CHLORINE & DISINFECTION

CONTINUING EDUCATION PROFESSIONAL DEVELOPMENT COURSE

ORIGINAL VERSION

Technical Learning College

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

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

Library of Congress Card Number 6571433
ISBN 978-0-9799559-2-1

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Precept-Based Training Course

This training course is based upon a form of induction training, made of topical and technical precepts. The training topics are made up of “micro-content” or “precepts”– or small chunks of information that can be easily digested. These bite-size pieces of technical information are considered to be one of the most effective ways of teaching people new information because it helps the mind retain knowledge easier.

Micro-learning or precept-based training doesn’t rely on the student to process a large amount of information before breaking it down. Our method includes short modules with clearly defined learning goals for each section. This method allows a student to hone in on a particular skill, then given the opportunity to exhibit their knowledge in the final assessment.

Important Information about this Manual

This manual has been prepared to educate students and operators in general safety awareness of dealing with the often-complex and various water disinfectants, including dangerous chemicals, Chlorine and other toxic materials. This CEU course will also cover respirator protection devices, methods, and applications.

This manual will cover general laws, regulations, required procedures and accepted policies relating to the use of disinfectants, DDBPs, Ozone, Ultraviolet Radiation, Respirator Protection Devices, Methods, and Applications. It should be noted, however, that the regulation of respirator protection devices and hazardous materials is an ongoing 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 a not a guidance document for applicators or operators who are involved with pesticides. It is not designed to meet the requirements of the United States Environmental Protection Agency, Office of Health and Safety Administration (OSHA) or your local State environmental protection agency or health department. This course manual will provide general respirator protection and safety awareness and should not be used as a basis for respirator protection method/device guidance. This document is not a detailed safety manual or a source or remedy for respirator protection or control.

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 respirator protection should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, EPA and other appropriate federal, state and local agencies.

Chlorine rail tank inside a chlorine storage room. Since 9/11, many water providers have been too scared to utilize the rail car in fear of a terrorist activity.

Technical Learning College's Scope and Function

Welcome to the Program,

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

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

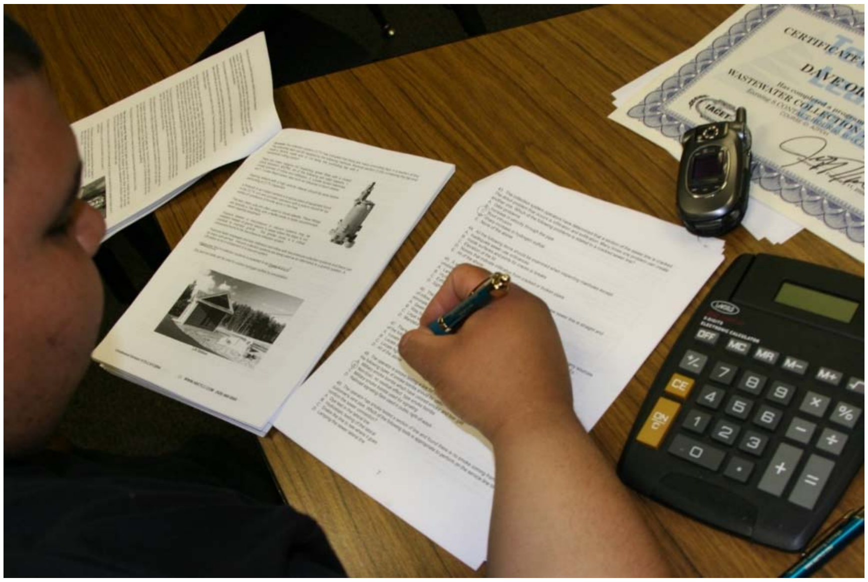
Our courses are designed to be flexible and for you to finish the material at your convenience. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and instruction to obtain the assignments. All of TLC's CEU courses allow students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

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

Flexible Learning
At TLC there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You 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 (S.M.E.) are assigned at the beginning of each course providing the academic support you need to successfully complete each course. Please call or email us for assistance.



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

Chlorine & Disinfection CEU Training Course

This course will cover the fundamentals of water disinfection beginning with the different and alternative water disinfectants and ending with the biological analysis of the water, insuring that the water meets federal compliance.

Task Analysis and Training Needs Assessments have been conducted to determine or set Needs-To-Know for this course. The goal of this CEU Course is to provide awareness training to help workers recognize the occupational hazards and health effects of different disinfectants, halogens, chlorine exposure and the exposure controls; and to familiarize the participants with the properties and safe handling of chlorine - solid, liquid, gas, and the operation of gas chlorinators and other related equipment. This course covers properties of chlorine, purpose of chlorine, chlorine terminology, dosage calculations, chlorinator equipment, chlorine cylinders, and operation of gas chlorinators, start up and shut down, chlorinator maintenance, troubleshooting common problems, chlorine safety, and chlorine testing procedures.

Water Distribution, Well Drillers, Pump Installers, Water Treatment Operators, Wastewater Operators. The target audience for this course is the person interested in working in a water treatment/wastewater treatment or distribution facility and/or wishing to maintain CEUs for certification license or to learn how to do the job safely and effectively, and/or to meet education needs for promotion. This CEU course will cover the fundamentals of water disinfection beginning with the source of water and ending with the disinfection and distribution making sure that it meets federal compliance.

Final Examination for Credit

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

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.

Instructions for Written Assignments

The Chlorine and Disinfection CEU training course uses a multiple-choice style answer key. TLC would prefer that the answer key and registration, and survey sheet is faxed or e-mailed to, info@tlch2o.com. If you are unable to do so, please make a copy for yourself and mail me the completed manual.

Feedback Mechanism (examination procedures)

Each student will receive a feedback form as part of their study packet. You will be able to find this form in the front of the course assignment 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 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. (Certificate)

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.

Mission Statement
Our only product is educational service. Our goal is to provide you with the best education service possible. TLC will attempt to make your learning experience an enjoyable educational *opportunity.*

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,

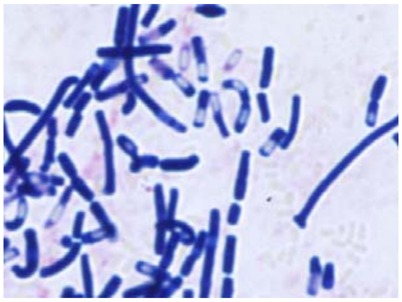
To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,

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.

Table of Contents

Chlorine Glossary



Anthrax*:* The disease caused by bacillus Anthracis.

AOX: Absorbable organic halogen.

AWWA: American Water Works Association.

°C: degrees Celsius (a/k/a centigrade).

CDC: Centers for Disease Control.

Chlorate ion ($\mathrm{ClO3}^-$): A product of the disproportionation of chlorine dioxide, for example by sunlight.

Chlorine dioxide ($\mathrm{ClO2}$): A free radical; a powerful, selective oxidant.

Chloride ion (Cl^-): The principal reduction product of chlorine.

Chlorite ion ($\mathrm{ClO2}^-$): A product of the partial reduction of chlorine dioxide.

CxT value: The product of the net residual [concentration] of a disinfectant and [time], used as a measure of the amount of disinfection applied to a system.

DOT: (United States) Department of Transportation.

EPA: (United States) Environmental Protection Agency.

°F: degrees Fahrenheit.

FDA: (United States) Food & Drug Administration.

FIFRA: Federal Insecticide Fungicide & Rodenticide Act.

HAA: Haloacetic acid(s), by-products of chlorination of water containing organics which are suspected carcinogens.

ICR: Information Collection Rule.

L: Liter.

Legionella: The microorganism that causes Legionnaire’s disease.

MCL: Maximum Contaminant Level.

MCLG: Maximum Contaminant Level Goal.

mg: Milligram.

MRDL: Maximum Residual Disinfectant Level.

MGD: Millions of Gallons per Day

NIH: National Institutes of Health.

OSHA: (United States) Occupational Safety and Health Administration.

Oxidation: The net transfer of electrons from a source to an acceptor.

Pathogen: A disease-causing organism.

ppb: Parts-per-billion.

ppm: parts-per-million; in water, equivalent to mg/L.

SDWA: Safe Drinking Water Act.

Sodium chlorate (NaClO3): The sodium salt of chloric acid; a precursor for chlorine dioxide production, especially for pulp bleaching.

Sodium chlorite (NaClO2): The sodium salt of chlorous acid, a precursor for chlorine dioxide production, especially for drinking water treatment.

Stachybotrys: A particularly virulent type of toxic mold.

TLV: Threshold Limit Value.

TOC: Total Organic Carbon.

TOX: Total organic halogen.

Trihalomethanes: (THM) by-products of chlorination of water containing organics which are suspected carcinogens.

USDA: United States Department of Agriculture.

UV: Ultraviolet light.

WTP: Water treatment plant.

Commonly Used Water Disinfectants

Contaminant	MRDL[1] (mg/L)[2]	MRDL[1] (mg/L)[2]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Chloramines (as Cl_2)	MRDLG=4[1]	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes
Chlorine (as Cl_2)	MRDLG=4[1]	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes
Chlorine dioxide (as ClO_2)	MRDLG=0.8[1]	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes

Disinfection Preface

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

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

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

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

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

State and Local Regulations

State and local regulations vary considerably in their requirements to disinfect wastewater, so the decision of what type of system to use can be affected by the chemical and physical composition of the wastewater stream, the environment to which it will be discharged, and the concerns of the local health department. "It's all over the place," says Bach. "The chemical itself is a pesticide and is regulated by the US EPA. The states will specify what sort of *E. coli* or *coliform* counts you're going to have on discharge, and the regulations vary all over the map in the states. You've got a lot of things like that throughout the country and it goes down to ultimately the views of local health departments and reflects the local topography, their local population density, and also their experience of whether or not people have gotten sick."

Alternative Disinfectants More information in the Alternative Section

Unknown Factors Associated with Alternatives

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

Drinking Water Disinfectants At a Glance

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

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

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

Modern Water Treatment Disinfectants

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

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

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

Disinfectant alternatives will include Ozone, and Ultraviolet light. You will see an increase of these technologies in the near future.

Disinfection Byproducts (DBPS)
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 the 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.

1- ton chlorine containers. Automatic shutoff device connected to the liquid side only. The top valve is used for the gas. Remember that containers lay on their sides and cylinders stand upright.

Disinfection Rules   Chapter 1

Disinfection Byproduct Regulations

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

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 became 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 will 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 became 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. 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 back 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 annual average of **10 parts per billion** in drinking water.

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

Chlorite is a byproduct formed when chlorine dioxide is used to disinfect water. 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 back in December 2001 and for small surface water and all ground water public water systems back 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**. The 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 will tighten turbidity standards by 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 is promulgating a Long Term 1 Enhanced Surface Water Treatment Rule, for systems serving fewer than 10,000 people. This is to improve physical removal of *Cryptosporidium*, and to maintain control of pathogens while systems comply with **Stage 1 Disinfectants/Disinfection Byproducts Rule**.

Microbes *More Information in the water Monitoring Section*

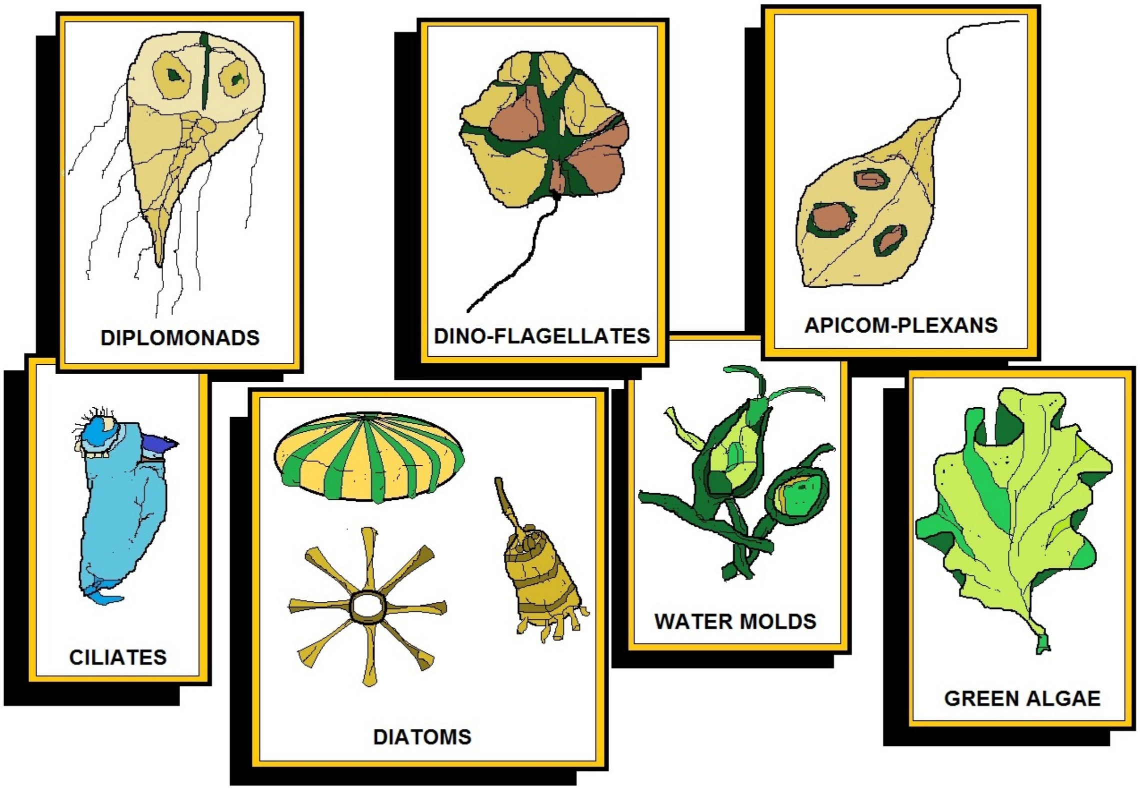
Coliform bacteria are common in the environment and are generally not harmful. However, the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipes which distribute water, and indicates that the water may be contaminated with germs that can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

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

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

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

Heterotrophic Plate Count Bacteria: A broad group of bacteria including non-pathogens, pathogens, and opportunistic pathogens; they may be an indicator of poor general biological quality of drinking water. Often referred to as HPC. The above photo is of a SimPlate for HPC multi-dose used for the quantification of HPC in water.



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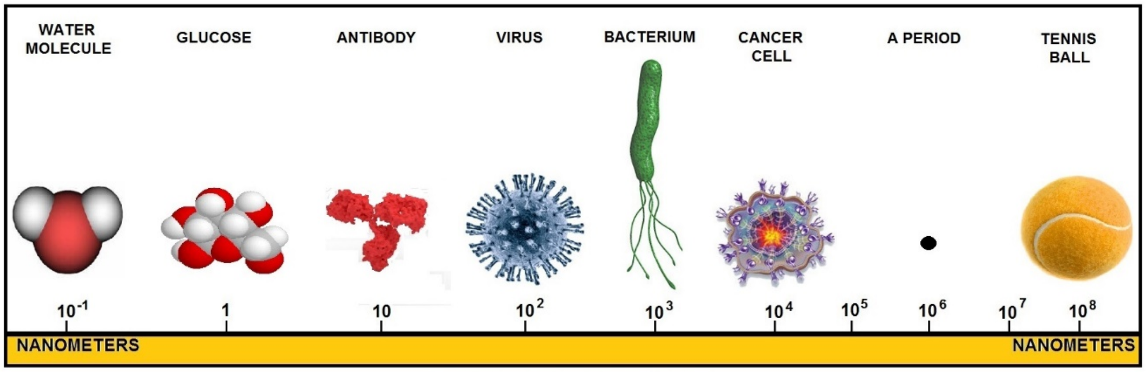


SIZE COMPARISON
HOW SMALL IS SMALL ?

Chlorine Disinfection Byproducts (DDBP)

Today, most of our drinking water supplies are free of the micro-organisms — viruses, bacteria and protozoa — that cause serious and life-threatening diseases, such as cholera and typhoid fever. This is largely due to the introduction of water treatment, particularly chlorination, at the turn of the century. Living cells react with chlorine and reduce its concentration while they die. The organic matter and other substances that are present, convert to chlorinated derivatives, some of which are effective killing agents. Chlorine present as Cl, HOCl, and OCl^{-} is called ***free available chlorine***, and that which is bound but still effective is ***combined chlorine***. A particularly important group of compounds with combined chlorine is the chloramines formed by reactions with ammonia.

One especially important feature of disinfection using chlorine is the ease of overdosing to create a "**residual**" concentration. There is a constant danger that safe water leaving the treatment plant may become contaminated later. There may be breaks in water mains, loss of pressure that permits an inward leak, or plumbing errors. This residual concentration of chlorine provides some degree of protection right to the water faucet. With free available chlorine, a typical residual is from 0.1 to 0.5 ppm. Because chlorinated organic compounds are less effective, a typical residual is 2 ppm for combined chlorine. There will be no chlorine residual unless there is an excess over the amount that reacts with the organic matter present. However, reaction kinetics complicates interpretation of chlorination data. The correct excess is obtained in a method called ***"Break Point Chlorination"***.

Chlorine By-Products

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

The Principal Trihalomethanes are:

Chloroform, bromodichloromethane, chlorodibromomethane and bromoform. Other less common chlorination by-products includes the haloacetic acids and haloacetonitriles.

The amount of THMs formed in drinking water can be influenced by a number of factors, including the season and the source of the water. For example, THM concentrations are generally lower in winter than in summer, because concentrations of natural organic matter are lower and less chlorine is required to disinfect at colder temperatures. THM levels are also low when wells or large lakes are used as the drinking water source, because organic matter concentrations are generally low in these sources. The opposite — high organic matter concentrations and high THM levels — is true when rivers or other surface waters are used as the source of the drinking water.

Health Effects

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

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

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

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

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

Chlorine Disinfectants/Disinfectant By-Products (DDBPs)

- Chlorine is a naturally existing element that has been used to disinfect drinking water supplies in America for most of the 20th Century.
- Chlorine disinfection has been extremely effective in protecting drinking water resources from bacterial and viral contamination. It has virtually wiped out instances of water-borne diseases like typhoid fever, cholera and dysentery in America and other developed countries.
- Over 200 million Americans currently drink water that has been disinfected.
- The three primary chemical agents used in chlorine disinfection are: free chlorine, chloramine (chlorine and ammonia bonded together) and chlorine dioxide (chlorine and oxygen bonded together).
- Ozone is also used to disinfect water.
- Disinfectants are very active compounds. When added to a water supply, disinfectants not only kill bacteria and viruses, but also react with other chemicals present in the water. These chemicals generally enter the water supply through natural plant and soil breakdown.
- When disinfectants react with other chemicals, new compounds known as disinfectant by-products or "DBPs", are created. DBPs associated with chlorine disinfection include trihalomethanes (THMs), such as chloroform.
- Because chlorination has been used for almost 100 years to disinfect water supplies, approximately 40 percent of the DBPs from chlorination have been identified and researched. Much less is known about the kind of DBPs produced by other disinfectants because of their relatively recent emergence.
- Use of chloramine or chlorine dioxide in chlorine disinfection produces fewer DBPs than chlorine, but each has associated risks. Chloramine is not as strong a disinfectant as chlorine, and disinfection with chlorine dioxide produces its own DBPs.
- Animal research using high concentration of DBPs found increased occurrence of cancer development, although why this occurs has not yet been determined. Research on the relationship between DBPs and cancer and other health risks is ongoing.
- American drinking water has **very low** concentrations of DBPs.
- The U.S. Environmental Protection Agency (USEPA) has **not** been able to link exposure to DBPs at low concentration levels and the health risks associated with high concentration level exposure.
- Since 1984, American drinking water utilities have spent almost $23 million researching the production of DBPs, the risks posed by them and methods to treat them. These research efforts are ongoing. In addition, the 300 largest drinking water utilities have spent more than $150 million to conduct the information gathering required by the Information Collection Rule (ICR). The ICR is the largest study to date pertaining to the occurrence of DBPs and associated treatment practices.
- Since 1979, the U.S. Environmental Protection Agency (USEPA), under the authority of the Safe Drinking Water Act, has regulated the acceptable levels of some DBPs. USEPA cites the large population of Americans potentially at-risk from low-level DPB exposure as the impetus for regulation.

- The Safe Drinking Water Act Amendments of 1996 required USEPA to comply with the regulatory timeline it set forth in its initial Disinfectant and Disinfectant-By-Product (DDPB) rule and Interim Enhanced Surface Water Treatment Rule (IESWTR). USEPA proposed both in 1994.

The research on DBPs and their impact on public health continues, and serious questions about the actual health risks posed by DBPs still remain.

Risks and Benefits of Chlorine

Current evidence indicates that the benefits of chlorinating our drinking water — reduced incidence of water-borne diseases — are much greater than the risks of health effects from THMs. Although other disinfectants are available, chlorine continues to be the choice of water treatment experts.

When used with modern water filtration practices, chlorine is effective against virtually all infective agents — bacteria, viruses and protozoa. It is easy to apply, and, most importantly, small amounts of chlorine remain in the water and continue to disinfect throughout the distribution system. This ensures that the water remains free of microbial contamination on its journey from the treatment plant to the consumer’s tap.

A number of cities use ozone to disinfect their source water and to reduce THM formation. Although ozone is a highly effective disinfectant, it breaks down quickly, so that small amounts of chlorine or other disinfectants must be added to the water to ensure continued disinfection as the water is piped to the consumer’s tap. Modifying water treatment facilities to use ozone can be expensive, and ozone treatment can create other undesirable by-products that may be harmful to health if they are not controlled (e.g., bromate).

Examples of other disinfectants include chloramines and chlorine dioxide. Chloramines are weaker disinfectants than chlorine, especially against viruses and protozoa; however, they are very persistent and, as such, can be useful for preventing re-growth of microbial pathogens in drinking water distribution systems.

Chlorine dioxide can be an effective disinfectant, but it forms chlorate and chlorite, compounds whose toxicity has not yet been fully determined. Assessments of the health risks from these and other chlorine-based disinfectants and chlorination by-products are currently under way.

In general, the preferred method of controlling chlorination by-products is removal of the naturally occurring organic matter from the source water so it cannot react with the chlorine to form by-products. THM levels may also be reduced through the replacement of chlorine with alternative disinfectants. A third option is removal of the by-products by adsorption on activated carbon beds. It is extremely important that water treatment plants ensure that methods used to control chlorination by-products do not compromise the effectiveness of water disinfection.

Safe Drinking Water Act of 1974 Introduction

In 1974, Congress passed the Safe Drinking Water Act (SDWA) setting up a regulatory program among local, state, and federal agencies to help ensure the provision of safe drinking water in the U.S. The states are expected to administer and enforce these regulations for public water systems (systems that either have 15 or more service connections or regularly serve an average of 25 or more people daily for at least 60 days each year). Public water systems must provide water treatment, ensure proper drinking water quality through monitoring, and provide public notification of contamination problems.

(PL 93-523) as amended by:

- The Safe Drinking Water Act Amendments of 1986
- National Primary Drinking Water Regulations, 40 CFR 141
- National Interim Primary Drinking Water Regulations Implementation, 40 CFR142
- National Secondary Drinking Water Regulations, 40 CFR 143

This is the primary Federal legislation protecting drinking water supplied by public water systems (those serving more than 25 people). The Environmental Protection Agency (EPA) is the lead agency and is mandated to set standards for drinking water. The EPA establishes national standards of which the states are responsible for enforcing.

The act provides for the establishment of primary regulations for the protection of the public health and secondary regulations relating to the taste, odor, and appearance of drinking water. Primary drinking water regulations, by definition, include either a maximum contaminant level (MCL) or, when a MCL is not economically or technologically feasible, a prescribed treatment technique which would prevent adverse health effects to humans.

An MCL is the permissible level of a contaminant in water that is delivered to any user of a public water system. Primary and secondary drinking water regulations are stated in 40 CFR 141 and 143, respectively. As amended in 1986, the EPA is required to set maximum contaminant levels for 83 contaminants deemed harmful to humans (with specific deadlines). It also has authority over groundwater. Water agencies are required to monitor water to ensure it meets standards.

National Drinking Water Regulations

The Act instructs the EPA on how to select contaminants for regulation and specifies how the EPA must establish national primary drinking water regulations once a contaminant has been selected (Section 1412). As of late 1996, the EPA had promulgated 84 drinking water regulations.

Contaminant Selection

P.L. 104-182 establishes a new process for the EPA to select contaminants for regulatory consideration based on occurrence, health effects, and meaningful opportunity for health risk reduction. By February 1998 and every 5 years thereafter, the EPA must publish a list of contaminants that may warrant regulation. Every 5 years thereafter, the EPA must determine whether or not to regulate at least 5 of the listed contaminants.

The Act directs the EPA to evaluate contaminants that present the greatest health concern and to regulate contaminants that occur at concentration levels and frequencies of public health concern. The law also includes a schedule for the EPA to complete regulations for disinfectants and disinfection byproducts (D/DBPs) and *Cryptosporidium* (a waterborne pathogen).

Standard Setting

Developing national drinking water regulations is a two-part process. For each contaminant that the EPA has determined merits regulation, the EPA must set a non-enforceable maximum contaminant level goal (MCLG) at a level at which no known or anticipated adverse health effects occur, and which allows an adequate margin of safety.

The EPA must then set an enforceable standard, a maximum contaminant level (MCL), as close to the MCLG as is "*feasible*" using the best technology, treatment techniques, or other means available (taking costs into consideration).

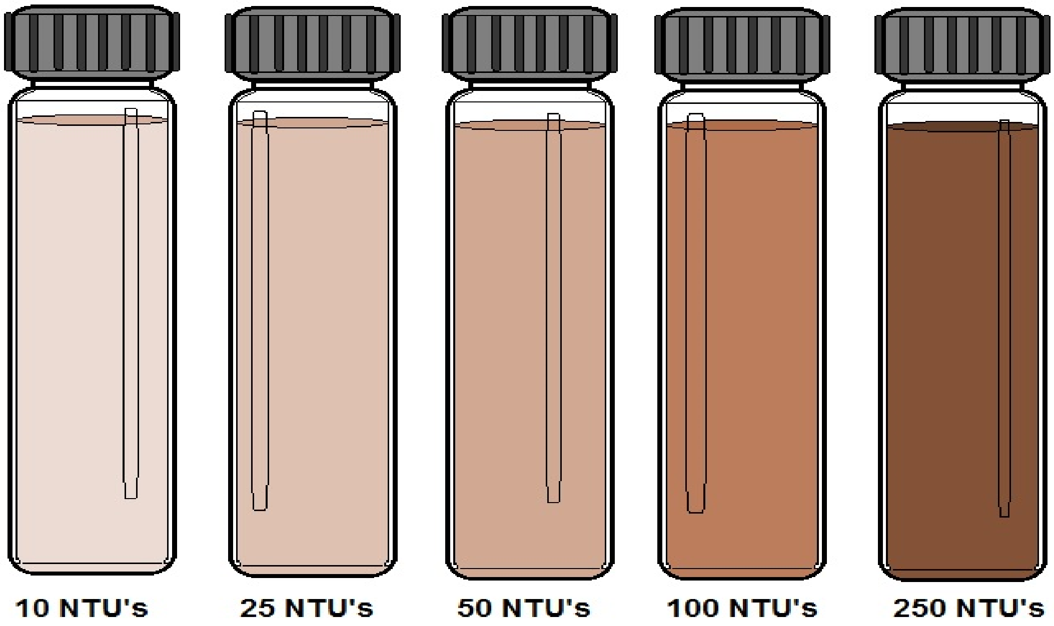
Standards are generally based on technologies that are affordable for large communities; however, under P.L. 104-182, each regulation establishing an MCL must list any technologies, treatment techniques, or other means that comply with the MCL and that are affordable for three categories of small public water systems.

The 1996 Amendments authorize the EPA to set a standard at other than the feasible level if the feasible level would lead to an increase in health risks by increasing the concentration of other contaminants or by interfering with the treatment processes used to comply with other SDWA regulations. In such cases, the standard or treatment techniques must minimize the overall health risk.

In addition, when proposing a regulation, the EPA must now publish a determination as to whether or not the benefits of the standard justify the costs. If the EPA determines that the benefits do not justify the costs, the EPA may, with certain exceptions, promulgate a standard that maximizes health risk reduction benefits at a cost that is justified by the benefits.

Relating to prevention of waterborne disease, the SDWA required EPA to:
1) set numerical standards, referred to as Maximum Contaminant Levels (MCLs — the highest allowable contaminant concentrations in drinking water) or treatment technique requirements for contaminants in public water supplies;
2) issue regulations requiring monitoring of all regulated and certain unregulated contaminants, depending on the number of people served by the system, the source of the water supply, and the contaminants likely to be found;
3) set criteria under which systems are obligated to filter water from surface water sources; it must also develop procedures for states to determine which systems have to filter;
4) develop disinfection rules for all public water supplies; and
5) require all states to develop Wellhead Protection Programs designed to protect from sources of contamination areas around wells that supply public drinking water systems.

Through the Surface Water Treatment Rule (SWTR), EPA has set treatment requirements to control microbiological contaminants in public water systems using surface water sources (and ground-water sources under the direct influence of surface water). These requirements include the following:
1) treatment must remove or inactivate at least 99.9% of *Giardia lamblia* cysts and 99.99% of viruses;
2) all systems must disinfect, and are required to filter if certain source water quality criteria and site-specific criteria are not met;
3) the regulations set criteria for determining if treatment, including turbidity (suspended particulate matter) removal and disinfection requirements, is adequate for filtered systems; and
4) all systems must be operated by qualified operators as determined by the states.



TURBIDITY SAMPLES IN NTU's (Neophelometric Turbidity Unit)

Turbidity Introduction

One physical characteristic of water is turbidity. A measure of the cloudiness of water caused by suspended particles. The cloudy appearance of water caused by the presence of tiny particles. High levels of turbidity may interfere with proper water treatment and monitoring. If high quality raw water is low in turbidity, there will be a reduction in water treatment costs. Turbidity is undesirable because it causes health hazards.

The turbidity in natural surface waters is composed of a large number of sizes of particles. The sizes of particles can be changing constantly, depending on precipitation and manmade factors.

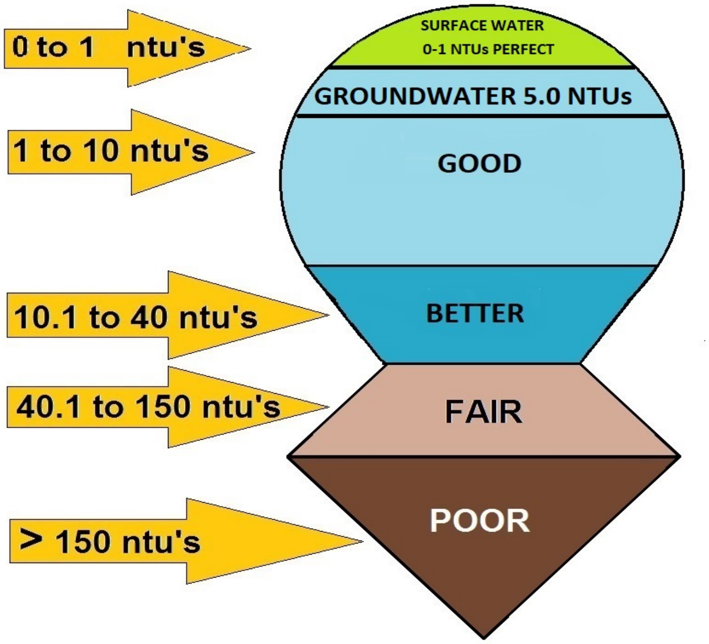
When heavy rains occur, runoff into streams, rivers, and reservoirs occurs, causing turbidity levels to increase. In most cases, the particle sizes are relatively large and settle relatively quickly in both the water treatment plant and the source of supply. However, in some instances, fine, colloidal material may be present in the supply, which may cause some difficulty in the coagulation process.

Generally, higher turbidity levels require higher coagulant dosages. However, seldom is the relationship between turbidity level and coagulant dosage linear. Usually, the additional coagulant required is relatively small when turbidities are much higher than normal due to higher collision probabilities of the colloids during high turbidities.

Conversely, low turbidity waters can be very difficult to coagulate due to the difficulty in inducing collision between the colloids.

In this instance, floc formation is poor, and much of the turbidity is carried directly to the filters. Organic colloids may be present in a water supply due to pollution, and these colloids can be difficult to remove in the coagulation process. In this situation, higher coagulant dosages are generally required.

Turbidity MCL
An MCL for turbidity established by the EPA because turbidity interferes with disinfection. This characteristic of water changes the most rapidly after a heavy rainfall. The following conditions may cause an inaccurate measure of turbidity; the temperature variation of a sample, a scratched or unclean sample tube in the nephelometer and selecting an incorrect wavelength of a light path.



TURBIDITY PARAMETERS (NTU) FOR WATER QUALITY

Surface Water System Compliance Information
(Depends on Systems and Rule)

- 0.34 NTU in 95% of samples, never to exceed 1.0 NTU spike
- Sample turbidity at each individual filter effluent
- Sample the combined filter turbidity at the clear well
- (Groundwater turbidity ≤ 5.0 NTU allowed)

Turbidity Key

- Turbidity can also be measured in ppm (parts per million) and its size is measured in microns. Turbidity can be particles in the water consisting of finely divided solids, larger than molecules, but not visible by the naked eye; ranging in size from .001 to .150mm (1 to 150 microns).
- 0.34 NTU in 95% of surface water

Disinfection Rules Stages 1 & 2 DBPR

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

Stage 2 DBPR

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

General Requirements

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

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

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

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

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

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

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

- **Identify when TTHM or HAA5 levels exceed the operational evaluation level** and, when this happens, look at source water, operational practices, and treatment to find ways to reduce TTHM and HAA5 concentrations in the distribution system. Each of these general requirements are covered in more detail in the rest of this guidance manual. The Stage 2 DBPR is an extension of the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR). Systems must also continue to comply with the other requirements of the Stage 1 DBPR in addition to meeting the requirements of the Stage 2 DBPR. This includes compliance with the MCLs for bromate (for systems using ozone) and chlorite (for systems using chlorine dioxide), the MRDLs for chlorine or chloramine (depending on the residual disinfectant used), as well as TOC removal requirements.

Compliance Timeline

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

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

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

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

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

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

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

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

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

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

Where do DBPs come from?

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

Ensuring Safe Drinking Water

All drinking water systems want to provide water that is safe. One aspect of providing safe drinking water is limiting the levels of DBPs in it. Long-term exposure to DBPs has been linked to bladder cancer, and possibly colon and rectal cancers. More recent studies have shown that shorter-term exposure to high levels of DBPs may be associated with adverse reproductive and developmental health effects.

Limiting the levels of DBPs in your drinking water may require you to make some adjustments to your current operations, such as:

- Making operational improvements at the plant or in the distribution system • Modifying current treatment operations to remove more DBP precursors or form lower levels of DBPs
- Upgrading or installing a new treatment technology

What Does Compliance Monitoring Involve?
Monitoring requirements for TTHM and HAA5 are based on your source water type and the population your system serves. Note that this is different than the Stage 1 DBPR monitoring requirements that were based on the number of treatment plants in your system.

With population-based monitoring, there are five categories of small systems under the Stage 2 DBPR:
- Subpart H systems that serve fewer than 500 people.
- Subpart H systems that serve 500 to 3,300 people.
- Subpart H systems that serve 3,301 to 9,999 people.
- Ground water systems that serve fewer than 500 people.
- Ground water systems that serve 500 to 9,999 people.

If you do not know what type of system you are, you should contact your State to confirm this information.

Older Stage 1 DBPR Information

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

Total Trihalomethanes (TTHM)	80 parts per billion (pp
Haloacetic Acids (HAA5)	60 ppb
Bromate	10 ppb
Chlorite	1.0 parts per million (p

Trihalomethanes were 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 became effective in December 2003 for small surface water and all ground water public water systems.

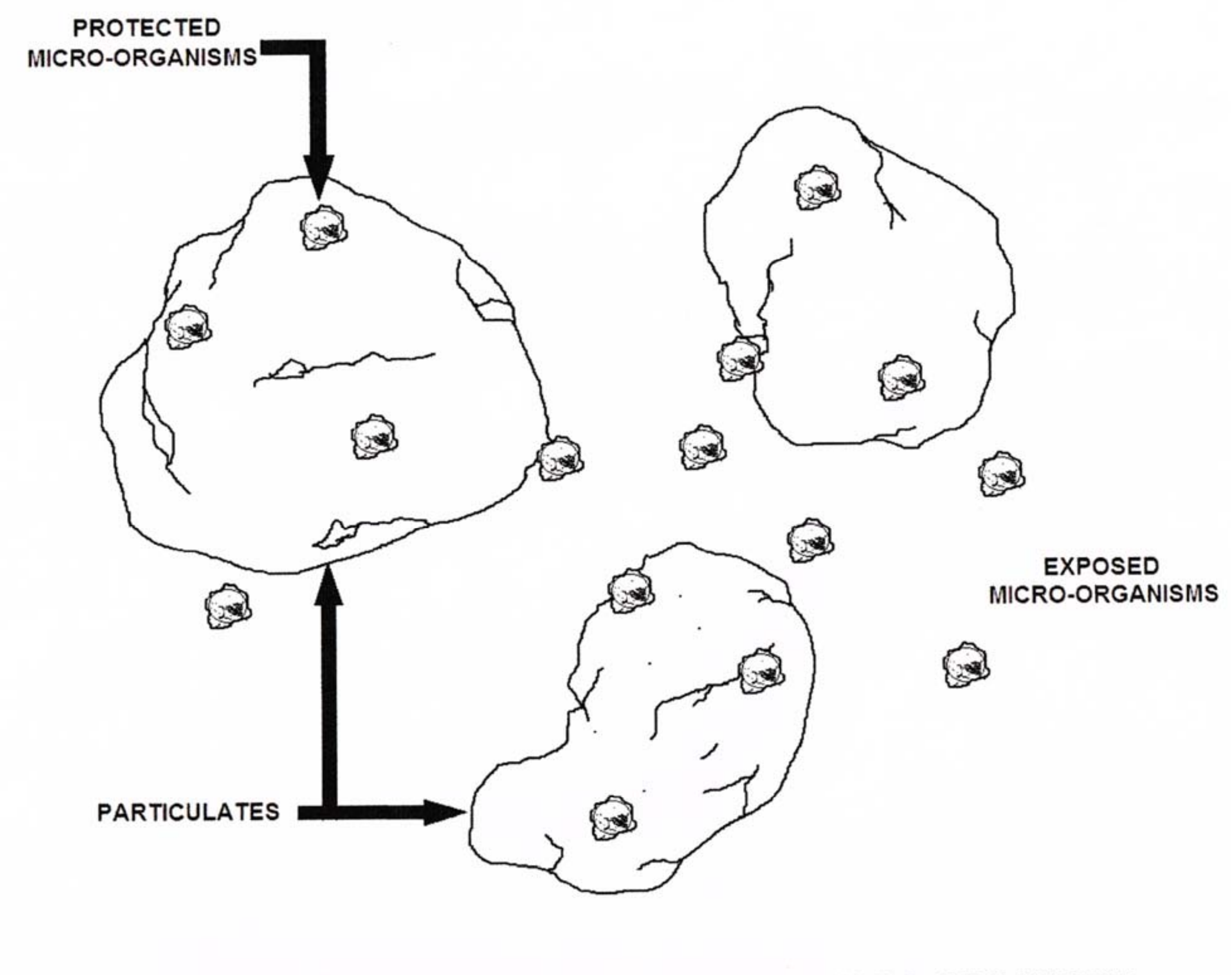
Disinfection byproducts are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts 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 new standard replaced the old standard of a maximum allowable annual average level of 100 parts per billion back in December 2001 for large surface water public water systems. The standard became effective for the first time back 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. 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 back in December 2001 and for small surface water and all ground water public water systems back in December 2003.



TURBIDITY PROVIDES PROTECTION FOR MICRO-ORGANISMS
(HINDERS DISINFECTION)

More on the Stage 2 DBP Rule

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

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

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

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

What is the Stage 2 DBPR?

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

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

What does the rule require?

Under the Stage 2 DBPR, systems will conduct an evaluation of their distribution systems, known as an Initial Distribution System Evaluation (IDSE), to identify the locations with high disinfection byproduct concentrations. These locations will then be used by the systems as the sampling sites for Stage 2 DBPR compliance monitoring. Compliance with the maximum contaminant levels for two groups of disinfection byproducts (TTHM and

HAA5) will be calculated for each monitoring location in the distribution system. This approach, referred to as the locational running annual average (LRAA), differs from current requirements, which determine compliance by calculating the running annual average of samples from all monitoring locations across the system.
The Stage 2 DBPR also requires each system to determine if they have exceeded an operational evaluation level, which is identified using their compliance monitoring results. The operational evaluation level provides an early warning of possible future MCL violations, which allows the system to take proactive steps to remain in compliance.

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

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

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

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

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

Total trihalomethanes (TTHM - chloroform, bromoform, bromodichloromethane, and dibromochloromethane) and haloacetic acids (HAA5 - monochloro-, dichloro-, trichloro-, monobromo-, dibromo-) are widely occurring classes of DBPs formed during disinfection with chlorine and chloramine.

The amount of trihalomethanes and haloacetic acids in drinking water can change from day to day, depending on the season, water temperature, amount of disinfectant added, the amount of plant material in the water, and a variety of other factors.

Are THMs and HAAs the only disinfection byproducts?
No. The four THMs (TTHM) and five HAAs (HAA5) measured and regulated in the Stage 2 DBPR act as indicators for DBP occurrence. There are many other known DBPs, in addition to the possibility of unidentified DBPs present in disinfected water. THMs and HAAs typically occur at higher levels than other known and unknown DBPs.

The presence of TTHM and HAA5 is representative of the occurrence of many other chlorination DBPs; thus, a reduction in the TTHM and HAA5 generally indicates a reduction of DBPs from chlorination.

Other THMS

Chlorite

Chlorite is a byproduct formed when chlorine dioxide is used to disinfect water. 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 for small surface water and all ground water public water systems in December 2003.

Chloroform

Chloroform, typically the most prevalent THM measured in chlorinated water, is probably the most thoroughly studied disinfection byproduct. Toxicological studies have shown that high levels of chloroform can cause cancer in laboratory animals. Extensive research conducted since the early 1990s provides a clearer picture of what this means for humans exposed to far lower levels through drinking water.

One study (Larson et al. 1994a) conducted by the Centers for Health Research (CIIT) observed that a very large dose of chloroform, when given to mice once per day into the stomach (a procedure known as gavage), produced liver damage and eventually cancer. In a second CIIT cancer study (Larson et al., 1994b), mice were given the same daily dose of chloroform through the animals' drinking water.

This time, no cancer was produced. Follow-up research showed that the daily gavage doses overwhelmed the capability of the liver to detoxify the chloroform, causing liver damage, cell death and regenerative cell growth, thereby increasing risks for cell mutation and cancer in exposed organs. When chloroform was given through drinking water, however, the liver could continually detoxify the chloroform as the mice sipped the water throughout the day. Without the initial liver toxicity, there was no cancer in the liver, kidney or other exposed organs (Butterworth et al., 1998).

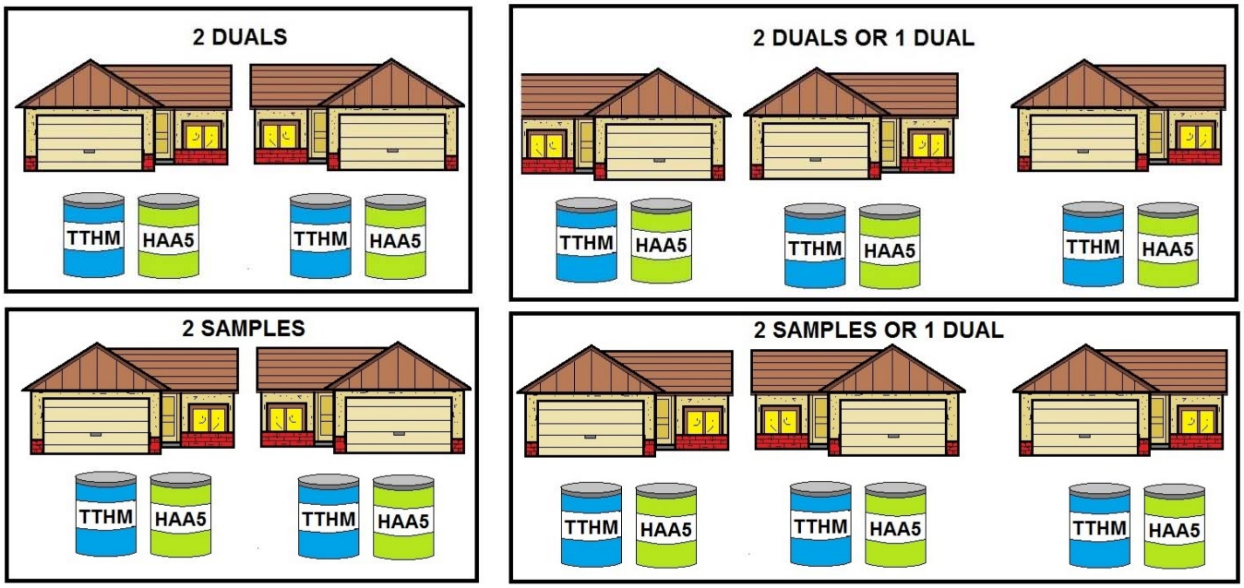
In its most recent risk assessment, EPA considered the wealth of available information on chloroform, including the important work done at CIIT. EPA concludes that exposure to chloroform below the threshold level that causes cell damage is unlikely to increase the risk of cancer. While chloroform is likely to be carcinogenic at a high enough dose, exposures below a certain dose range are unlikely to pose any cancer risk to humans (US EPA, 2002a). For drinking water meeting EPA standards, chloroform is unlikely to be a health concern.

Sodium Chlorate

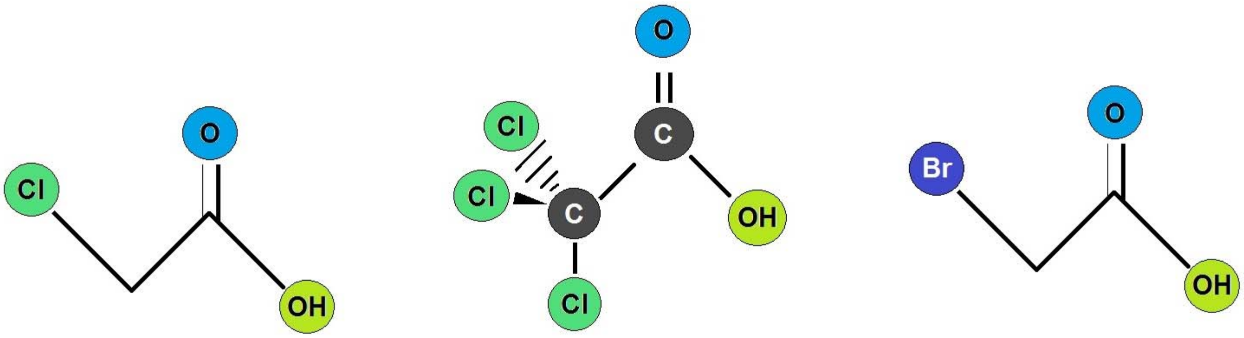
Sodium chlorate is a chemical compound with the chemical formula ($NaClO_3$). When pure, it is a white crystalline powder that is readily soluble in water. It is hygroscopic. It decomposes above 250 °C to release oxygen and leave sodium chloride. Industrially, sodium chlorate is synthesized from the electrolysis of a hot sodium chloride solution in a mixed electrode tank:

$$NaCl + 3H_2O - NaClO_3 + 3H_2$$

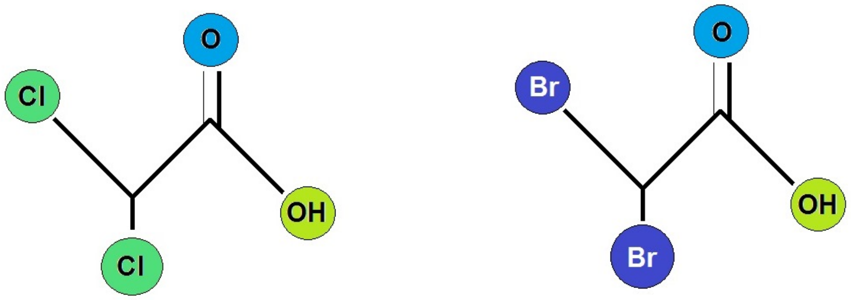
It can also be synthesized by passing chlorine gas into a hot sodium hydroxide solution. It is then purified by crystallization.



STAGE 2 DISINFECTION BYPRODUCT RULE



CHLOROACETIC ACID TRICHLOROACETIC ACID BROMOACETIC ACID



DICHLOROACETIC ACID DIBROMOACETIC ACID

HALOACETIC ACIDS (HAA5)

Disinfection Rule

In the past 25 years, the Safe Drinking Water Act (SDWA) has been highly effective in protecting public health and has also evolved to respond to new and emerging threats to safe drinking water. Disinfection of drinking water is one of the major public health advances in the 20th century. One hundred years ago, typhoid and cholera epidemics were common through American cities; disinfection was a major factor in reducing these epidemics.

However, the disinfectants themselves can react with naturally-occurring materials in the water to form unintended byproducts which may pose health risks. In addition, in the past ten years, we have learned that there are specific microbial pathogens, such as *Cryptosporidium*, which can cause illness and is resistant to traditional disinfection practices.

Chlorine is the most widely used water disinfectant due to its effectiveness and cost. Using chlorine as a drinking water disinfectant has prevented millions of water borne diseases, such as typhoid, cholera, dysentery, and diarrhea. Most states require community water systems to use chlorination. However, research shows that chlorine has side effects. It reacts with organic matter present in water and forms a series of compounds that have been linked to cancer in animals.

These compounds are called disinfection by-products (DBPs). All disinfectants form DBPs in one of two reactions:
(1) chorine and chlorine-based compounds (halogens) react with organics in water causing the chlorine atom to substitute other atoms resulting in halogenated by-products and
(2) oxidation reactions, where chlorine oxidizes compounds present in water. Secondary by-products are also formed when multiple disinfectants are used.

All living organisms have carbon as an essential element in their cells. When trees shed their leaves, they start decomposing and are ultimately broken down by bacteria into carbon-containing compounds.

Similarly, dead animals on land and fish and other aquatic life decompose and disintegrate into compounds that contain carbon as an essential element. Hence, all surface water and groundwater contain varying amounts of carbon-containing compounds called organic matter (primarily humic and fulvic acids).

The EPA Surface Water Treatment Rule (SWTR) requires systems using public water supplies from either surface water or groundwater under the direct influence of surface water to disinfect.

Also, since some disinfectants produce chemical by-products, the dual objective of disinfection is to provide the required level of organism destruction and remain within the maximum contaminant level (MCL) for the SWTR disinfection set by EPA. At this time, an MCL is set for only Total Trihalomethanes, and proposed for additional disinfection byproducts.

What are the microbial/disinfection byproducts (MDBP) rules and which ones apply to me?
The MDBP requirements have been in place for close to 30 years and include the following federal rules:

- Total Trihalomethanes monitoring and MCL, promulgated Nov 1979
- Surface Water Treatment Rule, promulgated June 1989
- Interim Enhanced Surface Water Treatment Rule and Stage 1 Disinfectants / Disinfection Byproducts Rule, promulgated Dec 1998
- Filter Backwash Rule, promulgated June 2001
- Long Term 1 Enhanced Surface Water Treatment Rule, promulgated Jan 2002
- Long Term 2 Enhanced Surface Water Treatment Rule and Stage 2 Disinfectants / Disinfection Byproducts Rule, promulgated Jan 2006
- Groundwater Rule, promulgated Nov 2006

The Disinfectants and Disinfection Byproducts (DBP) rules apply to all community and non-community water systems using a disinfectant such as chlorine, chloramines, ozone and chlorine dioxide.

Compliance with the Stage 1 DBP requirements began in 2000. The Stage 2 DBP requirements began in 2006 with the Initial Distribution System Evaluation (IDSE). Compliance monitoring for the Stage 2 DBP began in April 2012. See phased compliance schedule dependent on system population below.

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2) rule applies to all water systems using surface water, groundwater under the influence of a surface water, as well as groundwater/surface water blends.

The LT2 requirements began in 2006 with the characterization of raw water Cryptosporidium and E.coli levels. Systems serving <10,000 monitor for E.coli only every two weeks for one year. Compliance with the LT2 requirements began in April 2013.

The Groundwater Rule (GWR) applies to all public water systems using groundwater. The GWR requirements begin in March 2009 with 6-months investigative monitoring (IM) for source water E.coli, for systems currently applying disinfection only. All other requirements for the GWR began back in Dec 2009.

Amendments to the SDWA in 1996 require EPA to develop rules to balance the risks between microbial pathogens and disinfection byproducts (DBPs). It is important to strengthen protection against microbial contaminants, especially *Cryptosporidium*, and at the same time, reduce potential health risks of DBPs.

The Stage 1 Disinfectants and Disinfection Byproducts Rule and Interim Enhanced Surface Water Treatment Rule, announced in December 1998, are the first of a set of rules under the 1996 SDWA Amendments.

Public Health Concerns

While disinfectants are effective in controlling many microorganisms, they react with natural organic and inorganic matter in source water and distribution systems to form DBPs. Results from toxicology studies have shown several DBPs (e.g., bromodichloromethane, bromoform, chloroform, dichloroacetic acid, and bromate) to be carcinogenic in laboratory animals. Other DBPs (e.g., chlorite, bromodichloromethane, and certain haloacetic acids) have also been shown to cause adverse reproductive or developmental effects in laboratory animals.

Several epidemiology studies have suggested a weak association between certain cancers (e.g., bladder) or reproductive and developmental effects, and exposure to chlorinated surface water. More than 200 million people consume water that has been disinfected. Because of the large population exposed, health risks associated with DBPs, even if small, need to be taken seriously.

Who Must Comply With The Rule?

The Stage 1 Disinfectants and Disinfection Byproducts Rule applies to all community and nontransient non-community water systems that treat their water with a chemical disinfectant for either primary or residual treatment.

What Does The Rule Require?

The Stage 1 Disinfectant and Disinfection Byproduct Rule updates and supersedes the 1979 regulations for total trihalomethanes. In addition, it will reduce exposure to three disinfectants and many disinfection byproducts.

The rule establishes maximum residual disinfectant level goals (MRDLGs) and maximum residual disinfectant levels (MRDLs) for three chemical disinfectants - chlorine, chloramine and chlorine dioxide (see Table 1). It also establishes maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs) for total trihalomethanes, haloacetic acids, chlorite and bromate (see Table 1).

Table 1
MRDLGs, MRDLs, MCLGs and MCLs for Stage 1 Disinfectants and Disinfection Byproducts Rule

DISINFECTANT RESIDUAL	MRDLG (mg/L)	MRDL (mg/L)	COMPLIANCE BASED ON
Chlorine	**4 (as Cl_2)**	**4.0 (as Cl_2)**	**Annual Average**
Chloramine	**4 (as Cl_2)**	**4.0 (as Cl_2)**	**Annual Average**
Chlorine Dioxide	**0.8 (as ClO_2)**	**0.8 (as ClO_2)**	**Daily Samples**
DISINFECTION BYPRODUCTS	MCLG (mg/L)	MCL (mg/L)	COMPLIANCE BASED ON
Total trihalomethanes (TTHM)[1] **- Chloroform** **- Bromodichloromethane** **- Dibromochloromethane** **- Bromoform**	**N/A** *** **0** **0.06** **0**	**0.080**	**Annual Average**

Haloacetic acids (five) (HAA5)[2] **- Dichloroacetic acid** **- Trichloroacetic acid**	**N/A** **0** **0.3**	**0.060**	**Annual Average**
Chlorite	**0.8**	**1.0**	**Monthly Average**
Bromate	**0**	**0.010**	**Annual Average**

N/A - Not applicable because there are individual MCLGs for TTHMs or HAAs
1-Total trihalomethanes is the sum of the concentrations of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.
2-Haloacetic acids (five) is the sum of the concentrations of mono-, di-, and trichloroacetic acids and mono- and dibromoacetic acids.
*** EPA removed the zero MCLG for chloroform from its National Primary Drinking Water Regulations, effective May 30, 2000, in accordance with an order of the U.S. Court of Appeals for the District of Columbia Circuit.

Water systems that use surface water or ground water under the direct influence of surface water and use conventional filtration treatment are required to remove specified percentages of organic materials, measured as total organic carbon (TOC) that may react with disinfectants to form DBPs (See Table 2). Removal will be achieved through a treatment technique (enhanced coagulation or enhanced softening) unless a system meets alternative criteria.

Table 2
Required Removal of Total Organic Carbon by Enhanced Coagulation and Enhanced Softening for Subpart H Systems Using Conventional Treatment[1]

Source Water TOC (mg/L)	**Source Water Alkalinity (mg/L as $CaCO_3$)**		
	0-60	**>60-120**	**>120[2]**
>2.0-4.0	**35.0%**	**25.0%**	**15.0%**
>4.0-8.0	**45.0%**	**35.0%**	**25.0%**
>8.0	**50.0%**	**40.0%**	**30.0%**

[1] Systems meeting at least one of the alternative compliance criteria in the rule are not required to meet the removals in this table.
[2] Systems practicing softening must meet the TOC removal requirements in the last column to the right.

What Are The Compliance Deadlines?

Large surface water systems are required to comply with the Stage 1 Disinfectants and Disinfection Byproducts Rule and Interim Enhanced Surface Water Treatment Rule by January 2002. Ground water systems and small surface water systems must comply with the Stage 1 Disinfectants and Disinfection Byproducts Rule by January 2004.

What Are The Costs And Benefits Of The Rule?

EPA estimates that implementation of the Stage 1 Disinfectants and Disinfection Byproducts Rule will result in:

- As many as 140 million people receiving increased protection from DBPs.
- 24 percent national average reduction in TTHM levels.
- Reduction in exposure to the major DBPs from use of ozone (bromate) and chlorine dioxide (chlorite).

The total annual cost of the rule is about $700 million. EPA believes that the benefits exceed the costs of the Stage 1 Disinfectants and Disinfection Byproducts Rule. An estimated 116 million households are affected by the Stage 1 Disinfectants and Disinfection Byproducts Rule.

EPA estimates that 95 percent of the households will incur additional costs of less than $1 per month on their water bills.

An additional four percent will pay between $1 and $10 per month more, and one percent are expected to incur increased water bills of $10 to $33 per month, if they choose to install treatment. However, many of these systems may chose less costly non-treatment options, such as consolidation. The majority of households incurring the highest costs are small systems serving less than 10,000 people that have never been regulated for DBPs.

Stage 2 DBP Rule Federal Register Notices

Balancing DBP and Microbial Risks

Continuing evidence of waterborne disease occurrence suggests that microbial risks should receive a much higher level of attention than disinfection byproducts. For this reason, The American Academy of Microbiology (Ford and Colwell, 1996) has recommended, the health risks posed by microbial pathogens should be placed as the highest priority in water treatment to protect public health. A report published by the International Society of Regulatory Toxicology and Pharmacology (Coulston and Kolbye, 1994) stated “The reduction in mortality due to waterborne infectious diseases, attributed largely to chlorination of potable water supplies, appears to outweigh any theoretical cancer risks (which may be as low as zero) posed by the minute quantities of chlorinated organic chemicals reported in drinking waters disinfected with chlorine.”

The IPCS (IPCS 2000, p. 375) reached similar conclusions:

Disinfection is unquestionably the most important step in the treatment of water for drinking water supplies. The microbial quality of drinking water should not be compromised because of concern over the potential long-term effects of disinfectants and DBPs. The risk of illness and death resulting from exposure to pathogens in drinking water is very much greater than the risks from disinfectants and DBPs.

Controlling Disinfection Byproducts

Treatment techniques are available that provide water suppliers the opportunity to maximize potable water safety and quality while minimizing the risk of DBP risks. Generally, the best approach to reduce DBP formation is to remove natural organic matter precursors prior to disinfection. EPA has published a guidance document for water system operators entitled, Controlling Disinfection byproducts and Microbial Contaminants in Drinking Water (EPA, 2001).

The EPA guidance discusses three processes to effectively remove natural organic matter prior to disinfection:

1. Coagulation and Clarification

Most treatment plants optimize their coagulation process for turbidity (particle) removal. However, coagulation processes can also be optimized for natural organic matter removal with higher doses of inorganic coagulants (such as alum or iron salts), and optimization of pH.

2. Absorption
Activated carbon can be used to absorb soluble organics that react with disinfectants to form byproducts.

3. Membrane Technology
Membranes, used historically to desalinate brackish waters, have also demonstrated excellent removal of natural organic matter.

Membrane processes use hydraulic pressure to force water through a semi-permeable membrane that rejects most contaminants. Variations of this technology include reverse osmosis (RO), nanofilitration (low pressure RO), and microfiltration (comparable to conventional sand filtration).

Other conventional methods of reducing DBP formation include changing the point of chlorination and using chloramines for residual disinfection. EPA predicts that most water systems will be able to achieve compliance with new DBP regulations through the use of one or more of these relatively low cost methods (EPA, 1998).

Water system managers may also consider switching from chlorine to alternative disinfectants to reduce formation of THMs and HAAs.

However, all chemical disinfectants form some DBPs. Much less is known about the byproducts of these alternatives than is known about chlorination byproducts. Furthermore, each disinfection method has other distinct advantages and disadvantages.

Disinfection Byproduct Research and Regulations Summary

Drinking water chlorination has contributed to a dramatic decline in waterborne disease rates and increased life expectancy in the United States. Largely because of this success, many Americans take it for granted that their tap water will be free of disease-causing organisms.

In recent years, regulators and the public have focused greater attention on potential health risks from chemical contaminants in drinking water. One such concern relates to disinfection byproducts (DBPs), chemical compounds formed unintentionally when chlorine and other disinfectants react with certain organic matter in water.

In the early 1970s, EPA scientists first determined that drinking water chlorination could form a group of byproducts known as trihalomethanes (THMs), including chloroform. Concerned that these chemicals may be carcinogenic to humans, EPA set the first regulatory limits for THMs in 1979. Since that time, a wealth of research has improved our understanding of how DBPs are formed, their potential health risks, and how they can be controlled. It is now recognized that all chemical disinfectants form some potentially harmful byproducts. The byproducts of chlorine disinfection are by far the most thoroughly studied.

While the available evidence does not prove that DBPs in drinking water cause adverse health effects in humans, high levels of these chemicals are certainly undesirable. Cost-effective methods to reduce DBP formations are available and should be adopted where possible.

The health risks from these byproducts at the levels at which they occur in drinking water are extremely small in comparison with the risks associated with inadequate disinfection. Thus, it is important that disinfection not be compromised in attempting to control such byproducts.

Recent EPA regulations have further limited THMs and other DBPs in drinking water. Most water systems are meeting these new standards by controlling the amount of natural organic matter prior to disinfection, while ensuring that microbial protection remains the top priority.

Based largely on these animal data, EPA considers individual THMs and HAAs to be either possible or probable human carcinogens, although any risk from the low levels found in drinking water would be slight. After reviewing the full body of toxicology studies, the IPCS concluded, “None of the chlorination byproducts studied to date is a potent carcinogen at concentrations normally found in drinking water” (IPCS 2000, p. 376).

Some epidemiology studies have reported an association between human exposure to DBPs and elevated cancer risks, while other studies have found no association. EPA evaluated the existing cancer epidemiology studies and found that only for bladder cancer were associations with chlorinated water somewhat consistent.

Even in these studies, cancer risks were not strongly correlated to measured THM levels, indicating that other factors cannot be ruled out (Craun et al., 2001). EPA has concluded, “The present epidemiologic data do not support a causal relationship between exposure to chlorinated drinking water and development of cancer at this time” (EPA 1998). The IPCS reached a similar conclusion in 2000, noting that a causal relationship between DBPs and increased cancer remains an open question (IPCS 2000).

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Halogen Section Chapter 2

Halogens

Before we get started, let’s review the halogens. The halogens are a chemical series. They are the elements in Group 17 (old-style: VII or VIIA) of the periodic table: fluorine (F), chlorine (Cl), bromine (Br), iodine (I), astatine (At) and the as yet undiscovered ununseptium (Uus). The periodic table is the single most unifying concept in chemistry. It is a structured listing of all known elements, or substances, that consist of one type of atom. Elements cannot be reduced to simpler substances.

The term "*halogen*" means "*salt-former*" and compounds containing halogens are called "salts". The word halogen was coined to mean elements which produce salt in union with a metal. It comes from 18th c. scientific French nomenclature based on erring adaptations of Greek roots.

Halogens are highly reactive, and as such can be harmful or lethal to biological organisms in sufficient quantities. Chlorine and iodine are both used as disinfectants for such things as drinking water, swimming pools, fresh wounds, dishes, and surfaces. They kill bacteria and other potentially harmful microorganisms, a process known as sterilization. Their reactive properties are also put to use in bleaching. Chlorine is the active ingredient of most fabric bleaches and is used in the production of most paper products.

Halides

These elements are diatomic molecules in their natural form. They require one more electron to fill their outer electron shells, and so have a tendency to form a singly-charged negative ion. This negative ion is referred to as a halide ion; salts containing these ions are known as halides.

Halide ions combined with single hydrogen atoms form the hydrohalic acids (i.e., HF, HCl, HBr, HI), a series of particularly strong acids. (HAt, or "hydrastatic acid", should also qualify, but it is not typically included in discussions of hydrohalic acid due to astatine's extreme instability toward alpha decay.)They react with each other to form interhalogen compounds. Diatomic interhalogen compounds (BrF, ICl, ClF, etc.) bear strong superficial resemblance to the pure halogens. Many synthetic organic compounds such as plastic polymers, and a few natural ones, contain halogen atoms; these are known as halogenated compounds or organic halides.

Chlorine

Chlorine is by far the most abundant of the halogens, and the only one needed in relatively large amounts (as chloride ions) by humans. For example, chloride ions play a key role in brain function by mediating the action of the inhibitory transmitter GABA and are also used by the body to produce stomach acid. Iodine is needed in trace amounts for the production of thyroid hormones such as thyroxine.

On the other hand, neither fluorine nor bromine are believed to be really essential for humans, although small amounts of fluoride can make tooth enamel resistant to decay.

Halogens

All halogens have 7 electrons in their outer shells, giving them an oxidation number of -1. The halogens exist, at room temperature, in all three states of matter:

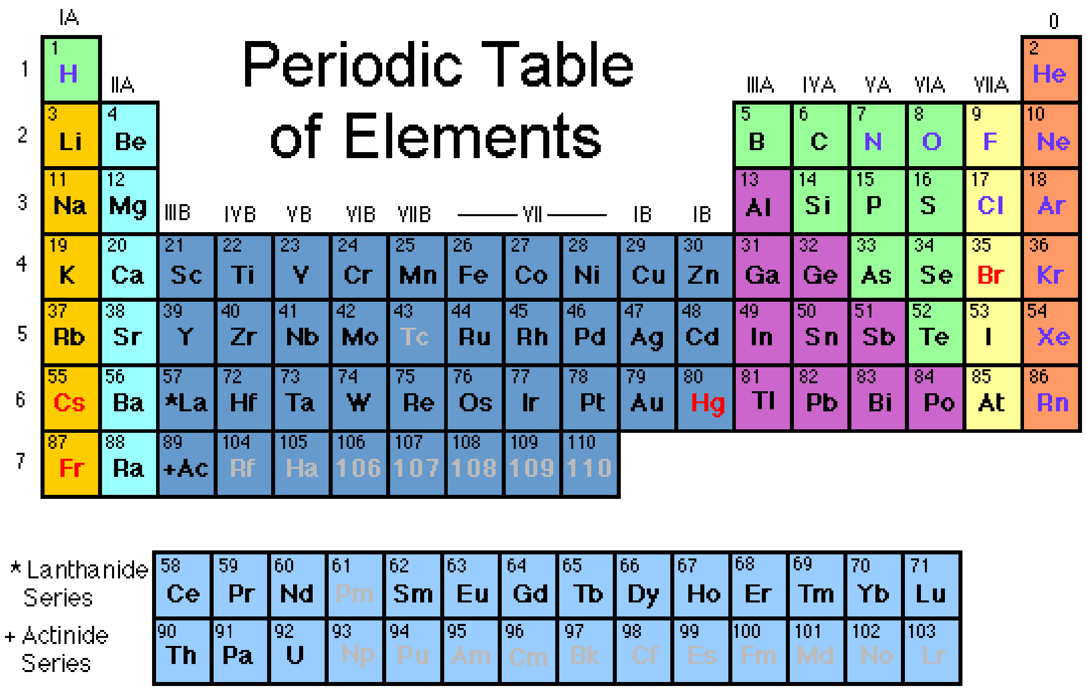
- **Solid**- Iodine, Astatine
- **Liquid**- Bromine
- **Gas**- Fluorine, Chlorine

The Halogens are:

Halogen	Atomic Mass	Melting Point	Boiling Point	Electronegativity
Fluorine	19	53.53	85.03	3.98
Chlorine	35.5	171.6	239.11	3.16
Bromine	80	265.8	332.0	2.96
Iodine	127	396.85	457.4	2.66
Astatine	210	575	610	2.2
Ununseptium	291*	*	*	*

- Ununseptium has not yet been discovered; values are either unknown if no value appears, or are estimates based on other similar chemicals.

Chlorine gas rotometer



Periodic Table of Elements

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VII	VII	VII	IB	IB	IIIA	IVA	VA	VIA	VIIA	0
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 +Ac	104 Rf	105 Ha	106 106	107 107	108 108	109 109	110 110								

* Lanthanide Series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
+ Actinide Series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Legend - click to find out more...

H - gas	Li - solid	Br - liquid	Tc - synthetic
Non-Metals	Transition Metals	Rare Earth Metals	Halogens
Alkali Metals	Alkali Earth Metals	Other Metals	Inert Elements

How is the Periodic Table Organized?

The periodic table is organized with eight principal vertical columns called groups and seven horizontal rows called periods. (The groups are numbered I to VIII from left to right, and the periods are numbered 1 to 7 from top to bottom.)

All the metals are grouped together on the left side of the periodic table, and all the nonmetals are grouped together on the right side of the periodic table. Semimetals are found in between the metals and nonmetals.

What are the Eight Groups of the Periodic Table?

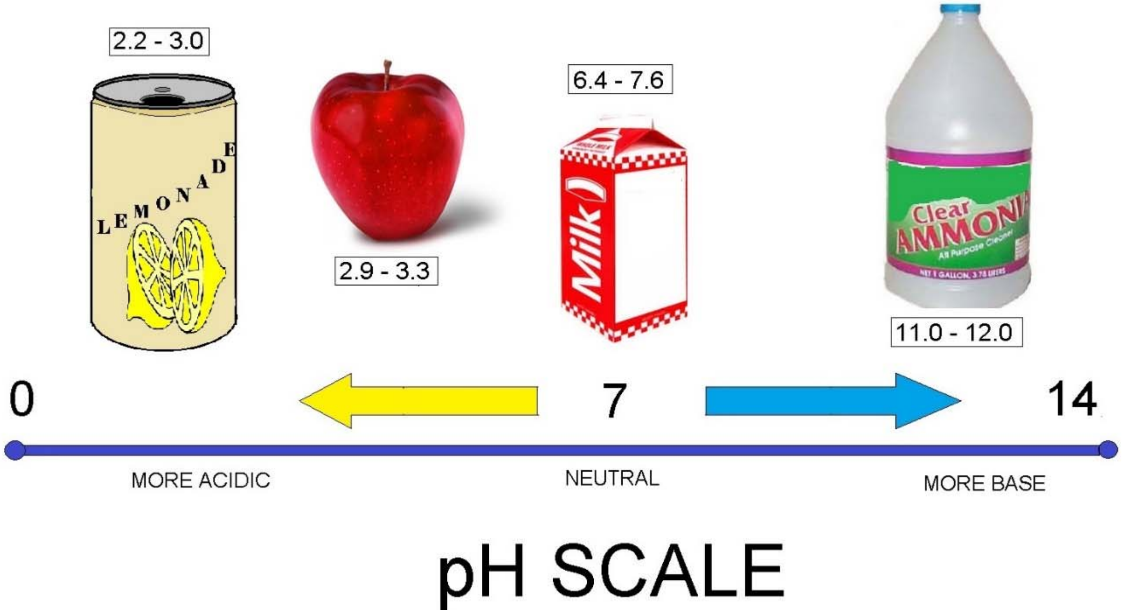
✓ **Group I: Alkali Metals - Li, Na, K, Rb, Cs, Fr**
known as alkali metals
most reactive of the metals
react with all nonmetals except the noble gases
contain typical physical properties of metals (ex. shiny solids and good conductors of heat and electricity)
softer than most familiar metals; can be cut with a knife

- ✓ **Group II: Alkaline Earth Metals-Be, Mg, Ca, Sr, Ba, Ra**
  known as alkaline earth metals
  react with nonmetals, but more slowly than the Group I metals
  solids at room temperature
  have typical metallic properties
  harder than the Group I metals
  higher melting points than the Group I metals
- ✓ **Group III: B, Al, Ga, In, Tl**
  boron is a semimetal; all the others are metals
- ✓ **Group IV: C, Si, Ge, Sn, Pb**
  carbon is a nonmetal; silicon and germanium are semimetals; tin and lead are metals
- ✓ **Group V: N, P, As, Sb, Bi**
  nitrogen and phosphorus are nonmetals; arsenic and antimony are semimetals; bismuth is a metal
- ✓ **Group VI: O, S, Se, Te, Po**
  oxygen, sulfur, and selenium are nonmetals; tellurium and polonium are semimetals
- ✓ **Group VII: Halogens-F, Cl, Br, I, At**
  very reactive nonmetals
- ✓ **Group VIII: Noble Gases-He, Ne, Ar, Kr, Xe, Rn**
  very unreactive

Properties of Metals
Solids at room temperature
Conduct heat very well
Have electrical conductivities that increase with decreasing temperature
Have a high flexibility and a shiny metallic luster
Are malleable-can be beaten out into sheets or foils
Are ductile-can be pulled into thin wires without breaking
Emit electrons when they are exposed to radiation of sufficiently high energy or when
They are heated (known as photoelectric effect and thermionic effect)

Properties of Nonmetals
May be gases, liquids, or solids at room temperature
Poor conductors of heat
Are insulators-very poor conductors of electricity
Do not have a high reflectivity or a shiny metallic appearance
In solid form generally brittle and fracture easily under stress
Do not exhibit photoelectric or thermionic effects

The pH Scale



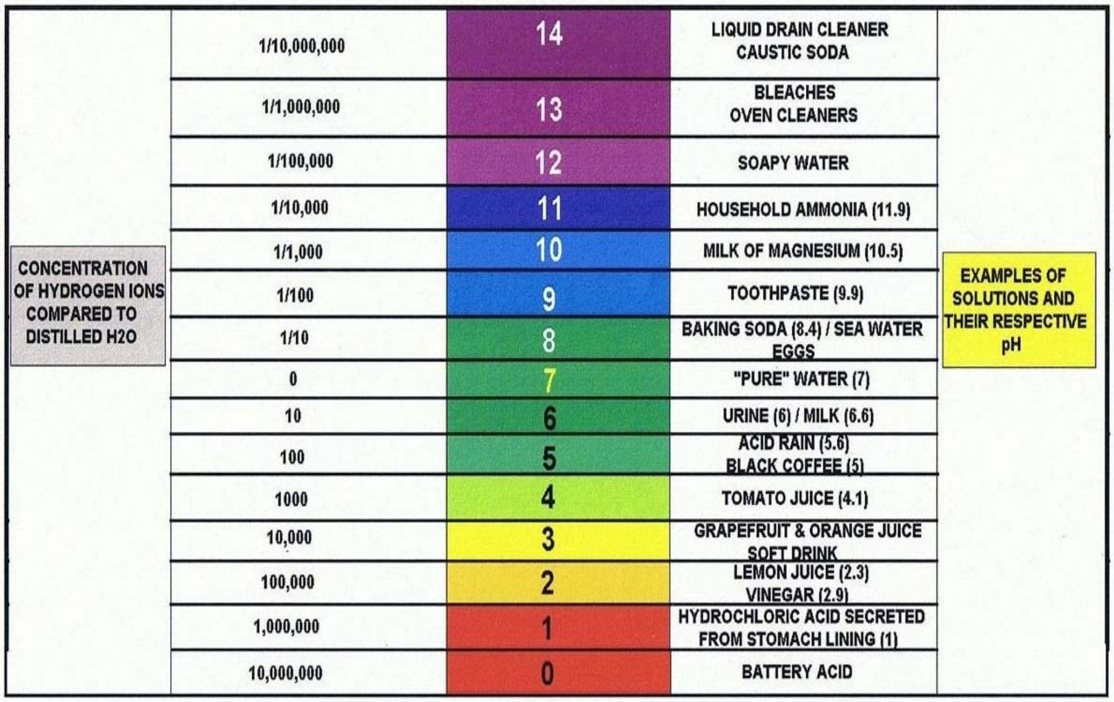
pH: A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest 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**.

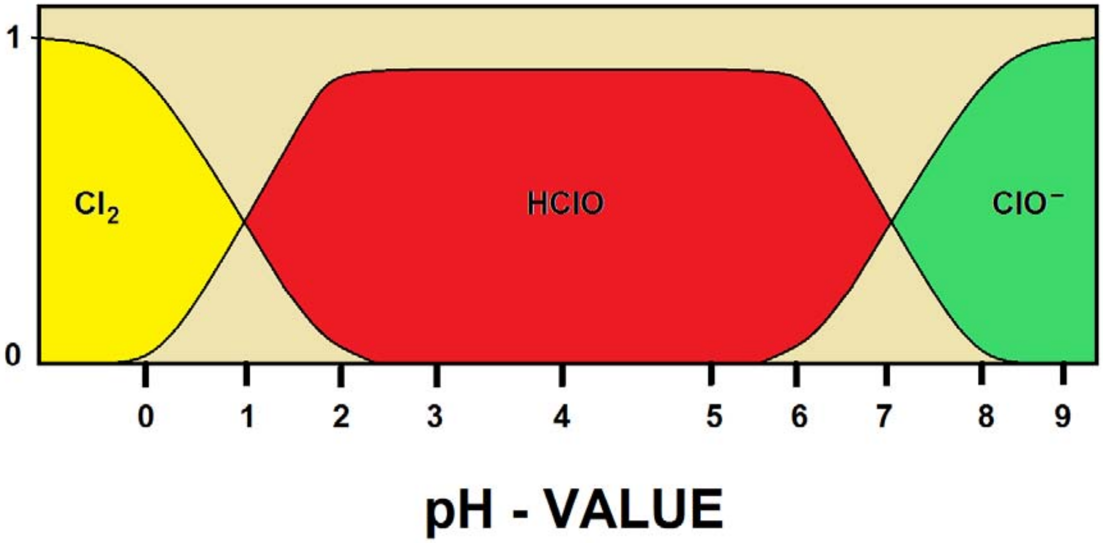
Because the scale is logarithmic, a difference of one pH unit represents a tenfold change. For example, the acidity of a sample with a pH of **5** is ten times greater than that of a sample with a pH of **6**. A difference of 2 units, from **6** to **4**, would mean that the acidity is one hundred times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



CONCENTRATION OF HYDROGEN IONS COMPARED TO DISTILLED H2O		EXAMPLES OF SOLUTIONS AND THEIR RESPECTIVE pH
1/10,000,000	14	LIQUID DRAIN CLEANER CAUSTIC SODA
1/1,000,000	13	BLEACHES OVEN CLEANERS
1/100,000	12	SOAPY WATER
1/10,000	11	HOUSEHOLD AMMONIA (11.9)
1/1,000	10	MILK OF MAGNESIUM (10.5)
1/100	9	TOOTHPASTE (9.9)
1/10	8	BAKING SODA (8.4) / SEA WATER EGGS
0	7	"PURE" WATER (7)
10	6	URINE (6) / MILK (6.6)
100	5	ACID RAIN (5.6) BLACK COFFEE (5)
1000	4	TOMATO JUICE (4.1)
10,000	3	GRAPEFRUIT & ORANGE JUICE SOFT DRINK
100,000	2	LEMON JUICE (2.3) VINEGAR (2.9)
1,000,000	1	HYDROCHLORIC ACID SECRETED FROM STOMACH LINING (1)
10,000,000	0	BATTERY ACID

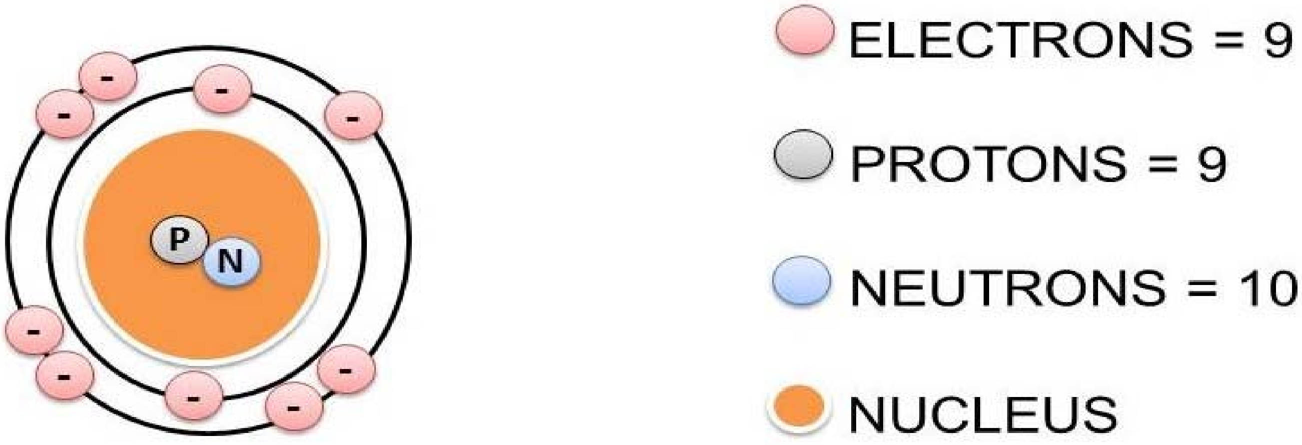
pH Scale



Halogens
Fluorine Section

Name: Fluorine
Symbol: F
Atomic Number: 9
Atomic Mass: 18.998404 amu
Melting Point: -219.62 °C (53.530006 K, -363.31598 °F)
Boiling Point: -188.14 °C (85.01 K, -306.652 °F)
Number of Protons/Electrons: 9
Number of Neutrons: 10
Classification: Halogen
Crystal Structure: Cubic
Density @ 293 K: 1.696 g/cm^3
Color: Greenish

Atomic Structure



Isotopes

Isotope	Half Life
F-18	1.8 hours
F-19	Stable

Facts

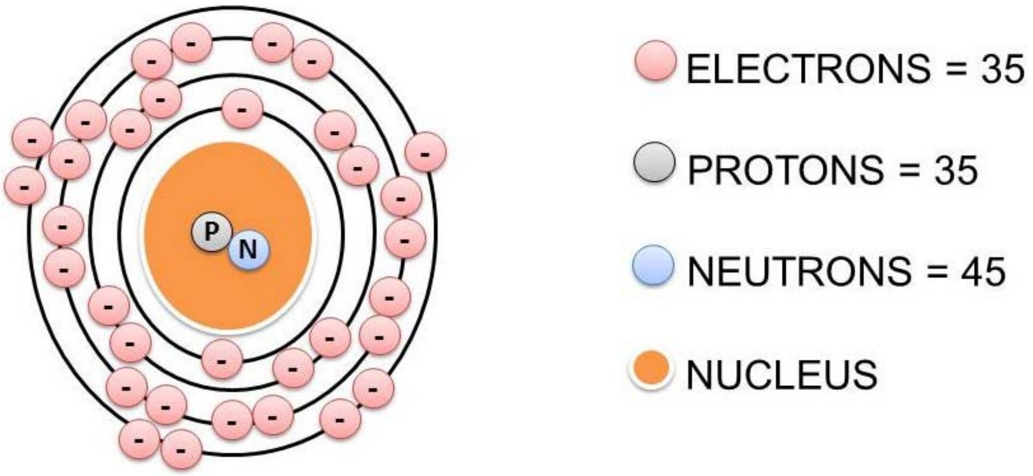
Date of Discovery: 1886
Discoverer: Joseph Henri Moissan
Name Origin: From the Latin word *fluo* (flow)
Uses: Refrigerants
Obtained From: Mineral fluorite

Bromine Section

Name: Bromine
Symbol: Br
Atomic Number: 35
Atomic Mass: 79.904 amu
Melting Point: -7.2 °C (265.95 K, 19.04 °F)
Boiling Point: 58.78 °C (331.93 K, 137.804 °F)
Number of Protons/Electrons: 35
Number of Neutrons: 45

Classification: Halogen
Crystal Structure: Orthorhombic
Density @ 293 K: 3.119 g/cm^3
Color: Red
Date of Discovery: 1826
Discoverer: Antoine J. Balard
Name Origin: From the Greek word *brômos* (stench)
Uses: Poisonous
Obtained From: Sea Water

Atomic Structure



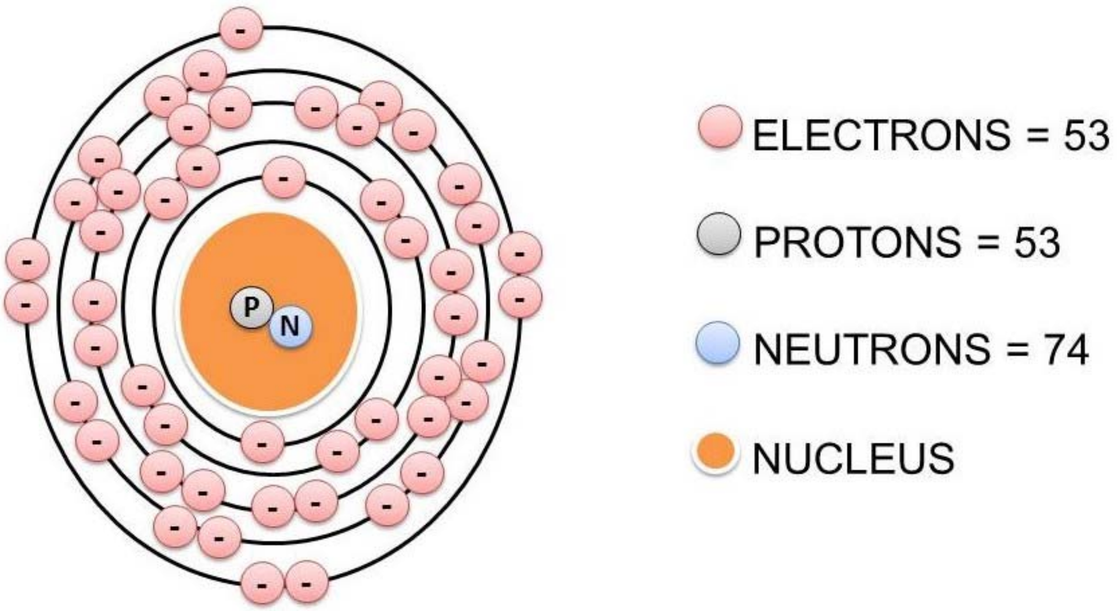
Isotopes

Isotope	Half Life
Br-76	16.0 hours
Br-77	2.4 days
Br-79	Stable
Br-80	17.7 minutes
Br-80m	4.42 hours
Br-81	Stable
Br-82	1.5 days
Br-83	2.4 hours
Br-84	31.8 minutes
Br-85	2.9 minutes

Iodine Section

Name: Iodine
Symbol: I
Atomic Number: 53
Atomic Mass: 126.90447 amu
Melting Point: 113.5 °C (386.65 K, 236.3 °F)
Boiling Point: 184.0 °C (457.15 K, 363.2 °F)
Number of Protons/Electrons: 53
Number of Neutrons: 74
Classification: Halogen
Crystal Structure: Orthorhombic
Density @ 293 K: 4.93 g/cm^3
Color: Blackish
Facts:
Date of Discovery: 1811
Discoverer: Bernard Courtois
Name Origin: From the Greek word *iôdes* (violet)
Uses: Required in humans
Obtained From: Sodium and potassium compounds

Atomic Structure



Isotopes

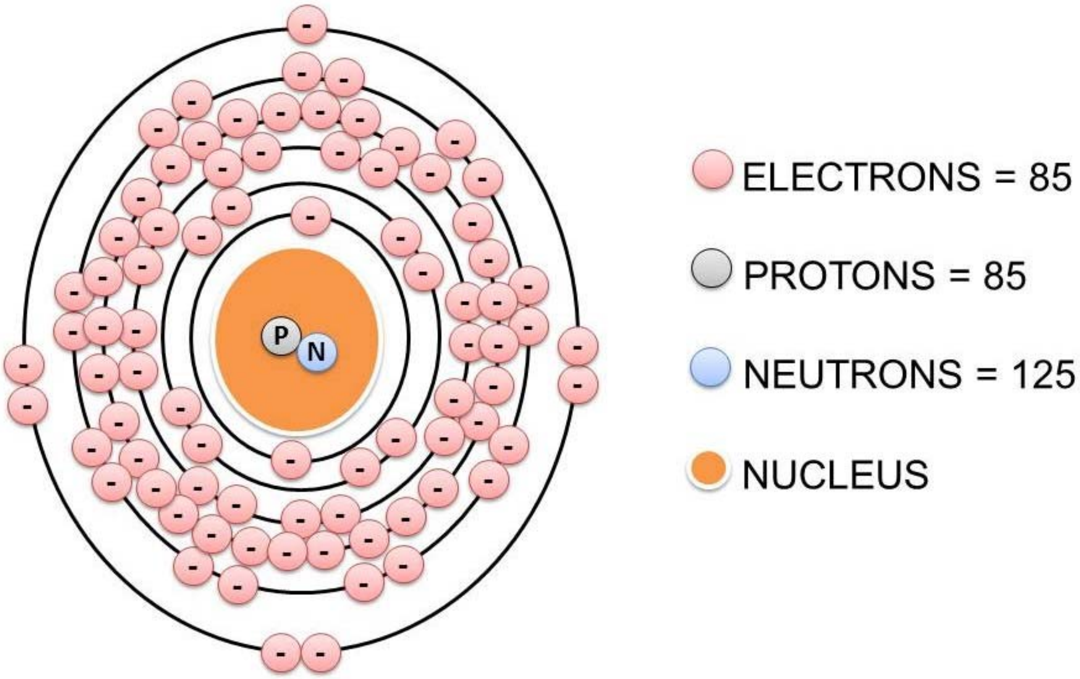
Isotope	Half Life
I-122	3.6 minutes
I-123	13.2 hours
I-124	4.2 days
I-125	60.1 days
I-126	13.0 days
I-127	Stable
I-128	25.0 minutes
I-129	1.57E7 years
I-130	12.4 hours
I-131	8.0 days
I-132	2.3 hours
I-133	20.8 hours
I-134	52.6 minutes
I-135	6.6 hours
I-136	1.4 minutes

Astatine Section

Name: Astatine
Symbol: At
Atomic Number: 85
Atomic Mass: (210.0) amu
Melting Point: 302.0 °C (575.15 K, 575.6 °F)
Boiling Point: 337.0 °C (610.15 K, 638.6 °F)
Number of Protons/Electrons: 85
Number of Neutrons: 125

Classification: Halogen
Crystal Structure: Unknown
Density @ 293 K: Unknown
Color: Unknown
Date of Discovery: 1940
Discoverer: D.R. Corson
Name Origin: From the Greek word *astatos* (unstable)
Uses: No uses known
Obtained From: Man-made

Atomic Structure



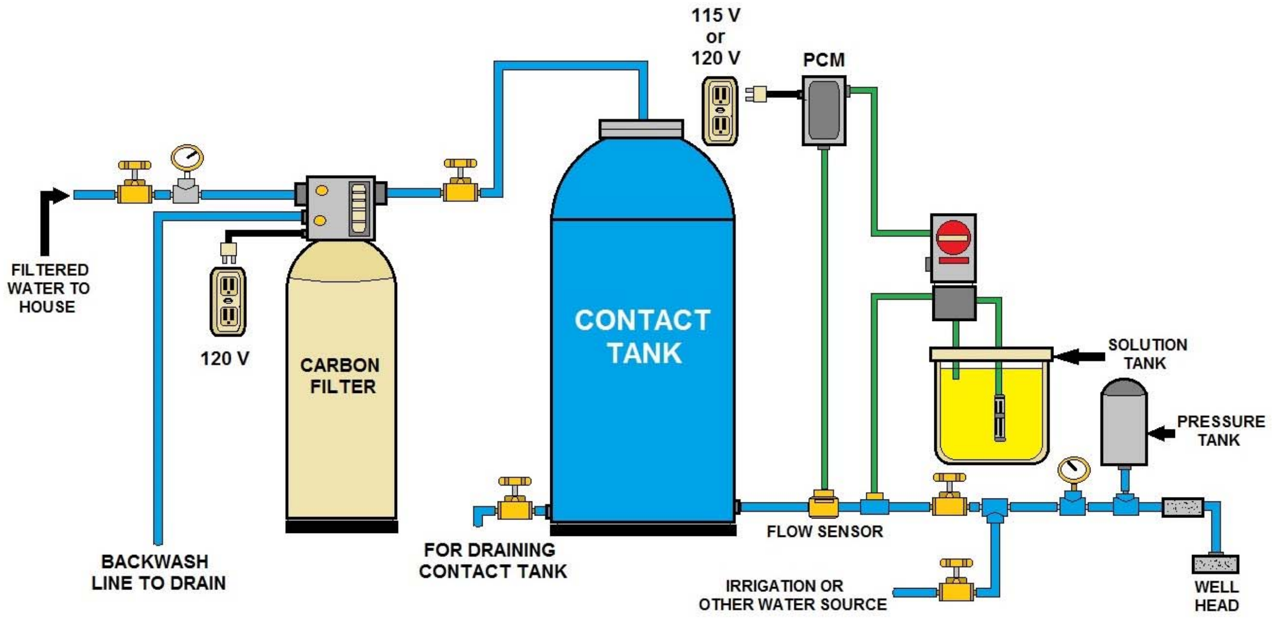
Isotopes

Isotope	Half Life
At-206	29.4 minutes
At-208	1.6 hours
At-211	7.2 hours
At-215	0.1 milliseconds
At-217	32.0 milliseconds
At-218	1.6 seconds
At-219	50.0 seconds

1 Ton Cylinders

The top lines are for extracting the gas, and the bottom lines are for extracting the Cl_2 liquid. Never place water on a leaking metal cylinder. The water will help create acid which will make the leak larger.

150 Pound Chlorine Cylinder



CHLORINATING WELL WATER

Chlorine Exposure Limits and Related Information

This information is necessary to pass your pre-test.

*** OSHA PEL 1 PPM - IDLH 10 PPM and Fatal Exposure Limit 1,000 PPM**
The current Occupational Safety and Health Administration (**OSHA**) permissible exposure limit (**PEL**) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m(3))) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level. *** IDLH 10 PPM**

Physical and chemical properties of chlorine: A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber-colored liquid, a noncombustible gas, and a strong oxidizer. Solid chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air. Atomic number of chlorine is 17. Cl is the elemental symbol and Cl_2 is the chemical formula.

Monochloramine, dichloramine, and trichloramine are also known as Combined Available Chlorine. $Cl_2 + NH_4$.

HOCl and OCl-; the **OCL-** is the hypochlorite ion and the both of these two species are known as free available chlorine; they are the two main chemical species formed by chlorine in water and they are known collectively as hypochlorous acid and the hypochlorite ion. When chlorine gas is added to water, it rapidly hydrolyzes. The chemical equation that best describes this reaction is **$Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$.** Hypochlorous acid is the most germicidal of the chlorine compounds with the possible exception of chlorine dioxide.

Yoke-type connectors should be used on a chlorine cylinder's valve assuming that the threads on the valve may be worn.

The connection from a chlorine cylinder to a chlorinator should be replaced by using a new, approved gasket on the connector. Always follow your manufacturer’s instructions.

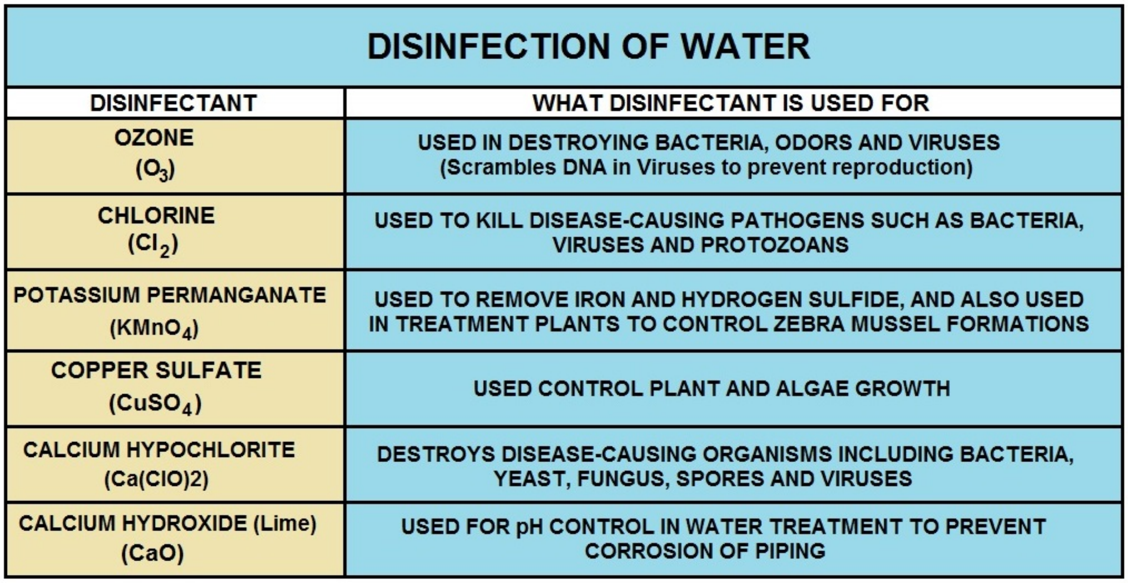
On 1 ton containers, the chlorine pressure reducing valve should be located downstream of the evaporator when using an evaporator. This is the liquid chlorine supply line and it is going to be made into Chlorine gas.

In water treatment, chlorine is added to the effluent before the contact chamber (before the clear well) for complete mixing. One reason for not adding it directly to the chamber is that the chamber has very little mixing due to low velocities.

Here are several safety precautions when using chlorine gas. In addition to protective clothing and goggles, chlorine gas should be used only in a well ventilated area so that any leaking gas cannot concentrate. Emergency procedures in the case of a large uncontrolled chlorine leak are as follows: Notify local emergency response team, warn and evacuate people in adjacent areas, and be sure that no one enters the leak area without adequate self-contained breathing equipment.

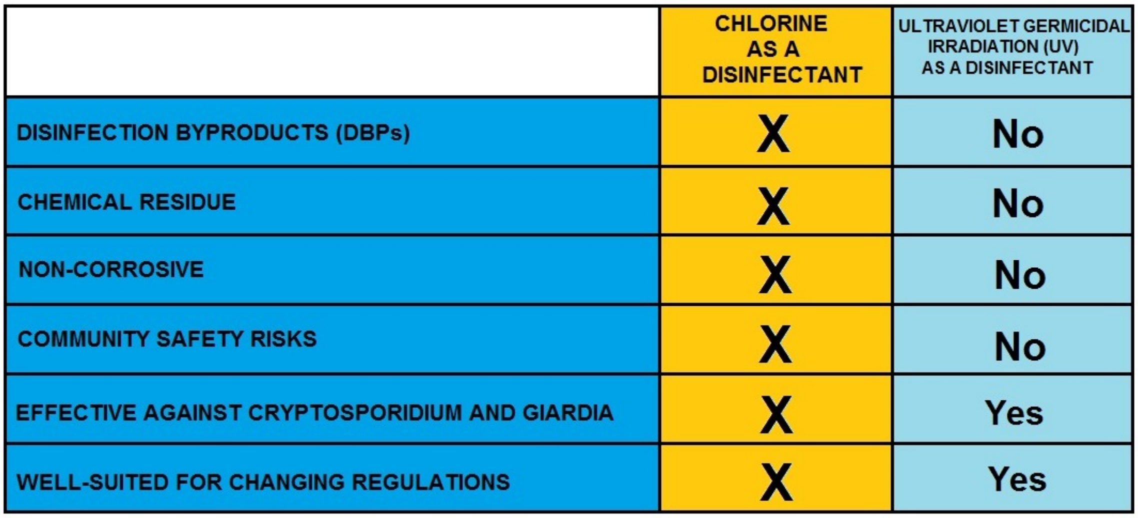
Here are several symptoms of chlorine exposure. Burning of eyes, nose, and mouth, coughing, sneezing, choking, nausea and vomiting, headaches and dizziness, fatal pulmonary edema, pneumonia, and skin blisters. A little Cl_2 will corrode the teeth and then progress to throat cancer.

Approved method for storing a 150 - 200 pound chlorine cylinder: Secure each cylinder in an upright position, attach the protective bonnet over the valve and firmly secure each cylinder. Never store near heat. Always store the empty in an upright, secure position with proper signage.



DISINFECTION OF WATER	
DISINFECTANT	**WHAT DISINFECTANT IS USED FOR**
OZONE (O_3)	USED IN DESTROYING BACTERIA, ODORS AND VIRUSES (Scrambles DNA in Viruses to prevent reproduction)
CHLORINE (Cl_2)	USED TO KILL DISEASE-CAUSING PATHOGENS SUCH AS BACTERIA, VIRUSES AND PROTOZOANS
POTASSIUM PERMANGANATE ($KMnO_4$)	USED TO REMOVE IRON AND HYDROGEN SULFIDE, AND ALSO USED IN TREATMENT PLANTS TO CONTROL ZEBRA MUSSEL FORMATIONS
COPPER SULFATE ($CuSO_4$)	USED CONTROL PLANT AND ALGAE GROWTH
CALCIUM HYPOCHLORITE (Ca(ClO)2)	DESTROYS DISEASE-CAUSING ORGANISMS INCLUDING BACTERIA, YEAST, FUNGUS, SPORES AND VIRUSES
CALCIUM HYDROXIDE (Lime) (CaO)	USED FOR pH CONTROL IN WATER TREATMENT TO PREVENT CORROSION OF PIPING

TYPES OF DISINFECTION FOR WATER TREATMENT



	CHLORINE AS A DISINFECTANT	ULTRAVIOLET GERMICIDAL IRRADIATION (UV) AS A DISINFECTANT
DISINFECTION BYPRODUCTS (DBPs)	X	No
CHEMICAL RESIDUE	X	No
NON-CORROSIVE	X	No
COMMUNITY SAFETY RISKS	X	No
EFFECTIVE AGAINST CRYPTOSPORIDIUM AND GIARDIA	X	Yes
WELL-SUITED FOR CHANGING REGULATIONS	X	Yes

CHLORINE vs. UV FOR DISINFECTION

Chlorine Timeline

1879
- This marked the first time that chlorine was applied as a disinfectant. William Soper of England treated the feces of typhoid patients before disposal into the sewer. He used chlorinated lime, which was a common form of chlorine used initially. (White, 1972)

1893
- This date was the first time that chlorine was applied as a disinfectant on a plant scale basis. This application was made at Hamburg, Germany. (White, 1972)

1903
- This marked the first time chlorine gas was used as a disinfectant in drinking water. This took place in Middlekerke, Belgium. Prior to this date, chlorine was applied through the use of hydrated lime, chloride of lime, or bleaching powder. The use of chlorine gas was designed by Maurice Duyk, a chemist for the Belgian Ministry of Public Works. (Pontius, 1990)

1908
- The first full scale chlorine installation at a drinking water plant in the United States was initiated in this year. This installation took place at the Bubbly Creek Filter Plant in Chicago. This plant served the Chicago Stockyards and was designed by George A. Johnson. The raw water contained a large amount of sewage which was causing sicknesses in the livestock. Johnson implemented chlorine through chloride of lime, and the bacterial content of the water dropped drastically. (Pontius, 1990)

1910
- C. R. Darnall became the first to use compressed chlorine gas from steel cylinders, which is an approach still commonly used today. His installation was in Youngstown, Ohio. His implementation used a pressure-reducing mechanism, a metering device, and an absorption chamber. It was moderately successful, but his setup was only used once.

1912
- John Kienle, chief engineer of the Wilmington, Delaware water department, invented another way to apply chlorine to drinking water. He developed a way to push compressed chlorine from cylinders into an absorption tower in which water was flowing opposite the flow of the chlorine. Because the gas flow was opposite the water flow, the chlorine was able to disinfect the water. (Pontius, 1990)

1913
- An Ornstein chlorinator was installed at Kienle's Wilmington, Delaware water treatment plant. This marked the first time a commercial chlorination system was installed at a municipal water treatment plant. The chlorinator used the same basic premise that Kienle's previous installation did, but the Ornstein chlorinator used both a high and low pressure gauge to more accurately control the amount of chlorine added to the system. (Pontius, 1990)

1914
- On October 14, 1914, the Department of the Treasury enacted the first set of standards that required the use of disinfection for drinking water. These standards called for a maximum level of bacterial concentration of 2 coliforms per 100 milliliters. Because chlorination was the main disinfectant at the time, these standards dramatically increased the number of treatment plants using chlorine. (White, 1972)

1919
- Two important discoveries were made during this year. Wolman and Enslow discovered the concept of chlorine demand which states that the amount of chlorine needed to disinfect the water is related to the concentration of the waste and the amount of time the chlorine has to contact the water. The other important discovery of 1919 was by Alexander Houston. He discovered that chlorine can also eliminate taste and odor problems in water. (Pontius, 1990)

1925
- New drinking water standards were enacted that reduced the maximum permissible limit of coliforms from 2 to 1 coliform per 100 milliliters. This increased the amount and frequency of chlorination again. (White, 1972)

1939
- The theory of the chlorine breakpoint was discovered in this year. Chlorine breakpoint theory is discussed in the following section. (White, 1972)

1960
- A new implementation practice was discovered in this year. The compound loop principle of chlorinator control was implemented, which is the most recent major discovery in chlorine application. (White, 1972)

1972
- A report entitled "Industrial Pollution of the Lower Mississippi River in Louisiana" was published containing the first evidence of disinfection byproducts in drinking water resulting from organic pollution in source water. (Pontius, 1990)

As is evident by the dates in the timeline, most of the innovation in chlorination occurred over 70 years ago. Very few innovations or discoveries have been made recently. Most of the current research is being performed in other areas of disinfection. These areas include ozone, chlorine dioxide, and UV radiation. Chlorine is still the most widely used disinfectant in the United States, but other areas of the world are beginning to use other methods of disinfection with increasing frequency. Since chlorine is still widely used, a thorough understanding of how it disinfects and is implemented is important to those interested in water treatment.

Chlorine Supplement **Pre-Quiz**

1. How should the connection from a chlorine cylinder to a chlorinator be replaced?

2. How many turns should a chlorine gas cylinder be initially opened?

3. If the temperature of a full chlorine cylinder is increased by 50°F or 30°C, what is the most likely result?

4. What is meant by the specific gravity of a liquid?

5. Which metals are the only metals that are ***TOTALLY*** inert to moist chlorine gas?

6. What will be discharged when opening the top valve on a one-ton chlorine cylinder?

7. What are the approved methods for storing a chlorine cylinder?

8. What are normal conditions for a gas chlorination start-up?

9. Name a safety precaution when using chlorine gas?

10. What compounds are formed in water when chlorine gas is introduced?

11. Why should roller bearings not be used to rotate a one-ton chlorine cylinder?

12. What are the physical and chemical properties of chlorine?

13. What are the necessary emergency procedures in the case of a large uncontrolled chlorine leak?

14. Name several symptoms of chlorine exposure.

15. 5 lbs. of a 70% concentration sodium hypochlorite solution is added to a tank containing 650 gallons of water. What is the chlorine dosage?

16. As soon as Cl2 gas enters the throat area, a victim will sense a sudden stricture in this area - nature's way of signaling to prevent passage of the gas to the lungs. At this point, the victim must attempt to do two things. Name them.

17. Positive pressure SCBAs and full face piece SARs can be used in oxygen deficient atmospheres containing less than what percentage of oxygen in the atmosphere?

18. Death is possible from asphyxia, shock, reflex spasm in the larynx, or massive pulmonary edema. Populations at special risk from chlorine exposure are individuals with pulmonary disease, breathing problems, bronchitis, or chronic lung conditions.
A. TRUE
B. FALSE

19. Chlorine gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining the respiratory tract when the tissue is exposed to chlorine. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of chlorine gas in air, causing acute discomfort that warns of the presence of the toxicant.
A. TRUE
B. FALSE

20. Even brief exposure to 1,000 ppm of Cl2 can be fatal.
A. TRUE
B. FALSE

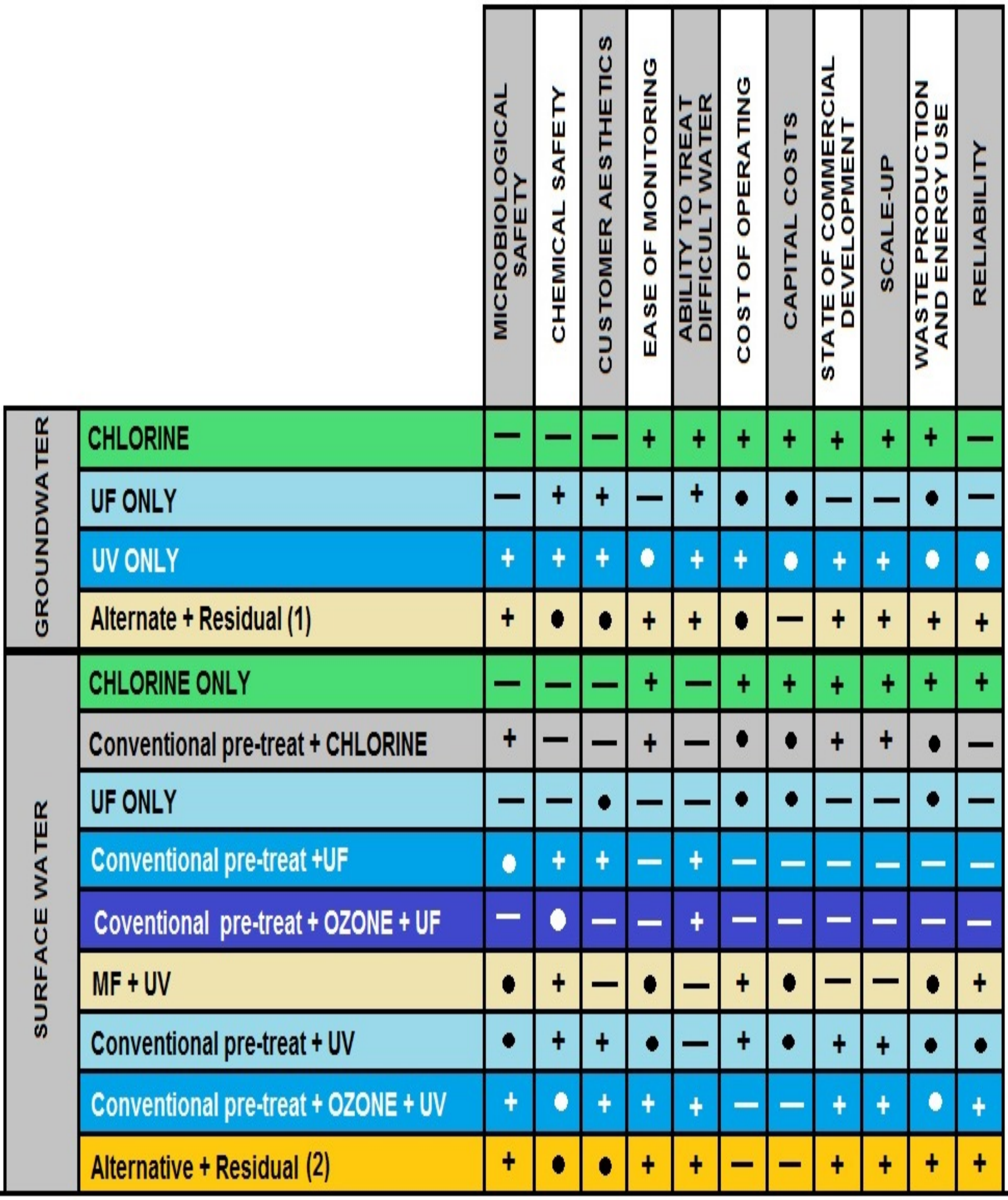
21. What are the two main chemical species formed by chlorine in water and what name are they known by collectively?

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

23. Which chemical reaction equation represents the dissociation of hypochlorous acid?

24. This species of chlorine is the most germicidal of all chlorine compounds with the possible exception of chlorine dioxide.

Here are both one ton and 150 pound cylinders
Answers in rear section before the final assignment.



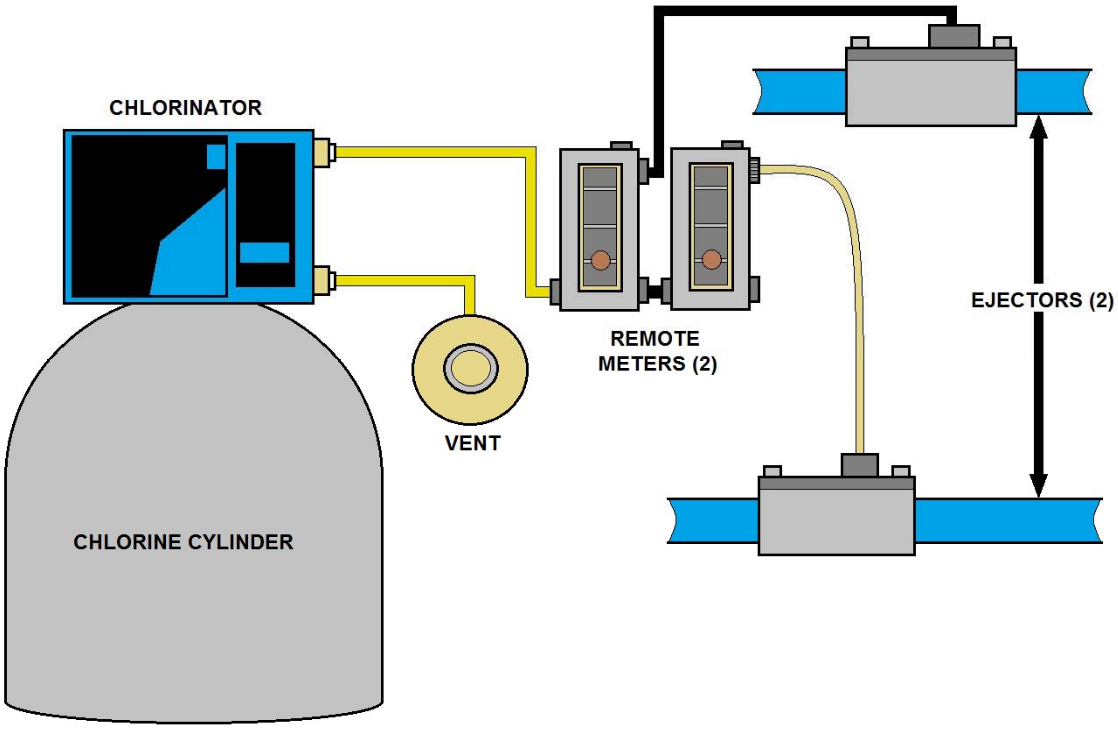
		MICROBIOLOGICAL SAFETY	CHEMICAL SAFETY	CUSTOMER AESTHETICS	EASE OF MONITORING	ABILITY TO TREAT DIFFICULT WATER	COST OF OPERATING	CAPITAL COSTS	STATE OF COMMERCIAL DEVELOPMENT	SCALE-UP	WASTE PRODUCTION AND ENERGY USE	RELIABILITY
GROUNDWATER	CHLORINE	—	—	—	+	+	+	+	+	+	+	—
	UF ONLY	—	+	+	—	+	●	●	—	—	●	—
	UV ONLY	+	+	+	●	+	+	●	+	+	●	●
	Alternate + Residual (1)	+	●	●	+	+	●	—	+	+	+	+
SURFACE WATER	CHLORINE ONLY	—	—	—	+	—	+	+	+	+	+	+
	Conventional pre-treat + CHLORINE	+	—	—	+	—	●	●	+	+	●	—
	UF ONLY	—	—	●	—	—	●	●	—	—	●	—
	Conventional pre-treat +UF	●	+	+	—	+	—	—	—	—	—	—
	Coventional pre-treat + OZONE + UF	—	●	—	—	+	—	—	—	—	—	—
	MF + UV	●	+	—	●	—	+	●	—	—	●	+
	Conventional pre-treat + UV	●	+	+	●	—	+	●	+	+	●	●
	Conventional pre-treat + OZONE + UV	+	●	+	+	+	—	—	+	+	●	+
	Alternative + Residual (2)	+	●	●	+	+	—	—	+	+	+	+

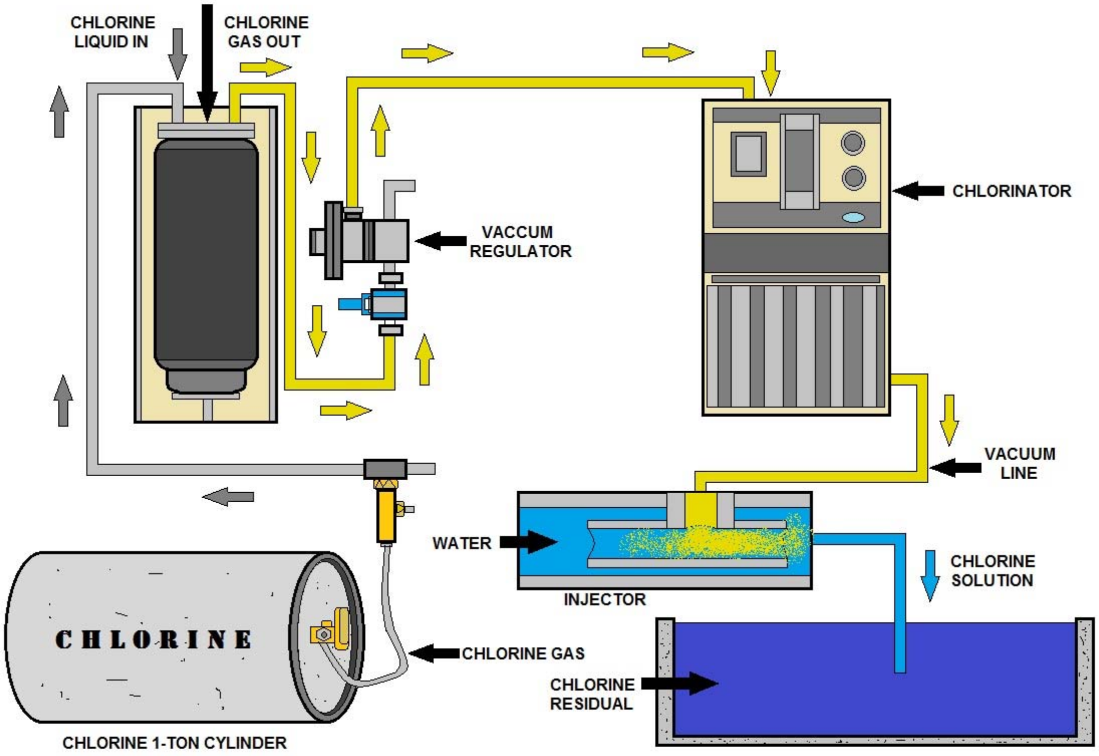
Conventional pre-treat = Coagulation / Sedimentation
UF - Ultafiltration MF - Microfiltration
+ = Better than average
— = Worse than average
● = Average

(1) UF + Chlorine residual or Conv + UV + Chlorine residual

(2) Conv pre-treat + UF + Chlorine residual or MF + UV + Chlorine residual or Conv pre-treat + UV + Residual

ASSESSMENT TO DETERMINE EFFECTIVE DISINFECTION METHODS


CHLORINATOR
REMOTE METERS (2)
EJECTORS (2)
VENT
CHLORINE CYLINDER


CHLORINE LIQUID IN
CHLORINE GAS OUT
CHLORINATOR
VACCUM REGULATOR
VACUUM LINE
WATER
INJECTOR
CHLORINE SOLUTION
CHLORINE
CHLORINE GAS
CHLORINE RESIDUAL
CHLORINE 1-TON CYLINDER

Chlorine Introduction

Name: Chlorine
Symbol: Cl
Atomic Number: 17
Atomic Mass: 35.4527 amu
Melting Point: -100.98 °C (172.17 K, -149.764 °F)
Boiling Point: -34.6 °C (238.55 K, -30.279997 °F)
Number of Protons/Electrons: 17
Number of Neutrons: 18
Classification: Halogen
Crystal Structure: Orthorhombic
Density @ 293 K: 3.214 g/cm^3
Color: Green
Uses: Water purification, bleaches
Obtained From: Salt
Date of Discovery: 1774
Discoverer: Carl Wilhelm Scheele
Name Origin: From the Greek word *khlôros* (green)

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

Chlorinators

Safety Data
NIOSH IDHL: 25 ppm
NIOSH Ceiling: **0.5ppm/15 minutes**
PEL/TWA: **1 ppm**
TLV/TWA: **1 ppm**
TLV/STEL: **3 ppm**
TLV/IDLH: **25 ppm**

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

Chlorine’s Appearance and Odor

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

Reactivity

1. **Conditions Contributing to Instability**: Cylinders of chlorine may burst when exposed to elevated temperatures. Chlorine in solution forms a corrosive material.
2. **Incompatibilities**: Flammable gases and vapors form explosive mixtures with chlorine. Contact between chlorine and many combustible substances (such as gasoline and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydrogen, ammonia, and sulfur), reducing agents, and finely divided metals may cause fires and explosions. Contact between chlorine and arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane, oxomonosilane, potassium, propylene, and silicon should be avoided. Chlorine reacts with hydrogen sulfide and water to form hydrochloric acid, and it reacts with carbon monoxide and sulfur dioxide to form phosgene and sulfuryl chloride. Chlorine is also incompatible with moisture, steam, and water.
3. **Hazardous Decomposition Products:** None reported.
4. **Special Precautions:** Chlorine will attack some forms of plastics, rubber, and coatings.

Flammability

Chlorine is a non-combustible gas.

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

1. **Flash point:** Not applicable.
2. **Autoignition temperature**: Not applicable.
3. **Flammable limits in air:** Not applicable.
4. **Extinguishant:** For small fires use water only; do not use dry chemical or carbon dioxide. Contain and let large fires involving chlorine burn. If fire must be fought, use water spray or fog.

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

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

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

Chlorine Exposure Limits

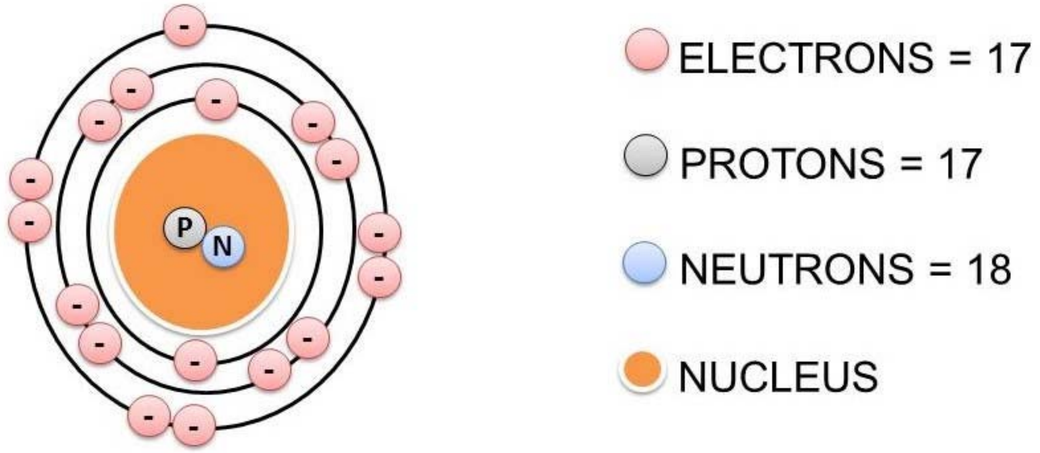
*** OSHA PEL 1 PPM   IDLH 10 PPM**
The current Occupational Safety and Health Administration (**OSHA**) permissible exposure limit (**PEL**) for chlorine is 1 ppm (3 milligrams per cubic meter (mg/m(^{3}))) as a ceiling limit. A worker's exposure to chlorine shall at no time exceed this ceiling level [29 CFR 1910.1000, Table Z-1].

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

*** ACGIH TLV**
The American Conference of Governmental Industrial Hygienists (**ACGIH**) has assigned chlorine a threshold limit value (**TLV**) of 0.5 ppm (1.5 mg/m(^{3})) as a TWA for a normal 8-hour workday and a 40-hour workweek and a short-term exposure limit (**STEL**) of 1.0 ppm (2.9 mg/m(3)) for periods not to exceed 15 minutes. Exposures at the STEL concentration should not be repeated more than four times a day and should be separated by intervals of at least 60 minutes [ACGIH 1994, p. 15].

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

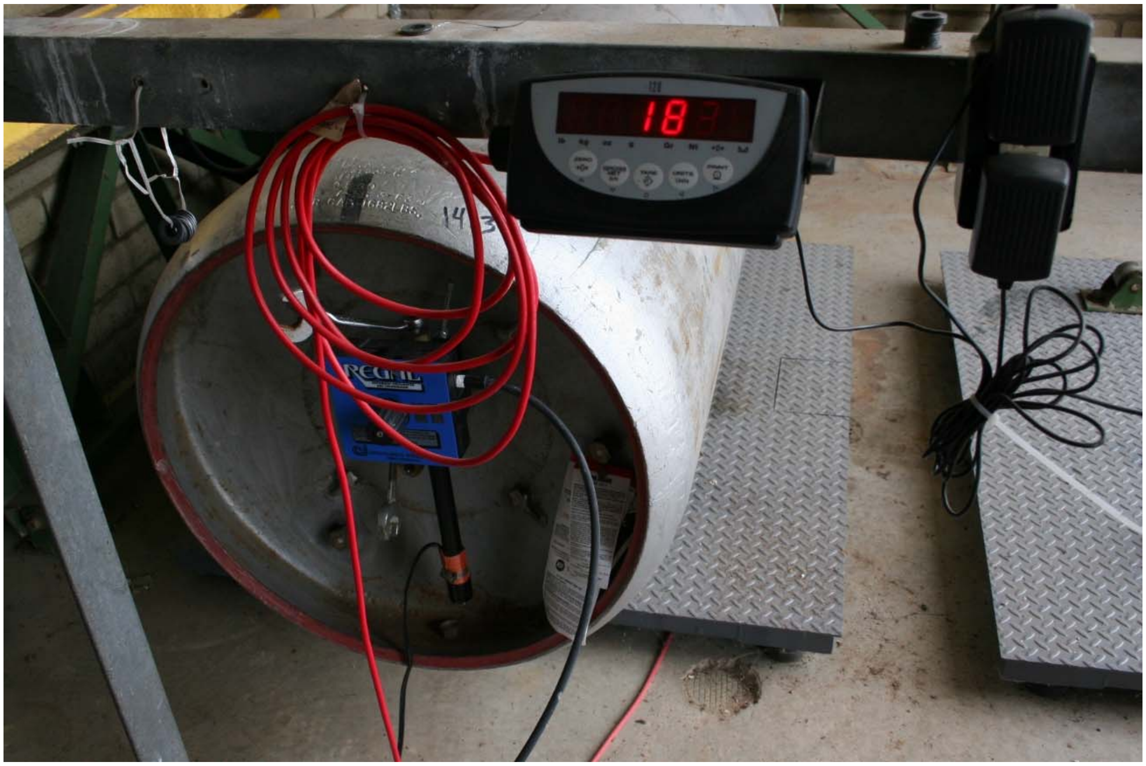
Chlorine's Atomic Structure



Isotopes

Isotope	**Half Life**
Cl-35	Stable
Cl-36	301000.0 years
Cl-37	Stable
Cl-38	37.2 minutes

Top photo, adjusting the chlorine leak alarm sensor. Bottom photo, chlorine cylinder scales.



Chlorine Basics

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

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

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

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

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

What Happens to Chlorine When it Enters the Environment?

- When released to air, chlorine will react with water to form hypochlorous acid and hydrochloric acid, which are removed from the atmosphere by rainfall.

- Chlorine is slightly soluble in water. It reacts with water to form hypochlorous acid and hydrochloric acid. The hypochlorous acid breaks down rapidly. The hydrochloric acid also breaks down; its breakdown products will lower the pH of the water (makes it more acidic).

- Since chlorine is a gas it is rarely found in soil. If released to soil, chlorine will react with moisture forming hypochlorous acid and hydrochloric acid. These compounds can react with other substances found in soil.

- Chlorine does not accumulate in the food chain.

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

Disinfectant Qualities

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

Properties

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

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

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

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

Released From the Salt of the Earth

Chlorine is produced industrially from the compound sodium chloride, one of the many salts found in geologic deposits formed from the slow evaporation of ancient seawater. When electricity is applied to a brine solution of sodium chloride, chlorine gas (Cl_2), caustic soda (NaOH) and hydrogen gas (H_2) are generated according to the following reaction:

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

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

Co-Products

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

Definitions

Chlorine Gas Feed Room

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

Chlorine Gas Storage Room

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

Gas Chlorinator

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

Chlorine Cabinet

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

Hard to tell, but these are one ton cylinders. Notice the five gallon bucket of motor oil in the bottom photo. Also notice that this photo 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:

$\mathrm{Cl\ 2 + H\ 2\ O \rightarrow HOCl + HCl}$
(chlorine gas) (water) (hypochlorous acid) (hydrochloric acid)

$\mathrm{CaOCl + H\ 2\ O \rightarrow 2HOCl + Ca(OH)}$
(calcium hypochlorite) (water) (hypochlorous acid) (calcium hydroxide)

$\mathrm{NaOCl + H\ 2\ O \rightarrow HOCl + Na(OH)}$
(sodium hypochlorite) (water) (hypochlorous acid) (sodium hydroxide)

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

($\mathrm{OCl\ -}$): $\mathrm{HOCl\ H + + OCl -}$ Also expressed $\mathrm{HOCl \rightarrow H + + OCl -}$
(hypochlorous acid) (hydrogen) (hypochlorite ion)
The hypochlorite ion is a much weaker disinfecting agent than hypochlorous acid, about 100 times less effective.

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

Types of Residual

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

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

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

Total residual is all chlorine that is available for disinfection.

Total chlorine residual = free + combined chlorine residual.

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

Break-point chlorination is where the chlorine demand has been satisfied, and 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.

Required Giardia/Virus Reduction

All surface water treatment systems shall ensure a minimum reduction in pathogen levels:
3-log reduction in Giardia; and 4-log reduction in viruses.

These requirements are based on unpolluted raw water sources with Giardia levels of = 1 cyst/100 L, and a finished water goal of 1 cyst/100,000 L (equivalent to 1 in 10,000 risk of infection per person per year). Higher raw water contamination levels may require greater removals as shown on Table 4.1.

TABLE 4.1
Level of Giardia Reduction
Raw Water Giardia Levels*
Recommended Giardia Log Reduction
< 1 cyst/100 L 3-log
1 cyst/100 L - 10 cysts/100 L 3-log - 4-log
10 cysts/100 L - 100 cysts/100 L 4-log - 5-log
> 100 cysts/100 L > 5-log
*Use geometric means of data to determine raw water Giardia levels for compliance.

Required CT Value

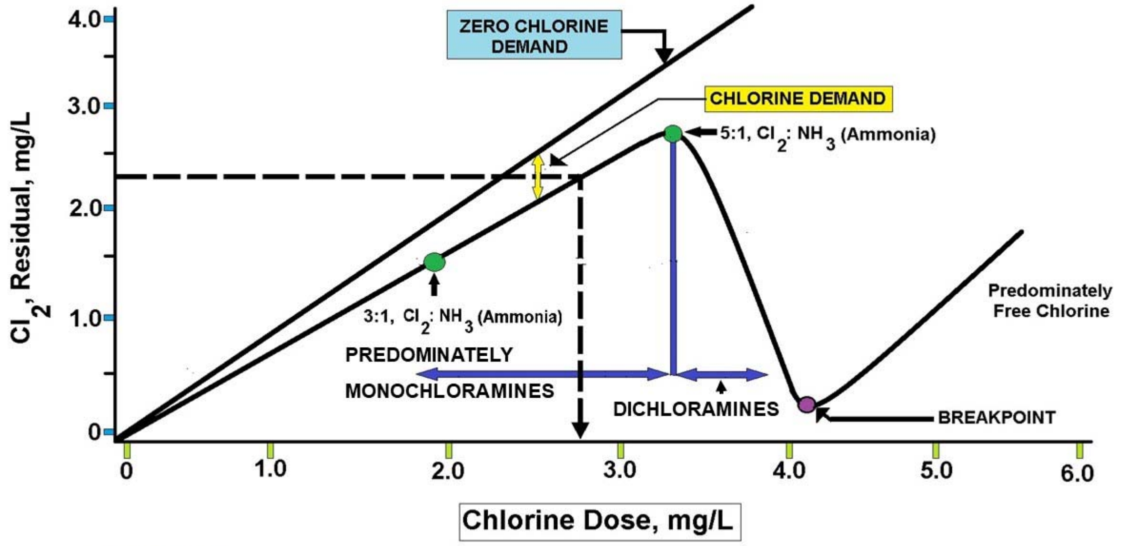
Required CT values are dependent on pH, residual concentration, temperature and the disinfectant used. The tables attached to Appendices A and B shall be used to determine the required CT.

Calculation and Reporting of CT Data

Disinfection CT values shall be calculated daily using either the maximum hourly flow and the disinfectant residual at the same time, or by using the lowest CT value if it is calculated more frequently. Actual CT values are then compared to required CT values.

Results shall be reported as a reduction Ratio, along with the appropriate pH, temperature, and disinfectant residual. The reduction Ratio must be greater than 1.0 to be acceptable.

Users may also calculate and record actual log reductions.
Reduction Ratio = CT actual : CT required.



Technical Learning College

CHLORAMINATION DOSING CURVE

Chlorinator Components

A. **Ejector**
B. **Check Valve Assembly**
C. **Rate Valve**
D. **Diaphragm Assembly**
E. **Interconnection Manifold**
F. **Rotometer Tube and Float**
G. **Pressure Gauge**
H. **Gas Supply**

Chlorine measurement devices or Rotometers

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

Chlorine's Effectiveness

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

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

The safest way to be sure that the amount of chlorine added is sufficient is to add a little more than is required. This will result in a free chlorine residual that can be measured easily. This chlorine residual must be maintained for several minutes depending on chlorine level and water quality. Table 4 lists the free chlorine residual level needed for different contact times, water temperatures and pH levels.

Kits are available for measuring the chlorine residual by looking for a color change after the test chemical is added. The test is simple and easy for a homeowner to perform. If chlorination is required for the water supply, the chlorine residual should be tested regularly to make sure the system is working properly. The kit should specify that it measures the free chlorine residual and not the total chlorine. Once chlorine has combined with other chemicals it is not effective as a disinfectant. If a test kit does not distinguish between free chlorine and chlorine combined with other chemicals, the test may result in an overestimation of the chlorine residual.

Chlorine will kill bacteria in water, but it takes some time (Table 4) . The time needed depends on the concentration of chlorine. Two methods of chlorination are used to disinfect water: **simple chlorination** and **superchlorination**.

Table 4. Necessary chlorine residual to disinfect water for various contact times, water temperatures and pH

Water Temp. 50 degrees F

Contact time (minutes)	**Necessary chlorine residual (mg/l)**		
	pH 7	**pH 7.5**	**pH 8**
40	0.2	0.3	0.4
30	0.3	0.4	0.5
20	0.4	0.6	0.8
10	0.8	1.2	1.6
5	1.6	2.4	3.2
2	4.0	6.0	8.0
1	8.0	12.0	16.0

Water Temp. 32 - 40 degrees F

Contact time (minutes)	**Necessary chlorine residual (mg/l)**		
	pH 7	**pH 7.5**	**pH 8**
40	0.3	0.5	0.6
30	0.4	0.6	0.8
20	0.6	0.9	1.2
10	1.2	1.8	2.4
5	2.4	3.6	4.8
2	6.0	9.0	12.0
1	12.0	18.0	24.0

Example: What is the necessary chlorine residual for well water with pH 7.5?

The well water is 38 degrees F when it enters the house. The pump delivers 7 gallons per minute and after the chlorine is added it is held in a 100 gallon holding tank.

1. Contact time (from Table 5) - gallons per minute for 50 gallon tank = 5 minutes
2. Multiply by 2 for a 100 gallon tank = 10 minutes.
3. Necessary chlorine residual (from Table 4)- for water at 38 degrees F and pH 7.5 = **1.8 mg/l.**

Simple chlorination involves maintaining a low level of free residual chlorine at a concentration of 0.30.5 mg/1 for at least 30 minutes. The residual is measured at the faucet most distant from the where chlorine is added to the water supply.

To ensure the proper contact time of at least 30 minutes, a holding tank can be installed (Table 5). Pressure tanks, while often thought to be sufficient, are usually too small to always provide 30 minutes of contact time.

Table 5. Available contact time from a 50-gallon holding tank	
Water flow rate (gallons per minute)	**Holding time (minutes)**
5	7
7	5
10	3.5

Another way to maintain necessary contact time is to run the chlorinated water through a coil of pipe (Table 6).

Table 6. Available contact time from 1000 feet of 1-1/4 inch pipe	
Water flow rate (gallons per minute)	**Holding time (minutes)**
5	9.2
7	6.6
10	4.6

When the water cannot be held for at least 30 minutes before it is used, super chlorination is an alternative. For **superchlorination**, a chlorine solution is added to the water to produce a chlorine residual of between 3.0 and 5.0 mg/1, which is about ten times stronger than for simple chlorination.

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

Oxidation Chemistry

Oxidation chemistry has long been an accepted and effective part of many water treatment programs. Oxidizing chemicals used in today's water treatment programs include: chlorine, chlorine dioxide, bromine, bromine/chlorine releasing compounds, ozone and hydrogen peroxide.

Oxidizing microbiocides are often found at the forefront of many cooling water treatment programs. In large volume or once-through cooling systems they are usually the primary biocide and often are the most cost-effective programs available to a plant. When selecting these economical and versatile chemicals, several factors should be considered before a technically sound program is implemented. Environmental and regulatory impact, system pH, process contamination, and equipment capital and maintenance expense all play a role in the decision-making process.

The primary killing mechanism these types of microbiocides use is oxidizing protein groups within a microorganism. Proteins are the basic components of essential cellular enzymes that are necessary for life-sustaining cellular processes such as respiration. The destruction of these proteins deprives the cell of its ability to carry out fundamental life functions and quickly kills it. One oxidant is chlorine dioxide, which appears to provide an additional killing mechanism. Chlorine dioxide is able to diffuse readily through hydrophobic lipid layers of an organism, allowing it to react with cellular amino acids, which directly inhibits protein synthesis. Since amino acids are the basic building blocks of all cellular proteins, destruction of these molecules has a devastating effect on the microorganism.

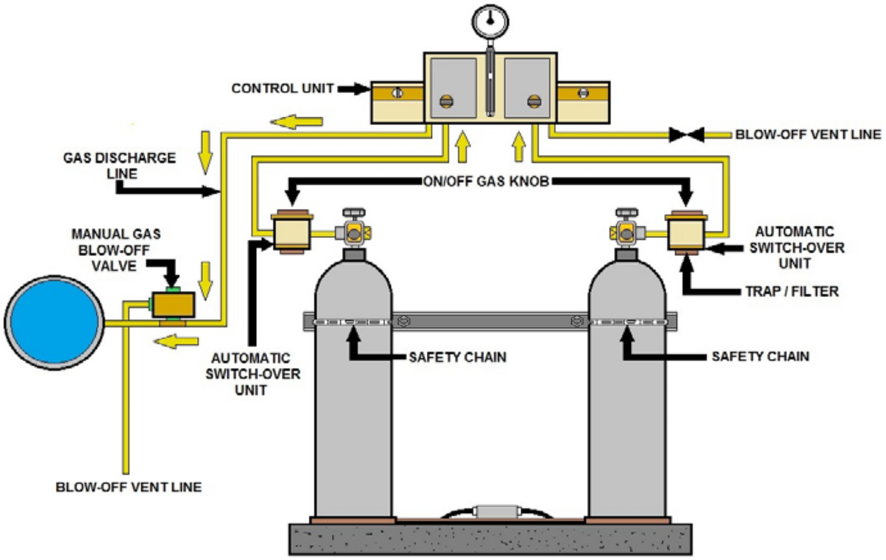
Staff shall be familiar with the locations of the chemical feed building as indicated by a posted site plan. Self-contained breathing apparatus (SCBA) and personal protective equipment should be facing the chemical feed building. Emergency repair kits “B” and “C” should be stored on site close to the chemical feed building.

Chlorine scrubber

Chlorine Gas Sub-Section

Chlorine Gas

Background: Chlorine gas is a pulmonary irritant with intermediate water solubility that causes acute damage in the upper and lower respiratory tract. Chlorine gas was first used as a chemical weapon at Ypres, France in 1915. Of the 70,552 American soldiers poisoned with various gasses in World War I, 1843 were exposed to chlorine gas. Approximately 10.5 million tons and over 1 million containers of chlorine are shipped in the U.S. each year.



TWO CYLINDER CHLORINE SCALE

Chlorine is a yellowish-green gas at standard temperature and pressure. It is extremely reactive with most elements. Because its density is greater than that of air, the gas settles low to the ground. It is a respiratory irritant, and it burns the skin. Just a few breaths of it are fatal. Cl2 gas does not occur naturally, although Chlorine can be found in a number of compounds.

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

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

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

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

High chlorine concentrations have also been shown to directly attack traditional organic-based corrosion inhibitors. When these inhibitors are "deactivated," the metal surface would then be susceptible to corrosion. Process Safety Management (PSM) guidelines dictated by the U.S. Occupational Safety and Health Administration (OSHA), discharge problems related to chlorinated organic compounds such as trihalomethane (THM), dezincification of admiralty brass and delignification of cooling tower wood are other significant concerns associated with the use of chlorine.

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

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

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

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

Although the idea that chlorine causes direct tissue damage by generating free oxygen radicals was once accepted, this idea is now controversial. The cylinders on the right contain chlorine gas. The gas comes out of the cylinder through a gas regulator. The cylinders are on a scale that operators use to measure the amount used each day. The chains are used to prevent the tanks from falling over. Chlorine gas is stored in vented rooms that have panic bar equipped doors.

Operators have the equipment necessary to reduce the impact of a gas leak, but rely on trained emergency response teams to contain leaks.

Solubility Effects

Hydrochloric acid is highly soluble in water. The predominant targets of the acid are the epithelia of the ocular conjunctivae and upper respiratory mucus membranes. Hypochlorous acid is also highly water soluble with an injury pattern similar to hydrochloric acid. Hypochlorous acid may account for the toxicity of elemental chlorine and hydrochloric acid to the human body.

Early Response to Chlorine Gas

Chlorine gas, when mixed with ammonia, reacts to form chloramine gas. In the presence of water, chloramines decompose to ammonia and hypochlorous acid or hydrochloric acid.

The early response to chlorine exposure depends on the (1) concentration of chlorine gas, (2) duration of exposure, (3) water content of the tissues exposed, and (4) individual susceptibility.

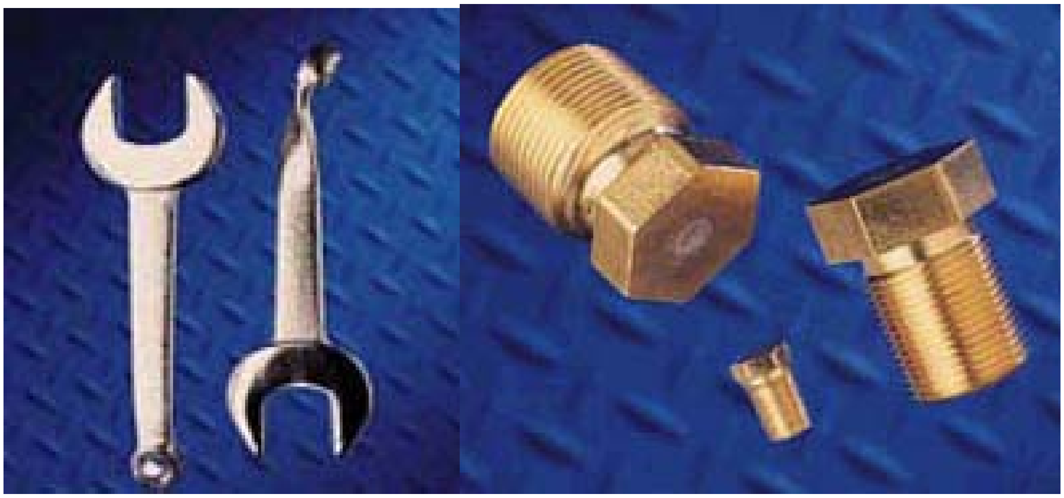
Immediate Effects

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

Pathological Findings

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

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



Chlorine Gas Cylinder Wrenches and Fusible Plugs

CHLORINE

DO NOT TAKE INTERNALLY

AVOID CONTACT WITH EYES, MOUTH OR CLOTHING

WARNING

AVOID BREATHING FUMES

FLAMMABLE - KEEP FIRE AWAY

USE ONLY IN WELL VENTILATED AREAS.
USE ONLY WHERE THERE ARE NO OPEN FLAMES
OR OTHER SOURCES OF IGNITION

EXTREMELY FLAMMABLE
KEEP AWAY FROM HEAT, SPARKS AND OPEN FLAME
KEEP CONTAINER CLOSED

HAZARD IDENTIFICATION

CODE NUMBERS

4 - SEVERE
3 - SERIOUS
2 - MODERATE
1 - SLIGHT
0 - MINIMAL

Using DPD Method for Chlorine Residuals

N, N – diethyl-p-phenylenediame

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

Measuring Chlorine Residual
Chlorine residual is the amount of chlorine remaining in water that can be used for disinfection. A convenient, simple and inexpensive way to measure chlorine residual is to use a small portable kit with pre-measured packets of chemicals that are added to water.

(Make sure you buy a test kit using the ***DPD method***, and not the outdated orthotolodine method.)

Chlorine test kits are very useful in adjusting the chlorine dose you apply. You can measure what chlorine levels are being found in your system (especially at the far ends).

Free chlorine residuals need to be checked and recorded daily. These results should be kept on file for a health or regulatory agency inspection during a regular field visit.

The most accurate method for determining chlorine residuals to use the laboratory ampermetric titration method.

Amperometric Titration

The chlorination of water supplies and polluted waters serves primarily to destroy or deactivate disease-producing microorganisms. A secondary benefit, particularly in treating drinking water, is the overall improvement in water quality resulting from the reaction of chlorine with ammonia, iron, manganese, sulfide, and some organic substances.

Chlorination may produce adverse effects. Taste and odor characteristics of phenols and other organic compounds present in a water supply may be intensified. Potentially carcinogenic chloro-organic compounds such as chloroform may be formed.

Combined chlorine formed on chlorination of ammonia- or amine-bearing waters adversely affects some aquatic life. To fulfill the primary purpose of chlorination and to minimize any adverse effects, it is essential that proper testing procedures be used with a foreknowledge of the limitations of the analytical determination.

Chlorine applied to water in its molecular or hypochlorite form initially undergoes hydrolysis to form free chlorine consisting of aqueous molecular chlorine, hypochlorous acid, and hypochlorite ion. The relative proportion of these free chlorine forms is pH- and temperature-dependent. At the pH of most waters, hypochlorous acid and hypochlorite ion will predominate.

Free chlorine reacts readily with ammonia and certain nitrogenous compounds to form combined chlorine. With ammonia, chlorine reacts to form the chloramines: monochloramine, dichloramine, and nitrogen trichloride.

The presence and concentrations of these combined forms depend chiefly on pH, temperature, initial chlorine-to-nitrogen ratio, absolute chlorine demand, and reaction time. Both free and combined chlorine may be present simultaneously. Combined chlorine in water supplies may be formed in the treatment of raw waters containing ammonia or by the addition of ammonia or ammonium salts.

Chlorinated wastewater effluents, as well as certain chlorinated industrial effluents, normally contain only combined chlorine. Historically the principal analytical problem has been to distinguish between free and combined forms of chlorine.

Hach's AutoCAT 9000™ Automatic Titrator is the newest solution to hit the disinfection industry – a comprehensive, benchtop chlorine-measurement system that does it all: calibration, titration, calculation, real-time graphs, graphic print output, even electrode cleaning. More a laboratory assistant than an instrument, the AutoCAT 9000 gives you:

- High throughput, performs the titration and calculates concentration, all automatically.
- Forward titration, USEPA-accepted methods for free and total chlorine and chlorine dioxide with chlorite.
- Back titration, USEPA-accepted method for total chlorine in wastewater.
- Accurate, yet convenient: the easiest way to complete ppb-level amperometric titration.

Chlorine Residual Sub-Section

Chlorine Demand: The minimum amount of chlorine needed to react in a water purification system; used as a monitoring measurement by system operators.

Chlorine Residual: The concentration of chlorine in the water after the chlorine demand has been satisfied. The concentration is normally expressed in terms of total chlorine residual, which includes both the free and combined or chemically bound chlorine residuals.

Combined Chlorine Residual: The amount of chlorine used up in a water purification system; used as a monitoring measurement by system operators. Combined chlorine is defined as the residual chlorine existing in water in chemical combination with ammonia or organic amines which can be found in natural or polluted waters. Ammonia is sometimes deliberately added to chlorinated public water supplies to provide inorganic chloramines.

Free Chlorine: Free chlorine is defined as the concentration of residual chlorine in water present as dissolved gas (Cl_2), hypochlorous acid (HOCl), and/or hypochlorite ion (OCl-). The three forms of free chlorine exist together in equilibrium.

$$Cl_2 + H_2O \qquad HOCl + H^+ + Cl^-$$

$$HOCl \qquad H^+ + OCl^-$$

Their relative proportions are determined by the pH value and temperature. Regardless of whether pre-chloration is practiced or not, a free chlorine residual of at least 1.0 mg/L should be maintained in the clear well or distribution reservoir immediately downstream from the point of post-chlorination and .2 mg/L in the distribution system to guard against backflow.

Total Chlorine Residual: The total of free residual and combined residual chlorine in a water purification system; used as a monitoring measurement by system operators.

Total chlorine is the sum of free and combined chlorine. When chlorinating most potable water supplies, total chlorine is essentially equal to free chlorine since the concentration of ammonia or organic nitrogen compounds (needed to form combined chlorine) will be very low. When chloramines are present in the municipal water supply, then total chlorine will be higher than free chlorine.

Common Terms

Pre-chlorination: The addition of chlorine at the plant headworks or prior to other water treatment or groundwater production processes and mainly used for disinfection and control of tastes, odors, and aquatic growths.

Post-chlorination: The addition of chlorine after a process or adding chlorine downstream to meet a demand in the system.

Breakpoint chlorination: Breakpoint chlorination means adding Cl_2 to the water until the Cl_2 demand is satisfied. Until all the microorganisms are killed.

What is the process of chlorination called as a treatment process and how does it differ from sterilization?
Chlorination: A method of water disinfection where gaseous, liquid, or dissolved chlorine is added to a water supply system. Water which has been treated with chlorine is effective in preventing the spread of disease. The chlorination of public drinking supplies was originally met with resistance, as people were concerned about the health effects of the practice. The use of chlorine has greatly reduced the prevalence of waterborne disease as it is effective against almost all bacteria and viruses, as well as amoeba. Sterilization kills everything.

What are the physical properties of chlorine, what hazards does it present, what advantages does it have over most other disinfectants, and how does it react with bacteria?
Physical and chemical properties of chlorine: A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber-colored liquid, a noncombustible gas, and a strong oxidizer. Solid chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air. Atomic number of chlorine is 17. Cl is the elemental symbol and Cl_2 is the chemical formula.

Chlorine reacts with bacteria as if it was very corrosive and burns the skin or covering killing the bacteria.

What is the purpose of a fusible plug, at what temperature does it melt, and where is it located on 150-lb. and 1-ton cylinders?
Fusible plug is a safety device that melts. If the temperature of a full Cl2 cylinder is increased by 50^{o} F or 30^{o} C, a rupture may occur. It will melt at 158 to 165 degrees F. It is found on the side of a 1-ton container and on top of the 150-pound cylinder and is located in the valve below the valve seat.

What is the correct procedure to follow in changing a chlorine cylinder and what item should always be replaced with a new one in doing so?
Hook up the chlorinator to the container or cylinder with the chlorine valve turned off. Use the gas side not the liquid if using a 1-ton container.

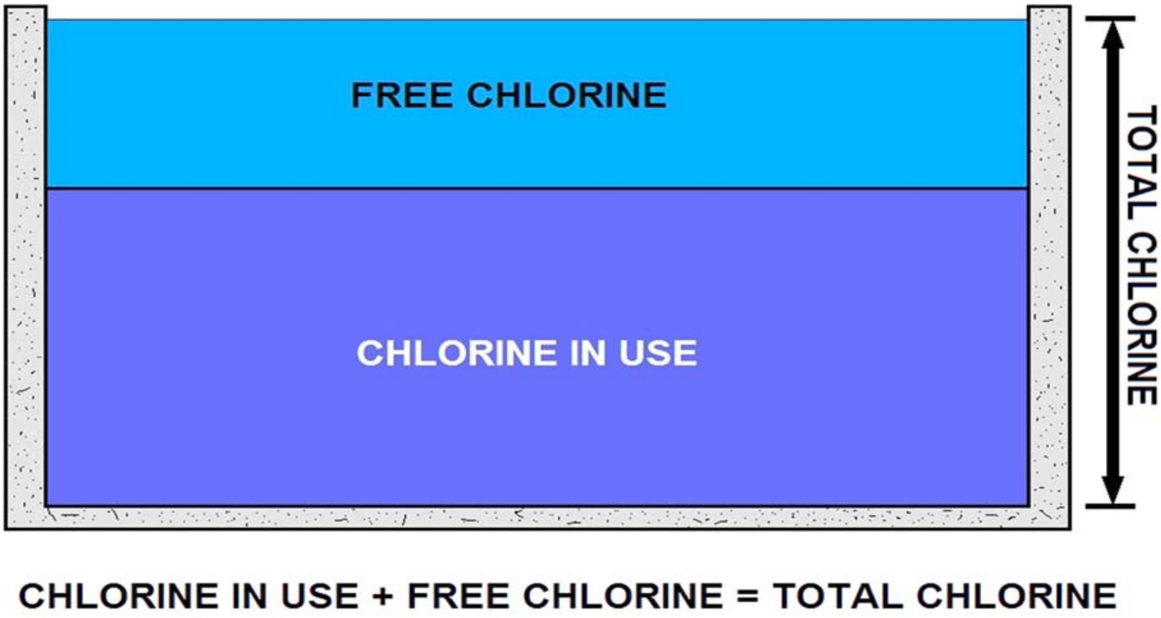
Remove the cylinder valve outlet cap and check the valve face or damage. Clean with wire brush if necessary. If the valve face is smooth, clean proceed with hooking up the cylinder.

Check the inlet face of the chlorinator and clean if necessary. Place a new lead gasket on the chlorinator inlet, place the chlorinator on the cylinder valve, install the yoke clamp and slowly tighten the yoke clamp until the two faces are against the lead gasket. Tighten the yoke, compressing the gasket one half to three quarters turn, do not over tighten. Replace the lead gasket with every change out.

How, when and where should chlorine residuals be taken and what information do they provide? The sample must be taken within the distribution system of your PWS. If you take it before the distribution system you will not get an accurate reading. The sample must be taken at the same tap that you take the Bac-t sample.

Types of Residual Review

If water were pure, the measured amount of chlorine in the water should be the same as the amount added. Nevertheless, 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.

Chlorine Demand

The minimum amount of chlorine needed to react in a water purification system; used as a monitoring measurement by system operators.

Chlorine Residual

The concentration of chlorine in the water after the chlorine demand has been satisfied. The concentration is normally expressed in terms of total chlorine residual, which includes both the free and combined or chemically bound chlorine residuals.

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When chloramines are present in the municipal water supply, then total chlorine will be higher than free chlorine.

Free, Total, and Combined Chlorine
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, and any additional chlorine will be considered ***free chlorine*****.**

Sodium Hypochlorite Sub-Section

Physical Properties - Sodium Hypochlorite
Description: Clear greenish yellow liquid.
Warning properties: Chlorine odor; inadequate warning of hazardous concentrations.
Molecular weight: 74.44 daltons
Boiling point (760 mm Hg): Decomposes above 40ºC (HSDB 2001)
Freezing point: 6ºC (21ºF)
Specific gravity: 1.21 (14% NAOCl solution) (water=1)
Water solubility: 29.3 g/100 g at 32ºF (0ºC)
Flammability: Not flammable

Alternative Names
Bleach; Clorox; Carrel-Dakin solution

Incompatibilities
Calcium or sodium hypochlorite react explosively or form explosive compounds with many common substances such as ammonia, amines, charcoal, or organic sulfides

Introduction
The world's most universal and reliable means of water and wastewater disinfection is chlorination. Two fundamental methods include gas chlorination (Cl2) and liquid chlorination (NaOCl) otherwise known as Sodium Hypochlorite. Sodium hypochlorite (NaOCl) is a solution made from reacting chlorine with a sodium hydroxide solution. These two reactants are the major co-products from most chlor-alkali cells. Sodium hypochlorite has a variety of uses and is an excellent disinfectant/antimicrobial agent. Sodium hypochlorite also significantly increases the pH of the water. When sodium hypochlorite is used, it must be counterbalanced by a strong acid like sodium bisulfate or muriatric acid to keep the pH within the ideal range.

The hypochlorite form of chlorine has been used since 1850. The most widely used form of hypochlorite is the liquid, sodium hypochlorite (NaOCl), with more than 150 tons per day consumed in the United States. Sodium hypochlorite application in cooling water is essentially the same as with gas chlorine; HOCl is produced as the active toxicant. The HOCl is equally susceptible to process contamination, has the same chlorine demand as gas chlorine and displays the same tendency to dissociate.

Sodium hypochlorite differs from chlorine gas in two respects: method of feed and hydrolization properties. Sodium hypochlorite can either be gravity-fed or applied with a metering pump. The latter is generally recognized as a consistently more accurate method. The second difference, in hydrolysis, lies in the end products. The NaOCl reaction with water liberates sodium hydroxide (NaOH).

The addition of NaOH differs in that it tends to add alkalinity to the water. In large concentrations it may artificially elevate pH, leading to precipitation of calcium carbonate. While NaOCl eliminates low pH corrosion as a concern, the use of large quantities in contaminated systems still introduces a high concentration of the chloride ion, which can be very aggressive to cooling system metals. Many of the other problems associated with chlorine remain present with sodium hypochlorite.

When was Sodium Hypochlorite Discovered?

Sodium hypochlorite has a long history. Around 1785 the Frenchman Berthollet developed liquid bleaching agents based on sodium hypochlorite. The Javel company introduced this product and called it 'liqueur de Javel'. At first, it was used to bleach cotton. Because of its specific characteristics it soon became a popular compound. Hypochlorite can remove stains from clothes at room temperature. In France, sodium hypochlorite is still known as 'eau de Javel'.

Characteristics of Sodium hypochlorite

Sodium hypochlorite is a clear, slightly yellowish solution with a characteristic odor.

Sodium hypochlorite has a relative density of is 1,1 (5,5% watery solution).

As a bleaching agent for domestic use it usually contains 5% sodium hypochlorite (with a pH of around 11, it is irritating). If it is more concentrated, it contains a concentration 10-15% sodium hypochlorite (with a pH of around 13, it burns and is corrosive).

Sodium hypochlorite is unstable. Chlorine evaporates at a rate of 0,75 gram active chlorine per day from the solution. Then heated sodium hypochlorite disintegrates. This also happens when sodium hypochlorite comes in contact with acids, sunlight, certain metals and poisonous and corrosive gasses, including chlorine gas. Sodium hypochlorite is a strong oxidator and reacts with flammable compounds and reductors. Sodium hypochlorite solution is a weak base that is inflammable. These characteristics must be kept in mind during transport, storage and use of sodium hypochlorite.

pH value When Sodium Hypochlorite is Added to Water

Due to the presence of caustic soda in sodium hypochlorite, the pH of the water is increased. When sodium hypochlorite dissolves in water, two substances form, which play a role in oxidation and disinfection. These are hypochlorous acid (HOCl) and the less active hypochlorite ion (OCl-). The pH of the water determines how much hypochlorous acid is formed. While sodium hypochlorite is used, acetic acid (HCl) is used to lower the pH. Sulfuric acid (H_2SO_4) can be used as an alternative for acetic acid. Less harmful gasses are produced when sulfuric acid is used. Sulfuric acid is a strong acid that strongly reacts with bases and is very corrosive.

How Can Sodium Hypochlorite be produced?

Sodium hypochlorite can be produced in two ways:

- By dissolving salt in softened water, which results in a concentrated brine solution. The solution is electrolyzed and forms a sodium hypochlorite solution in water. This solution contains 150 g active chlorine (Cl_2) per liter. During this reaction the explosive hydrogen gas is also formed.
- By adding chlorine gas (Cl_2) to caustic soda (NaOH). When this is done, sodium hypochlorite, water (H_2O) and salt (NaCl) are produced according to the following reaction:

$$Cl2 + 2NaOH \rightarrow NaOCl + NaCl + H_2O$$

Applications of Sodium Hypochlorite

Sodium hypochlorite is used on a large scale; for example agriculture, chemical industries, paint- and lime industries, food industries, glass industries, paper industries, pharmaceutical industries, synthetics industries and waste disposal industries all use it. In the textile industry sodium hypochlorite is used to bleach textile. It is sometimes added to industrial waste water--this is done to reduce odors.

Hypochlorite neutralizes sulphur hydrogen gas (SH) and ammonia (NH3). It is also used to detoxify cyanide baths in metal industries. Hypochlorite can be used to prevent algae and shellfish growth in cooling towers. In water treatment, hypochlorite is used to disinfect water. In households, hypochlorite is used frequently for the purification and disinfection of the house.

How does Sodium Hypochlorite Disinfection Work?
By adding hypochlorite to water, hypochlorous acid (HOCl) is formed:

$$NaOCl + H2O \rightarrow HOCl + NaOH$$

Hypochlorous acid is divided into hydrochloric acid (HCl) and oxygen (O). The oxygen atom is a very strong oxidator.

Sodium hypochlorite is effective against bacteria, viruses and fungi. Sodium hypochlorite disinfects the same way as chlorine does.

There are various ways to use sodium hypochlorite. For on-site salt electrolysis, a solution of salt (NaCl) in water is applied. Sodium (Na+) and chloride (Cl-) ions are produced.

$$4NaCl \rightarrow 4Na+ + 4Cl-$$

Subsequently, chlorine and hydroxide react to form hypochlorite:

$$OH- + Cl_2 \rightarrow HOCl + Cl-$$

You can work these problems in this section.

Salt Electrolysis System
The advantage of the salt electrolysis system is that no transport or storage of sodium hypochlorite is required. When sodium hypochlorite is stored for a long time, it becomes inactive. Another advantage of the onsite process is that chlorine lowers the pH and no other acid is required to lower pH.

The hydrogen gas that is produced is explosive and as a result ventilation is required for explosion prevention. This system is slow and a buffer of extra hypochlorous acid needs to be used. The maintenance and purchase of the electrolysis system is much more expensive than sodium hypochlorite.

When sodium hypochlorite is used, acetic or sulfuric acid are added to the water. An overdose can produce poisonous gasses. If the dosage is too low, the pH becomes too high and can irritate the eyes.

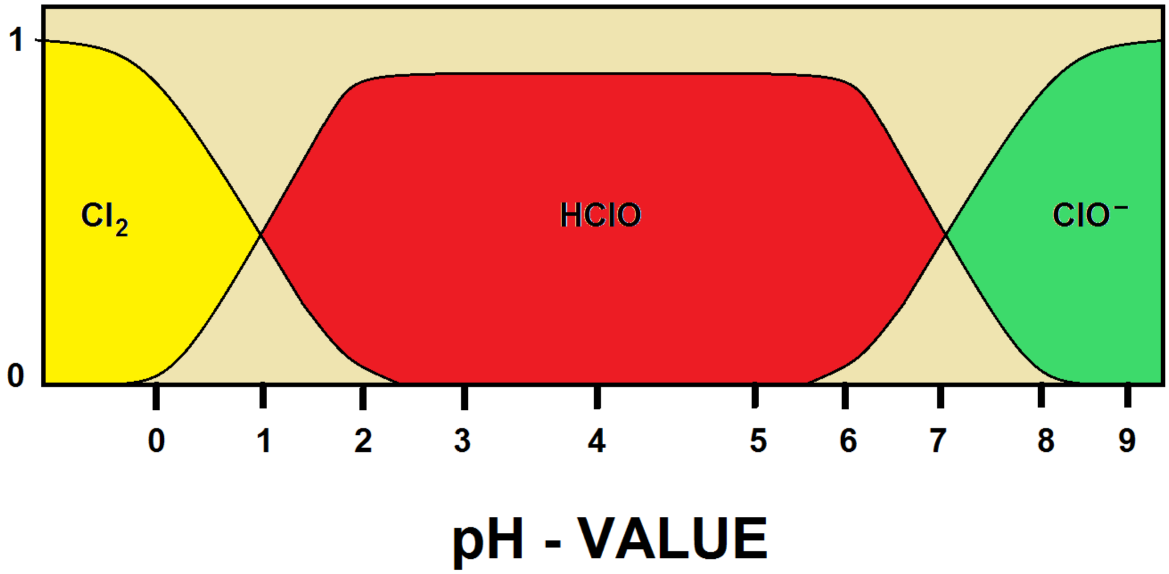
Because sodium hypochlorite is used both to oxidize pollutions (urine, sweat, cosmetics) and to remove pathogenic microorganisms, the required concentration of sodium hypochlorite depends on the concentrations of these pollutions. Especially the amount of organic pollution helps determine the required concentration. If the water is filtered before sodium hypochlorite is applied, less sodium hypochlorite is needed.

Theory

Disinfection with chlorine is very popular in water and wastewater treatment because of its low cost, ability to form a residual, and its effectiveness at low concentrations. Although it is used as a disinfectant, it is a dangerous and potentially fatal chemical if used improperly.

Despite the fact the disinfection process may seem simple, it is actually a quite complicated process. Chlorination in wastewater treatment systems is a fairly complex science which requires knowledge of the plant's effluent characteristics.

When free chlorine is added to the wastewater, it takes on various forms depending on the pH of the wastewater. It is important to understand the forms of chlorine which are present because each has a different disinfecting capability. The acid form, HOCL, is a much stronger disinfectant than the hypochlorite ion, OCL-. The graph below depicts the chlorine fractions at different pH values (Drawing by Erik Johnston).



Ammonia present in the effluent can also cause problems as chloramines are formed, which have very little disinfecting power. Some methods to overcome the types of chlorine formed are to adjust the pH of the wastewater prior to chlorination or to simply add a larger amount of chlorine. An adjustment in the pH would allow the operators to form the most desired form of chlorine, hypochlorous acid, which has the greatest disinfecting power.

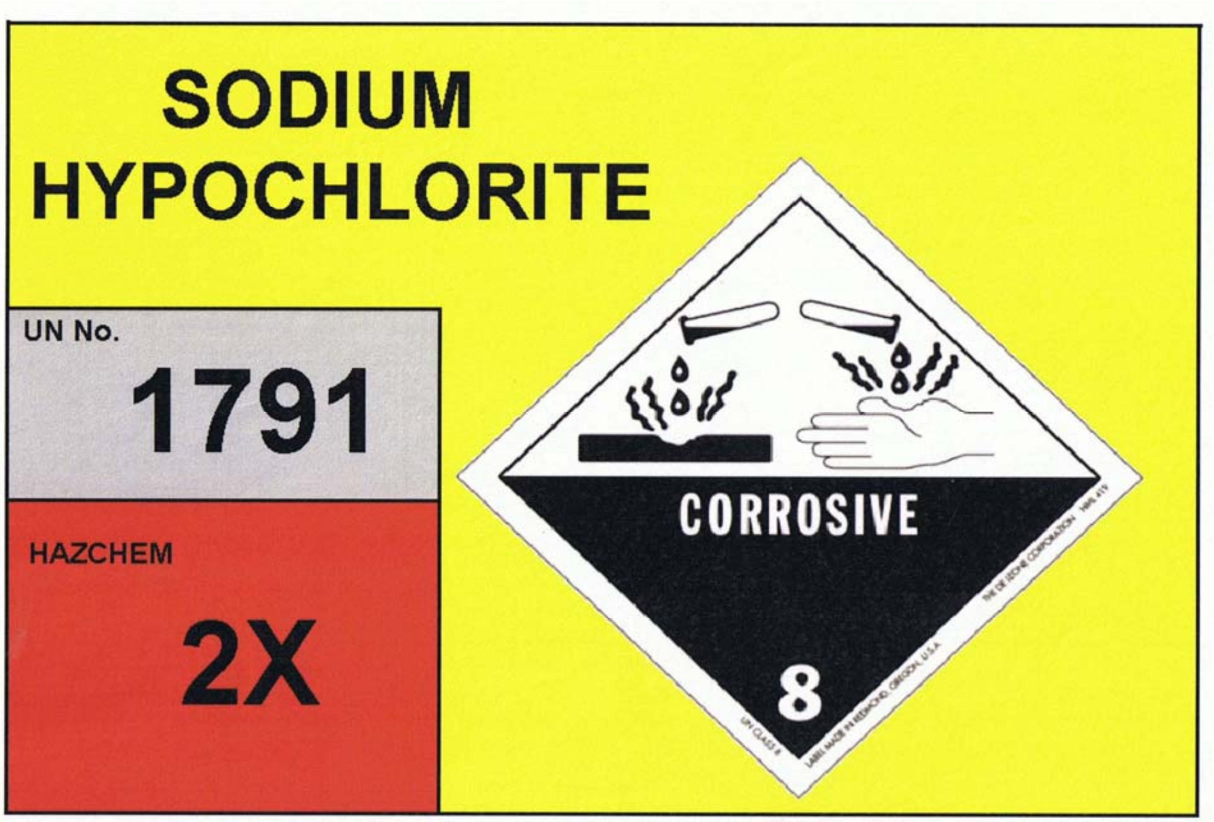
Adding larger amounts of chlorine would be an excellent method to combat the chloramines because the ammonia present would bond to the chlorine but further addition of chlorine would stay in the hypochlorous acid or hypochlorite ion state.

a) Chlorine gas, when exposed to water reacts readily to form hypochlorous acid, HOCl, and hydrochloric acid. $Cl_2 + H_2O \rightarrow HOCl + HCl$

b) If the pH of the wastewater is greater than 8, the hypochlorous acid will dissociate to yield hypochlorite ion. $HOCl \leftrightarrow H^+ + OCl^-$- If however, the pH is much less than 7, then HOCl will not dissociate.

c) If ammonia is present in the wastewater effluent, then the hypochlorous acid will react to form one three types of chloramines depending on the pH, temperature, and reaction time.

Recommendations for Preparing/Handling/Feeding Sodium Hypochlorite Solutions



As a result of the pressures brought to bear by Health and Safety requirements, some users of gas have chosen to seek alternative forms of disinfectants for their water and wastewater treatment plants. One of these alternative forms is sodium hypochlorite (NaOCl)). This is often purchased commercially at 10 to 15% strength.

The handling and storage of NaOCl presents the plant with a new and sometimes unfamiliar, set of equipment installation configurations and operating conditions.

Product Stability The oxidizing nature of this substance means that it should be handled with extreme care. As NaOCl is relatively unstable, it degrades over time.

There are Three Ways in Which NaOCl Solutions Degrade
- Chlorate-forming reaction due to age, temperature, light and minor reduction in pH.
- Oxygen-producing reaction that occurs when metals, such as iron, copper or nickel, or metal oxides are brought into contact with the solution.
- Chlorine-producing reaction when solution pH falls below 6.

There are Many Factors that Affect the Stability of a NaOCl Solution
- Initial solution strength.
- pH solution.
- Temperature of the solution.
- Exposure of the solution to sunlight.

Chlor-Alkali Membrane Process

The electrolysis occurs in a cell containing electrodes submerged in solutions called electrolytes. One electrode is referred to as the anode and is submerged in a salt water solution. The second electrode is the cathode and is submerged in a sodium hydroxide (caustic soda) solution. A membrane is used to keep the two different solutions from mixing. This particular method of producing chlorine is called the chlor-alkali membrane process.

When a low voltage direct current (DC) power supply is applied to the electrodes in the cell, the sodium and chlorine ions in the brine are attracted in opposite directions to the polarized electrodes. The sodium ion passes across an ion selective membrane leaving the chlorine ion to combine with a second chlorine ion, which makes a chlorine gas bubble at the anode (electrode).

When the sodium crosses the membrane, it combines with a hydroxyl ion at the cathode (electrode) making sodium hydroxide, or caustic soda (NaOH). The hydroxyl ion originates from the dissolution of water at the cathode where hydrogen gas also develops. The membrane in the cell keeps the two solutions separate; otherwise, the chlorine gas bubble would immediately combine with the caustic soda forming sodium hypochlorite, or bleach. This process, which uses a membrane to separate the two solutions, is called the chlor-alkali process. The chemical equation for the chlor-alkali process is illustrated in the following equation:

$2NaCl + 2H_2O$ + electric current $(2NaOH + Cl_2$- +- $H_2)$

Exposure

There is no threshold value for to sodium hypochlorite exposure. Various health effects occur after exposure to sodium hypochlorite. People are exposed to sodium hypochlorite by inhalation of aerosols. This causes coughing and a sore throat. After swallowing sodium hypochlorite the effects are stomach ache, a burning sensation, coughing, diarrhea, a sore throat and vomiting. Sodium hypochlorite on skin or eyes causes redness and pain. After prolonged exposure, the skin can become sensitive. Sodium hypochlorite is poisonous for water organisms. It is mutagenic and very toxic when it comes in contact with ammonium salts.

Routes of Exposure

Inhalation

Hypochlorite solutions can liberate toxic gases such as chlorine. Chlorine's odor or irritant properties generally provide adequate warning of hazardous concentrations. However, prolonged, low-level exposures, such as those that occur in the workplace, can lead to olfactory fatigue and tolerance of chlorine's irritant effects. Chlorine is heavier than air and may cause asphyxiation in poorly ventilated, enclosed, or low-lying areas.

Children exposed to the same levels of gases as adults may receive a larger dose because they have greater lung surface area/body weight ratios and higher minute volumes/weight ratios. Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of chlorine found nearer to the ground.

Skin/Eye Contact

Direct contact with hypochlorite solutions, powder, or concentrated vapor causes severe chemical burns, leading to cell death and ulceration. Because of their relatively larger surface area/weight ratio, children are more vulnerable to toxicants affecting the skin.

Ingestion

Ingestion of hypochlorite solutions causes vomiting and corrosive injury to the gastrointestinal tract. Household bleaches (3 to 6% sodium hypochlorite) usually cause esophageal irritation, but rarely cause strictures or serious injury such as perforation. Commercial bleaches may contain higher concentrations of sodium hypochlorite and are more likely to cause serious injury. Metabolic acidosis is rare, but has been reported following the ingestion of household bleach. Pulmonary complications resulting from aspiration may also be seen after ingestion.

Sources/Uses

Sodium and calcium hypochlorite are manufactured by the chlorination of sodium hydroxide or lime. Sodium and calcium hypochlorite are used primarily as oxidizing and bleaching agents or disinfectants. They are components of commercial bleaches, cleaning solutions, and disinfectants for drinking water and waste water purification systems and swimming pools.

Sodium Hypochlorite as a Disinfectant has the Following Advantages:

It can be easily stored and transported when it is produced on-site. Dosage is simple; transport and storage of sodium hypochlorite are safe. Sodium hypochlorite is as effective as chlorine gas for disinfection. Sodium hypochlorite produces residual disinfectant.

Disadvantages
Sodium hypochlorite is a dangerous and corrosive substance. While working with sodium hypochlorite, safety measures have to be taken to protect workers and the environment.

Sodium hypochlorite should not come in contact with air, because that will cause it to disintegrate. Both sodium hypochlorite and chlorine do not deactivate Giardia Lambia and Cryptosporidium. The regulation for sodium hypochlorite is the same as the regulation considering chlorine.

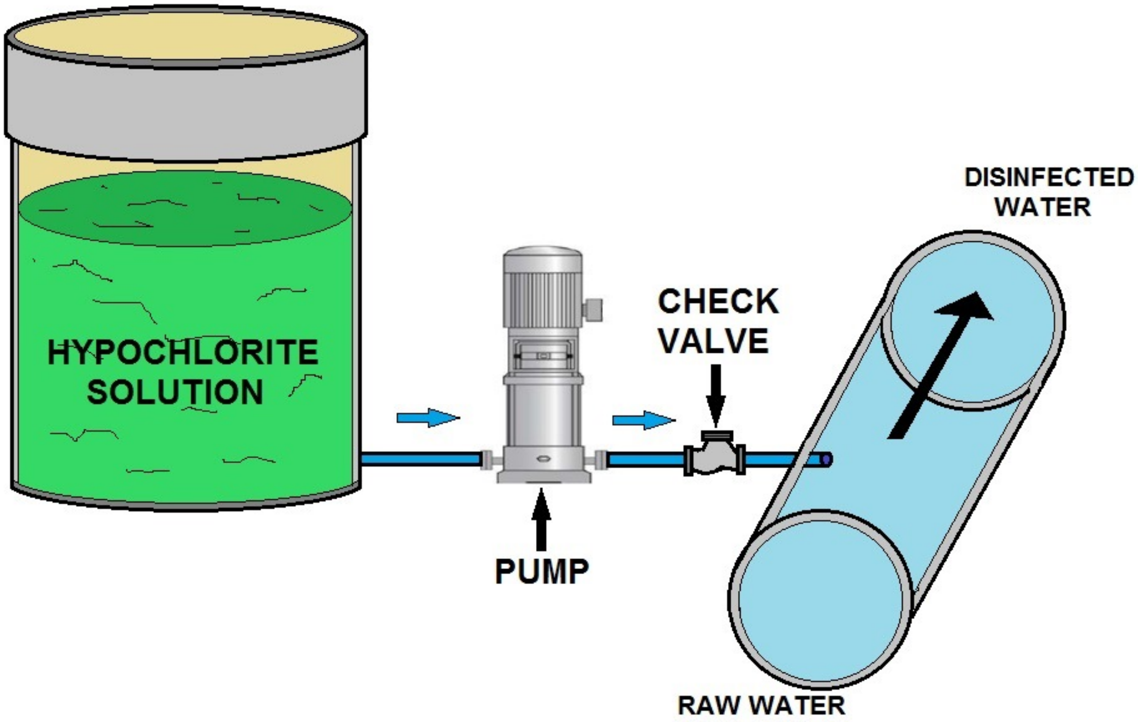
Household bleaches usually contain sodium hypochlorite in a 3% to 6% solution. Some sodium hydroxide (lye) is added to keep the pH high to avoid decomposition. If the solution is made more acidic, sodium hypochlorite will dissociate, producing chlorine gas and oxygen. It is made by bubbling chlorine gas through a solution of sodium hydroxide. In the environment, it breaks down into water, oxygen, and table salt.

Conditions that tend to increase gassing in Sodium Hypochlorite Solutions are:
* Elevated temperatures
* High concentration solution
* Exposure to sunlight or UV rays
* Reduction in pressure
* Cavitation
* Poor piping conditions
* Contact with metallic impurities
* Contact with organic impurities
* Age of solution
* Quality of solution

Reciprocating Piston Metering Pumps
When handling sodium hypochlorite and acids, be certain to wear gloves and a face shield for protection. Sodium hypochlorite is introduced to treated water by a chemical feeder (pump.) Chemical feeders tend to clog often, so it's important to clean the feeder regularly. Sodium Hypochlorite is subject to degradation within the piping and pump systems as it releases oxygen gas and results in crystallization of the residual. If the oxygen gas or vapor is allowed to build up within the piping and reagent head in sufficient volume, a typical reciprocating piston metering pump, used for accurately feeding chlorine to the process, will not function properly as gas in the pump head is compressed, minimizing the discharge check valve to open upon discharge stroke of the pump. Consequently, this effect could require that the pump be reprimed for operation. Reciprocating piston metering pumps or diaphragm metering pumps have been historically preferred in the dispensing of Sodium Hypochlorite because of their superior ability to accurately dose chemicals into a process stream with great precision and repeatability at a constant pressure. Additionally, the diaphragm metering pump is sealless and leak proof by design with negligible maintenance and simple commissioning.

Traditionally, the diaphragm metering pump industry has promoted the use of degas valves on the discharge port of the pump which diverts gas back to the suction supply source of the bleach. This method has been widely accepted and successful in many applications. However, the small diameter ports in the valve system tend to plug and require continuous flushing or cleaning through human intervention since the system is open to atmosphere on the discharge side of the orifice. Additionally, an external bypass piping system and degas valve assembly require additional costs and maintenance while presenting more opportunities for undesired chlorine leak paths.

Troubleshooting Hypochlorination Problems



HYPOCHLORINATOR

Problem
1. Chemical feed pump won’t run.
2. Low chlorine residual at POE.
2. Low chlorine residual at POE.
3. Chemical feed pump won’t prime.
4. Loss of prime

Possible Causes
1A. No power.
1B. Electrical problem with signal from well pump or flow sensor.
1C. Motor failure.
2A. Improper procedure for running chlorine residual test or expired chemical reagents.
2B. Pump not feeding an adequate quantity of chlorine.
2C. Change in raw water quality.
2D. Pump **air bound**.
2E. Chlorine supply tank empty.
2F. Reduced effectiveness of chlorine solution.
2G. Damaged suction or discharge lines. (cracks or crimps)
2H. Connection at point of **injection** clogged or leaking.
3A. Speed and stroke setting inadequate.
3B. Suction lift too high due to feed pump relocation.
3C. Discharge pressure too high.
3D. Suction fitting clogged.

3E. Trapped air in suction line.
3F. Suction line not submerged in solution.
4A. Solution tank empty.
4B. Air leaks in suction fittings.
4C. Foot valve not in vertical position.
4D. Air trapped in suction tubing.

Possible Solutions
1A. Check to see if plug is securely in place.
Insure that there is power to the outlet and control systems.
1B. Check pump motor starter. Bypass flow sensor to determine if pump will operate manually.
1C. Check manufacturer's information.
2A Check expiration date on **chemical reagents**. Check test procedure as described in test kit manual. Speed or stroke setting too low.
2B. Damaged **diaphragm** or suction leak.
2C. Test raw water for constituents that may cause increased chlorine demand. (i.e. iron, manganese, etc.)
2D. Check foot valve.
2E. Fill supply tank.
2F. Check date that chlorine was received. Sodium hypochlorite solution may lose effectiveness after 30 days. If that is the case, the feed rate must be increased to obtain the desired residual.
2G. Clean or repair lines with problems.
2H. Flush line and connection with mild acid such as **Acetic** or **Muriatic**. Replace any damaged parts that may be leaking.
3A. Check manufacturers' recommendations for proper settings to prime pump.
3B. Check maximum suction lift for pump and relocate as necessary.
3C. Check well pump discharge pressure.
Check pressure rating on chemical feed pump.
3D. Clean or replace screen.
3E. Insure all fittings are tight.
3F. Add chlorine solution to supply tank.
4A. Fill tank.
4B. Check for cracked fittings.
4C. Adjust foot valve to proper position.
4D. Check connections and fittings.

Calcium Hypochlorite Sub-Section
($CaCl_2O_2$)

Physical Properties - Calcium Hypochlorite
Description: White powder, pellets or flat plates
Warning properties: Chlorine odor; inadequate warning of hazardous concentrations
Molecular weight: 142.98 daltons
Boiling point (760 mm Hg): Decomposes at 100ºC (HSDB 2001)
Freezing point: Not applicable
Specific gravity: 2.35 (water = 1)
Water solubility: 21.4% at 76ºF (25ºC)
Flammability: Not flammable

There are two forms of calcium hypochlorite: powder and tablets. Tablets range in size from 5 mg about the size of an Aspirin to 3 inch tablets. Synonyms of calcium hypochlorite include Losantin, hypochlorous acid, calcium salt, BK powder, Hy-Chlor, chlorinated lime, lime chloride, chloride of lime, calcium oxychloride, HTH, mildew remover X-14, perchloron, and pittchlor.

Calcium hypochlorite is generally available as a white powder, pellets, or flat plates; sodium hypochlorite is usually a greenish yellow, aqueous solution. Although not flammable, they may react explosively.

Calcium hypochlorite decomposes in water to release chlorine and oxygen; sodium hypochlorite solutions can react with acids or ammonia to release chlorine or chloramine. Odor may not provide an adequate warning of hazardous concentrations.

Toxic

Both hypochlorites are toxic by the oral and dermal routes and can react to release chlorine or chloramine which can be inhaled. The toxic effects of sodium and calcium hypochlorite are primarily due to the corrosive properties of the hypochlorite moiety. Systemic toxicity is rare, but metabolic acidosis may occur after ingestion.

Description

Solid chlorine stands alone as the safest form of chlorine disinfection. Requiring only minimal safety equipment for handling, users can breathe easy knowing our tablets are safe for both people and the environment. The elimination of costly scrubbers, containment, or hazard response capability, guarantees lower initial costs and reduced operating expense. Calcium hypochlorite is generally available as a white powder, pellets, or flat plates. It decomposes readily in water or when heated, releasing oxygen and chlorine. It has a strong chlorine odor, but odor may not provide an adequate warning of hazardous concentrations. Calcium hypochlorite is not flammable, but it acts as an oxidizer with combustible material and may react explosively with ammonia, amines, or organic sulfides. Calcium hypochlorite should be stored in a dry, well ventilated area at a temperature below 120ºF (50ºC) separated from acids, ammonia, amines, and other chlorinating or oxidizing agents.

Chlorine Tablet Feeder

These feed systems are low maintenance and an extremely effective means to treat water or wastewater. Dry tablet feeder may or may not have mechanical components and most require no electricity. The dry tablet feeding system is a good alternative to liquid bleach and potential gas hazards. With no chlorine gas cylinders to handle, chlorine releases are non existent. Process safety Management and Risk Management Program compliance worries disappear.

Chlorine Tablet Feeder Capacities: range - 1,500 to 200,000 (GPD)

Chlorine tablets are stable for 3 years or more.

If a tablet produces 1000 PPM in a liter of water when first off the press, the tablet will produce 1000 PPM plus. This guarantees the activity will be at least 100% 3 years later and probably for much longer than that.

In fact, tablets have been stored for 6 years at 6% C and 42% C and still contained the specified levels of available chlorine. Sodium hypochlorite liquid, on the other hand, is inherently unstable and degrades with age until all the active strength disappears. This degradation accelerates in conditions of high temperature or strong sunlight.

These two different tablet chlorinator feeding systems are installed as a sidestream (see the clear plastic line) to the mainstream water flow or directly in the well casing. Using a flow meter or timed device, a chlorine tablet is dropped or delivered inside the well casing or to another location in the distribution system. Sometimes, the chlorinated balance is piped to an integrated solution tank. Then the resulting concentrated chlorine solution is pumped into a pressurized line or holding tank. By mixing chlorinated water from the solution tank with unchlorinated water from the main stream, a controllable level of available chlorine is achieved.

Accuracy

Because of their stability, chlorine tablets are an accurate dose, always yielding the stated level of available chlorine in water or very slightly over, never under. Liquid chlorine strengths vary so widely and are mostly unknown (the container usually says "less than 5%") that it is impossible to make up accurate in-use solutions without access to laboratory equipment.

Storage and Distribution

In recent years, concern regarding the safety hazards associated with liquid chlorine has grown to such an extent that several major cities now restrict transportation of chlorine within their boundaries. Tablets, on the other hand, are easy and convenient to store and transport. One pallet containing 600 jars each of 200 tablets is equivalent to 120,000 x 1 liter in use bleach solutions of 1,000 PPM active chlorine concentration.

Liquid chlorine is bulky, heavy and prone to leakage and spillage. Chlorine tablets are compact, economical and safe to ship and can even be sent by airfreight.

Effectiveness

Both chlorine tablets and liquid Sodium hypochlorite produce Hypochlorous Acid (HOCl) and Hypochlorite ion (OCl-) in solution. It has been postulated by Ortenzio and Stuart in 1959 and again by Trueman in 1971 that Hypochlorous Acid is the predominantly active species whilst Hypochlorite ion has little activity due to its negative charge impeding penetration of the cell wall and membrane. The ratio of Hypochlorous Acid to Hypochlorite ion increases with acidity. Chlorine tablets have a pH of 6.7 and liquid hypochlorite a pH of between 9 and 12. Ergo; tablets have a greater disinfection capacity and are less prone to inactivation due to soiling.

Safety

Chlorine tablets in dry form will not leak or splash and do not damage clothing. Liquid chlorine can affect eyes, skin and mucous membranes; it is easily splashed and rots clothing.

Corrosion

Chlorine tablets are much less corrosive than liquid chlorine, which is highly corrosive to most metals

Comparison

The final very important comparison to be made between Sodium hypochlorite (NaOCL) and Sodium dichloroisocyanurate (NaDCC) is their neutralization by organic matter. They are both prone to this but by using horse serum, it has been shown (Coates 1988) that the degree of neutralization is directly proportional to the concentration of serum present. However, the degree of neutralization of Naocl disinfectant is much greater than that of NaDCC disinfectant and the disparity increases with the concentration of serum. Hence, where there is a high concentration of organic material present, NaDCC will be very much more effective than NaOCL.

The degree of inactivation of NaOCL and NaDCC solutions by different concentrations of horse serum demonstrates that NaDCC solutions are less prone to inactivation by serum than are NaOCL solutions. For example, in 30% serum it required only 4000 PPM av. Cl of NaDCC as opposed to 17000 PPM av Cl of NaOCL to exhibit similar bactericidal activity.

System Sizing

To determine the correct system for your application, some specific information is required:

What form of chlorination is used now? ___ Gas ___ Liquid Bleach ___ Granular

Source water temperature ______ ___ Other (specify: _________________________)

Is chlorination performed ___ intermittently or ___ continuously?

What is the current consumption? ______ LBS or GALS/DAY

What is the system pressure to be treated?________________ PSI

What is the system flow rate to be treated?______________ GPM

What is the final desired chlorine concentration?__________ PPM

Dose Rate Math

_______ System Flow Rate (GPM)

x _______ Tablets Demand (PPM)

x 0.0005 Conversion Factor

Total _______ = LBS/HR Tablets Required

System Selection

Compare the LBS/HR of chlorine requirement above with the following system capacity and delivery characteristics. An additional factor that needs to be considered is how frequently the unit must be refilled in light of the volume of tablets that the feeder holds.

Health Effects

* Hypochlorite powder, solutions, and vapor are irritating and corrosive to the eyes, skin, and respiratory tract. Ingestion and skin contact produces injury to any exposed tissues. Exposure to gases released from hypochlorite may cause burning of the eyes, nose, and throat; cough as well as constriction and edema of the airway and lungs can occur.

* Hypochlorite produces tissue injury by liquefaction necrosis. Systemic toxicity is rare, but metabolic acidosis may occur after ingestion.

Acute Exposure

The toxic effects of sodium and calcium hypochlorite are primarily due to the corrosive properties of the hypochlorite moiety. Hypochlorite causes tissue damage by liquefaction necrosis. Fats and proteins are saponified, resulting in deep tissue destruction. Further injury is caused by thrombosis of blood vessels. Injury increases with hypochlorite concentration and pH. Symptoms may be apparent immediately or delayed for a few hours. Calcium hypochlorite decomposes in water releasing chlorine gas.

Sodium Hypochlorite Solutions

Sodium hypochlorite solutions liberate the toxic gases chlorine or chloramine if mixed with acid or ammonia (this can occur when bleach is mixed with another cleaning product). Thus, exposure to hypochlorite may involve exposure to these gases.

Children do not always respond to chemicals in the same way that adults do. Different protocols for managing their care may be needed.

Gastrointestinal

Pharyngeal pain is the most common symptom after ingestion of hypochlorite, but in some cases (particularly in children), significant esophagogastric injury may not have oral involvement. Additional symptoms include dysphagia, stridor, drooling, odynophagia, and vomiting. Pain in the chest or abdomen generally indicates more severe tissue damage. Respiratory distress and shock may be present if severe tissue damage has already occurred. In children, refusal to take food or drink liquid may represent odynophagia.

Ingestion of hypochlorite solutions or powder can also cause severe corrosive injury to the mouth, throat, esophagus, and stomach, with bleeding, perforation, scarring, or stricture formation as potential sequelae.

Dermal

Hypochlorite irritates the skin and can cause burning pain, inflammation, and blisters. Damage may be more severe than is apparent on initial observation and can continue to develop over time. Because of their relatively larger surface area/body weight ratio, children are more vulnerable to toxins affecting the skin.

Ocular

Contact with low concentrations of household bleach causes mild and transitory irritation if the eyes are rinsed, but effects are more severe and recovery is delayed if the eyes are not rinsed. Exposure to solid hypochlorite or concentrated solutions can produce severe eye injuries with necrosis and chemosis of the cornea, clouding of the cornea, iritis, cataract formation, or severe retinitis.

Respiratory

Ingestion of hypochlorite solutions may lead to pulmonary complications when the liquid is aspirated. Inhalation of gases released from hypochlorite solutions may cause eye and nasal irritation, sore throat, and coughing at low concentrations. Inhalation of higher concentrations can lead to respiratory distress with airway constriction and accumulation of fluid in the lungs (pulmonary edema). Patients may exhibit immediate onset of rapid breathing, cyanosis, wheezing, rales, or hemoptysis. Pulmonary injury may occur after a latent period of 5 minutes to 15 hours and can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma.

Children may be more vulnerable to corrosive agents than adults because of the smaller diameter of their airways. Children may also be more vulnerable to gas exposure because of increased minute ventilation per kg and failure to evacuate an area promptly when exposed.

Metabolic

Metabolic acidosis has been reported in some cases after ingestion of household bleach.

Potential Sequelae
Exposure to toxic gases generated from hypochlorite solutions can lead to reactive airways dysfunction syndrome (RADS), a chemical irritant-induced type of asthma. Chronic complications following ingestion of hypochlorite include esophageal obstruction, pyloric stenosis, squamous cell carcinoma of the esophagus, and vocal cord paralysis with consequent airway obstruction.

Chronic Exposure
Chronic dermal exposure to hypochlorite can cause dermal irritation.

Carcinogenicity
The International Agency for Research on Cancer has determined that hypochlorite salts are not classifiable as to their carcinogenicity to humans.

Reproductive and Developmental Effects
No information was located regarding reproductive or developmental effects of calcium or sodium hypochlorite in experimental animals or humans. Calcium and sodium hypochlorite are not included in Reproductive and Developmental Toxicants, a 1991 report published by the U.S. General Accounting Office (GAO) that lists 30 chemicals of concern because of widely acknowledged reproductive and developmental consequences.

Sources/Uses
Sodium and calcium hypochlorite are manufactured by the chlorination of sodium hydroxide or lime. Sodium and calcium hypochlorite are used primarily as oxidizing and bleaching agents or disinfectants. They are components of commercial bleaches, cleaning solutions, and disinfectants for drinking water and waste water purification systems and swimming pools.

Chloramine Sub-Section

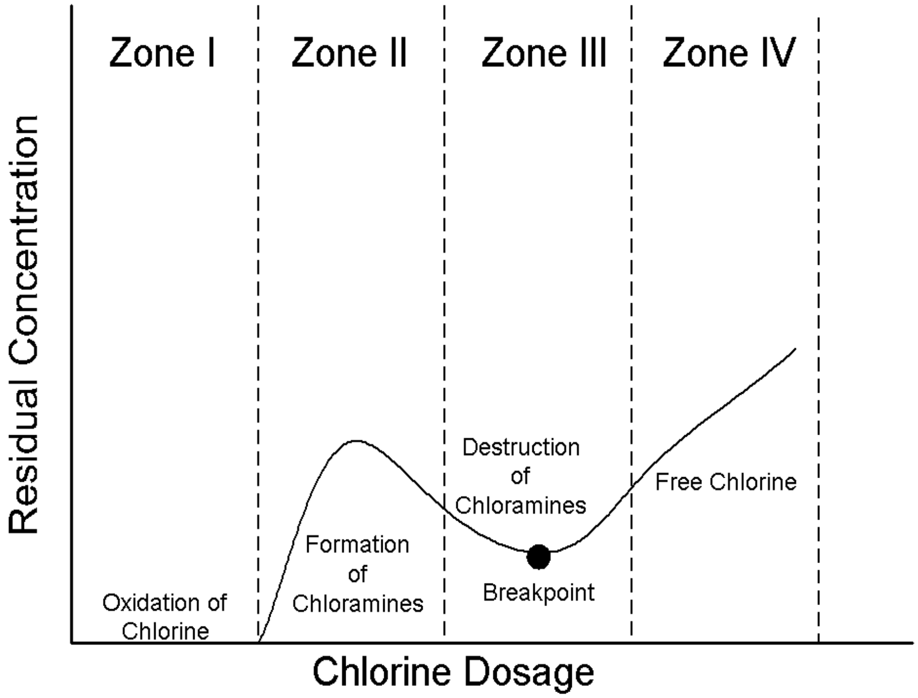
Monochloramine and dichloramine are formed in the pH range of 4.5 to 8.5, however, monochloramine is most common when the pH is above 8. When the pH of the wastewater is below 4.5, the most common form of chloramine is trichloramine which produces a very foul odor. The equations for the formation of the different chloramines are as follows: (Reynolds & Richards, 1996)

Monochloramine: $NH_3 + HOCl \rightarrow NH_2Cl + H_2O$
Dichloramine: $NH_2Cl + 2HOCl \rightarrow NHCl_2 + 2H_2O$
Trichloramine: $NHCl_2 + 3HOCl \rightarrow NHCl_3 + 3H_2O$

Chloramines are an effective disinfectant against bacteria but not against viruses. As a result, it is necessary to add more chlorine to the wastewater to prevent the formation of chloramines and form other stronger forms of disinfectants.
d) The final step is that additional free chlorine reacts with the chloramine to produce hydrogen ion, water, and nitrogen gas which will come out of solution. In the case of the monochloramine, the following reaction occurs:
$2NH_2Cl + HOCl \rightarrow N_2 + 6HCl + H_2O$

Thus, added free chlorine reduces the concentration of chloramines in the disinfection process. Instead the chlorine that is added is allowed to form the stronger disinfectant, hypochlorus acid.

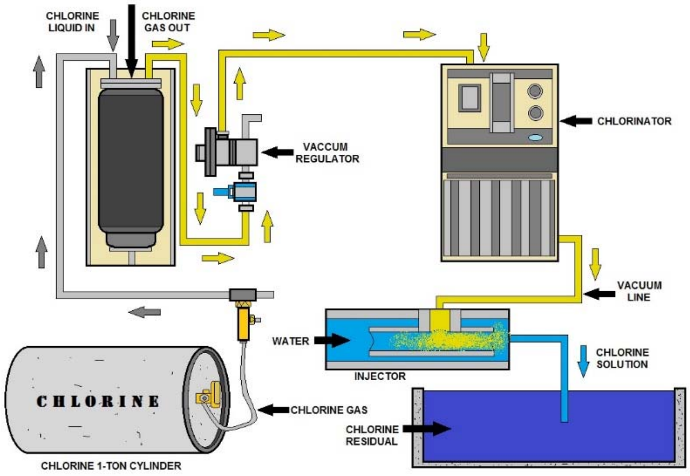
Perhaps the most important stage of the water or wastewater treatment process is the disinfection stage. This stage is most critical because it has the greatest effect on public health as well as the health of the world's aquatic systems. It is important to realize that wastewater treatment is not a cut and dry process but requires in depth knowledge about the type of wastewater being treated and its characteristics to obtain optimum results.



The graph shown on the last page depicts the chlorine residual as a function of increasing chlorine dosage with descriptions of each zone given below (Drawing by Erik Johnston, adapted from Reynolds and Richards, 1996).
· Zone I: Chlorine is reduced to chlorides.
· Zone II: Chloramines are formed.
· Zone III: Chloramines are broken down and converted to nitrogen gas which leaves the system (Breakpoint).
· Zone IV: Free residual.
Therefore, it is very important to understand the amount and type of chlorine that must be added to overcome the difficulties in the strength of the disinfectant which results from the water or wastewater's characteristics.

Water Treatment

The following is a schematic of a water treatment plant.



In water treatment, pre-chlorination is utilized mainly in situations where the inflow is taken from a surface water source such as a river, lake, or reservoir. Chlorine is usually added in the rapid mixing chamber and effectively prevents the majority of algal growth. Algae is a problem in water treatment plants because it builds up on the filter media and increases the head which means that the filters need to be backwashed more frequently. In addition, the algal growth on the filter media causes taste and odor problems in the treated water.

Post Chlorination

Post chlorination is almost always done in water treatment, but can be replaced with chlorine dioxide or chloramines. In this stage chlorine is fed to the drinking water stream which is then sent to the chlorine contact basin to allow the chlorine a long enough detention time to kill all viruses, bacteria, and protozoa that were not removed and rendered inactive in the prior stages of treatment.

Drinking water requires a large addition of chlorine because there must be a residual amount of chlorine in the water that will carry through the system until it reaches the tap of the user. After post chlorination, the water is retained in a clear well prior to distribution.

Chlorine-Based Disinfectants Chloramines

This process involves the addition of ammonia and chlorine compounds to a water filtration plant. When properly controlled, the mixture forms chloramines. They are commonly used to maintain a residual in the distribution system following treatment with a stronger disinfectant, such as free chlorine.

Chloramine Advantages

- Persistent residual.
- Taste and odor minimization.
- Lower levels of trihalomethane (THM) and haloacetic acid (HAA) formation.
- Effective disinfection of biofilms in the distribution system.

Chloramine Disadvantages

- Produces disinfection by-products (DBPs), including nitrogen-based compounds and chloral hydrate, which may be regulated as a DBP in the future. There is limited information on the toxicity of chloramine DBPs. In an analysis of the health effects of alternatives, Bull states that "there is little information on which to base an estimate of the health hazard that chloramine poses."
- Presents problems to individuals on dialysis machines. Chloramine residuals in tap water can pass through membranes in dialysis machines and directly induce oxidant damage to red blood cells.
- Causes eye irritation. Exposure to high levels of chloramine may result in eye irritation.
- Requires increased dosage and contact time (higher CT values, *i.e.,* concentration X time).
- Has questionable value as viral and parasitic biocide.
- Can promote growth of algae in reservoirs and an increase in distribution system bacteria due to residual ammonia.
- Can produce HAAs.
- Provides weaker oxidation and disinfection capabilities than free chlorine.

		MICROBIOLOGICAL SAFETY	CHEMICAL SAFETY	CUSTOMER AESTHETICS	EASE OF MONITORING	ABILITY TO TREAT DIFFICULT WATER	COST OF OPERATING	CAPITAL COSTS	STATE OF COMMERCIAL DEVELOPMENT	SCALE-UP	WASTE PRODUCTION AND ENERGY USE	RELIABILITY
GROUNDWATER	CHLORINE	—	—	—	+	+	+	+	+	+	+	—
	UF ONLY	—	+	+	—	+	●	●	—	—	●	—
	UV ONLY	+	+	+	●	+	+	●	+	+	●	●
	Alternate + Residual (1)	+	●	●	+	+	●	—	+	+	+	+
SURFACE WATER	CHLORINE ONLY	—	—	—	+	—	+	+	+	+	+	+
	Conventional pre-treat + CHLORINE	+	—	—	+	—	●	●	+	+	●	—
	UF ONLY	—	—	●	—	—	●	●	—	—	●	—
	Conventional pre-treat +UF	●	+	+	—	+	—	—	—	—	—	—
	Coventional pre-treat + OZONE + UF	—	●	—	—	+	—	—	—	—	—	—
	MF + UV	●	+	—	●	—	+	●	—	—	●	+
	Conventional pre-treat + UV	●	+	+	●	—	+	●	+	+	●	●
	Conventional pre-treat + OZONE + UV	+	●	+	+	+	—	—	+	+	●	+
	Alternative + Residual (2)	+	●	●	+	+	—	—	+	+	+	+

Conventional pre-treat = Coagulation / Sedimentation
UF - Ultafiltration MF - Microfiltration
+ = Better than average
— = Worse than average
● = Average

(1) UF + Chlorine residual or Conv + UV + Chlorine residual

(2) Conv pre-treat + UF + Chlorine residual or MF + UV
+ Chlorine residual or Conv pre-treat + UV + Residual

ASSESSMENT TO DETERMINE EFFECTIVE DISINFECTION METHODS

Chlorine Production Sub-Section

Faraday's laws states that one coulomb of electricity deposits 0.00111801 grams (g) of silver, or 1 ampere of electric current deposits 0.00111801 g of silver in one second.

Faraday's second law states that the quantity of electricity that liberates one gram equivalent weight (e.w.) of an element is the same for all elements. Since the equivalent weight of silver is 107.880, it takes one faraday, or 96,493 coulombs (107.88 e.w. / 0.00111801 g), to liberate 1 gram equivalent weight of any element.

The 1986 recommended value for one faraday is 96,485.309 coulomb. Being consistent with Faraday's laws, one faraday (96,485.3 coulomb) of electricity liberates 1.008 gram of hydrogen and 35.457 grams of chlorine in the chlor-alkali process. Since there are 86,400 seconds in each day (60 sec/min x 60 min/hour x 24 hour/day) and 454 grams in each pound of element, 14.3 amperes of current are required to liberate one pound of chlorine gas during a 24 hour period:

$$\frac{454\ \text{g/lb}}{35.457\ \text{g Cl}} \quad x \quad \frac{96{,}485.3\ \text{coulomb}}{86{,}400\ \text{sec/day}} \quad = \quad 14.3\ \text{amperes}$$

Coulomb (C)

The SI unit of electric charge. One coulomb is the amount of charge accumulated in one second by a current of one ampere. Electricity is actually a flow of charged particles, such as electrons, protons, or ions. The charge on one of these particles is a whole-number multiple of the charge *e* on a single electron, and one coulomb represents a charge of approximately 6.241 506 x 10^{18} *e*. The coulomb is named for a French physicist, Charles-Augustin de Coulomb (1736-1806), who was the first to measure accurately the forces exerted between electric charges.

Considering typical current efficiencies of 95 percent, the actual electrochemical reaction requires roughly 15 amperes of direct current to produce one pound of chlorine gas during a 24-hour period:

14.3 amperes / 0.95 (efficiency factor) = 15 amperes

The chlorine gas is vacuum swept from the chlorine cell by a Venturi ejector. The chlorine mixes with the ejector water to form hypochlorous acid and/or hypochlorite ion depending on the water pH.

Industrial Uses

In addition to water treatment chemicals, chlorine is used to make plastics such as PVC (polyvinyl chloride) and polyurethanes, pulp and paper treatment chemicals, solvents and a large number of chemicals.

The most common industrial use of chlorine is the manufacture of a versatile plastic known as polyvinyl chloride, or PVC. PVC is a polymer, meaning on a microscopic level many small units of the same types of atoms are bound together to form long chains, similar to the linking of multiple paper clips. One use of PVC is as lightweight, durable pipes for safe drinking water delivery. PVC pipes resist the pitting and corrosion common in metal pipes which often develop a slimy build-up of disease-causing microbes known as "biofilm." Biofilms can be destroyed by elevated levels of chlorine disinfectant.

With so many varied and valuable uses, chlorine chemistry is truly an indispensable asset to modern life.

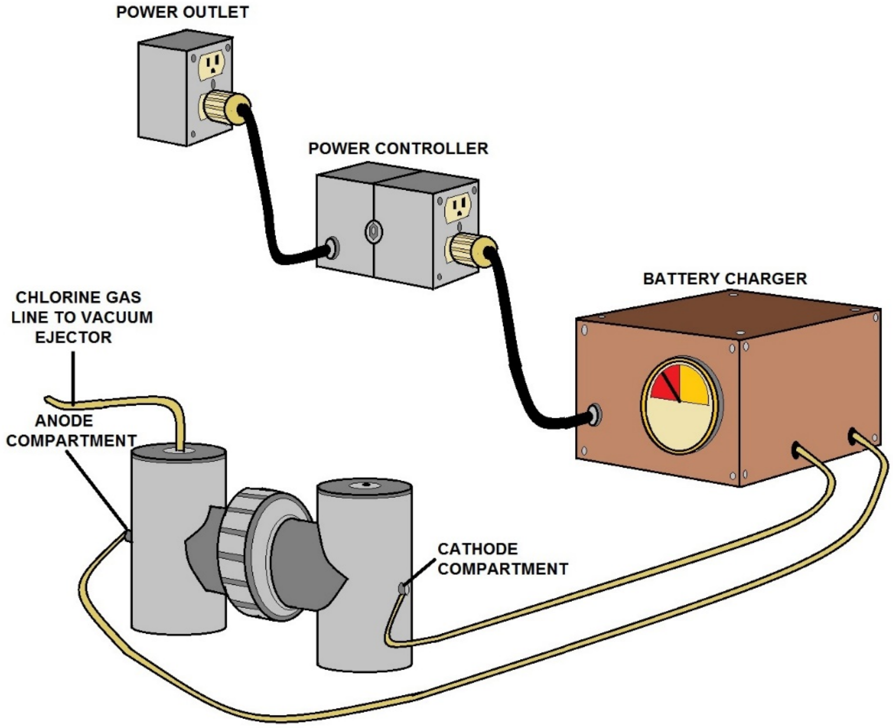
Chlorine Generator Process

The chlorine generator is as simple as a battery. There are no moving parts; however, the chlorine generator does require operation and maintenance. On this page you will discover:

- Process Components
- Process Installation
- System Operation
- Dose Control
- Salt Addition
- Sodium Hydroxide Dilution
- System Maintenance

Process Components

The chlorine generator requires a cell, DC power supply (battery charger, battery, solar power), power controller, energy source (power outlet, generator), and a pressurized water supply to operate the Venturi ejector.



CHLORINE PRODUCTION PROCESS

Cell: The cell includes the anode and cathode compartments that are hydraulically isolated by an ion selective membrane located between the two cell compartments. The anode compartment contains the anode (electrode), salt, saltwater electrolyte, and chlorine. Chlorine gas generated from the anode compartment is swept under vacuum by the Venturi ejector into the water supply. The cathode compartment contains the cathode (electrode), sodium hydroxide (caustic soda) electrolyte, and hydrogen.

The hydrogen produced from the cathode compartment is vented to the outside atmosphere. The two cell compartments are joined together by a union pipe fitting that also holds the ion selective membrane between the union flanges. Please note that the use of a union pipe fitting in the cell configuration is patented and subject to royalty fees.

DC Power Supply
The DC power supply can be any DC battery charger of adequate size to handle the needed chlorine demand. See our power supply sizing page for determining the size of power supply needed.

Power Controller
The power controller is simply a common dimmer switch (used to dim lights) that the power supply is plugged into to adjust the voltage input to the power supply. Like dimming your lights, the power controller will "dim" your chlorine production to the desired chlorine level.

Energy Source
The energy source can basically be a 120 VAC power outlet you plug the Power Controller into.

Pressurized Water Supply
The water passes through a Venturi creating a vacuum that is applied to the anode compartment of the cell. The Venturi ejector also includes a flow switch connected to a relay that operates the Power Controller. This safety feature ensures that flow is going through the Venturi ejector before chlorine is generated. The discharge from the vacuum ejectors is highly chlorinated water in the form of hypochlorous acid and/or hypochlorite ion.

Process Installation
Provided the plumbing for the system is complete (existing vacuum ejector, or simply using a garden hose connected to the ejector); it should not take longer than 30 minutes to an hour to have your chlorine generator completely operational. The installation includes the following steps:

- Remove components from the box, check contents for any missing or broken parts
- Soak the membrane in warm water
- Install the membrane on the cell flange
- Add salt and water to the anode compartment
- Add water and dry sodium hydroxide (i.e. Draino) to the cathode compartment
- Connect water supply to Venturi ejector
- Connect the vacuum tubing from the anode compartment to the Venturi ejector
- Clamp red (positive) power clamp from power supply to anode
- Clamp black (negative) power clamp from power supply to cathode
- Turn on power supply switch
- Plug power supply into power controller
- Plug power controller into power circuit
- Operate Venturi ejector and energize power circuit, adjust power controller to desired chlorine level.

System Operation

The system operation includes the control of the system, addition of salt and water to the anode compartment, periodic dilution of the sodium hydroxide in the cathode compartment, and occasional cleaning of the cell membrane. There are several ways the chlorine generator can be operated. The simplest way is to plug the power controller into a power outlet that is only energized at times when the generator is needed for chlorine production. This on/off operation procedure can be accomplished by installing a power control relay on the power outlet circuit. Nearly all municipal well installations include this type of circuit typically used for a hypochlorination pump.

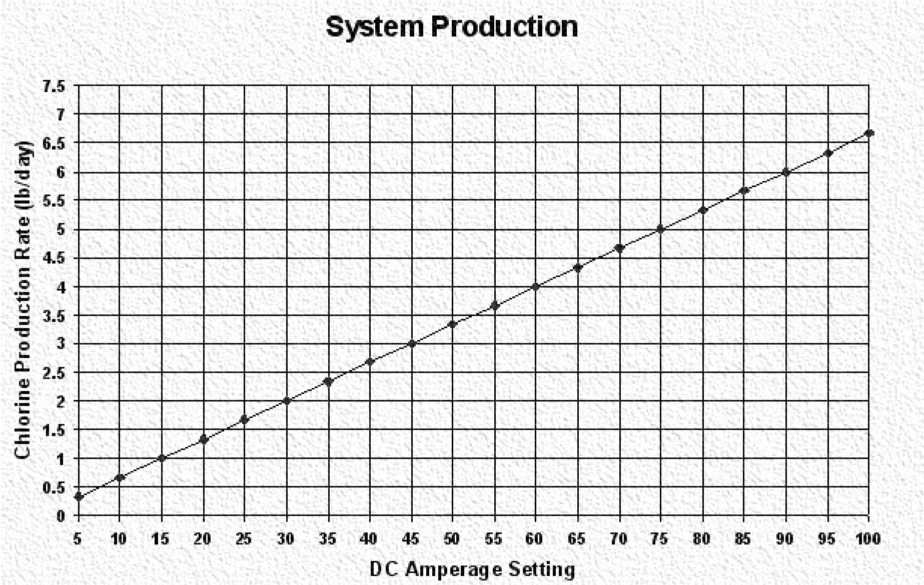
The power controller includes a flow switch that ensures operation of the chlorine generator only when there is flow through the Venturi ejector. Having the pool filter and water supply fill line on the vacuum ejector will allow the chlorine generator to operate at any moment when water is moving into the pool.

At a booster pump station having multiple pumps, a chlorine generator for each pump circuit will supply the step chlorine dosage needed depending on the number of pumps operating. This operational procedure eliminates the need for an electronic logic controlled loop and/or pacing valve systems.

The chlorine generator can be controlled in an automatic mode associated with a chlorine demand change. The automatic mode requires an electronic input signal (4-20 mA) associated with the demand change that controls an optional EP1 Series - SCR Power.

Dose Control

Chlorine output is adjusted by the power input of the process. Every 15 amps of direct current (DC) provide a chlorine production rate of 1 pound per day (24 hours). The graph below illustrates the equivalent chlorine production at the desired amperage setting.



Note: With time, the membrane accumulates calcium and other mineral deposits that increase the resistance between the electrodes. The increased resistance causes a reduced amperage output and a corresponding reduced chlorine output. The system needs periodic membrane cleaning to recover the desired amperage output. A water softener system can be added to the system water supply to reduce the amount of calcium, thus increasing the service life of the membrane.

Connecting your power supply (battery charger) into the power controller will allow you to manually adjust the voltage supply to your battery charger, thus controlling the DC amperage output to the cell. The power controller provided with each cell includes a 600 watt dimmer switch to manually adjust the input voltage to the battery charger. Adjustment of the dimmer switch will increase or decrease the voltage output of your battery charger to the desired amperage setting. For example, a chlorine output of 0.5 lbs per day is desired for a 50 gpm well. Based on amperage conversions, approximately 8 amperes of DC power is needed for the well. The operator would adjust the dimmer switch to achieve a power output of 8 DC amperes for the cell.

Salt Addition

For every 50 lb bag of water softener salt, approximately 30 lbs of chlorine is made. The amount of salt that can be added to the cell depends on the shape of the salt pellets; however, a typical amount of salt added in each cycle is roughly 12 lbs. Twelve pounds of salt in the anode compartment will generate 7 lbs of chlorine considering that not all the salt is used in each cycle. The frequency of salt addition depends on the operating cycle. For example:

A 150 gpm municipal well operating a total of 6 hours per day (54,000 gpd) using a 1.5 lb/day (22 amperes) chlorine dosage rate (0.5 mg/l chlorine residual w/ a 0.35 mg/l chlorine demand) will need to have salt added every 18 days (7 lbs/cell / [1.5 lb/day * 6 hr / 24 hr]).

Salt replenishment in the anode compartment requires the drainage of the brine, flushing the anode compartment with water, and addition of new salt and water to the cell. Adding of salt to the cell without flushing and cleaning is not recommended for several reasons. First, the anode compartment contains residual chlorine gas that will be displaced when salt is added. The amount of chlorine gas in this space is small (0.02 lbs); however, this amount of chlorine gas is irritating, especially if in a confined space. Second, the brine contains concentrated mineral impurities that will foul the membrane at a more rapid rate if it is not removed.

Replenishing the Salt Consists of:

- Turn off the power supply to the cell.
- Add roughly 1 cup of sodium hydroxide to the anode compartment. The sodium hydroxide will neutralize the residual chlorine in the brine and make a salt saturated hypochlorite solution.
- Drain the brine solution to waste and flush out the cell removing all the residual matter in the bottom of the cell.
- Add new salt and water to the anode compartment (it is desirable to use softened water to reduce the mineral fouling of the membrane).
- Place system back into service.

Chlorination Equipment Requirement Sub-Section

For all water treatment facilities, chlorine gas under pressure shall not be permitted outside the chlorine room. A chlorine room is where chlorine gas cylinders and/or ton containers are stored. Vacuum regulators shall also be located inside the chlorine room. The chlorinator, which is the mechanical gas proportioning equipment, may or may not be located inside the chlorine room.

For new and upgraded facilities, from the chlorine room, chlorine gas vacuum lines should be run as close to the point of solution application as possible. Injectors should be located to minimize the length of pressurized chlorine solution lines. A gas pressure relief system shall be included in the gas vacuum line between the vacuum regulator(s) and the chlorinator(s) to ensure that pressurized chlorine gas does not enter the gas vacuum lines leaving the chlorine room.

The gas pressure relief system shall vent pressurized gas to the atmosphere at a location that is not hazardous to plant personnel; vent line should be run in such a manner that moisture collecting traps are avoided. The vacuum regulating valve(s) shall have positive shutdown in the event of a break in the downstream vacuum lines.

As an alternative to chlorine gas, it is permissible to use hypochlorite with positive displacement pumping. Anti-siphon valves shall be incorporated in the pump heads or in the discharge piping.

Capacity

The chlorinator shall have the capacity to dose enough chlorine to overcome the demand and maintain the required concentration of the "***free***" or "***combine***d" chlorine.

Methods of Control

A chlorine feed system shall be automatic proportional controlled, or automatic residual controlled, or compound loop controlled. In the automatic proportional controlled system, the equipment adjusts the chlorine feed rate automatically in accordance with the flow changes to provide a constant pre-established dosage for all rates of flow. In the automatic residual controlled system, the chlorine feeder is used in conjunction with a chlorine residual analyzer which controls the feed rate of the chlorine feeders to maintain a particular residual in the treated water.

In the compound loop control system, the feed rate of the chlorinator is controlled by a flow proportional signal and a residual analyzer signal to maintain particular chlorine residual in the water.

Manual chlorine feed systems may be installed for groundwater systems with constant flow rates.

Standby Provision

As a safeguard against malfunction and/or shut-down, standby chlorination equipment having the capacity to replace the largest unit shall be provided. For uninterrupted chlorination, gas chlorinators shall be equipped with an automatic changeover system. In addition, spare parts shall be available for all chlorinators.

Weigh Scales

Scales for weighing cylinders shall be provided at all plants using chlorine gas to permit an accurate reading of total daily weight of chlorine used. At large plants, scales of the recording and indicating type are recommended. As a minimum, a platform scale shall be provided. Scales shall be of corrosion-resistant material.

Securing Cylinders

All chlorine cylinders shall be securely positioned to safeguard against movement. Tag the cylinder ”***empty***” and store upright and chained.

Ton containers may not be stacked.

Chlorine Leak Detection

Automatic chlorine leak detection and related alarm equipment shall be installed at all water treatment plants using chlorine gas. Leak detection shall be provided for the chlorine rooms. Chlorine leak detection equipment should be connected to a remote audible and visual alarm system and checked on a regular basis to verify proper operation.

Leak detection equipment shall not automatically activate the chlorine room ventilation system in such a manner as to discharge chlorine gas. During an emergency if the chlorine room is unoccupied, the chlorine gas leakage shall be contained within the chlorine room itself in order to facilitate a proper method of clean-up.

Consideration should also be given to the provision of caustic soda solution reaction tanks for absorbing the contents of leaking one-ton cylinders where such cylinders are in use.

Chlorine leak detection equipment may not be required for very small chlorine rooms with an exterior door (e.g., floor area less than $3m^2$).

You can use a spray solution of ammonia or a rag soaked with ammonia to detect a small Cl_2 leak. If there is a leak, the ammonia will create a white colored smoke.

Safety Equipment

The facility shall be provided with personnel safety equipment including the following: Respiratory equipment; safety shower, eyewash, gloves, eye protection; protective clothing; cylinder and/or ton repair kits.

Respiratory equipment shall be provided which has been approved under the Occupational Health and Safety Act, General Safety Regulation - Selection of Respiratory Protective Equipment. Equipment shall be in close proximity to the access door(s) of the chlorine room.

Chlorine Room Design Requirements

Where gas chlorination is practiced, the gas cylinders and/or the ton containers up to the vacuum regulators shall be housed in a gas-tight, well illuminated, and corrosion resistant and mechanically ventilated enclosure. The chlorinator may or may not be located inside the chlorine room. The chlorine room shall be located at the ground floor level.

Ventilation

Gas chlorine rooms shall have entirely separate exhaust ventilation systems capable of delivering one (1) complete air change per minute during periods of chlorine room occupancy only. The air outlet from the room shall be 150 mm above the floor and the point of discharge located to preclude contamination of air inlets to buildings or areas used by people. The vents to the outside shall have insect screens.

Air inlets should be louvered near the ceiling, the air being of such temperature as to not adversely affect the chlorination equipment. Separate switches for fans and lights shall be outside the room at all entrance or viewing points, and a clear wire-reinforced glass window shall be installed in such a manner as to allow the operator to inspect from the outside of the room.

Heating

Chlorine rooms shall have separate heating systems, if a forced air system is used to heat the building. The hot water heating system for the building will negate the need for a separate heating system for the chlorine room. The heat should be controlled at approximately 15^{o}C.

Cylinders or containers shall be protected to ensure that the chlorine maintains its gaseous state when entering the chlorinator.

Access

All access to the chlorine room shall only be from the exterior of the building. Visual inspection of the chlorination equipment from inside may be provided by the installation of glass window(s) in the walls of the chlorine room. Windows should be at least 0.20 m2 in area, and be made of clear wire reinforced glass.

There should also be a ***'panic bar'*** on the inside of the chlorine room door for emergency exit.

Storage of Chlorine Cylinders

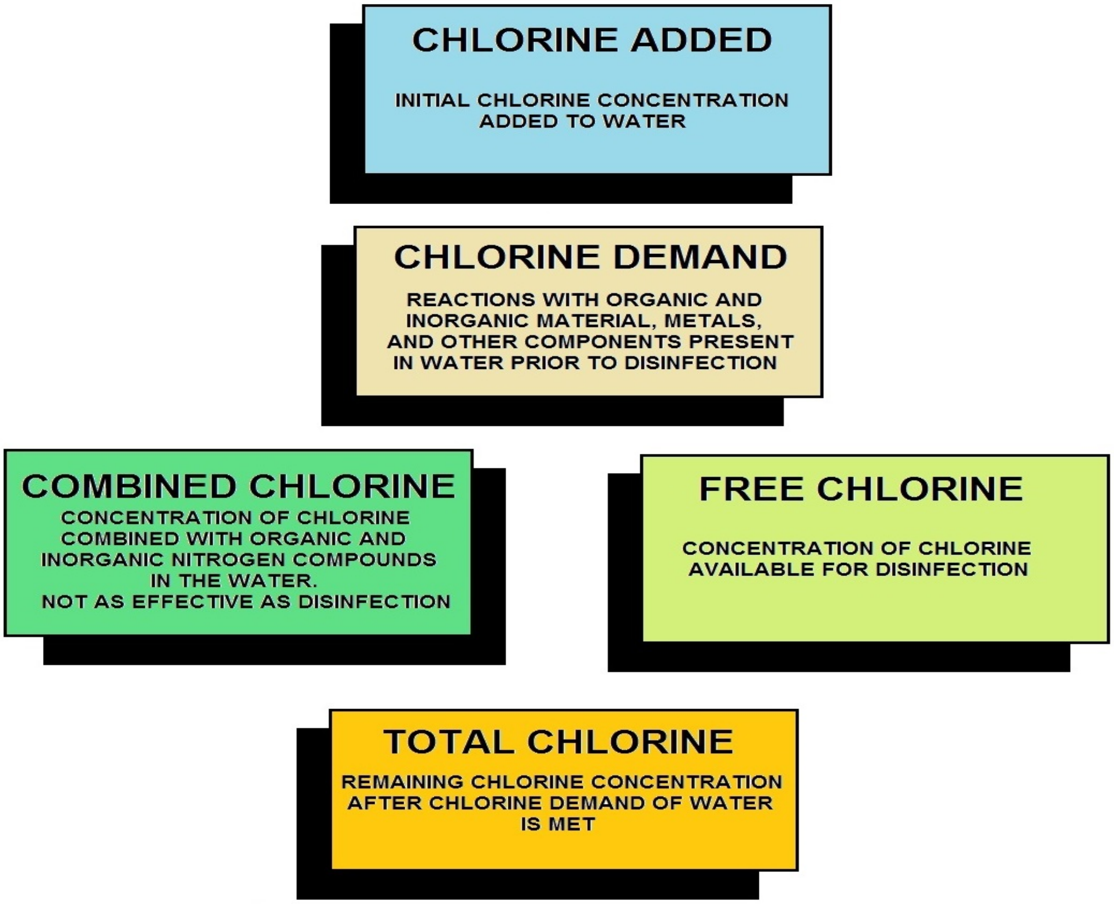
If necessary, a separate storage room may be provided to simply store the chlorine gas cylinders, with no connection to the line. The chlorine cylinder storage room shall have access either to the chlorine room or from the plant exterior, and arranged to prevent the uncontrolled release of spilled gas.

The chlorine gas storage room shall have provision for ventilation at thirty air changes per hour. Viewing glass windows and a panic button on the inside of the door should also be provided.

In very large facilities, entry into the chlorine rooms may be through a vestibule from outside.

Scrubbers

For facilities located within residential or densely populated areas, consideration shall be given to provide scrubbers for the chlorine room.



Chlorine Demand

Chlorine combines with a wide variety of materials. These side reactions complicate the use of chlorine for disinfecting purposes. Their demand for chlorine must be satisfied before chlorine becomes available to accomplish disinfection. The amount of chlorine required to react on various water impurities before a residual is obtained. Also, it means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by Iodometric method of a sample at a temperature of twenty degrees in conformance with Standard methods.

Chlorine Questions and Answer Review

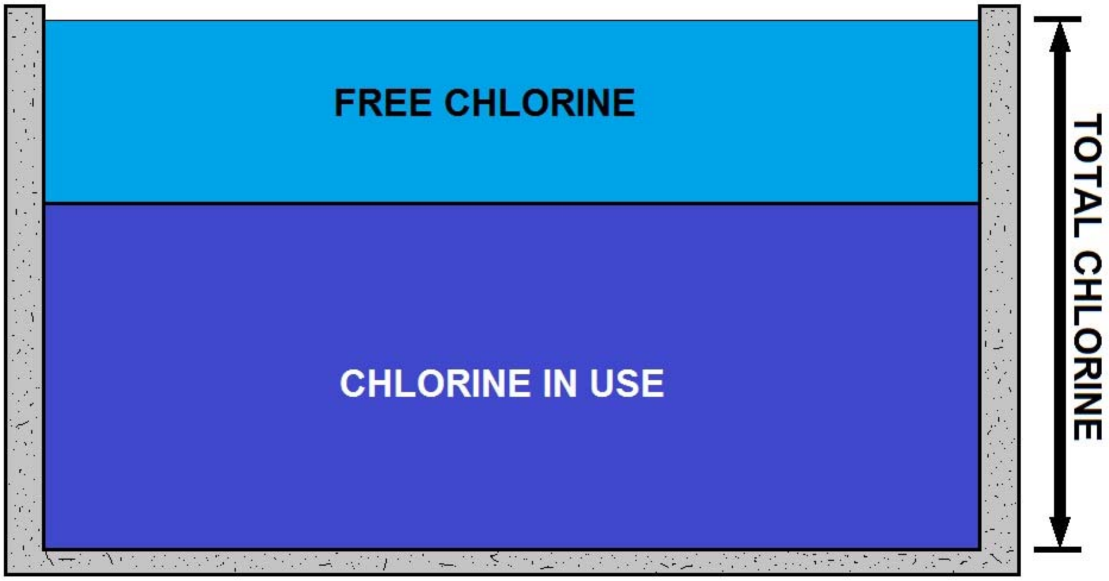
Downstream from the point of post chlorination, what should the concentration of a free chlorine residual be in a clear well or distribution reservoir? 0.5 mg/L.

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

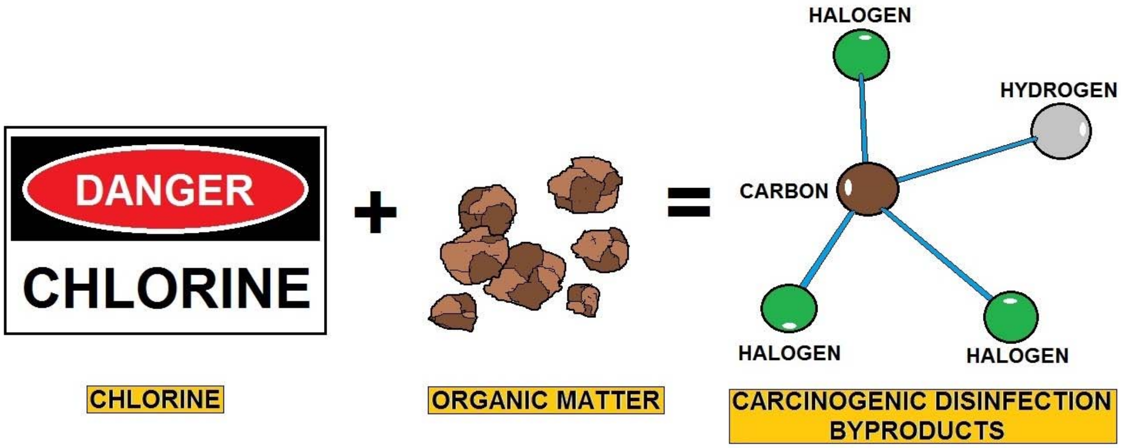
How does one determine the ambient temperature in a chlorine room? Use a regular thermometer because ambient temperature is simply the air temperature of the room.

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

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



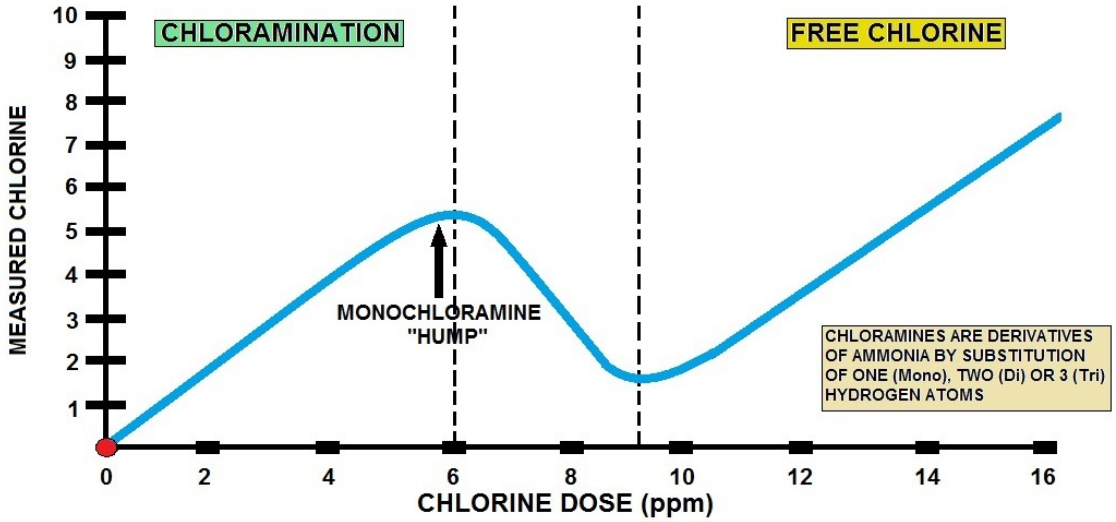
CHLORINE IN USE + FREE CHLORINE = TOTAL CHLORINE



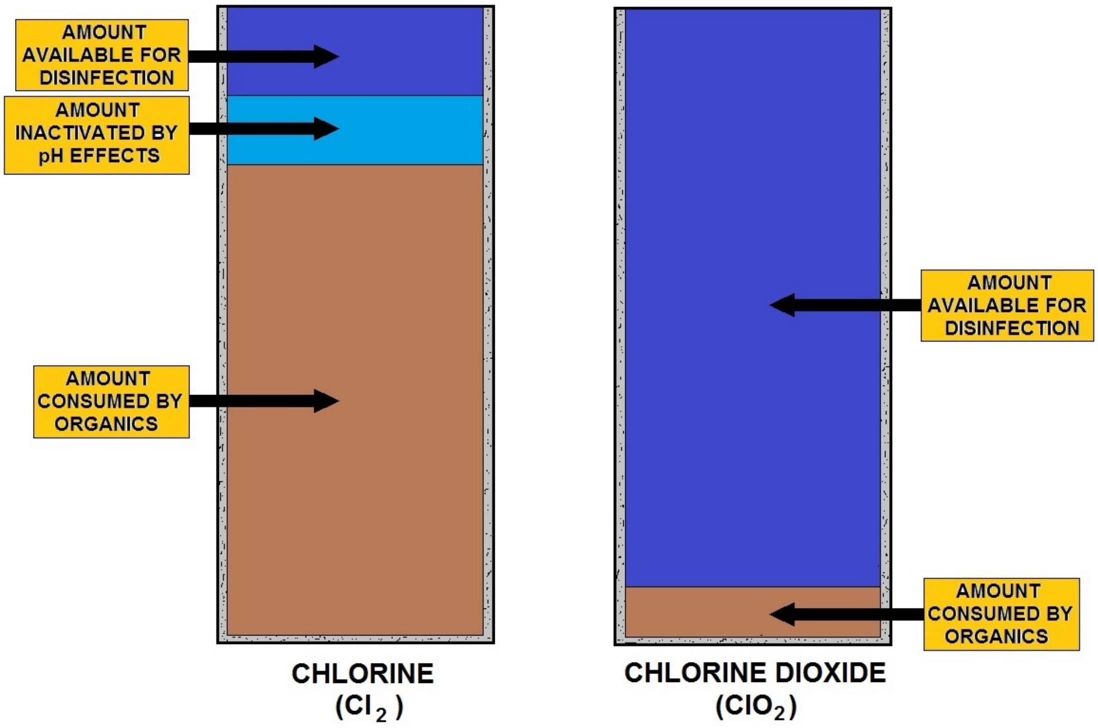
DISINFECTION BYPRODUCT PRODUCTION DIAGRAM

BREAKPOINT (CHLORINE)

(Based on the Assumption that Ammonia is Present)



EXAMPLE OF MONOCHLORAMINE



THE DIFFERENCE IN USING CHLORINE AND CHLORINE DIOXIDE AS A DISINFECTANT

Chlorine Health Hazard Sub-Section

Signs and Symptoms of Exposure

1. Acute exposure: Acute exposure to low levels of chlorine results in eye, nose, and throat irritation, sneezing, excessive salivation, general excitement, and restlessness. Higher concentrations causes difficulty in breathing, violent coughing, nausea, vomiting, cyanosis, dizziness, headache, choking, laryngeal edema, acute tracheobronchitis, chemical pneumonia. Contact with the liquid can result in frostbite burns of the skin and eyes [Genium 1992].
2. Chronic exposure: Chronic exposure to low levels of chlorine gas can result in a dermatitis known as chloracne, tooth enamel corrosion, coughing, severe chest pain, sore throat, hemoptysis and increased susceptibility to tuberculosis [Genium 1992].

Inhalation

Immediately remove the exposed person upwind from the contaminated area and contact the poison control center. Inhalation can cause coughing, sneezing, shortness of breath, sensation of tightness in the chest, as well as severe restlessness or anxiety, nausea, and vomiting. The nose and throat may become irritated; a stinging and burning sensation may be experienced. Immediate fatalities can occur as a result of suffocation. Delayed fatalities can occur as a result of pulmonary edema (fluid in the lungs). For this reason, rest and immediate attention after inhalation is important. Persons with known cardiovascular or lung problems should not risk chlorine exposure. If breathing has stopped, give artificial respiration; if breathing is difficult, give oxygen if equipment and trained personnel are available. If exposed person is breathing, place in a comfortable position and keep person warm and at rest until medical assistance becomes available.

Eye/Skin Contact

Liquid and concentrated gas could produce severe burns and injury on contact.

Eye

Pour a gentle stream of warm water through the affected eye for at least 15 minutes. Contact the poison control center, emergency room or physician right away as further treatment will be necessary.

Skin

Run a gentle stream of water over the affected area for 15 minutes. A mild soap may be used if available. Contact the poison control center, emergency room or physician right away as further treatment will be necessary.

Chronic

Repeated exposures can result in a loss of ability to detect the odor of chlorine. Long term exposures may cause damage to teeth and inflammation or ulceration of the nasal passages.

Ingestion

Not applicable for gas. Liquid could produce severe burns and injury on contact.

Pre-hospital Management

* Rescue personnel are at low risk of secondary contamination from victims who have been exposed only to gases released from hypochlorite solutions. However, clothing or skin soaked

with industrial-strength bleach or similar solutions may be corrosive to rescuers and may release harmful gases.
* Ingestion of hypochlorite solutions may cause pain in the mouth or throat, dysphagia, stridor, drooling, odynophagia, and vomiting. Hypochlorite irritates the skin and can cause burning pain, inflammation, and blisters. Acute exposure to gases released from hypochlorite solutions can cause coughing, eye and nose irritation, lacrimation, and a burning sensation in the chest. Airway constriction and noncardiogenic pulmonary edema may also occur.
* There is no specific antidote for hypochlorite poisoning. Treatment is supportive.

Hot Zone
Rescuers should be trained and appropriately attired before entering the Hot Zone. If the proper equipment is not available, or if rescuers have not been trained in its use, assistance should be obtained from a local or regional HAZMAT team or other properly equipped response organization.

Rescuer Protection
Hypochlorite is irritating to the skin and eyes and in some cases may release toxic gases.

Respiratory Protection: Positive-pressure, self-contained breathing apparatus (SCBA) is recommended in response to situations that involve exposure to potentially unsafe levels of chlorine gas.

Skin Protection: Chemical-protective clothing should be worn due to the risk of skin irritation and burns from direct contact with solid hypochlorite or concentrated solutions.

ABC Reminders
Quickly establish a patient airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible.

Victim Removal
If victims can walk, lead them out of the Hot Zone to the Decontamination Zone. Victims who are unable to walk may be removed on backboards or gurneys; if these are not available, carefully carry or drag victims to safety.

Consider appropriate management in victims with chemically-induced acute disorders, especially children who may suffer separation anxiety if separated from a parent or other adult.

Decontamination Zone
Victims exposed only to chlorine gas released by hypochlorite who have no skin or eye irritation do not need decontamination. They may be transferred immediately to the Support Zone. All others require decontamination as described below.

Rescuer Protection
If exposure levels are determined to be safe, decontamination may be conducted by personnel wearing a lower level of protection than that worn in the Hot Zone (described above).

ABC Reminders
Quickly establish a patient airway, ensure adequate respiration and pulse. Stabilize the cervical spine with a collar and a backboard if trauma is suspected. Administer supplemental oxygen as required. Assist ventilation with a bag-valve-mask device if necessary.

Basic Decontamination
Rapid decontamination is critical. Victims who are able may assist with their own decontamination. Remove and double-bag contaminated clothing and personal belongings. Flush exposed skin and hair with copious amounts of plain tepid water. Use caution to avoid hypothermia when decontaminating victims, particularly children or the elderly. Use blankets or warmers after decontamination as needed.

Irrigate exposed or irritated eyes with saline, Ringer's lactate, or D5W for at least 20 minutes. Eye irrigation may be carried out simultaneously with other basic care and transport. Remove contact lenses if it can be done without additional trauma to the eye. If a corrosive material is suspected or if pain or injury is evident, continue irrigation while transferring the victim to the support zone.

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

Consider appropriate management of chemically contaminated children at the exposure site. Provide reassurance to the child during decontamination, especially if separation from a parent occurs.

Transfer to Support Zone
As soon as basic decontamination is complete, move the victim to the Support Zone.

Support Zone
Be certain that victims have been decontaminated properly (see Decontamination Zone above). Victims who have undergone decontamination or have been exposed only to vapor pose no serious risks of secondary contamination to rescuers. In such cases, Support Zone personnel require no specialized protective gear.

ABC Reminders
Quickly establish a patient airway, ensure adequate respiration and pulse. If trauma is suspected, maintain cervical immobilization manually and apply a cervical collar and a backboard when feasible. Administer supplemental oxygen as required and establish intravenous access if necessary. Place on a cardiac monitor, if available.

Additional Decontamination
Continue irrigating exposed skin and eyes, as appropriate.
In cases of ingestion, do not induce emesis or offer activated charcoal.
Victims who are conscious and able to swallow should be given 4 to 8 ounces of water or milk; if the victim is symptomatic, delay decontamination until other emergency measures have been instituted. Dilutants are contraindicated in the presence of shock, upper airway obstruction, or in the presence of perforation.

Advanced Treatment

In cases of respiratory compromise, secure airway and respiration via endotracheal intubation. Avoid blind nasotracheal intubation or use of an esophageal obturator: only use direct visualization to intubate. When the patient's condition precludes endotracheal intubation, perform cricothyrotomy if equipped and trained to do so.

Treat patients who have bronchospasm with an aerosolized bronchodilator such as albuterol. Consider racemic epinephrine aerosol for children who develop stridor. Dose 0.25-0.75 mL of 2.25% racemic epinephrine solution in water, repeat every 20 minutes as needed cautioning for myocardial variability.

Patients who are comatose, hypotensive, or having seizures or who have cardiac arrhythmias should be treated according to advanced life support (ALS) protocols.

Transport to Medical Facility

Only decontaminated patients or those not requiring decontamination should be transported to a medical facility. "Body bags" are not recommended.

Report to the base station and the receiving medical facility the condition of the patient, treatment given, and estimated time of arrival at the medical facility.

If a chemical has been ingested, prepare the ambulance in case the victim vomits toxic material. Have ready several towels and open plastic bags to quickly clean up and isolate vomitus.

Multi-Casualty Triage

Consult with the base station physician or the regional poison control center for advice regarding triage of multiple victims.

Patients who have ingested hypochlorite, or who show evidence of significant exposure to hypochlorite or chlorine (e.g., severe or persistent cough, dyspnea or chemical burns) should be transported to a medical facility for evaluation. Patients who have minor or transient irritation of the eyes or throat may be discharged from the scene after their names, addresses, and telephone numbers are recorded. They should be advised to seek medical care promptly if symptoms develop or recur.

Routes of Exposure

Exposure to chlorine can occur through inhalation, ingestion, and eye or skin contact [Genium 1992].

Summary of Toxicology

1. Effects on Animals: Chlorine is a severe irritant of the eyes, mucous membranes, skin, and lungs in experimental animals. The 1 hour LC(50) is 239 ppm in rats and 137 ppm in mice ()[Sax and Lewis 1989]. Animals surviving sublethal inhalation exposures for 15 to 193 days showed marked emphysema, which was associated with bronchiolitis and pneumonia [Clayton and Clayton 1982]. Chlorine injected into the anterior chamber of rabbits' eyes resulted in severe damage with inflammation, opacification of the cornea, atrophy of the iris, and injury to the lens [Grant 1986].

2. Effects on Humans: Severe acute effects of chlorine exposure in humans have been well documented since World War I when chlorine gas was used as a chemical warfare agent.

Other severe exposures have resulted from the accidental rupture of chlorine tanks. These exposures have caused death, lung congestion, and pulmonary edema, pneumonia, pleurisy, and bronchitis [Hathaway et al. 1991]. The lowest lethal concentration reported is 430 ppm for 30 minutes [Clayton and Clayton 1982].

Exposure to 15 ppm causes throat irritation, exposures to 50 ppm are dangerous, and exposures to 1000 ppm can be fatal, even if exposure is brief [Sax and Lewis 1989; Clayton and Clayton 1982]. Earlier literature reported that exposure to a concentration of about 5 ppm caused respiratory complaints, corrosion of the teeth, inflammation of the mucous membranes of the nose and susceptibility to tuberculosis among chronically-exposed workers.

However, many of these effects are not confirmed in recent studies and are of very dubious significance [ACGIH 1991]. A study of workers exposed to chlorine for an average of 10.9 years was published in 1970. All but six workers had exposures below 1 ppm; 21 had TWAs above 0.52 ppm.

No evidence of permanent lung damage was found, but 9.4 percent had abnormal EKGs compared to 8.2 percent in the control group. The incidence of fatigue was greater among those exposed above 0.5 ppm [ACGIH 1991]. In 1981, a study was published involving 29 subjects exposed to chlorine concentrations up to 2.0 ppm for 4- and 8-hour periods. Exposures of 1.0 ppm for 8 hours produced statistically significant changes in pulmonary function that were not observed at a 0.5 ppm exposure concentration. Six of 14 subjects exposed to 1.0 ppm for 8 hours showed increased mucous secretions from the nose and in the hypopharynx.

Responses for sensations of itching or burning of the nose and eyes, and general discomfort were not severe, but were perceptible, especially at the 1.0 ppm exposure level [ACGIH 1991]. A 1983 study of pulmonary function at low concentrations of chlorine exposure also found transient decreases in pulmonary function at the 1.0 ppm exposure level, but not at the 0.5 ppm level [ACGIH 1991]. Acne (chloracne) is not unusual among persons exposed to low concentrations of chlorine for long periods of time. Tooth enamel damage may also occur [Parmeggiani 1983]. There has been one confirmed case of myasthenia gravis associated with chlorine exposure [NLM 1995].

Emergency Medical Procedures: [NIOSH to Supply]

- Rescue: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the Material Safety Data Sheet required by OSHA's Hazard Communication Standard [29 CFR 1910.1200]).
- All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and methods of protecting themselves during rescue operations.

Exposure Sources and Control Methods

The following operations may involve chlorine and lead to worker exposures to this substance:

The Manufacture and Transportation of Chlorine

- Used as a chlorinating and oxidizing agent in organic and inorganic synthesis; in the manufacture of chlorinated solvents, automotive antifreeze and antiknock compounds, polymers (synthetic rubber and plastics), resins, elastomers, pesticides, refrigerants, and in the manufacture of rocket fuel.
- Used as a fluxing, purification, and extraction agent in metallurgy.
- Used as a bacteriostat, disinfectant, odor control, and demulsifier in treatment of drinking water, swimming pools, and in sewage.
- Used in the paper and pulp, and textile industries for bleaching cellulose for artificial fibers; used in the manufacture of chlorinated lime; used in detinning and dezincing iron; used to shrink-proof wool.
- Used in the manufacture of pharmaceuticals, cosmetics, lubricants, flameproofing, adhesives, in special batteries containing lithium or zinc, and in hydraulic fluids; use in the processing of meat, fish, vegetables, and fruit.
- Used as bleaching and cleaning agents, and as a disinfectant in laundries, dishwashers, cleaning powders, cleaning dairy equipment, and bleaching cellulose.

Methods that are effective in controlling worker exposures to chlorine, depending on the feasibility of implementation, are as follows: process enclosure, local exhaust ventilation, general dilution, ventilation and personal protective equipment.

Workers responding to a release or potential release of a hazardous substance must be protected as required by paragraph (q) of OSHA's Hazardous Waste Operations and Emergency Response Standard 29 CFR.

Good Sources of Information about Control Methods are as Follows:

1. ACGIH [1992]. Industrial ventilation--a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
2. Burton DJ [1986]. Industrial ventilation--a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.
4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.
5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

Chlorine Storage

Chlorine should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's Hazard Communication Standard [29 CFR 1910.1200].

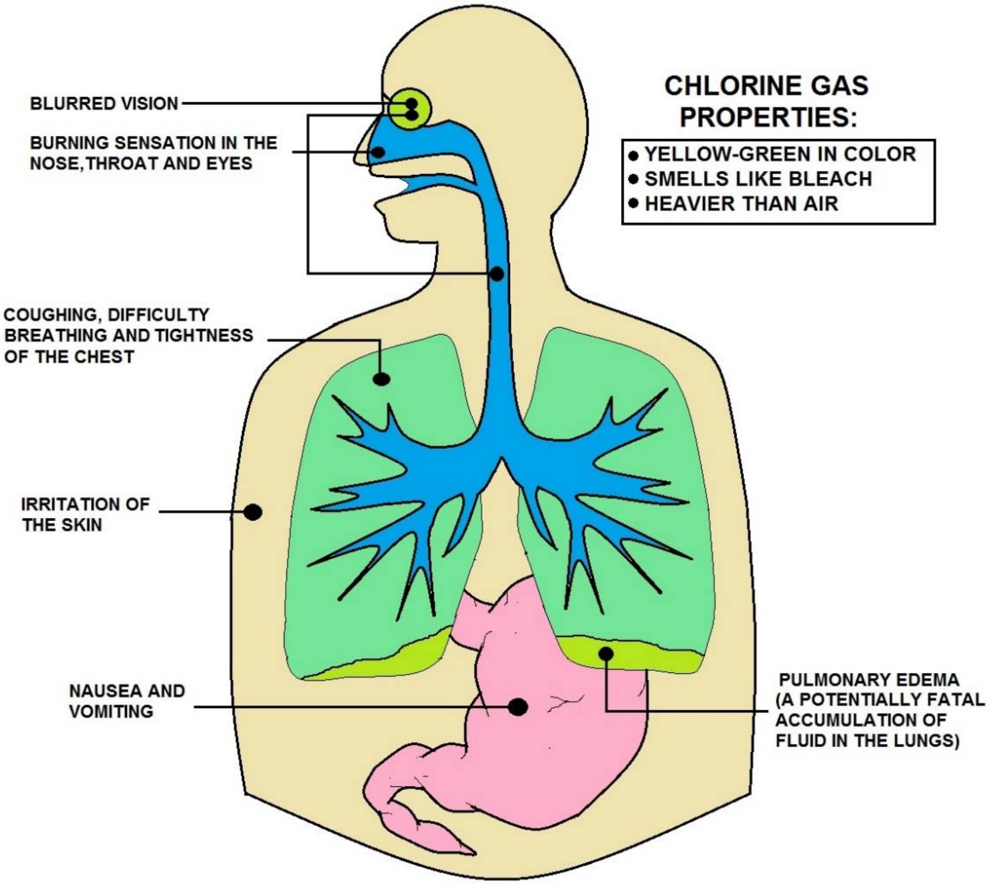
Containers of chlorine should be protected from exposure to weather, extreme temperatures changes, and physical damage, and they should be stored separately from flammable gases and vapors, combustible substances (such as gasoline and petroleum products, hydrocarbons, turpentine, alcohols, acetylene, hydrogen, ammonia, and sulfur), reducing agents, finely divided metals, arsenic, bismuth, boron, calcium, activated carbon, carbon disulfide, glycerol, hydrazine, iodine, methane, oxomonosilane, potassium, propylene, silicon, hydrogen sulfide and water, carbon monoxide and sulfur dioxide, moisture, steam, and water.

Workers handling and operating chlorine containers, cylinders, and tank wagons should receive special training in standard safety procedures for handling compressed corrosive gases. All pipes and containment used for chlorine service should be regularly inspected and tested. Empty containers of chlorine should have secured protective covers on their valves and should be handled appropriately.

Spills and Leaks

In the event of a spill or leak involving chlorine, persons not wearing protective equipment and fully-encapsulating, vapor-protective clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak:

1. Notify safety personnel.
2. Remove all sources of heat and ignition.
3. Keep all combustibles (wood, paper, oil, etc.) away from the leak.
4. Ventilate potentially explosive atmospheres.
5. Evacuate the spill area at least 50 feet in all directions.
6. Find and stop the leak if this can be done without risk; if not, move the leaking container to an isolated area until gas has dispersed. The cylinder may be allowed to empty through a reducing agent such as sodium bisulfide and sodium bicarbonate.
7. Use water spray to reduce vapors; do not put water directly on the leak or spill area.



HEALTH RISKS OF CHLORINE GAS

Chemical Spill Procedure Example

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

DANGER: Evacuate the area. Close all fire doors. Contact the fire department or appropriate emergency response crew immediately. If the substance is liquid and a drain is in the area of the spill, contact the sewer department.

If it is safe for you to clean up the spill:
READ SAFETY DATA SHEET (SDS) FOR SPILLED CHEMICAL.

Read the section STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED.

Read the **WASTE DISPOSAL METHOD** listed.

LOCATE CHEMICAL SPILLS KIT:

Apply gloves and protective eyewear.

Use chemical pads located in the kit to soak up the spill.

Place contaminated pads and gloves in the disposal bag and seal.

IF THE CHEMICAL IS A HAZARDOUS CHEMICAL WASTE, write the name of the chemical on the chemical label, attach the label to the disposal bag and notify a licensed Hazardous Waste Hauler for pick up. All other chemicals can be placed in regular trash.

Follow the methods listed on the MSDS for cleaning the contaminated area.

Replace items used from the Chemical Spill Kit.

Evacuation and Emergency Procedures

Leak Procedures

Minor Leak

Note: A minor leak is a small leak which can be discharged to the environment without danger or when the source of the leak can be readily controlled.

If you determine from outside the chlorine feed room that there is a minor leak, do the following:

1. Notify your supervisor.
2.Have your safety partner don SCBA and be watching you from outside the chlorine room.
3. Equip yourself with a SCBA.
4. Enter chlorine gas room.

Once Inside

5. Turn chlorine cylinder(s) OFF, leave water on.
6. Adjust feed rate to maximum to purge system.
7. Vacate room and remove air pack. Wait for 15 minutes, until chlorine pressure drops to zero or vacuum goes to maximum.
8. Do the Pre-Entry Check, put SCBA back on.
9. Crack open cylinder(s) and shut off right away.
10. Use ammonium hydroxide solution to find the leak.
11. Mark the leak.
12. Purge the system of gas as indicated on page 18, Section C (3), with the water still on.
13. Repair gently, using correct tools.
14. Start-up and re-check for leaks.
15. If no more leaks, place system back into service.

NOTE: If unable to repair the source of the leak, call it a Major Leak, and follow the appropriate emergency steps.

16. **Clean up:**

- remove air pack and recharge;
- air or launder clothes; and
- take a shower.

17. **Document the event completely**. Report the events which may have serious health or safety implications to the State or Federal Occupational Safety and Health Administration and/or Environmental Protection Agency (for Possible Air Violations and Toxic Releases). Also contact the local Fire Department and your Risk Management personnel.

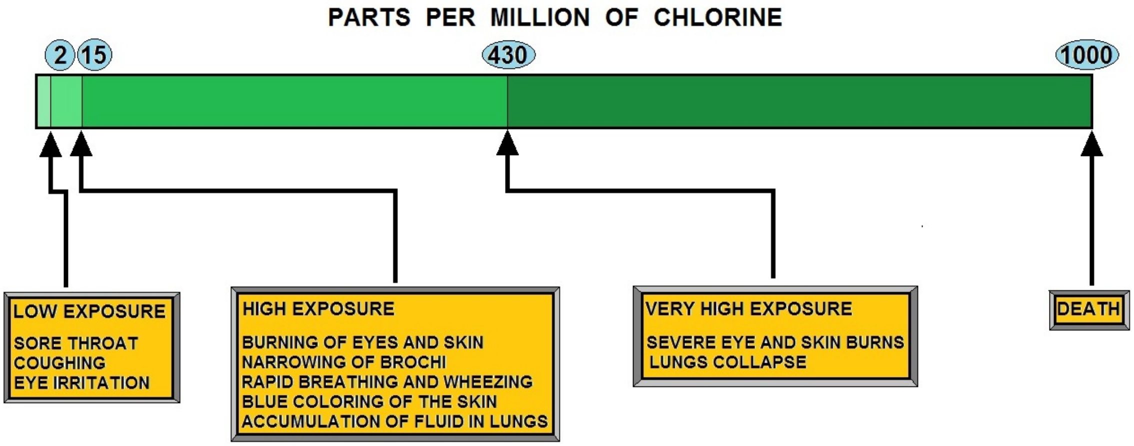
Major Leak

If you determine from outside the chlorine gas feed or storage room that there is a major leak, you could have a real problem not only for your fellow workers but also for nearby residents and for the plant equipment! Workers can protect themselves with SCBA. Residents may have to be evacuated.

We recommend the following steps, if you discover a Major Leak at your facility.
1. Protect yourself at all times during the emergency, and make sure you will not be overcome by the leaking gas. Stay out of the chlorine gas room. Keep the SCBA ready. Chlorine gas escaping through the ventilation outlet may be collecting outside the chlorine gas room, so be careful outside as well.
2. Isolate the area.
3. Notify your supervisor.
4. Implement the Emergency Response Contingency Plan that has been established for your facility, in consultation with the Safety/Health Committee and/or Risk Management Department.

NOTE: The following steps should be customized as necessary.

5. Notify your Chlorep/Supplier, fire department, police, Spill Report Center, according to your facility's policy.
6. Follow directions given by Chlorep/Supplier.
7. Document the events. Take photographs. Measure the Chlorine in the air.
8. Notify the your State or Occupational Safety and Health Administration and/or Environmental Protection Agency (for Possible Air Violations and Toxic Releases). Also contact the local Fire Department and your Risk Management personnel.



EFFECTS OF CHLORINE GAS ON HEALTH

Emergency Response Contingency Plans

General Planning Considerations
This can be utilized as the alternative assignment.

1. The plan should be clear, concise and easy to use.
2. Include diagrams of the surrounding land use and occupancy (e.g. schools, residences, hospitals, businesses,...etc.), with the approximate distances.
3. Include a diagram of the chlorine room layout. It should show equipment location, floor drainage direction, and show the north direction with an arrow. If a floor drain is installed, include drainage system details.
4. Prepare a complete telephone list of the current employees, persons, organizations or other necessary contacts, including 24-hour emergency contact telephone numbers. The list should be revised, updated and distributed periodically by an assigned person.
5. List the personal protective equipment available on-site and from the local fire department. Include phone number(s).
6. List the emergency equipment and supplies available 24 hours a day on-site and from local suppliers. Include phone number(s).
7. Refer to the Occupational Safety and Health Administration and/or Environmental Protection Agency for any assistance and advice.
8. Routinely set up an emergency chlorine leak safety exercise. Practice makes perfect.

When developing your detailed Emergency Response Contingency Plan, consider the following questions:

- Who may be affected by a potential incident? This is governed by site location, adjacent population, terrain, the amount of chemical stored at your facility and its potential for release.
- Is an emergency phone list of trained personnel available and updated periodically?
- When should outside emergency response agencies (chlorine supplier, CHLOREP team, government agency, etc.) be called? By whom?
- When should the news media be notified? By whom? What information should a statement include?
- Who should be contacted first, second, etc.? An emergency notification list should be developed and periodically updated. It should prioritize who is called, including your own utility personnel.
- Is there an evacuation procedure for employees at the facility? Was this reviewed in the last year?
- How do you notify the public (in close proximity to the facility) when to evacuate?
- Should barricades be set up to keep unauthorized personnel from the scene?
- Are proper chlorine leak detectors installed and functioning? Are the alarm systems routinely checked? Are audible and/or visual alarms observable from any approach to the contaminated area?
- Is the local fire department familiar with the facility and your chlorine emergency procedure?
- Does the treatment facility heating and air-conditioning system have to be shut down in a chlorine emergency at the facility?
- Should doors and windows in close proximity to the affected area be closed?
- Are the duty operator(s) familiar with emergency procedures?
- Are proper warning signs in place?
- Is a manual with chlorine emergency guidelines readily available?
- Is there proper documentation of training, equipment inspection, and incidents?
- Is emergency training adequate? Is the training instructor knowledgeable?
- Are personnel trained in the use of self-contained air packs and leak-repair kits? Is this equipment routinely inspected?

- Are medical examinations given to personnel who are trained in the use of self-contained air packs?
- Are chlorine material safety data sheet (MSDS) and first-aid procedures readily available?
- Stopping a leak-who, when and how? Personnel must be trained to determine when it is best to stop the leak or when to spend their efforts in other areas such as evacuation, you often cannot do both. Who is going to help you stop the leak? Are they nearby or must they travel a great distance?
- Who determines when it is safe to return to evacuated neighborhoods?
- How can your facility be put back into operation? What are the most likely sources of help to put your facility back into operation? How does the emergency plan fit into your operational plan for equipment breakdowns?
- Should the facility designer be notified?
- What else should I plan for?

Emergency Phone Contacts

(To Be Posted Next To Chlorine Room Switches and Phone)

Name
Telephone

Supervisor:
Supervisor:
Operator:
Operator:
Operator:

Emergency Measures Organization (EMO) or Risk Management Team/Response Team
EMO Coordinator:

Fire Department:

Local Ambulance:

Local Hospital:

Fire Department

CHLORINE EMERGENCY RESPONSE: 24 hour collect call
Chlorine Supplier:
Chlorine Supplier:
CHLOREP TEAM:

CHLORINE INFORMATION:

Special Requirements

The U.S. Environmental Protection Agency (**EPA**) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

Emergency Planning Requirements
Employers owning or operating a facility at which there are 100 pounds or more of chlorine must comply with the EPA's emergency planning requirements [40 CFR Part 355.30].

Reportable Quantity Requirements for Hazardous Releases
A hazardous substance release is defined by the EPA as any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment, including the abandonment or discarding of contaminated containers) of hazardous substances. In the event of a release that is above the reportable quantity for that chemical, employers are required to notify the proper Federal, State, and local authorities [40 CFR

The Reportable Quantity of Chlorine is 10 Pounds.
If an amount equal to or greater than this quantity is released within a 24-hour period in a manner that will expose persons outside the facility, employers are required to do the following:

Notify the National Response Center immediately at (800) or at (202) 426-2675 in Washington, D.C. [40 CFR 302.6]. Notify the emergency response commission of the State likely to be affected by the release [40 CFR 355.40]. Notify the community emergency coordinator of the local emergency planning committee (or relevant local emergency response personnel) of any area likely to be affected by the release [40 CFR 355.40].

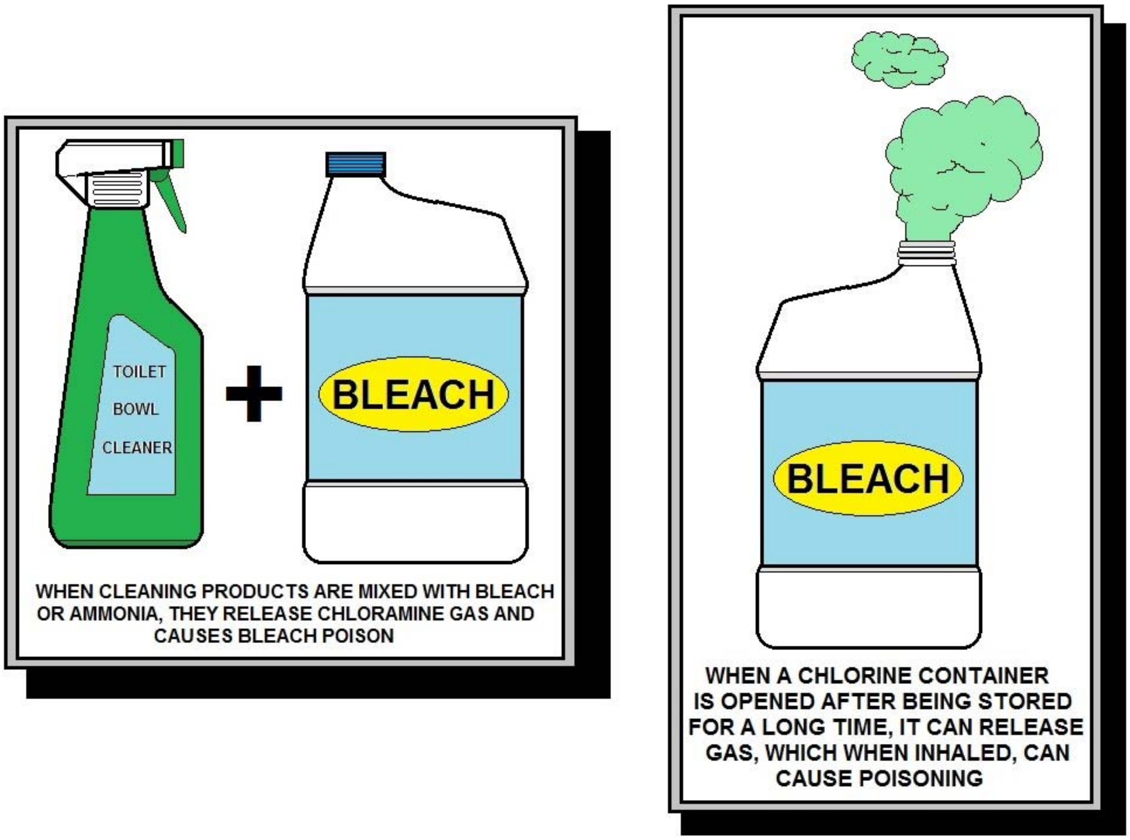
Community Right-to-Know Requirements
Employers who own or operate facilities in SIC codes 20 to 39 that employ 10 or more workers and that manufacture 25,000 pounds or more of chlorine per calendar year or otherwise use 10,000 pounds or more of chlorine per calendar year are required by EPA [40 CFR Part 372.30] to submit a Toxic Chemical Release Inventory form (Form R) to the EPA reporting the amount of chlorine emitted or released from their facility annually.

Hazardous Waste Management Requirements
EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Under the Resource Conservation and Recovery Act (**RCRA**) [40 USC 6901 et seq.], the EPA has specifically listed many chemical wastes as hazardous.

Although chlorine is not specifically listed as a hazardous waste under RCRA, the EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, the EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations.

To be certain that chemical waste disposal meets the EPA regulatory requirements, employers should address any questions to the RCRA hotline at (703) 412-9810 (in the Washington, D.C. area) or toll-free at (800) 424-9346 (outside Washington, D.C.). In addition, relevant State and local authorities should be contacted for information on any requirements they may have for the waste removal and disposal of this substance.



WHEN CLEANING PRODUCTS ARE MIXED WITH BLEACH OR AMMONIA, THEY RELEASE CHLORAMINE GAS AND CAUSES BLEACH POISON

WHEN A CHLORINE CONTAINER IS OPENED AFTER BEING STORED FOR A LONG TIME, IT CAN RELEASE GAS, WHICH WHEN INHALED, CAN CAUSE POISONING

POSSIBLE SOURCES OF CHLORINE POISONING

Chlorine Dioxide Sub-Section

Skin contact	Solutions are highly irritant
Skin Absorption	Gas may be absorbed, causing tissue and blood cell damage.
Eye Contact	Severe Irritant. Exposure may cause visual disturbance, i.e., seeing haloes around lights.
Inhalation	A severe respiratory irritant. May cause bronchiospasm and pulmonary edema, which may be delayed in onset. May also cause severe headache. All symptoms may be delayed and long-lasting. Long term exposure may cause bronchitis. An LC_{50} value of 500 ppm/ $15m^3$ (rat) is quoted in the literature.
Ingestion	Not applicable except for solutions, in which case the symptoms would be expected to parallel those for inhalation.
Exposure Limits	ACGIH 1992-93: TWA 0.1 ppm, STEL 0.3 ppm. Most legal limits are similar.
Irritancy	Severe
Sensitization	Information not available.
Carcinogenicity	Not listed by IARC or ACGIH.
Teratogenicity & Mutagenicity	No information is available.
Reproductive Toxicology	No information is available.
Toxicological Synergism	May have synergistic effects in conjunction with chlorine, other chlorine oxides, and chlorine fluorine compounds

The threshold limit value (TLV) established by the American Conference of Governmental Industrial Hygienists is 0.1 ppm. Two cases of poisoning (one fatal) resulted from exposure to less than 19 ppm while the victims were inside an empty bleach tank. Concentrations of 150 ppm were fatal to guinea pigs in 44 minutes. Characteristic acute effects from over exposure are coughing, eyes and nose watering and the development of a sore throat. Burns resulting from chlorine are severe since the decomposition produces Cl_2.

More about Chlorine Dioxide
Chlorine dioxide is generated on-site at water treatment facilities. The popularity of chlorine dioxide as a water disinfectant increased in the 1970s when it was discovered that it did not promote THM formation. Chlorine dioxide (ClO_2), long used in the paper industry, has been an acceptable and effective alternative to chlorination in cooling systems. Chlorine dioxide is a yellow-green gas with an irritating odor not unlike chlorine. It cannot be compressed and shipped in a container, so it must be generated on site.

There are three proven methods of efficiently generating chlorine dioxide. The most common is the chlorine/chlorite or "one pump" method. ClO_2 generation uses sodium chlorite ($NaClO_2$) and chlorine gas. Chlorine gas is educted into a motive water stream in a ClO_2 generator forming HOCl and HCl. Sodium chlorite is pumped into the stream and allowed to react in a generating column to produce ClO_2.

A second, common method of generation uses NaOCl and HCl in place of chlorine gas. Also referred to as the "three pump" method of generation, this method is valuable to a facility that wants to eliminate gaseous chlorine.

A third, more recent method of generation uses sodium chlorate ($NaClO_3$) and sulfuric acid. This differs from the other two methods in that ClO_2 is generated in a vacuum and is then educted into the motive water stream.

Chlorine dioxide holds many advantages over chlorine in cooling water systems. ClO_2 is considerably more selective than chlorine in the presence of various compounds, which allows it to be more effective in contaminated systems. Table 2 lists a series of compounds for which chlorine would show a greater affinity than ClO_2. Under certain conditions ClO_2 may, in fact, be two-and-one-half times more reactive than chlorine. Under efficient ClO_2 generation, THMs are not formed and THM precursors are reduced. In one application, THM formation was reduced from 34 m g/l to 1 m g/l using ClO_2.

Chlorine dioxide does not hydrolyze in water as does chlorine and there is no dissociation of ClO_2. It remains fully active in a pH range far broader than chlorine or sodium hypochlorite.

Since ClO_2 remains a gas in water, it does not have the corrosive tendencies of chlorine gas. Its selectivity generally allows for lower dosages compared to chlorine, limiting the amount of aggressive Cl^- available to attack passivated metal surfaces. Finally, ClO_2 is much less aggressive to traditional corrosion inhibitors.

Hypochlorous acid, whether formed from the dissolution of chlorine gas or sodium hypochlorite in water, has satisfactorily controlled microorganisms in cooling water systems. However, dissolution does yield a mineral acid or caustic soda which may adversely affect system pH, inhibitor passivation layers or metal surfaces.

Hypochlorous acid is heavily pH-dependent, because as system pH increases, there is a correspondingly rapid decrease in the concentration of the biocidally active species. It is also a non-specific oxidant which readily reacts with various organic and inorganic compounds that may be present in a cooling water system. Some of these reactions tend to yield undesirable by-products which are regulated or may be regulated in the future.

The effects of pH on hypochlorous acid and its reactivity with a variety of compounds both combine to vastly diminish its effectiveness in contaminated, high-pH cooling water systems. Conversely, chlorine dioxide remains completely pH-independent in the range where recirculating and once-through cooling systems are typically operated.

Since ClO_2 is a dissolved gas in water, there is no mineral acid or caustic soda formation as happens when using HOCl. Chlorine dioxide tends to be much less, if not totally non-reactive, with many organic and inorganic compounds.

Chlorine Dioxide Advantages

- Acts as an excellent virucide.
- Does not react with ammonia nitrogen to form chlorinated amines.
- Does not react with oxidizable material to form THMs; destroys up to 30% of THM precursors.
- Destroys phenols that cause taste and odor problems in potable water supplies.
- Forms fewer chlorinated DBPs such as THMs, HAAs and TOX.
- Disinfects and oxidizes effectively, including good disinfection of both *Giardia* and *Cryptosporidium*.
- Works at low dosage in post-disinfection step with no need of booster stations.
- Improves removal of iron and manganese by rapid oxidation and settling of oxidized compounds.
- Does not react with bromide to form bromate or brominated by-products.
- Has enhanced turbidity removal under certain conditions.

Chlorine Dioxide Disadvantages

- Reacts with natural organic matter and forms inorganic by-products. Chlorite ion, and to a lesser extent chlorate ion, are formed when chlorine dioxide is used.
- Requires on-site generation equipment and handling of chemicals.
- Occasionally poses unique odor and taste problems.

First Aid and Treatment

a) Remove the victim from the contaminated area at once. Loosen all constrictive clothing around the neck.

b) If breathing has stopped, apply artificial respiration.

c) Oxygen should be administered by an (external) Emergency Response Team in case of severe exposure.

d) Call a physician as soon as possible and keep patient warm and quiet.

e) If conscious, discourage coughing; essence of peppermint is sometimes given.

Reactive Chemical Hazards

- During preparation of gaseous ClO_2 decomposition can occur beyond 100 mm Hg partial pressure or above 100°C.

- Chlorine dioxide is incompatible with ammonia, mercury vapors, methane, phosphine and hydrogen sulfide.

- Chlorine dioxide gas is a highly unstable substance. Long stagnation of the vapors will result in an explosive decomposition. Vapors are reactive with most organics.

Phosphine

Phosphine is the common name for phosphorus hydride (PH^3), also known by the IUPAC name phosphane. It is a colorless, flammable gas with a boiling point of 88 °C at standard pressure. Pure phosphine is odorless, but "technical grade" phosphine has a highly unpleasant odor like garlic or rotting fish, due to the presence of substituted phosphine and diphosphine (P^2H^4).

Phosphine is highly toxic; it can easily kill in relatively low concentrations. Because of this, the gas is used for pest control by fumigation. For farm use, it is often sold in the form of aluminum phosphide pellets, which yield phosphine on contact with atmospheric water. These pellets also contain other chemicals which evolve ammonia which helps to reduce the potential for spontaneous ignition or explosion of the phosphine gas. They also contain other agents (e.g. methanethiol) to give the gas a detectable garlic smell to help warn against its presence in the atmosphere. Phosphine is also used as a dopant in the semiconductor industry.

Chlorine Dioxide Questions

1) Q: Is chlorine dioxide more expensive than chlorine?
A: Yes. Generally, chlorine dioxide is used only when chlorine is not capable of doing the job at hand, or when the use of chlorine creates unacceptable levels of by-products, such as THM or HAA.

2) Q: When applying chlorine dioxide for drinking water treatment, how do I ensure that I don't exceed the chlorite MCL?
A: To make sure that chlorite levels in drinking water treated with chlorine dioxide don't exceed the MCL, you should apply pure chlorine dioxide at a dose of no more than about 1.5ppm, depending on the particular water matrix being treated. (Generally, 50-70% of the applied chlorine dioxide "winds up" as chlorite.)

3) Q: What is the chlorite MCL for drinking water?
A: The chlorite MCL allowed in drinking water is 1.0 mg/l.

4) Q: What is the chlorate MCL for drinking water?
A: There is no MCL for chlorate for drinking water, due to insufficient toxicology data. However, the State of California has set an "advisory level" for chlorate of 0.8mg/l.

5) Q: What is the practical dosage limit for chlorine dioxide for drinking water treatment?
A: The practical dosage limit for chlorine dioxide in drinking is driven by compliance with the chlorite MCL, and is about 1.5mg/l unless chlorite is removed prior to the water leaving the plant.

6) Q: Will switching from chlorine gas to hypochlorite (bleach) help control disinfection byproducts (THM, HAA)?
A: Switching from chlorine gas to hypochlorite addresses risks associated with potential chlorine gas release; the chemistry of chlorine and hypochlorite in water are substantially the same, so far as DBP formation is concerned.

7) Q: Can chlorine dioxide kill Cryptosporidium?
A: Chlorine dioxide can kill Cryptosporidium far better than chlorine. However, a relatively high CxT (concentration x time) product is still required to get substantial Cryptosporidium kill with chlorine dioxide, especially in cold water. Only water treatment utilities with very long intake structures and low-demand raw water can expect to achieve significant Cryptosporidium reduction (1-2 logs) with chlorine dioxide alone.

8) Q: Can chlorine dioxide remove off-tastes and odors from drinking water?
A: Chlorine dioxide is effective at the removal of many off-tastes and odors associated with drinking water. However, chlorine dioxide is substantially ineffective in controlling certain "earthy-musty" odor causing compounds, such as MIB and Geosmin.

9) Q: Does chlorine dioxide form bromate ion when used to treat bromide-containing water?
A: Chlorine dioxide does not oxidize bromide ion to form bromate ion, unless the reaction is photolyzed. That is, some bromate ion may be formed in the presence of light.

10) Q: Does chlorine dioxide react with organics to produce trihalomethanes (THM) or haloacetic acids (HAA)?
A: In contrast to chlorine, chlorine dioxide does not react with organics (to any appreciable extent) to produce THM or HAA.

11) Q: **What is the typical chlorine dioxide dosage for drinking water treatment?**
A: The chlorine dioxide dosage for drinking water treatment depends on the particular application, as well as on the water matrix being treated. For example, a typical dosage for manganese removal might be 0.25-0.50ppm; for primary disinfection, a dose of 0.75 to 1.25ppm is more likely.

Chlorine Dioxide Testing Methods

Most tests for chlorine dioxide rely upon its oxidizing properties. Consequently, numerous test kits are readily available that can be adapted to measure chlorine dioxide. In addition, new methods that are specific for chlorine dioxide are being developed.

The following are the common analytical methods for chlorine dioxide:

	DPD glycine	**Chlorophenol Red**	**Direct Absorbance**	**Iodometric Titration**	**Amperometric Titration**
Method Type:	Colorimetric	Colorimetric	Colorimetric	Titrametric	Titrametric
How It Works	Glycine removes Cl_2; ClO_2 forms a pink color, whose intensity is proportional to the ClO_2 concentration.	ClO_2 bleaches chlorophenol red indicator. The degree of bleaching is proportional to the concentration of ClO_2.	The direct measurement of ClO_2 is determined between 350 and 450 nM.	Two aliquots are taken one is sparged with N_2 to remove ClO_2. KI is added to the other sample at pH7 and titrated to a colorless endpoint. The pH is lower to 2, the color allowed to reform and the titration continued. These titrations are repeated on the sparged sample.	
Range	0.5 to 5.0 ppm.	0.1 to 1.0 ppm	100 to 1000 ppm	> 1 ppm	< 1ppm
Interferences	Oxidizers	None	Color, turbidity	Oxidizers	
Complexity	Simple	Moderate	Simple	Moderate	High
Equipment Required	Spectrophotometer or Colorimeter			Titration equipment	Amperometric Titrator
EPA Status	Approved	Not approved	Not approved	Not approved	Approved
Recommendation	Marginal	Yes	Marginal	Yes	Marginal

Conclusions

- Chlorine is one of nature's most common chemical elements.
- Electricity applied to salt solutions enables the chlor-alkali industry to harness chlorine captured in salt deposits of ancient oceans.
- Chlorine's chemical properties make it an extremely effective disinfectant and essential component in the chemical manufacture of literally thousands of vital products used every day.
- Pairs of substances that chlorine will react explosively or form explosive compounds with are acetylene and ether, turpentine and ammonia and hydrogen and finely divided metals.
- Monochloramine, dichloramine, and trichloramine are known as combined available chlorine.
- The chlorine pressure reducing valve should be located downstream of the evaporator when using an evaporator.
- Chlorine is added to the effluent before the contact chamber for complete mixing. What is the reason for not adding it directly to the chamber? The chamber has very little mixing due to low velocities.
- The two main chemical species formed by chlorine in water and the name that are they known by collectively are HOCl and OCl-; free available chlorine.
- When chlorine gas is added to water, it rapidly hydrolyzes. The chemical equation that best describes this reaction is Cl2 + H2O --> H+ + Cl- + HOCl.
- Yoke-type connectors should be used on a chlorine cylinder's valve; always assume the threads on the valve may be worn.
- Excessive chlorine can kill the aerobic organisms in the secondary treatment plant. Take precaution when applying chlorine in the sewer line near a wastewater treatment plant to control hydrogen sulfide production and anaerobic bacteria.
- When replacing the connection from a chlorine cylinder to a chlorinator always use a new, approved gasket on the connector and follow the manufacturer’s instructions.
- Safety precautions when using chlorine gas: In addition to protective clothing and goggles, chlorine gas should be used only in a well ventilated area so that any leaking gas cannot concentrate.
- Several symptoms of chlorine exposure: Burning of eyes, nose, and mouth, coughing, sneezing, choking, nausea and vomiting; headaches and dizziness; fatal pulmonary edema, pneumonia, and skin blisters.
- Approved method for storing a chlorine cylinder: Secure each cylinder in an upright position, attach the protective bonnet over the valve and firmly secure each cylinder.
- Emergency procedures in the case of a large uncontrolled chlorine leak: Notify local emergency response team, warn and evacuate people in adjacent areas, be sure that no one enters the leak area without adequate self-contained breathing equipment.

Alternative Disinfectants - Chapter 4

Ultraviolet Disinfection

This process involves exposing water to ultraviolet (UV) radiation, which inactivates various microorganisms. The technique has enjoyed increased application in wastewater treatment but very limited application in potable water treatment.

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.

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.

The lamp itself does not come intro contact with 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 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.

UV disinfection transfers electromagnetic energy from a mercury arc lamp to a pathogen's DNA material, thus affecting its ability to replicate itself. UV's effectiveness depends on the characteristics of the wastewater, the intensity of the UV radiation being emitted, the length of time that the wastewater comes in contact with the UV radiation, and the arrangement of the UV reactor.

UV has the advantage of being effective at inactivating viruses and, because it's a physical process rather than a chemical process, there are no residual constituents remaining in the treated wastewater after exposure to UV. Also, the contact time for the wastewater with the UV source is the shortest of any of the disinfectant strategies, lasting no longer than 20 to 30 seconds. Disadvantages include the effects of turbidity in the water reducing the infiltration and therefore the effectiveness of UV and the need to provide an effective cleaning and replacement program for the UV components.

"If you just need pure disinfection you probably would tend towards UV rather than ozone". "The cost of the UV just for disinfection is usually less than ozone, and the amount of equipment needed is less. But every water treatment has to be looked at individually in order to get what you want. Sometimes you cannot use UV because the waste treatment is too turbid; if you can filter it to get the turbidity levels down, maybe you'll use UV."

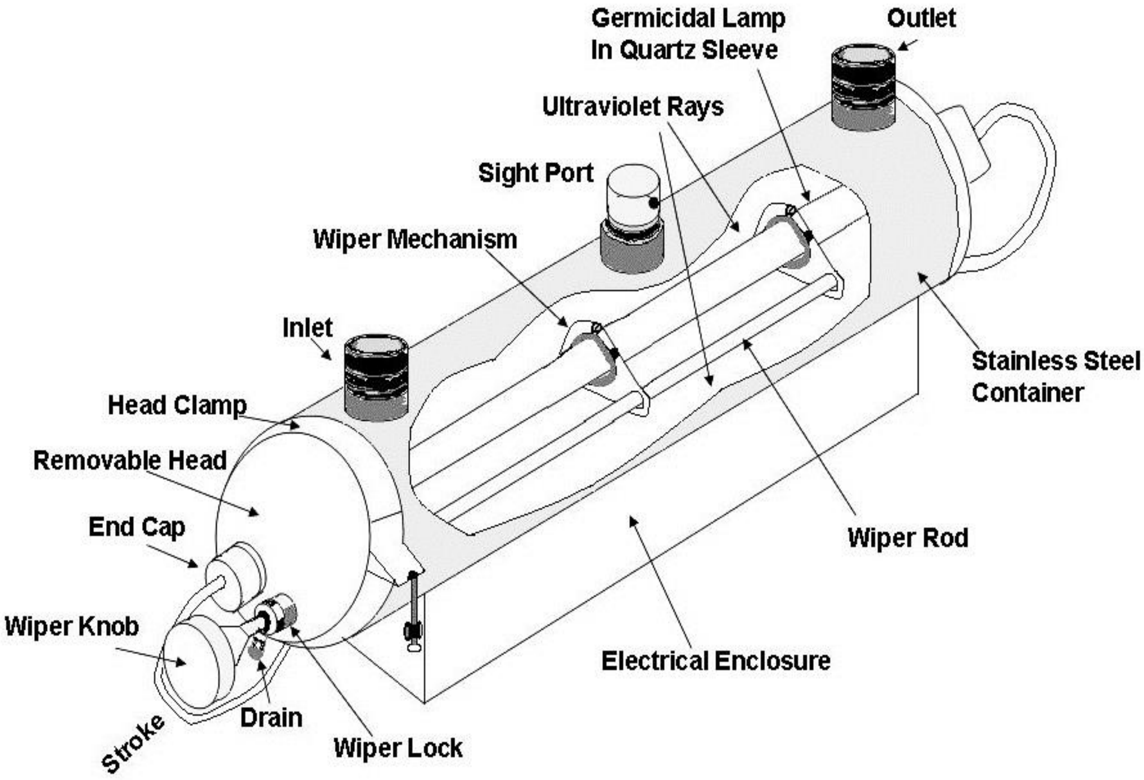
Primarily, there are two designs for UV systems. One system involves a non-contact design in which the UV-light system is suspended away from contact with the water. The second system is the contact reactor-type design in which the lamps are encased in a quartz sleeve that is submerged in the water. This contact-type system is further separated by whether it is an open- or closed-channel system. The open-channel system submerges the lamps in either a horizontal or vertical arrangement. A closed-channel system is within a sealed chamber that can be used in a pressurized system. The open-channel system is mostly used in wastewater treatment.

Ensuring that the UV maintains good contact with the water requires control of the water level within the channel to ensure that the UV is making total contact at the designed depths. Also, because of the heat generated by the electric components of the system, adequate ventilation and cooling must be applied to the UV arrays to reduce heat build-up, otherwise the ballasts could fail. UV lamps have a rated life of up to 14,000 hours, and should be routinely replaced at 12,000 hours or roughly every 1.5 years of continuous operation. The electrical consumption of this system, combined with the cost of routine replacement of ballasts and shields, should be considered against other systems.

Photoelectric Cell

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 preset 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.



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 rays. 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

Disinfectant	***Disinfectant By-product***	***Disinfectant By-product Removal***
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 Fe2+ 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.

Ultraviolet Radiation *Advantages and Disadvantages*

Ultraviolet Radiation Advantages
- No chemical storage, handling or feed equipment required.
- No identified disinfection by-products.

Ultraviolet Radiation Disadvantages
- No residual action.
- High maintenance requirements.
- High initial capital costs.
- High operating (energy) costs.

Disinfecting action can be compromised by variables such as water clarity, hardness (scaling on the UV tubes), fouling (biological materials) of UV lamps, wavelength of the UV radiation or power failure.

Ozone Sub-**Section**

Ozone has been used for several decades in Europe and is now starting to be found in the U.S. for taste and odor control, color removal and disinfection.

Strongest Oxidizing Agent

Ozone (**O_3**) is probably the strongest oxidizing agent available for water treatment. Although it is widely used throughout the world, is 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.

$$3O_2 + \text{electrical discharge} \rightarrow 2O_3$$

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.

$$O_3 \rightarrow O_2 + O$$

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.

Oxygen tank is necessary to generate O_3

Ozone Advantages

- Acts as an excellent virucide.
- Disinfects and oxidizes very effectively.
- Produces no chlorinated THMs, HAAs or other chlorinated by-products.
- Enhances turbidity removal under certain conditions.
- Inactivates both *Cryptosporidium* and *Giardia*, as well as other known pathogens.
- Controls taste and odor.

Ozone Disadvantages

- Produces disinfection by-products, including:
  ~Aldehydes
  ~Ketones
  ~Carboxylic acids
  ~Brominated THMs (including bromoform)
  ~Brominated acetic acids
  ~Bromate (in the presence of bromide)
  ~Quinones
  ~Peroxides
- Fosters THM formation when some ozonation by-products combine with secondary disinfection processes. A biologically active filter will likely be necessary to remove these newly formed precursors.
- Does not provide a persistent residual.
- Raises regulatory concerns. Future DBP regulations may require plants using ozone to install costly precursor removal systems (such as granular activated carbon filtration systems).
- Requires capital investment. Ozone must be produced on-site by costly generation that requires a high level of maintenance and substantial operator training.
- Promotes microbial growth. Ozone readily reacts with more complex organic matter and can break this down to smaller compounds that serve to increase nutrients in water supplies, thus enhancing microbial regrowth in water distribution systems.

Alternate Disinfectants Section Summary

Chloramines

Chloramine is a very weak disinfectant for Giardia and virus reduction. It is recommended that it be used in conjunction with a stronger disinfectant. It is best utilized as a stable distribution system disinfectant. In the production of chloramines the ammonia residuals in the finished water, when fed in excess of stoichiometric amount needed, should be limited to inhibit growth of nitrifying bacteria.

Chlorine Dioxide

Chlorine dioxide may be used for either taste and odor control or as a pre-disinfectant. Total residual oxidants (including chlorine dioxide and chlorite, but excluding chlorate) shall not exceed 0.30 mg/L during normal operation or 0.50 mg/L (including chlorine dioxide, chlorite and chlorate) during periods of extreme variations in the raw water supply.

Chlorine dioxide provides good Giardia and virus protection but its use is limited by the restriction on the maximum residual of 0.5 mg/L ClO2/chlorite/chlorate allowed in finished water. This limits usable residuals of chlorine dioxide at the end of a process unit to less than 0.5 mg/L. Where chlorine dioxide is approved for use as an oxidant, the preferred method of generation is to entrain chlorine gas into a packed reaction chamber with a 25% aqueous solution of sodium chlorite (NaClO2).

Warning: Dry sodium chlorite is explosive and can cause fires in feed equipment if leaking solutions or spills are allowed to dry out.

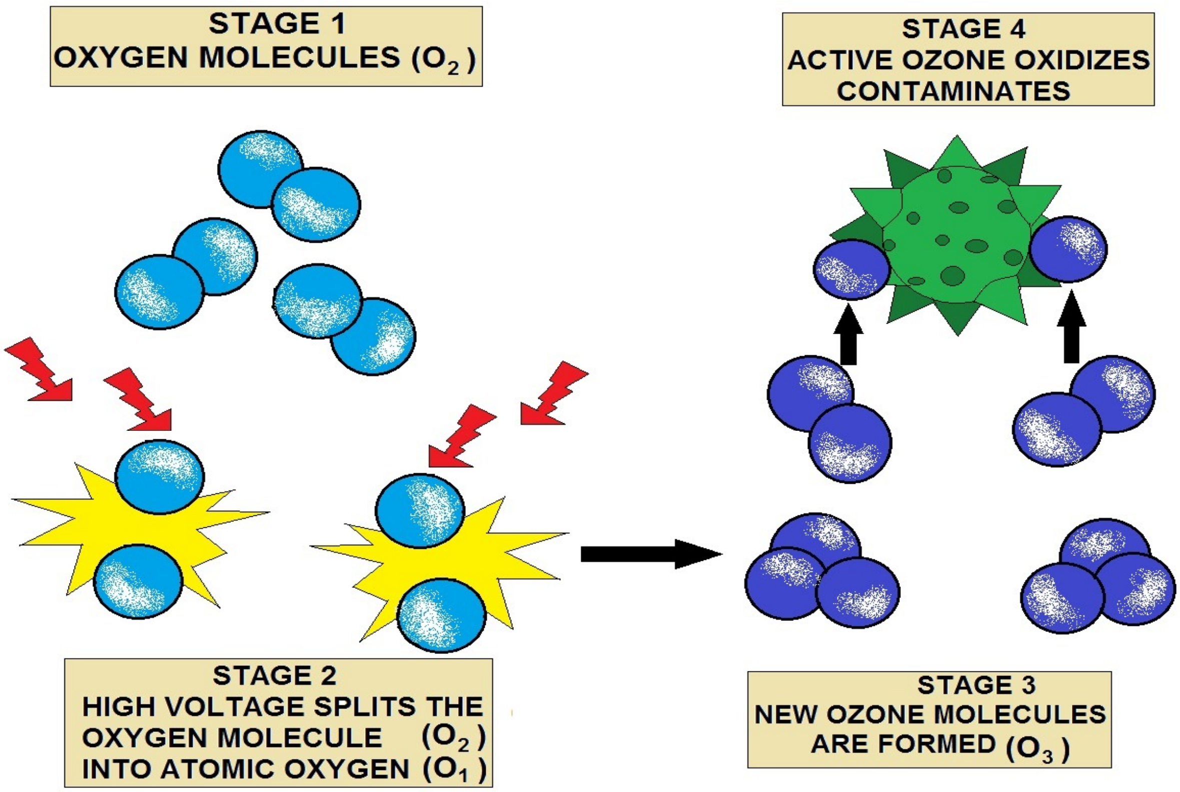
Ozone

Ozone is a very effective disinfectant for both Giardia and viruses. Ozone CT values must be determined for the ozone basin alone; an accurate T10 value must be obtained for the contact chamber, residual levels measured through the chamber and an average ozone residual calculated. Ozone does not provide a system residual and should be used as a primary disinfectant only in conjunction with free and/or combined chlorine.

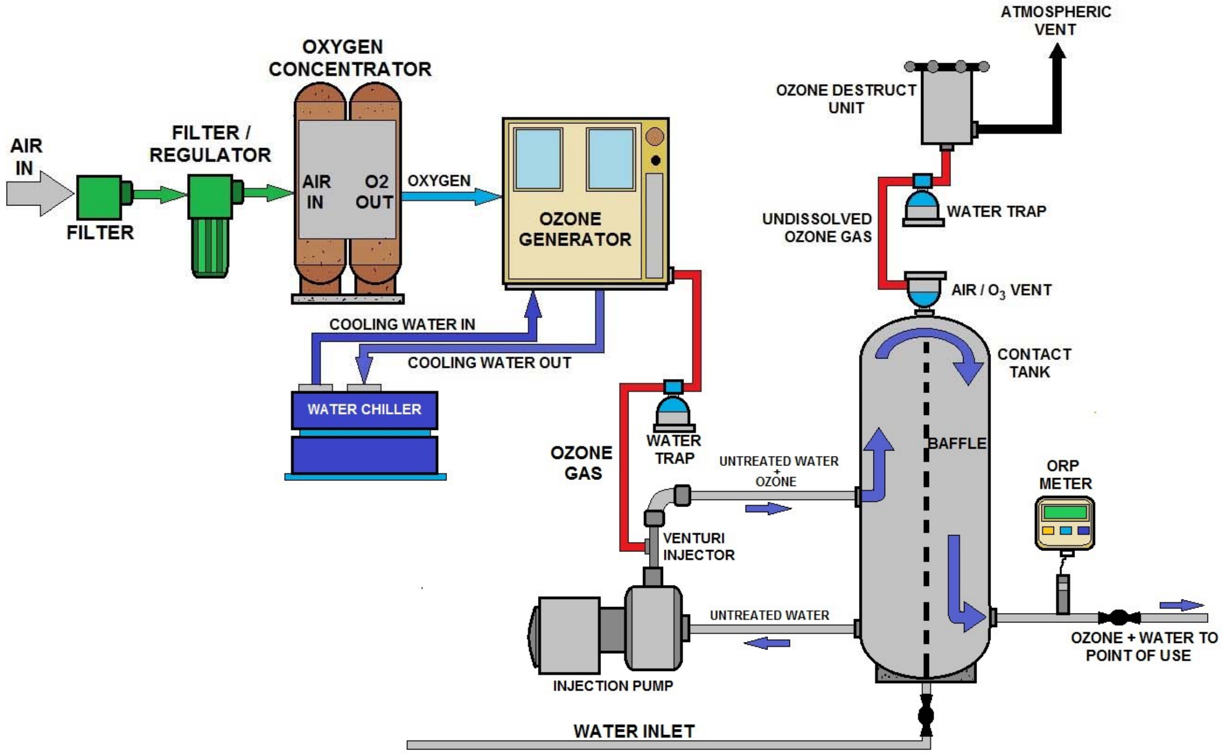
Ozone does not produce chlorinated byproducts (such as trihalomethanes) but it may cause an increase in such byproduct formation if it is fed ahead of free chlorine; ozone may also produce its own oxygenated byproducts such as aldehydes, ketones or carboxylic acids. Any installed ozonation system must include adequate ozone leak detection alarm systems, and an ozone off-gas destruction system. Ozone may also be used as an oxidant for removal of taste and odor or may be applied as a pre-disinfectant.

UV

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.



HOW OZONE IS PRODUCED



OZONE GENERATION SYSTEM

Waterborne Pathogens Chapter 5

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

Cryptosporidium

How Diseases are Transmitted.

Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral, or feces-to-mouth, route.

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

Human or animal wastes in watersheds, failing septic systems, failing sewage treatment plants or cross-connections of water lines with sewage lines provide the potential for contaminating water with pathogens. The water may not appear to be contaminated because feces have been broken up, dispersed and diluted into microscopic particles. These particles, containing pathogens, may remain in the water and be passed to humans or animals unless adequately treated. Only proper treatment will ensure eliminating the spread of disease. In addition to water, other methods exist for spreading pathogens by the fecal-oral route. The foodborne route is one of the more common methods.

A frequent source is a food handler who does not wash his hands after a bowel movement and then handles food with "***unclean***" hands. The individual who eats feces-contaminated food may become infected and ill.

It is interesting to note the majority of foodborne diseases occur in the home, not restaurants. Day care centers are another common source for spreading pathogens by the fecal-oral route.

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

Chain of Transmission

Water is contaminated with feces. This contamination may be of human or animal origin. The feces must contain pathogens (disease-causing bacteria, viruses or protozoa); if the human or animal source is not infected with a pathogen, no disease will result.

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

The pathogens in the water must enter the water system's intake, in numbers sufficient to infect people. The water is either not treated or inadequately treated for the pathogens present. A susceptible person must drink the water that contains the pathogen; illness (disease) will occur. This chain lists the events that must occur for the transmission of disease via drinking water. By breaking the chain at any point, the transmission of disease will be prevented.

Bacterial Diseases

Campylobacteriosis is the most common diarrhea illness caused by bacteria. 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, and Yersiniosis, are other bacterial diseases that can be transmitted through water. All bacteria in water are readily killed or inactivated with chlorine or other disinfectants.

Microbiological Contaminants

The sources of drinking water include rivers, lakes, streams, ponds, reservoirs, springs, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally occurring minerals and in some cases, radioactive material, and can pick up substances resulting from the presence of animals or human activity.

Contaminants that may be present in sources of drinking water include:

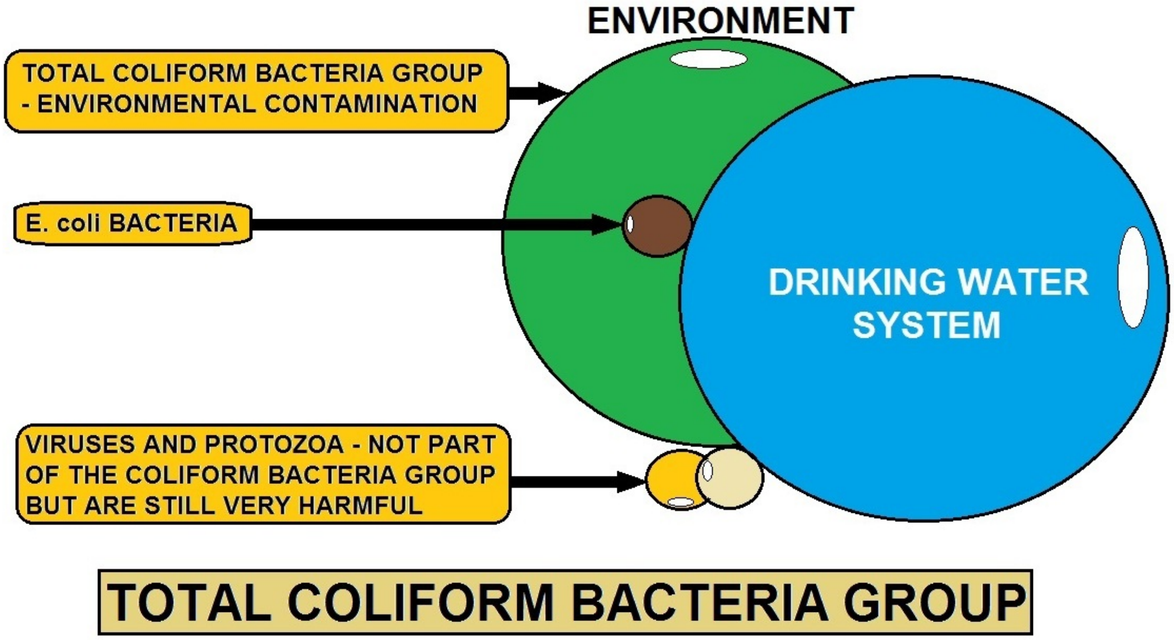
Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife;

Inorganic contaminants, such as salts and metals, which can be naturally occurring or result from urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining or farming;

Pesticides and herbicides, which may come from a variety of sources such as agriculture, urban stormwater run-off, and residential uses;

Organic chemical contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban stormwater run-off, and septic systems;

Radioactive contaminants, which can be naturally occurring or be the result of oil and gas production and mining activities.



Background

Coliform bacteria and chlorine residual are the only routine sampling and monitoring requirements for small ground water systems with chlorination. The coliform bacteriological sampling is governed by the Total Coliform Rule (**TCR**) of the SDWA. Although there is presently no requirement for chlorination of groundwater systems under the SDWA, State regulations require chlorine residual monitoring of those systems that do chlorinate the water.

TCR

The TCR requires all Public Water Systems (**PWS**) to monitor their distribution system for coliform bacteria according to the written sample sitting plan for that system. The sample sitting plan identifies sampling frequency and locations throughout the distribution system that are selected to be representative of conditions in the entire system.

Coliform contamination can occur anywhere in the system, possibly due to problems such as; low pressure conditions, line breaks, or well contamination, and therefore routine monitoring is required. A copy of the sample sitting plan for the system should be kept on file and accessible to all who are involved in the sampling for the water system.

Number of Monthly Samples

The number of samples to be collected monthly depends on the size of the system. The TCR specifies the minimum number of coliform samples collected, but it may be necessary to take more than the minimum number in order to provide adequate monitoring.

This is especially true if the system consists of multiple sources, pressure zones, booster pumps, long transmission lines, or extensive distribution system piping. Since timely detection of coliform contamination is the purpose of the sample-sitting plan, sample sites should be selected to represent the varying conditions that exist in the distribution system. The sample sitting plan should be updated as changes are made in the water system, especially the distribution system.

Sampling Procedures

The sample-sitting plan must be followed and all operating staff must be clear on how to follow the sampling plan. In order to properly implement the sample-sitting plan, staff must be aware of how often sampling must be done, the proper procedures and sampling containers to be used for collecting the samples, and the proper procedures for identification, storage and transport of the samples to an approved laboratory. In addition, proper procedures must be followed for repeat sampling whenever a routine sample result is positive for total coliform.

Routine Sampling Requirements

Total coliform samples must be collected by PWSs at sites which are representative of water quality throughout the distribution system according to a written sample siting plan subject to state review and revision.

For PWSs collecting more than one sample per month, collect total coliform samples at regular intervals throughout the month, except that ground water systems serving 4,900 or fewer people may collect all required samples on a single day if the samples are taken from different sites.

Each total coliform-positive (TC+) routine sample must be tested for the presence of E. coli.

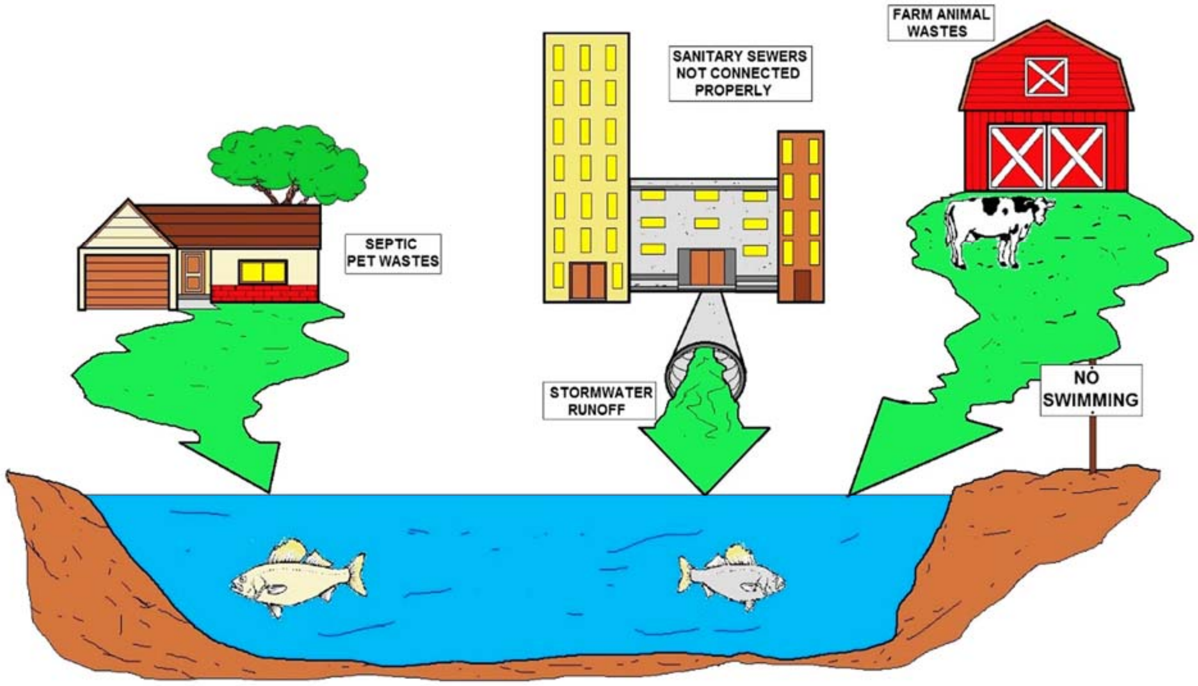
► If any TC+ sample is also E. coli-positive (EC+), then the EC+ sample result must be reported to the state by the end of the day that the PWS is notified.

► If any routine sample is TC+, repeat samples are required. – PWSs on quarterly or annual monitoring must take a minimum of three additional routine samples (known as additional routine monitoring) the month following a TC+ routine or repeat sample.

► Reduced monitoring may be available for PWSs using only ground water and serving 1,000 or fewer persons that meet certain additional PWS criteria.

Coliform Bacteria - Introduction

Total coliforms are a group of related bacteria that are (with few exceptions) not harmful to humans. A variety of bacteria, parasites, and viruses, known as pathogens, can potentially cause health problems if humans ingest them. EPA considers total coliforms a useful indicator of other pathogens for drinking water because they are easier to measure and associate with water contamination.



SOURCES OF FECAL COLIFORM BACTERIA

Total coliforms are used to determine the adequacy of water treatment and the integrity of the distribution system.

All bacteriological samples are analyzed for the coliform group; however, a positive reaction to these coliform analyses may be from sources other than fecal. In order to differentiate between these sources, all samples that are total coliform positive must be analyzed again to determine if fecal coliform or *E. coli* are present.

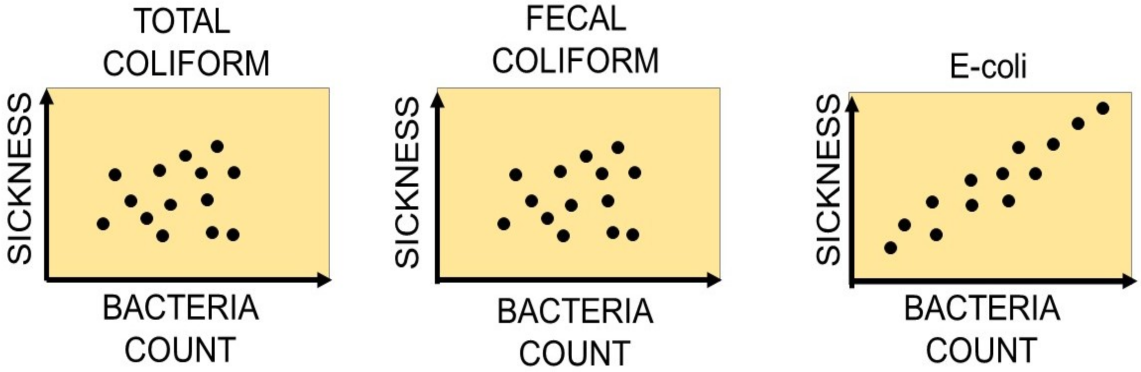
Key provisions of the RTCR include:

- Setting a maximum contaminant level goal (MCLG) and maximum contaminant level (MCL) for E. coli for protection against potential fecal contamination.
- Setting a total coliform treatment technique (TT) requirement.
- Requirements for monitoring total coliforms and E. coli according to a sample siting plan and schedule specific to the PWS.
- Provisions allowing PWSs to transition to the RTCR using their existing Total Coliform Rule (TCR) monitoring frequency, including PWSs on reduced monitoring under the existing TCR.
- Requirements for seasonal systems (such as Non-Community Water Systems not operated on a year-round basis) to monitor and certify the completion of a state-approved start-up procedures.

- Requirements for assessments and corrective action when monitoring results show that PWSs may be vulnerable to contamination.
- Public notification (PN) requirements for violations.
- Specific language for CWSs to include in their Consumer Confidence Reports (CCRs) when they must conduct an assessment or if they incur an E. coli MCL violation.

TCR Key Provisions

- To comply with the monthly MCL for total coliforms (TC), PWSs must not find coliforms in more than five percent of the samples they take each month to meet EPA's standards. If more than five percent of the samples contain coliforms, PWS operators must report this violation to the state and the public.
- If a sample tests positive for TC, the system must collect a set of repeat samples located within 5 or fewer sampling sites adjacent to the location of the routine positive sample within 24 hours.
- When a routine or repeat sample tests positive for total coliforms, it must also be analyzed for fecal coliforms or E. coli, which are types of coliform bacteria that are directly associated with feces. A positive result for fecal coliforms or E. coli can signify an acute MCL violation, which necessitates rapid state and public notification because it represents a direct health risk.
- At times, an acute violation due to the presence of fecal coliform or E. coli may result in a "boil water" notice. The system must also take at least 5 routine samples the next month of operation if any sample tests positive for total coliforms.



DRINKING WATER BACTERIA DIAGRAMS

All public water systems (PWSs), except aircraft PWSs subject to the Aircraft Drinking Water Rule (ADWR) (40 CFR 141 Subpart X), must comply with the RTCR starting April 1, 2016, or an earlier state effective date. Until then, PWSs must continue complying with the 1989 TCR.

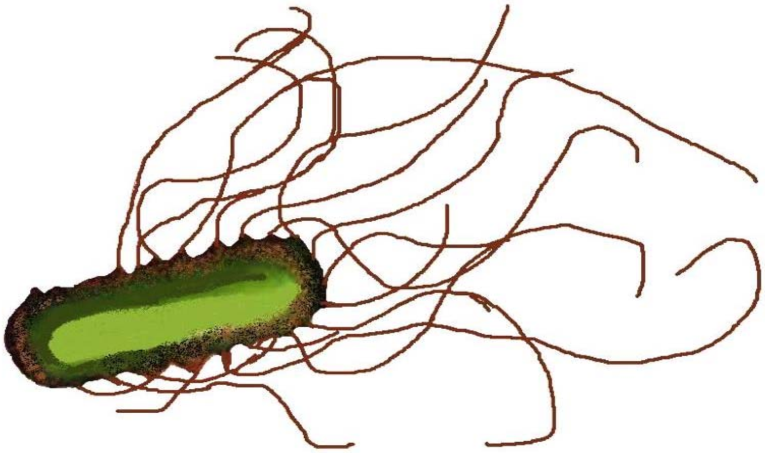
Related and Dangerous Waterborne Microbes

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

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

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

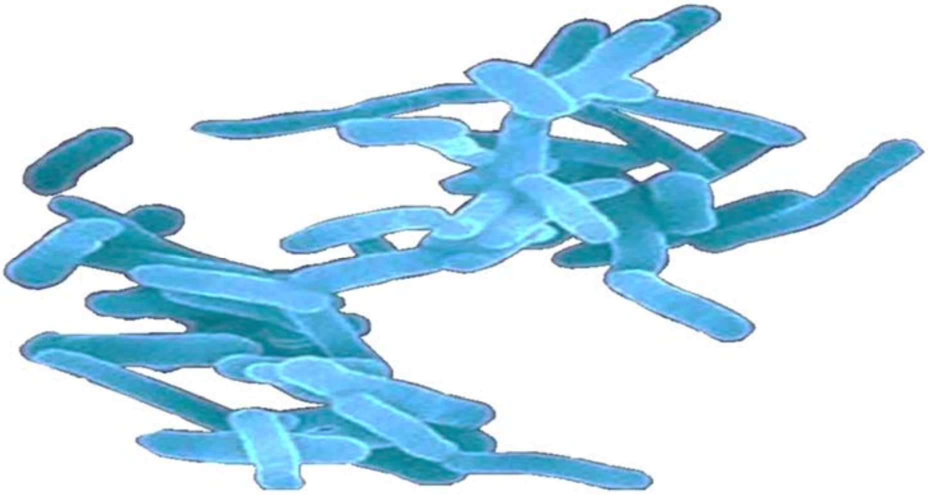
Giardia lamblia is a parasite that enters lakes and rivers through sewage and animal waste. It causes gastrointestinal illness (e.g. diarrhea, vomiting, and cramps).



PERITRICHOUS SHAPED BACTERIA EXAMPLE

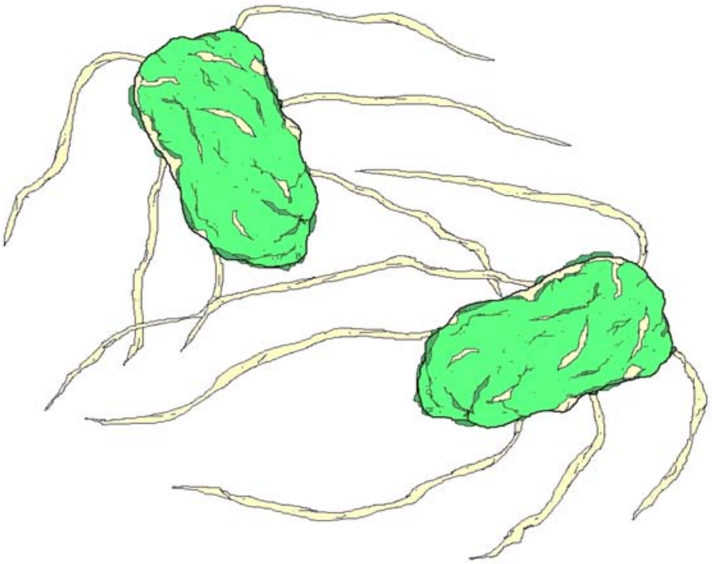
Microbiologists broadly classify bacteria according to their shape: spherical, rod-shaped, and spiral-shaped. Pleomorphic bacteria can assume a variety of shapes. Bacteria may be further classified according to whether they require oxygen (aerobic or anaerobic) and how they react to a test with Gram’s stain.

Bacteria in which alcohol washes away Gram’s stain are called gram-negative, while bacteria in which alcohol causes the bacteria’s walls to absorb the stain are called gram-positive.



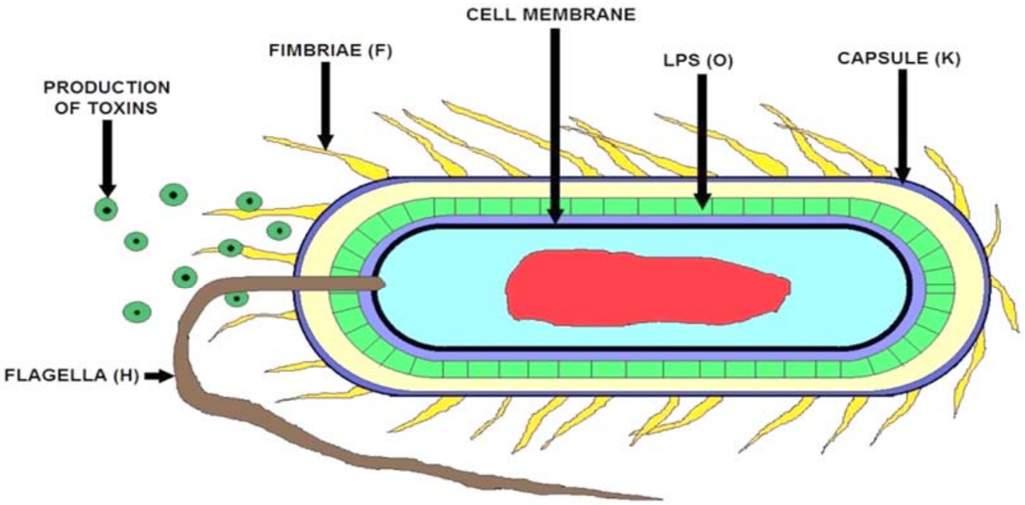
SHIGELLA DYSENTARIAE EXAMPLE

Shigella dysenteriae is a species of the rod-shaped bacterial genus Shigella. Shigella can cause shigellosis (bacillary dysentery). Shigellae are Gram-negative, non-spore-forming, facultatively anaerobic, non-motile bacteria.



SALMONELLA EXAMPLE

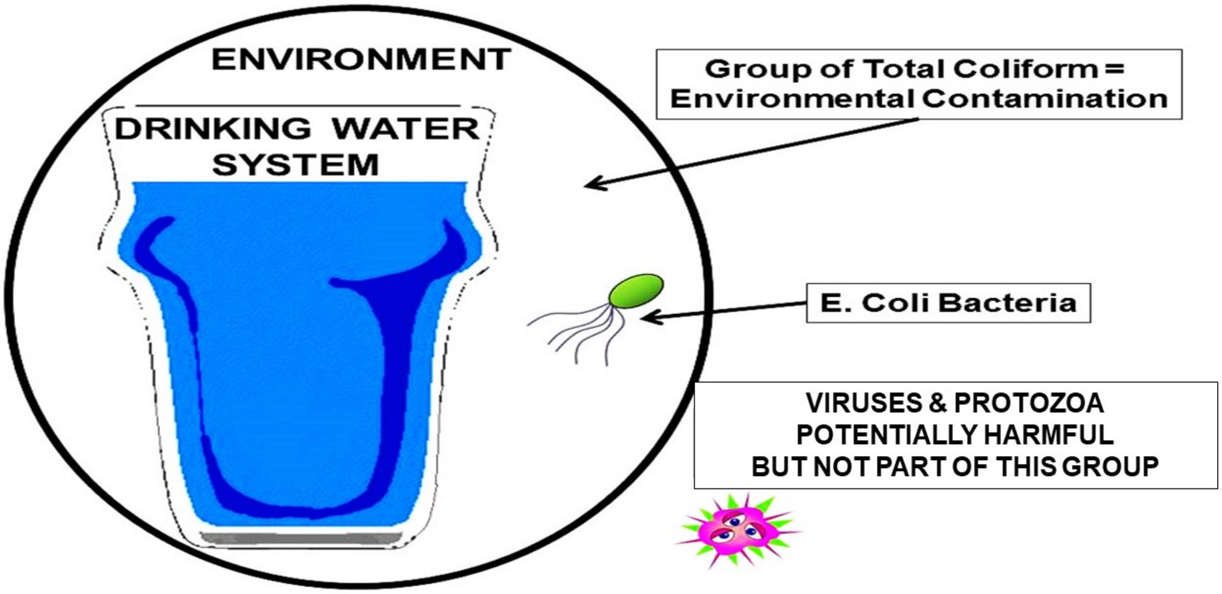
Salmonellae usually do not ferment lactose; most of them produce hydrogen sulfide that in media containing ferric ammonium citrate reacts to form a black spot in the center of the creamy colonies.



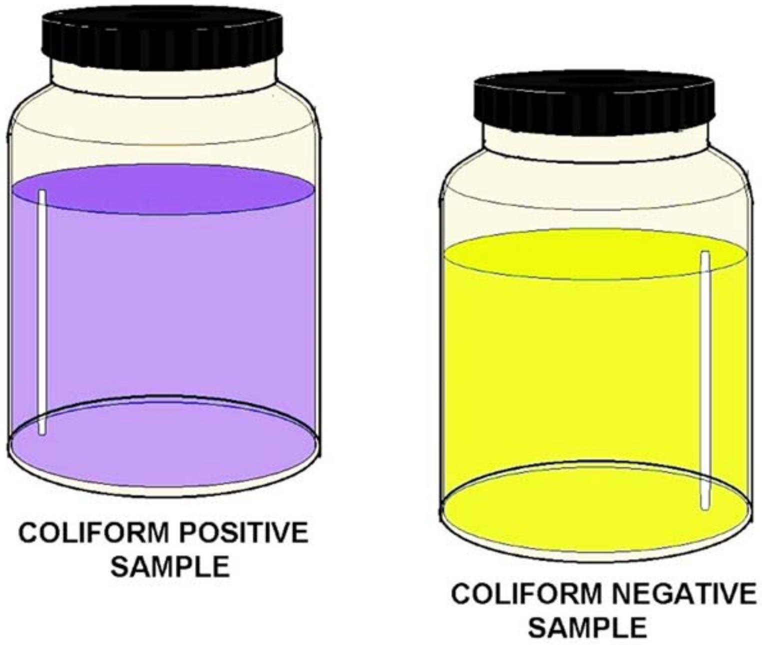
E. COLI

Fecal Coliform Bacteria

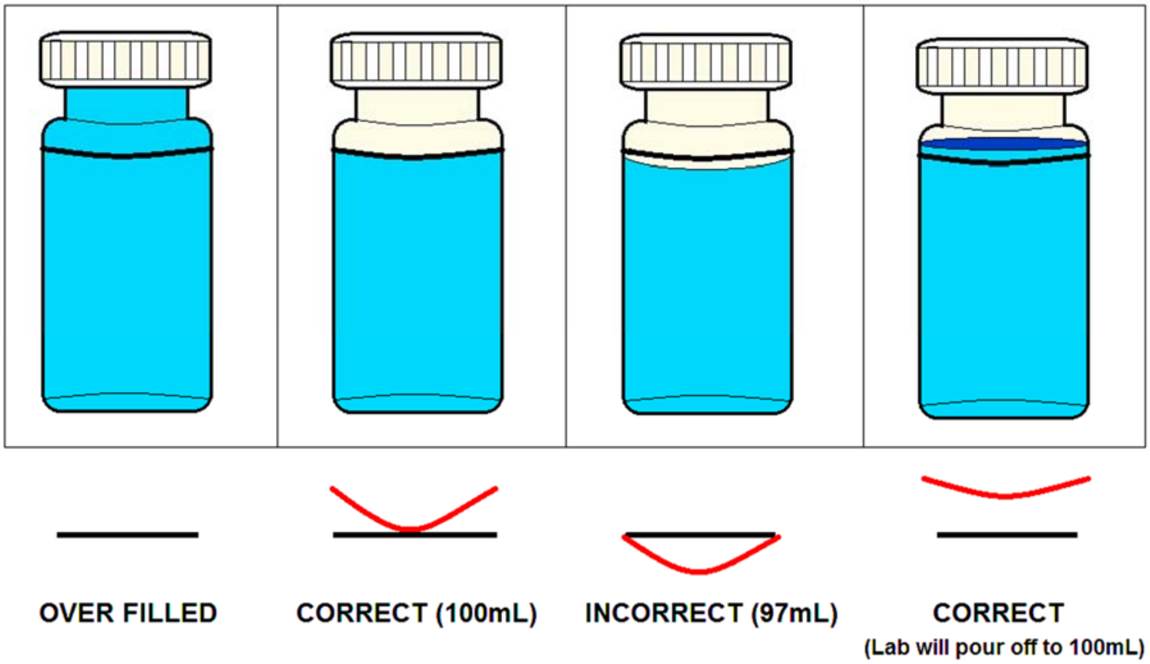
Fecal coliform bacteria are microscopic organisms that live in the intestines of warm-blooded animals. They also live in the waste material, or feces, excreted from the intestinal tract. When fecal coliform bacteria are present in high numbers in a water sample, it means that the water has received fecal matter from one source or another. Although not necessarily agents of disease, fecal coliform bacteria may indicate the presence of disease-carrying organisms, which live in the same environment as the fecal coliform bacteria.



GROUP OF TOTAL COLIFORM BACTERIA



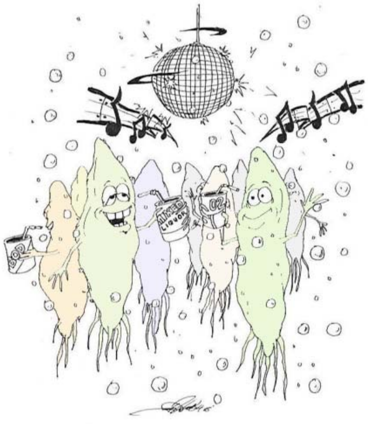
COLIFORM BACTERIA PRESENCE TEST EXAMPLE



BAC-T SAMPLE BOTTLE DIAGRAM

Bacteriological Monitoring - Introduction

Most waterborne diseases 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 - 1 Example
Water samples for bacteria tests must always be collected in a sterile container. Take the sample from an outside faucet with the aerator removed. Sterilize by spraying a 5% Household beach or alcohol solution or flaming the end of the tap with a propane torch. Run the water for five minutes to clear the water lines and bring in fresh water. Do not touch or contaminate the inside of the bottle or cap. Carefully open the sample container and hold the outside of the cap. Fill the container and replace the top. Refrigerate the sample and transport it to the testing laboratory within six hours (in an ice chest). Many labs will not accept bacteria samples on Friday so check the lab's schedule. Mailing bacteria samples is not recommended because laboratory analysis results are not as reliable. Iron bacteria forms an obvious slime on the inside of pipes and fixtures. A water test is not needed for identification. Check for a reddish-brown slime inside a toilet tank or where water stands for several days.

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:

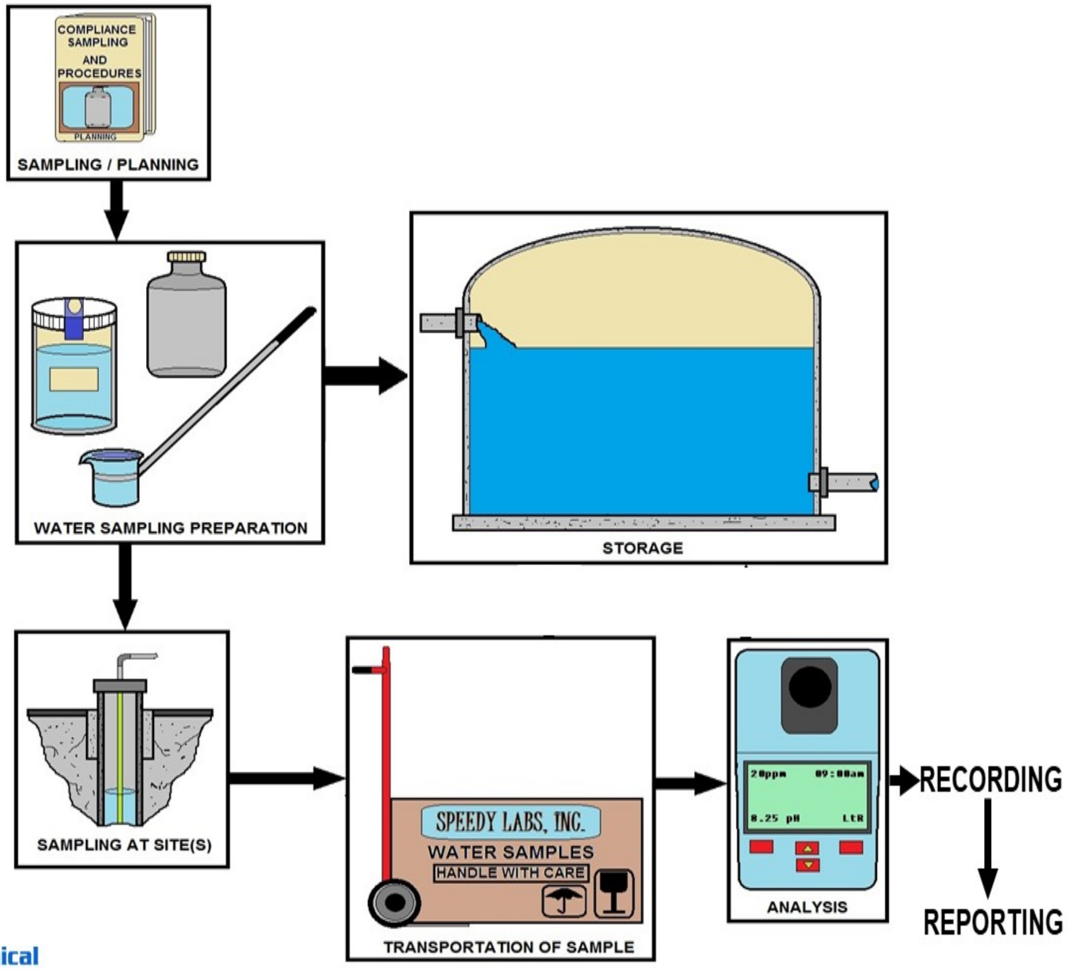
Methods

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.

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.



WATER SAMPLING FLOW CHART

Basic 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) primary 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.

A. **Trigger: Level 1 Assessment** is triggered if any one of the following occurs:
► A PWS collecting fewer than 40 samples per month has 2 or more TC+ routine/ repeat samples in the same month.
► A PWS collecting at least 40 samples per month has greater than 5.0 percent of the routine/repeat samples in the same month that are TC+.
► A PWS fails to take every required repeat sample after any single TC+ sample

B. **Trigger: Level 2 Assessment** is triggered if any one of the following occurs:
► A PWS incurs an E. coli MCL violation.
► A PWS has a second Level 1 Assessment within a rolling 12-month period.
► A PWS on state-approved annual monitoring has a Level 1 Assessment trigger in 2 consecutive years.

Routine Coliform Sampling
The number of routine samples and frequency of collection for community public water systems is shown in Table 3-1 below.

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.

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

Repeat Sampling Introduction

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 has 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.

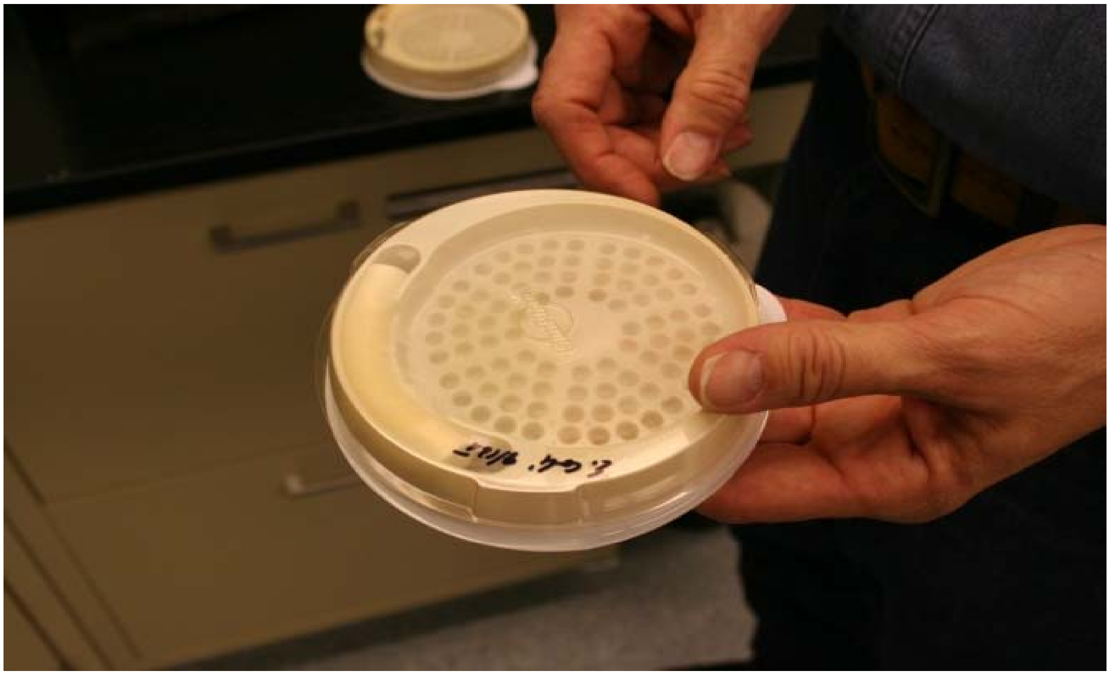
This list provides some basic operation and maintenance procedures that could help eliminate potential bacteriological problems, check with your state drinking water section or health department for further instructions.

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 on toxicological properties of the contaminants, risk assessments and factors, short term (**acute**) exposure, and long term (**chronic**) exposure. You 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.



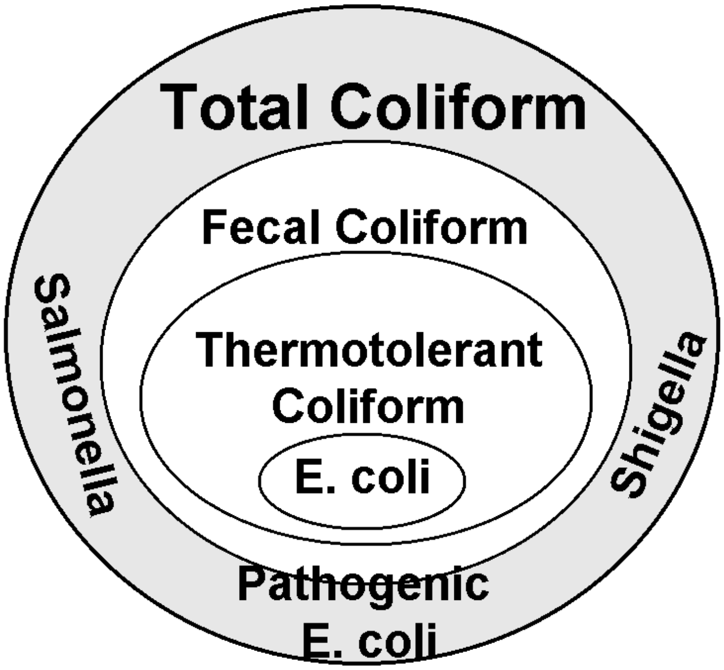
SIM PLATE METHOD

Looking under a black light to identify the presence of E. coli.

Colilert tests simultaneously detect and confirms coliform and E. coli in water samples in 24 hours or less.

Simply add the Colilert reagent to the sample, incubate for 24 hours, and read results.

Colilert is easy to read, as positive coliform samples turn yellow or blue, and when E. coli is present, samples fluoresce under UV light.



FECAL COLIFORM BACTERIA COLONIES
(Per 100 Milliliters)

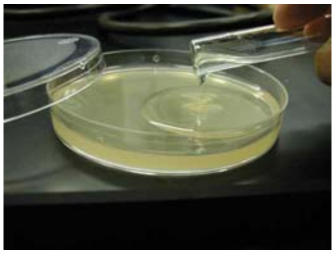
Heterotrophic Plate Count - Introduction

Heterotrophic organisms utilize organic compounds as their carbon source (food or substrate). In contrast, autotrophic organisms use inorganic carbon sources. The Heterotrophic Plate Count provides a technique to quantify the bacteriological activity of a sample. The R2A agar provides a medium that will support a large variety of heterotrophic bacteria. After an incubation period, a bacteriological colony count provides an estimate of the concentration of heterotrophs in the sample of interest.

Heterotrophic Plate Count (**HPC**) --- formerly known as the standard plate count, is a procedure for estimating the number of live heterotrophic bacteria and measuring changes during water treatment and distribution in water or in swimming pools. Colonies may arise from pairs, chains, clusters, or single cells, all of which are included in the term "*colony-forming units*" (CFU).

Method:

There are three methods for standard plate count:



1. **Pour Plate Method**
The colonies produced are relatively small and compact, showing less tendency to encroach on each other than those produced by surface growth. On the other hand, submerged colonies often are slower growing and are difficult to transfer.
2. **Spread Plate Method**
All colonies are on the agar surface where they can be distinguished readily from particles and bubbles. Colonies can be transferred quickly, and colony morphology can be easily discerned and compared to published descriptions. See next page
3. **Membrane Filter Method**
This method permits testing large volumes of low-turbidity water and is the method of choice for low-count waters.

Material

- i) Apparatus
  - Glass rod
  - Erlenmeyer flask
  - Graduated Cylinder
  - Pipette
  - Petri dish
  - Incubator
- ii) Reagent and sample
  - Reagent-grade water
  - Nutrient agar
  - Sample

Procedure*

1. Boil mixture of nutrient agar and nutrient broth for 15 minutes, then cool for about 20 minutes.
2. Pour approximately 15 ml of medium in each Petri dish, let medium solidify.

3. Pipette 0.1 ml of each dilution onto surface of pre-dried plate, starting with the highest dilution.
4. Distribute inoculum over surface of the medium using a sterile bent glass rod.
5. Incubate plates at 35°C for 48h.
6. Count all colonies on selected plates promptly after incubation, consider only plates having 30 to 300 colonies in determining the plate count.
*Duplicate samples

Computing and Reporting
Compute bacterial count per milliliter by the following equation:
CFU/ml = colonies counted / actual volume of sample in dish a)If there is no plate with 30 to 300 colonies, and one or more plates have more than 300 colonies, use the plate(s) having a count nearest 300 colonies.
b) If plates from all dilutions of any sample have no colony, report the count as less than 1/actual volume of sample in dish estimated CFU/ml.
c) Avoid creating fictitious precision and accuracy when computing CFU by recording only the first two left-hand digits.

Heterotrophic Plate Count (Spread Plate Method)

Laboratory Equipment Needed
100 x 15 Petri Dishes
Turntable
Glass Rods: Bend fire polished glass rod 45 degrees about 40 mm from one end. Sterilize before using.
Pipette: Glass, 1.1 mL. Sterilize before using.
Quebec Colony Counter
Hand Tally Counter

Reagents
1) R2A Agar: Dissolve and dilute 0.5 g of yeast extract, 0.5 g of proteose peptone No. 3, 0.5 g of casamino acids, 0.5 g of glucose, 0.5 g of soluble starch, 0.3 g of dipotassium hydrogen phosphate, 0.05 g of magnesium sulfate heptahydrate, 0.3 g of sodium pyruvate, 15.0 g of agar to 1 L. Adjust pH to 7.2 with dipotassium hydrogen phosphate ***before adding agar***. Heat to dissolve agar and sterilize at 121 C for 15 minutes.

2) Ethanol: As needed for flame sterilization.

Preparation of Spread Plates
Immediately after agar sterilization, pour 15 mL of R2A agar into sterile 100 x 15 Petri dishes; let agar solidify. Pre-dry plates inverted so that there is a 2 to 3 g water loss overnight with the lids on. Use pre-dried plates immediately or store up to two weeks in sealed plastic bags at 4°C.

Sample Preparation
Mark each plate with sample type, dilution, date, and any other information before sample application.

Prepare at least duplicate plates for each volume of sample or dilution examined. Thoroughly mix all samples by rapidly making about 25 complete up-and-down movements.

Sample Application
Uncover pre-dried agar plate. Minimize time plate remains uncovered. Pipette 0.1 or 0.5 mL sample onto surface of pre-dried agar plate.

Record Volume of Sample Used.
Using a sterile bent glass rod, distribute the sample over surface of the medium by rotating the dish by hand on a turntable. Let the sample be absorbed completely into the medium before incubating. Put cover back on Petri dish and invert for duration of incubation time. Incubate at 28°C for 7 days. Remove Petri dishes from incubator for counting.

Counting and Recording
After incubation period, promptly count all colonies on the plates. To count, uncover plate and place on Quebec colony counter. Use a hand tally counter to maintain count. Count all colonies on the plate, regardless of size. Compute bacterial count per milliliter by the following equation:

$$\text{CFU}/\text{mL} = \frac{\text{colonies counted}}{\text{actual volume of sample in dish, mL}}$$

To report counts on a plate with no colonies, report the count as less than one (<1) divided by the sample volume put on that plate (remember to account for any dilution of that sample).

If plates of all dilutions for a sample have no colonies, report the count as less than one (<1) divided by the largest sample volume used. Example: if 0.1 mL of a 100:1 and 10000:1 dilution of a sample both turned up with no colonies formed, the reported result would be <1 divided by the largest sample volume 0.001 mL (0.1 mL divided by 100). The final reported result for the sample is <1000 CFU per mL.

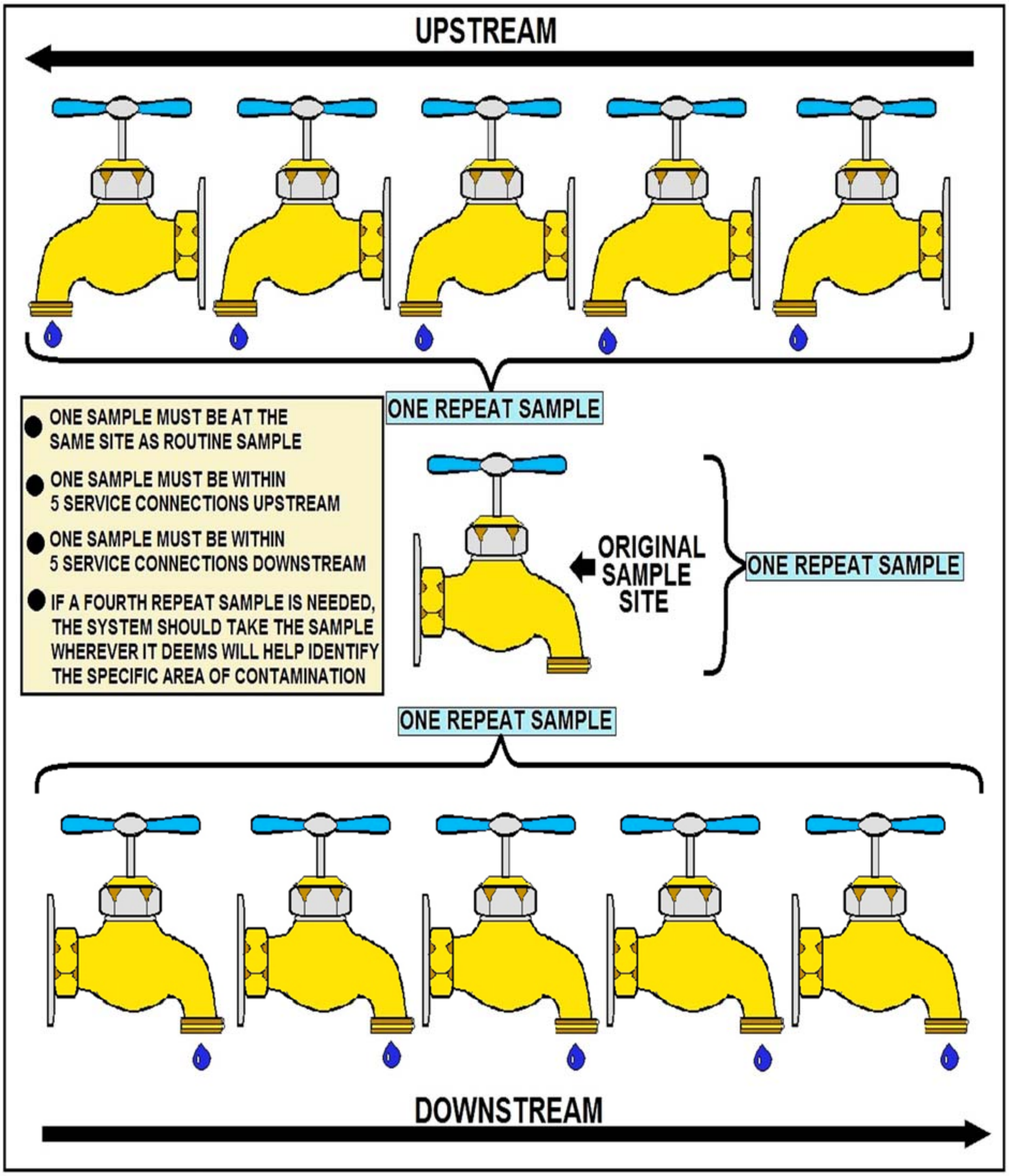
Assignment

1. Report the number of colony forming units (**CFU**) found on each plate.
2. Calculate the **CFU** per mL for each plate.
3. The aim of diluting samples is to produce a plate having 30 to 300 colonies, which plates meet these criteria. If no sample produces a plate with a count in this range, use the plate(s) with a count closest to 300. Based on these criteria, use your calculated results to report the CFU per mL for each sample.

In the conclusion of your lab report, comment on your final results for each sample type as well as the quality of your application of this analysis technique. Feel free to justify your comments using statistical analysis. Also, comment on the general accuracy of this analytical technique and the factors that affect its accuracy and or applicability.

Data Table for Samples

Sample ID	Volume of Sample, mL	Colonies Counted per plate



EXAMPLE OF WHAT HAS TO BE DONE IF A PRESENCE OF COLIFORMS ARE DETECTED WHEN CONDUCTING ROUTINE SAMPLES AT DESIGNATED SAMPLE SITES

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 24 hours after notification from your laboratory of the test results.

Certain language may be 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.

Sim Plate Method

IDEXX's SimPlate for HPC method is used for the quantification of heterotrophic plate count (HPC) in water.

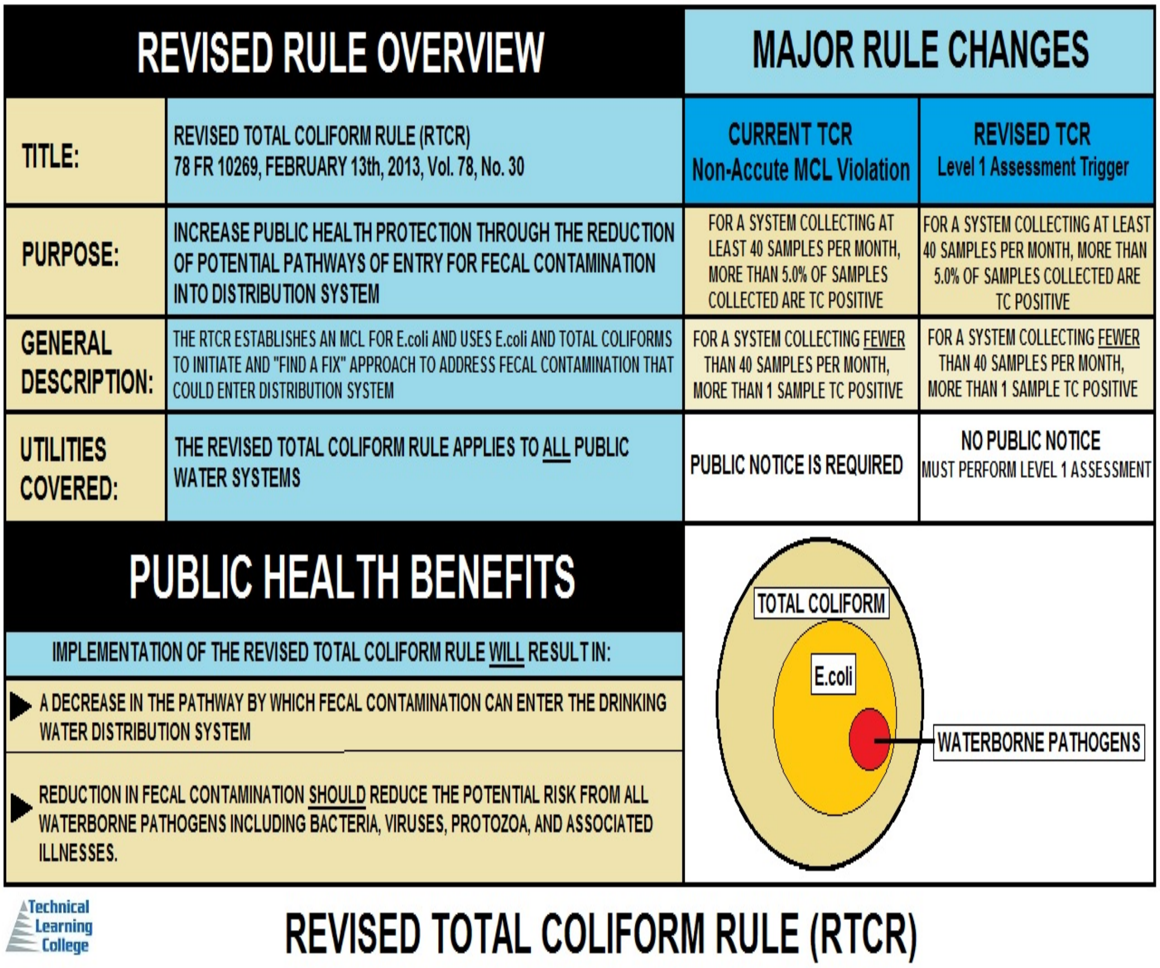
It is based on the Multiple Enzyme Technology which detects viable bacteria in water by testing for the presence of key enzymes known to be present in these little organisms.

This technique uses enzyme substrates that produce a blue fluorescence when metabolized by waterborne bacteria. The sample and media are added to a SimPlate Plate, incubated and then examined for fluorescing wells.

The number of wells corresponds to a Most Probable Number (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 the Total Plate Count Agar, incubated at 35°C for 48 hours as described in *Standard Methods for the Examination of Water and Wastewater, 19th Edition.*

Revised Total Coliform Rule (RTCR) Summary



REVISED RULE OVERVIEW		MAJOR RULE CHANGES	
TITLE:	REVISED TOTAL COLIFORM RULE (RTCR) 78 FR 10269, FEBRUARY 13th, 2013, Vol. 78, No. 30	CURRENT TCR Non-Accute MCL Violation	REVISED TCR Level 1 Assessment Trigger
PURPOSE:	INCREASE PUBLIC HEALTH PROTECTION THROUGH THE REDUCTION OF POTENTIAL PATHWAYS OF ENTRY FOR FECAL CONTAMINATION INTO DISTRIBUTION SYSTEM	FOR A SYSTEM COLLECTING AT LEAST 40 SAMPLES PER MONTH, MORE THAN 5.0% OF SAMPLES COLLECTED ARE TC POSITIVE	FOR A SYSTEM COLLECTING AT LEAST 40 SAMPLES PER MONTH, MORE THAN 5.0% OF SAMPLES COLLECTED ARE TC POSITIVE
GENERAL DESCRIPTION:	THE RTCR ESTABLISHES AN MCL FOR E.coli AND USES E.coli AND TOTAL COLIFORMS TO INITIATE AND "FIND A FIX" APPROACH TO ADDRESS FECAL CONTAMINATION THAT COULD ENTER DISTRIBUTION SYSTEM	FOR A SYSTEM COLLECTING FEWER THAN 40 SAMPLES PER MONTH, MORE THAN 1 SAMPLE TC POSITIVE	FOR A SYSTEM COLLECTING FEWER THAN 40 SAMPLES PER MONTH, MORE THAN 1 SAMPLE TC POSITIVE
UTILITIES COVERED:	THE REVISED TOTAL COLIFORM RULE APPLIES TO ALL PUBLIC WATER SYSTEMS	PUBLIC NOTICE IS REQUIRED	NO PUBLIC NOTICE MUST PERFORM LEVEL 1 ASSESSMENT

PUBLIC HEALTH BENEFITS

IMPLEMENTATION OF THE REVISED TOTAL COLIFORM RULE WILL RESULT IN:

- A DECREASE IN THE PATHWAY BY WHICH FECAL CONTAMINATION CAN ENTER THE DRINKING WATER DISTRIBUTION SYSTEM
- REDUCTION IN FECAL CONTAMINATION SHOULD REDUCE THE POTENTIAL RISK FROM ALL WATERBORNE PATHOGENS INCLUDING BACTERIA, VIRUSES, PROTOZOA, AND ASSOCIATED ILLNESSES.

Technical Learning College

REVISED TOTAL COLIFORM RULE (RTCR)

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

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

Why revise the 1989 TCR?
The 1996 amendments to the Safe Drinking Water Act [Section 1412(b) (9)] require the Administrator to review and revise, as appropriate, each national primary drinking water regulation not less often that every six years. EPA published its decision to revise the TCR in July 2003 as part of its National Primary Drinking Water Regulation (NPDWR) review.

The RTCR:

- Upholds the purpose of the 1989 TCR to protect public health by ensuring the integrity of the drinking water distribution system and monitoring for the presence of microbial contamination.
- Requires public water systems (PWSs) to meet a legal limit for E. coli, as demonstrated by required monitoring.

- Specifies the frequency and timing of required microbial testing based on population served, public water system type and source water type: ground water or surface water.

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

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

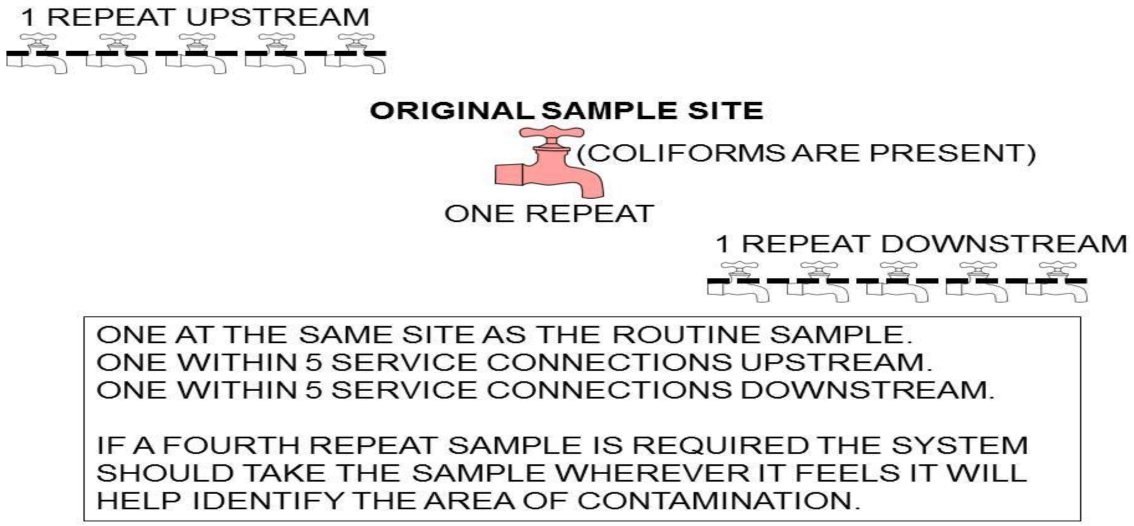
Minor Corrections to the Revised Total Coliform Rule (RTCR)
Minor corrections to the final RTCR became effective on April 28, 2014. No comments were received on the Direct Final Rule published on February 26, 2014 and the corrections therefore became effective without further notice. See the **Direct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

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

The RTCR:

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

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



ONE AT THE SAME SITE AS THE ROUTINE SAMPLE.
ONE WITHIN 5 SERVICE CONNECTIONS UPSTREAM.
ONE WITHIN 5 SERVICE CONNECTIONS DOWNSTREAM.

IF A FOURTH REPEAT SAMPLE IS REQUIRED THE SYSTEM SHOULD TAKE THE SAMPLE WHEREVER IT FEELS IT WILL HELP IDENTIFY THE AREA OF CONTAMINATION.

REPEAT SAMPLING PROCEDURES

RTCR Key Provisions *Most of this section comes from the USEPA.*

Provision Category	**Key Provisions**
Contaminant Level	Addresses the presence of total coliforms and E. coli in drinking water. For E. coli (EC), the Maximum Contaminant Level Goal (MCLG) is set at zero. The Maximum Contaminant Level (MCL) is based on the occurrence of a condition that includes routine and repeat samples. For total coliforms (TC), PWSs must conduct a Level 1 or Level 2 assessment of their system when they exceed a specified frequency of total coliform occurrences. An MCL violation or failure to take repeat samples following a routine total coliform-positive sample will trigger a Level 1 or Level 2 assessment. Any sanitary defect identified during a Level 1 or Level 2 assessment must be corrected by the PWS. These are the treatment technique requirements of the RTCR.
Monitoring	Develop and follow a sample-siting plan that designates the PWS's collection schedule. This includes location of routine and repeat water samples. Collect routine water samples on a regular basis (monthly, quarterly, annually). Have samples tested for the presence of total coliforms by a state certified laboratory. Analyze all routine or repeat samples that are total coliform positive (TC+) for E. coli. Collect repeat samples (at least 3) for each TC+ positive routine sample. For PWSs on quarterly or annual routine sampling, collect additional routine samples (at least 3) in the month after a TC+ routine or repeat sample.

RTCR Key Provisions *Most of this section comes from the USEPA.*

	Seasonal systems must monitor and certify the completion of a state-approved start-up procedures.
Level 1 and Level 2 Assessments and Corrective Actions	PWSs are required to conduct a Level 1 or Level 2 assessment if conditions indicate they might be vulnerable to contamination. PWSs must fix any sanitary defects within a required timeframe.
Reporting and Recordkeeping	PWSs are required to report certain items to their states. These reporting and recordkeeping requirements are essentially the same as under TCR. The addition to the Requirements is the Level 1 and Level 2 requirements.
Violations, Public Notification (PN) and Consumer Confidence Report (CCR)	PWSs incur violations if they do not comply with the requirements of the RTCR. The violation types are essentially the same as under the TCR with few changes. The biggest change is no acute or monthly MCL violation for total coliform positive samples only. PN is required for violations incurred. Within required timeframes, the PWS must use the required health effects language and notify the public if they did not comply with certain requirements of the RTCR. The type of PN depends on the severity of the violation. Community water systems (CWSs) must use specific language in their CCRs when they must conduct an assessment or if they incur an E. coli MCL violation.

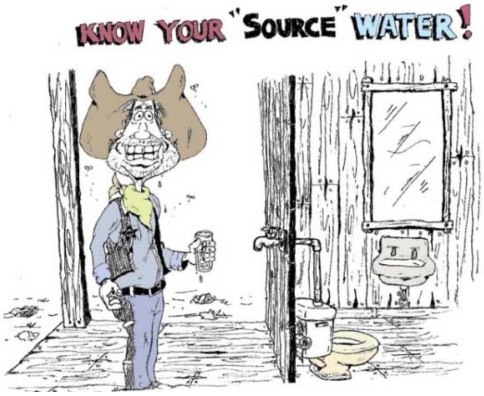
Disinfection Key

- ▶ Contact time is required
  - ▶ 99% or 2 log inactivation of crypto
  - ▶ 99.9% or 3 log inactivation of giardia lamblia cysts
  - ▶ 99.99% or 4 log inactivation of enteric viruses
- ▶ CT = Concentration of disinfectant x contact time

The chlorine residual leaving the plant must be = or > 0.2 mg/L and measurable throughout the system

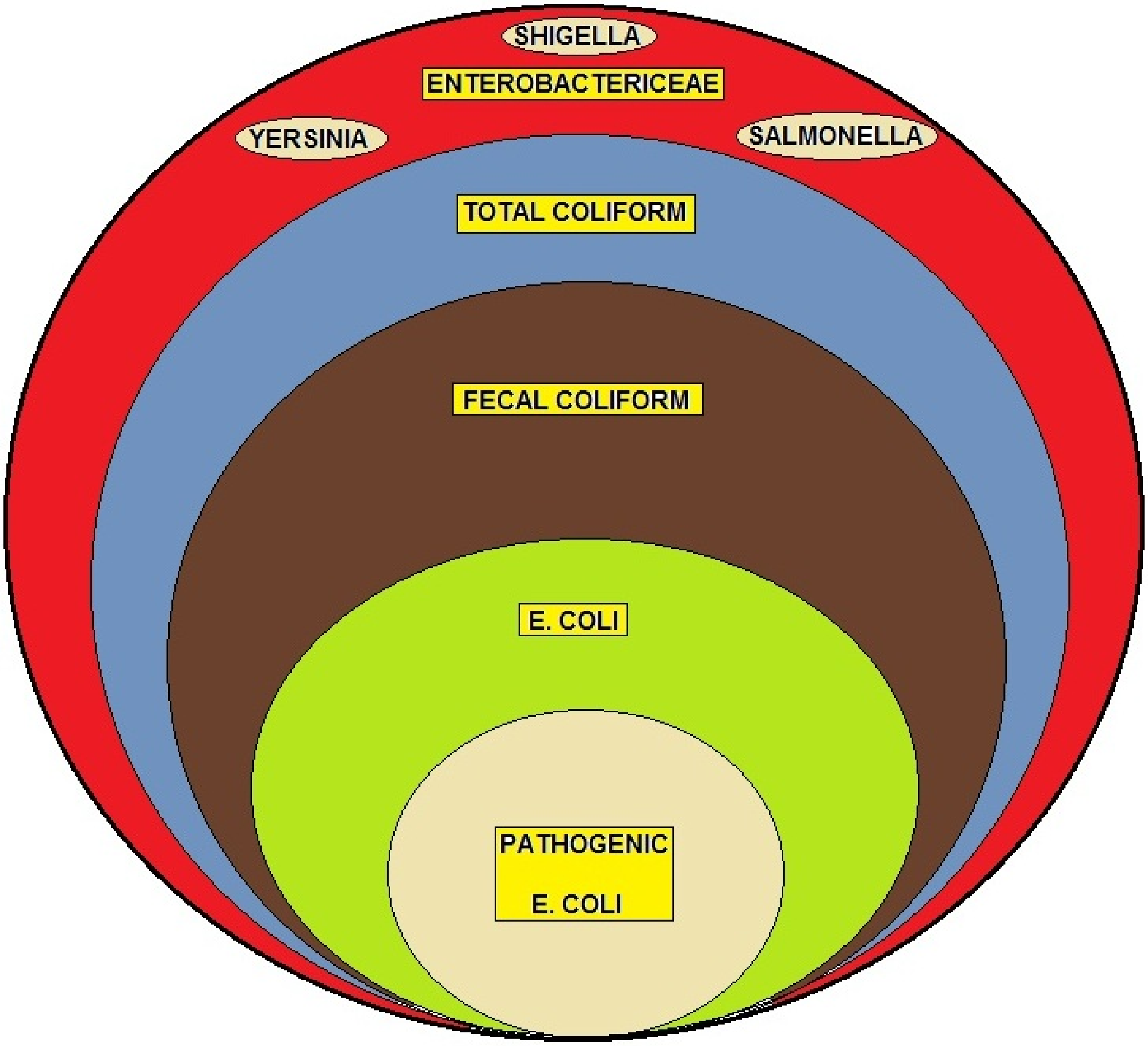
Troubleshooting Table for Bacteriological Monitoring

Problems
1. Positive Total Coliform.
2. Chlorine taste and odor.
3. Inability to maintain an adequately free chlorine residual at the furthest points of the distribution system or at dead end lines.



Possible Causes
1A. Improper sampling technique.
1B. Contamination entering distribution system.
1C. Inadequate chlorine residual at the sampling site.
1D. Growth of biofilm in the distribution system.
2A. High total chlorine residual and low free residual.
3A. Inadequate chlorine dose at treatment plant.
3B. Problems with chlorine feed equipment.
3C. Ineffective distribution system flushing program.
3D. Growth of biofilm in the distribution system.

Possible Solutions
1A. Check distribution system for low-pressure conditions, possibly due to line breaks or excessive flows that may result in a backflow problem.
1B. Insure that all staff are properly trained in sampling and transport procedures as described in the TCR.
1C. Check the operation of the chlorination feed system. Refer to issues described in the sections on pumps and hypochlorination systems. Insure that residual test is being performed properly.
1D. Thoroughly flush effected areas of the distribution system. Superchlorination may be necessary in severe cases.
2A. The free residual should be at least 85% of the total residual. Increase the chlorine dose rate to get past the breakpoint in order to destroy some of the combined residual that causes taste and odor problems. Additional system flushing may also be required.
3A. Increase chlorine feed rate at point of application.
3B. Check operation of chlorination equipment.
3C. Review distribution system flushing program and implement improvements to address areas of inadequate chlorine residual.
3D. Increase flushing in area of biofilm problem.



COLIFORM BACTERIA SUB-SET #1
INDICATOR ORGANISMS

Waterborne Pathogen Section - Introduction

Bacteria, viruses, and protozoans that cause disease are known as pathogens. Most waterborne 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.

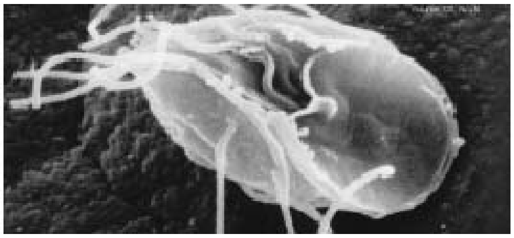
Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral (or feces-to-mouth) route. Pathogens may get into water and spread when infected humans or animals pass the bacteria, viruses, and protozoa in their stool. For another person 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 and a safe distribution system can ensure eliminating the spread of waterborne 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 for *Giardia* at these facilities.



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.

Chain of Transmission

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

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

The pathogens in the water must enter the water system's intake 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; then illness (disease) will occur.

Emerging Waterborne Pathogens

Emerging waterborne pathogens constitute a major health hazard in both developed and developing nations. A new dimension to the global epidemiology of cholera-an ancient scourge-was provided by the emergence of Vibrio cholerae O139. Also, waterborne enterohemorrhagic Escherichia coli (E. coli O157:H7), although regarded as a problem of the industrialized west, has recently caused outbreaks in Africa.

Outbreaks of chlorine-resistant Cryptosporidium in the US have motivated water authorities to reassess the adequacy of current water-quality regulations. Of late, a host of other organisms, such as hepatitis viruses (including hepatitis E virus), Campylobacter jejuni, microsporidia, cyclospora, Yersinia enterocolitica, calciviruses and environmental bacteria like Mycobacterium spp, aeromonads, Legionella pneumophila and multidrug-resistant Pseudomonas aeruginosa have been associated with water-borne illnesses.

The protection and enhancement of our nation's water quality remains a chief concern of the U.S. Environmental Protection Agency. The Office of Research and Development is committed, through the extensive waterborne disease research efforts earlier described, to ensure that the most effective and efficient methods are developed to identify, detect, and inactivate/remove pathogens that may be present in our drinking water supplies.

Life cycles, mechanisms of infection, protective or dormant states, emergence of disinfection resistant variants, optimal pathogen removal techniques, regrowth in distribution lines…all are areas that must be investigated and understood to afford the water quality safeguards that are so often taken for granted. The successes and failures of these research efforts, relayed to the public and appropriate federal, state, and local agencies, have helped to ensure safe drinking water.

More on this subject in the Microorganism Appendix. **Hyperlink to the Glossary and Appendix** *http://www.abctlc.com/downloads/PDF/WTGlossary.pdf*

Primary Waterborne Diseases Section - Alphabetical Order

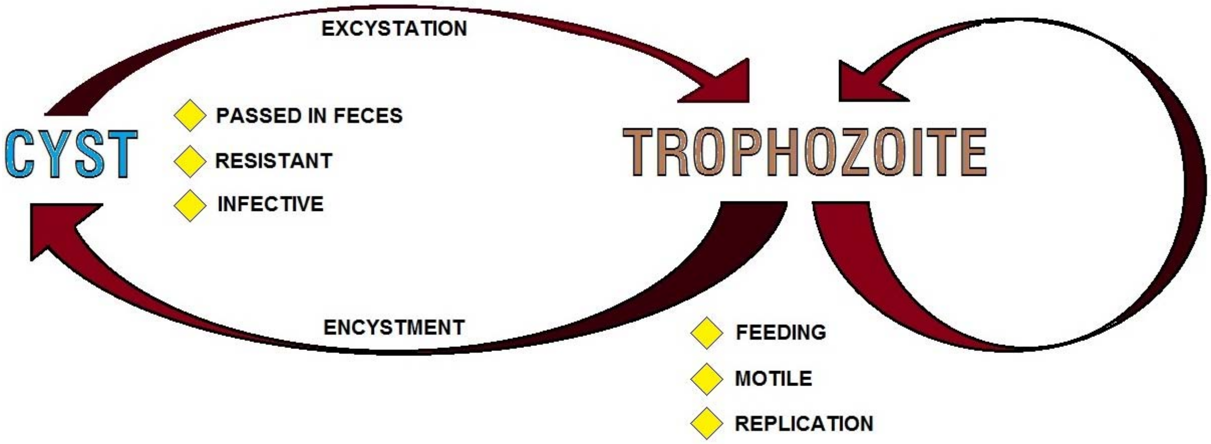
Campylobacter
Campylobacter, the basics. It is a bacterium. It causes diarrheal illness. Campylobacter is primarily associated with poultry, animals, and humans.

Campylobacter prevention: Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.

Cryptosporidium
Cryptosporidium, the basics. It is a parasite. It causes diarrheal illness known as cryptosporidiosis. It is typically associated with animals and humans, and it can be acquired through consuming fecally contaminated food, contact with fecal contaminated soil and water.

Cryptosporidium, prevention: Prevention strategies for this pathogen include source protection. A CT value of 9,600 is required when dealing with fecal accidents. CT equals a concentration, in parts per million, while time equals a contact time in minutes. Cryptosporidium can also be prevented or eliminated by boiling water for one minute.

Filtration with an "*absolute*" pore size of one micron or smaller can eliminate Cryptosporidium, and reverse osmosis is known to be effective as well.



TYPICAL FECAL-ORAL LIFE CYCLE DIAGRAM

E-Coli Section
Escherichia coli. Escherichia coli O157:H7, the basics. It's a bacteria. There are several pathogenic strains of Escherichia coli, which are classified under enterovirulent E. coli. They are enterohemorrhagic, enteroinvasive, enterotoxigenic, enteropathogenic, and enteroaggregative causes diarrheal illness, and it's classified as an enterohemorrhagic E. coli. In its most severe form, it can cause hemorrhagic colitis. The reservoir for this bacteria are cattle, deer, goats, and sheep. Humans can also be a reservoir. It is typically associated with contaminated food and water.

E. coli O157:H7 prevention: Prevention strategies for this pathogen include source protection, halogenation of water, or boiling water for one minute.

Giardia
Giardia, the basics. It is a parasite. It causes diarrheal illness known as giardiasis. It is typically associated with water. It is the most common pathogen in waterborne outbreaks. It can also be found in soil and food, and humans and animals are the reservoir for this pathogen.

Giardia prevention: Prevention strategies for this pathogen include source protection; filtration, coagulation, and halogenation of drinking water.

Hepatitis A
Hepatitis A, the basics. It is a virus. It causes inflammation of the liver, and the reservoir for Hepatitis A virus is humans.

Hepatitis A, Prevention: Prevention strategies for this pathogen include source protection and adequate disinfection. Fecal matter can protect Hepatitis A virus from chlorine. Additionally, Hepatitis A virus is resistant to combined chlorines, so it is important to have an adequate free chlorine residual.

Legionella
Legionella, the basics. It is a bacterium. It causes a respiratory illness known as Legionellosis. There are two illnesses associated with Legionellosis: the first, Legionnaire's disease, which causes a severe pneumonia, and the second, Pontiac fever, which is a non-pneumonia illness; It is typically an influenza-like illness, and it's less severe. Legionella is naturally found in water, both natural and artificial water sources.

Legionella, prevention: Maintaining hot water systems at or above 50 degrees Centigrade and cold water below 20 degrees Centigrade can prevent or control the proliferation of Legionella in water systems. Hot water in tanks should be maintained between 71 and 77 degrees Centigrade.

Proper recreational water system maintenance and disinfection can prevent the proliferation of Legionella in recreational water systems. It is important to prevent water stagnation. This can be accomplished by eliminating dead ends in distribution systems and in recreational water systems. Additionally, preventing biofilm development is important to control this particular pathogen in water systems.

Norovirus
Norovirus, the basics. It is a virus. It causes diarrheal illness, and humans are the reservoir for this virus.

Norovirus, prevention: Prevention strategies for this pathogen include source protection.

Pseudomonas
Pseudomonas, the basics. It is a bacterium. It is caused by dermal contact with water. It can cause dermatitis, which is an inflammation of the skin, or it can cause otitis, which is an infection of the ear. Pseudomonas is typically associated with soil and water.

Pseudomonas prevention: Proper maintenance and disinfection of recreational water systems is important in preventing Pseudomonas.

Salmonella Typhi
Salmonella typhi, the basics. It is a bacterium. It causes diarrheal illness, also known as typhoid fever. Humans are the reservoir for this pathogen. Salmonella species, the basics. It is a bacterium. It causes diarrheal illness known as salmonellosis.

Humans and animals are the reservoir, and it has typically associated with contaminated food and water. Salmonella species, prevention. Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.

Salmonella typhi, prevention: Prevention strategies for this pathogen include source protection, chlorination or halogenation of water, and boiling water for one minute.

Schistosomatidae
Schistosomatidae, the basics. It is a parasite. It is acquired through dermal contact, cercarial dermatitis. It is commonly known as swimmer's itch. The reservoir for this pathogen are aquatic snails and birds.

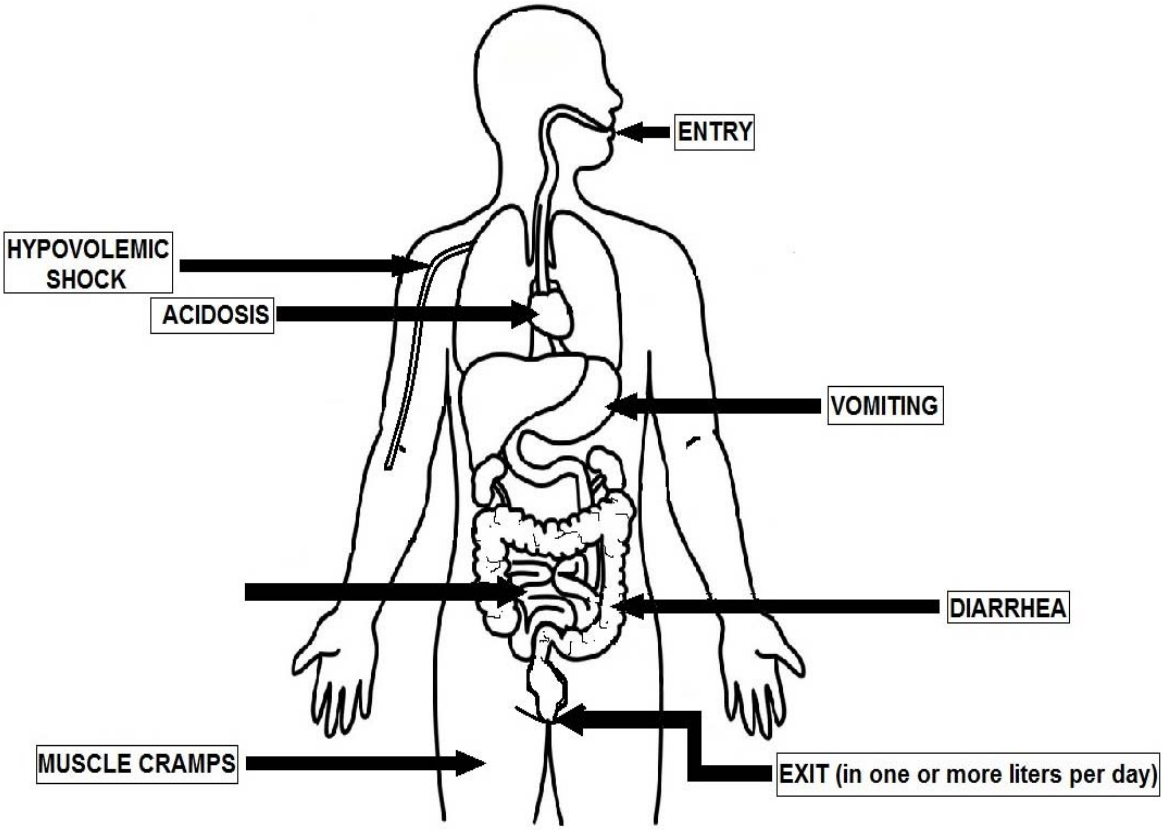
Schistosomatidae prevention: Prevention strategies for this pathogen include eliminating snails with a molluscicide or interrupting the life cycle of the parasite by treating birds with an antihelmetic drug.

Shigella Species
Shigella species, the basics. It is a bacterium. It causes diarrheal illness known as shigellosis. Humans and primates are the reservoir for this pathogen. Shigella species, in the United States two-thirds of the shigellosis in the U.S. is caused by Shigella sonnei, and the remaining one-third is caused by Shigella flexnieri. In developing countries, Shigella dysenteriae is the primary cause of illness associated with this pathogen.

Shigella species prevention: Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.

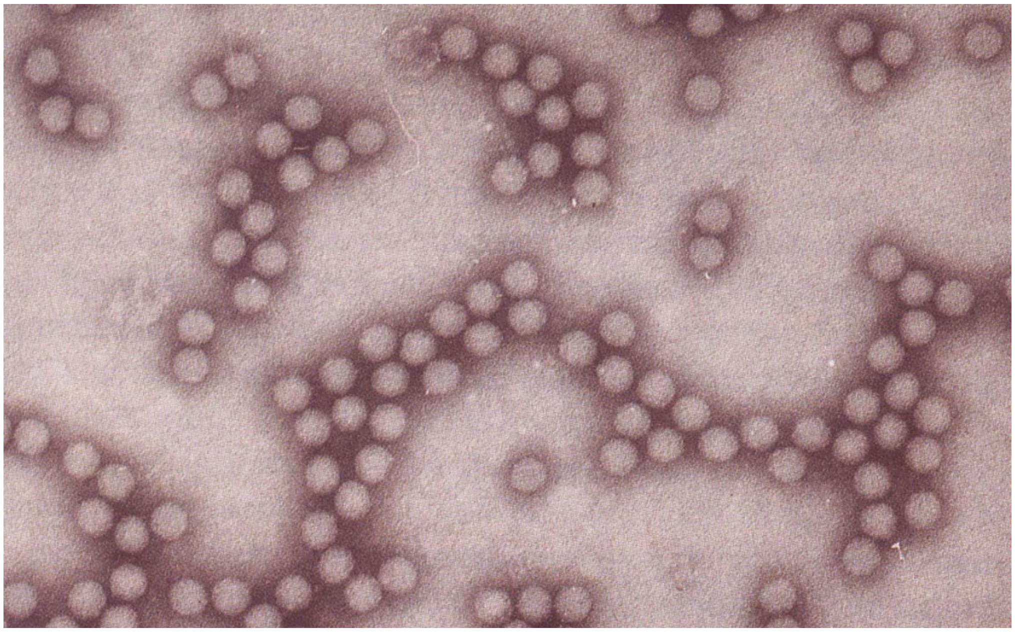
Vibrio Cholerae
Vibrio cholerae, the basics. It is a bacterium. It causes diarrheal illness, also known as cholera. It is typically associated with aquatic environments, shell stocks, and human. Vibrio cholerae has also been associated with ship ballast water, and there will be a discussion later on in this presentation of an outbreak associated with ship ballast water.

Vibrio cholerae prevention: Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.



CHOLERA DIAGRAM

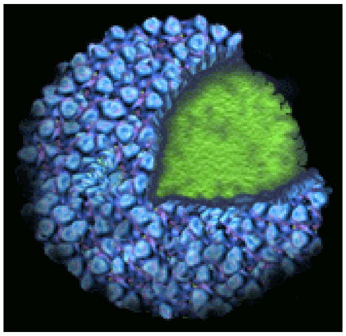
Viral-Caused Diseases



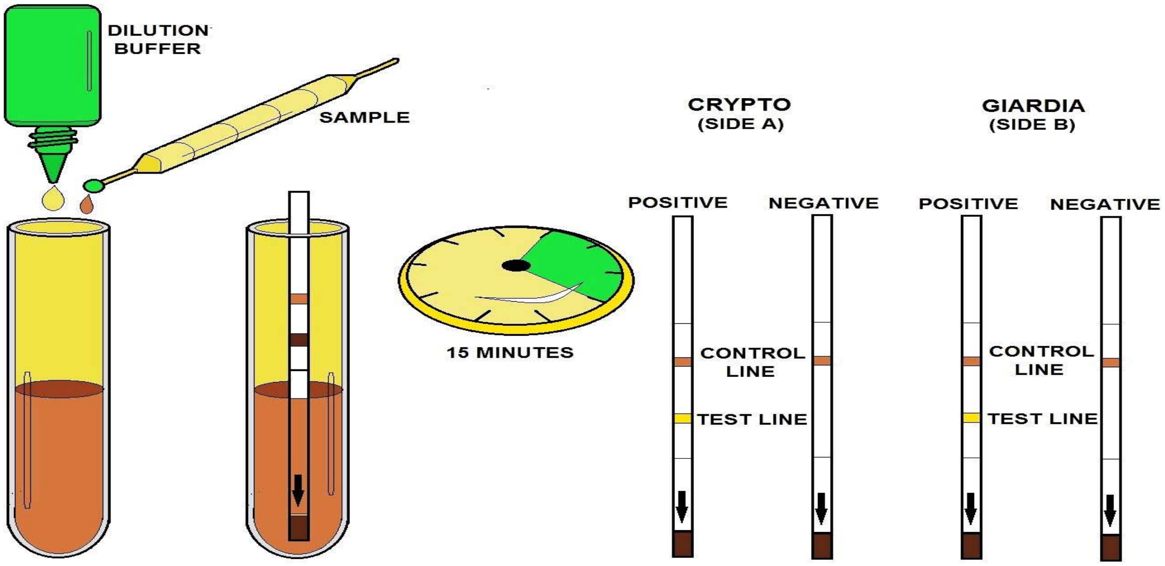
Hepatitis A is an example of a common viral disease that may be transmitted through water.

The onset is usually abrupt, with fever, malaise, loss of appetite, nausea and abdominal discomfort followed within a few days by jaundice. The disease varies in severity from a mild illness lasting one to two weeks to a severely disabling disease lasting several months (rare). The incubation period is 15-50 days and averages 28-30 days. Hepatitis A outbreaks have been related to fecally contaminated water; food contaminated by infected food handlers, including sandwiches and salads that are not cooked or are handled after cooking; and raw or undercooked mollusks harvested from contaminated waters.

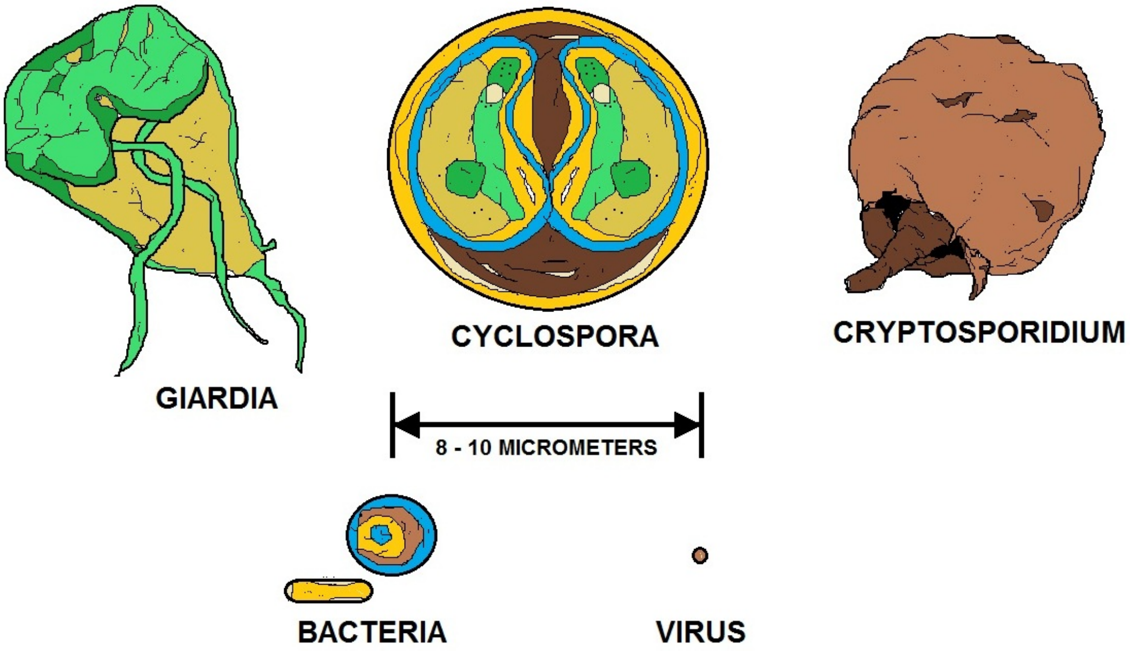
Aseptic meningitis, polio and viral gastroenteritis (**Norwalk agent**) are other viral diseases that can be transmitted through water. Most viruses in drinking water can be inactivated by chlorine or other disinfectants.



Norwalk Agent



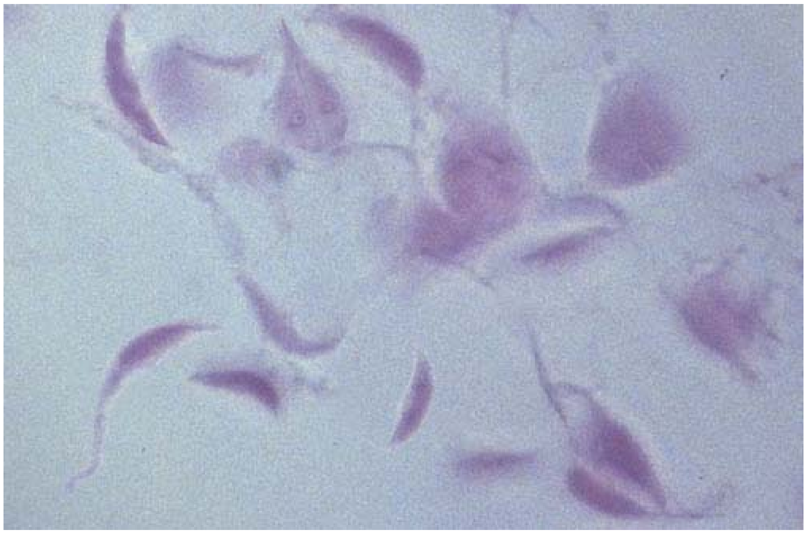
CRYPTO-GIARDIA DUO-STRIP



COMPARATIVE SIZES OF PROTOZOAN PARASITES

Protozoan Caused Diseases

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



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

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

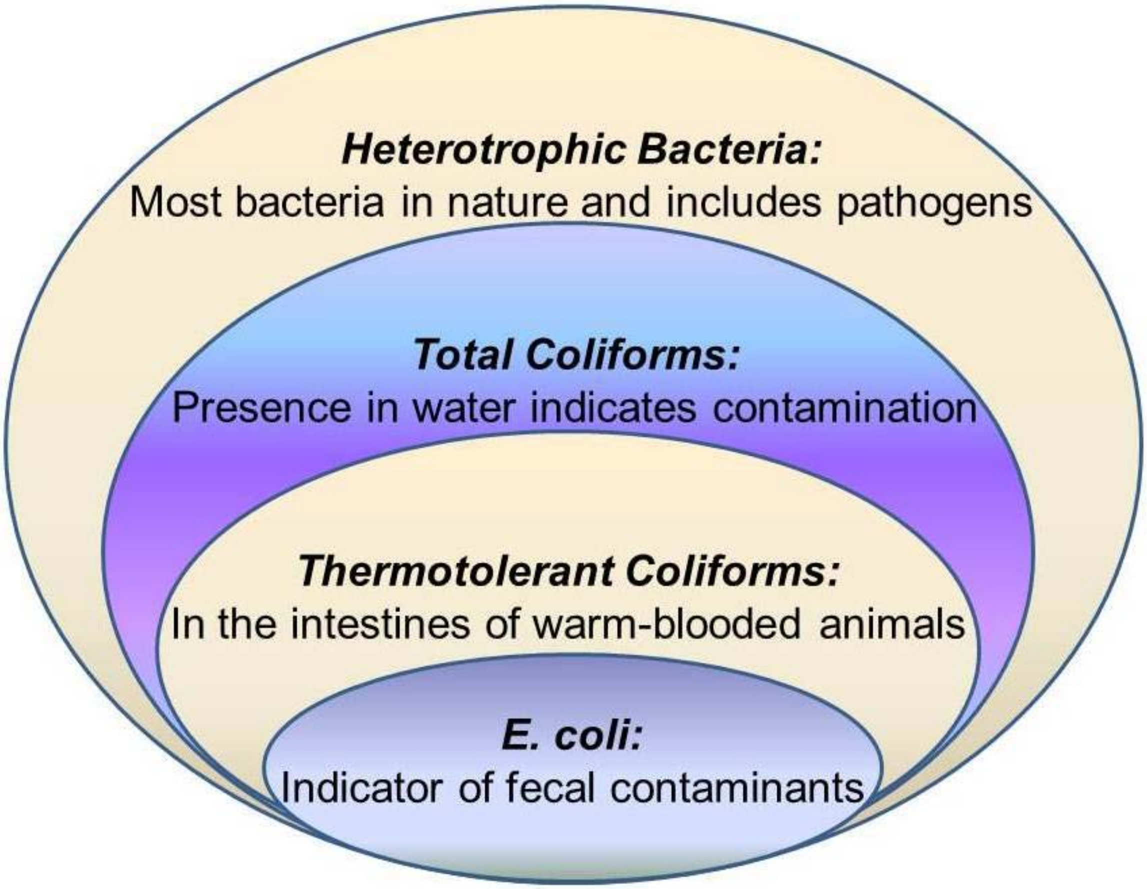
Cryptosporidiosis

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*** *lives mostly in young Human feces*, (Diarrhea or vomiting children)

Norwalk-like viruses *Human feces*; also, shellfish; lives in polluted waters (Diarrhea and vomiting)
Salmonellosis ***Salmonella*** (bacterium) *Animal or human feces* (Diarrhea or vomiting)

Escherichia *coli--* ***E. coli O1* 57:H7, *Other E. coli organisms*** (bacterium) *Human feces* (Symptoms vary with type caused; gastroenteritis)

Typhoid ***Salmonella typhi*** (bacterium) *Human feces, urine* (Inflamed intestine, enlarged spleen, high temperature— sometimes fatal)

Shigellosis ***Shigella*** (bacterium) *Human feces* (Diarrhea)

Cholera ***Vibrio choleras*** (bacterium) *Human feces; also, shellfish; lives in many coastal waters* (Vomiting, severe diarrhea, rapid dehydration, mineral loss —high mortality.)

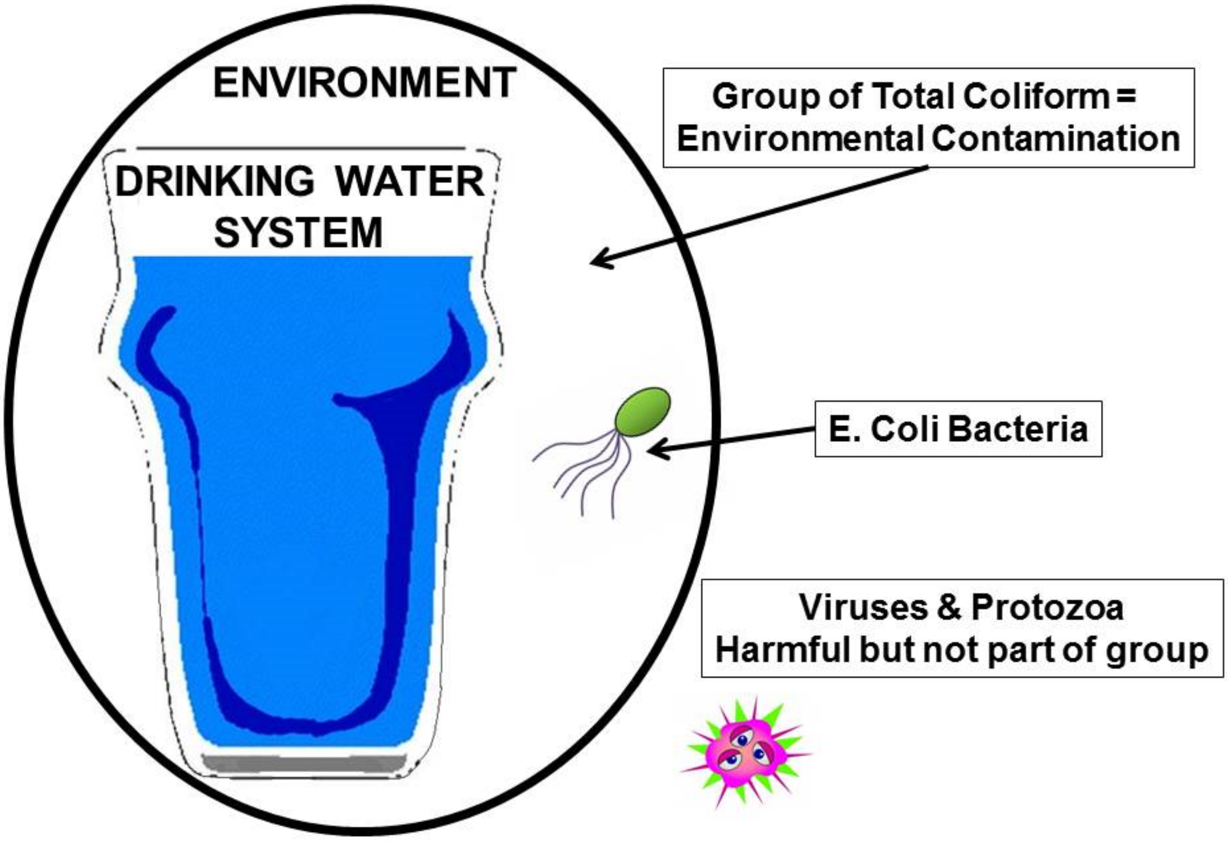
Hepatitis A **Hepatitis A** virus *Human feces; shellfish grown*; *lives in polluted waters* (fever Yellowed skin, enlarged liver, vomiting, weight loss, abdominal pain — low mortality, lasts up to four months)

Amebiasis ***Entamoeba histolytica*** *Human feces* (Mild diarrhea, dysentery, (protozoan) extra intestinal infection)

Giardiasis ***Giardia lamblia*** (protozoan) *Animal or human feces* (Diarrhea, cramps, nausea, and general weakness — lasts one week to months)

Cryptosporidiosis ***Cryptosporidium parvum*** *Animal or human feces* (Diarrhea, stomach pain — lasts (protozoan) days to weeks)

E. Coli O157



GROUP OF TOTAL COLIFORM BACTERIA

Pathogen Summary

Factors in Chlorine Disinfection: Concentration and Contact Time

In an attempt to establish more structured operating criteria for water treatment disinfection, the CXT concept came into use in 1980. Based on the work of several researchers, CXT values [final free chlorine concentration (mg/L) multiplied by minimum contact time (minutes)], offer water operators guidance in computing an effective combination of chlorine concentration and chlorine contact time required to achieve disinfection of water at a given temperature.

The CXT formula demonstrates that if an operator chooses to decrease the chlorine concentration, the required contact time must be lengthened. Similarly, as higher strength chlorine solutions are used, contact times may be reduced (Connell, 1996).

Detection and investigation of waterborne disease outbreaks is the primary responsibility of local, state and territorial public health departments, with voluntary reporting to the CDC. The CDC and the U.S. Environmental Protection Agency (EPA) collaborate to track waterborne disease outbreaks of both microbial and chemical origins. Data on drinking water and recreational water outbreaks and contamination events have been collected and summarized since 1971.

While useful, statistics derived from surveillance systems do not reflect the true incidence of waterborne disease outbreaks because many people who fall ill from such diseases do not consult medical professionals.

For those who do seek medical attention, attending physicians and laboratory and hospital personnel are required to report diagnosed cases of waterborne illness to state health departments. Further reporting of these illness cases by state health departments to the CDC is voluntary, and statistically more likely to occur for large outbreaks than small ones.

Despite these limitations, surveillance data may be used to evaluate the relative degrees of risk associated with different types of source water and systems, problems in current technologies and operating conditions, and the adequacy of current regulations. (Craun, Nwachuku, Calderon, and Craun, 2002).

Understanding Cryptosporidiosis

Cryptosporidium is an emerging parasitic protozoan pathogen because its transmission has increased dramatically over the past two decades. Evidence suggests it is newly spread in increasingly popular day-care centers and possibly in widely distributed water supplies, public pools and institutions such as hospitals and extended-care facilities for the elderly.

Recognized in humans largely since 1982 and the start of the AIDS epidemic, Cryptosporidium is able to cause potentially life-threatening disease in the growing number of immunocompromised patients.

Cryptosporidium was the cause of the largest reported drinking water outbreak in U.S. history, affecting over 400,000 people in Milwaukee in April 1993. More than 100 deaths are attributed to this outbreak. Cryptosporidium remains a major threat to the U.S. water supply (Ibid.).

The EPA is developing new drinking water regulations to reduce Cryptosporidium and other resistant parasitic pathogens. Key provisions of the Long Term 2 Enhanced Surface Water

Treatment Rule include source water monitoring for Cryptosporidium; inactivation by all unfiltered systems; and additional treatment for filtered systems based on source water

Cryptosporidium concentrations. EPA will provide a range of treatment options to achieve the inactivation requirements. Systems with high concentrations of Cryptosporidium in their source water may adopt alternative disinfection methods (e.g., ozone, UV, or chlorine dioxide).

However, most water systems are expected to meet EPA requirements while continuing to use chlorination. Regardless of the primary disinfection method used, water systems must continue to maintain residual levels of chlorine-based disinfectants in their distribution systems.

Understanding Giardia lamblia

Giardia lamblia, discovered approximately 20 years ago, is another emerging waterborne pathogen. This parasitic microorganism can be transmitted to humans through drinking water that might otherwise be considered pristine. In the past, remote water sources that were not affected by human activity were thought to be pure, warranting minimal treatment. However, it is known now that all warm-blooded animals may carry Giardia and that beaver are prime vectors for its transmission to water supplies.

There is a distinct pattern to the emergence of new pathogens. First, there is a general recognition of the effects of the pathogen in highly susceptible populations such as children, cancer patients and the immunocompromised.

Next, practitioners begin to recognize the disease and its causative agent in their own patients, with varied accuracy. At this point, some may doubt the proposed agent is the causative agent, or insist that the disease is restricted to certain types of patients.

Finally, a single or series of large outbreaks result in improved attention to preventive efforts. From the 1960’s to the 1980’s this sequence of events culminated in the recognition of Giardia lamblia as a cause of gastroenteritis (Lindquist, 1999).

Respiratory Protection Section - Chapter 5

Conditions for Respirator Use
Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit.

However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of chlorine exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should only use respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

Respiratory Protection Program
Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's Respiratory Protection Standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning.

The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the latest edition of the NIOSH Respirator Decision Logic [NIOSH 1987b] and the NIOSH Guide to Industrial Respiratory Protection [NIOSH 1987a].

Personal Protective Equipment
Workers should use appropriate personal protective clothing and equipment that must be carefully selected, used, and maintained to be effective in preventing skin contact with chlorine. The selection of the appropriate personal protective equipment (**PPE**) (e.g., gloves, sleeves, encapsulating suits) should be based on the extent of the worker's potential exposure to chlorine.

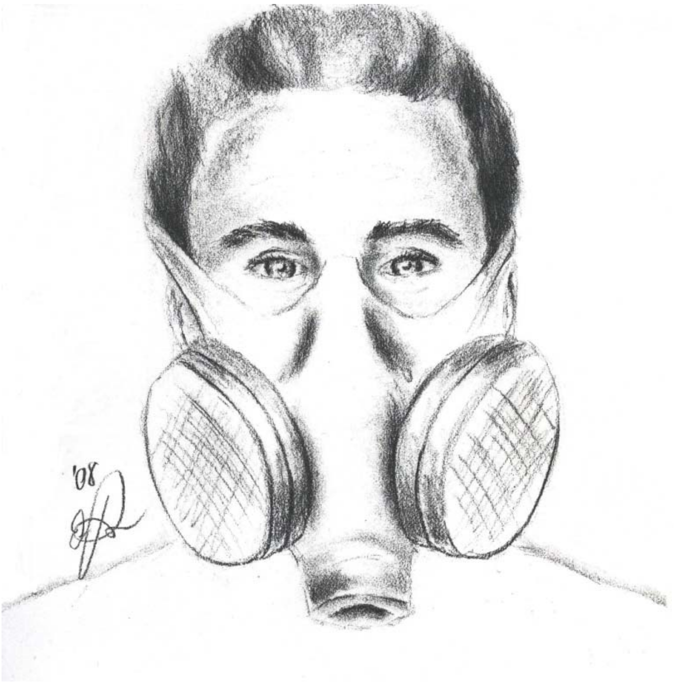
The resistance of various materials to permeation by both chlorine liquid and chlorine gas is shown below:

Material Breakthrough Time (hr) Chlorine Liquid Responder
Chlorine gas butyl rubber neoprene Teflon viton saranex barricade chemrel responder trellchem HPS nitrile rubber H (**PE/EVAL**) polyethylene polyvinyl chloride. Material is estimated (but not tested) to provide at least four hours of protection. Not recommended, degradation may occur.

To evaluate the use of these PPE materials with chlorine, users should consult the best available performance data and manufacturers' recommendations. Significant differences have been demonstrated in the chemical resistance of generically similar PPE materials (e.g., butyl) produced by different manufacturers. In addition, the chemical resistance of a mixture may be significantly different from that of any of its neat components.

Any chemical-resistant clothing that is used should be periodically evaluated to determine its effectiveness in preventing dermal contact. Safety showers and eye wash stations should be located close to operations that involve chlorine.

Splash-proof chemical safety goggles or face shields (20 to 30 cm long, minimum) should be worn during any operation in which a solvent, caustic, or other toxic substance may be splashed into the eyes.



In addition to the possible need for wearing protective outer apparel (e.g., aprons, encapsulating suits), workers should wear work uniforms, coveralls, or similar full-body coverings that are laundered each day.

Employers should provide lockers or other closed areas to store work and street clothing separately. Employers should collect work clothing at the end of each work shift and provide for its laundering. Laundry personnel should be informed about the potential hazards of handling contaminated clothing and instructed about measures to minimize their health risk.

Protective clothing should be kept free of oil and grease and should be inspected and maintained regularly to preserve its effectiveness. Protective clothing may interfere with the body's heat dissipation, especially during hot weather or during work in hot or poorly ventilated work environments.

SCBA Fit Test

Respiratory Protection Breakdown

General

In the Respiratory Protection program, hazard assessment and selection of proper respiratory PPE is conducted in the same manner as for other types of PPE. In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination.

This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used. References: OSHA Standards ***Respiratory Protection*** (**29 CFR 1910.134**)

Why Respirators Are Needed

Respirators protect against the inhalation of dangerous substances (vapors, fumes, dust, gases). They can also provide a separate air supply in a very hazardous situation.

Some of the health hazards that respirators prevent include:

- ***Lung damage***
- ***Respiratory diseases***
- ***Cancer and other illnesses***.

Respiratory Protection Responsibilities

The employer is responsible for:

- Providing training in the use and care of respirators.
- Ensuring that equipment is adequate, sanitary, and reliable.
- Allowing employees to leave area if ill, for breaks, and to obtain parts.
- Fit testing.
- Providing an annual medical evaluation.
- Providing a powered air-purifying respirator (**PAPR**) if an employee cannot wear a tight-fitting respirator.

The employee is responsible for:

- Properly using respirators.
- Maintaining respirator properly.
- Reporting malfunctions.
- Reporting medical changes.

Selection of Proper Respiratory Protection

When choosing the correct respiratory protection for your work environment, it is important to consider:

- Identification of the substance or substances for which respiratory protection is necessary.
- A substance's Safety Data Sheet (formerly MSDS) (**SDS**) (it will state which type of respirator is most effective for the substance).
- Activities of the workers.
- Hazards of each substance and its properties.
- Maximum levels of air contamination expected.
- Probability of oxygen deficiency.
- Period of time workers will need to use the respiratory protection devices.
- Capabilities and physical limitations of the device used.

Types of Respirators The following is a description of different types of respirators.

Commonly Used Respirators (*Air Purifying*)

- **Disposable Dust masks** are worn over the nose and mouth to protect the respiratory system from certain nuisance dusts, mists, etc. They can only provide protection against particular contaminants as specified by the manufacturer (e.g., general dust, fiberglass, etc.). These dust masks cannot be fit tested, and are generally single use. They are not recognized as respiratory protection and may not be worn if a potential for overexposure exists. They are not included in most companies' Respiratory Protection Program.

- **Half-Face Respirators** with interchangeable filter cartridges can protect the respiratory system from hazardous dusts, fumes, mists, etc. They can only provide protection against certain contaminants up to limited concentrations specified by the manufacturer for the particular cartridge type used (e.g., toluene, acetone). These generally operate under negative pressure within the respirator which is created by the wearer's breathing through the filter cartridges. As the protection is only gained if there is a proper seal of the respirator face piece, this type requires fit testing prior to respirator assignment and a fit check prior to each use.

- **Full-Face Respirators** operate under the same principle and requirements as the half-face type, however, they offer a better facepiece fit and also protect the wearer's eyes from particularly irritating gases or vapors.

- **Full-face, helmet or hood type powered air purifying respirators** (**PAPRs**) operate under positive pressure inside the facepiece using a battery operated motor blower assembly to force air through a filter cartridge into the wearer's breathing zone. Use of these respirators is also subject to the manufacturers' guidelines.

Less Commonly Used Types Respirators (Air Supplying)

- **Air-Line Respirators** supply clean air through a small diameter hose from a compressor or compressed air cylinders. The wearer must be attached to the hose at all times, which limits mobility. Use of these respirators is subject to the manufacturers' guidelines.
- **Self-Contained Breathing Apparatus** (**SCBA**) respirators supply clean air from a compressed air tank carried on the back of the wearer. These types of respirators are highly mobile and are used primarily for emergency response or rescue work, since only a limited amount of air can be supplied by a single tank, generally 20-60 minutes. Units must be thoroughly inspected on a monthly basis and written records must be kept of all inspections, operator training, etc. Use of these respirators is subject to the manufacturer's guidelines

Basic Types of Respirators

Air-purifying or filtering respirators. Such respirators are used when there is enough oxygen (at least 19.5 percent) and contaminants are present below IDLH level.

The respirator filters out or chemically "**scrubs**" contaminants, usually with a replaceable filter. Use color-coded filter cartridges or canisters for different types of contaminants. It's important to select the right filter for the situation.

Air-supplying respirators. These respirators are required when air-purifying respirators aren't effective. Air-purifying respirators are not sufficient in the following settings:

- When there is not enough oxygen.
- In Confined spaces.
- When contaminants cannot be filtered out.
- When contaminants are at or above IDLH level.

Different kinds of air-supplying respirators include

- Those connected by hose to a stationary air supply (airline)
- Portable tank self-contained breathing apparatus (**SCBA**).

The Importance of Correct Fit

Even a tiny gap between the respirator and the face can allow contaminants to enter. Respirators should be comfortable and properly fitted.

Proper fit includes:

- Secure but not too tight.
- No slipping or pinching.
- Allowance for head movement and speech.

An OSHA-accepted qualitative fit test or quantitative fit test must be performed prior to an employee using any tight-fitting respirator.

Tight-fitting respirators must be seal checked before each use by using positive- or negative-pressure check procedures or the manufacturer's instructions.

Respirator Filters/Cartridges

For protection against gases and vapors, the cartridges used for air-purifying respirators must be either equipped with an end-of-service-life indicator (**ESLI**), certified by NIOSH for the contaminant, or a cartridge change schedule has to be established.

For protection against particulates, there are nine classes of filters (three levels of filter efficiency, each with three categories of resistance to filter efficiency degradation). Levels of filter efficiency are 95 percent, 99 percent, and 99.97 percent. Categories of resistance to filter efficiency degradation are labeled N, R, and P.

Protection Factors

The protection factor of a respirator is an expression of performance based on the ratio of two concentrations: The contaminant concentration outside the respirator to the contaminant concentration inside the respirator.

Each class of respirator is also given an assigned protection factor (**APF**). The APF is a measure of the minimum anticipated level of respiratory protection that a properly functioning respirator or class of respirators would provide to a percentage of properly fitted and trained users. When a contaminant concentration is known, the APF can be used to estimate the concentration inside a particular type of respirator worn by a user.

Who Cannot Wear a Respirator?

Respirator fit is essential. Employees must have a medical checkup to make sure they can wear respirators safely.

Generally, Respirators cannot be Worn when a Person:

- Wears glasses or personal protective equipment that interferes with the seal of the face piece to the face of the user.
- Has facial hair that comes between the sealing surface of the face piece and the face or interferes with valve function.
- Has a breathing problem, such as asthma.
- Has a heart condition.
- Is heat sensitive.

Sometimes a person's facial features will not permit a good fit. Check with the supervisor or medical department if the fit is a problem.

Checking for Damage

Before each use, make sure there are no holes, tears, etc., in the respirator. Rubber parts can wear out and should be checked very carefully every time a respirator is used. Replace worn and damaged parts when necessary. Make sure air and oxygen cylinders are fully charged.

Staying Prepared for Respirator Use

Respirators are bulky and awkward, so getting used to them takes practice.

Possible problems with wearing respirators may include heat exhaustion or heat stroke.

Be alert for symptoms, use the "**buddy system**," and wear a lifeline or harness when necessary. Drink plenty of fluids and take frequent breaks.

Poor Maneuverability. Practice with respirators in narrow passages, on ladders, etc., if your use of respirators may be in these types of conditions.

Using up the Air Supply. When a SCBA is in use, keep checking the gauges and listening for alarms; be ready to leave the area immediately if there is a problem.

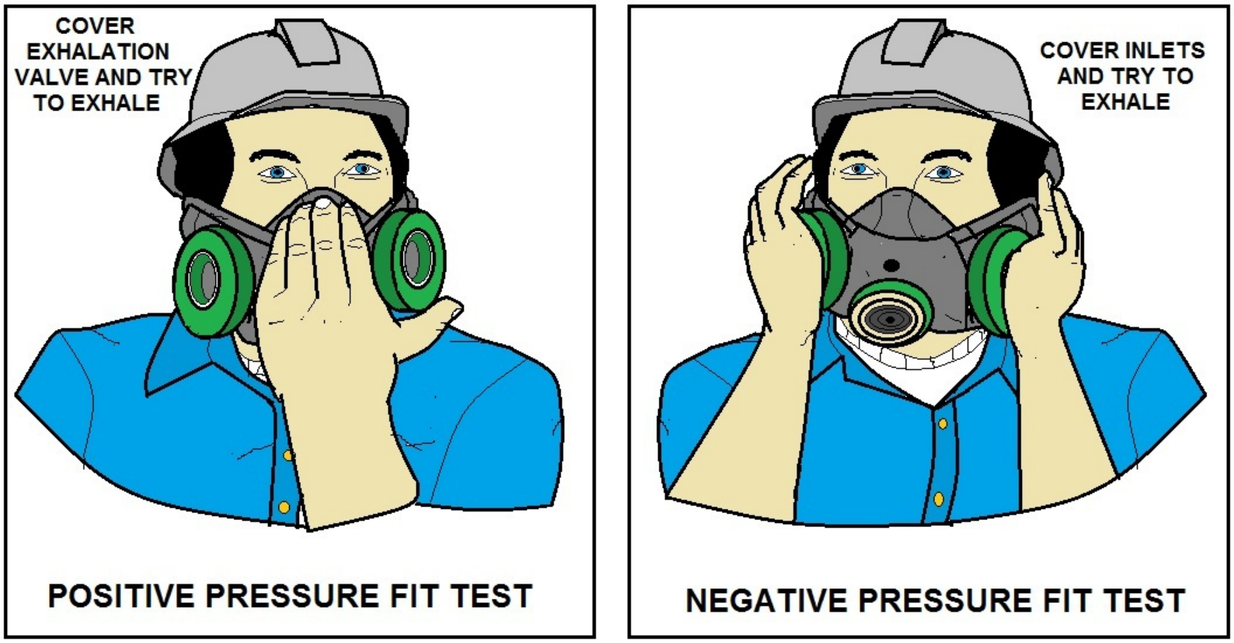
Panic. Remember the importance of staying calm in a hot, stressful, or awkward situation.

Cleaning Respirators

Respirators should be cleaned and disinfected after every use. Check the respirator for damage before putting it away; look for holes, cracks, deterioration, dented cartridges, etc. If any damage is found, it should be reported to a supervisor.

Respirators stored for emergency use must be inspected monthly when not in use, as well as after each use.

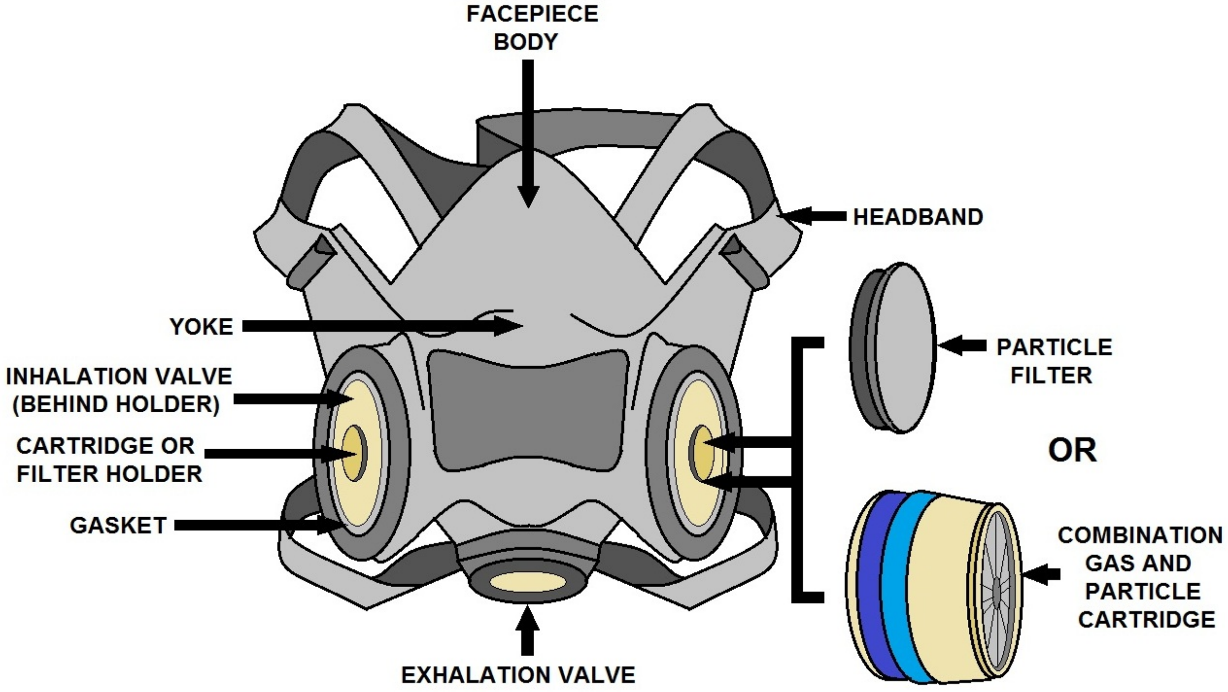
Respirators should be stored away from light, heat, cold, chemicals, and dust. Store respirators in a "***normal***" (natural, undistorted) position to hold their shape. Do not allow respirators to get crushed, folded, or twisted.



POSITIVE PRESSURE FIT TEST

NEGATIVE PRESSURE FIT TEST

POSITIVE AND NEGATIVE PRESSURE FIT CHECKS



BASIC PARTS OF A HALF-FACEPIECE RESPIRATOR

OSHA Regulation Overview

OSHA requires that supervisors consult with employees and encourage their participation in the process safety management plan. In fact, managers must have a written plan of action for employee participation in process safety management. Employee participation is critical because;

- Employees know a lot about the process they work on.
- They play key roles in making sure that process operation is conducted safely.

Operating Procedures

Managers must furnish written operating procedures that clearly explain how to perform each covered process safely.

The procedures must be accurate and must be written in language that people can understand. Avoid technical jargon and, if necessary, supply translations.

Operating procedures must include at least the following:

- Operating steps for initial startup, normal and temporary operations, emergency shutdown (including when it's called for and who does it), emergency operations, normal shutdown, and startup after a turnaround or an emergency shutdown.
- Operating limits, including what happens if workers don't conform to operating limits and how to avoid or correct such problems.
- Safety and health considerations, such as chemical or other hazards, precautions to prevent exposure, quality and inventory control for chemicals, and what to do if an employee is exposed to a hazardous substance.
- Safety systems and their functions, including up-to-date operating procedures and safe work practices.

Contractor Employees

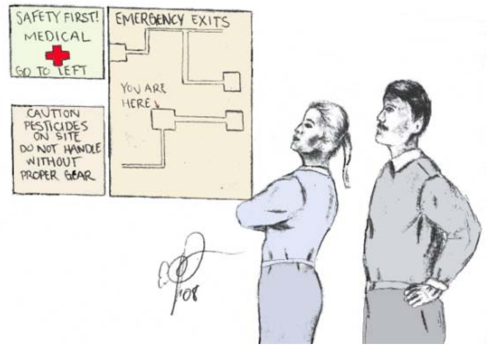
Process safety training and safety programs are also required for contractors who work on-site. Managers must check out the safety performance and programs of any contractors being considered for maintenance, repair, turnaround, major renovation, or specialty work on or around a process covered by the regulation.

When a contractor is hired, the manager must provide the contractor with information on the hazards of the process the contractor will work on. To further ensure contractor safety, managers must also:

- Provide the contractor with information on safe work practices for the process they're involved with and tell them what to do in an emergency.

- Keep a log of contractor employees' injuries or illnesses related to their work in process areas.

- Evaluate the contractor's performance to make sure they're living up to their safety obligations under the standard.



The Contractor has Responsibilities, too…

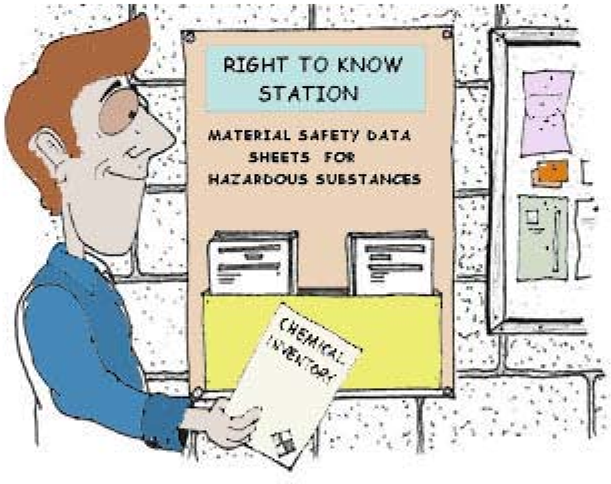
- Document that employees are trained to recognize hazards and to follow safe work practices on the job.
- Make sure that the contractor's employees understand potential job-related hazards, are trained to work safely, and follow the safety rules of the facility in which they're working.

Written Respiratory Protection Program

This paragraph requires the employer to develop and implement a written respiratory protection program with required worksite-specific procedures and elements for required respirator use. The program must be administered by a suitably trained program administrator. In addition, certain program elements may be required for voluntary use to prevent potential hazards associated with the use of the respirator.

The Small Entity Compliance Guide contains criteria for the selection of a program administrator and a sample program that meets the requirements of this paragraph. Copies of the Small Entity Compliance Guide will be available on or about April 8, 1998 from the Occupational Safety and Health Administration's Office of Publications, Room N 3101, 200 Constitution Avenue, NW, Washington, DC, 20210 (202-219-4667).

(c)(1) In any workplace where respirators are necessary to protect the health of the employee or whenever respirators are required by the employer, the employer shall establish and implement a written respiratory protection program with worksite-specific procedures. The program shall be updated as necessary to reflect those changes in workplace conditions that affect respirator use. The employer shall include in the program the following provisions of this section, as applicable:



(c)(1)(i) Procedures for selecting respirators for use in the workplace;

(c)(1)(ii) Medical evaluations of employees required to use respirators;

(c)(1)(iii) Fit testing procedures for tight-fitting respirators;

(c)(1)(iv) Procedures for proper use of respirators in routine and reasonably foreseeable emergency situations;

(c)(1)(v) Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators;

(c)(1)(vi) Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators;

(c)(1)(vii) Training of employees in the respiratory hazards to which they are potentially exposed during routine and emergency situations;

Example of RP Employee Responsibilities

All Employees shall follow the requirements of the Respiratory Protection Program.

Management

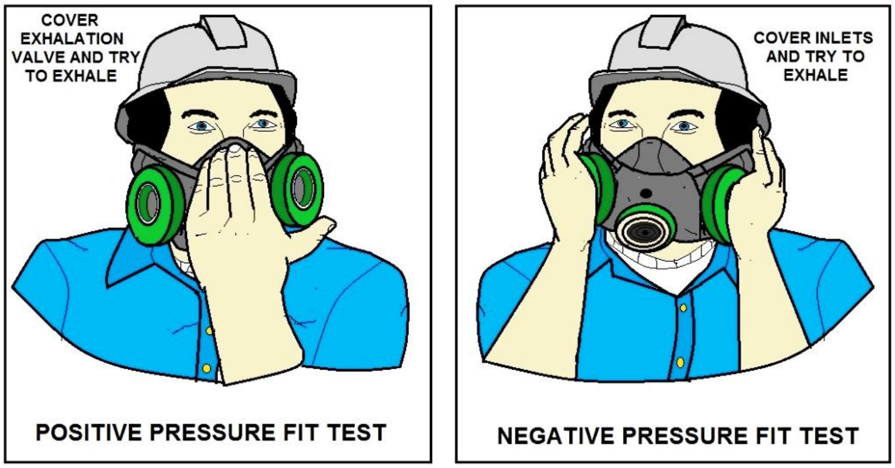
- implement the requirements of this program
- provide a selection of respirators as required
- enforce all provisions of this program
- appoint a *Specific Designated* individual to conduct the respiratory protection program

Administrative Department

- Review sanitation/storage procedures.
- ensure respirators are properly stored, inspected and maintained
- monitor compliance for this program
- provide training for affected Employees
- review compliance and ensure monthly inspection of all respirators
- provide respirator fit testing

Designated Occupational Health Care Provider

- conducts medical aspects of program



POSITIVE PRESSURE FIT TEST

NEGATIVE PRESSURE FIT TEST

POSITIVE AND NEGATIVE PRESSURE FIT CHECKS

Program Administrator

Each Department will designate a program administrator who is qualified by appropriate training or experience that is commensurate with the complexity of the program to administer or oversee the respiratory protection program and conduct the required evaluations of program effectiveness.

Voluntary Use of Respirators is Prohibited

OSHA requires that voluntary use of respirators, when not required by the Employer, must be controlled as strictly as under required circumstances. To prevent violations of the Respiratory Protection Standard, Employees are not allowed voluntary use of their own or Employer supplied respirators of any type.

Exception: Employees whose only use of respirators involves the voluntary use of filtering (non-sealing) face pieces (dust masks).

Respiratory Protection Program Statement Example

Facility ___________________________________
Policy Statement

A respiratory protection program is hereby established so as to coordinate the use and maintenance or respiratory protective equipment as determined necessary to:

1. Reduce Personnel exposure to toxic chemical agents, harmful dusts, mist and fumes and
2. Allow trained personnel to work safely in hazardous environments, such as welding, oxygen deficient atmospheres, toxic atmospheres, etc.

Designation of Program Administrator

Management has designated ______________________________________ to be responsible for the respiratory protection program at this facility. He/she has been delegated authority by Management to make decisions and implement changes in the respirator program anywhere in this facility.

The following responsibilities apply:

1. Supervision of respirator selection process and procedures
2. Establishment of respiratory protection training sessions
3. Establishment of a continuing program of cleaning and inspections
4. Establishment of medical screening program
5. Establishment of issuing procedures
6. Establishment of periodic inspections
7. Continuing evaluation of all aspects of the respiratory protection program to assure continued effectiveness
8. Establishment of annual fit tests procedures

Any questions or problems concerning respirators or their use should be directed to the Program Administrator

____ ______________
Facility Manager Date

Inspection of the respirator includes the filter and storage areas.

Program Evaluation

Evaluations of the workplace are necessary to ensure that the written respiratory protection program is being properly implemented; this includes consulting with employees to ensure that they are using the respirators properly.

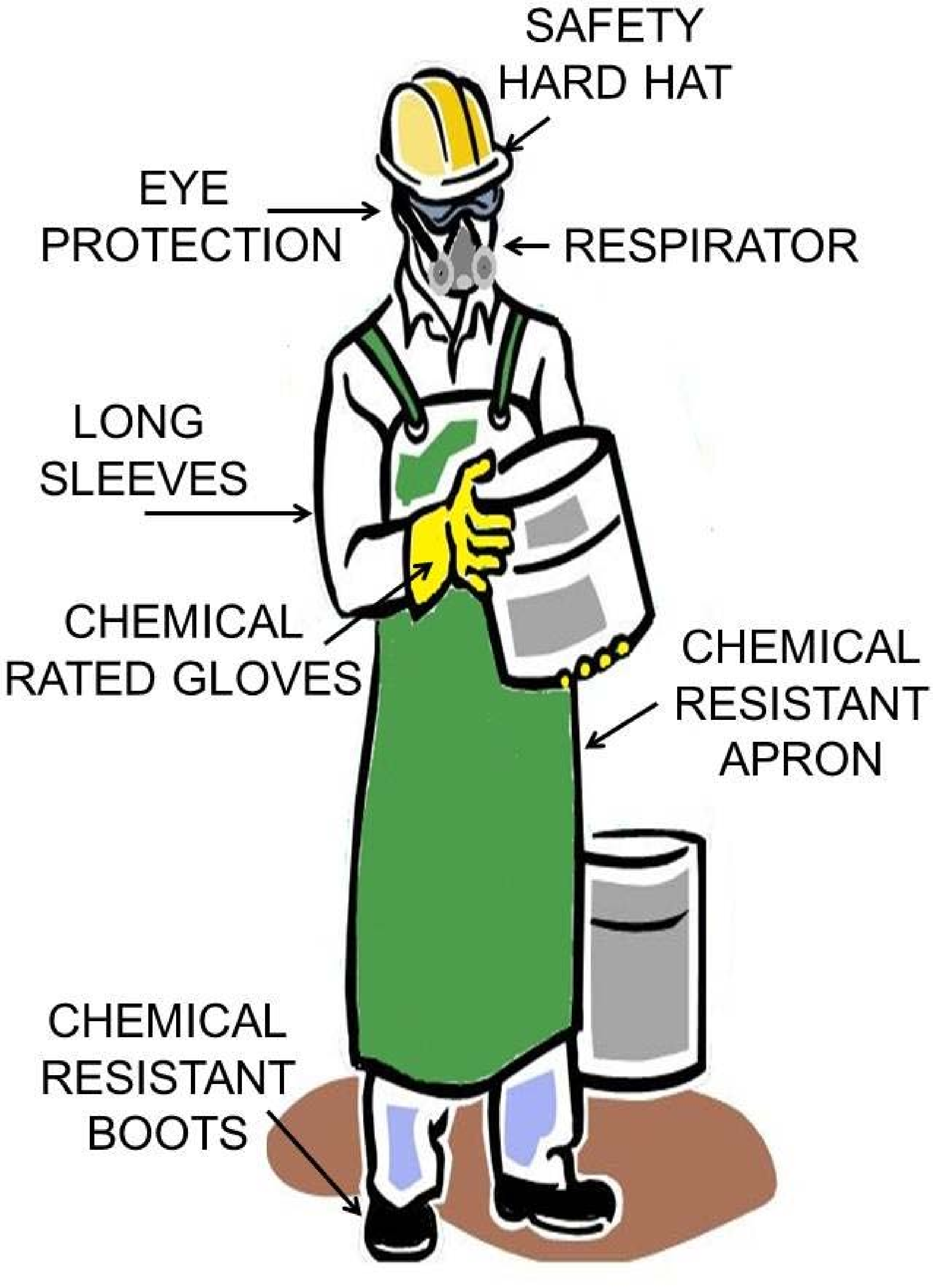
Evaluations shall be conducted as necessary to ensure that the provisions of the current written program are being effectively implemented and that it continues to be effective.

Program evaluation will include discussions with employees required to use respirators to assess the employees' views on program effectiveness and to identify any problems.

Any problems that are identified during this assessment shall be corrected. Factors to be assessed include, but are not limited to:

- Respirator fit (including the ability to use the respirator without interfering with effective workplace performance);
- Appropriate respirator selection for the hazards to which the employee is exposed;
- Proper respirator use under the workplace conditions the employee encounters; and
- Proper respirator maintenance.

Examples of half-face and full-face respirators with HEPA filters (left and center). The mask on the right is only suitable for non-hazardous, non-respirable nuisance dusts.


SAFETY
HARD HAT
EYE
PROTECTION
RESPIRATOR
LONG
SLEEVES
CHEMICAL
RATED GLOVES
CHEMICAL
RESISTANT
APRON
CHEMICAL
RESISTANT
BOOTS

Recordkeeping

The Employer will retain written information regarding medical evaluations, fit testing, and the respirator program. This information will facilitate employee involvement in the respirator program, assist the Employer in auditing the adequacy of the program, and provide a record for compliance determinations by OSHA.

Training and Information
Effective training for employees who are required to use respirators is essential. The training must be comprehensive, understandable, and recur annually and more often if necessary. Training will be provided prior to requiring the employee to use a respirator in the workplace.

The training shall ensure that each employee can demonstrate knowledge of at least the following:

- Why the respirator is necessary and how improper fit, usage, or maintenance can compromise the protective effect of the respirator.
- Limitations and capabilities of the respirator.
- How to use the respirator effectively in emergency situations, including situations in which the respirator malfunctions.
- How to inspect, put on and remove, use, and check the seals of the respirator.
- Procedures for maintenance and storage of the respirator.
- How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators.
- The general requirements of this program.

Retraining shall be conducted annually and when:

- changes in the workplace or the type of respirator render previous training obsolete
- inadequacies in the employee's knowledge or use of the respirator indicate that the employee has not retained the requisite understanding or skill
- other situation arises in which retraining appears necessary to ensure safe respirator use

Training is divided into the following sections:
Classroom Instruction

1. Overview of the Employer’s Respiratory Protection Program & OSHA Standard
2. Respiratory Protection Safety Procedures
3. Respirator Selection
4. Respirator Operation and Use
5. Why the respirator is necessary
6. How improper fit, usage, or maintenance can compromise the protective effect.
7. Limitations and capabilities of the respirator.
8. How to use the respirator effectively in emergency situations, including respirator malfunctions
9. How to inspect, put on and remove, use, and check the seals of the respirator.
10. Procedures for maintenance and storage of the respirator.
11. How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators.
12. Change out schedule and procedure for air purifying respirators.

Respiratory Protection Program

Training Certificate *Example*

Name:____

Department:__________________________ Date:___________

I have received Training on the Respiratory Protection Program. The Training included the following:

Classroom Training

- ✓ Overview of the Company Respiratory Protection Program
- ✓ Respiratory Protection Safety Procedures
- ✓ Respirator Selection
- ✓ Respirator Operation and Use
- ✓ Why the respirator is necessary
- ✓ How improper fit, usage, or maintenance can compromise the protective effect.
- ✓ Limitations and capabilities of the respirator.
- ✓ How to use the respirator effectively in emergency situations, including respirator malfunctions.
- ✓ How to inspect, put on and remove, use, and check the seals of the respirator.
- ✓ Procedures for maintenance and storage of the respirator.
- ✓ How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators.
- ✓ Respirator filter & cartridge change-out schedule
- ✓ The general requirements of this program

Hands-on Training

- ✓ Respirator Inspection
- ✓ Respirator cleaning and sanitizing
- ✓ Fit Check
- ✓ Record Keeping
- ✓ Respirator Storage
- ✓ Emergencies

____

Employees Signature

____

Trainer's Signature

Fit Testing Hands-on Respirator Training

1. **Respirator Inspection**
2. **Respirator cleaning and sanitizing**
3. **Record Keeping**
4. **Respirator Storage**
5. **Respirator Fit Check**
6. **Emergencies**

CONTROL MEASURES

Basic Respiratory Protection Safety Procedures

1. Only authorized and trained Employees may use Respirators. Those Employees may use only the Respirator that they have been trained on and properly fitted to use.
2. Only Physically Qualified Employees may be trained and authorized to use Respirators. A pre-authorization and annual certification by a qualified physician will be required and maintained. Any changes in an Employees health or physical characteristics will be reported to the Occupational Health Department and will be evaluated by a qualified physician.
3. Only the proper prescribed respirator or SCBA may be used for the job or work environment. Air cleansing respirators may be worn in work environments when oxygen levels are between 19.5 percent to 23.5 percent and when the appropriate air cleansing canister, as determined by the Manufacturer and approved by NIOSH or MESA, for the known hazardous substance is used. SCBAs will be worn in oxygen deficient and oxygen rich environments (below 19.5 percent or above 23.5 percent oxygen).
4. Employees working in environments where a sudden release of a hazardous substance is likely will wear an appropriate respirator for that hazardous substance (example: Employees working in an ammonia compressor room will have an ammonia APR respirator on their person.).
5. Only SCBAs will be used in oxygen deficient environments, environments with an unknown hazardous substance or unknown quantity of a known hazardous substance or any environment that is determined "Immediately Dangerous to Life or Health" (IDLH).
6. Employees with respirators loaned on "permanent check out" will be responsible for the sanitation, proper storage and security. Respirators damaged by normal wear will be repaired or replaced by the Employer when returned.
7. The last Employee using a respirator and/or SCBA that are available for general use will be responsible for proper storage and sanitation. Monthly and after each use, all respirators will be inspected with documentation to assure its availability for use.
8. All respirators will be located in a clean, convenient and sanitary location.
9. In the event that Employees must enter a confined space, work in environments with hazardous substances that would be dangerous to life or health should an RPE fail (a SCBA is required in this environment), and/or conduct a HAZMAT entry, a "**buddy system**" detail will be used with a Safety Watchman with constant voice, visual or signal line communication.
10. Employees will follow the established Emergency Response Program and/or Confined Space Entry Program when applicable.
11. Management will establish and maintain surveillance of jobs and work place conditions and degree of Employee exposure or stress to maintain the proper procedures and to provide the necessary RPE.

12. Management will establish and maintain safe operation procedures for the safe use of RPE with strict enforcement and disciplinary action for failure to follow all general and specific safety rules. Standard Operation Procedures for General RPE use will be maintained as an attachment to the Respiratory Protection Program and Standard Operation Procedures for RPE use under emergency response situations will be maintained as an attachment to the Emergency Response Program.

Selection of Respirators

The Employer is responsible and needs to have evaluated the respiratory hazard(s) in each workplace, identified relevant workplace and user factors and have based respirator selection on these factors. Also included are estimates of employee exposures to respiratory hazard(s) and an identification of the contaminant's chemical state and physical form.

This selection has included appropriate protective respirators for use in IDLH atmospheres, and has limited the selection and use of air-purifying respirators. All selected respirators are NIOSH-certified.

Filter Classifications - These classifications are marked on the filter or filter package

N-Series: Not Oil Resistant

- Approved for non-oil particulate contaminants
- Examples: dust, fumes, mists not containing oil

R-Series: Oil Resistant

- Approved for all particulate contaminants, including those containing oil
- Examples: dusts, mists, fumes
- Time restriction of 8 hours when oils are present

P-Series: Oil Proof

- Approved for all particulate contaminants including those containing oil
- Examples: dust, fumes, mists
- See Manufacturer's time use restrictions on packaging

Respirators for IDLH Atmospheres.

- The following respirators will be used in IDLH atmospheres:
- A full face piece pressure demand SCBA certified by NIOSH for a minimum service life of thirty minutes, or
- A combination full face piece pressure demand supplied-air respirator (**SAR**) with auxiliary self-contained air supply.
- Respirators provided only for escape from IDLH atmospheres shall be NIOSH-certified for escape from the atmosphere in which they will be used.

Respirators for Atmospheres that are not IDLH.

The respirators selected shall be adequate to protect the health of the employee and ensure compliance with all other OSHA statutory and regulatory requirements, under routine and reasonably foreseeable emergency situations. The respirator selected shall be appropriate for the chemical state and physical form of the contaminant.

Identification of Filters & Cartridges

All filters and cartridges shall be labeled and color coded with the NIOSH approval label; the label is never to be removed and must remain legible. A change out schedule for filters and canisters has been developed to ensure these elements of the respirators remain effective.

Respirator Filter & Canister Replacement
An important part of the Respiratory Protection Program includes identifying the useful life of canisters and filters used on air-purifying respirators. Each filter and canister shall be equipped with an end-of-service-life indicator (**ESLI**) certified by NIOSH for the contaminant; or If there is no ESLI appropriate for conditions, a change schedule for canisters and cartridges that is based on objective information or data that will ensure that canisters and cartridges are changed before the end of their service life.

Unacceptable maintenance and storage (OSHA Violation).

Filter & Cartridge Change Schedule
Stock of spare filters and cartridges shall be maintained to allow immediate change when required or desired by the employee.

Cartridges shall be changed based on the most limiting factor below:

- Prior to expiration date
- Manufacturer's recommendations for the specific use and environment
- After each use
- When requested by employee
- When contaminate odor is detected
- When restriction to air flow has occurred as evidenced by increase effort by user to breathe normally
- Cartridges shall remain in their original sealed packages until needed for immediate use

Filters shall be changed on the most limiting factor below:

- Prior to expiration date
- Manufacturer's recommendations for the specific use and environment
- When requested by employee
- When contaminate odor is detected
- When restriction to air flow has occurred as evidenced by increase effort by user to breathe normally
- When discoloring of the filter media is evident
- Filters shall remain in their original sealed package until needed for immediate use.

Respirator Selection and Use

HAZARD	RESPIRATOR TYPE
Asbestos	Half-mask, air-purifying respirator with HEPA filters Full-face, air-purifying respirator with HEPA filters Full-face, powered air-purifying respirator with HEPA filters
Epoxy- or Oil-based Paints	Half-face, air-purifying respirators with organic vapor filters Full-face powered air-purifying respirator with organic vapor filters
Lead-based Paint removal	Half-face, air-purifying respirators with HEPA filters Full-face, air-purifying respirators with HEPA filters Full-face, powered air-purifying respirators with HEPA filters
Use of Pesticides, Herbicides, and Rodenticides	Full-face, air-purifying respirator with combination particulate and pesticide cartridges Full-face, powered air-purifying respirator with combination particulate and pesticide cartridges
Use of Formaldehyde	Full-face, air-purifying respirator with organic vapor or specific formaldehyde cartridges Full-face, powered air-purifying respirator with organic vapor or specific formaldehyde cartridges Type C supplied air respirator with pressure- demand mode

RESPIRATORY PROTECTION PROGRAM CHECKLIST	**PAGE 1 OF 1 PAGES**

DIVISION:	**SECTION:**	**SUPERVISOR:**	**DATE:**

		YES	NO	NA
1	Is respiratory protection (RP) being worn in the section?			
2	Has air sampling been accomplished that mandates using RP?			
3	Where air sampling results greater than Occupational Exposure Limits? (If NO, why are you using a respirator?)			
4	Has a Hazard Assessment been generated concerning the task or process that placed the section on the RP Program?			
5	Have all processes that may warrant the use of RP been evaluated? (If NO, request an assessment from the Department Safety Analyst /Personnel Safety, unless the operation is emergency response).			
6	Have workers received physicals and been found medically qualified to wear RP?			
7	Is there documentation that workers were formally briefed on air sampling results and why RP is required?			
8	Is respiratory protection training and fit-testing documentation available on everyone who wears a respirator?			
9	Are RP wearers being fit-tested at least annually?			
10	Are section employees wearing RP voluntarily when conditions have not mandated their use?			
11	Are employees wearing contacts in hazardous atmospheres or using eye-wear that negates face to face piece seal?			
12	Do RP users have facial hair that negates face to face piece seal?			
13	Has a respirator inventory been compiled that list the type of respirator(s) used in the workplace? (Use Respirator Inventory Worksheet attach to this checklist)			
14	Has the Section Supervisor received formal RP training on OSHA, City Personnel Safety and Respiratory Protection Program requirements and his or her responsibilities?			
15	Does the section have written standard operating instructions governing the selection, fit-testing, use, cleaning, storage and maintenance of respirators?			
16	Is the Fire Department the only source being used to charge SCBA's with compressed air?			
17	Are SCBA's being inspected at least every 30 days?			
18	Does the section have on hand, applicable OSHA, CITY, and Section Respiratory Protection Program guidance documents?			
19	Are periodic audits of the section's RP program conducted with discrepancies tracked until closed out?			
20	Have program deficiencies been elevated to the Director and Department Safety Analyst?			

SURVEYED BY:	REVIEWED BY:

SDS Terminology

The Hazard Communication Standard requires employees to understand chemical hazards, labels, and SDSs and to use them on the job. Before starting jobs involving possible exposure to hazardous substances, employees must read SDSs to know what they're working with and procedures for safe handling.

Hundreds, perhaps thousands, of terms could be included in a listing like the one provided in this session. The list of terms and definitions included in this session is not comprehensive or all-inclusive.

The intent is to provide users with a brief list of some of the terms that may appear in common SDSs. Additional terms specific to the substances your company uses or keeps on-site should be added to the list.

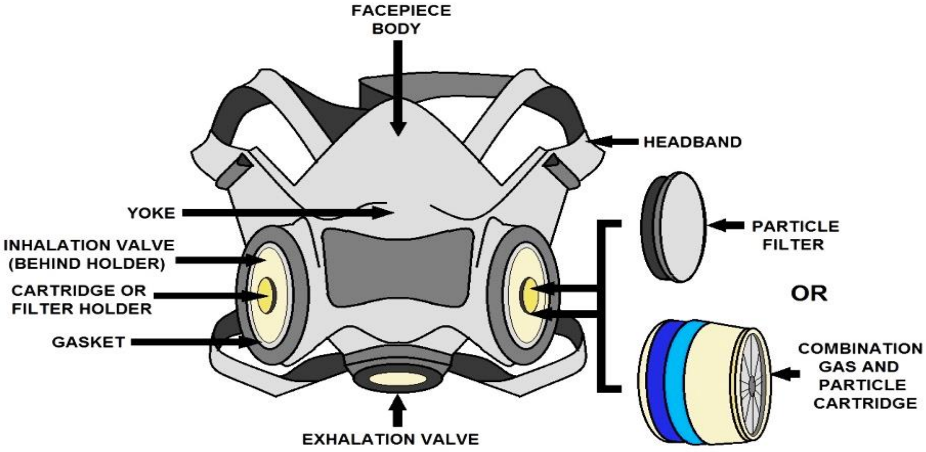
Respiratory Protection Schedule by Job and Working Condition

The Employer needs to maintain a Respiratory Protection Schedule by Job and Working Condition. This schedule is provided to each authorized and trained Employee.

The Schedule provides the following information:
1. Job/Working Conditions
2. Work Location
3. Hazards Present
4. Type of Respirator or SCBA Required
5. Type of Filter/Canister Required
6. Location of Respirator or SCBA
7. Filter/Cartridge change out schedule

The schedule will be reviewed and updated at least annually and whenever any changes are made in the work environments, machinery, equipment, or processes or if different respirator models are introduced or existing models are removed.

Permanent Respirator Schedule Assignments Are:
Each person who engages in welding will have their own Employer provided dust-mist-fume filter APR. This respirator will be worn during all welding operations.

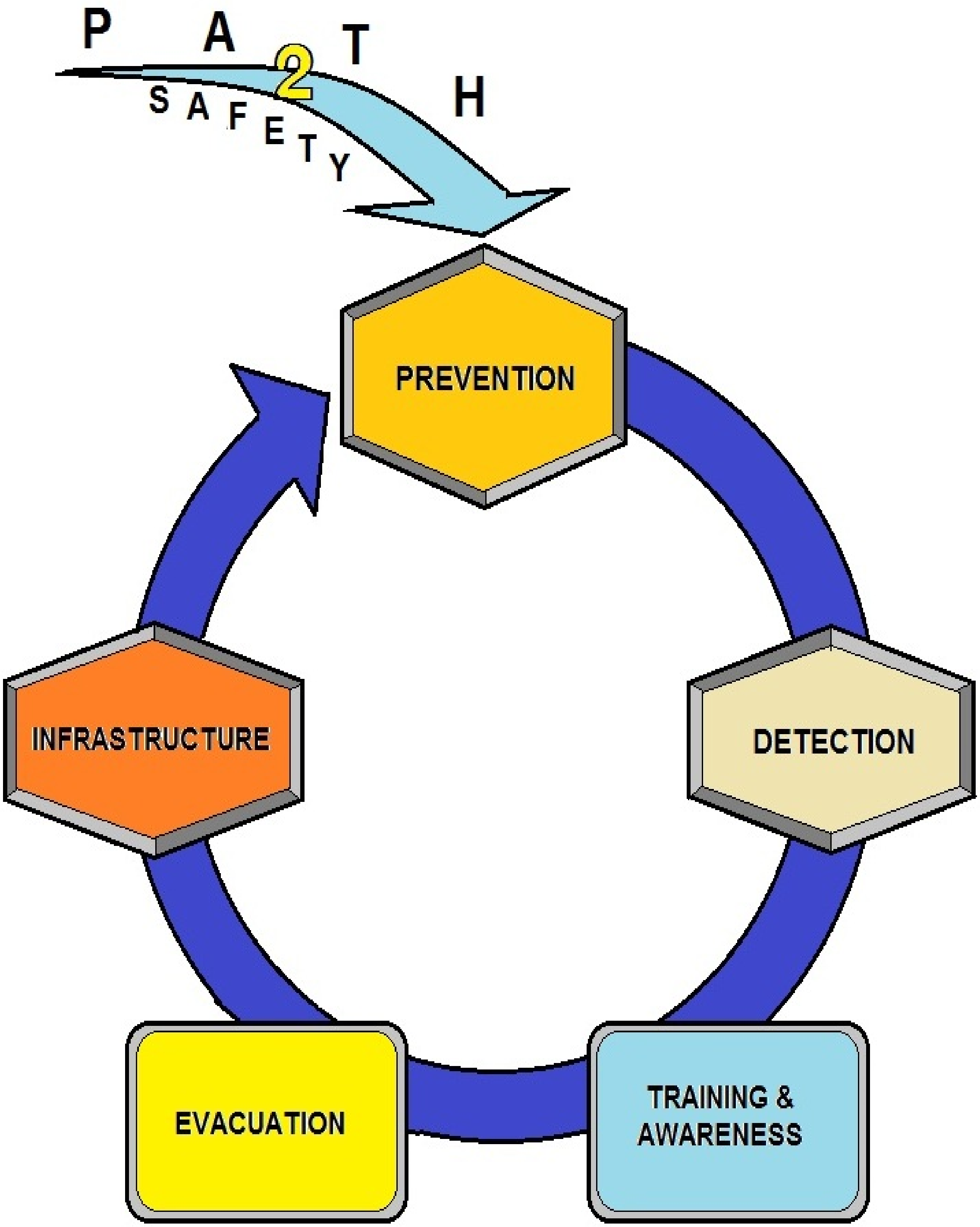


BASIC PARTS OF A HALF-FACEPIECE RESPIRATOR

Physical and Medical Qualifications
Records of medical evaluations must be retained and made available in accordance with 29 CFR 1910.1020.

Medical Evaluation Required
Using a respirator may place a physiological burden on employees that varies with the type of respirator worn, the job and workplace conditions in which the respirator is used, and the medical status of the employee. The Employer is required to provide a medical evaluation to determine the employee's ability to use a respirator before the employee is fit tested or required to use the respirator in the workplace.

Medical Evaluation Procedures
The employee will be provided a medical questionnaire by the designated Occupational Health Care Provider


PATH
2
SAFETY
PREVENTION
DETECTION
TRAINING & AWARENESS
EVACUATION
INFRASTRUCTURE

Follow-up Medical Examination

The Employer shall ensure that a follow-up medical examination is provided for an employee who gives a positive response to any question among questions in Part B of the questionnaire or whose initial medical examination demonstrates the need for a follow-up medical examination. The follow-up medical examination shall include any medical tests, consultations, or diagnostic procedures that the Physician deems necessary to make a final determination.

Administration of the Medical Questionnaire and Examinations

The medical questionnaire and examinations shall be administered confidentially during the employee's normal working hours or at a time and place convenient to the employee. The medical questionnaire shall be administered in a manner that ensures that the employee understands its content. The Employer shall provide the employee with an opportunity to discuss the questionnaire and examination results with the Physician.

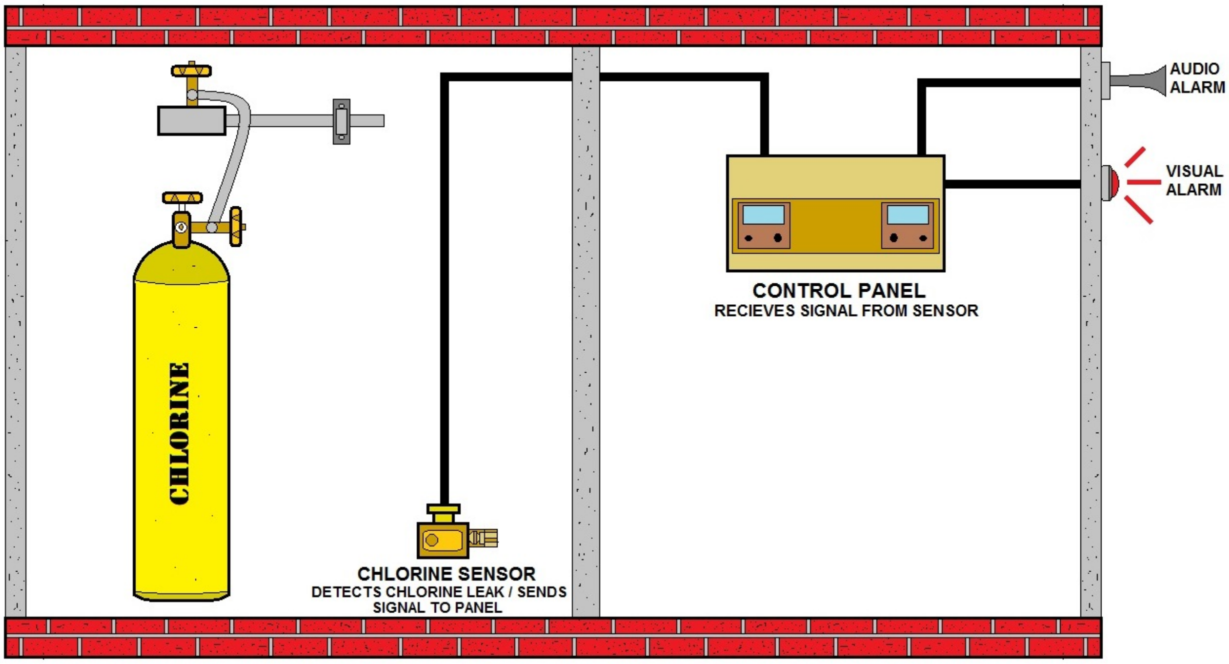
Supplemental Information for the Physician

The following information must be provided to the Physician before the Physician makes a recommendation concerning an employee's ability to use a respirator;

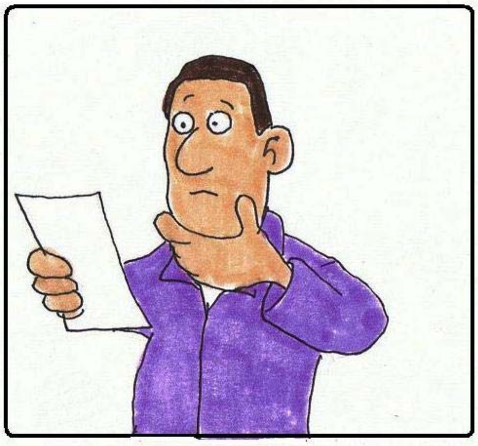
- The type and weight of the respirator to be used by the employee.
- The duration and frequency of respirator use (including use for rescue and escape).
- The expected physical work effort.
- Additional protective clothing and equipment to be worn.
- Temperature and humidity extremes that may be encountered.
- Any supplemental information provided previously to the Physician regarding an employee need not be provided for a subsequent medical evaluation if the information and the Physician remain the same

The Employer has provided the Physician with a copy of the written respiratory protection program and a copy of the OSHA Standard 1910.134

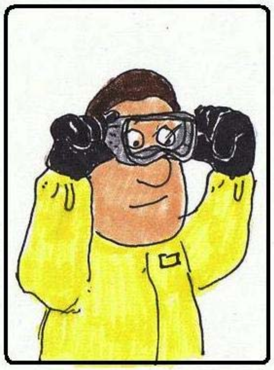
Half face type respirator.



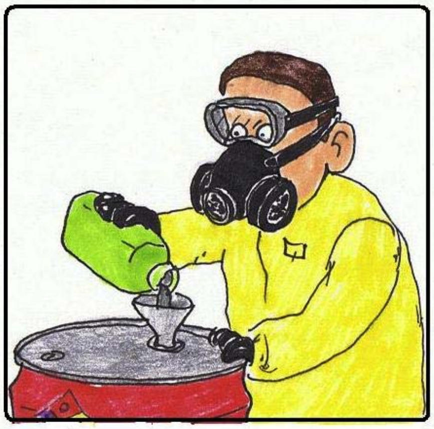
CHLORINE STORAGE ROOM



READ THE SAFETY DATA SHEET



WEAR PROPER PPE



HANDLING CHEMICALS

Medical Determination

In determining the employee's ability to use a respirator, the Employer shall:

W Obtain a written recommendation regarding the employee's ability to use the respirator from the Physician. The recommendation shall provide only the following information:

- ➢ Any limitations on respirator use related to the medical condition of the employee, or relating to the workplace conditions in which the respirator will be used, including whether or not the employee is medically able to use the respirator.
- ➢ The need, if any, for follow-up medical evaluations.
- ➢ A statement that the Physician has provided the employee with a copy of the Physician's written recommendation.
- ➢ If the respirator is a negative pressure respirator and the Physician finds a medical condition that may place the employee's health at increased risk if the respirator is used, the Employer shall provide a APR if the Physician's medical evaluation finds that the employee can use such a respirator; if a subsequent medical evaluation finds that the employee is medically able to use a negative pressure respirator, then the Employer is no longer required to provide a APR.

Additional Medical Evaluations
At a minimum, the Employer shall provide additional medical evaluations that comply with the requirements of this section if:

- An employee reports medical signs or symptoms that are related to ability to use a respirator.
- A Physician, supervisor, or the respirator program administrator informs the Employer that an employee needs to be reevaluated.
- Information from the respiratory protection program, including observations made during fit testing and program evaluation, indicates a need for employee reevaluation.
- A change occurs in workplace conditions (e.g., physical work effort, protective clothing, and temperature) that may result in a substantial increase in the physiological burden placed on an employee.

Respirator Fit Testing *(see Appendix A for more information)*
Before an employee is required to use any respirator with a negative or positive pressure tight-fitting face piece, the employee must be fit tested with the same make, model, style, and size of respirator that will be used. The Employer shall ensure that an employee using a tight-fitting face piece respirator is fit tested prior to initial use of the respirator, whenever a different respirator face piece (size, style, model or make) is used, and at least annually thereafter
The Employer has established a record of the qualitative and quantitative fit tests administered to employees including:

- The name or identification of the employee tested.
- Type of fit test performed.
- Specific make, model, style, and size of respirator tested.
- Date of test.
- The pass/fail results for QLFTs or the fit factor and strip chart recording or other recording of the test results for QNFTs.

Additional fit tests will be conducted whenever the employee reports, or the Employer, Physician, supervisor, or program administrator makes visual observations of, changes in the employee's physical condition that could affect respirator fit. Such conditions include, but are not limited to, facial scarring, dental changes, cosmetic surgery, or an obvious change in body weight.

If after passing a QLFT or QNFT, the employee notifies the Employer’s program administrator, supervisor, or Physician that the fit of the respirator is unacceptable, the employee shall be given a reasonable opportunity to select a different respirator face piece and to be retested.

Types of Fit Tests
The fit test shall be administered using an OSHA-accepted QLFT or QNFT protocol. The OSHA-accepted QLFT and QNFT protocols and procedures are contained in Appendix A of OSHA Standard 1910.134.

- QLFT may only be used to fit test negative pressure air-purifying respirators that must achieve a fit factor of 100 or less.
- If the fit factor, as determined through an OSHA-accepted QNFT protocol, is equal to or greater than 100 for tight-fitting half face pieces, or equal to or greater than 500 for tight-fitting full face pieces, the QNFT has been passed with that respirator.
- Fit testing of tight-fitting atmosphere-supplying respirators and tight-fitting powered air-purifying respirators shall be accomplished by performing quantitative or qualitative fit testing in the negative pressure mode, regardless of the mode of operation (negative or positive pressure) that is used for respiratory protection.
- Qualitative fit testing of these respirators shall be accomplished by temporarily converting the respirator user's actual face piece into a negative pressure respirator with appropriate filters, or by using an identical negative pressure air-purifying respirator face piece with the same sealing surfaces as a surrogate for the atmosphere-supplying or powered air-purifying respirator face piece.
- Quantitative fit testing of these respirators shall be accomplished by modifying the face piece to allow sampling inside the face piece in the breathing zone of the user, midway between the nose and mouth. This requirement shall be accomplished by installing a permanent sampling probe onto a surrogate face piece, or by using a sampling adapter designed to temporarily provide a means of sampling air from inside the face piece.
- Any modifications to the respirator face piece for fit testing shall be completely removed, and the face piece restored to NIOSH approved configuration, before that face piece can be used in the workplace.

Fit test records shall be retained for respirator users until the next fit test is administered. Written materials required to be retained shall be made available upon request to affected employees.

Respirator Operation and Use
Respirators will only be used following the respiratory protection safety procedures established in this program. The Operations and Use Manuals for each type of respirator will be maintained by the Program Administrator and be available to all qualified users.

Surveillance by the direct supervisor shall be maintained of work area conditions and degree of employee exposure or stress. When there is a change in work area conditions or degree of employee exposure or stress that may affect respirator effectiveness, the Employer shall reevaluate the continued effectiveness of the respirator.

For continued protection of respirator users, the following general use rules apply:

- Users shall not remove respirators while in a hazardous environment .
- Respirators are to be stored in sealed containers out of harmful atmospheres.
- Store respirators away from heat and moisture.
- Store respirators such that the sealing area does not become distorted or warped
- Store respirators such that the face piece is protected.
- Face piece seal protection.

The Employer does not permit respirators with tight-fitting face pieces to be worn by employees who have:

- Facial hair that comes between the sealing surface of the face piece and the face or that interferes with valve function; or
- Any condition that interferes with the face-to-face piece seal or valve function.

If an employee wears corrective glasses or goggles or other personal protective equipment, the Employer shall ensure that such equipment is worn in a manner that does not interfere with the seal of the face piece to the face of the user.

Continuing Effectiveness of Respirators

The Employer shall ensure the following when employees leave the respirator use area:

- To wash their faces and respirator face pieces as necessary to prevent eye or skin irritation associated with respirator use.
- If they detect vapor or gas breakthrough, changes in breathing resistance, or leakage of the face piece.
- To replace the respirator or the filter, cartridge, or canister elements.

If the employee detects vapor or gas breakthrough, changes in breathing resistance, or leakage of the face piece, the Employer will replace or repair the respirator before allowing the employee to return to the work area.

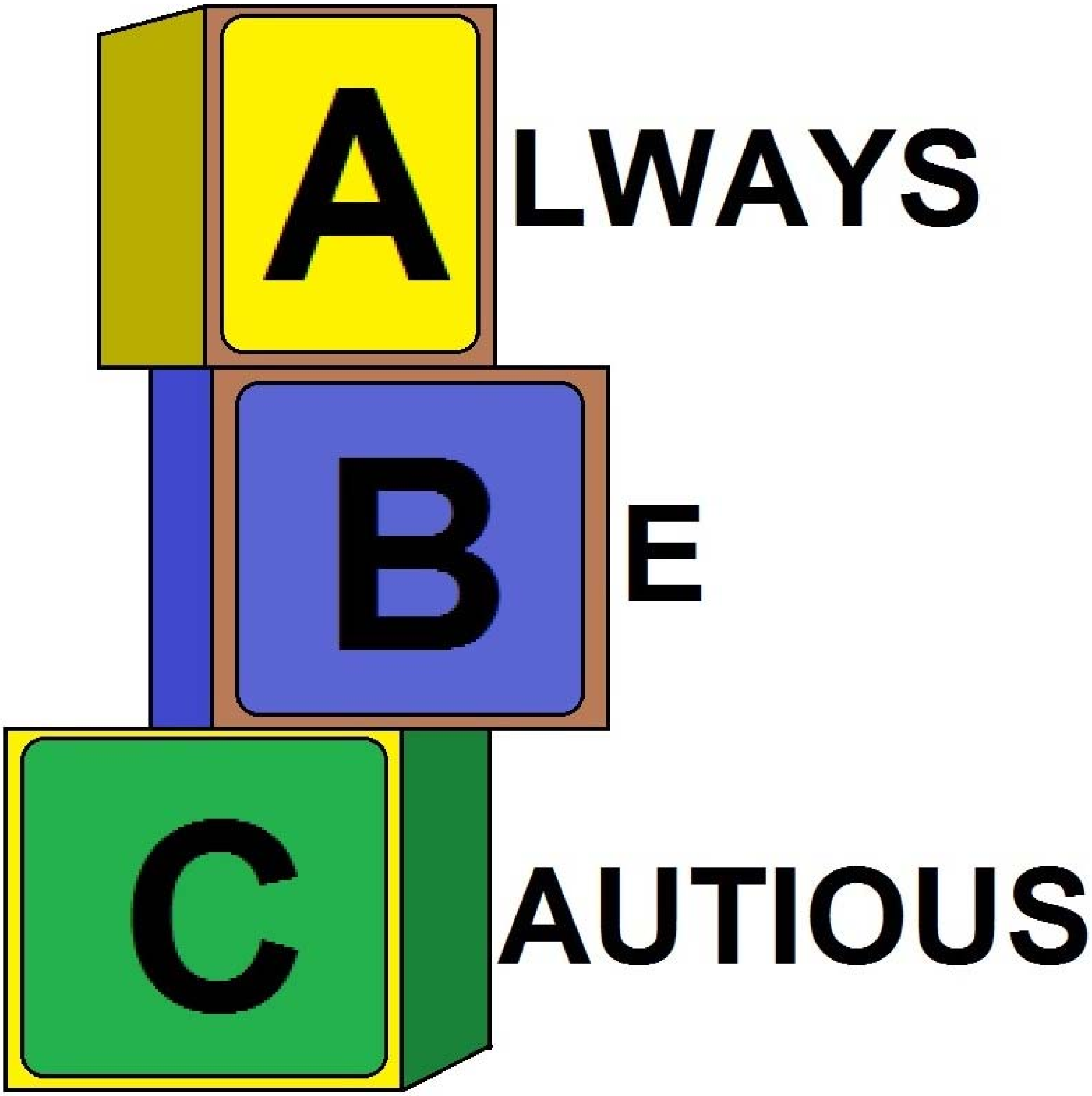
Procedures for IDLH atmospheres

For all IDLH atmospheres, the Employer shall ensure that:

- One employee or, when needed, more than one employee is located outside the IDLH atmosphere.
- Visual, voice, or signal line communication is maintained between the employee(s) in the IDLH atmosphere and the employee(s) located outside the IDLH atmosphere.
- The employee(s) located outside the IDLH atmosphere are trained and equipped to provide effective emergency rescue.
- The Employer or designee is notified before the employee(s) located outside the IDLH atmosphere enter the IDLH atmosphere to provide emergency rescue.
- The Employer or designee authorized to do so by the Employer, once notified, provides necessary assistance appropriate to the situation.

Employee(s) located outside the IDLH atmospheres will be equipped with:

- Pressure demand or other positive pressure SCBAs, or a pressure demand or other positive pressure supplied-air respirator with auxiliary SCBA; and either
- Appropriate retrieval equipment for removing the employee(s) who enter(s) these hazardous atmospheres where retrieval equipment would contribute to the rescue of the employee(s) and would not increase the overall risk resulting from entry; or
- Equivalent means for rescue where retrieval equipment is not required.



ABC OF SAFETY

Related Gas and Vapor Contaminants

Gas and vapor contaminants can be classified according to their chemical characteristics. True gaseous contaminants are similar to air in that they possess the same ability to diffuse freely within an area or container. Nitrogen, chlorine, carbon monoxide, carbon dioxide and sulfur dioxide are examples.

Vapors are the gaseous state of substances that are liquids or solids at room temperature. They are formed when the solid or liquid evaporates. Gasoline, solvents and paint thinners are examples of liquids that evaporate easily, producing vapors.
In terms of chemical characteristics, gaseous contaminants may be classified as follows:

- **Inert Gases** —These include such true gases as helium, argon, neon, etc. Although they do not metabolize in the body, these gases represent a hazard because they can produce an oxygen deficiency by displacement of air.
- **Acidic Gases** —Often highly toxic, acidic gases exist as acids or produce acids by reaction with water. Sulfur dioxide, hydrogen sulfide and hydrogen chloride are examples.
- **Alkaline Gases** —These gases exist as alkalis or produce alkalis by reaction with water. Ammonia and phosphine are two examples.

In terms of chemical characteristics, vaporous contaminants may be classified as follows:

- **Organic Compounds** —Contaminants in this category can exist as true gases or vapors produced from organic liquids. Gasoline, solvents and paint thinners are examples.
- **Organometallic Compounds** —These are generally comprised of metals attached to organic groups. Tetraethyllead and organic phosphates are examples.

Hazard Assessment
Proper assessment of the hazard is the first important step to protection. This requires a thorough knowledge of processes, equipment, raw materials, end-products and by-products that can create an exposure hazard.

To determine an atmosphere's oxygen content or concentration levels of particulate and/or gaseous contaminants, air samples must be taken with proper sampling instruments during all conditions of operation. The sampling device and the type and frequency of sampling (spot testing or continuous monitoring) will be dictated by the exposure and operating conditions.

Breathing zone samples are recommended and sampling frequency should be sufficient to assess the average exposure under the variable operating and exposure conditions.
Should contaminant concentrations exceed exposure limits recommended by the American

Conference of Governmental Industrial Hygienists (**ACGIH**), OSHA or NIOSH, hazard control procedures must be implemented promptly.

Exposure monitoring plays a critical role in the respirator selection process. The results from such tests will help you determine whether respiratory protection is needed and, if it is, the type of respirator required.

Generally, respirator selection is based on three factors:

- The results of your atmospheric monitoring or sampling program;
- The accepted ACGIH, OSHA or NIOSH exposure limits for the substance(s) present;
- And the maximum use concentration (of a substance) for which a respirator can be used.

Exposure limits include ACGIH Threshold Limit Values (**TLVs**), OSHA Permissible Exposure Limits (**PELs**), NIOSH Recommended Exposure Levels (**RELs**) and AIHA Workplace Environmental Exposure Levels (**WEELs**).

These values are guides for exposure concentrations that healthy individuals can normally tolerate for eight hours a day, five days a week without harmful effects. Unless otherwise noted, exposure limits are eight-hour, time-weighted-average (**TWA**) concentrations.

In general, gas and vapor exposure limits are expressed in ppm by volume (parts of contaminant per million parts of air), while particulate concentrations are expressed as mg/m^3 (milligrams of concentrations per cubic meter of air).

For substances that can exist in more than one form (particulate or gaseous), concentrations are expressed in both values.

It is important to note that exposure limits and other exposure standards are constantly changing as more data is gathered about specific chemicals and substances. As such, you must be certain that you are using the most recent data when determining allowable exposure levels for employees.

Hazard Control

Hazard control should start at the process, equipment and plant design levels where contaminants can be effectively controlled at the outset. With operating processes, the problem becomes more difficult. In all cases, however, consideration should be given to the use of effective engineering controls to eliminate and/or reduce exposures to respiratory hazards.

This includes consideration of process encapsulation or isolation, use of less toxic materials in the process and suitable exhaust ventilation, filters and scrubbers to control the effluents.

Because it is sometimes not practical to maintain engineering controls that eliminate all airborne concentrations of contaminants, proper respiratory protective devices should be used whenever such protection is required.

Hazard Assessment or Hazard Certification sheet example is on the following page.

Even if you have a written RP Program and complete training records, OSHA will ask for a hazard certification or assessment form on where or why you need RP.

For example, if you were required to don SCBA to change a chlorine cylinder once a week, OSHA would request to see how that task was evaluated and certified.

HAZARD ASSESSMENT SURVEY DATA SHEET

DATE OF EVALUATION:	**DATE LAST EVALUATED**: N/A

DEPARTMENT:

DEPARTMENT:	**TELEPHONE:**
ADDRESS/LOCATION:	**NAME OF SECTION SUPERVISOR**:
Actions are required by: 29 CFR 1910.1200, 29 CFR 1910.146	**NAME OF HAZARD COMMUNICATION PROGRAM MONITOR:**

NON-ROUTINE POTENTIAL HAZARDS

(Describe the Process) (Who, What, When, Where, How, Why) (Review SDS)

EVALUATION

(Your Findings/Discrepancies)

CONTROLS

(Existing or Recommended Protective Equipment, Engineering or Administrative Controls)

Existing:

Recommended:

Surveyed By:	**Reviewed By:**

The revised Hazard Communication Standard specifically requires every hazardous chemical container to have a label. Labels are part of the company's Hazard Communication Program, which gives employees the Right to Understand about the chemical hazards they face on the job.

Each label will tell the worker

- ✓ ***What a chemical's identity is***
- ✓ ***Who made it***
- ✓ ***Why it's hazardous***
- ✓ ***How to protect himself or herself.***

Cleaning and Disinfecting

The Employer shall provide each respirator user with a respirator that is clean, sanitary, and in good working order.

The Employer shall ensure that respirators are cleaned and disinfected using the Standard Operating Procedure SOP: Cleaning and Disinfecting.

The Respirators Shall be Cleaned and Disinfected when:

- Respirators issued for the exclusive use of an employee shall be cleaned and disinfected as often as necessary to be maintained in a sanitary condition.
- Respirators issued to more than one employee shall be cleaned and disinfected before being worn by different individuals.
- Respirators maintained for emergency use shall be cleaned and disinfected after each use.
- Respirators used in fit testing and training shall be cleaned and disinfected after each use.

Cleaning and Storage of respirators assigned to specific employees is the responsibility of that Employee.

Respirator Inspection

All respirators/SCBAs, both available for "**General Use**" and those on "**Permanent Check-out**", will be inspected after each use and at least monthly. Should any defects be noted, the respirator/SCBA will be taken to the program Administrator. Damaged Respirators will be either repaired or replaced. The inspection of respirators loaned on "**Permanent Check-out**" is the responsibility of that trained Employee.

Respirators Shall be Inspected as Follows:

- All respirators used in routine situations shall be inspected before each use and during cleaning.
- All respirators maintained for use in emergency situations shall be inspected at least monthly and in accordance with the manufacturer's recommendations, and shall be checked for proper function before and after each use.
- Emergency escape-only respirators shall be inspected before being carried into the workplace for use.

Respirator Inspections Include the Following:

- A check of respirator function, tightness of connections, and the condition of the various parts including, but not limited to, the face piece, head straps, valves, connecting tube, and cartridges, canisters or filters.
- Check of elastomeric parts for pliability and signs of deterioration.
- Self-contained breathing apparatus shall be inspected monthly. Air and oxygen cylinders shall be maintained in a fully charged state and shall be recharged when the pressure falls to 90% of the manufacturer's recommended pressure level. The Employer shall determine that the regulator and warning devices function properly.

For Emergency Use Respirators the additional requirements apply:

- Certify the respirator by documenting the date the inspection was performed, the name (or signature) of the person who made the inspection, the findings, required remedial action, and a serial number or other means of identifying the inspected respirator.
- Provide this information on a tag or label that is attached to the storage compartment for the respirator, is kept with the respirator, or is included in inspection reports stored as paper or electronic files. This information shall be maintained until replaced following a subsequent certification.

CLEANING AN SCBA MASK

Cleaning and Storage of respirators should be assigned to specific employees is the responsibility of that Employee.

Respirator Storage Section

Respirators are to be stored as follows:

- All respirators shall be stored to protect them from damage, contamination, dust, sunlight, extreme temperatures, excessive moisture, and damaging chemicals, and they shall be packed or stored to prevent deformation of the face piece and exhalation valve.

Emergency Respirators shall be:

- Kept accessible to the work area;
- Stored in compartments or in covers that are clearly marked as containing emergency respirators; and stored in accordance with any applicable manufacturer instructions.

Repair of Respirators

Respirators that fail an inspection or are otherwise found to be defective will be removed from service to be discarded, repaired or adjusted in accordance with the following procedures:

- Repairs or adjustments to respirators are to be made only by persons appropriately trained to perform such operations and shall use only the respirator manufacturer's NIOSH-approved parts designed for the respirator;
- Repairs shall be made according to the manufacturer's recommendations and specifications for the type and extent of repairs to be performed; and
- Reducing and admission valves, regulators, and alarms shall be adjusted or repaired only by the manufacturer or a technician trained by the manufacturer.

Breathing Air Quality and Use

The Employer shall ensure that compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration accords with the following specifications:

- Compressed and liquid oxygen shall meet the United States Pharmacopoeia requirements for medical or breathing oxygen; and
- Compressed breathing air shall meet at least the requirements for Grade D breathing air described in ANSI/Compressed Gas Association Commodity Specification for Air, G-7.1-1989, to include:
- Oxygen content (**v/v**) of 19.5-23.5%;
- Hydrocarbon (condensed) content of 5 milligrams per cubic meter of air or less;
- Carbon monoxide (**CO**) content of 10 ppm or less;
- Carbon dioxide content of 1,000 ppm or less; and
- Lack of noticeable odor.
- Compressed oxygen will not be used in atmosphere-supplying respirators that have previously used compressed air.
- Oxygen concentrations greater than 23.5% are used only in equipment designed for oxygen service or distribution.

Cylinders used to supply breathing air to respirators meet the following requirements.

- Cylinders are tested and maintained as prescribed in the Shipping Container Specification Regulations of the Department of Transportation (49 CFR part 173 and part 178).
- Cylinders of purchased breathing air have a certificate of analysis from the supplier that the breathing air meets the requirements for Grade D breathing air.
- Moisture content in breathing air cylinders does not exceed a dew point of -50 deg. F (-45.6 deg. C) at 1 atmosphere pressure.

- Breathing air couplings are incompatible with outlets for non-respirable worksite air or other gas systems. No asphyxiating substance shall be introduced into breathing air lines.
- Breathing gas containers shall be marked in accordance with the NIOSH respirator certification standard, 42 CFR part 84.

Summary

Following this training session, employees should

- Wear the respirator assigned to him or her.
- Always check for fit before wearing.
- Always check for damage and deterioration before wearing.
- Know when to replace canisters and cartridges.
- Practice maneuvering with a respirator.
- Store carefully in the proper location.

Personal Protective Equipment Example Sub-Section

Purpose

Your Employer is required to provide all Employees with required PPE to suit the task and known hazards. This Chapter covers the requirements for Personal Protective Equipment with the exception of PPE used for respiratory protection or PPE required for hazardous material response to spills or releases. Applicable OSHA Standards are 1910 Subpart 1 App B and 1910.120 App B, 132, 133, 136, and 138.

General Rules Design

All personal protective equipment shall be of safe design and construction for the work to be performed.

Hazard Assessment and Equipment Selection

Hazard analysis procedures shall be used to assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of personal protective equipment (PPE). If such hazards are present, or likely to be present, the following actions will be taken:

1) Select, and have each affected Employee use, the proper PPE.
2) Communicate selection decisions to each affected Employee.
3) Select PPE that properly fits each affected employee.

Defective and Damaged Equipment.

Defective or damaged personal protective equipment shall not be used.

Training

All Employees who are required to use PPE shall be trained to know at least the following:

1) When PPE is necessary;
2) What PPE is necessary;
3) How to properly don, remove, adjust, and wear PPE;
4) The limitations of the PPE
5) The proper care, maintenance, useful life and disposal of the PPE.

Each affected Employee shall demonstrate an understanding of the training and the ability to use PPE properly, before being allowed to perform work requiring the use of PPE.

Certification of training for PPE is required by OSHA and shall be accomplished by using the Job Safety Checklist to verify that each affected Employee has received and understood the required PPE training.

Personal Protective Equipment Selection

Controlling Hazards

PPE devices alone should not be relied on to provide protection against hazards, but should be used in conjunction with guards, engineering controls, and sound manufacturing practices.

Selection Guidelines

The general procedure for selection of protective equipment is to:

a) Become familiar with the potential hazards and the type of protective equipment that is available, and what it can do; i.e., splash protection, impact protection, etc.
b) Compare the hazards associated with the environment (i.e., impact velocities, masses, projectile shape, radiation intensities) with the capabilities of the available protective equipment;
c) Select the protective equipment which ensures a level of protection greater than the minimum required to protect employees from the hazards;
d) Fit the user with the protective device and give instructions on care and use of the PPE. It is very important that end users be made aware of all warning labels for and limitations of their PPE.

Fitting the Device

Careful consideration must be given to comfort and fit. PPE that fits poorly will not afford the necessary protection. Continued wearing of the device is more likely if it fits the wearer comfortably. Protective devices are generally available in a variety of sizes. Care should be taken to ensure that the right size is selected.

Devices with Adjustable Features

Adjustments should be made on an individual basis for a comfortable fit that will maintain the protective device in the proper position. Particular care should be taken in fitting devices for eye protection against dust and chemical splash to ensure that the devices are sealed to the face. In addition, proper fitting of helmets is important to ensure that it will not fall off during work operations.

In some cases a chin strap may be necessary to keep the helmet on an employee's head. (Chin straps should break at a reasonably low force, however, so as to prevent a strangulation hazard). Where manufacturer's instructions are available, they should be followed carefully.

Eye and Face Protection

Each affected employee shall use appropriate eye or face protection when exposed to eye or face hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation.

Each affected employee shall use eye protection that provides side protection when there is a hazard from flying objects. Detachable side protectors are acceptable.

Each affected employee who wears prescription lenses while engaged in operations that involve eye hazards shall wear eye protection that incorporates the prescription in its design, or shall wear eye protection that can be worn over the prescription lenses without disturbing the proper position of the prescription lenses or the protective lenses.

Eye and face PPE shall be distinctly marked to facilitate identification of the manufacturer.

Each affected employee shall use equipment with filter lenses that have a shade number appropriate for the work being performed for protection from injurious light radiation. The following is a listing of appropriate shade numbers for various operations.

Filter Lenses for Protection Against Radiant Energy

Operations	Electrode Size 1/32 in	Arc Current	Protective Shade
Shielded metal arc welding	Less than 3	Less than 60	7
	3-5	60-160	8
	5-8	160-250	10
	More than 8	250-550	11
Torch brazing			3
Torch soldering			2

Note: as a rule of thumb, start with a shade that is too dark to see the weld zone. Then go to a lighter shade which gives sufficient view of the weld zone without going below the minimum. In oxyfuel gas welding or cutting where the torch produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line in the visible light of the (spectrum) operation.

Always utilize a chemical fume hood and ventilation system when working or testing Chlorine.

Selection Chart Guidelines for Eye and Face Protection

The following chart provides general guidance for the proper selection of eye and face protection to protect against hazards associated with the listed hazard "source" operations.

Source	Hazard	Protection
IMPACT - Chipping, grinding machining, masonry work, woodworking, sawing, drilling, chiseling, powered fastening, riveting, and sanding	Flying fragments, objects, large chips, particles, sand, dirt, etc.	Spectacles with side protection, goggles, face shield For severe exposure, use face shield
HEAT - Furnace operation and arc welding	Hot sparks	Face shields, spectacles with side. For severe exposure use faceshield.
CHEMICALS - Acid and chemical handling, degreasing, plating	Splash	Goggles, eyecup and cover types. For severe exposure, use face shield.
DUST - Woodworking, buffing, general, buffing, general dusty conditions.	Nuisance dust	Goggles, eye cup and cover type

READ THE SAFETY DATA SHEET

WEAR PROPER PPE

HANDLING CHEMICALS

Selection Guidelines for Head Protection

All head protection is designed to provide protection from impact and penetration hazards caused by falling objects. Head protection is also available which provides protection from electric shock and burn.

When selecting head protection, knowledge of potential electrical hazards is important.

Class A helmets, in addition to impact and penetration resistance, provide electrical protection from low-voltage conductors (they are proof tested to 2,200 volts).

Class B helmets, in addition to impact and penetration resistance; provide electrical protection from high-voltage conductors (they are proof tested to 20,000 volts).

Class C helmets provide impact and penetration resistance (they are usually made of aluminum which conducts electricity), and should not be used around electrical hazards.

Where falling object hazards are present, helmets must be worn.

Some examples include: working below other workers who are using tools and materials which could fall; working around or under conveyor belts which are carrying parts or materials; working below machinery or processes which might cause material or objects to fall; and working on exposed energized conductors.

Foot Protection Section

General Requirements

Each affected employee shall wear protective footwear when working in areas where there is a danger of foot injuries due to falling or rolling objects, or objects piercing the sole, and where employee's feet are exposed to electrical hazards.

Selection Guidelines for Foot Protection

Safety shoes and boots provide both impact and compression protection. Where necessary, safety shoes can be obtained which provide puncture protection. In some work situations, metatarsal protection should be provided, and in other special situations electrical conductive or insulating safety shoes would be appropriate.

Safety shoes or boots with impact protection would be required for carrying or handling materials such as packages, objects, parts or heavy tools, which could be dropped; and, for other activities where objects might fall onto the feet.

Safety shoes or boots with compression protection would be required for work activities involving skid trucks (manual material handling carts) around bulk rolls (such as paper rolls) and around heavy pipes, all of which could potentially roll over an employee's feet.

Safety shoes or boots with puncture protection would be required where sharp objects such as nails, wire, tacks, screws, large staples, scrap metal etc., could be stepped on by employees causing a foot injury.

Hand Protection

General Requirements

Hand protection is required when employees' hands are exposed to hazards such as those from skin absorption of harmful substances; severe cuts or lacerations; severe abrasions; punctures; chemical or thermal burns; and harmful temperature extremes.

Selection Guidelines for Hand Protection

Selection of hand PPE shall be based on an evaluation of the performance characteristics of the hand protection relative to the task(s) to be performed, conditions present, duration of use, and the hazards and potential hazards identified. Gloves are often relied upon to prevent cuts, abrasions, burns, and skin contact with chemicals that are capable of causing local or systemic effects following dermal exposure.

There is no glove that provides protection against all potential hand hazards, and commonly available glove materials provide only limited protection against many chemicals. Therefore, it is important to select the most appropriate glove for a particular application and to determine how long it can be worn and whether it can be reused.

It is also important to know the performance characteristics of gloves relative to the specific hazard anticipated; e.g., chemical hazards, cut hazards, flame hazards, etc. Before purchasing gloves, request documentation from the manufacturer that the gloves meet the appropriate test standard(s) for the hazard(s) anticipated.

Other Factors to be Considered for Glove Selection in General Include:

(A) As long as the performance characteristics are acceptable, in certain circumstances it may be more cost effective to regularly change cheaper gloves than to reuse more expensive types.
(B) The work activities of the employee should be studied to determine the degree of dexterity required, the duration, frequency, and degree of exposure of the hazard, and the physical stresses that will be applied.

Selection of Gloves for Protection Against Chemical Hazards:

(A) The toxic properties of the chemical(s) must be determined; in particular, the ability of the chemical to cause local effects on the skin and/or to pass through the skin and cause systemic effects.

(B) Generally, any "**chemical resistant**" glove can be used for dry powders;

(C) For mixtures and formulated products (unless specific test data are available), a glove should be selected on the basis of the chemical component with the shortest breakthrough time, since it is possible for solvents to carry active ingredients through polymeric materials.

(D) Employees must be able to remove the gloves in such a manner as to prevent skin contamination.

Protective Clothing Applications

A. The purpose of chemical protective clothing and equipment is to shield or isolate individuals from the chemical, physical, and biological hazards that may be encountered during hazardous materials operations. During chemical operations, it is not always apparent when exposure occurs. Many chemicals pose invisible hazards and offer no warning properties.

B. These guidelines describe the various types of clothing that are appropriate for use in various chemical operations, and provides recommendations in their selection and use. The final paragraph discusses heat stress and other key physiological factors that must be considered in connection with protective clothing use.

C. It is important that protective clothing users realize that no single combination of protective equipment and clothing is capable of protecting you against all hazards. Thus protective clothing should be used in conjunction with other protective methods.

For example, engineering or administrative controls to limit chemical contact with personnel should always be considered as an alternative measure for preventing chemical exposure.

The use of protective clothing can itself create significant wearer hazards, such as heat stress, physical and psychological stress, in addition to impaired vision, mobility, and communication. In general, the greater the level of chemical protective clothing, the greater the associated risks.

For any given situation, equipment and clothing should be selected that provide an adequate level of protection. Overprotection as well as under-protection can be hazardous and should be avoided.

Protective Clothing Applications

1. Protective clothing must be worn whenever the wearer faces potential hazards arising from chemical exposure. Some examples include:

- ➢ Emergency response;
- ➢ Chemical manufacturing and process industries;
- ➢ Hazardous waste site cleanup and disposal;
- ➢ Asbestos removal and other particulate operations; and
- ➢ Agricultural application of pesticides.

2. Within each application, there are several operations which require chemical protective clothing. For example, in emergency response, the following activities dictate chemical protective clothing use:

- ✓ **Site Survey**: The initial investigation of a hazardous materials incident; these situations are usually characterized by a large degree of uncertainty and mandate the highest levels of protection.

- ✓ **Rescue**: Entering a hazardous materials area for the purpose of removing an exposure victim; special considerations must be given to how the selected protective clothing may affect the ability of the wearer to carry out the rescue and to the contamination of the victim.

- ✓ **Spill Mitigation:** Entering a hazardous materials area to prevent a potential spill or to reduce the hazards from an existing spill (i.e., applying a chlorine kit on railroad tank car). Protective clothing must accommodate the required tasks without sacrificing adequate protection.

- ✓ **Emergency Monitoring**: Outfitting personnel in protective clothing for the primary purpose of observing a hazardous materials incident without entry into the spill site. This may be applied to monitoring contract activity for spill cleanup.

- ✓ **Decontamination:** Applying decontamination procedures to personnel or equipment leaving the site; in general a lower level of protective clothing is used by personnel involved in decontamination.

The Clothing Ensemble. The approach in selecting personal protective clothing must encompass an "**ensemble**" of clothing and equipment items which are easily integrated to provide both an appropriate level of protection and still allow one to carry out activities involving chemicals.

In many cases, simple protective clothing by itself may be sufficient to prevent chemical exposure, such as wearing gloves in combination with a splash apron and faceshield (or safety goggles).

1. The following is a checklist of components that may form the chemical protective ensemble:
    - ➢ **Protective clothing (suit, coveralls, hoods, gloves, boots);**
    - ➢ **Respiratory equipment (SCBA, combination SCBA/SAR, air purifying respirators);**
    - ➢ **Cooling system (ice vest, air circulation, water circulation);**
    - ➢ **Communications device;**
    - ➢ **Head protection;**
    - ➢ **Eye protection;**
    - ➢ **Ear protection;**
    - ➢ **Inner garment; and**
    - ➢ **Outer protection (overgloves, overboots, flashcover).**

2. **Factors that affect the selection of ensemble components include:**

    - ✓ How each item accommodates the integration of other ensemble components. Some ensemble components may be incompatible due to how they are worn (e.g., some SCBA's may not fit within a particular chemical protective suit or allow acceptable mobility when worn).

    - ✓ The ease of interfacing ensemble components without sacrificing required performance (e.g. a poorly fitting overglove that greatly reduces wearer dexterity).

    - ✓ Limiting the number of equipment items to reduce donning time and complexity (e.g. some communications devices are built into SCBA's which as a unit are NIOSH certified).

Level of Protection

1. Table VIII:1-1 lists ensemble components based on the widely used EPA Levels of Protection: Levels A, B, C, and D. These lists can be used as the starting point for ensemble creation; however, each ensemble must be tailored to the specific situation in order to provide the most appropriate level of protection.

For example, if an emergency response activity involves a highly contaminated area or if the potential of contamination is high, it may be advisable to wear a disposable covering such as Tyvek coveralls or PVC splash suits, over the protective ensemble.

TABLE VIII:1-1. EPA's Levels of Protection

Level A:
Vapor protective suit (meets NFPA 1991)
Pressure-demand, full-face SCBA
Inner chemical-resistant gloves, chemical-resistant safety boots, two-way radio communication
Optional: Cooling system, outer gloves, hard hat
Protection Provided: Highest available level of respiratory, skin, and eye protection from solid, liquid and gaseous chemicals.
Used When: The chemical(s) have been identified and have high level of hazards to respiratory system, skin and eyes. Substances are present with known or suspected skin toxicity or carcinogenity. Operations must be conducted in confined or poorly ventilated areas.
Limitations: Protective clothing must resist permeation by the chemical or mixtures present. Ensemble items must allow integration without loss of performance.

Level B:
Liquid splash-protective suit (meets NFPA 1992)
Pressure-demand, full-facepiece SCBA
Inner chemical-resistant gloves, chemical-resistant safety boots, two-way radio communications and Hard hat.
Optional:: Cooling system, outer gloves
Protection Provided: Provides same level of respiratory protection as Level A, but less skin protection. Liquid splash protection, but no protection against chemical vapors or gases.
Used When: The chemical(s) have been identified but do not require a high level of skin protection. Initial site surveys are required until higher levels of hazards are identified. The primary hazards associated with site entry are from liquid and not vapor contact.
Limitations: Protective clothing items must resist penetration by the chemicals or mixtures present. Ensemble items must allow integration without loss of performance.

Level C:
Support Function Protective Garment (meets NFPA 1993)
Full-facepiece, air-purifying, canister-equipped respirator
Chemical resistant gloves and safety boots
Two-way communications system, hard hat
Optional: Faceshield, escape SCBA
Protection Provided: The same level of skin protection as Level B, but a lower level of respiratory protection. Liquid splash protection but no protection against chemical vapors or gases.
Used When: Contact with site chemical(s) will not affect the skin. Air contaminants have been identified and concentrations measured. A canister is available which can remove the contaminant. The site and its hazards have been completely characterized.

Limitations: Protective clothing items must resist penetration by the chemical or mixtures present. Chemical airborne concentration must be less than IDLH levels. The atmosphere must contain at least 19.5% oxygen.
Not Acceptable for Chemical Emergency Response

Level D:
Coveralls, safety boots/shoes, safety glasses or chemical splash goggles
Optional: Gloves, escape SCBA, face-shield
Protection Provided: No respiratory protection, minimal skin protection.
Used When: The atmosphere contains no known hazard. Work functions preclude splashes, immersion, potential for inhalation, or direct contact with hazard chemicals.
Limitations: This level should not be worn in the Hot Zone. The atmosphere must contain at least 19.5% oxygen.
Not Acceptable for Chemical Emergency Response

2. The type of equipment used and the overall level of protection should be reevaluated periodically as the amount of information about the chemical situation or process increases, and when workers are required to perform different tasks. Personnel should upgrade or downgrade their level of protection only with concurrence with the site supervisor, safety officer, or plant industrial hygienist.

3. The recommendations in Table VIII:1-1 serve only as guidelines. It is important for you to realize that selecting items by how they are designed or configured alone is not sufficient to ensure adequate protection. In other words, just having the right components to form an ensemble is not enough. The EPA levels of protection do not define what performance the selected clothing or equipment must offer. Many of these considerations are described in the ***"limiting criteria***" column of Table VIII: 1-1. Additional factors relevant to the various clothing and equipment items are described in subsequent Paragraphs.

Ensemble Selection Factors.
1. **Chemical Hazards**. Chemicals present a variety of hazards such as toxicity, corrosiveness, flammability, reactivity, and oxygen deficiency. Depending on the chemicals present, any combination of hazards may exist.

2. **Physical Environment.** Chemical exposure can happen anywhere: in industrial settings, on the highways, or in residential areas.

It may occur either indoors or outdoors; the environment may be extremely hot, cold, or moderate; the exposure site may be relatively uncluttered or rugged, presenting a number of physical hazards; chemical handling activities may involve entering confined spaces, heavy lifting, climbing a ladder, or crawling on the ground. The choice of ensemble components must account for these conditions.

3. **Duration of Exposure**. The protective qualities of ensemble components may be limited to certain exposure levels (e.g. material chemical resistance, air supply). The decision for ensemble use time must be made assuming the worst case exposure so that safety margins can be applied to increase the protection available to the worker.

4. **Protective Clothing or Equipment Available.** Hopefully, an array of different clothing or equipment is available to workers to meet all intended applications. Reliance on one particular clothing or equipment item may severely limit a facility's ability to handle a broad range of chemical exposures. In its acquisition of equipment and clothing, the safety department or other responsible authority should attempt to provide a high degree of flexibility while choosing protective clothing and equipment that is easily integrated and provides protection against each conceivable hazard.

Classification of Protective Clothing.
Personal protective clothing includes the following:
* Fully encapsulating suits;
* Nonencapsulating suits;
* Gloves, boots, and hoods;
* Firefighter's protective clothing;
* Proximity, or approach clothing;
* Blast or fragmentation suits; and
* Radiation-protective suits.

1. Firefighter turnout clothing, proximity gear, blast suits, and radiation suits by themselves are not acceptable for providing adequate protection from hazardous chemicals.

2. Table VIII:1-2 describes various types of protection clothing available, details the type of protection they offer, and lists factors to consider in their selection and use.

TABLE VIII: 1-2. Types of Protective Clothing for Full Body Protection

One-piece garment. Boots and gloves may be integral, attached and replaceable, or separate.

- Protects against splashes, dust gases, and vapors.

- Does not allow body heat to escape. May contribute to heat stress in wearer, particularly if worn in conjunction with a closed-circuit SCBA; a cooling garment may be needed. Impairs worker mobility, vision, and communication.
  Nonencapsulating suit

Jacket, hood, pants or bib overalls, and one-piece coveralls.

Protects against splashes, dust, and other materials but not against gases and vapors. Does not protect parts of head or neck.

- Do not use where gas-tight or pervasive splashing protection is required. May contribute to heat stress in wearer. Tape-seal connections between pant cuffs and boots and between gloves and sleeves.

Aprons, leggings, and sleeve protectors

- Fully sleeved and gloved apron. Separate coverings for arms and legs. Commonly worn over nonencapsulating suit.

- Provides additional splash protection of chest, forearms, and legs.

- Whenever possible, should be used over a non-encapsulating suit to minimize potential heat stress. Useful for sampling, labeling, and analysis operations. Should be used only when there is a low probability of total body contact with contaminants.

Firefighters' Protective Clothing

- Gloves, helmet, running or bunker coat, running or bunker pants (NFPA No. 1971, 1972, 1973, and boots (1974).

- Protects against heat, hot water, and some particles. Does not protect against gases and vapors, or chemical permeation or degradation. NFPA Standard No. 1971 specifies that a garment consists of an outer shell, an inner liner and a vapor barrier with a minimum water penetration of 25 lb/in2 (1.8 kg/cm2) to prevent passage of hot water.

- Decontamination is difficult. Should not be worn in areas where protection against gases, vapors, chemical splashes or permeation is required.

Proximity Garment (Approach Suit)

- One- or two-piece overgarment with boot covers, gloves, and hood of aluminized nylon or cotton fabric. Normally worn over other protective clothing, firefighters' bunker gear, or flame-retardant coveralls.

- Protects against splashes, dust, gases, and vapors.

- Does not allow body heat to escape. May contribute to heat stress in wearer, particularly if worn in conjunction with a closed-circuit SCBA; a cooling garment may be needed. Impairs worker mobility, vision, and communication.

Blast and Fragmentation Suit

- Blast and fragmentation vests and clothing, bomb blankets, and bomb carriers.

- Provides some protection against very small detonations. Bomb blankets and baskets can help redirect a blast.

- Does not provide for hearing protection.

Radiation-Contamination Protective Suit

- Various types of protective clothing designed to prevent contamination of the body by radioactive particles.

- Protects against alpha and beta particles. Does not protect against gamma radiation.

- Designed to prevent skin contamination. If radiation is detected on site, consult an experienced radiation expert and evacuate personnel until the radiation hazard has been evaluated.

Flame/Fire Retardant Coveralls.

- Normally worn as an undergarment.

- Provides protection from flash fires; adds bulk and may exacerbate heat stress problems and impair mobility.

Glossary

A

ABIOGENESIS: The concept of spontaneous generation (that life can come from non-life). This idea was refuted by Pasteur.

ABIOTIC: The non-living components of an organism's environment. The term abiotic is also used to denote a process which is not facilitated by living organisms.

ABORAL: Pertaining to the region of the body opposite that of the mouth. Normally used to describe radially symmetrical animals.

ABSCISIC ACID (ABA): A plant hormone that generally acts to inhibit growth, promote dormancy, and help the plant withstand stressful conditions.

ABSENCE OF OXYGEN: The complete absence of oxygen in water described as Anaerobic.

ABSOLUTE ZERO: A theoretical condition concerning a system at zero Kelvin where a system does not emit or absorb energy (all atoms are at rest).

ABSORPTION SPECTRUM: The range of a material's ability to absorb various wavelengths of light. The absorption spectrum is studied to evaluate the function of photosynthetic pigments.

ACCESSORY PIGMENT: A photosynthetic pigment which absorbs light and transfers energy to chlorophylls during photosynthesis. Because accessory pigments have different absorption optima than chlorophylls, presence of accessory pigments allows photosynthetic systems to absorb light more efficiently than would be possible otherwise.

ACCURACY: How close a value is to the actual or true value; also see precision. How closely an instrument measures the true or actual value.

ACELLULAR: Not within cells. Sometimes used as a synonym for unicellular (but multinucleate). Unicellular also pertains to single: celled organisms.

ACETYL COA: Acetyl CoenzymeA is the entry compound for the Krebs cycle in cellular respiration; formed from a fragment of pyruvic acid attached to a coenzyme.

ACETYLCHOLINE: A neurotransmitter substance that carries information across vertebrate neuromuscular junctions and some other synapses.

ACID AND BASE ARE MIXED: When an acid and a base are mixed, an explosive reaction occurs and decomposition products are created under certain conditions.

ACID ANHYDRIDE: A compound with two acyl groups bound to a single oxygen atom.

ACID DISSOCIATION CONSTANT: An equilibrium constant for the dissociation of a weak acid.

ACID RAIN: Rain that is excessively acidic due to the presence of acid: causing pollutants in the atmosphere. Pollutants include nitrogen and sulfur oxides due to burning of coal and oil.

ACID: Slowly add the acid to water while stirring. An operator should not mix acid and water or acid to a strong base.

ACIDOSIS: A condition whereby the hydrogen ion concentration of the tissues is increased (and pH decreased). Respiratory acidosis is due to the retention of CO_2; metabolic acidosis by retention of acids due either to kidney failure or diarrhea.

ACOELOMATE: Lacking a coelom.

ACQUIRED IMMUNITY: Results from exposure to foreign substances or microbes (also called natural immunity).

ACROSOME: An organelle at the tip of a sperm cell that helps the sperm penetrate the egg.

ACTH (adrenocorticotrophic hormone): A proteineinaceous hormone from the anterior pituitary that stimulates the adrenal cortex. Used to stimulate the production of cortisol.

ACTIN: A globular protein that links into chains, two of which twist helically about each other, forming microfilaments in muscle and other contractile elements in cells.

ACTINIDES: The fifteen chemicas that are between actinium (89) and lawrencium (103).

ACTION POTENTIAL: The stimulus- triggered change in the membrane potential of an excitable cell, caused by selective opening and closing of ion channels.

ACTION SPECTRUM: A graph which illustrates the relationship between some biological activity and wavelength of light.

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

ACTIVATED CHARCOAL (GAC or PAC): Granular Activated Charcoal or Powered Activated Charcoal. Used for taste and odor removal. A treatment technique that is not included in the grading of a water facility.

ACTIVATED COMPLEX: A structure that forms because of a collision between molecules while new bonds are formed.

ACTIVATED SLUDGE PROCESS: A biological wastewater treatment process in which a mixture of wastewater and biologically enriched sludge is mixed and aerated to facilitate aerobic decomposition by microbes.

ACTIVATED SLUDGE: The biologically active solids in an activated sludge process wastewater treatment plant.

ACTIVATING ENZYME: An enzyme that couples a low-energy compound with ATP to yield a high-energy derivative.

ACTIVATION ENERGY: In a chemical reaction, the initial investment required to energize the bonds of the reactants to an unstable transition state that precedes the formation of the products. The minimum energy that must be input to a chemical system.

ACTIVE SITE: That specific portion of an enzyme that attaches to the substrate by means of weak chemical bonds.

ACTIVE TRANSPORT: The movement of a substance across a biological membrane against its concentration or electrochemical gradient with the help of energy input and specific transport proteins.

ADAPTATION: Any genetically controlled characteristic that increases an organism's fitness, usually by helping the organism to survive and reproduce in the environment it inhabits.

ADAPTIVE RADIATION: This refers to the rapid evolution of one or a few forms into many different species that occupy different habitats within a new geographical area.

ADDITION REACTION: Within organic chemistry, when two or more molecules combine to make a larger one.

ADHESION: In chemistry, the phenomenon whereby one substance tends to cling to another substance. Water molecules exhibit adhesion, especially toward charged surfaces.

ADP (Adenosine diphosphate): A doubly phosphorylated organic compound that can be further phosphorylated to form ATP.

ADRENAL GLAND: An endocrine gland located adjacent to the kidney in mammals. It is composed of an outer cortex, and a central medulla, each involved in different hormone: mediated phenomena.

ADRENALIN: A hormone produced by the pituitary that stimulates the adrenal cortex.

ADSORB: Hold on a surface.

ADSORPTION CLARIFIERS: The concept of the adsorption clarifier package plant was developed in the early 1980s. This technology uses an up-flow clarifier with low-density plastic bead media, usually held in place by a screen. This adsorption media is designed to enhance the sedimentation/clarification process by combining flocculation and sedimentation into one step. In this step, turbidity is reduced by adsorption of the coagulated and flocculated solids onto the adsorption media and onto the solids already adsorbed onto the media. Air scouring cleans adsorption clarifiers followed by water flushing. Cleaning of this type of clarifier is initiated more often than filter backwashing because the clarifier removes more solids. As with the tube-settler type of package plant, the sedimentation/ clarification process is followed by mixed-media filtration and disinfection to complete the water treatment.

ADSORPTION: *Not to be confused with absorption.* Adsorption is a process that occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a film of molecules or atoms (the adsorbate). It is different from absorption, in which a substance diffuses into a liquid or solid to form a solution. The term sorption encompasses both processes, while desorption is the reverse process. Adsorption is present in many natural physical, biological, and chemical systems, and is widely used in industrial applications such as activated charcoal, synthetic resins, and water purification. Adsorption, ion exchange, and chromatography are sorption processes in which certain adsorbates are selectively transferred from the fluid phase to the surface of insoluble, rigid particles suspended in a vessel or packed in a column. Similar to surface tension, adsorption is a consequence of surface energy. In a bulk material, all the bonding requirements (be they ionic, covalent, or metallic) of the constituent atoms of the material are filled by other atoms in the material. However, atoms on the surface of the adsorbent are not wholly surrounded by other adsorbent atoms, and therefore can attract adsorbates. The exact nature of the bonding depends on the details of the species involved, but the adsorption process is generally classified as physisorption (characteristic of weak van der Waals forces) or chemisorption (characteristic of covalent bonding).

ADVANCED: New, unlike the ancestral condition.

AERATION: The addition of air or oxygen to water or wastewater, usually by mechanical means, to increase dissolved oxygen levels and maintains aerobic conditions. The mixing of air into a liquid or solid.

AEROBIC DIGESTION: Sludge stabilization process involving direct oxidation of biodegradable matter and oxidation of microbial cellular material.

AEROBIC: The condition of requiring oxygen; an aerobe is an organism which can live and grow only in the presence of oxygen.

AGE STRUCTURE: The relative numbers of individuals of each age in a population.

AGGLOMERATION: A jumbled cluster or mass of varied parts. The act or process of agglomerating.

AGNATHAN: A member of a jawless class of vertebrates represented today by the lampreys and hagfishes.

AGONISTIC BEHAVIOR: A type of behavior involving a contest of some kind that determines which competitor gains access to some resource, such as food or mates.

AIDS (acquired immune deficiency syndrome): A condition in which the body's helper T lymphocytes are destroyed, leaving the victim subject to opportunistic diseases.

AIR ENTRAINMENT: The dissolution or inclusion of air bubbles into water.

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

AIR HOOD: The most suitable protection when working with a chemical that produces dangerous fumes.

ALCOHOL: Any of a class of organic compounds in which one or more - OH groups are attached to a carbon compound.

ALDEHYDE: An organic molecule with a carbonyl group located at the end of the carbon skeleton.

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

ALKALI METALS: The metals of Group 1 on the periodic table.

ALKALINE: Having a pH of more than 7. Alkaline solutions are also said to be basic.

ALKALINITY: Alkalinity or AT is a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate. Alkalinity is closely related to the acid neutralizing capacity (ANC) of a solution and ANC is often incorrectly used to refer to alkalinity. However, the acid neutralizing capacity refers to the combination of the solution and solids present (e.g., suspended matter, or aquifer solids), and the contribution of solids can dominate the ANC (see carbonate minerals below). The alkalinity is equal to the stoichiometric sum of the bases in solution. In the natural environment carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. Other common natural components that can contribute to alkalinity include borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulfide. Solutions produced in a laboratory may contain a virtually limitless number of bases that contribute to alkalinity. Alkalinity is usually given in the unit mEq/L (milliequivalent per liter). Commercially, as in the pool industry, alkalinity might also be given in the unit ppm or parts per million. Alkalinity is sometimes incorrectly used interchangeably with basicity. For example, the pH of a solution can be lowered by the addition of CO_2. This will reduce the basicity; however, the alkalinity will remain unchanged.

ALKANLINE EARTH METALS: The metals of Group 2 on the periodic table.

ALLANTOIS: One of the four extraembryonic membranes found associated with developing vertebrates; it serves in gas exchange and as a repository for the embryo's nitrogenous waste. In humans, the allantois is involved in early blood formation and development of the urinary bladder.

ALLELE: Alternate forms of a gene which may be found at a given location (locus) on members of a homologous set of chromosomes. Structural variations between alleles may lead to different phenotypes for a given trait.

ALLOMER: A substance that has different composition than another, but has the same crystalline structure.

ALLOMETRIC: The variation in the relative rates of growth of various parts of the body, which helps shape the organism.

ALLOPATRIC SPECIATION: A type of speciation which occurs when a population becomes segregated into two populations by some sort of geographic barrier (also called geographic speciation). This phenomenon is presumed to have been the mechanism whereby many species of organisms evolved.

ALLOPOLYPLOID: A common type of polyploid species resulting from two different species interbreeding and combining their chromosomes.

ALL-OR-NONE: (event) An action that occurs either completely or not at all, such as the generation of an action potential by a neuron.

ALLOSTERIC ENZYME: An enzyme that can exist in two or more conformations.

ALLOSTERIC SITE: A receptor on an enzyme molecule which is remote from the active site. Binding of the appropriate molecule to the allosteric site changes the conformation of the active site, making it either more or less receptive to the substrate.

ALLOTROPY: Elements that can have different structures (and therefore different forms), such as Carbon (diamonds, graphite, and fullerene).

ALPHA AND BETA RADIOACTIVITY: Represent two common forms of radioactive decay. Radioactive elements have atomic nuclei so heavy that the nucleus will break apart, or disintegrate spontaneously. When decay occurs, high-energy particles are released. These high-energy particles are called radioactivity. Although radioactivity from refined radioactive elements can be dangerous, it is rare to find dangerous levels of radioactivity in natural waters. An alpha particle is a doubly-charged helium nucleus comprised of two protons, two neutrons, and no electrons. A beta particle is a high-speed electron. Alpha particles do not penetrate matter easily, and are stopped by a piece of paper. Beta particles are much more penetrating and can pass through a millimeter of lead.

ALPHA HELIX: A spiral shape constituting one form of the secondary structure of proteins, arising from a specific hydrogen: bonding structure.

ALTERNATION OF GENERATIONS: Occurrences of a multicellular diploid form, the sporophyte, with a multicellular haploid form, the gametophyte.

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

ALTRUISM: The willingness of an individual to sacrifice its fitness for the benefit of another.

ALUMINUM SULFATE: The chemical name for Alum. The molecular formula of Alum is $Al_2(SO_4)3\sim14H_2O$. It is a cationic polymer.

ALVEOLUS: One of the dead-end, multilobed air sacs that constitute the gas exchange surface of the lungs.

AMINO ACID: An organic molecule possessing a carboxyl (COOH) and amino group. Amino acids serve as the monomers of polypeptides and proteins.

AMINO GROUP: A functional group consisting of a nitrogen atom bonded to two hydrogens; can act as a base in solution, accepting a hydrogen ion and acquiring a charge of +1.

AMINOACYL: tRNA synthetases- A family of enzymes, at least one for each amino acid, that catalyze the attachment of an amino acid to its specific tRNA molecule.

AMMONIA: A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water. Most ammonia in water is present as the ammonium ion rather than as ammonia.

AMMONIA: NH3 A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water. Most ammonia in water is present as the ammonium ion rather than as ammonia.

AMMONIATOR: AA control device which meters gaseous ammonia directly into water under positive pressure.

AMOEBA: Amoeba (sometimes amœba or ameba, plural amoebae) is a genus of protozoa that moves by means of pseudopods, and is well-known as a representative unicellular organism. The word amoeba or ameba is variously used to refer to it and its close relatives, now grouped as the Amoebozoa, or to all protozoa that move using pseudopods, otherwise termed amoeboids. (Movement) A streaming locomotion characteristic of Amoeba and other protists, as well as some individual cells, such as white blood cells, in animals.

AMP (Adenosine monophosphate): A singly phosphorylated organic compound that can be further phosphorylated to form ADP.

AMYLASE: A starch-digesting enzyme.

ANABOLISM: A metabolic pathway of biosynthesis that consumes energy to build a large molecule from simpler ones.

ANAEROBIC CONDITIONS: When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with Reduction in the stratified waters.

ANAEROBIC DIGESTION: Sludge stabilization process where the organic material in biological sludges are converted to methane and carbon dioxide in an airtight reactor.

ANAEROBIC: Without oxygen. An organism which lives in the absence of oxygen is called an anaerobe. An abnormal condition in which color and odor problems are most likely to occur.

ANAEROBIC: An abnormal condition in which color and odor problems are most likely to occur.

ARCHENTERON: The endoderm-lined cavity formed during the gastrulation process that develops into the digestive tract of the animal.

ARISTOTLE: A Greek philosopher often credited as the first to use empirical and deductive methods in logic.

AROMATICITY: Chemical property of conjugated rings that results in unusual stability. See also benzene.

ARTIFICIAL SELECTION: The selective breeding of domesticated plants and animals to encourage the occurrence of desirable traits.

AS NITROGEN: An expression that tells how the concentration of a chemical is expressed mathematically. The chemical formula for the nitrate ion is 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.

AS: The chemical symbol of Arsenic.

ASCUS: The elongate spore sac of a fungus of the Ascomycota group.

ASEPTIC: Free from the living germs of disease, fermentation, or putrefaction.

ASEXUAL: A type of reproduction involving only one parent that produces genetically identical offspring by budding or division of a single cell or the entire organism into two or more parts.

ASSORTATIVE MATING: A type of nonrandom mating in which mating partners resemble each other in certain phenotypic characters.

ASYMMETRIC CARBON: A carbon atom covalently bonded to four different atoms or groups of atoms.

ASYNCHRONOUS: Not occurring at the same time.

ATOM: The general definition of an ion is an atom with a positive or negative charge. Electron is the name of a negatively charged atomic particle.

ATOMIC NUMBER: The number representing an element which corresponds with the number of protons within the nucleus.

ATOMIC ORBITAL: The region where the electron of the atom may be found.

ATOMIC THEORY: The physical theory of the structure, properties and behavior of the atom.

ATOMIC WEIGHT: The total atomic mass, which is the mass in grams of one mole of the atom (relative to that of 12C, which is designated as 12).

ATP (Adenosine triphosphate): A triply phosphorylated organic compound that functions as "energy currency" for organisms, thus allowing life forms to do work; it can be hydrolyzed in two steps (first to ADP and then to AMP) to liberate 7.3 Kcal of energy per mole during each hydrolysis.

ATPASE: An enzyme that functions in producing or using ATP.

AUTOGENOUS MODEL: A hypothesis which suggests that the first eukaryotic cells evolved by the specialization of internal membranes originally derived from prokaryotic plasma membranes.

AUTOIMMUNE DISEASE: An immunological disorder in which the immune system goes awry and turns against itself.

AUTONOMIC NERVOUS SYSTEM: A subdivision of the motor nervous system of vertebrates that regulates the internal environment; consists of the sympathetic and parasympathetic subdivisions.

AUTOPOLYPLOID: A type of polyploid species resulting from one species doubling its chromosome number to become tetraploids, which may self-fertilize or mate with other tetraploids.

AUTOSOME: Chromosomes that are not directly involved in determining sex.

AUTOTROPH: An organism which is able to make organic molecules from inorganic ones either by using energy from the sun or by oxidizing inorganic substances.

B

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

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

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

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

BACTERIOPHAGE: Any of a group of viruses that infect specific bacteria, usually causing their disintegration or dissolution. A bacteriophage (from 'bacteria' and Greek phagein, 'to eat') is any one of a number of viruses that infect bacteria. The term is commonly used in its shortened form, phage. Typically, bacteriophages consist of an outer protein hull enclosing genetic material. The genetic material can be ssRNA (single stranded RNA), dsRNA, ssDNA, or dsDNA between 5 and 500 kilo base pairs long with either circular or linear arrangement. Bacteriophages are much smaller than the bacteria they destroy - usually between 20 and 200 nm in size.

BACTERIUM: A unicellular microorganism of the Kingdom Monera. Bacteria are prokaryotes; their cells have no true nucleus. Bacteria are classified into two groups based on a difference in cell walls, as determined by Gram staining.

BALANCED POLYMORPHISM: A type of polymorphism in which the frequencies of the coexisting forms do not change noticeably over many generations.

BARITE: Processed barium sulfate often used to increase drilling fluid densities in mud rotary.

BAROMETER: A device used to measure the pressure in the atmosphere.

BARR BODY: The dense object that lies along the inside of the nuclear envelope in cells of female mammals, representing the one inactivated X chromosome.

BASAL BODY: A cell structure identical to a centriole that organizes and anchors the microtubule assembly of a cilium or flagellum.

BASE PAIRING: Complementary base pairing refers to the chemical affinities between specific base pairs in a nucleic acid: adenine always pairs with thymine, and guanine always pairs with cytosine. In pairing between DNA and RNA, the uracil of RNA always pairs with adenine. Complementary base pairing is not only responsible for the DNA double helix, but it is also essential for various in vitro techniques such as PCR (polymerase chain reaction). Complementary base pairing is also known as Watson-Crick pairing.

BASE: A substance that reduces the hydrogen ion concentration in a solution.

BASE: A substance that accepts a proton and has a high pH; a common example is sodium hydroxide (NaOH).

BASEMENT MEMBRANE: The floor of an epithelial membrane on which the basal cells rest.

BASIDIUM: The spore-bearing structure of Basidiomycota.

BATESIAN MIMICRY: A type of mimicry in which a harmless species looks like a different species that is poisonous or otherwise harmful to predators.

B-CELL LYMPHOCYTE: A type of lymphocyte that develops in the bone marrow and later produces antibodies, which mediate humoral immunity.

BEHAVIORAL ECOLOGY: A heuristic approach based on the expectation that Darwinian fitness (reproductive success) is improved by optimal behavior.

BELT PRESS: A dewatering device utilizing two opposing synthetic fabric belts, revolving over a series of rollers to “squeeze” water from the sludge.

BENCH TEST: A small-scale test or study used to determine whether a technology is suitable for a particular application.

BENIGN TUMOR: A noncancerous abnormal growth composed of cells that multiply excessively but remain at their place of origin in the body.

BENTHIC: Pertaining to the bottom region of an aquatic environment.

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

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

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

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

BETA PLEATED SHEET: A zigzag shape, constituting one form of the secondary structure of proteins formed of hydrogen bonds between polypeptide segments running in opposite directions.

BILATERAL SYMMETRY: The property of having two similar sides, with definite upper and lower surfaces and anterior and posterior ends. The Bilateria are members of the branch of Eumetazoa (Kingdom Animalia) which possess bilateral symmetry.

BILE: A mixture of substances containing bile salts, which emulsify fats and aid in their digestion and absorption.

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

BRIDGING: The tendency of sediment, filter, or seal media to create an obstruction if installed in too small an annulus or to rapidly. Also can occur within filter packs requiring development.

BROMINE: Chemical disinfectant (HALOGEN) that kills bacteria and algae. This chemical disinfectant has been used only on a very limited scale for water treatment because of its handling difficulties. This chemical causes skin burns on contact, and a residual is difficult to obtain.

BRONSTED-LOWREY ACID: A chemical species that donates a proton.

BRONSTED-LOWREY BASE: A chemical species that accepts a proton.

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

BUFFERED SOLTION: An aqueous solution consisting of a weak acid and its conjugate base or a weak base and its conjugate acid that resists changes in pH when strong acids or bases are added.

BULKING SLUDGE: A phenomenon that occurs in activated sludge plants whereby the sludge occupies excessive volumes and will not concentrate readily. This condition refers to a decrease in the ability of the sludge to settle and consequent loss over the settling tank weir. Bulking in activated sludge aeration tanks is caused mainly by excess suspended solids (SS) content. Sludge bulking in the final settling tank of an activated sludge plant may be caused by improper balance of the BOD load, SS concentration in the mixed liquor, or the amount of air used in aeration. A poor or slow settling activated sludge that results from the prevalence of filamentous organisms.

BURETTE (also BURET): Glassware used to dispense specific amounts of liquid when precision is necessary (e.g. titration and resource dependent reactions).

C

Ca: The chemical symbol for calcium.

CADMIUM: A contaminant that is usually not found naturally in water or in very small amounts.

CAKE: Dewatered sludge material with a satisfactory solids concentration to allow handling as a solid material.

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

CALCIUM ION: Is divalent because it has a valence of +2.

CALCIUM, MAGNESIUM AND IRON: The three elements that cause hardness in water.

CaOCl2.4H2O: The molecular formula of Calcium hypochlorite.

CARBON DIOXIDE GAS: The pH will decrease and alkalinity will change as measured by the Langelier index after pumping carbon dioxide gas into water.

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CARBONATE HARDNESS: Carbonate hardness is the measure of Calcium and Magnesium and other hard ions associated with carbonate (CO32-) and bicarbonate (HCO3-) ions contained in a solution, usually water. It is usually expressed either as parts per million (ppm or mg/L), or in degrees (KH - from the German "Karbonathärte"). One German degree of carbonate hardness is equivalent to about 17.8575 mg/L. Both measurements (mg/L or KH) are usually expressed "as $CaCO_3$" – meaning the amount of hardness expressed as if calcium carbonate was the sole source of hardness. Every bicarbonate ion only counts for half as much carbonate hardness as a carbonate ion does. If a solution contained 1 liter of water and 50 mg $NaHCO_3$ (baking soda), it would have a carbonate hardness of about 18 mg/L as $CaCO_3$. If you had a liter of water containing 50 mg of Na_2CO_3, it would have a carbonate hardness of about 29 mg/L as $CaCO_3$.

CARBONATE, BICARBONATE AND HYDROXIDE: Chemicals that are responsible for the alkalinity of water.

CAROLUS LINNAEUS: Swedish botanist and originator of the binomial nomenclature system of taxonomic classification

CATALYST: A chemical compound used to change the rate (either to speed up or slow down) of a reaction, but is regenerated at the end of the reaction.

CATHODIC PROTECTION: An operator should protect against corrosion of the anode and/or the cathode by painting the copper cathode. Cathodic protection interrupts corrosion by supplying an electrical current to overcome the corrosion-producing mechanism. Guards against stray current corrosion.

CATION: Positively charged ion.

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

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

CEILING AREA: The specific gravity of ammonia gas is 0.60. If released, this gas will accumulate first at the ceiling area. Cl_2 gas will settle on the floor.

CELL POTENIAL: The force in a galvanic cell that pulls electron through reducing agent to oxidizing agent.

CENTRATE: The liquid remaining after solids have been removed in a centrifuge.

CENTRIFUGAL FORCE: That force when a ball is whirled on a string that pulls the ball outward. On a centrifugal pump, it is that force which throws water from a spinning impeller.

CENTRIFUGAL PUMP: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.

CENTRIFUGE: A dewatering device relying on centrifugal force to separate particles of varying density such as water and solids. Equipment used to separate substances based on density by rotating the tubes around a centered axis

CESIUM (also Caesium): Symbol Cs- A soft, silvery-white ductile metal, liquid at room temperature, the most electropositive and alkaline of the elements, used in photoelectric cells and to catalyze hydrogenation of some organic compounds.

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

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

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

CHEMICAL LAW: Certain rules that pertain to the laws of nature and chemistry.

CHEMICAL OXIDIZER: $KMnO_4$ is used for taste and odor control because it is a strong oxidizer which eliminates many organic compounds.

CHEMICAL OXIDIZER: $KMnO_4$ or Potassium Permanganate is used for taste and odor control

CHEMICAL OXYGEN DEMAND (COD): The milligrams of oxygen required to chemically oxidize the organic contaminants in one liter of wastewater.

CHEMICAL REACTION RATE: In general, when the temperature decreases, the chemical reaction rate also decreases. The opposite is true for when the temperature increases.

CHEMICAL REACTION: The change of one or more substances into another or multiple substances.

CHEMICAL SLUDGE: Sludge resulting from chemical treatment processes of inorganic wastes that are not biologically active.

CHEMISORPTION: (or chemical adsorption) Is adsorption in which the forces involved are valence forces of the same kind as those operating in the formation of chemical compounds.

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

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

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

CHLORINE FEED: Chlorine may be delivered by vacuum-controlled solution feed chlorinators. The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.

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

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

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

CIRCULATION: The continual flow of drilling fluid from injection to recovery and recirculation at the surface.

CLARIFIER: A settling tank used to remove suspended solids by gravity settling. Commonly referred to as sedimentation or settling basins, they are usually equipped with a motor driven chain and flight or rake mechanism to collect settled sludge and move it to a final removal point.

CLEAR WELL: A large underground storage facility sometimes made of concrete. A clear well or a plant storage reservoir is usually filled when demand is low. The final step in the conventional filtration process, the clearwell provides temporary storage for the treated water. The two main purposes for this storage are to have filtered water available for backwashing the filter and to provide detention time (or contact time) for the chlorine (or other disinfectant) to kill any microorganisms that may remain in the water.

ClO2: The molecular formula of Chlorine dioxide.

COAGULATION: The best pH range for coagulation is between 5 and 7. Mixing is an important part of the coagulation process you want to complete the coagulation process as quickly as possible. A chemical added to initially destabilize, aggregate, and bind together colloids and emulsions to improve settleability, filterability, or drainability.

COLIFORM TESTING: The effectiveness of disinfection is usually determined by Coliform bacteria testing. A positive sample is a bad thing and indicates that you have bacteria contamination.

COLIFORM: Bacteria normally found in the intestines of warm-blooded animals. Coliform bacteria are present in high numbers in animal feces. They are an indicator of potential contamination of water. Adequate and appropriate disinfection effectively destroys coliform bacteria. Public water systems are required to deliver safe and reliable drinking water to their customers 24 hours a day, 365 days a year. If the water supply becomes contaminated, consumers can become seriously ill. Fortunately, public water systems take many steps to ensure that the public has safe, reliable drinking water. One of the most important steps is to regularly test the water for coliform bacteria. Coliform bacteria are organisms that are present in the environment and in the feces of all warm-blooded animals and humans. Coliform bacteria will not likely cause illness. However, their presence in drinking water indicates that disease-causing organisms (pathogens) could be in the water system. Most pathogens that can contaminate water supplies come from the feces of humans or animals. Testing drinking water for all possible pathogens is complex, time-consuming, and expensive. It is relatively easy and inexpensive to test for coliform bacteria. If coliform bacteria are found in a water sample, water system operators work to find the source of contamination and restore safe drinking water. There are three different groups of coliform bacteria; each has a different level of risk.

COLLIOD: Mixture of evenly dispersed substances, such as many milks.

COLLOIDAL SUSPENSIONS: Because both iron and manganese react with dissolved oxygen to form insoluble compounds, they are not found in high concentrations in waters containing dissolved oxygen except as colloidal suspensions of the oxide.

COLORIMETRIC MEASUREMENT: A means of measuring an unknown chemical concentration in water by measuring a sample's color intensity.

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

COMBUSTION: An exothermic reaction between an oxidant and fuel with heat and often light

COMMUNITY WATER SYSTEM: A water system which supplies drinking water to 25 or more of the same people year-round in their residences.

COMPLIANCE CYCLE: A 9-calendar year time-frame during which a public water system is required to monitor. Each compliance cycle consists of 3 compliance periods.

COMPLIANCE PERIOD: A 3-calendar year time-frame within a compliance cycle.

COMPOSITE SAMPLE: A water sample that is a combination of a group of samples collected at various intervals during the day. A combination of individual samples of water or wastewater taken at predetermined intervals to minimize the effect of variability of individual samples. To have significant meaning, samples for laboratory tests on wastewater should be representative of the wastewater. The best method of sampling is proportional composite sampling over several hours during the day. Composite samples are collected because the flow and characteristics of the wastewater are continually changing. A composite sample will give a representative analysis of the wastewater conditions.

COMPOSTING: Stabilization process relying on the aerobic decomposition of organic matter in sludge by bacteria and fungi.

COMPOUND: A substance that is made up of two or more chemically bonded elements.

CONDENSATION: The process that changes water vapor to tiny droplets or ice crystals.

CONDUCTOR: Material that allows electric flow more freely.

CONTACT STABILIZATION PROCESS: Modification of the activated sludge process where raw wastewater is aerated with activated sludge for a short time prior to solids removal and continued aeration in a stabilization tank.

CONTACT TIME: If the water temperature decreases from 70°F (21°C) to 40°F (4°C). The operator needs to increase the detention time to maintain good disinfection of the water.

CONTAINS THE ELEMENT CARBON: A simple definition of an organic compound.

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

CONTAMINATION: A degradation in the quality of groundwater in result of the it’s becoming polluted with unnatural or previously non-existent constituents.

CONTROL TASTE AND ODOR PROBLEMS: $KMnO_4$ Potassium permanganate is a strong oxidizer commonly used to control taste and odor problems.

COPPER: The chemical name for the symbol Cu.

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

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CORROSIVITY: The Langelier Index measures corrosivity.

COUPON: A coupon placed to measure corrosion damage in the water mains.

COVALENT BOND: Chemical bond that involves sharing electrons.

CROSS-CONNECTION: A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow. Might be the source of an organic substance causing taste and odor problems in a water distribution system.

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

CRYPTOSPORIDIUM: A disease-causing parasite, resistant to chlorine disinfection. It may be found in fecal matter or contaminated drinking water. Cryptosporidium is a protozoan pathogen of the Phylum Apicomplexa and causes a diarrheal illness called cryptosporidiosis. Other apicomplexan pathogens include the malaria parasite Plasmodium, and Toxoplasma, the causative agent of toxoplasmosis. Unlike Plasmodium, which transmits via a mosquito vector, Cryptosporidium does not utilize an insect vector and is capable of completing its life cycle within a single host, resulting in cyst stages which are excreted in feces and are capable of transmission to a new host.

CRYSTAL: A solid that is packed with ions, molecules or atoms in an orderly fashion.

CUVETTE: Glassware used in spectroscopic experiments. It is usually made of plastic, glass or quartz and should be as clean and clear as possible.

CYANOBACTERIA: Cyanobacteria, also known as blue-green algae, blue-green bacteria or Cyanophyta, is a phylum of bacteria that obtain their energy through photosynthesis. The name "cyanobacteria" comes from the color of the bacteria (Greek: kyanós = blue). They are a significant component of the marine nitrogen cycle and an important primary producer in many areas of the ocean, but are also found on land.

CYANURIC ACID: White, crystalline, water-soluble solid, C3H3O3N3·2H2O, used chiefly in organic synthesis. Chemical used to prevent the decomposition of chlorine by ultraviolet (UV) light.

CYST: A phase or a form of an organism produced either in response to environmental conditions or as a normal part of the life cycle of the organism. It is characterized by a thick and environmentally resistant cell wall.

D

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

DANGEROUS CHEMICALS: The most suitable protection when working with a chemical that produces dangerous fumes is to work under an air hood.

DARCY’S LAW: (Q=KIA) A fundamental equation used in the groundwater sciences to determine aquifer characteristics, where Q=Flux, K=Hydraulic Conductivity (Permeability), I = Hydraulic Gradient (change in head), and A = Cross Sectional Area of flow.

DECANT: Separation of a liquid from settled solids by removing the upper layer of liquid after the solids have settled.

DECIBELS: The unit of measurement for sound.

DECOMPOSE: To decay or rot.

DECOMPOSTION OF ORGANIC MATERIAL: The decomposition of organic material in water produces taste and odors.

DEIONIZATION: The removal of ions, and in water's case mineral ions such as sodium, iron and calcium.

DELIQUESCENE: Substances that absorb water from the atmosphere to form liquid solutions.

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

DENITRIFICATION: A biological process by which nitrate is converted to nitrogen gas.

DENTAL CARIES PREVENTION IN CHILDREN: The main reason that fluoride is added to a water supply.

DEPOLARIZATION: The removal of hydrogen from a cathode.

DEPOSITION: Settling of particles within a solution or mixture.

DESICCANT: When shutting down equipment which may be damaged by moisture, the unit may be protected by sealing it in a tight container. This container should contain a desiccant.

DESORPTION: Desorption is a phenomenon whereby a substance is released from or through a surface. The process is the opposite of sorption (that is, adsorption and absorption). This occurs in a system being in the state of sorption equilibrium between bulk phase (fluid, i.e. gas or liquid solution) and an adsorbing surface (solid or boundary separating two fluids). When the concentration (or pressure) of substance in the bulk phase is lowered, some of the sorbed substance changes to the bulk state. In chemistry, especially chromatography, desorption is the ability for a chemical to move with the mobile phase. The more a chemical desorbs, the less likely it will adsorb, thus instead of sticking to the stationary phase, the chemical moves up with the solvent front. In chemical separation processes, stripping is also referred to as desorption as one component of a liquid stream moves by mass transfer into a vapor phase through the liquid-vapor interface.

DETENTION LAG: Is the period of time between the moment of change in a chlorinator control system and the moment when the change is sensed by the chlorine residual indicator.

DEVELOPMENT: The cleaning of the well and bore once construction is complete.

DIATOMACEOUS EARTH: A fine silica material containing the skeletal remains of algae.

DIGESTER: A tank or vessel used for sludge digestion.

DIGESTION: The biological decomposition of organic matter in sludge resulting in partial gasification, liquefaction, and mineralization of putrescible and offensive solids.

DIPOLE MOMENT: The polarity of a polar covalent bond.

DIPOLE: Electric or magnetic separation of charge.

DIRECT CURRENT: A source of direct current (DC) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.

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

DISINFECTION BY-PRODUCTS (DBPs): The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer. Chlorine is added to drinking water to kill or inactivate harmful organisms that cause various diseases. This process is called disinfection. However, chlorine is a very active substance and it reacts with naturally occurring substances to form compounds known as disinfection byproducts (DBPs). The most common DBPs formed when chlorine is used are trihalomethanes (THMs), and haloacetic acids (HAAs).

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

DISSOLUTION or SOLVATION: The spread of ions in a monosacharide.

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

DISSOLVED SOLIDS: Solids in solution that cannot be removed by filtration with a 0.45-micron filter.

DISTILLATION, REVERSE OSMOSIS AND FREEZING: Processes that can be used to remove minerals from the water.

DOUBLE BOND: Sharing of two pairs of electradodes.

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

E

E. COLI, Escherichia coli: A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

EARTH METAL: See alkaline earth metal.

E. COLI, Escherichia coli: A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.

ECDYSONE: A steroid hormone that triggers molting in arthropods.

ECOLOGICAL EFFICIENCY: The ratio of net productivity at one trophic level to net productivity at the next lower level.

ECOLOGICAL NICHE: The sum total of an organism's utilization of the biotic and abiotic resources of its environment. The fundamental niche represents the theoretical capabilities and the realized niche represents the actual role.

ECOLOGY: The study of how organisms interact with their environments.
ECOSYSTEM: The sum of physical features and organisms occurring in a given area.
ECTODERM: The outermost tissue layer of an animal embryo. Also, tissue derived from an embryonic ectoderm.
ECTOTHERM: An organism that uses environmental heat and behavior to regulate its body temperature.
EDWARD JENNER: A pioneer of vaccination; used vaccination with material from cowpox lesions to protect people against smallpox.
EFFECTIVENESS OF CHLORINE: The factors which influence the effectiveness of chlorination the most are pH, turbidity and temperature. Effectiveness of Chlorine decreases occurs during disinfection in source water with excessive turbidity.
EFFECTOR: The part of an organism that produces a response to a stimulus.
EFFLUENT: Partially or completely treated water or wastewater flowing out of a basin or treatment plant.
ELECTRIC CHARGE: A measured property (coulombs) that determine electromagnetic interaction
ELECTRICAL SYNAPSE: A junction between two neurons separated only by a gap junction, in which the local currents sparking the action potential pass directly between the cells.
ELECTROCARDIOGRAM: A plot of electrical activity of the heart over the cardiac cycle; measured via multiple skin electrodes.
ELECTROCHEMICAL CELL: Using a chemical reaction's current, electromotive force is made
ELECTROCHEMICAL GRADIENT: Combined electrostatic and osmotic-concentration gradient, such as the chemiosmotic gradient of mitochondria and chloroplasts.
ELECTROGENIC PUMP: An ion transport protein generating voltage across a membrane.
ELECTROLYTE: A solution that conducts a certain amount of current and can be split categorically as weak and strong electrolytes.
ELECTROMAGNETIC RADIATION: A type of wave that can go through vacuums as well as material and classified as a self-propagating wave.
ELECTROMAGNETIC SPECTRUM: The entire spectrum of radiation; ranges in wavelength from less than a nanometer to more than a kilometer.
ELECTROMAGNETISM: Fields that have electric charge and electric properties that change the way that particles move and interact.
ELECTROMOTIVE FORCE: A device that gains energy as electric charges pass through it.
ELECTRON MICROSCOPE: A microscope that focuses an electron beam through a specimen, resulting in resolving power a thousandfold greater that of a light microscope. A transmission EM is used to study the internal structure of thin sections of cells; a scanning EM is used to study the ultrastructure of surfaces.
ELECTRON SHELLS: An orbital around the atom's nucleus that has a fixed number electrons (usually two or eight).
ELECTRON TRANSPORT CHAIN: A series of enzymes found in the inner membranes of mitochondria and chloroplasts. These are involved in transport of protons and electrons either across the membrane during ATP synthesis.
ELECTRON: A subatomic particle with a net charge that is negative. The name of a negatively charged atomic particle.
ELECTRONEGATIVITY: A property exhibited by some atoms whereby the nucleus has a tendency to pull electrons toward itself.
ELECTRONIC CHARGE UNIT: The charge of one electron (1.6021 x 10e - 19 coulomb).
ELECTROSTATIC FORCE: The attraction between particles with opposite charges.
ELECTROSTATIC GRADIENT: The free-energy gradient created by a difference in charge between two points, generally the two sides of a membrane.
ELEMENT: Any substance that cannot be broken down into another substance by ordinary chemical means. An atom that is defined by its atomic number.
ELEMENTARY BUSINESS PLAN: Technical Capacity, Managerial Capacity, and Financial Capacity make up the elementary business plan. To become a new public water system, an owner shall file an elementary business plan for review and approval by state environmental agency.
ELIMINATION: The release of unabsorbed wastes from the digestive tract.
EMERGENCY RESPONSE TEAM: A local team that is thoroughly trained and equipped to deal with emergencies, e.g. chlorine gas leak. In case of a chlorine gas leak, get out of the area and notify your local emergency response team in case of a large uncontrolled chlorine leak.

EMERGENT PROGERTY: A property exhibited at one level of biological organization but not exhibited at a lower level. For example, a population exhibits a birth rate, an organism does not.

EMPOROCAL FORMULA: Also called the simplest formula, gives the simplest whole :number ratio of atoms of each element present in a compound.

EMULSION: A suspension, usually as fine droplets of one liquid in another. A mixture made up of dissimilar elements, usually of two or more mutually insoluble liquids that would normally separate into layers based on the specific gravity of each liquid.

ENDERGONIC: A phenomenon which involves uptake of energy.

ENDOCRINE: A phenomenon which relates to the presence of ductless glands of the type typically found in vertebrates. The endocrine system involves hormones, the glands which secrete them, the molecular hormone receptors of target cells, and interactions between hormones and the nervous system.

ENDOCYTOSIS: A process by which liquids or solid particles are taken up by a cell through invagination of the plasma membrane.

ENDODERM: The innermost germ layer of an animal embryo.

ENDODERMIS: A plant tissue, especially prominent in roots, that surrounds the vascular cylinder; all endodermal cells have Casparian strips.

ENDOMEMBRANE SYSTEM: The system of membranes inside a eukaryotic cell, including the membranous vesicles which associate with membrane sheets and/or tubes.

ENDOMETRIUM: The inner lining of the uterus, which is richly supplied with blood vessels that provide the maternal part of the placenta and nourish the developing embryo.

ENDONUCLEASE: An enzyme that breaks bonds within nucleic acids. A restriction endonuclease is an enzyme that breaks bonds only within a specific sequence of bases.

ENDOPLASMIC RETICULUM: A system of membrane-bounded tubes and flattened sacs, often continuous with the nuclear envelope, found in the cytoplasm of eukaryotes. Exists as rough ER, studded with ribosomes, and smooth ER, lacking ribosomes.

ENDORPHIN: A hormone produced in the brain and anterior pituitary that inhibits pain perception.

ENDOSKELETON: An internal skeleton.

ENDOSPERM: A nutritive material in plant seeds which is triploid (3n) and results from the fusion of three nuclei during double fertilization.

ENDOSYMBIOTIC: 1) An association in which the symbiont lives within the host 2) A widely accepted hypothesis concerning the evolution of the eukaryotic cell: the idea that eukaryotes evolved as a result of symbiotic associations between prokaryote cells. Aerobic symbionts ultimately evolved into mitochondria; photosynthetic symbionts became chloroplasts.

ENDOTHELIUM: The innermost, simple squamous layer of cells lining the blood vessels; the only constituent structure of capillaries.

ENDOTHERMIC: In chemistry, a phenomenon in which energy is absorbed by the reactants. In physiology, this term concerns organisms whose thermal relationship with the environment is dependent substantially on internal production of heat.

ENDOTOXIN: A component of the outer membranes of certain gram-negative bacteria responsible for generalized symptoms of fever and ache.

ENERGY: A system's ability to do work. The capacity to do work by moving matter against an opposing force.

ENHANCED COAGULATION: The process of joining together particles in water to help remove organic matter.

ENHANCER: A DNA sequence that recognizes certain transcription factors that can stimulate transcription of nearby genes.

ENTAMOEBA HISTOLYTICA: Entamoeba histolytica, another water-borne pathogen, can cause diarrhea or a more serious invasive liver abscess. When in contact with human cells, these amoebae are cytotoxic. There is a rapid influx of calcium into the contacted cell, it quickly stops all membrane movement save for some surface blebbing. Internal organization is disrupted, organelles lyse, and the cell dies. The ameba may eat the dead cell or just absorb nutrients released from the cell.

ENTERIC: Rod-shaped, gram-negative, aerobic but can live in certain anaerobic conditions; produce nitrite from nitrate, acids from glucose; include Escherichia coli, Salmonella (over 1000 types), and Shigella.

ENTEROVIRUS: A virus whose presence may indicate contaminated water; a virus that may infect the gastrointestinal tract of humans.

ENTHALPY: Measure of the total energy of a thermodynamic system (usually symbolized as H).

EUGLENA: Euglena are common protists, of the class Euglenoidea of the phylum Euglenophyta. Currently, over 1000 species of Euglena have been described. Marin et al. (2003) revised the genus so and including several species without chloroplasts, formerly classified as Astasia and Khawkinea. Euglena sometimes can be considered to have both plant and animal features. Euglena gracilis has a long hair-like thing that stretches from its body. You need a very powerful microscope to see it. This is called a flagellum, and the euglena uses it to swim. It also has a red eyespot. Euglena gracilis uses its eyespot to locate light. Without light, it cannot use its chloroplasts to make itself food.
EUKARYOTE: A life form comprised of one or more cells containing a nucleus and membrane - bound organelles. Included are members of the Kingdoms Protista, Fungi, Plantae and Animalia.
EUMETAZOA: Members of the subkingdom that includes all animals except sponges.
EUTROPHIC: A highly productive condition in aquatic environments which owes to excessive concentrations of nutrients which support the growth of primary producers.
EVAGINATED: Folded or protruding outward.
EVAPORATIVE COOLING: The property of a liquid whereby the surface becomes cooler during evaporation, owing to the loss of highly kinetic molecules to the gaseous state.
EVOLUTION: A theory that all of the changes that have transformed life on earth from its earliest beginnings to the diversity that characterizes it today. As used in biology, the term evolution means descent with change. See Intelligent Design.
EVOLUTION: Any process of formation or growth; development: the evolution of a language; the evolution of the airplane. A product of such development; something evolved: The exploration of space is the evolution of decades of research.
EXCITABLE CELLS: A cell, such as a neuron or a muscle cell that can use changes in its membrane potential to conduct signals.
EXCITATORY POSTSYNAPTIC POTENTIAL: An electrical change (depolarization) in the membrane of a postsynaptic neuron caused by the binding of an excitatory neurotransmitter from a presynaptic cell to a postsynaptic receptor. This phenomenon facilitates generation of an action potential in the PSP.
EXCRETION: Release of materials which arise in the body due to metabolism (e.g., CO_2, NH_3, H_20).
EXERGONIC: A phenomenon which involves the release of energy.
EXOCYTOSIS: A process by which a vesicle within a cell fuses with the plasma membrane and releases its contents to the outside.
EXON: A part of a primary transcript (and the corresponding part of a gene) that is ultimately either translated (in the case of mRNA) or utilized in a final product, such as tRNA.
EXOSKELETON: An external skeleton, characteristic of members of the phylum, Arthropoda.
EXOTHERMIC: A process or reaction that is accompanied by the creation of heat.
EXOTOXIN: A toxic protein secreted by a bacterial cell that produces specific symptoms even in the absence of the bacterium.
EXPONENTIAL: (population growth) The geometric increase of a population as it grows in an ideal, unlimited environment.
EXTRAEMBRYONIC MEMBRANES: Four membranes (yolk sac, amnion, chorion, allantois) that support the developing embryo in reptiles, birds, and mammals.
EXTRINSIC: External to, not a basic part of; as in extrinsic isolating mechanism.

F

F PLASMID: The fertility factor in bacteria, a plasmid that confers the ability to form pili for conjugation and associated functions required for transfer of DNA from donor to recipient.
F: The chemical symbol of Fluorine.
F1 GENERATION: The first filial or hybrid offspring in a genetic cross-fertilization.
F2 GENERATION: Offspring resulting from interbreeding of the hybrid F1 generation.
FACILITATED DIFFUSION: Passive movement through a membrane involving a specific carrier protein; does not proceed against a concentration gradient.
FACULTATIVE: An organism which exhibits the capability of changing from one habit or metabolic pathway to another, when conditions warrant. (anaerobe) An organism that makes ATP by aerobic respiration if oxygen is present but that switches to fermentation under anaerobic conditions.
FARADAY CONSTANT: A unit of electrical charge widely used in electrochemistry and equal to ~ 96,500 coulombs. It represents 1 mol of electrons, or the Avogadro number of electrons: 6.022 × 1023 electrons. F = 96 485.339 9(24) C/mol.

FARADAY'S LAW OF ELECTROLYSIS: A two part law that Michael Faraday published about electrolysis. The mass of a substance altered at an electrode during electrolysis is directly proportional to the quantity of electricity transferred at that electrode. The mass of an elemental material altered at an electrode is directly proportional to the element's equivalent weight.

FAT: A biological compound consisting of three fatty acids linked to one glycerol molecule.

FATE MAP: A means of tracing the fates of cells during embryonic development.

FATTY ACID: A long carbon chain carboxylic acid. Fatty acids vary in length and in the number and location of double bonds; three fatty acids linked to a glycerol molecule form fat.

FAUCET WITH AN AERATOR: When collecting a water sample from a distribution system, a faucet with an aerator should not be used as a sample location.

FAUNA: The animals of a given area or period.

FEATURE DETECTOR: A circuit in the nervous system that responds to a specific type of feature, such as a vertically moving spot or a particular auditory time delay.

FECAL COLIFORM: A group of bacteria that may indicate the presence of human or animal fecal matter in water. Total coliform, fecal coliform, and E. coli are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. E. coli is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform. If total coliform is present, the sample will also be tested for either fecal coliform or E. coli, depending on the lab testing method.

FLOCCULATION: The process of bringing together destabilized or coagulated particles to form larger masses that can be settled and/or filtered out of the water being treated. Conventional coagulation–flocculation-sedimentation practices are essential pretreatments for many water purification systems—especially filtration treatments. These processes agglomerate suspended solids together into larger bodies so that physical filtration processes can more easily remove them. Particulate removal by these methods makes later filtering processes far more effective. The process is often followed by gravity separation (sedimentation or flotation) and is always followed by filtration. A chemical coagulant, such as iron salts, aluminum salts, or polymers, is added to source water to facilitate bonding among particulates. Coagulants work by creating a chemical reaction and eliminating the negative charges that cause particles to repel each other. The coagulant-source water mixture is then slowly stirred in a process known as flocculation. This water churning induces particles to collide and clump together into larger and more easily removable clots, or "flocs." The process requires chemical knowledge of source water characteristics to ensure that an effective coagulant mix is employed. Improper coagulants make these treatment methods ineffective. The ultimate effectiveness of coagulation/flocculation is also determined by the efficiency of the filtering process with which it is paired.

FLOOD RIM: The point of an object where the water would run over the edge of something and begin to cause a flood.

FLORA: The plants of a given area or period.

FLOW CYTOMETER: A particle-sorting instrument capable of counting protozoa.

FLOW MUST BE MEASURED: A recorder that measures flow is most likely to be located in a central location.

FLUID FEEDER: An animal that lives by sucking nutrient-rich fluids from another living organism.

FLUID MOSAIC MODEL: The currently accepted model of cell membrane structure, which envisions the membrane as a mosaic of individually inserted protein molecules drifting laterally in a fluid bilayer of phospholipids.

FLUORIDE FEEDING: Always review fluoride feeding system designs and specifications to determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and correct.

FLUORIDE: High levels of fluoride may stain the teeth of humans. This is called Mottling. This chemical must not be overfed due to a possible exposure to a high concentration of the chemical. The most important safety considerations to know about fluoride chemicals are that all fluoride chemicals are extremely corrosive. These are the substances most commonly used to furnish fluoride ions to water: Sodium fluoride, Sodium silicofluoride and Hydrofluosilicic acid.

FLUX: The term flux describes the rate of water flow through a semipermeable membrane. When the water flux decreases through a semipermeable membrane, it means that the mineral concentration of the water is increasing.

FLY ASH: The noncombustible particles in flue gas. Often used as a body feed or solidification chemical.

FOLLICLE STIMULATING HORMONE (FSH): A gonadotropic hormone of the anterior pituitary that stimulates growth of follicles in the ovaries of females and function of the seminiferous tubules in males.
FOLLICLE: A jacket of cells around an egg cell in an ovary.
FOOD CHAIN: Sequence of organisms, including producers, consumers, and decomposers, through which energy and materials may move in a community.

G

G: (protein) A membrane protein that serves as an intermediary between hormone receptors and the enzyme adenylate cyclase, which converts ATP to cAMP in the second messenger system in non-steroid hormone action. Depending on the system, G proteins either increase or decrease cAMP production.
G1 PHASE: The first growth phase of the cell cycle, consisting of the portion of interphase before DNA synthesis is initiated.
G2 PHASE: The second growth phase of the cell cycle, consisting of the portion of interphase after DNA synthesis but before mitosis.
GAIA HYPOTHESIS: An idea, first formulated by James E. Lovelock in 1979, which suggests that the biosphere of the earth exists as a "superorganism" which exhibits homeostatic self- regulation of the environment-biota global system.
GALVANIC CELL: Battery made up of electrochemical with two different metals connected by salt bridge.
GAMETANGIUM: The reproductive organ of bryophytes, consisting of the male antheridium and female archegonium; a multi-chambered jacket of sterile cells in which gametes are formed.
GAMETE: A sexual reproductive cell that must usually fuse with another such cell before development begins; an egg or sperm.
GAMETOPHYTE: A haploid plant that can produce gametes.
GANGLION: A structure containing a group of cell bodies of neurons.
GAP JUNCTION: A narrow gap between plasma membranes of two animal cells, spanned by protein channels. They allow chemical substances or electrical signals to pass from cell to cell.
GAS: Particles that fill their container though have no definite shape or volume.
GASTRULA: A two-layered, later three-layered, animal embryonic stage.
GASTRULATION: The process by which a blastula develops into a gastrula, usually by an involution of cells.
GATED ION CHANNEL: A membrane channel that can open or close in response to a signal, generally a change in the electrostatic gradient or the binding of a hormone, transmitter, or other molecular signal.
GEL ELECTROPHORESIS: In general, electrophoresis is a laboratory technique used to separate macromolecules on the basis of electric charge and size; the technique involves application of an electric field to a population of macromolecules which disperse according to their electric mobilities. In gel electrophoresis, the porous medium through which the macromolecules move is a gel.
GEL: Colloid in which the suspended particles form a relatively orderly arrangement.
GENE AMPLIFICATION: Any of the strategies that give rise to multiple copies of certain genes, thus facilitating the rapid synthesis of a product (such as rRna for ribosomes) for which the demand is great.
GENE CLONING: Formation by a bacterium, carrying foreign genes in a recombinant plasmid, of a clone of identical cells containing the replicated foreign genes.
GENE DELIVERY: This is a general term for the introduction of new genetic elements into the genomes of living cells. The delivery problem is essentially conditioned by the fact that the new genetic elements are usually large, and by the presence of the outer cell membrane and the nuclear membrane acting as barriers to incorporation of the new DNA into the genome already present in the nucleus. Viruses possess various natural biochemical methods for achieving gene delivery; artificial gene delivery is one of the essential problems of "genetic engineering". The most important barrier is apparently the outer cell membrane, which is essentially a lipid barrier, and introduction of any large complex into the cell requires a fusion of one kind or another with this membrane. Liposomes, which consist of lipid membranes themselves, and which can fuse with outer cell membranes, are thus potential vehicles for delivery of many substances, including DNA.
GENE FLOW: The movement of genes from one part of a population to another, or from one population to another, via gametes.
GENE POOL: The sum total of all the genes of all the individuals in a population.
GENE REGULATION: Any of the strategies by which the rate of expression of a gene can be regulated, as by controlling the rate of transcription.

GONADOTROPIN: Refers to a member of a group of hormones capable of promoting growth and function of the gonads. Includes hormones such as follicle stimulating hormone (FSH) and luteinizing hormone (LH) which are stimulatory to the gonads.
GOOD CONTACT TIME, pH and LOW TURBIDITY: These are factors that are important in providing good disinfection when using chlorine.
GPM: Gallons per minute.
GRAB SAMPLE: A sample which is taken from a water or wastestream on a one-time basis with no regard to the flow of the water or wastestream and without consideration of time. A single grab sample should be taken over a period of time not to exceed 15 minutes. A single water or wastewater sample taken at a time and place representative of total discharge.
GRADED POTENTIAL: A local voltage change in a neuron membrane induced by stimulation of a neuron, with strength proportional to the strength of the stimulus and lasting about a millisecond.
GRANUM: A stack-like grouping of photosynthetic membranes in a chloroplast
GRAVITROPISM: A response of a plant or animal in response to gravity.
GRAVITY BELT THICKENER: A sludge dewatering device utilizing a filter belt to promote gravity drainage of water. Usually precedes additional dewatering treatment.
GRAVITY FILTER: A filter that operates at atmospheric pressure.
GRAVITY THICKENING: A sedimentation basin designed to operate at high solids loading rates.
GREENHOUS EFFECT: The warming of the Earth due to atmospheric accumulation of carbon dioxide which absorbs infrared radiation and slows its escape from the irradiated Earth.
GREGOR MENDEL: The first to make quantitative observations of the patterns of inheritance and proposing plausible explanations for them.
GROWTH FACTOR: A protein that must be present in a cell's environment for its normal growth and development.
GT: Represents (Detention time) x (mixing intensity) in flocculation.
GUARD CELL: A specialized epidermal cell that regulates the size of stoma of a leaf.
GYMNOSPERM: A vascular plant that bears naked seeds not enclosed in any specialized chambers.

H

H2SO4: The molecular formula of Sulfuric acid.
HABIT: In biology, the characteristic form or mode of growth of an organism.
HABITAT: The kind of place where a given organism normally lives.
HABITUATION: The process that results in a long-lasting decline in the receptiveness of interneurons to the input from sensory neurons or other interneurons (sensitization, adaptation).
HALF: The average amount of time it takes for one-half of a specified quantity of a substance to decay or disappear.
HALIDES: A halide is a binary compound, of which one part is a halogen atom and the other part is an element or radical that is less electronegative than the halogen, to make a fluoride, chloride, bromide, iodide, or astatide compound. Many salts are halides. All Group 1 metals form halides with the halogens and they are white solids. A halide ion is a halogen atom bearing a negative charge. The halide anions are fluoride (F), chloride (Cl), bromide (Br), iodide (I) and astatide (At). Such ions are present in all ionic halide salts.
HALL EFFECT: Refers to the potential difference (Hall voltage) on the opposite sides of an electrical conductor through which an electric current is flowing, created by a magnetic field applied perpendicular to the current. Edwin Hall discovered this effect in 1879.
HALOACETIC ACIDS: Haloacetic acids are carboxylic acids in which a halogen atom takes the place of a hydrogen atom in acetic acid. Thus, in a monohaloacetic acid, a single halogen would replace a hydrogen atom. For example, chloroacetic acid would have the structural formula CH2ClCO2H. In the same manner, in dichloroacetic acid two chlorine atoms would take the place of two hydrogen atoms (CHCl2CO2H).
HALOGENS: Group 7 on the Periodic Table and are all non-metals.
HAPLOID: The condition of having only one kind of a given type of chromosome.
HARD WATER: Hard water causes a buildup of scale in household hot water heaters. Hard water is a type of water that has high mineral content (in contrast with soft water). Hard water primarily consists of calcium (Ca2+), and magnesium (Mg2+) metal cations, and sometimes other dissolved compounds such as bicarbonates and sulfates. Calcium usually enters the water as either calcium carbonate (CaCO3), in

the form of limestone and chalk, or calcium sulfate ($CaSO_4$), in the form of other mineral deposits. The predominant source of magnesium is dolomite ($CaMg(CO_3)_2$). Hard water is generally not harmful. The simplest way to determine the hardness of water is the lather/froth test: soap or toothpaste, when agitated, lathers easily in soft water but not in hard water. More exact measurements of hardness can be obtained through a wet titration. The total water 'hardness' (including both Ca^{2+} and Mg^{2+} ions) is read as parts per million or weight/volume (mg/L) of calcium carbonate ($CaCO_3$) in the water. Although water hardness usually only measures the total concentrations of calcium and magnesium (the two most prevalent, divalent metal ions), iron, aluminum, and manganese may also be present at elevated levels in some geographical locations.

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

HETEROCHROMATIN: Non-transcribed eukaryotic chromatin that is so highly compacted that it is visible

HOMEOSTASIS: A phenomenon whereby a state or process (for example, within an organism) is regulated automatically despite the tendency for fluctuations to occur.

HOMEOTHEMIC: Capable of regulation of constancy with respect to temperature.

HOMEOTIC GENES: Genes that control the overall body plan of animals by controlling the developmental fate of groups of cells.

HOMEOTIC: (mutation) A mutation in genes regulated by positional information that results in the abnormal substitution of one type of body part in place of another.

HOMOLOGOUS CHROMOSOMES: Chromosomes bearing genes for the same characters.

HOMOLOGOUS STRUCTURES: Characters in different species which were inherited from a common ancestor and thus share a similar ontogenetic pattern.

HOMOLOGY: Similarity in characteristics resulting from a shared ancestry.

HOMOPLASY: The presence in several species of a trait not present in their most common ancestor. Can result from convergent evolution, reverse evolution, or parallel evolution.

HOMOSPOROUS: Referring to plants in which a single type of spore develops into a bisexual gametophyte having both male and female sex organs.

HOMOZYGOUS: Having two copies of the same allele of a given gene.

HORMONE: A control chemical secreted in one part of the body that affects other parts of the body.

HOST RANGE: The limited number of host species, tissues, or cells that a parasite (including viruses and bacteria) can infect.

HUMORAL IMMUNITY: The type of immunity that fights bacteria and viruses in body fluids with antibodies that circulate in blood plasma and lymph, fluids formerly called humors.

HYBIRD VIGOR: Increased vitality (compared to that of either parent stock) in the hybrid offspring of two different, inbred parents.

HYBIRD: In evolutionary biology, a cross between two species. In genetics, a cross between two genetic types.

HYBIRDIZATION: The process whereby a hybrid results from interbreeding two species; 2) DNA hybridization is the comparison of whole genomes of two species by estimating the extent of hydrogen bonding that occurs between single-stranded DNA obtained from the two species.

HYBRIDOMA: A hybrid cell that produces monoclonal antibodies in culture, formed by the fusion of a myeloma cell with a normal antibody-producing lymphocyte.

HYDRATED LIME: The calcium hydroxide product that results from mixing quicklime with water. Chemical formula is $CaOH_2$.

HYDRATION SHELL: A "covering" of water molecules which surrounds polar or charged substances in aqueous solutions. The association is due to the charged regions of the polar water molecules themselves.

hydraulic conductivity: A primary factor in Darcy’s Law, the measure of a soil or formations ability to transmit water, measured in gallons per day (gpd) See also Permeability and Darcy’s Law.

HYDRIDES: Hydride is the name given to the negative ion of hydrogen, H. Although this ion does not exist except in extraordinary conditions, the term hydride is widely applied to describe compounds of hydrogen with other elements, particularly those of groups 1–16. The variety of compounds formed by hydrogen is vast, arguably greater than that of any other element. Various metal hydrides are currently being studied for use as a means of hydrogen storage in fuel cell-powered electric cars and batteries.

They also have important uses in organic chemistry as powerful reducing agents, and many promising uses in hydrogen economy.

HYDROCARBON: Any compound made of only carbon and hydrogen.

HYDROCHLORIC AND HYPOCHLOROUS ACIDS: HCL and HOCL: The compounds that are formed in water when chlorine gas is introduced.

HYDROFLUOSILICIC ACID: (H2SiF6) a clear, fuming corrosive liquid with a pH ranging from 1 to 1.5. Used in water treatment to fluoridate drinking water.

HYDROGEN BOND: A type of bond formed when the partially positive hydrogen atom of a polar covalent bond in one molecule is attracted to the partially negative atom of a polar covalent bond in another.

HYDROGEN ION: A single proton with a charge of +1. The dissociation of a water molecule (H2O) leads to the generation of a hydroxide ion (OH-) and a hydrogen ion (H+).

HYDROGEN SULFIDE OR CHLORINE GAS: These chemicals can cause olfactory fatigue.

HYDROGEN SULFIDE: A toxic gas formed by the anaerobic decomposition of organic matter. Chemical formula is H2S.

Hydrologic Cycle: (Water Cycle) The continual process of precipitation (rain and snowfall), evaporation (primarily from the oceans), peculation (recharge to groundwater), runoff (surface water), and transpiration (plants) constituting the renew ability and recycling of each component.

HYDROLYSIS: The chemical reaction that breaks a covalent bond through the addition of hydrogen (from a water molecule) to the atom forming one side of the original bond, and a hydroxyl group to the atom on the other side.

HYDROPHILIC: Having an affinity for water.

HYDROPHOBIC INTERACTION: A type of weak chemical bond formed when molecules that do not mix with water coalesce to exclude the water.

HYDROPHOBIC: The physicochemical property whereby a substance or region of a molecule resists association with water molecules. Does not mix readily with water.

HYDROSTATIC: Pertaining to the pressure and equilibrium of fluids. A hydrostatic skeleton is a skeletal system composed of fluid held under pressure in a closed body compartment; the main skeleton of most cnidarians, flatworms, nematodes, and annelids.

HYDROXYL GROUP: A functional group consisting of a hydrogen atom joined to an oxygen atom by a polar covalent bond. Molecules possessing this group are soluble in water and are called alcohols.

HYDROXYL ION: The OH- ion.

HYGROSCOPIC: Absorbing or attracting moisture from the air.

HYPEROSMOTIC: A solution with a greater solute concentration than another, a hypoosmotic solution. If the two solutions are separated from one another by a membrane permeable to water, water would tend to move from the hypo- to the hyperosmotic side.

HYPERPOLARIZATION: An electrical state whereby the inside of the cell is made more negative relative to the outside than was the case at resting potential. A neuron membrane is hyperpolarized if the voltage is increased from the resting potential of about -70 mV, reducing the chance that a nerve impulse will be transmitted.

HYPERTROPHY: Abnormal enlargement, excessive growth.

HYPHA: A fungal filament.

HYPOCHLORITE (OCL-) AND ORGANIC MATERIALS: Heat and possibly fire may occur when hypochlorite is brought into contact with an organic material.

HYPOCHLORITE AND ORGANIC MATERIALS: Heat and possibly fire may occur when hypochlorite is brought into contact with an organic material.

HYPOCOTYL: The portion of the axis of a plant embryo below the point of attachment of the cotyledons; forms the base of the shoot and the root.

HYPOLIMNION: The layer of water in a thermally stratified lake that lies below the thermocline, is noncirculating, and remains perpetually cold.

HYPOOSMOTIC SOLUTION: A solution with a lesser solute concentration than another, a hyperosmotic solution. If the two solutions are separated from one another by a membrane permeable to water, water would tend to move from the hypo- to the hyperosmotic side.

HYPOTHESIS: A formal statement of supposition offered to explain observations. Note that a hypothesis is only useful if it can be tested. Even if correct, it is not scientifically useful if untestable.

HYPOTHETICO-DEDUCTIVE: A method used to test hypotheses. If deductions formulated from the hypothesis are tested and proven false, the hypothesis is rejected.

I

INORGANIC CHEMISTRY: A part of chemistry concerned with inorganic compounds.
INORGANIC COMPOUND: Compounds that contain no carbon or contain only carbon bound to elements other than hydrogen.
INORGANIC COMPOUND: Compounds that do not contain carbon, though there are exceptions.
INORGANIC CONTAMINANTS: Mineral-based compounds such as metals, nitrates, and asbestos. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities. EPA has set legal limits on 15 inorganic contaminants.
INORGANIC IONS: Present in all waters. Inorganic ions are essential for human health in small quantities, but in larger quantities they can cause unpleasant taste and odor or even illness. Most community water systems will commonly test for the concentrations of seven inorganic ions: nitrate, nitrite, fluoride, phosphate, sulfate, chloride, and bromide. Nitrate and nitrite can cause an illness in infants called methemoglobinemia. Fluoride is actually added to the drinking water in some public water systems to promote dental health. Phosphate, sulfate, chloride, and bromide have little direct effect on health, but high concentrations of inorganic ions can give water a salty or briny taste.
INOSITOL TRIPHOSPHATE: The second messenger, which functions as an intermediate between certain non-steroid hormones and the third messenger, a rise in cytoplasmic Ca++ concentration.
INSERTION: A mutation involving the addition of one or more nucleotide pairs to a gene.
INSIGHT LEARNING: The ability of an animal to perform a correct or appropriate behavior on the first attempt in a situation with which it has had no prior experience.
INSOLUBLE COMPOUNDS: are types of compounds cannot be dissolved. When iron or manganese reacts with dissolved oxygen (DO) insoluble compound are formed.
INSULATOR: Material that resists the flow of electric current.
INSULIN: The vertebrate hormone that lowers blood sugar levels by promoting the uptake of glucose by most body cells and promoting the synthesis and storage of glycogen in the liver; also stimulates protein and fat synthesis; secreted by endocrine cells of the pancreas called islets of Langerhans.
INTAKE FACILITIES: One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for cathodic protection.
INTEGRAL PROTEIN: A protein of biological membranes that penetrates into or spans the membrane.
INTERBREED: To breed with another kind or species; hybridize.
INTERFERON: A chemical messenger of the immune system, produced by virus: infected cells and capable of helping other cells resist the virus.
INTERLEUKIN: 1: A chemical regulator (cytokine) secreted by macrophages that have ingested a pathogen or foreign molecule and have bound with a helper T cell; stimulates T cells to grow and divide and elevates body temperature. Interleukin: 2, secreted by activated T cells, stimulates helper T cells to proliferate more rapidly.
INTERMEDIATE FILAMENT: A component of the cytoskeleton that includes all filaments intermediate in size between microtubules and microfilaments.
INTERNEURON: An association neuron; a nerve cell within the central nervous system that forms synapses with sensory and motor neurons and integrates sensory input and motor output.
INTERNODE: The segment of a plant stem between the points where leaves are attached.
INTERSTITIAL CELLS: Cells scattered among the seminiferous tubules of the vertebrate testis that secrete testosterone and other androgens, the male sex hormones.
INTERSTITIAL FLUID: The internal environment of vertebrates consisting of the fluid filling the spaces between cells.
INTERTIDAL ZONE: The shallow zone of the ocean where land meets water.
INTRINSIC RATE OF INCREASE: The difference between number of births and number of deaths, symbolized as rmax; maximum population growth rate.
INTROGRESSION: Transplantation of genes between species resulting from fertile hybrids mating successfully with one of the parent species.
INTRON: The noncoding, intervening sequence of coding region (exon) in eukaryotic genes.
INVAGINATION: The buckling inward of a cell layer, caused by rearrangements of microfilaments and microtubules; an important phenomenon in embryonic development.

INVERSION: 1) An aberration in chromosome structure resulting from an error in meiosis or from mutagens; reattachment in a reverse orientation of a chromosomal fragment to the chromosome from which the fragment originated. 2) A phenomenon which occurs during early development of sponges at which time the external ciliated cells become inward-directed.

INVERTEBRATE: An animal without a backbone; invertebrates make up about 95% of animal species.

ION EXCHANGE: An effective treatment process used to remove iron and manganese in a water supply. The hardness of the source water affects the amount of water an ion exchange softener may treat before the bed requires regeneration.

ION: A charged chemical formed when an atom or group of atoms has more or less electrons than protons (rather than an equal number). A molecule that has gained or lost one or more electrons.

IONIC BOND: A chemical bond due to attraction between oppositely charged ions.

IONIZATION: The breaking up of a compound into separate ions.

IRON AND MANGANESE: Fe and Mn In water they can usually be detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

IRON AND MANGANESE: In water they can usually be detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

IRON BACTERIA: Perhaps the most troublesome consequence of iron and manganese in the water is they promote the growth of a group of microorganism known as Iron Bacteria.

IRON FOULING: You should look for an orange color on the resin and backwash water when checking an ion exchange unit for iron fouling

IRON: Fe The elements iron and manganese are undesirable in water because they cause stains and promote the growth of iron bacteria.

IRRUPTION: A rapid increase in population density often followed by a mass emigration.

ISOGAMY: A condition in which male and female gametes are morphologically indistinguishable.

ISOMER: Molecules consisting of the same numbers and kinds of atoms, but differing in the way in which the atoms are combined.

ISOSMOTIC: Solutions of equal concentration with respect to osmotic pressure.

ISOTOPE: An atomic form of an element, containing a different number of neutrons than another isotope. Isotopes vary from one another with respect to atomic mass.

It is also worth noting that the LSI is temperature sensitive. The LSI becomes more positive as the water temperature increases. This has particular implications in situations where well water is used. The temperature of the water when it first exits the well is often significantly lower than the temperature inside the building served by the well or at the laboratory where the LSI measurement is made.

IUPAC: International Union of Pure and Applied Chemistry

J

JODIUM: Latin name of the halogen element iodine.

JOULE: The SI unit of energy, defined as a newton-meter.

JUXTAGLOMERULAR APPARATUS (JGA): Specialized tissue located near the afferent arteriole that supplies blood to the kidney glomerulus; JGA raises blood pressure by producing renin, which activates angiotensin.

K

K- SELECTION: The concept that life history of the population is centered upon producing relatively few offspring that have a good chance of survival.

KARYOGAMY: The fusion of nuclei of two cells, as part of syngamy.

KARYOTYPE: A method of classifying the chromosomes of a cell in relation to number, size and type.

KEYSTONE PREDATOR: A species that maintains species richness in a community through predation of the best competitors in the community, thereby maintaining populations of less competitive species.

KILL = C X T: Where other factors are constant, the disinfecting action may be represented by: Kill=C x T. Kill=C x T. C= Chlorine T= Contact time.

KILOCALORIE: A thousand calories; the amount of heat energy required to raise the temperature of 1 kilogram of water by primary C.

KIN SELECTION: A phenomenon of inclusive fitness, used to explain altruistic behavior between related individuals.

KINESIS: A change in activity rate in response to a stimulus.

KINETIC ENERGY: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head. The energy of motion. Moving matter does work by transferring some of its kinetic energy to other matter.

KINETICS: A sub-field of chemistry specializing in reaction rates.

KINETOCHORE: A specialized region on the centromere that links each sister chromatid to the mitotic spindle.

KINGDOM: A taxonomic category, the second broadest after domain.

KREBS CYCLE: A chemical cycle involving eight steps that completes the metabolic breakdown of glucose molecules to carbon dioxide; occurs within the mitochondrion; the second major stage in cellular respiration. Also called citric acid cycle or tricarboxylic acid (TCA) cycle.

L

L.O.T.O.: If a piece of equipment is locked out, the key to the lock-out device the key should be held by the person who is working on the equipment. The tag is an identification device and the lock is a physical restraint.

LABORATORY BLANK: See Method blank

LABORATORY CONTROL SAMPLE (LCS): See Ongoing precision and recovery (OPR) standard

LACRIMATION: The secretion of tears, esp. in abnormal abundance Also, lachrymation, lachrimation.

LACTEAL: A tiny lymph vessel extending into the core of the intestinal villus and serving as the destination for absorbed chylomicrons.

LACTIC ACID: Gram-positive, anaerobic; produce lactic acid through fermentation; include Lactobacillus, essential in dairy product formation, and Streptococcus, common in humans.

LAGGING STRAND: A discontinuously synthesized DNA strand that elongates in a direction away from the replication fork.

LAMARCK: Proposed, in the early 1800s, that evolutionary change may occur via the inheritance of acquired characteristics. This idea, which has since been discredited, holds that the changes in characteristics which occur during an individual's life can be passed on to its offspring.

LAND APPLICATION: The disposal of wastewater or municipal solids onto land under controlled conditions.

LAND DISPOSAL: Application of municipal wastewater solids to the soil without production of usable agricultural products.

LANDFILL: A land disposal site that employs an engineering method of solid waste disposal to minimize environmental hazards and protect the quality of surface and subsurface waters.

LANGELIER INDEX: A measurement of Corrosivity. The water is becoming corrosive in the distribution system causing rusty water if the Langelier index indicates that the pH has decreased from the equilibrium point. Mathematically derived factor obtained from the values of calcium hardness, total alkalinity, and pH at a given temperature. A Langelier index of zero indicates perfect water balance (i.e., neither corroding nor scaling). The Langelier Saturation Index (sometimes Langelier Stability Index) is a calculated number used to predict the calcium carbonate stability of water. It indicates whether the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. Langelier developed a method for predicting the pH at which water is saturated in calcium carbonate (called pHs). The LSI is expressed as the difference between the actual system pH and the saturation pH.

LANTHANIDES: Elements 57 through 71.

M

M PHASE: The mitotic phase of the cell cycle, which includes mitosis and cytokinesis.

M.S.D.S.: Material Safety Data Sheet, now S.D.S. (Safety Data Sheet). A safety document must an employer provide to an operator upon request.

MACROEVOLUTION: Evolutionary change on a grand scale, encompassing the origin of novel designs, evolutionary trends, adaptive radiation, and mass extinction.

MACROMOLECULE: A giant molecule of living matter formed by the joining of smaller molecules, usually by condensation synthesis. Polysaccharides, proteins, and nucleic acids are macromolecules.

MACROPHAGE: An amoeboid cell that moves through tissue fibers, engulfing bacteria and dead cells by phagocytosis.

MAGNESIUM HARDNESS: Measure of the magnesium salts dissolved in water – it is not a factor in water balance.

MAJOR HISTOCOMPATIBILITY COMPLEX: A large set of cell surface antigens encoded by a family of genes. Foreign MHC markers trigger T-cell responses that may lead to rejection of transplanted tissues and organs.

MAKEUP WATER: Fluid introduced in a recirculating stream to maintain an equilibrium of temperature, solids concentration or other parameters. Also refers to the quantity of water required to make a solution.

MATTER: Anything that takes up space and has mass.

MAXIMUM CONTAMINANT LEVEL (MCLs): The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL.

MAXIMUM CONTAMINANT LEVEL GOAL (MCLG): The level of a contaminant at which there would be no risk to human health. This goal is not always economically or technologically feasible, and the goal is not legally enforceable.

MCL for TURBIDITY: Turbidity is undesirable because it causes health hazards. An MCL for turbidity was established by the EPA because turbidity does not allow for proper disinfection.

MEGAPASCAL: A unit of pressure equivalent to 10 atmospheres of pressure.

MEGGER: Used to test the insulation resistance on a motor.

MEIOSIS: A two-stage type of cell division in sexually reproducing organisms that results in gametes with half the chromosome number of the original cell.

MELTING: The phase change from a solid to a liquid.

MEMBRANE POTENTIAL: The charge difference between the cytoplasm and extracellular fluid in all cells, due to the differential distribution of ions. Membrane potential affects the activity of excitable cells and the transmembrane movement of all charged substances.

MEMBRANE: A thin barrier that permits passage of particles of a certain size or of particular physical or chemical properties.

M-ENDO BROTH: The coliform group are used as indicators of fecal pollution in water, for assessing the effectiveness of water treatment and disinfection, and for monitoring water quality. m-Endo Broth is used for selectively isolating coliform bacteria from water and other specimens using the membrane filtration technique. m-Endo Broth is prepared according to the formula of Fifield and Schaufus.1 It is recommended by the American Public Health Association in standard total coliform membrane filtration procedure for testing water, wastewater, and foods.2,3 The US EPA specifies using m-Endo Broth in the total coliform methods for testing water using single-step, two-step, and delayed incubation membrane filtration methods.

MESENTERIES: Membranes that suspend many of the organs of vertebrates inside fluid- filled body cavities.

MESODERM: The middle primary germ layer of an early embryo that develops into the notochord, the lining of the coelom, muscles, skeleton, gonads, kidneys and most of the circulatory system.

MESOSOME: A localized infolding of the plasma membrane of a bacterium.

MESSENGER: (RNA) A type of RNA synthesized from DNA in the genetic material that attaches to ribosomes in the cytoplasm and specifies the primary structure of a protein.

METABOLISM: The sum total of the chemical and physical changes constantly taking place in living substances.

METAL: Chemical element that is a good conductor of both electricity and heat and forms cations and ionic bonds with non-metals.

METALIMNION: Thermocline, middle layer of a thermally stratified lake which is characterized by a rapid decrease in temperature in proportion to depth.

METALLOID: Metalloid is a term used in chemistry when classifying the chemical elements. On the basis of their general physical and chemical properties, nearly every element in the periodic table can be termed either a metal or a nonmetal. A few elements with intermediate properties are, however, referred to as metalloids. (In Greek metallon = metal and eidos = sort)

METAMORPHOSIS: The resurgence of development in an animal larva that transforms it into a sexually mature adult.

METANEPHRIDIUM: A type of excretory tubule in annelid worms that has internal openings called nephrostomes that collect body fluids and external openings called nephridiopores.

METASTASIS: The spread of cancer cells beyond their original site.

METAZOAN: A multicellular animal. Among important distinguishing characteristics of Metazoa are cell differentiation and intercellular communication. For certain multicellular colonial entities such as sponges, some biologists prefer the term "parazoa".

METHANE: Methane is a chemical compound with the molecular formula CH4. It is the simplest alkane, and the principal component of natural gas. Methane's bond angles are 109.5 degrees. Burning methane in the presence of oxygen produces carbon dioxide and water. The relative abundance of methane and its clean burning process makes it a very attractive fuel. However, because it is a gas at normal temperature and pressure, methane is difficult to transport from its source. In its natural gas form, it is generally transported in bulk by pipeline or LNG carriers; few countries still transport it by truck.

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

MICROSCOPE: An instrument which magnifies images either by using lenses in an optical system to bend light (light microscope) or electromagnets to direct the movement of electrons (electron microscope).

MICROTUBULE: A minute tubular structure found in centrioles, spindle apparati, cilia, flagella, and other places in the cytoplasm of eukaryotic cells. Microtubules play a role in movement and maintenance of shape.

MICROVILLUS: Collectively, fine, fingerlike projections of the epithelial cells in the lumen of the small intestine that increase its surface area.

MILLIGRAMS PER LITER: (mg/L) A common unit of measurement of the concentration of a material in solution.

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

MIMICRY: A phenomenon in which one species benefits by a superficial resemblance to an unrelated species. A predator or species of prey may gain a significant advantage through mimicry.

MISCIBLE: Capable of being mixed together.

MISSENSE: (mutation) The most common type of mutation involving a base- pair substitution within a gene that changes a codon, but the new codon makes sense, in that it still codes for an amino acid.

MITOCHONDRIAL MATRIX: The compartment of the mitochondrion enclosed by the inner membrane and containing enzymes and substrates for the Krebs cycle.

MITOCHONDRION: An organelle that occurs in eukaryotic cells and contains the enzymes of the citric acid cycle, the respiratory chain, and oxidative phosphorylation. A mitochondrion is bounded by a double membrane.

MITOSIS: A process of cell division in eukaryotic cells conventionally divided into the growth period (interphase) and four stages: prophase, metaphase, anaphase, and telophase. The stages conserve chromosome number by equally allocating replicated chromosomes to each of the daughter cells.

MIXED LIQUOR SUSPENDED SOLIDS: Suspended solids in the mixture of wastewater and activated sludge undergoing aeration in the aeration basin.

MODEM SYNTHESIS: A comprehensive theory of evolution emphasizing natural selection, gradualism, and populations as the fundamental units of evolutionary change; also called Neo-Darwinism.

MOISTURE AND POTASSIUM PERMANGANATE: The combination of moisture and potassium permanganate produces heat.

N

NAD+: Nicatinamide adenine dinucleotide (oxidized); a coenzyme present in all cells that assists enzymes in transferring electrons during the redox reactions of metabolism.

NANO-FILTRATION: A specialty membrane filtration process that rejects solutes larger than approximately one nanometer (10 angstroms) in size.

NANOMETER: A unit of measure (length). 1 nm is equal to 1 x 10: 9 m, or 1/1,000,000 mm.

NaOCl: Is the molecular formula of Sodium hypochlorite.

NaOH: Is the molecular formula of Sodium hydroxide.

NASCENT: Coming into existence; emerging.

NATURAL ORGANIC MATTER: Organic matter present in natural waters.

NEAT: Conditions with a liquid reagent or gas performed with no added solvent or co-solvent.

NEGATIVE CONTROL: See Method blank.

NEGATIVE FEEDBACK: A primary mechanism of homeostasis, whereby a change in a physiological variable that is being monitored triggers a response that counteracts the initial fluctuation.

NEURAMINIDASE: A surface enzyme possessed by some influenza viruses which help the virus penetrate the mucus layer protecting the respiratory epithelium and also plays a role in budding of new virus particles from infected cells.

NEURON: A nerve cell; the fundamental unit of the nervous system, having structure and properties that allow it to conduct signals by taking advantage of the electrical charge across its cell membrane.

NEUROSECRETORY CELLS: Cells that receive signals from other nerve cells, but instead of signaling to an adjacent nerve cell or muscle, release hormones into the blood stream.

NEUROTRANSMITTER: The chemical messenger released from the synaptic terminals of a neuron at a chemical synapse that diffuses across the synaptic cleft and binds to and stimulates the postsynaptic cell.

NEUTRAL VARIATION: Genetic diversity that confers no apparent selective advantage.

NEUTRALIZATION REACTIONS: Chemical reactions between acids and bases where water is an end product.

NEUTRALIZATION: The chemical process that produces a solution that is neither acidic nor alkaline. Usually with a pH between 6 and 8.

NEUTRINO: A particle that can travel at speeds close to the speed of light and are created as a result of radioactive decay.

NEUTRON: An uncharged subatomic particle of about the same size and mass as a proton.

NH4+: The molecular formula of the Ammonium ion.

NITRATES: A dissolved form of nitrogen found in fertilizers and sewage by-products that may leach into groundwater and other water sources. Nitrates may also occur naturally in some waters. Over time, nitrates can accumulate in aquifers and contaminate groundwater.

NITROGEN AND PHOSPHORUS: Pairs of elements and major plant nutrients that cause algae to grow.

NITROGEN: Nitrogen is a nonmetal, with an electronegativity of 3.0. It has five electrons in its outer shell and is therefore trivalent in most compounds. The triple bond in molecular nitrogen (N2) is one of the strongest in nature. The resulting difficulty of converting (N_2) into other compounds, and the ease (and associated high energy release) of converting nitrogen compounds into elemental N2, have dominated the role of nitrogen in both nature and human economic activities. At atmospheric pressure molecular nitrogen condenses (liquefies) at 77 K (-195.8 °C) and freezes at 63 K (-210.0 °C) into the beta hexagonal close-packed crystal allotropic form. Below 35.4 K (-237.6 °C) nitrogen assumes the alpha cubic crystal allotropic form. Liquid nitrogen, a fluid resembling water, but with 80.8% of the density, is a common cryogen. Unstable allotropes of nitrogen consisting of more than two nitrogen atoms have been produced in the laboratory, like N3 and N4.[1] Under extremely high pressures (1.1 million atm) and high temperatures (2000 K), as produced under diamond anvil conditions, nitrogen polymerizes into the single bonded diamond crystal structure, an allotrope nicknamed "nitrogen diamond."

NITROGEN-FIXING: Rod-shaped, gram-negative, aerobic; convert atmospheric nitrogen gas to ammonium in soil; include Azotobacter, a common genus.

NO3-: The molecular formula of the Nitrate ion.

NOBLE GASES: Group 18 elements, those whose outer electron shell is filled.

NOMENCLATURE: The method of assigning names in the classification of organisms.

NON-CARBONATE HARDNESS: The portion of the total hardness in excess of the alkalinity.

NON-CARBONATE IONS: Water contains non-carbonate ions if it cannot be softened to a desired level through the use of lime only.

NONCOMPETITIVE INHIBITOR: A substance that reduces the activity of an enzyme by binding to a location remote from the active site, changing its conformation so that it no longer binds to the substrate.

NONCYCLIC ELECTRON FLOW: A route of electron flow during the light reactions of photosynthesis that involves both photosystems and produces ATP, NADPH, and oxygen; the net electron flow is from water to NADP+.

NONCYCLIC PHOTOPHOSPHORYLATION: The production of ATP by noncyclic electron flow.

NONDISJUNCTION: An accident of meiosis or mitosis, in which both members of a pair of homologous chromosomes or both sister chromatids fail to separate normally.

NON-METAL: An element which is not metallic.

NON-POINT SOURCE POLLUTION: Air pollution may leave contaminants on highway surfaces. This non-point source pollution adversely impacts reservoir water and groundwater quality.

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NONPOLAR: Electrically symmetrical. For example, in many molecules with covalent bonds, the electrons are shared equally; the poles are electrically neutral.

NONSENSE MUTATION: A mutation that changes an amino acid codon to one of the three stop codons, resulting in a shorter and usually nonfunctional protein.

NON-TRANSIENT, NON-COMMUNITY WATER SYSTEM: A water system which supplies water to 25 or more of the same people at least six months per year in places other than their residences. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.

NORM OF REACTION: The range of phenotypic possibilities for a single genotype, as influenced by the environment.

O

O3: The molecular formula of ozone.

OLIGOTROPHIC: A reservoir that is nutrient-poor and contains little plant or animal life. An oligotrophic ecosystem or environment is one that offers little to sustain life. The term is commonly utilized to describe bodies of water or soils with very low nutrient levels. It derives etymologically from the Greek oligo (small, little, few) and trophe (nutrients, food). Oligotrophic environments are of special interest for the alternative energy sources and survival strategies upon which life could rely.

ONGOING PRECISION AND RECOVERY (OPR) STANDARD: A method blank spiked with known quantities of analytes. The OPR is analyzed exactly like a sample. Its purpose is to assure that the results produced by the laboratory remain within the limits specified in this method for precision and recovery.

OOCYST AND CYST STOCK SUSPENSION: See Stock suspension.

OOCYST: The encysted zygote of some sporozoa; e.g., *Cryptosporidium*. The oocyst is a phase or form of the organism produced as a normal part of the life cycle of the organism. It is characterized by a thick and environmentally resistant outer wall.

ORBITAL: May refer to either an atomic orbital or a molecular orbital.

ORGANIC CHEMISTRY: A part of chemistry concerned with organic compounds.

ORGANIC COMPOUND: Compounds that contain carbon.

ORGANIC MATTER: Substances containing carbon compounds, usually of animal or vegetable origin.

ORGANIC PRECURSORS: Natural or man-made compounds with chemical structures based upon carbon that, upon combination with chlorine, leading to trihalomethane formation.

ORGANIC: Relating to, or derived from, a living thing. A description of a substance that contains carbon atoms linked together by carbon-carbon bonds.

OSMOSIS: Osmosis is the process by which water moves across a semi permeable membrane from a low concentration solute to a high concentration solute to satisfy the pressure differences caused by the solute.

OVER-RANGE PROTECTION DEVICES: Mechanical dampers, snubbers and an air cushion chamber are examples of surging and over range protection devices.

OXIDE: An oxide is a chemical compound containing at least one oxygen atom as well as at least one other element. Most of the Earth's crust consists of oxides. Oxides result when elements are oxidized by oxygen in air. Combustion of hydrocarbons affords the two principal oxides of carbon, carbon monoxide and carbon dioxide. Even materials that are considered to be pure elements often contain a coating of oxides. For example, aluminum foil has a thin skin of Al2O3 that protects the foil from further corrosion.

OXIDIZING: The process of breaking down organic wastes into simpler elemental forms or by products. Also used to separate combined chlorine and convert it into free chlorine.
OXYGEN DEFICIENT ENVIRONMENT: One of the most dangerous threats to an operator upon entering a manhole.
OZONE DOES NOT PROVIDE A RESIDUAL: One of the major drawbacks to using ozone as a disinfectant.
OZONE: Ozone or trioxygen (O_3) is a triatomic molecule, consisting of three oxygen atoms. It is an allotrope of oxygen that is much less stable than the diatomic O_2. Ground-level ozone is an air pollutant with harmful effects on the respiratory systems of animals. Ozone in the upper atmosphere filters potentially damaging ultraviolet light from reaching the Earth's surface. It is present in low concentrations throughout the Earth's atmosphere. It has many industrial and consumer applications. Ozone, the first allotrope of a chemical element to be recognized by science, was proposed as a distinct chemical compound by Christian Friedrich Schönbein in 1840, who named it after the Greek word for smell (ozein), from the peculiar odor in lightning storms. The formula for ozone, O_3, was not determined until 1865 by Jacques-Louis Soret and confirmed by Schönbein in 1867. Ozone is a powerful oxidizing agent, far better than dioxygen. It is also unstable at high concentrations, decaying to ordinary diatomic oxygen (in about half an hour in atmospheric conditions):$2\ O_3 = 3\ O_2$.

P

PAC: A disadvantage of using PAC is it is very abrasive and requires careful maintenance of equipment.
PERMEATE: The term for water which has passed through the membrane of a reverse osmosis unit. The liquid that passes through a membrane.
pH OF SATURATION: The ideal pH for perfect water balance in relation to a particular total alkalinity level and a particular calcium hardness level, at a particular temperature. The pH where the Langelier Index equals zero.
pH: A unit of measure which describes the degree of acidity or alkalinity of a solution. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. The term pH is derived from “p”, the mathematical symbol of the negative logarithm, and “H”, the chemical symbol of Hydrogen. The definition of pH is the negative logarithm of the Hydrogen ion activity. $pH=-\log[H+]$.
PHENOL RED: Chemical reagent used for testing pH in the range of 6.8 - 8.4.
PHENOLPHTHALEIN/TOTAL ALKALINITY: The relationship between the alkalinity constituent’s bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity measurement.
PHOSPHATE, NITRATE AND ORGANIC NITROGEN: Nutrients in a domestic water supply reservoir may cause water quality problems if they occur in moderate or large quantities.
PHOTON: A carrier of electromagnetic radiation of all wavelength (such as gamma rays and radio waves).
PHYSICAL CHEMICAL TREATMENT: Treatment processes that are non-biological in nature.
PHYSISORPTION: (Or physical adsorption) Is adsorption in which the forces involved are intermolecular forces (van der Waals forces) of the same kind as those responsible for the imperfection of real gases and the condensation of vapors, and which do not involve a significant change in the electronic orbital patterns of the species involved. The term van der Waals adsorption is synonymous with physical adsorption, but its use is not recommended.
PICOCURIE: A unit of radioactivity. "Pico" is a metric prefix that means one one-millionth of one one-millionth. A picocurie is one one-millionth of one one-millionth of a Curie. A Curie is that quantity of any radioactive substance that undergoes 37 billion nuclear disintegrations per second. Thus a picocurie is that quantity of any radioactive substance that undergoes 0.037 nuclear disintegrations per second.
PIEZOMETRIC SURFACE: See potentiometric surface.
PIN FLOC: Small flocculated particle size.
PLANKTON: The aggregate of passively floating, drifting, or somewhat motile organisms occurring in a body of water, primarily comprising microscopic algae and protozoa.
PLASMA: State of matter similar to gas in which a certain portion of the particles are ionized.
PLUNGER: See Surge-block.
POINT OF ENTRY: POE.

POINT SOURCE DISCHARGE: A pipe, ditch, channel or other container from which pollutants may be discharged.

POLLUTANT: A substance, organism or energy form present in amounts that impair or threaten an ecosystem to the extent that its current or future uses are prevented.

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

POLYMER: A type of chemical when combined with other types of coagulants aid in binding small suspended particles to larger particles to help in the settling and filtering processes. Chemical used for flocculation in dewatering. Also known as a "polyelectrolyte" which is a substance made of giant molecules formed by the union of simple smaller molecules.

POLYPHOSPHATES: Chemicals that may be added to remove low levels of iron and manganese.

POSITIVE CONTROL: See Ongoing precision and recovery standard.

POST TREATMENT: Treatment of finished water or wastewater to further enhance its quality.

POST-CHLORINE: Where the water is chlorinated to make sure it holds a residual in the distribution system.

POST-CHLORINE: Where the water is chlorinated to make sure it holds a residual in the distribution system.

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

POTENTIAL ENERGY: The energy that a body has by virtue of its position or state enabling it to do work.

PPM: Abbreviation for parts per million.

PRE-CHLORINE: Where the raw water is dosed with a large concentration of chlorine.

PRECIPITATE: A solid that separates from a solution.

PRECIPTATION: The phenomenon that occurs when a substance held in solution passes out of solution into a solid form.

PRELIMINARY TREATMENT: Treatment steps including comminution, screening, grit removal, pre-aeration, and/or flow equalization that prepares wastewater influent for further treatment.

PRESIPATATE: Formation of a solid in a solution or inside another solid during a chemical reaction or by diffusion in a solid.

PRESSURE FILTER: Filter unit enclosed in a vessel that may be operated under pressure.

PRESSURE HEAD: The height of a column of water capable of being maintained by pressure. See also Total Head, Total Dynamic Head.

Q

QUANTA: It is the minimum amount of bundle of energy.

QUANTITATIVE TRANSFER: The process of transferring a solution from one container to another using a pipette in which as much solution as possible is transferred, followed by rinsing of the walls of the source container with a small volume of rinsing solution (e.g., reagent water, buffer, etc.), followed by transfer of the rinsing solution, followed by a second rinse and transfer.

QUANTUM MECHANICS: The study of how atoms, molecules, subatomic particles, etc. behave and are structured.

QUARKS: Elementary particle and a fundamental constituent of matter.

QUICKLIME: A calcium oxide material produced by calcining limestone to liberate carbon dioxide, also called “calcined lime” or “pebble lime”, commonly used for pH adjustment. Chemical formula is CaO.

R

RADIATION: Energy in the form of waves or subatomic particles when there is a change from high energy to low energy states.

RADIOACTIVE DECAY: The process of an unstable atomic nucleus losing energy by emitting radiation.

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

RAW SEWAGE: Untreated wastewater and its contents.

RAW SLUDGE: Undigested sludge recently removed from a sedimentation basin.

RAW TURBIDITY: The turbidity of the water coming to the treatment plant from the raw water source.

RAW WATER: Water that has not been treated in any way; it is generally considered to be unsafe to drink.
REAGENT: A substance used in a chemical reaction to measure, detect, examine, or produce other substances.
REAGENT WATER BLANK: see Method blank.
REAGENT WATER: Water demonstrated to be free from the analytes of interest and potentially interfering substances at the method detection limit for the analyte.
REAGENT: A substance used in a chemical reaction to measure, detect, examine, or produce other substances.
RECHARGE: The infiltration component of the hydrologic cycle. Often used in the context of referring to: The infiltration of water back into an aquifer, resulting in the restoration of lost storage and water levels which had been decreased due to pumping and/or natural discharges from the aquifer.
RECLAIMED WATER: Wastewater that has been treated to a level that allows for its reuse for a beneficial purpose.
RECLAMATION: The process of improving or restoring the condition of land or other material to a better or more useful state.
RSD: See Relative standard deviation.

S

S- BLOCK ELEMENTS: Group 1 and 2 elements (alkali and alkaline metals), which includes Hydrogen and Helium.
S.T.P.: Standard temperature and pressure standard temperature and pressure the temperature of 0°C and pressure of 1 atmosphere, usually taken as the conditions when stating properties of gases.
SAFE YIELD: A possible consequence when the “safe yield” of a well is exceeded and water continues to be pumped from a well, is land subsidence around the well will occur. Safe yield refers to a long-term balance between the water that is naturally and artificially recharged to an aquifer and the groundwater that is pumped out. When more water is removed than is recharged, the aquifer is described as being out of safe yield. When the water level in the aquifer then drops, we are said to be mining groundwater.
SALINE SOLUTION: General term for NaCl in water.
SALT BRIDGE: Devices used to connection reduction with oxidation half-cells in an electrochemical cell.
SALTS ARE ABSENT: Is a strange characteristic that is unique to water vapor in the atmosphere.
SALTS: Ionic compounds composed of anions and cations.
SAMPLE: The water that is analyzed for the presence of EPA-regulated drinking water contaminants. Depending on the regulation, EPA requires water systems and states to take samples from source water, from water leaving the treatment facility, or from the taps of selected consumers. Sampling Location: A location where soil or cuttings samples may be readily and accurately collected.
SANITARY SURVEY: Persons trained in public health engineering and the epidemiology of waterborne diseases should conduct the sanitary survey. The importance of a detailed sanitary survey of a new water source cannot be overemphasized. An on-site review of the water sources, facilities, equipment, operation, and maintenance of a public water systems for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water. The purpose of a non-regulatory sanitary survey is to identify possible biological and chemical pollutants which might affect a water supply.
SANITIZER: A disinfectant or chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.
SATURATED ZONE: Where an unconfined aquifer becomes saturated beneath the capillary fringe.
SATURATION INDEX: See Langelier's Index.
SATURATOR: A device which produces a fluoride solution for the fluoride process. Crystal-grade types of sodium fluoride should be fed with a saturator. Overfeeding must be prevented to protect public health when using a fluoridation system.
SCADA: A remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to with stand. If the level controller may be set with too close a tolerance 45 could be the cause of a control system that is frequently turning a pump on and off.
SCALE: Crust of calcium carbonate, the result of unbalanced water. Hard insoluble minerals deposited (usually calcium bicarbonate) which forms on pool and spa surfaces and clog filters, heaters and pumps. Scale is caused by high calcium hardness and/or high pH. The regular use of stain prevention chemicals can prevent scale.

SECONDARY DRINKING WATER STANDARDS: Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

SECONDARY SLUDGE: The sludge from the secondary clarifier in a wastewater treatment plant.

SECONDARY TREATMENT: The treatment of wastewater through biological oxidation after primary treatment.

SEDIMENT: Grains of soil, sand, gravel, or rock deposited by and generated by water movement.

SEDIMENTATION BASIN: A quiescent tank used to remove suspended solids by gravity settling. Also called clarifiers or settling tanks, they are usually equipped with a motor driven rake mechanism to collect settled sludge and move it to a central discharge point.

SEDIMENTATION BASIN: Where the thickest and greatest concentration of sludge will be found. Twice a year sedimentation tanks should be drained and cleaned if the sludge buildup interferes with the treatment process.

SEDIMENTATION: The process of suspended solid particles settling out (going to the bottom of the vessel) in water. The removal of settleable suspended solids from water or wastewater by gravity in a quiescent basin or clarifier.

SEMICONDUCTOR: An electrically conductive solid that is between a conductor and an insulator.

SENSOR: A float and cable system are commonly found instruments that may be used as a sensor to control the level of liquid in a tank or basin.

SEPTIC: Condition characterized by bacterial decomposition under anaerobic conditions.

SESSILE: Botany. attached by the base, or without any distinct projecting support, as a leaf issuing directly from the stem. Zoology. permanently attached; not freely moving.

SETTLEABILITY: The tendency of suspended solids to settle.

SETTLEABLE SOLIDS: That portion of suspended solids which are of a sufficient size and weight to settle to the bottom of an Imhoff cone in one hour.

SETTLED SLUDGE VOLUME: Volume of settled sludge measured at predetermined time increments for use in process control calculations.

SETTLED SOLIDS: Solids that have been removed from the raw water by the coagulation and settling processes.

SLUDGE DRYING BED: A closed area consisting of sand or other porous material upon which sludge is dewatered by gravity drainage and evaporation.

SLUDGE REDUCTION: Organic polymers are used to reduce the quantity of sludge. If a plant produces a large volume of sludge, the sludge could be dewatered, thickened, or conditioned to decrease the volume of sludge. Turbidity of source water, dosage, and type of coagulant used are the most important factors which determine the amount of sludge produced in a treatment of water.

SLUDGE: Accumulated and concentrated solids generated within a treatment process that have not undergone a stabilization process.

SLURRY: A mixture of a solid and a liquid that facilitates the transfer of the solid into a treatment solution.

SMALL WATER SYSTEM: 3,300 or fewer persons.

SOC: A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.

SOC: Synthetic organic chemical. A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.

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

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

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

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

SOFTENING WATER: When the water has a low alkalinity it is advantageous to use soda ash instead of caustic soda for softening water.

SOFTENING: The process that removes the ions which cause hardness in water.

SOL: A suspension of solid particles in liquid. Artificial examples include sol-gels.

SOLAR DRYING BEDS OR LAGOONS: Are shallow, small-volume storage pond where sludge is concentrated and stored for an extended periods.

SOLAR DRYING BEDS, CENTRIFUGES AND FILTER PRESSES: Are procedures used in the dewatering of sludge.

SOLDER: A fusible alloy used to join metallic parts.

SOLID: One of the states of matter, where the molecules are packed close together, there is a resistance of movement/deformation and volume change; see Young's modulus.

SOLID WASTE: Garbage, refuse, sludge and other discarded material resulting from community activities or commercial or industrial operations.

SOLID, LIQUID AND VAPOR: 3 forms of matter.

SOLUBILITY: The amount of a substance that can dissolve in a solution under a given set of conditions.

SOLUTE: The part of the solution that is mixed into the solvent (NaCl in saline water).

SOLUTION: Homogeneous mixture made up of multiple substances. It is made up of solutes and solvents.

SOLVENT: The part of the solution that dissolves the solute (H2O in saline water).

SPADNS: The lab reagent called SPADNS solution is used in performing the Fluoride test.

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SPECTROSCOPY: Study of radiation and matter, such as X:ray absorption and emission spectroscopy.

SPEED OF LIGHT: The speed of anything that has zero rest mass (Energyrest = mc^2 where m is the mass and c is the speed of light).

SPIKING SUSPENSION: Diluted stock suspension containing the organism(s) of interest at a concentration appropriate for spiking samples.

SPIRILLUM: Spiral-shaped, gram-negative, aerobic; include Bdellovibrio, predatory on other bacteria.

SPIRIT OF HARTSHORN: A colorless, pungent, suffocating, aqueous solution of about 28.5 percent ammonia gas: used chiefly as a detergent, for removing stains and extracting certain vegetable coloring agents, and in the manufacture of ammonium salts.

SPIROCHETE: Spiral-shaped, gram-negative, mostly anaerobic; common in moist environments, from mammalian gums to coastal mudflats; complex internal structures convey rapid movement; include *Treponemapallidum,* cause of syphilis.

SPLIT FLOW CONTROL SYSTEM: This type of control system is to control the flow to each filter influent which is divided by a weir.

SPOROZOITE: A motile, infective stage of certain protozoans; e.g., *Cryptosporidium*. There are four sporozoites in each *Cryptosporidium* oocyst, and they are generally banana-shaped.

SPRAY BOTTLE OF AMMONIA: An operator should use ammonia to test for a chlorine leak around a valve or pipe. You will see white smoke if there is a leak.

SPRING PRESSURE: Is what maintains contact between the two surfaces of a mechanical seal.

STABILIZATION POND: A large shallow basin used for wastewater treatment by natural processes involving the use of algae and bacteria to accomplish biological oxidation of organic matter.

STANDARD CONDITIONS FOR TEMPERATURE AND PRESSURE or SATP : A standardization used in order compare experimental results (25 °C and 100.000 kPa).

STANDPIPE: A water tank that is taller than it is wide. Should not be found in low point.

STATE OF MATTER: Matter having a homogeneous, macroscopic phase; gas, plasma, liquid, and solid are the most well-known (in increasing concentration).

STERILIZED GLASSWARE: The only type of glassware that should be used in testing for coliform bacteria.

STOCK SUSPENSION: A concentrated suspension containing the organism(s) of interest that is obtained from a source that will attest to the host source, purity, authenticity, and viability of the organism(s).

STORAGE TANKS: Three types of water usage that determine the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage. Equalization storage is the volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protects the interior about 3-5 years.

STUFFING BOX: That portion of the pump that houses the packing or mechanical seal.

SUBATOMIC PARTICLES: Particles that are smaller than an atom; examples are protons, neutrons and electrons.

SUBLIMATION: A phase transition from solid to limewater fuel or gas.

SUBNATANT: Liquid remaining beneath the surface of floating solids.

SUBSTANCE: Material with definite chemical composition.
SUCCESSION: Transition in the species composition of a biological community, often following ecological disturbance of the community; the establishment of a biological community in an area virtually barren of life.
SULFATE- AND SULFUR- REDUCING: Commonly rod-shaped, mostly gram-negative, anaerobic; include *Desulfovibrio,* ecologically important in marshes.
SULFATE: Will readily dissolve in water to form an anion. Sulfate is a substance that occurs naturally in drinking water. Health concerns regarding sulfate in drinking water have been raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulfate. Of particular concern are groups within the general population that may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations.
SULFIDE: The term sulfide refers to several types of chemical compounds containing sulfur in its lowest oxidation number of -2. Formally, "sulfide" is the dianion, S2-, which exists in strongly alkaline aqueous solutions formed from H2S or alkali metal salts such as Li2S, Na2S, and K2S. Sulfide is exceptionally basic and, with a pKa > 14, it does not exist in appreciable concentrations even in highly alkaline water, being undetectable at pH < ~15 (8 M NaOH). Instead, sulfide combines with electrons in hydrogen to form HS, which is variously called hydrogen sulfide ion, hydrosulfide ion, sulfhydryl ion, or bisulfide ion. At still lower pH's (<7), HS- converts to H2S, hydrogen sulfide. Thus, the exact sulfur species obtained upon dissolving sulfide salts depends on the pH of the final solution. Aqueous solutions of transition metals cations react with sulfide sources (H2S, NaSH, Na2S) to precipitate solid sulfides. Such inorganic sulfides typically have very low solubility in water and many are related to minerals. One famous example is the bright yellow species CdS or "cadmium yellow". The black tarnish formed on sterling silver is Ag2S. Such species are sometimes referred to as salts. In fact, the bonding in transition metal sulfides is highly covalent, which gives rise to their semiconductor properties, which in turn is related to the practical applications of many sulfide materials.

T

TALC: A mineral representing the one on the Mohs Scale and composed of hydrated magnesium silicate with the chemical formula H2Mg3(SiO3)4 or Mg3Si4O10(OH)2.
TASTE AND ODORS: The primary purpose to use potassium permanganate in water treatment is to control taste and odors. Anaerobic water undesirable for drinking water purposes because of color and odor problems are more likely to occur under these conditions. Taste and odor problems in the water may happen if sludge and other debris are allowed to accumulate in a water treatment plant.
TCE, trichloroethylene: A solvent and degreaser used for many purposes; for example dry cleaning, it is a common groundwater contaminant. Trichloroethylene is a colorless liquid which is used as a solvent for cleaning metal parts. Drinking or breathing high levels of trichloroethylene may cause nervous system effects, liver and lung damage, abnormal heartbeat, coma, and possibly death. Trichloroethylene has been found in at least 852 of the 1,430 National Priorities List sites identified by the Environmental Protection Agency (EPA).
TDS: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried. Demineralization may be necessary in a treatment process if the water has a very high value Total Dissolved Solids.
TDS-TOTAL DISSOLVED SOLIDS: An expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal sol) suspended form. Generally, the operational definition is that the solids (often abbreviated TDS) must be small enough to survive filtration through a sieve size of two micrometers. Total dissolved solids are normally only discussed for freshwater systems, since salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant (e.g. it is not deemed to be associated with health effects), but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants. Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total

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TELEMETERING: The use of a transmission line with remote signaling to monitor a pumping station or motors. Can be used to accomplish accurate and reliable remote monitoring and control over a long distribution system.

TEMPERATURE SAMPLE: This test should be performed immediately in the field, this is a grab sample.

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TEMPERATURE: The average energy of microscopic motions of particles.

TERTIARY TREATMENT: The use of physical, chemical, or biological means to improve secondary wastewater effluent quality.

THE RATE DECREASES: In general, when the temperature decreases, the chemical reaction rate decreases also.

THEORY: A model describing the nature of a phenomenon.

THERMAL CONDUCTIVITY: A property of a material to conduct heat (often noted as k).

THERMOCHEMISTRY: The study of absorption/release of heat within a chemical reaction.

THERMODYNAMIC STABILITY: When a system is in its lowest energy state with its environment (equilibrium).

THERMODYNAMICS: The study of the effects of changing temperature, volume or pressure (or work, heat, and energy) on a macroscopic scale.

THERMOMETER: Device that measures the average energy of a system.

THICKENING, CONDITIONING AND DEWATERING: Common processes that are utilized to reduce the volume of sludge.

THICKENING: A procedure used to increase the solids content of sludge by removing a portion of the liquid.

THOMAS MALTHUS: Formulated the concept that population growth proceeds at a geometric rate.

TIME FOR TURBIDITY BREAKTHROUGH AND MAXIMUM HEADLOSS: Are the two factors which determine whether or not a change in filter media size should be made.

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

TITRATION: The process of titrating one solution with another, also called volumetric analysis. A method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.

TITRIMETRIC: Chemistry. Using or obtained by titration. Titrimetrically, adverb.

TOROID: A surface generated by the revolution of any closed plane curve or contour about an axis lying in its plane. The solid enclosed by such a surface.

TORR: A unit to measure pressure (1 Torr is equivalent to 133.322 Pa or 1.3158×10^{-3} atm).

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

TOTAL COLIFORM: Total coliform, fecal coliform, and E. coli are all indicators of drinking water quality. The total coliform group is a large collection of different kinds of bacteria. Fecal coliforms are types of total coliform that mostly exist in feces. E. coli is a sub-group of fecal coliform. When a water sample is sent to a lab, it is tested for total coliform. If total coliform is present, the sample will also be tested for either fecal coliform or E. coli, depending on the lab testing method.

TOTAL DISSOLVED SOLIDS (TDS): The accumulated total of all solids that might be dissolved in water. The weight per unit volume of all volatile and non-volatile solids dissolved in a water or wastewater after a sample has been filtered to remove colloidal and suspended solids.

TOTAL DYNAMIC HEAD: The pressure (psi) or equivalent feet of water, required for a pump to lift water to its point of storage overcoming elevation head, friction loss, line pressure, drawdown and pumping lift.

TOTAL SOLIDS: The sum of dissolved and suspended solids in a water or wastewater.

TOTAL SUSPENDED SOLIDS: The measure of particulate matter suspended in a sample of water or wastewater.

TOXIC: Capable of causing an adverse effect on biological tissue following physical contact or absorption.

TRANSIENT, NON-COMMUNITY WATER SYSTEM: TNCWS A water system which provides water in a place such as a gas station or campground where people do not remain for long periods of time. These systems do not have to test or treat their water for contaminants which pose long-term health risks because fewer than 25 people drink the water over a long period. They still must test their water for microbes and several chemicals. A Transient Non-community Water System: Is not required to sample for VOC's.

TRANSITION METAL: Elements that have incomplete d sub-shells, but also may be referred to as the d-block elements.

TRANSURANIC ELEMENT: Element with atomic number greater than 92; none of the transuranic elements are stable.

TREATABILITY STUDY: A study in which a waste is subjected to a treatment process to determine treatment and/or to determine the treatment efficiency or optimal process conditions for treatment.

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

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.

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TRIPLE BOND: The sharing of three pairs of electrons within a covalent bond (example N2).

TRIPLE POINT: The place where temperature and pressure of three phases are the same (Water has a special phase diagram).

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

TUBERCLES: The creation of this condition is of the most concern regarding corrosive water effects on a water system. Tubercles are formed due to joining dissimilar metals, causing electro-chemical reactions. Like iron to copper pipe. We have all seen these little rust mounds inside cast iron pipe.

TUNDALL EFFECT: The effect of light scattering by colloidal (mixture where one substance is dispersed evenly through another) or suspended particles.

TURBIDIMETER: Monitoring the filter effluent turbidity on a continuous basis with an in-line instrument is a recommended practice. Turbidimeter is best suited to perform this measurement.

TURBIDITY: A measure of the cloudiness of water caused by suspended particles. A qualitative measurement of water clarity which results from suspended matter that scatters or otherwise interferes with the passage of light through the water.

U

U.S. ENVIRONMENTAL PROTECTION AGENCY: In the United States, this agency responsible for setting drinking water standards and for ensuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce.

ULTRAFILTRATION: A low pressure membrane filtration process which separates solutes up to 0.1 micron size range.

UN NUMBER: A four digit code used to note hazardous and flammable substances.

UNCERTAINTY PRINCIPLE: Knowing the location of a particle makes the momentum uncertain, while knowing the momentum of a particle makes the location uncertain.

UNCERTAINTY: A characteristic that any measurement that involves estimation of any amount cannot be exactly reproducible.

UNDER PRESSURE IN STEEL CONTAINERS: After chlorine gas is manufactured, it is primarily transported in steel containers.

UNIT CELL: The smallest repeating unit of a lattice.

UNIT FACTOR: Statements used in converting between units.

UNIT FILTER RUN VOLUME (UFRV): One of the most popular ways to compare filter runs. This technique is the best way to compare water treatment filter runs.

UNIVERSAL OR IDEAL GAS CONSTANT: Proportionality constant in the ideal gas law (0.08206 L·atm/(K·mol)).

UP FLOW CLARIFIER: Clarifier where flocculated water flows upward through a sludge blanket to obtain floc removal by contact with flocculated solids in the blanket.

V

VALENCE BOND THEORY: A theory explaining the chemical bonding within molecules by discussing valencies, the number of chemical bonds formed by an atom.

VALENCE ELECTRON: The outermost electrons of an atom, which are located in electron shells.

VAN DER WAALS FORCE: One of the forces (attraction/repulsion) between molecules.

VAN'T HOFF FACTOR: Ratio of moles of particles in solution to moles of solute dissolved.

VAPOR PRESSURE: Pressure of vapor over a liquid at equilibrium.

VAPOR: The gaseous phase of a material that is in the solid or liquid state at standard temperature and pressure.

VAPOR: When a substance is below the critical temperature while in the gas phase.

VAPORIZATION: Phase change from liquid to gas.

VELOCITY HEAD: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

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VENTURI: If water flows through a pipeline at a high velocity, the pressure in the pipeline is reduced. Velocities can be increased to a point that a partial vacuum is created.

VIBRIO: Rod- or comma-shaped, gram-negative, aerobic; commonly with a single flagellum; include *Vibrio cholerae,* cause of cholera, and luminescent forms symbiotic with deep-water fishes and squids.

VIRION: A complete viral particle, consisting of RNA or DNA surrounded by a protein shell and constituting the infective form of a virus.

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

VISCOSITY: The resistance of a liquid to flow (oil).

VITRIFICATION: Vitrification is a process of converting a material into a glass-like amorphous solid that is free from any crystalline structure, either by the quick removal or addition of heat, or by mixing with an additive. Solidification of a vitreous solid occurs at the glass transition temperature (which is lower than melting temperature, Tm, due to super cooling). When the starting material is solid, vitrification usually involves heating the substances to very high temperatures. Many ceramics are produced in such a manner. Vitrification may also occur naturally when lightning strikes sand, where the extreme and immediate heat can create hollow, branching rootlike structures of glass, called fulgurite. When applied to whiteware ceramics, vitreous means the material has an extremely low permeability to liquids, often but not always

water, when determined by a specified test regime. The microstructure of whiteware ceramics frequently contain both amorphous and crystalline phases.
VOC WAIVER: The longest term VOC waiver that a public water system using groundwater could receive is 9 years.
VOID: An opening, gap, or space within rock or sedimentary formations formed at the time of origin or deposition.
VOLATILE ORGANIC COMPOUNDS: (VOCs) Solvents used as degreasers or cleaning agents. Improper disposal of VOCs can lead to contamination of natural waters. VOCs tend to evaporate very easily. This characteristic gives VOCs very distinct chemical odors like gasoline, kerosene, lighter fluid, or dry cleaning fluid. Some VOCs are suspected cancer-causing agents. Volatile organic compounds (VOCs) are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. A wide range of carbon-based molecules, such as aldehydes, ketones, and other light hydrocarbons are VOCs. The term often is used in a legal or regulatory context and in such cases the precise definition is a matter of law. These definitions can be contradictory and may contain "loopholes"; e.g. exceptions, exemptions, and exclusions. The United States Environmental Protection Agency defines a VOC as any organic compound that participates in a photoreaction; others believe this definition is very broad and vague as organics that are not volatile in the sense that they vaporize under normal conditions can be considered volatile by this EPA definition. The term may refer both to well characterized organic compounds and to mixtures of variable composition.
VOLATILE: A substance that evaporates or vaporizes at a relatively low temperature.
VOLT: One joule of work per coulomb - the unit of electrical potential transferred.
VOLTAGE: Voltage (sometimes also called electric or electrical tension) is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts.[1] It measures the potential energy of an electric field to cause an electric current in an electrical conductor. Depending on the difference of electrical potential it is called extra low voltage, low voltage, high voltage or extra high voltage. Specifically Voltage is equal to energy per unit charge.
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VOLTIMETER: Instrument that measures the cell potential.
VOLUMETERIC ANALYSIS: See titration.
VOLUTE: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharge by the impeller.
VORTEX: The helical swirling of water moving towards a pump.
VORTICELLA: Vorticella is a genus of protozoa, with over 100 known species. They are stalked inverted bell-shaped ciliates, placed among the peritrichs. Each cell has a separate stalk anchored onto the substrate, which contains a contracile fibril called a myoneme. When stimulated this shortens, causing the stalk to coil like a spring. Reproduction is by budding, where the cell undergoes longitudinal fission and only one daughter keeps the stalk. Vorticella mainly lives in freshwater ponds and streams - generally anywhere protists are plentiful. Other genera such as Carchesium resemble Vorticella but are branched or colonial.
VULNERABILITY ASSESSMENT: An evaluation of drinking water source quality and its vulnerability to contamination by pathogens and toxic chemicals.

W
WAIVERS: Monitoring waivers for nitrate and nitrite are prohibited.
WASTE ACTIVATED SLUDGE: Excess activated sludge that is discharged from an activated sludge treatment process.
WASTEWATER: Liquid or waterborne wastes polluted or fouled from households, commercial or industrial operations, along with any surface water, storm water or groundwater infiltration.
WATER H2O: A chemical substance, a major part of cells and Earth, and covalently bonded.
WATER HAMMER: A surge in a pipeline resulting from the rapid increase or decrease in water flow. Water hammer exerts tremendous force on a system and can be highly destructive.
WATER PURVEYOR: The individuals or organization responsible to help provide, supply, and furnish quality water to a community.

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

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WATER QUALITY STANDARD: A statute or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

WATER QUALITY: The 4 broad categories of water quality are: Physical, chemical, biological, radiological. Pathogens are disease causing organisms such as bacteria and viruses. A positive bacteriological sample indicates the presence of bacteriological contamination. Source water monitoring for lead and copper be performed when a public water system exceeds an action level for lead of copper.

WATER RECLAMATION: The restoration of wastewater to a state that will allow its beneficial reuse.

WATER VAPOR: A characteristic that is unique to water vapor in the atmosphere is that water does not contain any salts.

WATERBORNE DISEASE: A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).

WATERSHED: An area that drains all of its water to a particular water course or body of water. The land area from which water drains into a stream, river, or reservoir.

WAVE FUNCTION: A function describing the electron's position in a three-dimensional space.

Weathered: The existence of rock or formation in a chemically or physically broken down or decomposed state. Weathered material is in an unstable state.

WHOLE EFFLUENT TOXICITY: The total toxic effect of an effluent measured directly with a toxicity test.

WORK: The amount of force over distance and is in terms of joules (energy).

WPCF: Water Pollution Control Facility

WTP: Water Treatment Plant

WWTP: Wastewater Treatment Plant

X

X-RAY DIFFRACTION: A method for establishing structures of crystalline solids using singe wavelength X-rays and looking at diffraction pattern.

X-RAY PHOTOELECTRON SPECTROSCOPY: A spectroscopic technique to measure composition of a material.

X-RAY: Form of ionizing, electromagnetic radiation, between gamma and UV rays.

Y

YIELD: The amount of product produced during a chemical reaction.

Z

ZERO DISCHARGE: A facility that discharges no liquid effluent to the environment.

ZONE MELTING: A way to remove impurities from an element by melting it and slowly travel down an ingot (cast).

Common Water Treatment and Distribution Chemicals

Chemical Name	Common Name	Chemical Formula
Aluminum hydroxide		Al(OH)3
Aluminum sulfate	Alum, liquid	AL2(SO4)3 . 14(H2O)
Ammonia		NH3
Ammonium		NH4
Bentonitic clay	Bentonite	
Calcium bicarbonate		Ca(HCO3)2
Calcium carbonate	Limestone	CaCO3
Calcium chloride		CaCl2
Calcium Hypochlorite	HTH	Ca(OCl)2 . 4H2O
Calcium hydroxide	Slaked Lime	Ca(OH)2
Calcium oxide	Unslaked (Quicklime)	CaO
Calcium sulfate	Gypsum	CaSO4
Carbon	Activated Carbon	C
Carbon dioxide		CO2
Carbonic acid		H2CO3
Chlorine gas		Cl2
Chlorine Dioxide		ClO2
Copper sulfate	Blue vitriol	CuSO4 . 5H2O
Dichloramine		NHCl2
Ferric chloride	Iron chloride	FeCl3
Ferric hydroxide		Fe(OH)3
Ferric sulfate	Iron sulfate	Fe2(SO4)3
Ferrous bicarbonate		Fe(HCO3)2
Ferrous hydroxide		Fe(OH)3
Ferrous sulfate	Copperas	FeSO4.7H20
Hydrofluorsilicic acid		H2SiF6
Hydrochloric acid	Muriatic acid	HCl
Hydrogen sulfide		H2S
Hypochlorous acid		HOCL
Magnesium bicarbonate		Mg(HCO3)2
Magnesium carbonate		MgCO3
Magnesium chloride		MgCl2
Magnesium hydroxide		Mg(OH)2
Magnesium dioxide		MgO2
Manganous bicarbonate		Mn(HCO3)2
Manganous sulfate		MnSO4
Monochloramine		NH2Cl
Potassium bicarbonate		KHCO3

Chemical Name	Common Name	Chemical Formula
Potassium permanganate		KMnO3
Sodium carbonate	Soda ash	Na2CO3
Sodium chloride	Salt	NaCl
Sodium chlorite		NaClO2
Sodium fluoride		NaF
Sodium fluorosilicate		Na2SiF6
Sodium hydroxide	Lye	NaOH
Sodium hypochlorite		NaOCl
Sodium Metaphosphate	Hexametaphosphate	NaPO3
Sodium phosphate	Disodium phosphate	Na3PO4
Sodium sulfate		Na2SO4
Sulfuric acid		H2SO4

Common Used Products	Chemical Name
acetone	dimethyl ketone
acid of sugar	oxalic acid
alcohol, grain	ethyl alcohol
alcohol, wood	methyl alcohol
alum	aluminum potassium sulfate
alumina	aluminum oxide
antichlor	sodium thiosulfate
aqua ammonia	aqueous solution of ammonium hydroxide
aqua regia	nitrohydrochloric acid
aqua fortis	nitric acid
aromatic spirit of ammonia	ammonia in alcohol
asbestos	magnesium silicate
aspirin	acetylsalicylic acid
baking soda	sodium bicarbonate
banana oil (artificial)	isoamyl acetate
benzol	benzene
bichloride of mercury	mercuric chloride
black copper oxide	cupric oxide
black lead	graphite (carbon)
bleaching powder	chlorinated lime
blue vitriol	copper sulfate
bluestone	copper sulfate
borax	sodium borate
brimstone	sulfur
brine	aqueous sodium chloride solution
butter of antimony	antimony trichloride
butter of tin	anhydrous stannic chloride
calomel	mercury chloride
carbolic acid	phenol
carbonic acid gas	carbon dioxide
caustic potash	potassium hydroxide
caustic soda	sodium hydroxide
chalk	calcium carbonate
Chile saltpeter	sodium nitrate
chrome, alum	chromic potassium sulfate
chrome, yellow	lead (VI) chromate
copperas	ferrous sulfate
cream of tartar	potassium bitartrate
crocus powder	ferric oxide
emery powder	impure aluminum oxide
Epsom salts	magnesium sulfate
ethanol	ethyl alcohol
fluorspar	natural calcium fluoride
formalin	aqueous formaldehyde solution
French chalk	natural magnesium silicate
galena	natural lead sulfide
Glauber's salt	sodium sulfate
gypsum	natural calcium sulfate
hydrocyanic acid	hydrogen cynanide
hypo (photography)	sodium thiosulfate solution
lime	calcium oxide

Common Used Products	**Chemical Name**
limewater	aqueous solution of calcium hydroxide
lunar caustic	silver nitrate
magnesia	magnesium oxide
mercury oxide, black	mercurous oxide
methanol	methyl alcohol
methylated spirits	methyl alcohol
muriatic acid	hydrochloric acid
oil of vitriol	sulfuric acid
oil of wintergreen (artificial)	methyl salicylate
Paris green	copper acetoarsenite
Paris white	powdered calcium carbonate
pear oil (artificial)	isoamyl acetate
pearl ash	potassium carbonate
plaster of Paris	calcium sulfate
plumbago	graphite
potash	potassium carbonate
potassa	potassium hydroxide
Prussic acid	hydrogen cyanide
pyro	tetrasodium pyrophosphate
quicklime	calcium oxide
quicksilver	mercury
red lead	lead tetraoxide
Rochelle salt	potassium sodium tartrate
rouge, jeweler's	ferric oxide
rubbing alcohol	isopropyl alcohol
sal ammoniac	ammonium chloride
sal soda	sodium carbonate
salt, table	sodium chloride
salt of lemon	potassium binoxalate
salt of tartar	potassium carbonate
saltpeter	potassium nitrate
silica	silicon dioxide
soda ash	sodium carbonate
soda lye	sodium hydroxide
soluble glass	sodium silicate
spirit of hartshorn	ammonium hydroxide solution
sugar, table	sucrose
talc or talcum	magnesium silicate
vinegar	impure dilute acetic acid
vitamin C	ascorbic acid
washing soda	sodium carbonate
water glass	sodium silicate

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 = 1Pound
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 Feet = 1 Mile

AREA

144 Square Inches = 1 Square Foot
43,560 Square Feet = 1 Acre

VOLUME

1000 Milliliters = 1 Liter
3.785 Liters = 1Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water

Dimensions

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

CIRCLE: Area (sq. ft.) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. Ft.) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

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

General

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

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

TEMPERATURE: ^{0}F = (^{0}C X 9/5) + 32
^{0}C = (^{0}F - 32) X 5/9

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

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

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

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

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

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

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

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

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

TOTAL HEAD (ft) = Suction Lift (ft) X Discharge Head (ft)

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

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

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

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

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

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

Hardness

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

Ca HARDNESS as mg/L $CaCo_3$ = 2.5 X (Ca, mg/L)

Mg HARDNESS as mg/L $CaCo_3$ = 4.12 (Mg, mg/L)

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

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

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

LANGELIER INDEX = $\text{pH} - \text{pH}_s$

Chemical Addition

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

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

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

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

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

Filtration

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

$$\underset{\text{(gpm)}}{\text{BACKWASH PUMPING RATE}} = \text{Filter Area (sq. ft) X Backwash Rate (gpm/sq. ft)}$$

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

C Factor

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

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

Chlorine Pre-Quiz Answers

1. Use a new, approved gasket on the connector
2. 1/4 turn to unseat the valve, then open one complete turn
3. The cylinder may rupture
4. The ratio of the density of the liquid to the density of water at 4 degrees C
5. Gold, Platinum, and Tantalum
6. Gas chlorine
7. Secure each cylinder in an upright position. Attach the protective bonnet over the valve. Firmly secure each cylinder.
8. Open chlorine metering orifice slightly. Inspect vacuum lines. Start injector water supply
9. In addition to protective clothing and goggles, chlorine gas should be used only in a well ventilated area so that any leaking gas cannot concentrate.
10. Chlorine gas forms a mixture of hydrochloric and hypochlorous acids
11. Because it is too easy to roll
12. A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber colored liquid, a noncombustible gas, and a strong oxidizer. Chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air.
13. Notify local emergency response team. Warn and evacuate people in adjacent areas. Be sure that no one enters the leak area without adequate self-contained breathing equipment.
14. Burning of eyes, nose, and mouth; lacrimation and rhinorrhea; Coughing, sneezing, choking, nausea and vomiting, headaches and dizziness, fatal pulmonary edema, pneumonia, conjunctivitis, keratitis, pharyngitis, burning chest pain, dyspnea, hemoptysis, hypoxemia, dermatitis; and skin blisters.
15. 646 mg/L
16. Get out of the area of the leak, proceeding upwind, and 2) take only very short breaths through the mouth
17. 0.195
18. True
19. True
20. True
21. HOCl and OCl-; free available chlorine
22. Cl2 + H2O --> H+ + Cl- + HOCl
23. HOCl <-- --> H+ + OCl-
24. Hypochlorous acid

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