE PRETREATMENT PROGRAM: A program administered by a State that meets the criteria established in 40 CFR §403.10 and which has been approved by a Regional Administrator

APPROVED /AUTHORIZED STATE: A State with an NPDES permit program approved pursuant to section 402(b) of the Act and an approved State Pretreatment Program.

AQUIFER: An underground geologic formation capable of storing significant amounts of water.

AS NITROGEN: Is an expression that tells how the concentration of a chemical is expressed mathematically. The chemical formula for the nitrate ion is NO₃, with a mass of 62. The concentration of nitrate can be expressed either in terms of the nitrate ion or in terms of the principal element, nitrogen. The mass of the nitrogen atom is 14. The ratio of the nitrate ion mass to the nitrogen atom mass is 4.43. Thus a concentration of 10 mg/L nitrate expressed as nitrogen would be equivalent to a concentration of 44.3 mg/L nitrate expressed as nitrate ion. When dealing with nitrate numbers it is very important to know how numeric values are expressed.

A concentration of 22 mg/L nitrate expressed as nitrate ion sounds very high compared to a standard of 10 mg/L, but the standard is expressed as nitrogen. Converting 22 mg/L nitrate expressed as nitrate is only 4.9 mg/L nitrate expressed as nitrogen, less than half the drinking water standard. Older nitrate data (pre-1980) were commonly reported as nitrate, and that makes comparison with the drinking water standard difficult. For purposes of drinking water regulations, standards are expressed in the form of the principal element.

BACKFLOW: To reverse the natural and normal directional flow of a liquid, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect.

BACKFLOW PREVENTION: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquid, gases, or solid substances back in to the public potable (drinking) water supply. See Cross-connection control.

BACKSIPHONAGE: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point.

BACTERIA: Are small, one-celled animals too small to be seen by the naked eye. Bacteria are found everywhere, including on and in the human body. Humans would be unable to live without the bacteria that inhabit the intestines and assist in digesting food. Only a small percentage of bacteria cause disease in normal, healthy humans. Other bacteria can cause infections if they get into a cut or wound. Bacteria are the principal concern in evaluating the microbiological quality of drinking water, because some of the bacteria-caused diseases that can be transmitted by drinking water are potentially life-threatening.

BASELINE MONITORING REPORT (BMR) [paraphrased from 40 CFR §403.12(b)]

A report submitted by categorical industrial users (CIUs) within 180 days after the effective date of an applicable categorical standard, or at least 90 days prior to commencement of discharge for new sources, which contains specific facility information, including flow and pollutant concentration data. For existing sources, the report must also certify as to the compliance status of the facility with respect to the categorical standards.

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE (BAT): A level of technology based on the best existing control and treatment measures that are economically achievable within the given industrial category or subcategory.

BEST MANAGEMENT PRACTICES (BMPs): Schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the U.S. BMPs also include treatment requirements, operating procedures and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE (BPT): A level of technology represented by the average of the best existing wastewater treatment performance levels within an industrial category or subcategory.

BEST PROFESSIONAL JUDGMENT (BPJ): The method used by a permit writer to develop technology-based limitations on a case-by-case basis using all reasonably available and relevant data.

BLOWDOWN: The discharge of water with high concentrations of accumulated solids from boilers to prevent plugging of the boiler tubes and/or steam lines. In cooling towers, blowdown is discharged to reduce the concentration of dissolved salts in the re-circulating cooling water.

BREAK POINT CHLORINATION: The process of chlorinating the water with significant quantities of chlorine to oxidize all contaminants and organic wastes and leave all remaining chlorine as free chlorine.

BROMINE: Chemical disinfectant (HALOGEN) that kills bacteria and algae.

BUFFER: Chemical that resists pH change, e.g. sodium bicarbonate

BYPASS [40 CFR §403.17(a)]: The intentional diversion of wastestreams from any portion of an Industrial User's treatment facility.

CALCIUM HARDNESS: A measure of the calcium salts dissolved in water.

CAUSTIC SODA: Also known as sodium hydroxide and is used to raise pH.

CATEGORICAL INDUSTRIAL USER (CIU): An industrial user subject to National categorical pretreatment standards.

CATEGORICAL PRETREATMENT STANDARDS [40 CFR § 403.6 and 40 CFR Parts 405-471]
Limitations on pollutant discharges to POTWs promulgated by EPA in accordance with Section 307 of the Clean Water Act, that apply to specific process wastewater discharges of particular industrial categories.

CHAIN OF CUSTODY (COC): A record of each person involved in the possession of a sample from the person who collects the sample to the person who analyzes the sample in the laboratory.

CHLORAMINES: A group of chlorine ammonia compounds formed when chlorine combines with organic wastes in the water. Chloramines are not effective as disinfectants and are responsible for eye and skin irritation as well as strong chlorine odors (also known as Combined Chlorine).

CHLORINE: Is a chemical used to disinfect water. Chlorine is extremely reactive, and when it comes in contact with microorganisms in water it kills them. Chlorine is added to swimming pools to keep the water safe for swimming. Chlorine is available as solid tablets for swimming pools. Some public water system's drinking water treatment plants use chlorine in a gas form because of the large volumes required. Chlorine is very effective against algae, bacteria and viruses. Protozoa are resistant to chlorine because they have thick coats. Protozoa are removed from drinking water by filtration.

CHRONIC: A stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of an organism. The measurement of chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality.

COMBINED CHLORINE: The reaction product of chlorine with ammonia or other pollutants, also known as chloramines.

CHLORINE DEMAND: Amount of chlorine required to react on various water impurities before a residual is obtained. Also, means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.

CHLORINE, FREE: Chlorine available to kill bacteria or algae. The amount of chlorine available for sanitization after the chlorine demand has been met. Also known as chlorine residual.

CHLORAMINATION: Treating drinking water by applying chlorine before or after ammonia. This creates a persistent disinfectant residual.

CHLORINATION: The process in water treatment of adding chlorine (gas or solid hypochlorite) for purposes of disinfection.

CHLORINE: A chemical which destroys small organisms in water.

CLEAN WATER ACT (CWA): The common name for the Federal Water Pollution Control Act. Public law 92-500; 33 U.S.C. 1251 et seq.; legislation which provides statutory authority for both NPDES and Pretreatment Programs.

CODE OF FEDERAL REGULATIONS (CFR): A codification of Federal rules published annually by the Office of the Federal Register National Archives and Records Administration. Title 40 of the CFR contains the regulations for *Protection of the Environment*.

COMBINED SEWER OVERFLOW (CSO): A discharge of untreated wastewater from a combined sewer system at a point prior to the headworks of a publicly owned treatment works. CSOs generally occur during wet weather (rainfall or snowfall). During periods of wet weather, these systems become overloaded, bypass treatment works, and discharge directly to receiving waters.

COLIFORM: Are bacteria normally found in the intestines of warm-blooded animals. Coliform bacteria are present in high numbers in animal feces. They are an indicator of potential contamination of water. Adequate and appropriate disinfection effectively destroys coliform bacteria.

CONTAMINANT: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

CONTAMINATION: To make something bad. To pollute or infect something. To reduce the quality of the potable (drinking) water and create an actual hazard to the water supply by poisoning or through spread of diseases.

CONVENTIONAL POLLUTANTS: BOD, TSS, fecal coliform, oil and grease, and pH

CORROSION: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

CROSS-CONTAMINATION: The mixing of two unlike qualities of water. For example the mixing of good water with a polluting substance like a chemical substance.

CRYPTOSPORIDIUM: A disease-causing parasite, resistant to chlorine disinfection. It may be found in fecal matter or contaminated drinking water.

CYANURIC ACID: Chemical used to prevent the decomposition of chlorine by ultraviolet (UV) light.

DAILY MAXIMUM LIMITATIONS: The maximum allowable discharge of pollutants during a 24 hour period. Where daily maximum limitations are expressed in units of mass, the daily discharge is the total mass discharged over the course of the day. Where daily maximum limitations are expressed in terms of a concentration, the daily discharge is the arithmetic average measurement of the pollutant concentration derived from all measurements taken that day.

DETECTION LIMIT: The minimum concentration of an analyte(substance) that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero as determined by the procedure set forth in 40 CFR Part 136, Appendix B.

DEVELOPMENT DOCUMENT: Detailed report of studies conducted by the U.S. EPA for the purpose of establishing effluent guidelines and categorical pretreatment standards.

DISINFECTION: Is the application of a chemical to kill most, but not all, microorganisms that may be present. Chlorine is added to public water drinking systems drinking water for disinfection. Depending on your state rule, drinking water must contain a minimum of 0.2 mg/L free chlorine. Disinfection makes drinking water safe to consume from the standpoint of killing pathogenic microorganisms including bacteria and viruses. Disinfection does not remove all bacteria from drinking water, but the bacteria that can survive disinfection with chlorine are not pathogenic bacteria that can cause disease in normal healthy humans.

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

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.

DRY ACID: A granular chemical used to lower pH and or total alkalinity.

EXISTING SOURCE: Any source of discharge, the construction or operation of which commenced prior to the publication by the EPA of proposed categorical pretreatment standards, which will be applicable to such source if the standard is thereafter promulgated in accordance with Section 307 of the Act.

FEDERAL WATER POLLUTION CONTROL ACT (FWPCA): The title of Public law 92-500; 33 U.S.C. 1251 et seq., also known as the Clean Water Act (**CWA**), enacted October 18, 1972.

FILTRATION: Is the process of passing water through materials with very small holes to strain out particles. Most conventional water treatment plants used filters composed of gravel, sand, and anthracite. These materials settle into a compact mass that forms very small holes. Particles are filtered out as treated water passes through these holes. These holes are small enough to remove microorganisms including algae, bacteria, and protozoans, but not viruses. Viruses are eliminated from drinking water through the process of disinfection using chlorine.

FLOW WEIGHTED AVERAGE FORMULA (FWA) [paraphrased from 40 CFR §403.6(e)]: A procedure used to calculate alternative limits where wastestreams regulated by a categorical pretreatment standard and nonregulated wastestreams combine after treatment but prior to the monitoring point.

FLOW PROPORTIONAL COMPOSITE SAMPLE: Combination of individual samples proportional to the flow of the wastestream at the time of sampling.

FUNDAMENTALLY DIFFERENT FACTORS [paraphrased from 40 CFR §403.13]: Case-by-case variance from categorical pretreatment standards based on the factors considered by EPA in developing the applicable category/subcategory being fundamentally different than factors relating to a specific industrial user.

GENERAL PROHIBITIONS [40 CFR §403.5(a)(1)]: No user shall introduce into a POTW any pollutant(s) which cause pass through or interference.

GRAB SAMPLE: A sample which is taken from a water or wastestream on a one-time basis with no regard to the flow of the water or wastestream and without consideration of time. A single grab sample should be taken over a period of time not to exceed 15 minutes.

HARDNESS: Is a measure of the amount of calcium and magnesium salts in water. More calcium and magnesium lead to greater hardness. The term "**hardness**" comes from the fact that it is hard to get soap suds from soap or detergents in hard water. This happens because calcium and magnesium react strongly with negatively-charged chemicals like soap to form insoluble compounds.

HETEROTROPHIC PLATE COUNT: Is a test performed on drinking water to determine the total number of all types of bacteria in the water.

INORGANIC IONS: Are present in all waters. Inorganic ions are essential for human health in small quantities, but in larger quantities they can cause unpleasant taste and odor or even illness. Most community water systems will commonly test the concentrations of seven inorganic ions: nitrate, nitrite, fluoride, phosphate, sulfate, chloride, and bromide. Nitrate and nitrite can cause an illness in infants called methemoglobinemia. Fluoride is actually added to the drinking water in some public water systems to promote dental health. Phosphate, sulfate, chloride, and bromide have little direct effect on health, but high concentrations of inorganic ions can give water a salty or briny taste.

LOCAL LIMITS [*paraphrased 40 CFR § 403.5(c)*]: Specific discharge limits developed and enforced by POTWs upon industrial or commercial facilities to implement the general and specific discharge prohibitions listed in 40 CFR §§403.5(a)(1) and (b).

mg/L :Stands for "**milligrams per liter.**" This is a common unit of chemical concentration. It expresses the mass of a chemical that is present in a given volume of water. A milligram (one one-thousandth of a gram) is equivalent to about 18 grains of table salt. A liter is equivalent to about one quart.

MICROORGANISMS: Are very small animals and plants that are too small to be seen by the naked eye and must be observed using a microscope. Microorganisms in water include algae, bacteria, viruses, and protozoa. Algae growing in surface waters can cause off-taste and odor by producing the chemicals MIB and geosmin. Certain types of bacteria, viruses, and protozoa can cause disease in humans. Bacteria are the most common microorganisms found in treated drinking water. The great majority of bacteria are not harmful. In fact, humans would not be able to live without the bacteria that inhabit the intestines. However, certain types of bacteria called coliform bacteria can signal the presence of possible drinking water contamination.

MILLILITER: Is one one-thousandth of a liter. A liter is a little more than a quart. A milliliter is about two drops from an eye dropper.

MONTHLY AVERAGE: The arithmetic average value of all samples taken in a calendar month for an individual pollutant parameter. The monthly average may be the average of all grab samples taken in a given calendar month, or the average of all composite samples taken in a given calendar month.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES): The national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing discharge permits from point sources to waters of the United States, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the CWA.

NATIONAL PRETREATMENT STANDARD OR PRETREATMENT STANDARD: [*40 CFR §403.3(j)*] Any regulation containing pollutant discharge limits promulgated by the EPA in accordance with section 307(b) and (c) of the Act, which applies to Industrial Users. This term includes prohibitive discharge limits established pursuant to §403.5.

90-DAY FINAL COMPLIANCE REPORT [*40 CFR §403.12(d)*]: A report submitted by categorical industrial users within 90 days following the date for final compliance with the standards. This report must contain flow measurement (of regulated process streams and other streams), measurement of pollutants, and a certification as to whether the categorical standards are being met.

NONCONVENTIONAL POLLUTANTS: Any pollutant that is neither a toxic pollutant nor a conventional pollutant (e.g., manganese, ammonia, etc.)

NON-CONTACT COOLING WATER: Water used for cooling which does not come into direct contact with any raw material, intermediate product, waste product, or finished product. The only pollutant contributed from the discharge is heat.

NON-REGULATED WASTESTREAM: Unregulated and dilute wastestreams (not regulated by categorical standards).

PASS THROUGH [40 CFR §403.3(n)]: A discharge which exits the POTW into waters of the United States in quantities or concentrations which, alone or in conjunction with a discharge or discharges from other sources, is a cause of a violation of any requirement of the POTW's NPDES permit (including an increase in the magnitude or duration of a violation).

PERIODIC COMPLIANCE REPORT [*paraphrased from 40 CFR §403.12(e) & (h)*]: A report on compliance status submitted by categorical industrial users and significant noncategorical industrial users to the control authority at least semiannually (once every six months).

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).**

pH OF SATURATION: The ideal pH for perfect water balance in relation to a particular total alkalinity level and a particular calcium hardness level, at a particular temperature. The pH where the Langelier Index equals zero.

PHENOL RED: Chemical reagent used for testing pH in the range of 6.8 - 8.4.

POLLUTION: To make something unclean or impure. See Contaminated.

PATHOGENS: Disease-causing pathogens; waterborne pathogens A pathogen is a bacterium, virus or parasite that causes or is capable of causing disease. Pathogens may contaminate water and cause waterborne disease.

PICOCURIE: Is a unit of radioactivity. "Pico" is a metric prefix that means one one-millionth of one one-millionth. A picocurie is one one-millionth of one one-millionth of a Curie. A Curie is that quantity of any radioactive substance that undergoes 37 billion nuclear disintegrations per second. Thus a picocurie is that quantity of any radioactive substance that undergoes 0.037 nuclear disintegrations per second.

pCi/L: picocuries per liter A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.

PIPELINE APPURTENANCE: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.

POINT SOURCE [40 CFR 122.2]: Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fixture, container, rolling stock concentrated animal feeding operation vessel, or other floating craft from which pollutants are or may be discharged.

POLLUTANT [40 CFR 122.2]: Dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials (except those regulated under the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011 et seq.)), heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal and agricultural waste discharged into water.

POTABLE: Good water which is safe for drinking or cooking purposes. **Non-Potable:** A liquid or water that is not approved for drinking.

PRETREATMENT STANDARDS FOR NEW SOURCES (PSNS): Categorical Standards and requirements applicable to industrial sources that began construction after the publication of the proposed pretreatment standards for that industrial category. (see individual standards at 40 CFR Parts 405-471.)

PRIORITY POLLUTANT: Pollutant listed by the Administrator of EPA under Clean Water Act section 307(a). The list of the current 126 Priority Pollutants can be found in 40 CFR Part 423 Appendix A.

PROCESS WASTEWATER: Any water which, during manufacturing or processing, comes into contact with or results from the production or use of any raw material, intermediate product, finished product, byproduct, or waste product.

PRODUCTION BASED STANDARDS: A discharge standard expressed in terms of pollutant mass allowed in a discharge per unit of product manufactured.

PROTOZOA: Are microscopic animals that occur as single cells. Some protozoa can cause disease in humans. Protozoa form cysts, which are specialized cells like eggs that are very resistant to chlorine. Cysts can survive the disinfection process, then "hatch" into normal cells that can cause disease. Protozoa must be removed from drinking water by filtration, because they cannot be effectively killed by chlorine.

PUBLICLY OWNED TREATMENT WORKS (POTW) [40 CFR §403.3(o)]: A treatment works as defined by section 212 of the Act, which is owned by a State or municipality (as defined by section 502(4) of the Act). This definition includes any devices or systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature. It also includes sewers, pipes or other conveyances only if they convey wastewater to a POTW Treatment Plant. The term also means the municipality as defined in section 502(4) of the Act, which has jurisdiction over the Indirect Discharges to and the discharges from such a treatment works.

REGULATED WASTESTREAM: For purposes of applying the combined wastestream formula, a wastestream from an industrial process that is regulated by a categorical standard.

REMOVAL CREDIT [*paraphrased from 40 CFR §403.7*]: Variance from a pollutant limit specified in a categorical pretreatment standard to reflect removal by the POTW of said pollutant.

REPRESENTATIVE SAMPLE: A sample from a water or wastestream that is as nearly identical as possible in composition to that in the larger volume of water or wastewater being discharged and typical of the treatment process or the discharge from the facility on a normal operating day.

SANITARY SEWER OVERFLOW (SSO): Untreated or partially treated sewage overflows from a sanitary sewer collection system.

SELF-MONITORING: Sampling and analyses performed by a facility to ensure compliance with a permit or other regulatory requirements.

SEWER USE ORDINANCE (SUO): A legal mechanism implemented by a local government entity which sets out, among others, requirements for the discharge of pollutants into a publicly owned treatment works.

SLUG DISCHARGE [40 CFR §403.8(f)(2)(v)]: Any discharge of a non-routine, episodic nature, including but not limited to, an accidental spill or a noncustomary batch discharge.

SODA ASH: Chemical used to raise pH and total alkalinity (sodium carbonate)

SODIUM BICARBONATE: Commonly used to increase alkalinity of water and stabilize pH.

SODIUM BISULFATE: Chemical used to lower pH and total alkalinity (dry acid).

SODIUM HYDROXIDE: Also known as caustic soda, A by-product chlorine generation and often used to raise pH.

SOLDER: A fusible alloy used to join metallic parts.

TCE, *trichloroethylene* : A solvent and degreaser used for many purposes; for example dry cleaning, it is a common groundwater contaminant.

TIME PROPORTIONAL COMPOSITE SAMPLE: A sample consisting of a series of aliquots collected from a representative point in the discharge stream at equal time intervals over the entire discharge period on the sampling day.

TITRATION: method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.

TOTAL ALKALINITY: A measure of the acid-neutralizing capacity of water which indicates its buffering ability, i.e. measure of its resistance to a change in pH. Generally, the higher the total alkalinity, the greater the resistance to pH change.

TOTAL DISSOLVED SOLIDS (**TDS**): The accumulated total of all solids that might be dissolved in water.

TREATED WATER: Disinfected and/or filtered water served to water system customers. It must meet or surpass all drinking water standards to be considered safe to drink.

TRIHALOMETHANES (**THM**): Four separate compounds including chloroform, dichlorobromomethane, dibromochloromethane, and bromoform. The most common class of disinfection by-products created when chemical disinfectants react with organic matter in water during the disinfection process. **See Disinfectant Byproducts.**

TURBIDITY: A measure of the cloudiness of water caused by suspended particles.

RADIOCHEMICALS: Or radioactive chemicals, occur in natural waters. Naturally radioactive ores are particularly common in the Southwestern United States, and some streams and wells can have dangerously high levels of radioactivity. Total alpha and beta radioactivity and isotopes of radium and strontium are the major tests performed for radiochemicals. The federal drinking water standard for gross alpha radioactivity is set at 5 picocuries per liter.

REVERSE OSMOSIS: Forces water through membranes that contain holes so small that even salts cannot pass through. Reverse osmosis removes microorganisms, organic chemicals, and inorganic chemicals, producing very pure water. For some people, drinking highly purified water exclusively can upset the natural balance of salts in the body. Reverse osmosis units require regular maintenance or they can become a health hazard.

VIRUSES: Are very small disease-causing microorganisms that are too small to be seen even with microscopes. Viruses cannot multiply or produce disease outside of a living cell.

VOLATILE ORGANIC COMPOUNDS: (**VOCs**) are solvents used as degreasers or cleaning agents. Improper disposal of VOCs can lead to contamination of natural waters. VOCs tend to evaporate very easily. This characteristic gives VOCs very distinct chemical odors like gasoline, kerosene, lighter fluid, or dry cleaning fluid. Some VOCs are suspected cancer-causing agents.

WATER QUALITY CRITERIA: Comprised of both numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or States for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

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MATH CONVERSION FACTORS

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
1 Gallon of Water = 8.34 lbs/gallon
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
5280 = 1 Mile

AREA

144 Square Inches = 1 Square Ft
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
62.38 Pounds = 1 Cubic Foot

DIMENSIONS

SQUARE: Area (sq.ft.) = Length X Width
Volume (cu.ft.) = Length (ft) X Width (ft) X Height (ft)

CIRCLE: Area (sq.ft.) = $3.14 \times \text{Radius (ft)} \times \text{Radius (ft)}$

CYLINDER: Volume (Cu. ft) = $3.14 \times \text{Radius (ft)} \times \text{Radius (ft)} \times \text{Depth (ft)}$

SPHERE: $\frac{(3.14)(\text{Diameter})^3}{(6)}$ Circumference = $3.14 \times \text{Diameter}$

GENERAL

POUNDS PER DAY = Concentration (mg/L) X Flow (MG) X 8.34

Percent Efficiency = $\frac{\text{In} - \text{Out}}{\text{In}} \times 100$

TEMPERATURE: ${}^{\circ}\text{F} = ({}^{\circ}\text{C} \times 9/5) + 32$
 ${}^{\circ}\text{C} = ({}^{\circ}\text{F} - 32) \times 5/9$

CONCENTRATION: Conc. (A) X Volume (A) = Conc. (B) X Volume (B)

FLOW RATE (Q): $Q = A \times V$ (Quantity = Area X Velocity)

FLOW RATE (gpm): Flow Rate (gpm) = $\frac{2.83 \times (\text{Diameter, in})^2 \times (\text{Distance, in})}{\text{Height, in}}$

% SLOPE = $\frac{\text{Rise (feet)}}{\text{Run (feet)}} \times 100$

$$\text{ACTUAL LEAKAGE} = \frac{\text{Leak Rate (GPD)}}{\text{Length (mi.)} \times \text{Diameter (in)}}$$

$$\text{VELOCITY} = \frac{\text{Distance (ft)}}{\text{Time (Sec)}}$$

$$\text{WATER HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960}$$

$$\text{BRAKE HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times \text{Pump Efficiency}}$$

$$\text{MOTOR HORSEPOWER} = \frac{\text{Flow (gpm)} \times \text{Head (ft)}}{3960 \times \text{Pump Eff.} \times \text{Motor Eff.}}$$

$$\text{MEAN OR AVERAGE} = \frac{\text{Sum of the Values}}{\text{Number of Values}}$$

$$\text{TOTAL HEAD (ft)} = \text{Suction Lift (ft)} \times \text{Discharge Head (ft)}$$

$$\text{SURFACE LOADING RATE} = \frac{\text{Flow Rate (gpm)}}{(\text{gal/min/sq.ft.}) \times \text{Surface Area (sq. ft)}}$$

$$\text{MIXTURE} = \frac{(\text{Volume 1, gal}) (\text{Strength 1, \%}) + (\text{Volume 2, gal}) (\text{Strength 2, \%})}{\text{STRENGTH (\%)} \quad (\text{Volume 1, gal}) + (\text{Volume 2, gal})}$$

$$\text{FLUORIDE ION PURITY} = \frac{(\text{Molecular weight of Fluoride}) (100\%)}{(\%) \times \text{Molecular weight of Chemical}}$$

$$\text{INJURY FREQUENCY RATE} = \frac{(\text{Number of Injuries})}{1,000,000} \times \frac{1}{\text{Number of hours worked per year}}$$

$$\text{DETENTION TIME (hrs)} = \frac{\text{Volume of Basin (gals)} \times 24 \text{ hrs}}{\text{Flow (GPD)}}$$

$$\text{BY-PASS WATER (gpd)} = \frac{\text{Total Flow (GPD)} \times \text{Plant Effluent Hardness (gpg)}}{\text{Filtered Hardness (gpg)}}$$

HARDNESS

$$\text{HARDNESS (mg/L as CaCO}_3) = \frac{\text{A (mls of titrant)} \times 1000}{\text{Mls of Sample}}$$

Ca HARDNESS as mg/L CaCO₃ = 2.5 X (Ca, mg/L)
Mg HARDNESS as mg/L CaCO₃ = 4.12 (Mg, mg/L)

$$\text{ALKALINITY-TOTAL} = \frac{\text{Mls of Titrant} \times \text{Normality} \times 50,000}{(\text{mg/L}) \quad \text{Mls of Sample}}$$

EXCHANGE CAPACITY (grains) = Resin Volume (cu. ft) X Removal Capacity

$$\text{HARDNESS TO GRAIN/GALLON} = \frac{\text{Hardness (mg/L)} \times \text{gr./gal}}{17.1 \text{ mg/L}}$$

LANGEIER INDEX = pH - pH_s

CHEMICAL ADDITION

$$\text{CHEMICAL FEED RATE} = \frac{\text{Chemical Feed (ml/min)}}{(\text{gpm}) \quad 3785 \text{ ml/gal}}$$

CHLORINE DOSE (mg/L) = Chlorine Demand (mg/L) + Chlorine Residual (mg/L)

$$\text{POLYMER \%} = \frac{\text{Dry Polymer (lbs.)}}{\text{Dry Polymer (lbs.)} + \text{Water (lbs.)}}$$

$$\text{DESIRED PAC} = \frac{\text{Volume (MG)} \times \text{Dose (mg/L)} \times 8.34}{(\text{lbs./MG}) \quad 1 \text{ MG}}$$

$$\text{PAC (lbs./gal)} = \frac{\text{PAC (mg/L)} \times 3.785 \text{ (1/gallon)}}{1000 \text{ (mg/g)} \times 454 \text{ (g/lb.)}}$$

FILTRATION

$$\text{FILTRATION RATE} = \frac{\text{Flow Rate (gpm)}}{(\text{gpm/sq. ft}) \quad \text{Surface Area (sq. ft)}}$$

BACKWASH PUMPING RATE = Filter Area (sq. ft) X Backwash Rate
(gpm/sq. ft)
(gpm)

$$\text{FILTRATION RATE} = \frac{\text{Flow Rate (gpm)}}{(\text{gpm/sq. ft}) \quad \text{Filter Area (sq. ft)}}$$

C FACTOR

Slope = $\frac{\text{Energy Loss, ft}}{\text{Distance, ft}}$

$$\frac{\text{Flow, GPM}}{193.75 (\text{Diameter, ft})^{2.63} (\text{Slope})^{0.54}}$$



Unapproved Air Gap from an Ice Machine and Carbon Filtration devices.
The discharge piping is not above the flood rim of the floor sink. This is a cross-connection.

Notice the mold growing on the potable water line drain.

Make sure that all of your treatment devices have adequate backflow protection.



We welcome you to complete the assignment in Microsoft Word. You can easily find the assignment at www.abctlc.com.

Once complete, just simply fax or e-mail the answer key along with the registration page to us and allow two weeks for grading.

Once we grade it, we will e-mail a certificate of completion to you.

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