DISTRIBUTION PRIMER 2

CONTINUING EDUCATION PROFESSIONAL DEVELOPMENT COURSE

Technical Learning College

Printing and Saving Instructions

TLC recommends that you download and save this pdf document to your computer desktop and open it with Adobe Acrobat DC reader.

Adobe Acrobat DC reader is a free computer software program and you can find it at Adobe Acrobat's website.

You can complete the course by viewing the course materials on your computer or you can print it out. Once you've paid for the service, we'll give you permission to print this document.

Printing Instructions: If you are going to print this document, this document is designed to be printed double-sided or duplexed but can be single-sided.

This course booklet does not have the assignment. Please visit our website and download the assignment also.

Hyperlink to Assignment…
http://www.abctlc.com/downloads/PDF/DistributionPrimer2ASS.pdf

State Approval Listing Link, check to see if your State accepts or has pre-approved this course. Not all States are listed. Not all courses are listed. Do not solely trust our list for it may be outdated. It is your sole responsibility to ensure this course is accepted for credit. No refunds.

State Approval Listing URL…
http://www.abctlc.com/downloads/PDF/CEU%20State%20Approvals.pdf

Hyperlink to the Glossary and Appendix
http://www.abctlc.com/downloads/PDF/WTGlossary.pdf

You can obtain a printed version from TLC for an additional $189.95 plus shipping charges.

All downloads are electronically tracked and monitored for security purposes.

Chlorine Container Safety Information

1. Never expose a container to excessive heat.
2. Never tamper with a fusible plug.
3. Do not move filled ton containers with equipment rated under two-ton capacity.
4. Do not connect liquid valves of two or more contain- ers to a common manifold.
5. Store containers in separately marked areas protected from heat sources.
6. Do not use or store containers near air intakes or basements where fumes could spread to other areas.

This course contains 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.

Library of Congress Card Number TX-6-825-267
DISTRIBUTION BASICS II

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

Do not solely depend on TLC's Approval list for it may be outdated.

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

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

Responsibility

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

Copyright Notice

1999-2022 Technical Learning College (TLC) No part of this work may be reproduced or distributed in any form or by any means without TLC's prior written approval. Permission has been sought for all images and text where we believe copyright exists and where the copyright holder is traceable and contactable. Other materials including text and artwork are in the public domain or fair use (the state of belonging or being available to the public as a whole, and therefore not subject to copyright.) All material that is not credited or acknowledged or referenced in the rear of this course is the copyright of Technical Learning College. Most unaccredited photographs have been taken by TLC instructors or TLC students. All written, graphic, photographic or other material is provided for educational information only. We will be pleased to hear from any copyright holder and will make good on your work if any unintentional copyright infringements were made as soon as these issues are brought to the editor's attention. This educational training course and assignment is intended for educational purposes only. Every possible effort was made to ensure that all information provided in this course is accurate. Therefore, Technical Learning College accepts no responsibility or liability whatsoever for the application or misuse of any information included herein.

Requests for acknowledgements or permission to make copies shall be made to the following address: TLC, P.O. Box 3060, Chino Valley, AZ 86323

Information in this document is subject to change without notice. TLC is not liable for errors or omissions appearing in this document.

Contributing Editors

James L. Six Received a Bachelor of Science Degree in Civil Engineering from the University of Akron in June of 1976, Registered Professional Engineer in the State of Ohio, Number 45031 (Retired), Class IV Water Supply Operator issued by Ohio EPA, Number WS4-1012914-08, Class II Wastewater Collection System Operator issued by Ohio EPA, Number WC2-1012914-94

Joseph Camerata has a BS in Management with honors (magna cum laude). He retired as a Chemist in 2006 having worked in the field of chemical, environmental, and industrial hygiene sampling and analysis for 40 years. He has been a professional presenter at an EPA analytical conference at the Biosphere in Arizona and a presenter at an AWWA conference in Mesa, Arizona. He also taught safety classes at the Honeywell and City of Phoenix, and is a motivational/inspirational speaker nationally and internationally.

James Bevan, Water Quality Inspector S.M.E. Twenty years of experience in the environmental field dealing with all aspects of water regulations on the federal, state, and local levels. Teacher and Proctor in Charge for Backflow Certification Testing at the ASETT Center in Tucson for the past 15 years and possess an Arizona Community College, Special Teaching Certificate in Environmental Studies.

Dr. Pete Greer S.M.E., Retired biology instructor, chemistry and biological review.

Jack White, Environmental, Health, Safety expert, City of Phoenix. Art Credits.

Important Information about this Manual

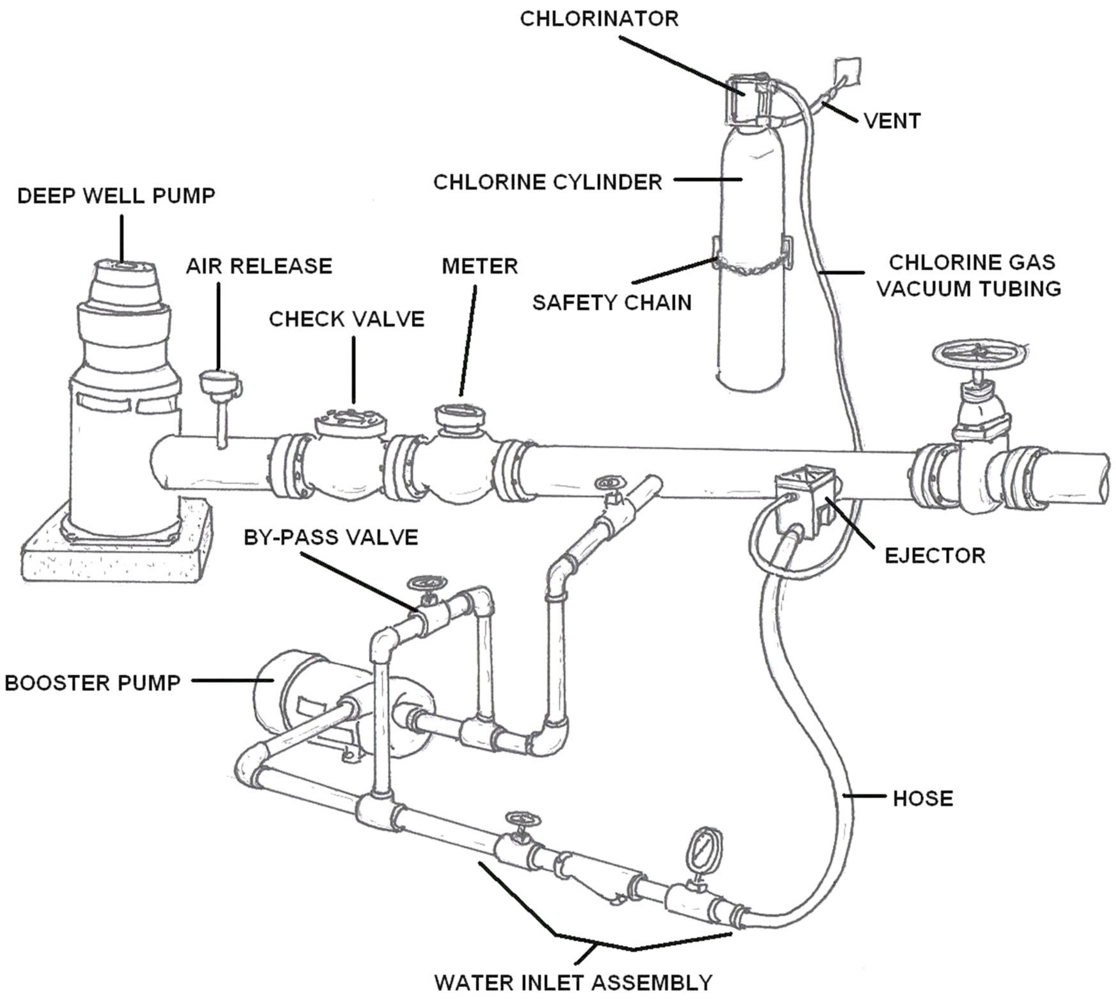
Disclaimer
This CEU training manual has been prepared to assist employees in the general awareness of the water distribution system and groundwater production system, complex pumping ideas, dangerous excavation techniques, water regulatory sampling and dealing with often-complex procedures and requirements for safely handling hazardous and toxic materials. The scope of the material is quite large, requiring a major effort to bring it under control. Employee health and safety, as well as that of the public, depend upon careful application of federal and state regulations and safe working procedures.

This manual will cover general laws, regulations, required procedures and work rules relating to water distribution and sampling. It should be noted, however, that the federal and state regulations are an ongoing process and subject to change over time. For this reason, a list of resources and hyperlinks is provided to assist in obtaining the most up-to-date information on various subjects. You can find these on our website or in this manual.

This manual is a guidance document for employees who are involved with water distribution, water quality and pollution control. It is not designed to meet the full requirements of the United States Environmental Protection Agency (EPA) or the Department of Labor-Occupational Safety and Health Administration (OSHA) rules and regulations.

This course manual will provide general guidance and should not be used as a preliminary basis for developing general water/wastewater sampling plans or water distribution safety plans or procedures. This document is not a detailed water/wastewater textbook or a comprehensive source book on water/wastewater/ safety rules and regulations. Technical Learning College makes 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 guidance and is not considered a legal document. Individuals who are responsible for water distribution, production and/or sampling and the health and safety of workers at hazardous waste sites should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, the EPA and other appropriate federal, state, and local agencies.



Chlorine Cylinder Change Out Procedure

1. Turn valve stem clockwise to close cylinder valve.
2. Allow float in flow meter to drop to zero. Indicator on front of gas feeder should indicate no gas.
3. Wait approximately one minute; float should re main at zero. If float flutters or does not drop to zero, valve may not be closed tightly. Make certain valve is closed before proceeding.
4. Turn off ejector and make certain the gas supply indicator stays in the “No Gas” position by turning the “Reset” knob. If the indicator resets, either gas pres sure is still present or there is an air leak in the system. Refer to the instruction manual if an air leak is evident.
5. Loosen gas feeder yoke screw. Remove gas feeder from valve.
6. Replace gas cylinder
7. Remove old lead gasket. Inspect and clean mating surfaces of gas feeder and valve. Install new unused lead gasket.

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.

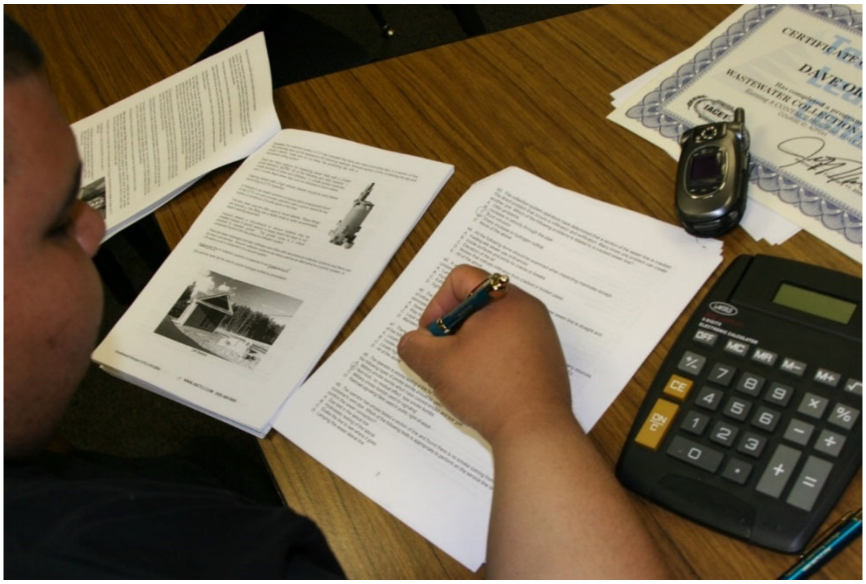
Course Structure

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.

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



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

We welcome you to complete the assignment in Word.

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

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

CEU Course Description

DISTRIBUTION PRIMER II CEU TRAINING COURSE
An 8 hour continuing education review of various water distribution/ groundwater disinfection components, chlorination systems and disinfection byproduct information. This course will cover disinfection, disinfection byproducts, chlorination, sampling and commonly found waterborne diseases and bacteriological sampling. You will not need any other materials for this course.

Water Distribution, Well Drillers, Pump Installers, Water Treatment Operators.
The target audience for this course is the person interested in working in a water 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.

Final Examination for Credit
Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Course Procedures for Registration and Support
All of Technical Learning College's correspondence courses have complete registration and support services offered. Delivery of services will include, e-mail, web site, telephone, fax and mail support. TLC will attempt immediate and prompt service.

When a student registers for a distance or correspondence course, he/she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work.

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

Instructions for Written Assignments
The Distribution Primer II training CEU course uses a multiple choice answer key. If you should need any assistance, please email all concerns and the final test to: info@tlch2o.com.

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

Feedback Mechanism (examination procedures)
Each student will receive a feedback form as part of their study packet. You will be able to find this form in the front of the 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.

Required Texts
The Distribution Primer II training CEU course will not require any other materials. This course comes complete. No other materials are needed.

Recordkeeping and Reporting Practices
TLC will keep all student records for a minimum of seven years. It is the student's responsibility to give the completion certificate to the appropriate agencies.

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

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

Educational Mission

The educational mission of TLC is:

To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,

To provide TLC students with opportunities to apply and understand the theory and skills needed for operator certification,

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

To provide a forum in which students can exchange experiences and ideas related to environmental education,

To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.

TABLE OF CONTENTS (Learning Objective Legend on Page 15)

Topic Legend

This CEU course covers several different educational topics/functions/purposes/objectives of conventional water distribution, cross-connection control, safety, pumps, groundwater production, disinfection, bacteriological monitoring and regulatory compliance. The topics listed below are to assist in determining which educational objective or goal is covered for a specific topic area:

CRAO - Compliance and Regulatory Affairs: The regulatory and compliance component of your need to know. May be a requirement of the SDWA act or State Regulations, i.e. Compliance, non-compliance, process control related sampling or other drinking water related requirement. This EPA information is to satisfy the regulatory portion of your operator training. Part of O&M or laboratory training requirement for many operators.

DISN - Disinfection: This area covers plant disinfection procedures. Part of O&M training for many operators. May include alternative disinfection procedures, i.e. Ozone and Ultraviolet

GP - GROUNDWATER MINING OR PRODUCTION: This may be considered O&M training for many operators or credit for pump engineers or well drillers.

M/O - Microorganisms: The biological component. The microorganisms that are specifically found in drinking water. This section may be part of required sampling, i.e. Total Coliform Rule or other biological related sampling. Part of O&M or laboratory training requirement for many operators.

MOTOR: Having to do with the electrical-mechanical portion of moving water. This may be considered O&M training for many operators. Maybe good for credit for those who hold an electrician or instrumentation certification.

O&M - Operations and Maintenance: This area is for normal Operation and/or Maintenance of the distribution system. Part of O&M training requirement for many operators.

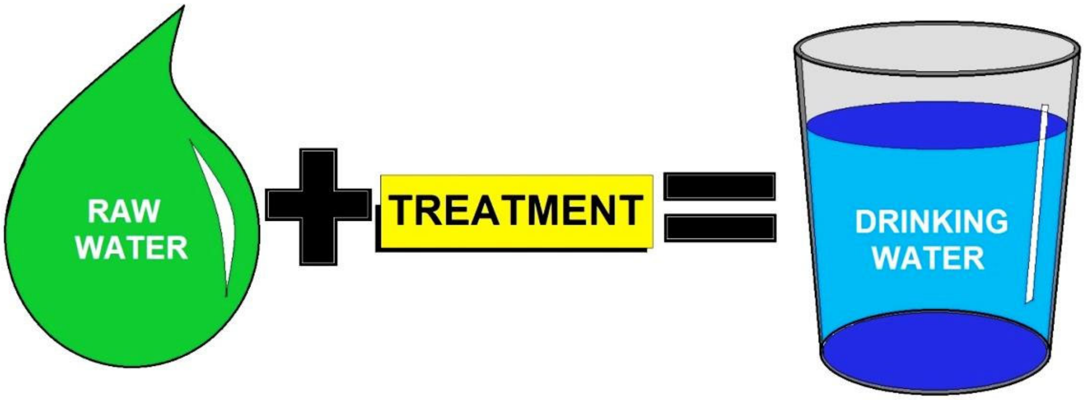
PE - PUMP ENGINEERING: The technical science of pumping and pump performance principles. May be a law or theory or calculation related to pumping. Information that a pump engineer or well operator may need.

SAFETY: This area describes process safety procedures. It may be part of O&M training requirement for many operators.

TECH - TECHNICAL: The daily operation of mechanical or physical treatment process/component. Part of O&M training for many operators.

WQ – Water Quality: Having to do with Water Quality or pollutants, i.e., hard water to primary water standards. May be a requirement of the SDWA and/or water chemistry concerns. This along with the EPA information is to satisfy the regulatory portion of your operator training.

Preface



Safe Drinking Water Act of 1974 Introduction

(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.

Also, 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.

More on these concerns in the Water Quality Section of the course.

Topic 1- Bacteriological Monitoring Section

Section Focus: You will learn the basics of the EPA's Total Coliform Rule and bacteriological sampling. At the end of this section, you the student will be able to describe the Total Coliform Rule. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

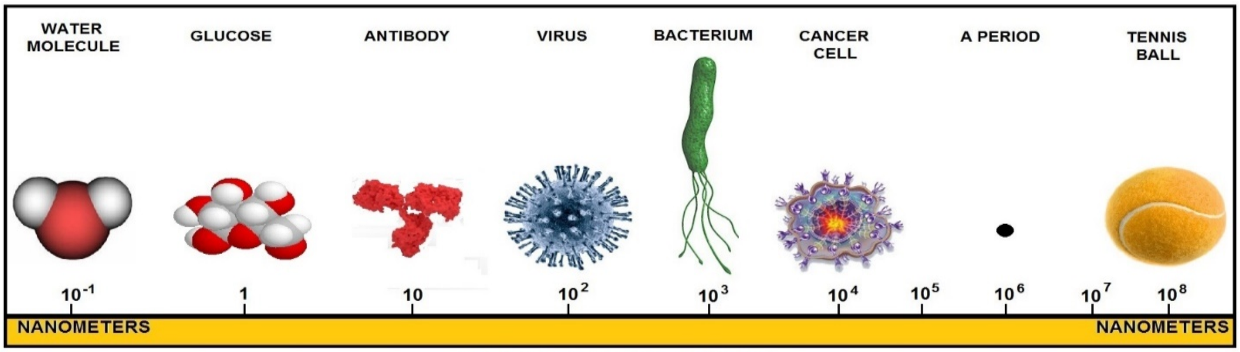
Scope/Background: The Environmental Protection Agency (EPA) published the Revised Total Coliform Rule (RTCR) in the Federal Register (FR) on February 13, 2013 (78 FR 10269) and minor corrections on February 26, 2014 (79 FR 10665). The RTCR is the revision to the 1989 Total Coliform Rule (TCR) and is intended to improve public health protection. The RTCR applies to all PWSs.

Microbiology Introduction

Microorganisms of greatest significance to water professionals can be classified into four groups:

1. Bacteria - Prokaryotes
2. Protozoans
3. Metazoans
4. Viruses

Each of these groups plays a key role in the complex world of wastewater biology.



SIZE COMPARISON
HOW SMALL IS SMALL ?

Bacteria Introduction

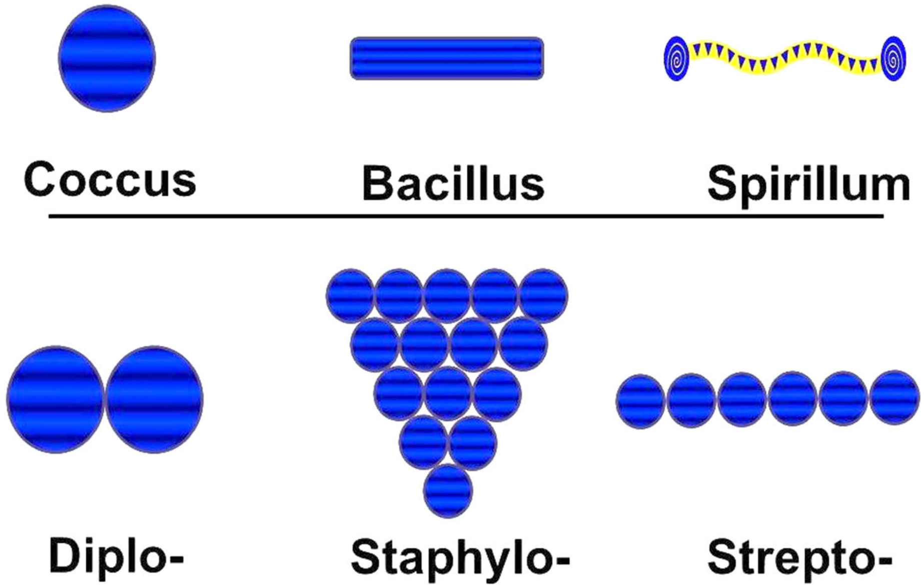
Bacteria are highly designed creatures formed in a variety of shapes. The simplest shape is a round sphere or ball.

Bacteria formed like this are called cocci (singular coccus). The next simplest shape is cylindrical.

Cylindrical bacteria are called rods (singular rod). Some bacteria are basically rods but instead of being straight they are twisted, bent or curved, sometimes in a spiral. These bacteria are called spirilla (singular spirillum). Spirochaetes are tightly coiled up bacteria.

Organisms Descriptors and Meanings Chart

Description	Meaning
Aerobic	With air
Anaerobic	Without air
Auto	Self (Inorganic carbon)
Facultative	With air or without air
Hetero	Other (Organic carbon)
Troph	Feed or nourish
Photo	Light
Chemo	Chemical
Organo	Organic
Litho	Rock

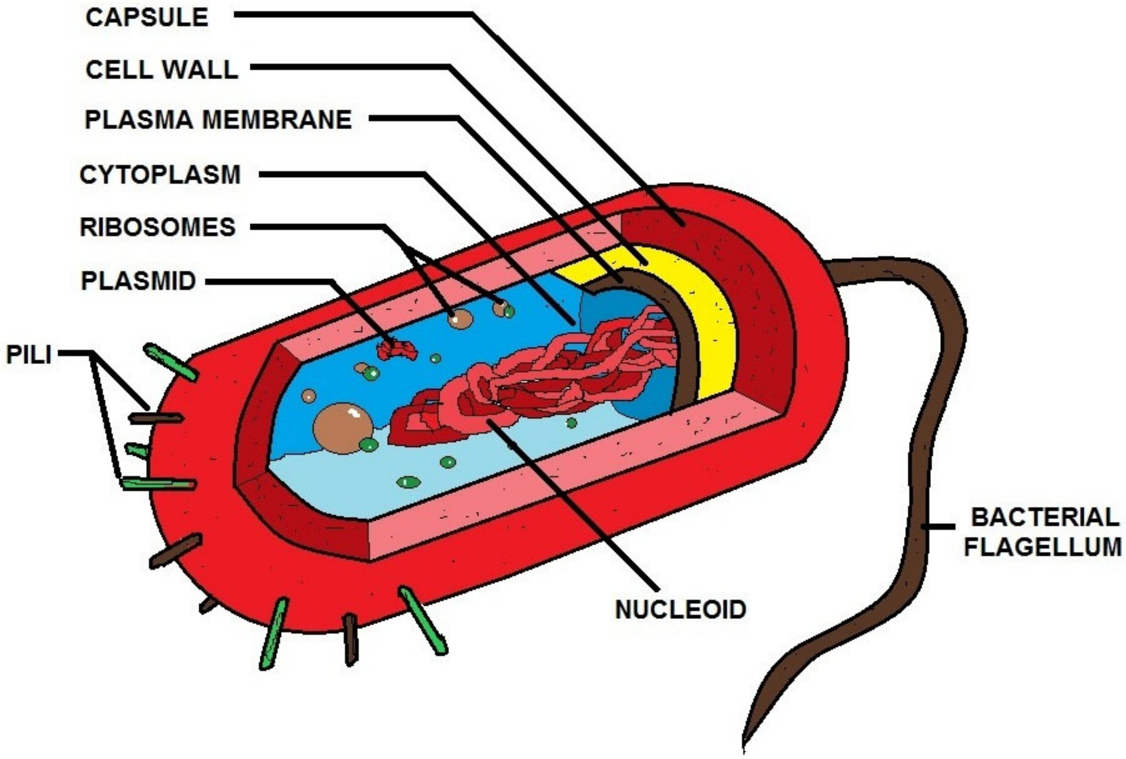


BASIC BACTERIA SHAPES DIAGRAM

Bacteria Biofilm or Colonies

Bacteria tend to live together in clumps, chains or planes. When they live in chains, one after the other, they are called filamentous bacteria - these often have long thin cells. When they tend to collect in a plane or a thin layer over the surface of an object, they are called a biofilm. Many bacteria exist as a biofilm and the study of biofilms is very important. Biofilm bacteria secrete sticky substances that form a sort of gel in which they live. The plaque on your teeth that causes tooth decay is a biofilm.

Bacteria Diagram



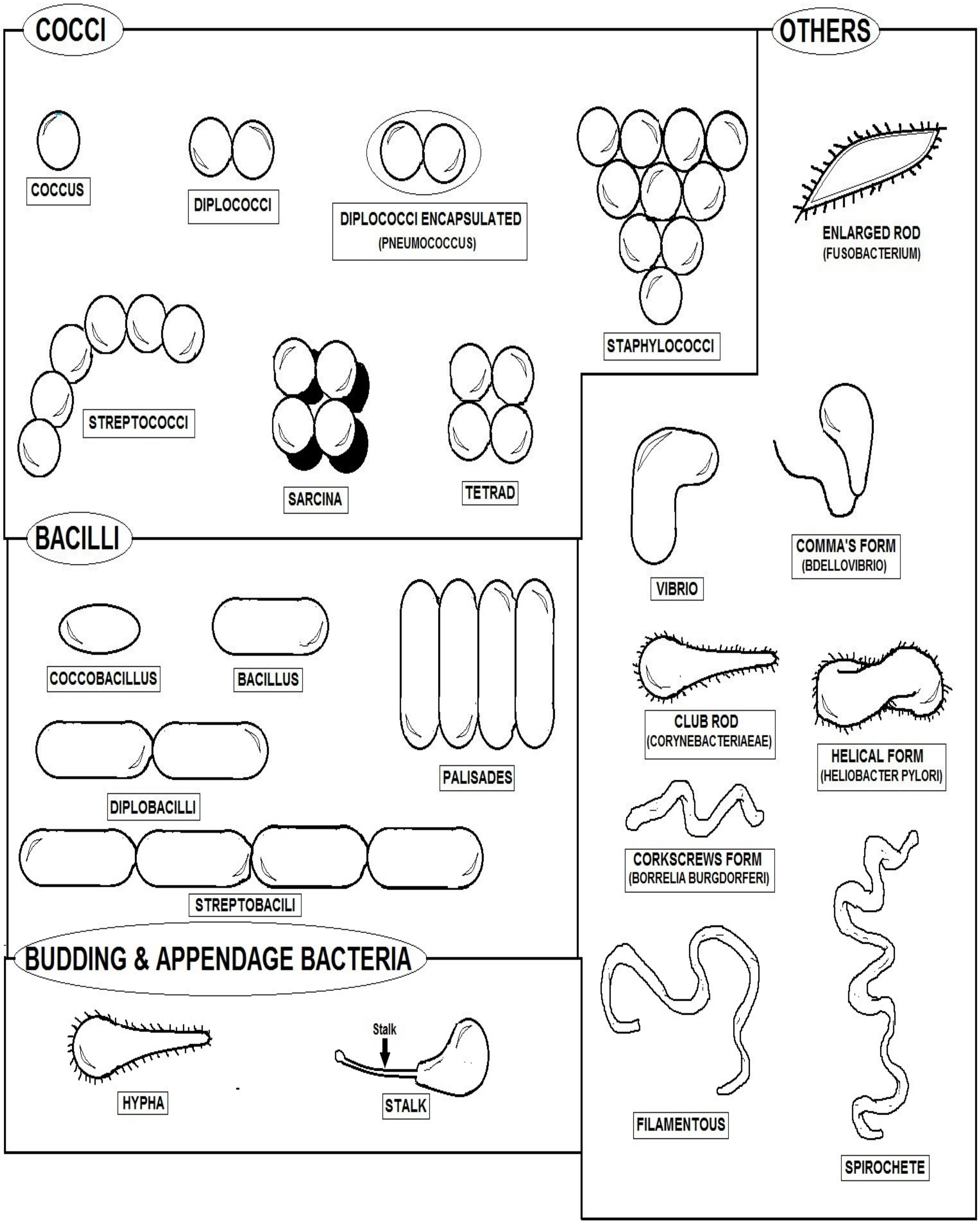
PROKARYOTIC CELL

Above is a typical bacterial cell has a rigid outer coating that gives them structure and maintains their shape. This is the cell wall. Bacteria also have an inner, flexible membrane called the *periplasmic membrane* or *cell membrane*. This dual-layered covering has been compared to a balloon inside a box.

The cell membrane is very important because it controls the intake of food and other nutrients and discharge of waste products. It keeps "in" what needs to be inside (e.g., enzymes, nutrients, and food) and keeps "out" what should be outside (e.g., excess water). The box is the cell wall. The cell wall provides the structural support and maintains the shape of the cell.

Much of the cellular contents are large protein molecules, known as enzymes, which are manufactured by the cell. Other cellular contents may include granules of polyphosphate, sulfur, or stored organic material.

Bacteria are somewhat predictable and, at a basic level, can be compared to miniature combustion engines. For an engine to function, it requires both a fuel and oxygen source. The oxygen sources is used to chemically burn fuel to release energy. The technically correct term for this process is oxidation. The byproducts of combustion when burning organic fuel with oxygen are carbon dioxide (CO_2) and water (H_2O).



BACTERIA SHAPES

Microbiological Contaminant Information

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:

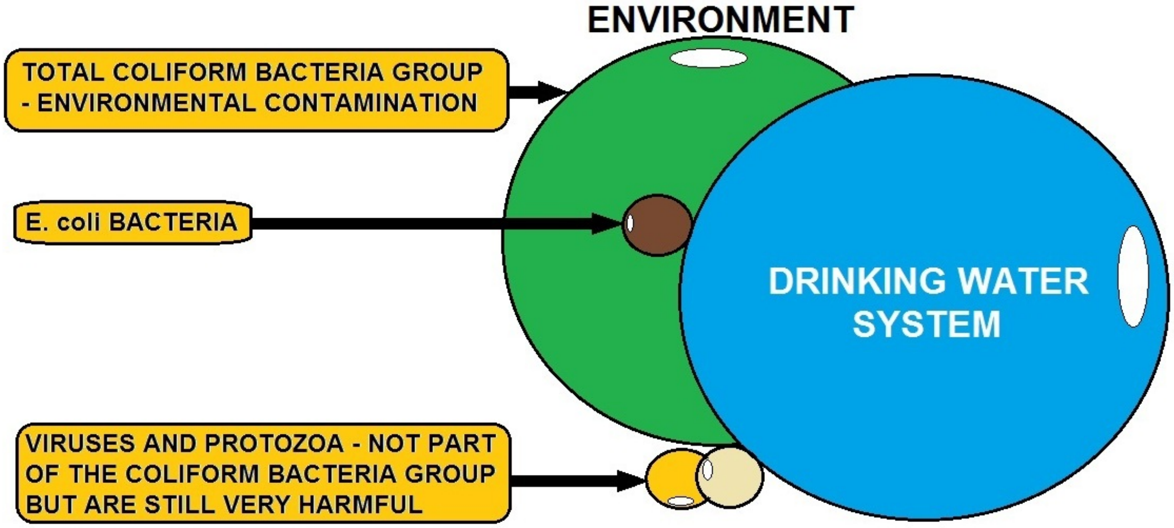
Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife;

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.



TOTAL COLIFORM BACTERIA GROUP

Background

Coliform bacteria and chlorine residual are the only routine sampling and monitoring requirements for small groundwater 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

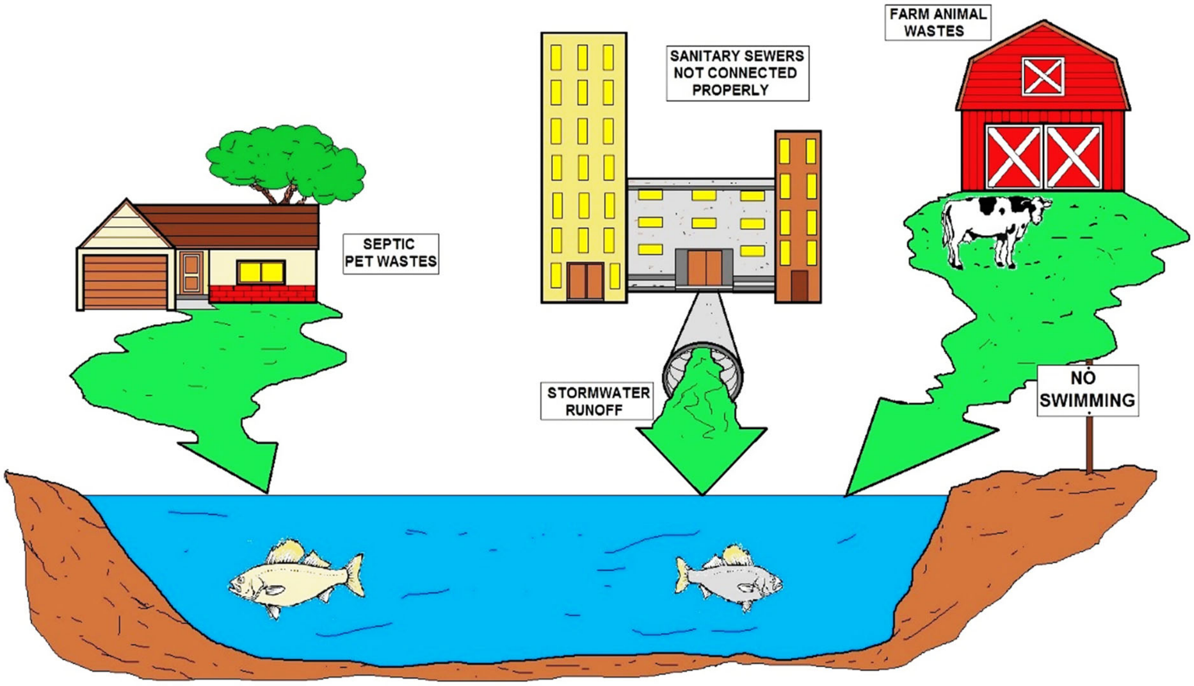
Total coliform samples must be collected by PWSs at sites which are representative of water quality throughout the distribution system according to a written sample siting plan subject to state review and revision.

For PWSs collecting more than one sample per month, collect total coliform samples at regular intervals throughout the month, except that groundwater 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 groundwater 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.

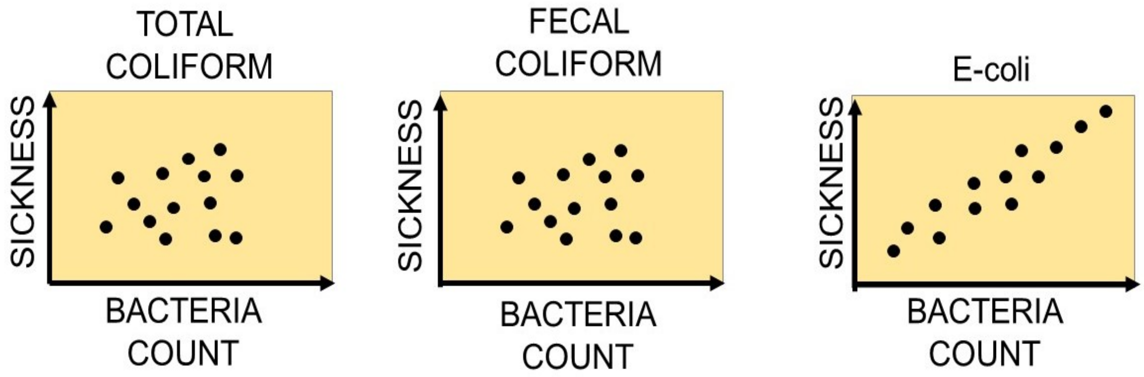
Key provisions of the RTCR include:

- 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.



BACTERIA IN DRINKING WATER DIAGRAM

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.

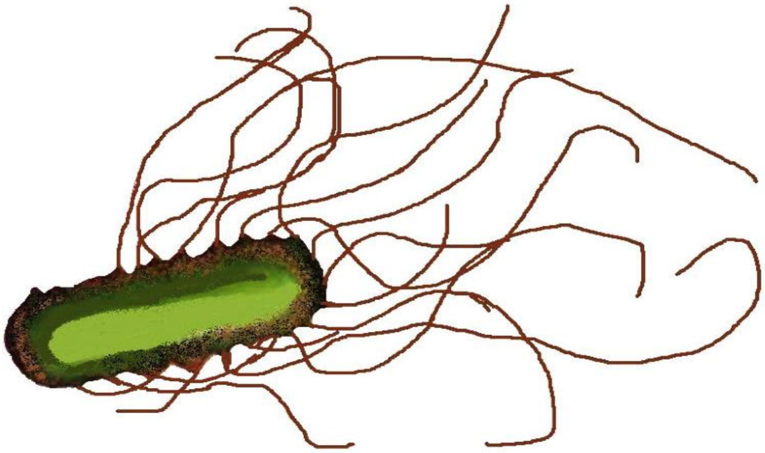
Related and Dangerous Waterborne Microbes

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*.

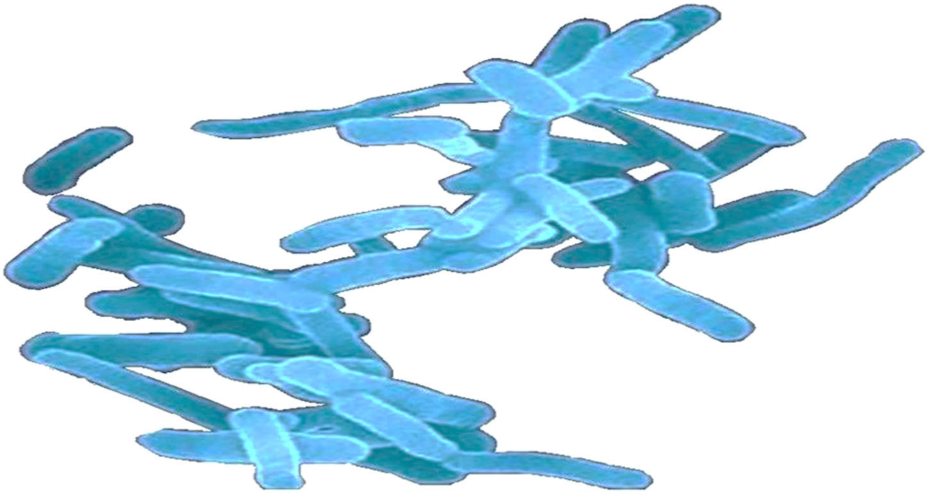
Giardia lamblia is a parasite that enters lakes and rivers through sewage and animal waste. It causes gastrointestinal illness (e.g. diarrhea, vomiting, and cramps).



PERITRICHOUS SHAPED BACTERIA EXAMPLE

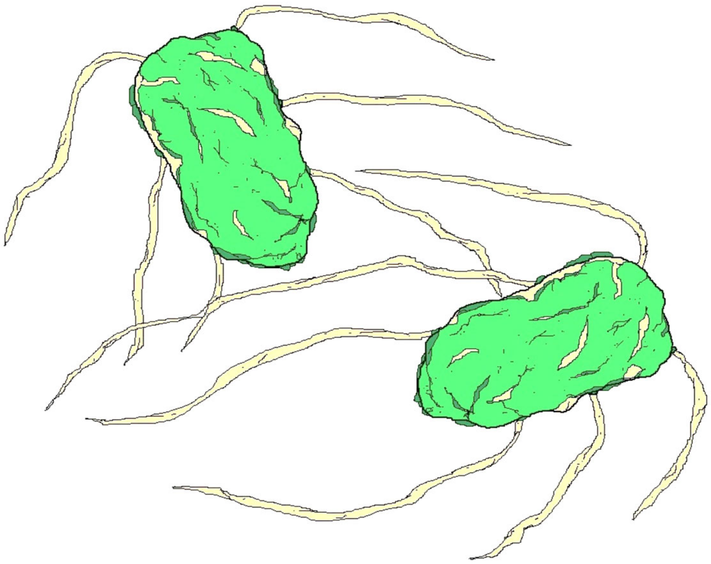
Microbiologists broadly classify bacteria according to their shape: spherical, rod-shaped, and spiral-shaped. Pleomorphic bacteria can assume a variety of shapes. Bacteria may be further classified according to whether they require oxygen (aerobic or anaerobic) and how they react to a test with Gram's 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.



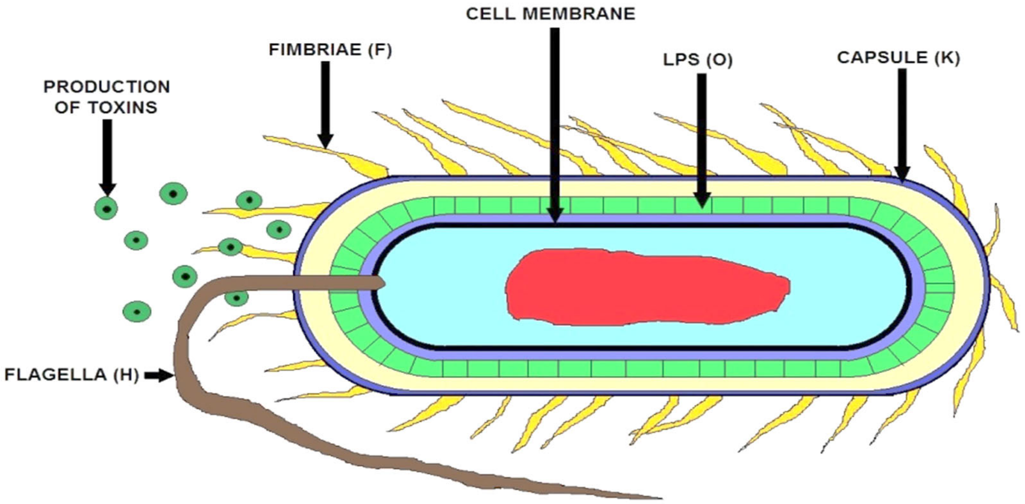
SHIGELLA DYSENTARIAE EXAMPLE

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

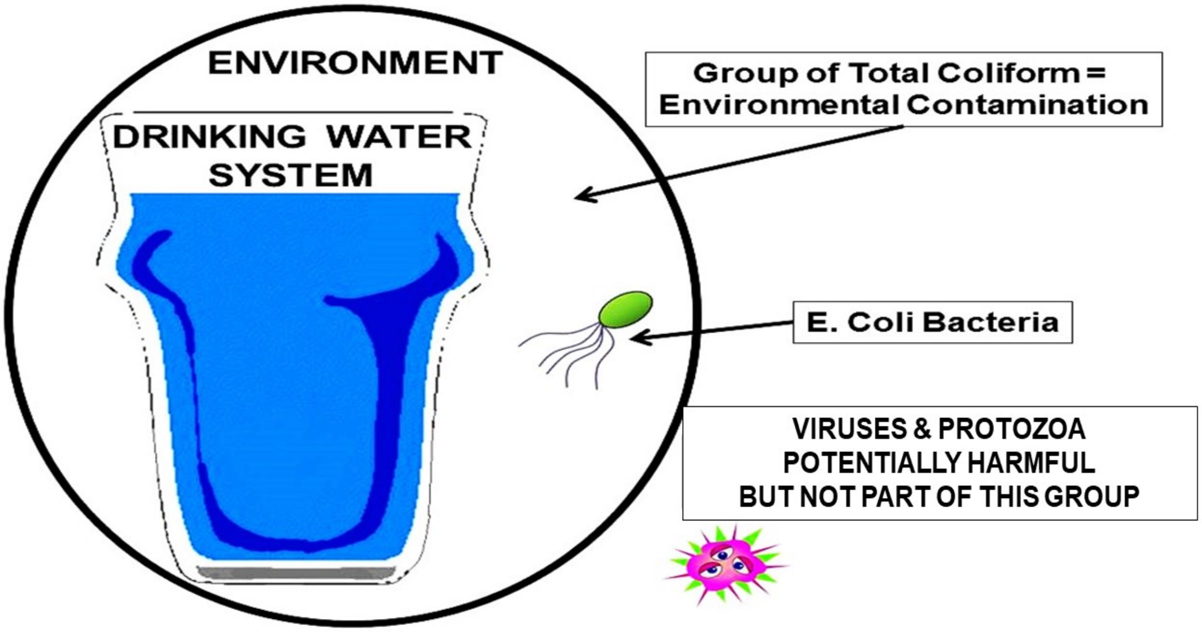
Salmonellae usually do not ferment lactose; most of them produce hydrogen sulfide that in media containing ferric ammonium citrate reacts to form a black spot in the center of the creamy colonies.



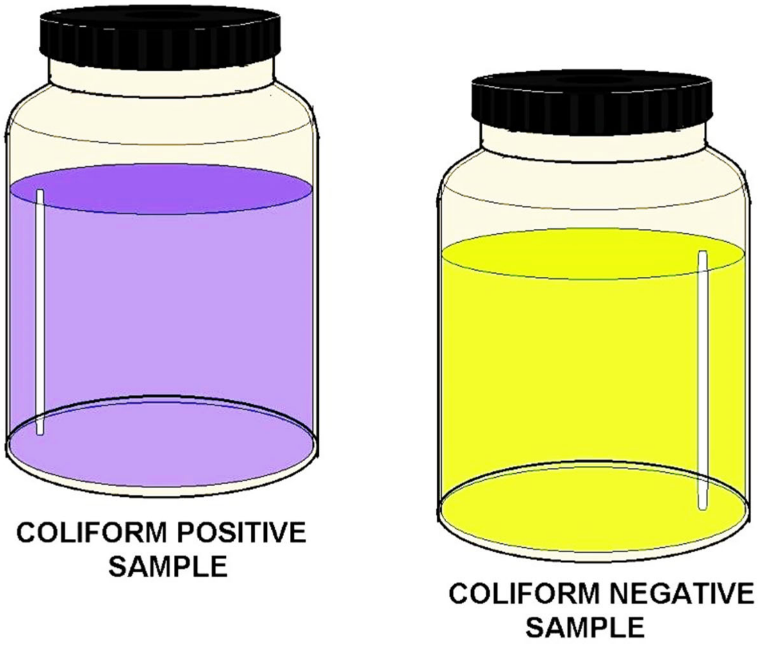
E. COLI

Fecal Coliform Bacteria

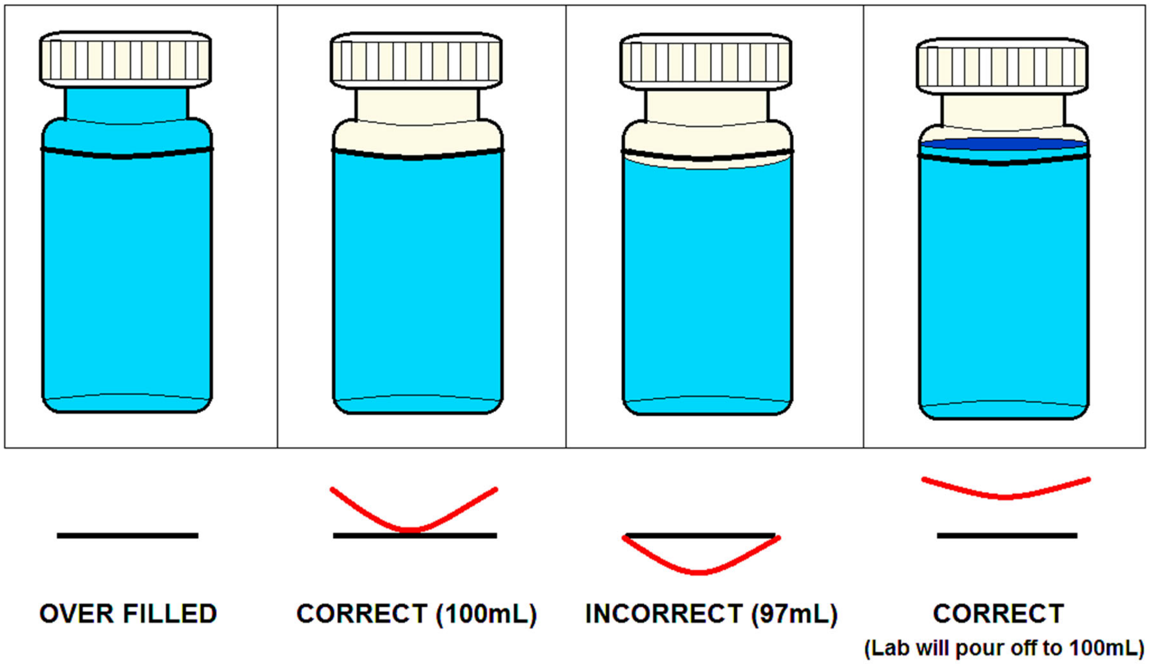
Fecal coliform bacteria are microscopic organisms that live in the intestines of warm-blooded animals. They also live in the waste material, or feces, excreted from the intestinal tract. When fecal coliform bacteria are present in high numbers in a water sample, it means that the water has received fecal 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



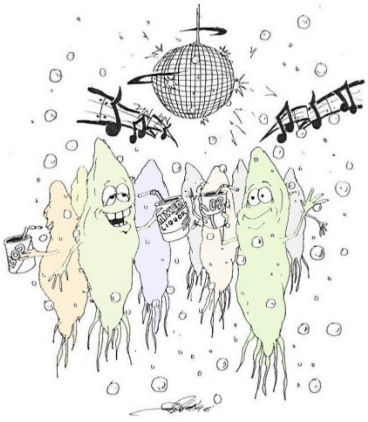
COLIFORM BACTERIA PRESENCE TEST EXAMPLE



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:

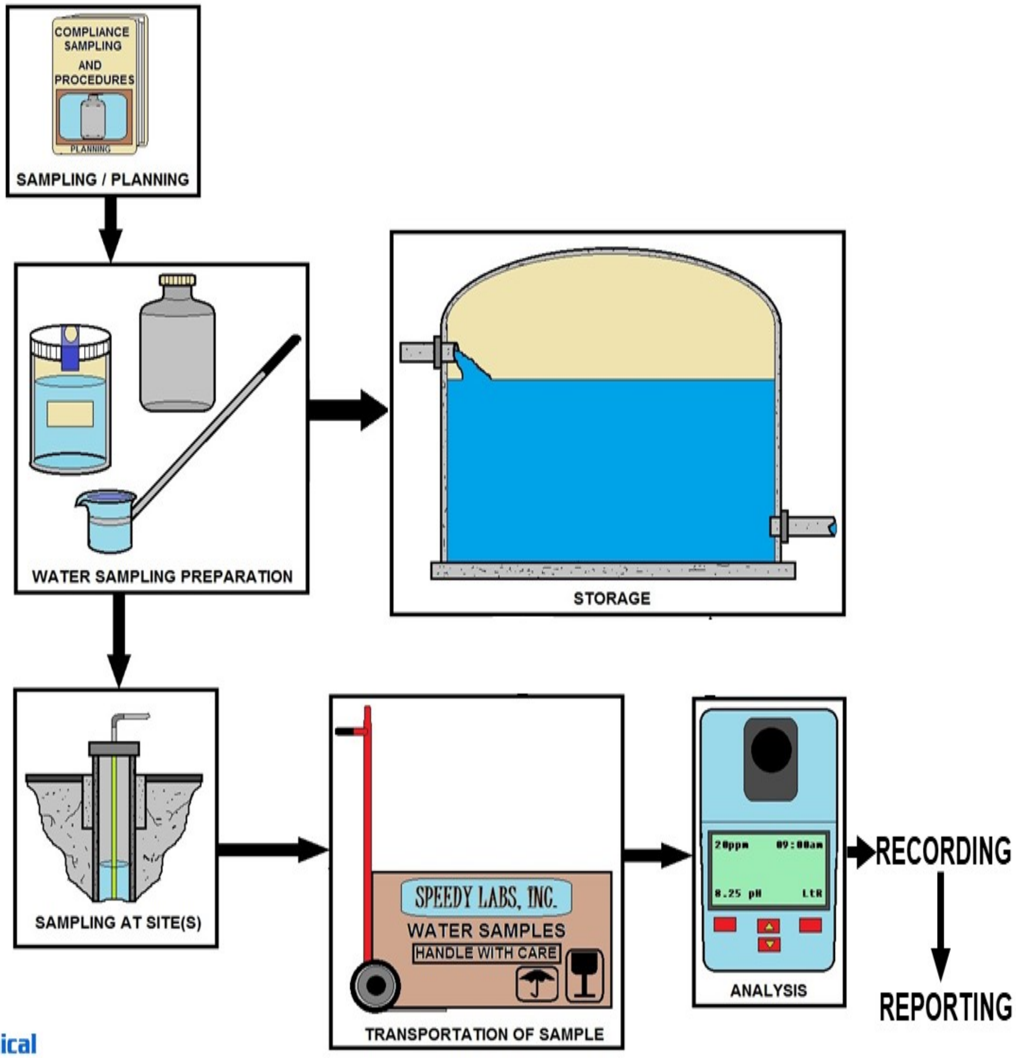
Methods

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 groundwater 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 Bac-T 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 groundwater as a source, or
2. It serves 25 or more daily population and utilizes surface water as a source or groundwater 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 groundwater 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.

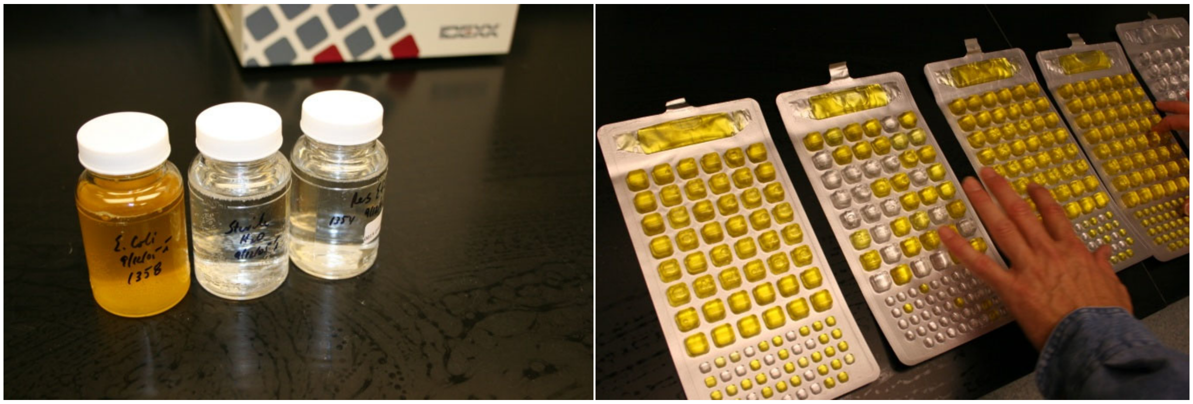
This list provides some basic operation and maintenance procedures that could help eliminate potential bacteriological problems, check with your state drinking water section or health department for further instructions.

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.



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.

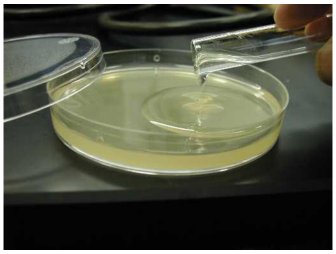
Heterotrophic Plate Count - Introduction

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

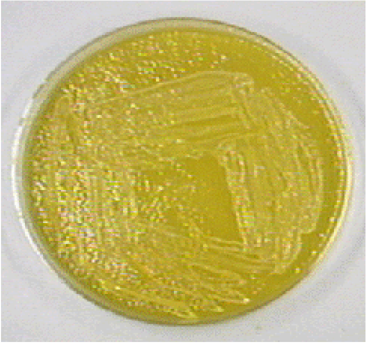
Procedure*

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.

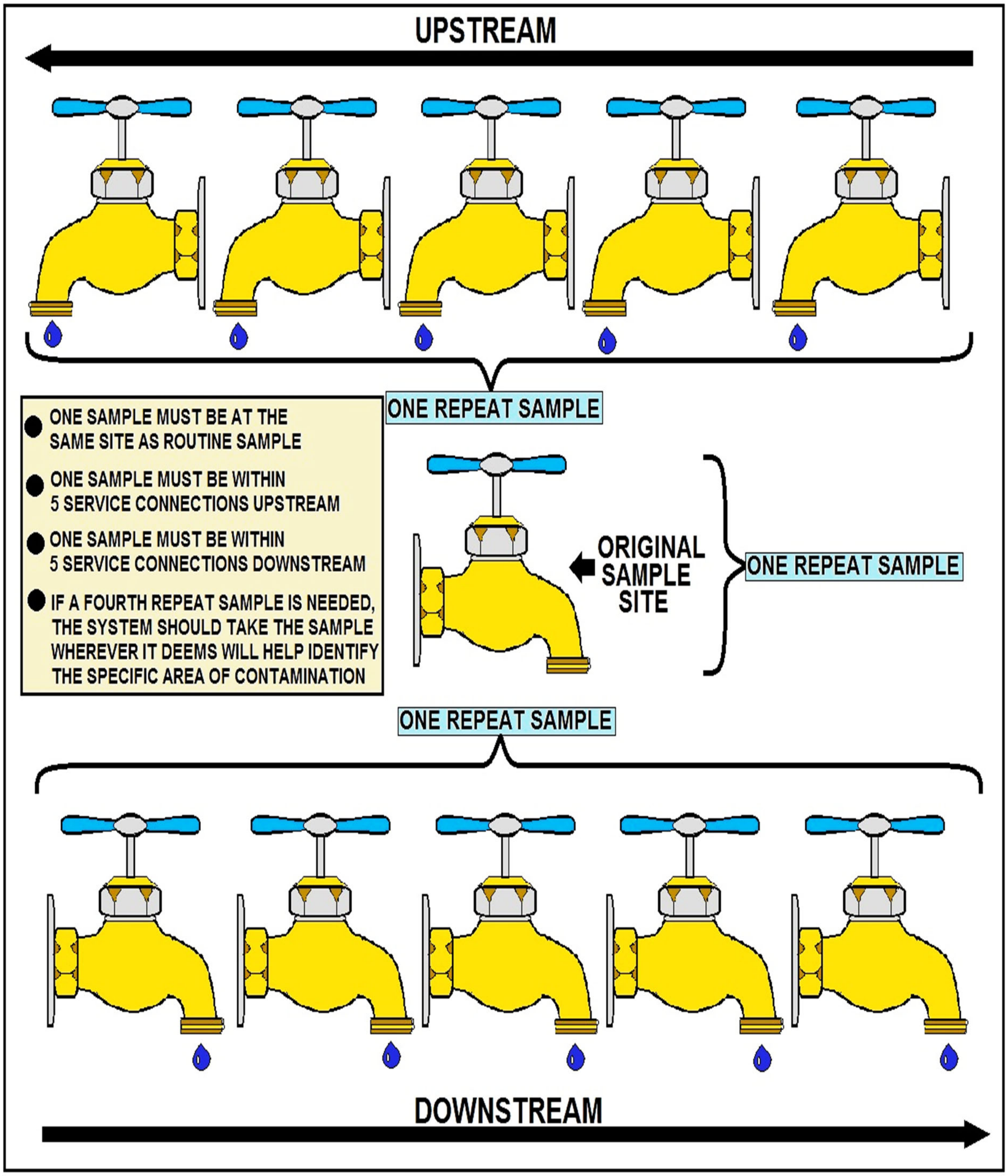
Assignment

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



- ONE SAMPLE MUST BE AT THE SAME SITE AS ROUTINE SAMPLE
- ONE SAMPLE MUST BE WITHIN 5 SERVICE CONNECTIONS UPSTREAM
- ONE SAMPLE MUST BE WITHIN 5 SERVICE CONNECTIONS DOWNSTREAM
- IF A FOURTH REPEAT SAMPLE IS NEEDED, THE SYSTEM SHOULD TAKE THE SAMPLE WHEREVER IT DEEMS WILL HELP IDENTIFY THE SPECIFIC AREA OF CONTAMINATION

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.

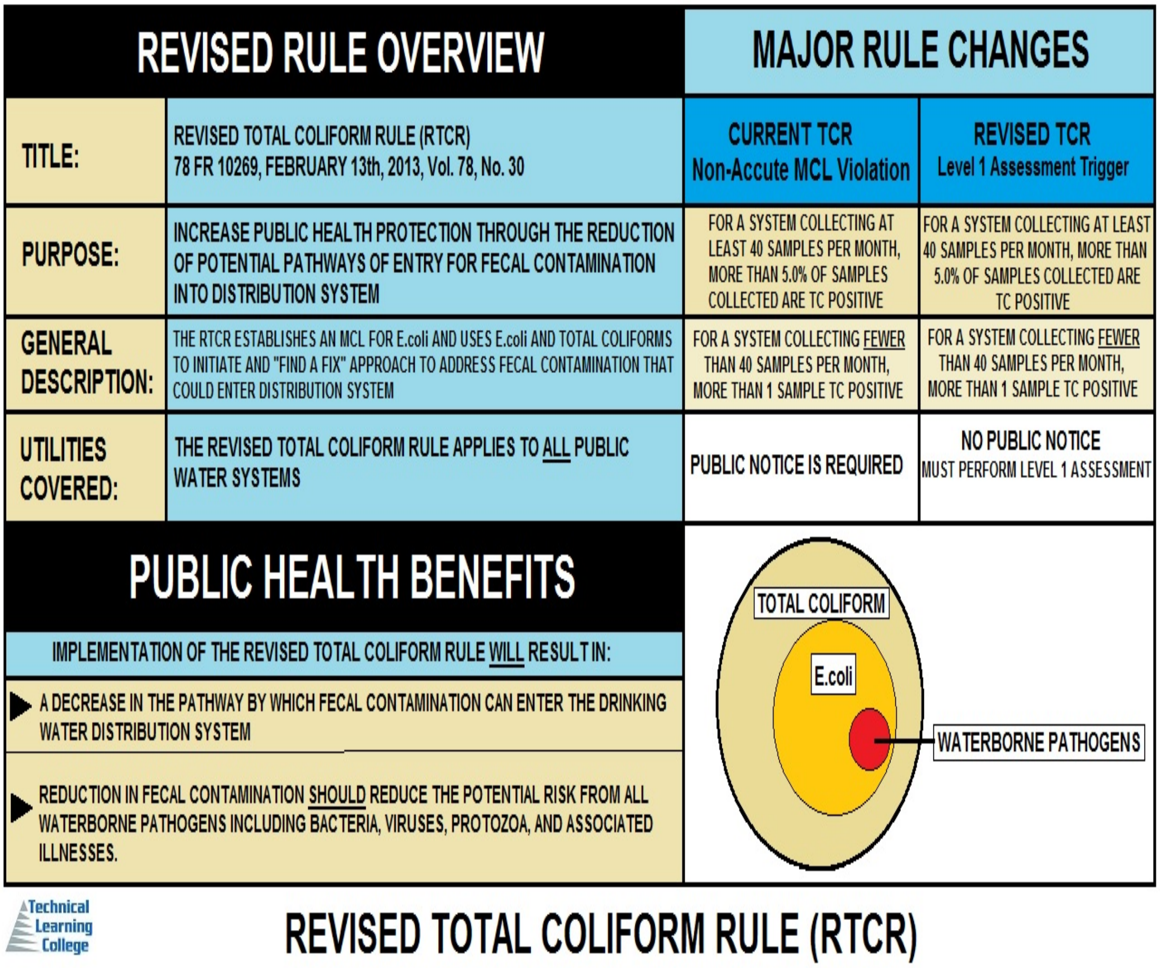
It is based on the Multiple Enzyme Technology which detects viable bacteria in water by testing for the presence of key enzymes known to be present in these little organisms.

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) Sub-Section



REVISED RULE OVERVIEW		MAJOR RULE CHANGES	
		CURRENT TCR Non-Accute MCL Violation	REVISED TCR Level 1 Assessment Trigger
TITLE:	REVISED TOTAL COLIFORM RULE (RTCR) 78 FR 10269, FEBRUARY 13th, 2013, Vol. 78, No. 30		
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.

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: groundwater 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.

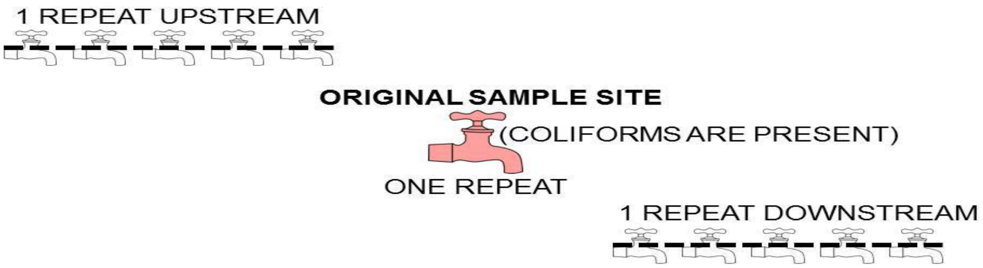
Revised Total Coliform Rule (RTCR) – Final Rule

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.

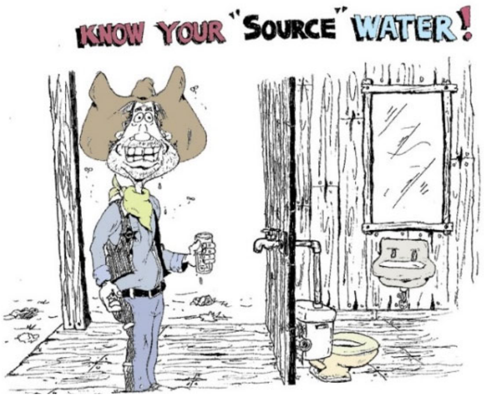
Disinfection Key

- ▶ 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

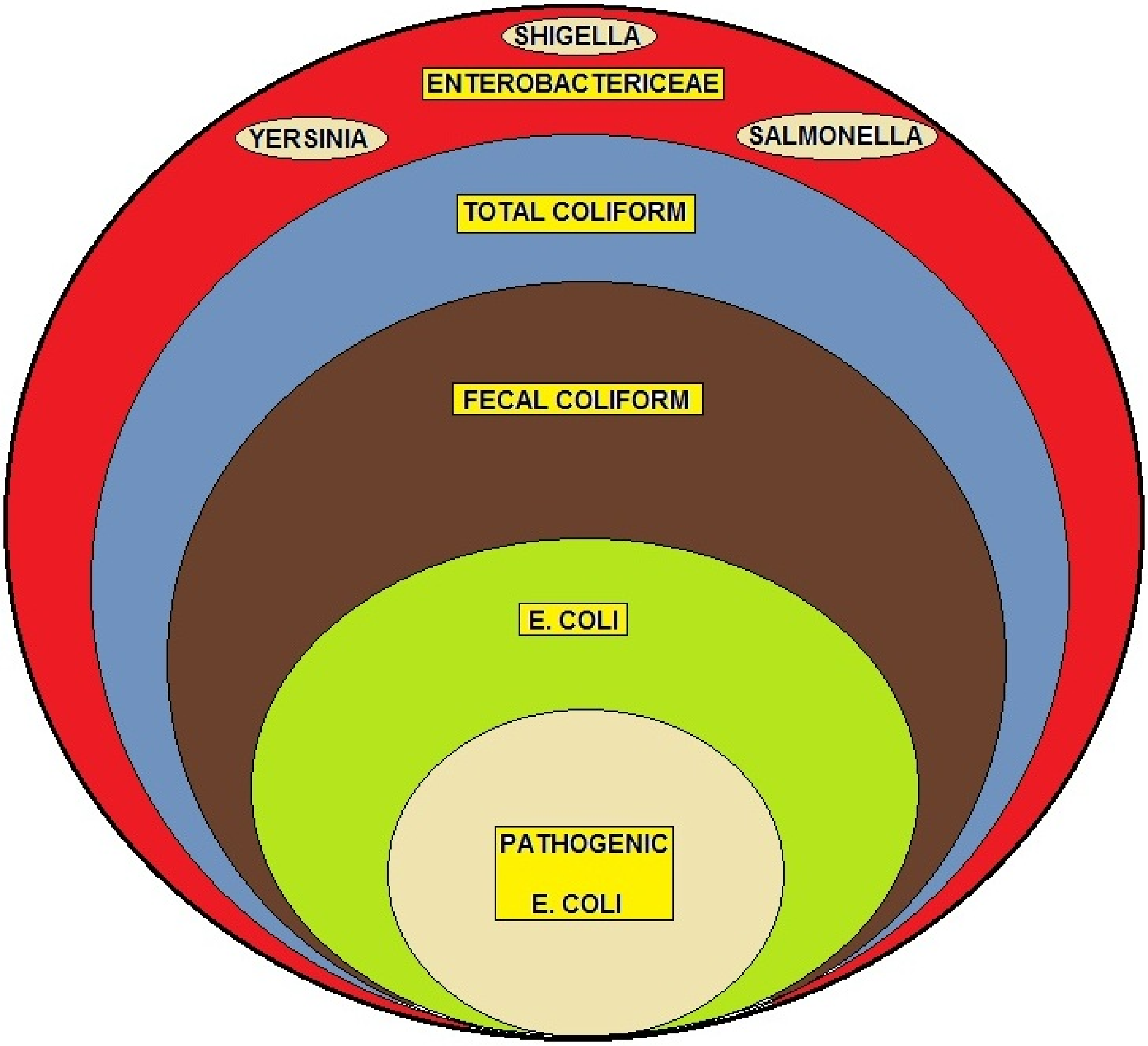
Troubleshooting Table for Bacteriological Monitoring

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.

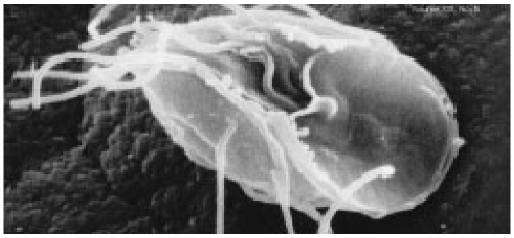
Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral (or feces-to-mouth) route. Pathogens may get into water and spread when infected humans or animals pass the bacteria, viruses, and protozoa in their stool. For another person 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

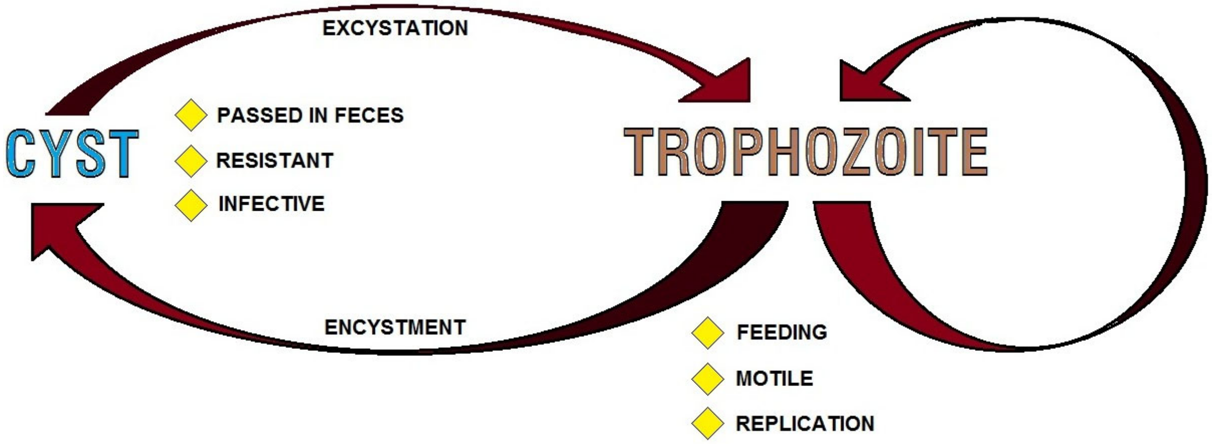
Campylobacter
Campylobacter, the basics. It is a bacterium. It causes diarrheal illness. Campylobacter is primarily associated with poultry, animals, and humans.

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.

almonella 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.

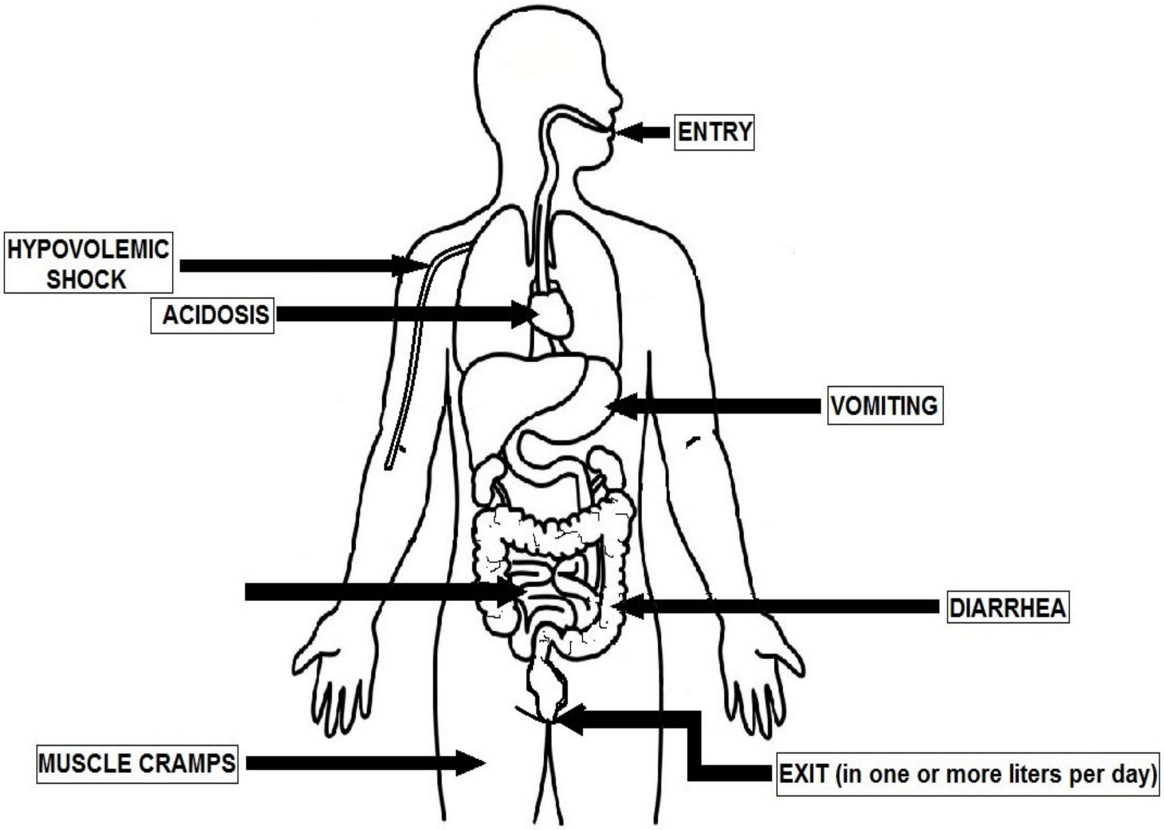
Schistosomatidae prevention: Prevention strategies for this pathogen include eliminating snails with a molluscicide or interrupting the life cycle of the parasite by treating birds with an antihelmetic drug.

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.

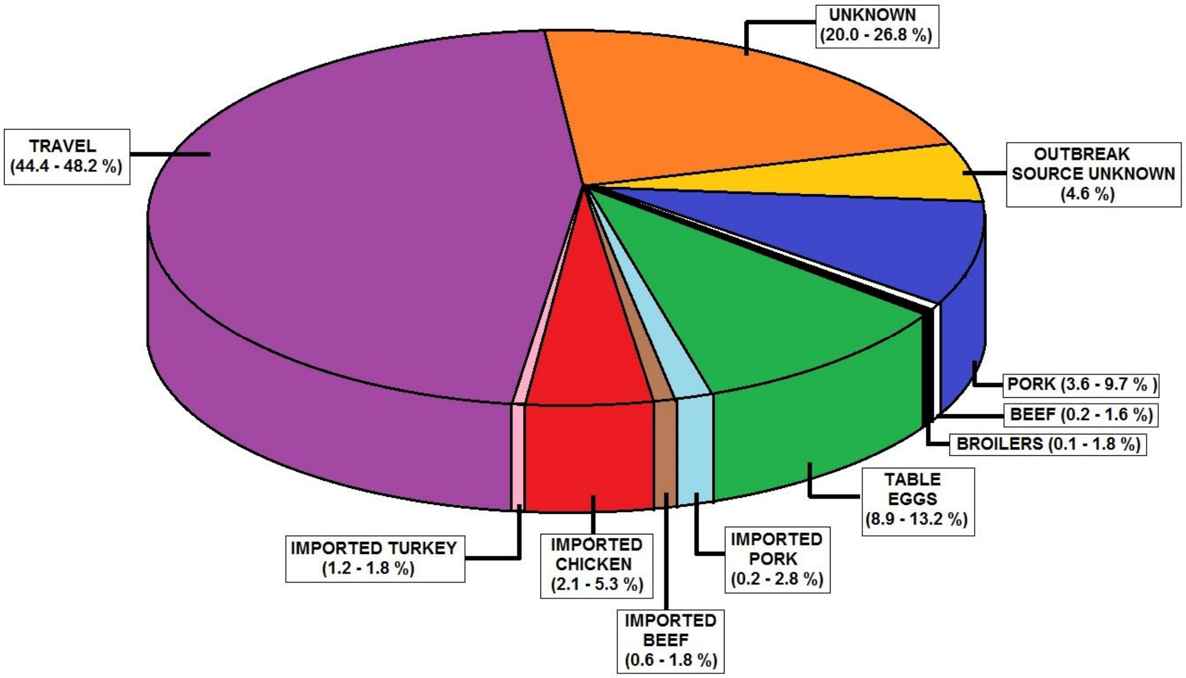
Vibrio Cholerae
Vibrio cholerae, the basics. It is a bacterium. It causes diarrheal illness, also known as cholera. It is typically associated with aquatic environments, shell stocks, and human. Vibrio cholerae has also been associated with ship ballast water, and there will be a discussion later on 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

Waterborne Bacterial Diseases



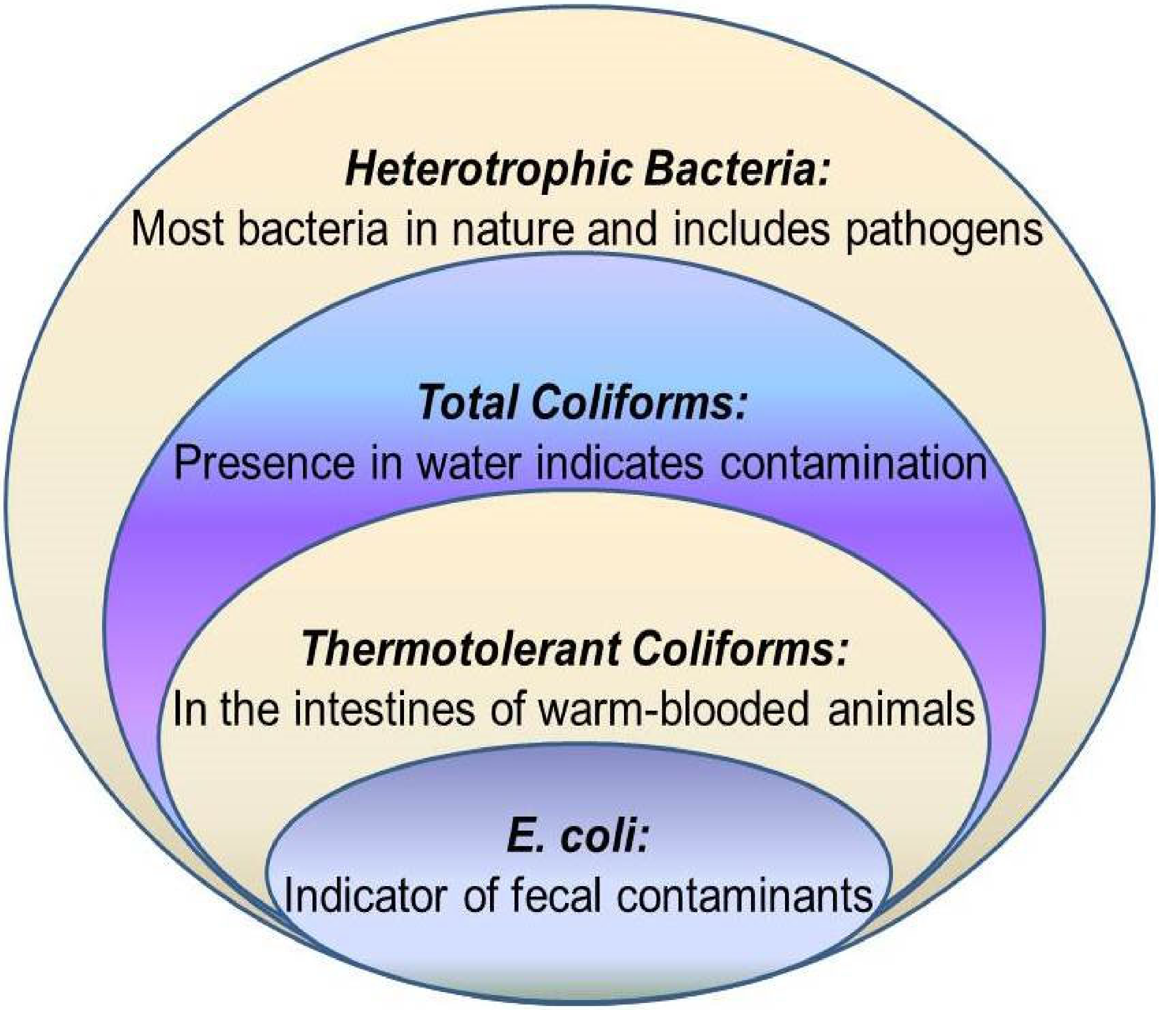
COURSES OF SAMONELLA PIE CHART

Campylobacteriosis is the most common diarrheal illness caused by bacteria. Other symptoms include abdominal pain, malaise, fever, nausea and vomiting; and 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 un-pasteurized milk, as well as un-chlorinated water. These organisms are also an important cause of "**travelers' diarrhea**." Medical treatment generally is not prescribed for campylobacteriosis because recovery is usually rapid.

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

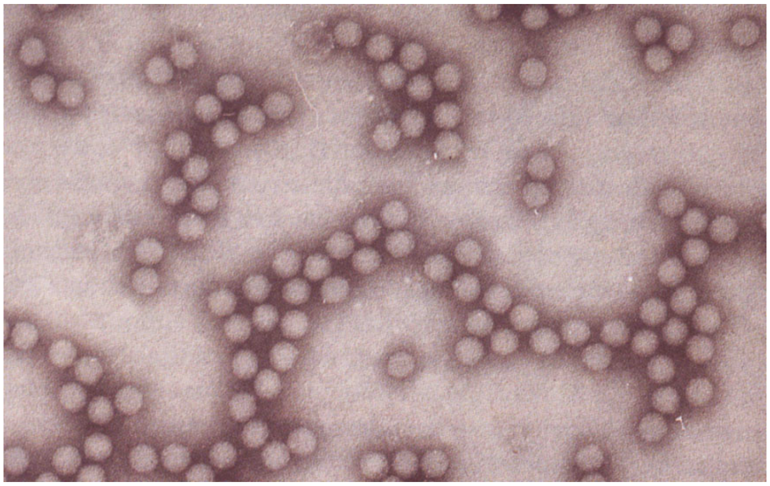
Gastroenteritis is an intestinal infection marked by watery diarrhea, abdominal cramps, nausea or vomiting, and sometimes fever. The most common way to develop viral gastroenteritis — often called stomach flu —is through contact with an infected person or by ingesting contaminated food or water. Because the symptoms are similar, it's easy to confuse viral diarrhea with diarrhea caused by bacteria, such as Clostridium difficile, salmonella and E. coli, or parasites, such as giardia.



BACTERIA SUB-SET #2

Waterborne Viral Diseases

- Drinking water must be free from viruses.
- Sometime viruses from intestinal tract of infected person get access to water along with feces.
- Some intestinal pathogenic viruses which are transmitted through contaminated water are- Rotavirus, Poliovirus, Hepatitis A and E, etc.



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.

Norovirus

Norovirus, sometimes referred to as the winter vomiting bug, is the most common cause of gastroenteritis. Infection is characterized by non-bloody diarrhea, vomiting, and stomach pain. Fever or headaches may also occur. Symptoms usually develop 12 to 48 hours after being exposed, and recovery typically occurs within 1 to 3 days. Complications are uncommon, but may include dehydration, especially in the young, the old, and those with other health problems.

The virus is usually spread by the fecal–oral route. This may be through contaminated food or water or person-to-person contact. It may also spread via contaminated surfaces or through air from the vomit of an infected person. Risk factors include unsanitary food preparation and sharing close quarters.

Diagnosis is generally based on symptoms. Confirmatory testing is not usually available but may be performed during outbreaks by public health agencies.

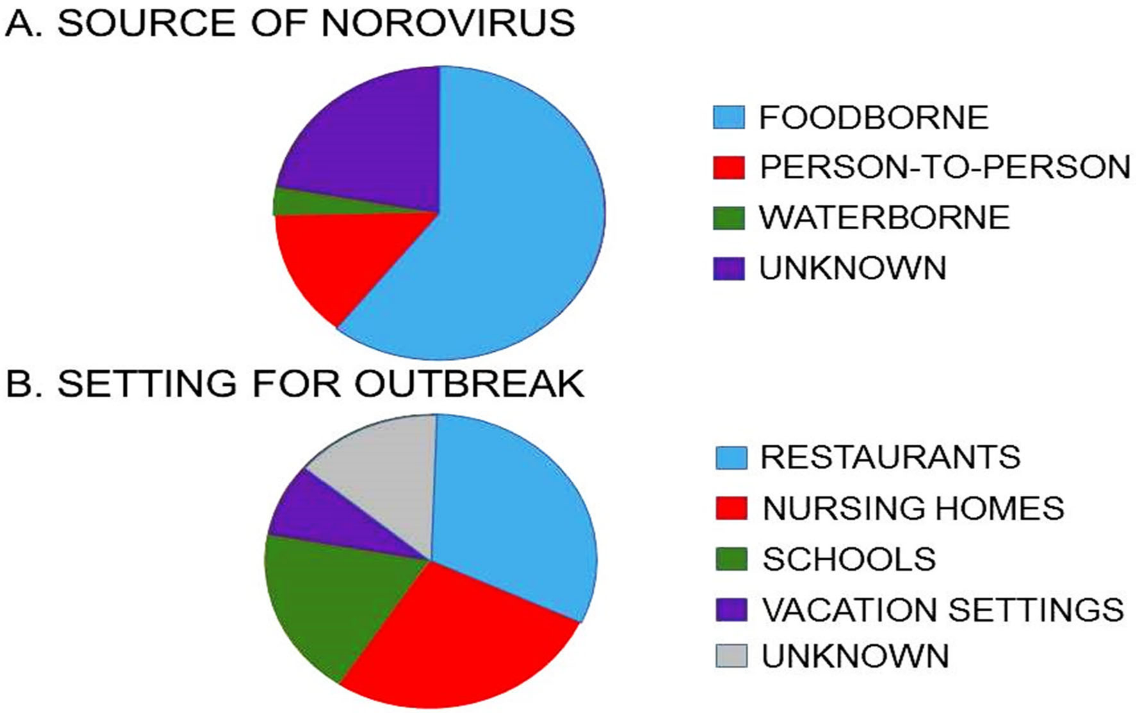
Norovirus results in about 685 million cases of disease and 200,000 deaths globally a year. It is common both in the developed and developing world. Those under the age of five are most often affected, and in this group it results in about 50,000 deaths in the developing world. Norovirus infections occur more commonly during winter months. It often occurs in outbreaks, especially among those living in close quarters. In the United States, it is the cause of about half of all foodborne disease outbreaks. The virus is named after the city of Norwalk, Ohio, where an outbreak occurred in 1968.

Coronavirus

It looks like the COVID-19 coronavirus may be able to live in water for a few days, potentially even a few weeks. Consider what is known about the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in water. Indeed studies have suggested that the SARS-CoV2 could actually hang out in the wet stuff for a little while.

SARS Virus

For example, a study published in the journal Water Research in 2009 found that two viruses that have similarities to the original SARS virus, the transmissible gastroenteritis (TGEV) and mouse hepatitis (MHV) viruses, could survive up to days and even weeks in water. The University of North Carolina team (Lisa Casanova, William A. Rutal, David J. Weber, and Mark D. Sobsey) that conducted the study concluded that “coronaviruses can remain infectious for long periods in water and pasteurized settled sewage, suggesting contaminated water is a potential vehicle for human exposure if aerosols are generated.”



Waterborne Protozoan Diseases

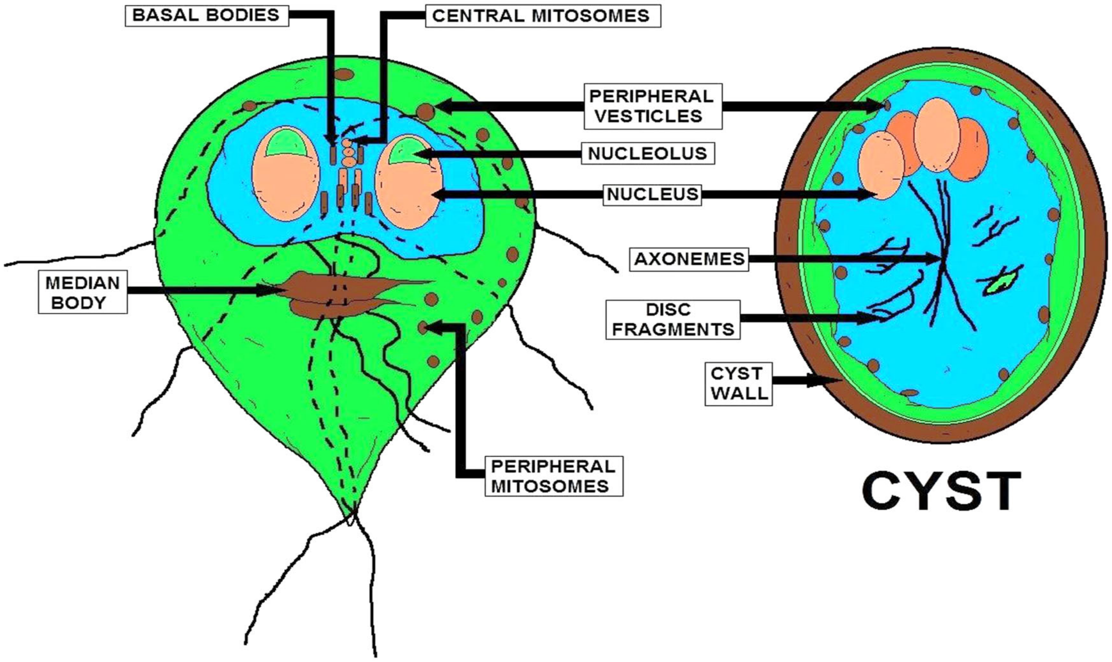
Protozoan pathogens are larger than bacteria and viruses, but still microscopic. They invade and inhabit the gastrointestinal tract. Some parasites enter the environment in a dormant form, with a protective cell wall called a "**cyst**." The cyst can survive in the environment for long periods of time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

Giardiasis is a commonly reported protozoan-caused disease. It has also been referred to as "backpacker's disease" and "beaver fever" because of the many cases reported among hikers and others who consume untreated surface water.

Symptoms include chronic diarrhea, abdominal cramps, bloating, frequent loose and pale greasy stools, fatigue and weight loss. The incubation period is 5-25 days or longer, with an average of 7-10 days.

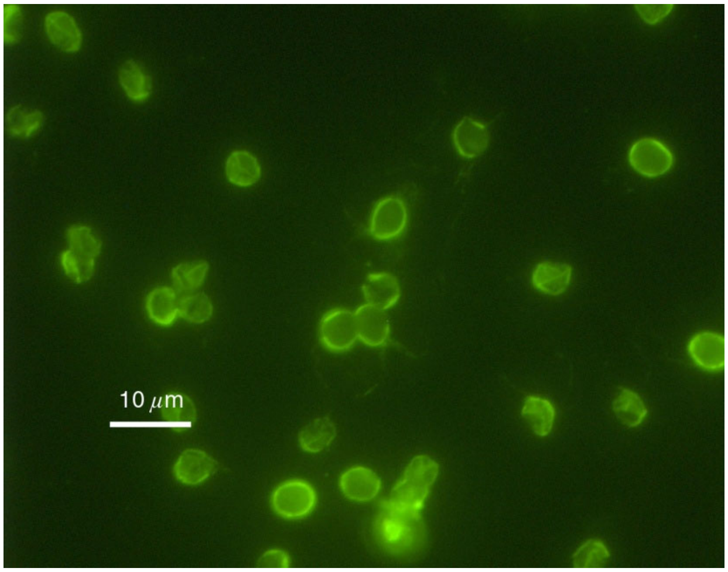
Many infections are asymptomatic (no symptoms). Giardiasis occurs worldwide. Waterborne outbreaks in the United States occur most often in communities receiving their drinking water from streams or rivers without adequate disinfection or a filtration system.

- Drinking water should be free from disease causing parasites.
- Many species of protozoa and helminthes that causes water borne disease contaminates water through feces of infected patients.



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.

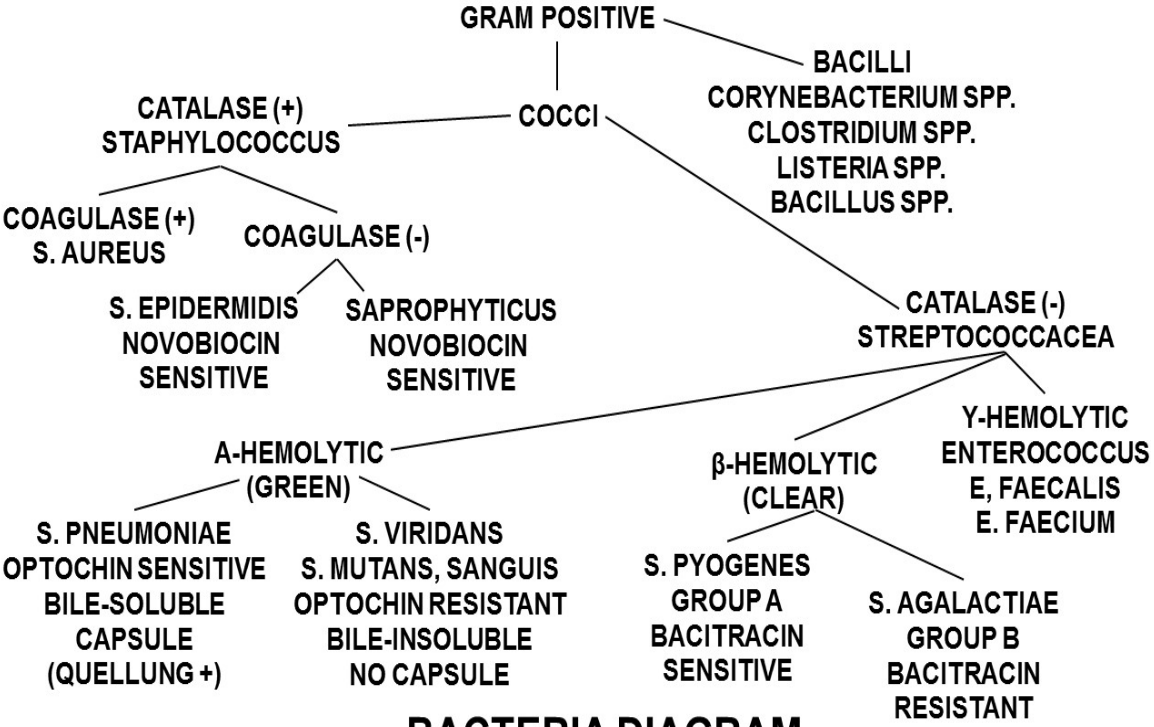
For those who operate water systems with inadequate source protection or treatment facilities, the potential risk of a waterborne disease outbreak is real. For those operating systems that currently provide adequate source protection and treatment, operating and maintaining the system at a high level on a continuing basis is critical to prevent disease.

Common Waterborne Diseases Chart

Name	Causative organism	Source of organism	Disease
Viral gastroenteritis	**Rotavirus** (mostly in young children)	Human feces	Diarrhea or vomiting
Norwalk Agent	**Noroviruses** (genus *Norovirus*, family *Caliciviridae*) *1	Human feces; also, shellfish; lives in polluted waters	Diarrhea and vomiting
Salmonellosis	***Salmonella*** (bacterium)	Animal or human feces	Diarrhea or vomiting
Gastroenteritis Escherichia *coli*	-- ***E. coli O1* 57:H7** (bacterium): Other *E. coli* organisms:	Human feces	Symptoms vary with type caused
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 in polluted waters	Yellowed skin, enlarged liver, fever, vomiting, weight loss, abdominal pain-low mortality, lasts up to four months
Amebiasis	***Entamoeba histolytica*** (protozoan)	Human feces	Mild diarrhea, dysentery, 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

Notes:

*1 http://www.cdc.gov/ncidod/dvrd/revb/gastro/norovirus.htm
http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5009a1.htm



BACTERIA DIAGRAM

Sampling Sitting Procedures –Sub-Section

The sample siting 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-siting 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.

What is a Sample Siting Plan?
A written sample siting plan specifies the routine sampling schedule and the locations (i.e., routine and repeat) in the distribution system where TC samples are collected. The locations selected must be representative of the finished water supplied to consumers. The purpose of sampling is to identify any coliform contamination so it can be dealt with quickly. Sample siting plans are subject to primacy agency review and revision. A sample siting plan must include the:

- PWS's sample sites (i.e., the location) where routine and repeat samples are collected: if approved by the primacy agency, also include sample sites for dual purpose samples that are used to meet the requirements for the RTCR repeat sampling and the Groundwater Rule (GWR) triggered source water monitoring.
- PWS's schedule for collecting the routine samples: For example, "[PWS_ID] will collect one routine TC sample every first Tuesday of the calendar month." The sample siting plan is a living document and should be updated to reflect changes to the PWS such as: major changes in population; new or additional water sources; infrastructure changes, such as a change in the distribution system (i.e., extended/ abandoned lines or pressure zones); or changes in disinfection or other treatment.

Most everyone can learn and master many of the basic lab procedures. Don't be intimidated, learn to take samples and analysis; it is an excellent career.

Chain of Custody Procedures

Because a sample is physical evidence, chain of custody procedures are used to maintain and document sample possession from the time the sample is collected until it is introduced as evidence.

Chain of custody requirements will vary from agency to agency. However, these procedures are similar and the chain of custody procedure outlined in this course manual is only a guideline. Consult your project manager or state agency for specific requirements.

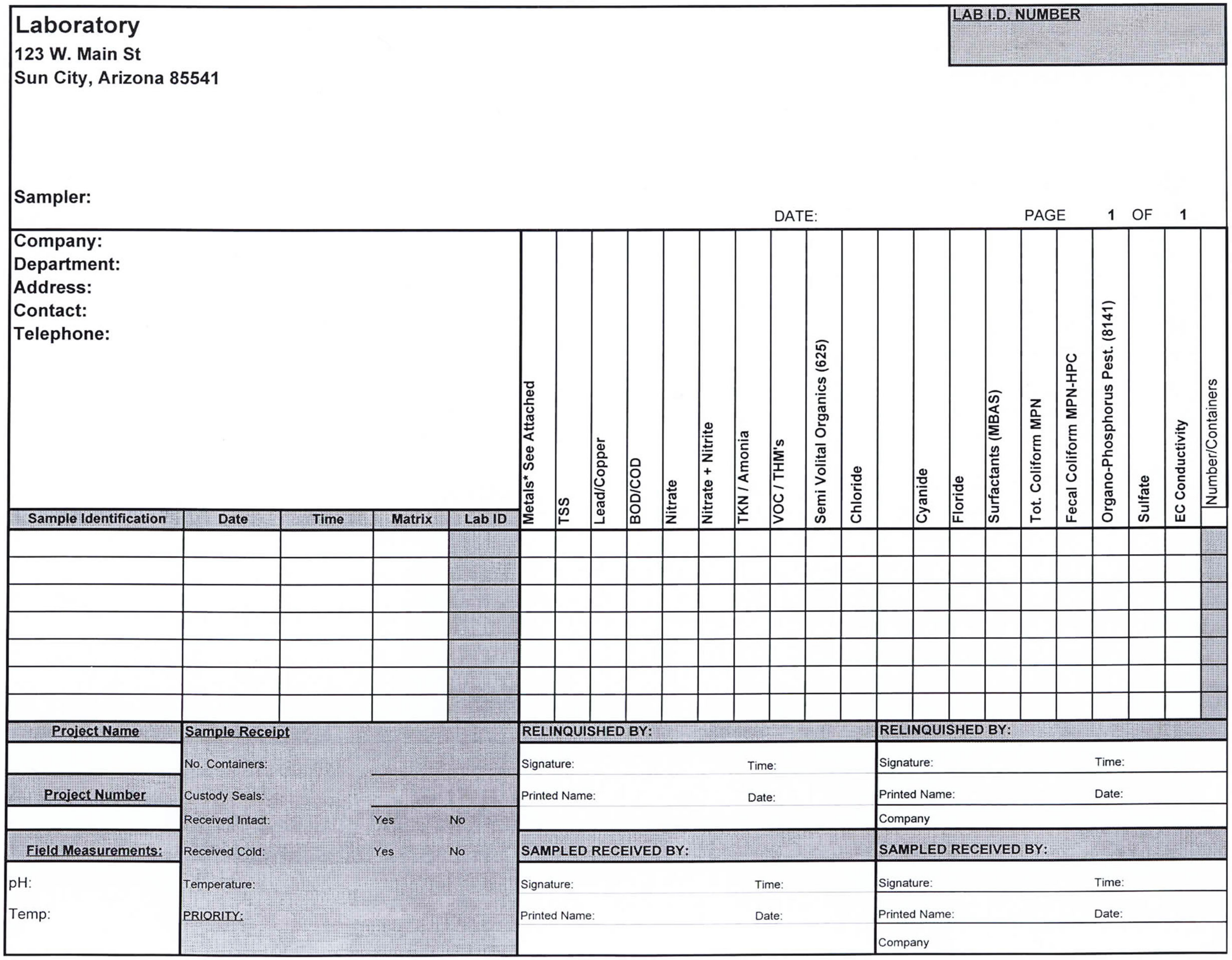
If you have physical possession of a sample, have it in view, or have physically secured it to prevent tampering then it is defined as being in ***"custody*."** A chain of custody record, therefore, begins when the sample containers are obtained from the laboratory. From this point on, a chain of custody record will accompany the sample containers.

Handle the samples as little as possible in the field. Each custody sample requires a chain of custody record and may require a seal. If you do not seal individual samples, then seal the containers in which the samples are shipped.

When the samples transfer possession, both parties involved in the transfer must sign, date and note the time on the chain of custody record. If a shipper refuses to sign the chain-of-custody you must seal the samples and chain of custody documents inside a box or cooler with bottle seals or evidence tape.

The recipient will then attach the shipping invoices showing the transfer dates and times to the custody sheets. If the samples are split and sent to more than one laboratory, prepare a separate chain of custody record for each sample. If the samples are delivered to after-hours night drop-off boxes, the custody record should note such a transfer and be locked with the sealed samples inside sealed boxes.

Using alcohol to disinfect a special sample tap before obtaining a sample.



Laboratory
123 W. Main St
Sun City, Arizona 85541

LAB I.D. NUMBER

Sampler:

DATE:

PAGE **1** OF **1**

Company:
Department:
Address:
Contact:
Telephone:

Sample Identification	Date	Time	Matrix	Lab ID	Metals* See Attached	TSS	Lead/Copper	BOD/COD	Nitrate	Nitrate + Nitrite	TKN / Amonia	VOC / THM's	Semi Volital Organics (625)	Chloride		Cyanide	Floride	Surfactants (MBAS)	Tot. Coliform MPN	Fecal Coliform MPN-HPC	Organo-Phosphorus Pest. (8141)	Sulfate	EC Conductivity	Number/Containers

Project Name

Project Number

Field Measurements:
pH:
Temp:

Sample Receipt
No. Containers:
Custody Seals:
Received Intact: Yes No
Received Cold: Yes No
Temperature:
PRIORITY:

RELINQUISHED BY:
Signature: Time:
Printed Name: Date:

SAMPLED RECEIVED BY:
Signature: Time:
Printed Name: Date:

RELINQUISHED BY:
Signature: Time:
Printed Name: Date:
Company

SAMPLED RECEIVED BY:
Signature: Time:
Printed Name: Date:
Company

Chain of Custody Example.

Various water sample bottles and chain-of-custody form.

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).

Bacteriological Monitoring Section Post Quiz

Hyperlink to Assignment…

http://www.abctlc.com/PDF/DistributionPrimer2ASS.pdf

Answers in the rear of book.

True or False

1. Total coliforms are a group of closely related viruses that are (with few exceptions) not harmful to humans. They are an indicator of other pathogens that can be present in water.

2. Fecal coliform bacteria are present in warm-blooded animals and they are shed from the body in the feces. Because these organisms are shed from the body in large numbers and are relatively easy to detect in the laboratory, they have been accepted as a guideline of water or food contamination.

3. 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.

4. To comply with the monthly MCL for total coliforms (TC), PWSs must not find coliforms in more than fifty percent of the samples they take each month to meet EPA's standards. If more than twenty percent of the samples contain coliforms, PWS operators must report this violation to the state and the public.

5. If a sample tests positive for TC, the system must collect a set of repeat samples located within 10 or fewer sampling sites adjacent to the location of the routine positive sample within 48 hours.

6. 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.

7. 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.

8. 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.

9. A coliform sample site plan is a list of sites by street address, lot number, or other permanent description, that identifies all the approved locations where your routine (monthly) coliform samples may be collected. The list of sites must be plotted on a map of your service area.

10. Small water systems shall divide their distribution system into specific sample areas.

Topic 2- Disinfection Section

Section Focus: You will learn the basics of water disinfection with an emphasis on Chlorine. At the end of this section, you the student will be able to describe chlorination. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: Traditionally, the use of chlorine gas was the most common method of water disinfection. Chlorine gas itself is relatively inexpensive but is a highly toxic chemical that must be transported and handled with extreme caution. It is stored under pressure in large tanks and is released into the water as a gas. Sodium hypochlorite is a diluted liquid form of chlorine that is also commonly used, primarily by groundwater wells but also as a safer alternative to chlorine gas.

Chlorine Introduction

Chlorine gas is the most widely used water disinfectant in the U.S., and it kills most bacteria, viruses, and other microorganisms that cause disease.

Chlorine is introduced to water in the form of gas, hypochlorites (tablets, solutions, or powder), and other compounds.

The different forms of chlorine used at water treatment plants are gaseous chlorine, sodium hypochlorite solution, calcium hypochlorite, and bromium chloride.

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 0.3-0.5 parts per million (ppm) of air have been reported. Prolonged exposures may result in olfactory fatigue. Prolonged, low-level exposures, such as those that occur in the workplace, can lead to olfactory fatigue and tolerance of chlorine's irritant effects.

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.

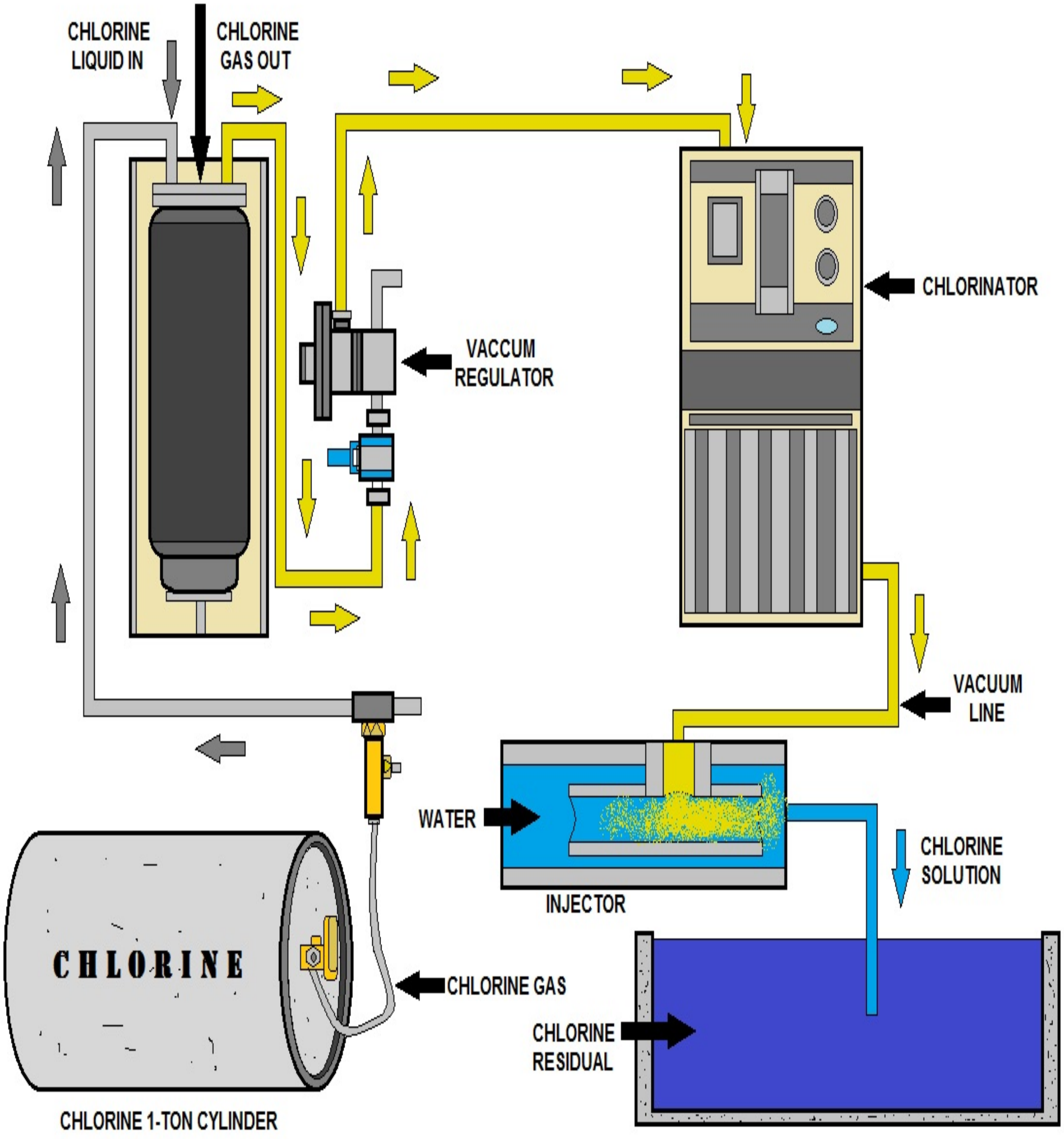
Safety Information- Brief and Critical Points
Chlorine is a greenish-yellow, noncombustible gas at room temperature and atmospheric pressure. The intermediate water solubility of chlorine accounts for its effect on the upper airway and the lower respiratory tract.

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.

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.

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. Even brief exposure to 1,000 ppm of Cl_2 can be fatal.

These are 1- ton chlorine gas containers. Notice the five-gallon bucket of motor oil (OSHA Violation) in the bottom photograph. Do you have an eye wash and emergency shower readily available? If not, it is a very common OSHA safety violation.



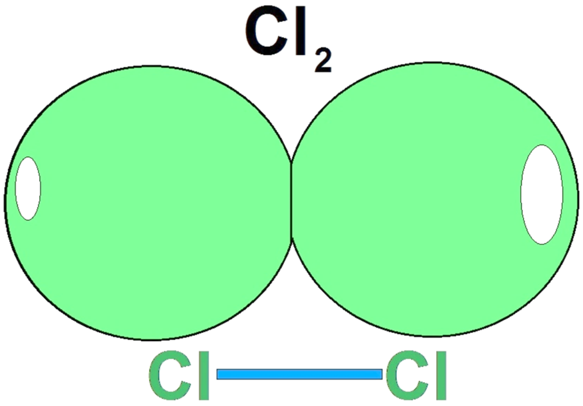
CHLORINE EVAPORATOR – CHLORINATION DIAGRAM

Chlorine Gas Introduction

Today, most of our drinking water supplies are free of the microorganisms — 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 the free chlorine residual concentration while they die. Their organic matter and other substances that are present convert to chlorinated derivatives, some of which are marginally effective killing agents.

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, so it can and is handled safety.



CHLORINE MOLECULAR STRUCTURE

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.

Atomic Number: 17
Standard State: Gas at 298K
Melting Point: 171.6K (-101.5 C)
Boiling Point: 239.11K (-34.04 C)
Density: N/A
Molar Volume: 17.39 cm^3
Electronegativity: 3.16 Pauling Units
Crystal Structure: The Diatomic Chlorine molecules arrange themselves in an orthorhombic structure.

Chlorine is a highly reactive gas. It is stable in many naturally occurring compounds, such as table salt. Chlorine is produced in very large amounts (23 billion pounds in 1992) by eighteen companies in the United States. US demand for chlorine is expected to increase slightly over the next several years and then decline. The expected decline in US demand is due to environmental concerns for chlorinated organic chemicals.

The largest users of chlorine are companies that make ethylene dichloride and other chlorinated solvents, polyvinyl chloride (PVC) resins, chlorofluorocarbons, and propylene oxide. Paper companies use chlorine to bleach paper. Water and wastewater treatment plants use chlorine to reduce water levels of microorganisms that can spread disease to humans.

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

Chlorine enters the body when breathed in with contaminated air or when consumed with contaminated food or water. It does not remain in the body as chlorine due to its reactivity – it forms destructive acids.

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

Exposure to high volumes of chlorine gas fumes can cause serious health problems, including death.

However, it is important to realize that chlorine gas, once entering the water, changes into hypochlorous acid and hypochlorite ions, and therefore its human toxic properties are not found in the drinking water we consume.

Chlorine gas is sold as a compressed liquid, which is amber in color. Chlorine, as a liquid, is heavier (more dense) than water. If the chlorine liquid is released from its container, it will quickly return back to its gas state. Chlorine gas is the least expensive form of chlorine to use. The typical amount of chlorine gas required for water treatment is 1-16 mg/L of water. Different amounts of chlorine gas are used depending on the quality of water that needs to be treated.

If the water quality is poor, a higher concentration of chlorine gas will be required to disinfect the water if the contact time cannot be increased.

Oxidizing Microbicide

Chlorine gas is likely the most widely used oxidizing microbiocide. Besides water and wastewater disinfection, 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). We will master this chemistry in a few more pages.

Alkaline Conditions

This hydrolyzation provides the active toxicant, HOCl, which is pH-dependent. In alkaline conditions, it readily dissociates to form the hypochlorite ion (OCl-). This dissociation phenomenon is important to remember.

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.

Non-Selective

It is also widely known that chlorine is non-selective, making it very sensitive to combining with many other compounds 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.

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 potentially 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.

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 tracheo-bronchitis.

The hallmark of pulmonary injury associated with chlorine toxicity is pulmonary edema, manifested as hypoxia. Non-cardiogenic pulmonary edema is thought to occur when there is a loss of pulmonary capillary integrity. Inhalation of chlorine gas is often fatal.

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 usually 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 (covering of the eye) and upper respiratory mucus membranes.

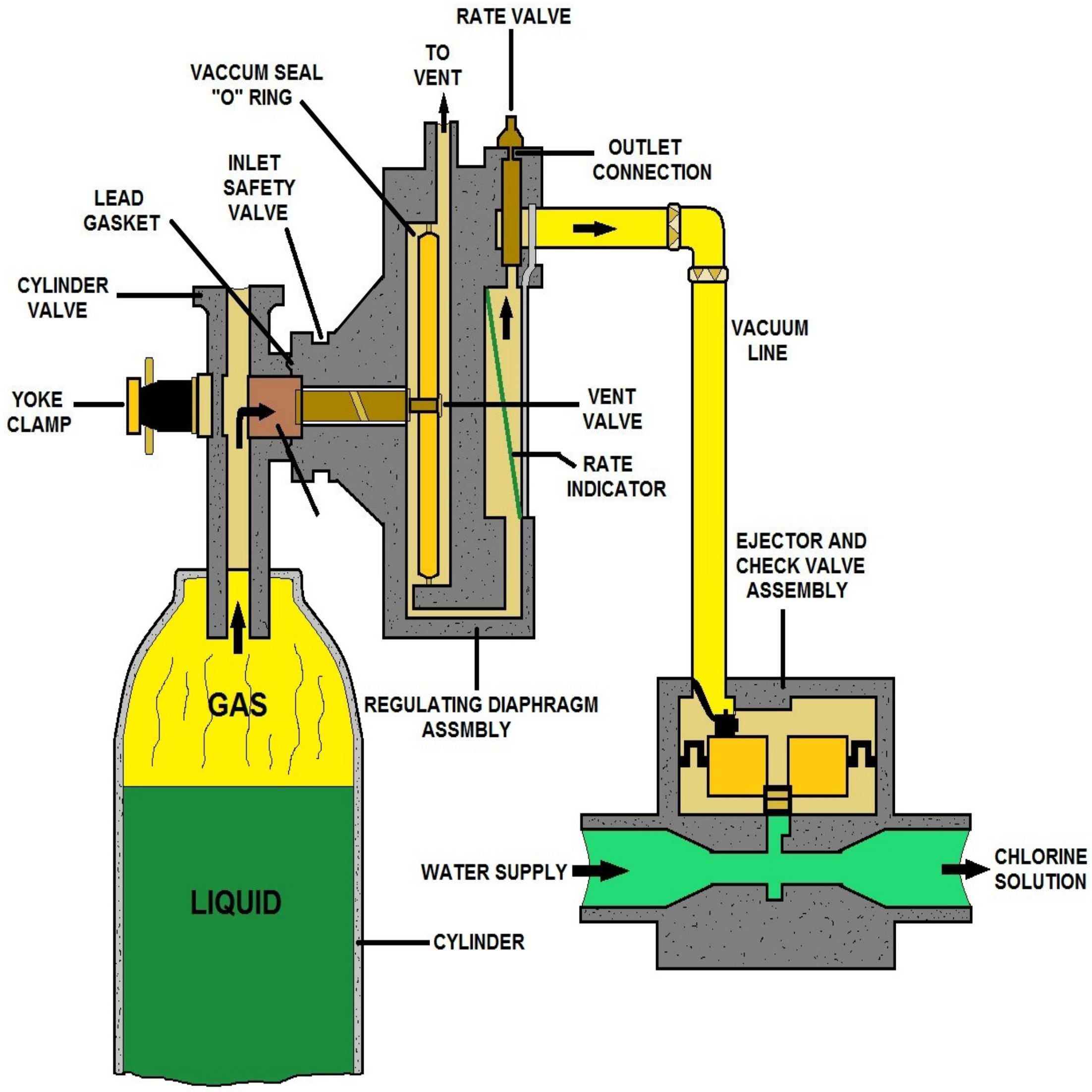
Hypochlorous acid is also highly water soluble with an injury pattern similar to hydrochloric acid.

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

Early Response to Chlorine Gas

Chlorine gas which is highly toxic 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.



150 Lb. SINGLE CYLINDER CHLORINATOR

Weight of Chlorine

The weight refers to the weight of chlorine that is being supplied, not the weight of the full cylinder. Full 150 pound cylinders will weigh from 235 pounds to 290 pounds. Full ton containers will weigh from 3,300 pounds to 3,650 pounds.

To equal the chlorine available from one 150 lb. chlorine cylinder, you would need to use:

- 180 gal. of sodium hypochlorite or
- 228 lb. of calcium hypochlorite.

To equal the chlorine available from a one-ton chlorine container, you would need to use:

- 2,400 gal. of sodium hypochlorite or
- 3,040 lb. of calcium hypochlorite.

1-ton chlorine gas containers

Unbelievably, this facility uses between 20 and 30 containers per day. 3 shifts are required to handle the chlorine change-outs each day. Normally this is a slow boring job if everything is working properly. This crew is also responsible for any and all chlorine leaks which is a little more exciting. Even when the fire crews show up for a Cl_2 leak, the fire crews are often too scared to touch a leaking cylinder and will ask the water treatment personnel to fix the leak.

Chemistry of Chlorination Sub-Section

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

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

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

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

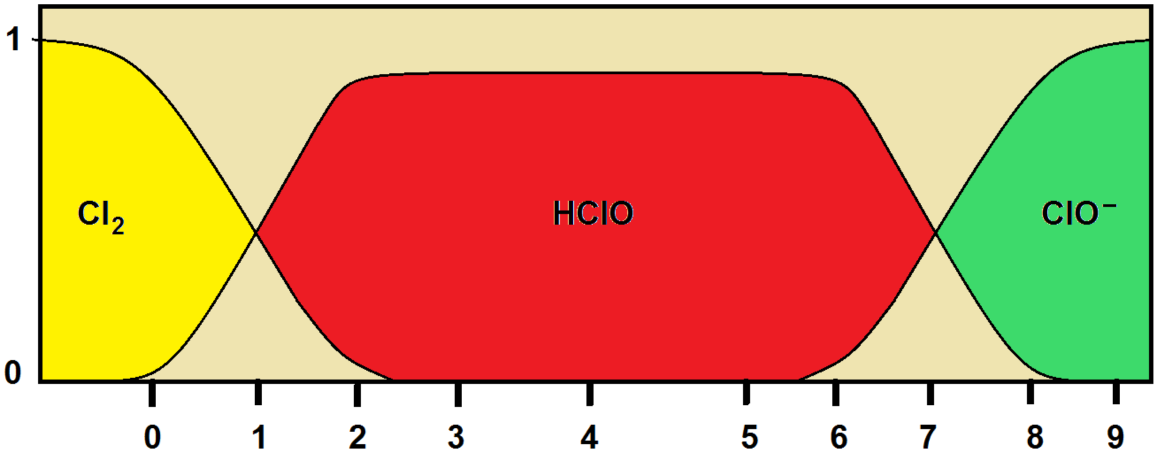
All three forms of chlorine produce hypochlorous acid (HOCl) when added to water. Hypochlorous acid is a weak acid but a strong disinfecting agent. The amount of hypochlorous acid depends on the pH and temperature of the water. Under normal water conditions, hypochlorous acid will also chemically react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

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

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

Let's now look at how pH and temperature affect the ratio of hypochlorous acid to hypochlorite ions. As the temperature is decreased, the ratio of hypochlorous acid increases. Temperature plays a small part in the acid ratio.

Although the ratio of hypochlorous acid is greater at lower temperatures, pathogenic organisms are actually harder to kill. All other things being equal, higher water temperatures and a lower pH are more conducive to chlorine disinfection.



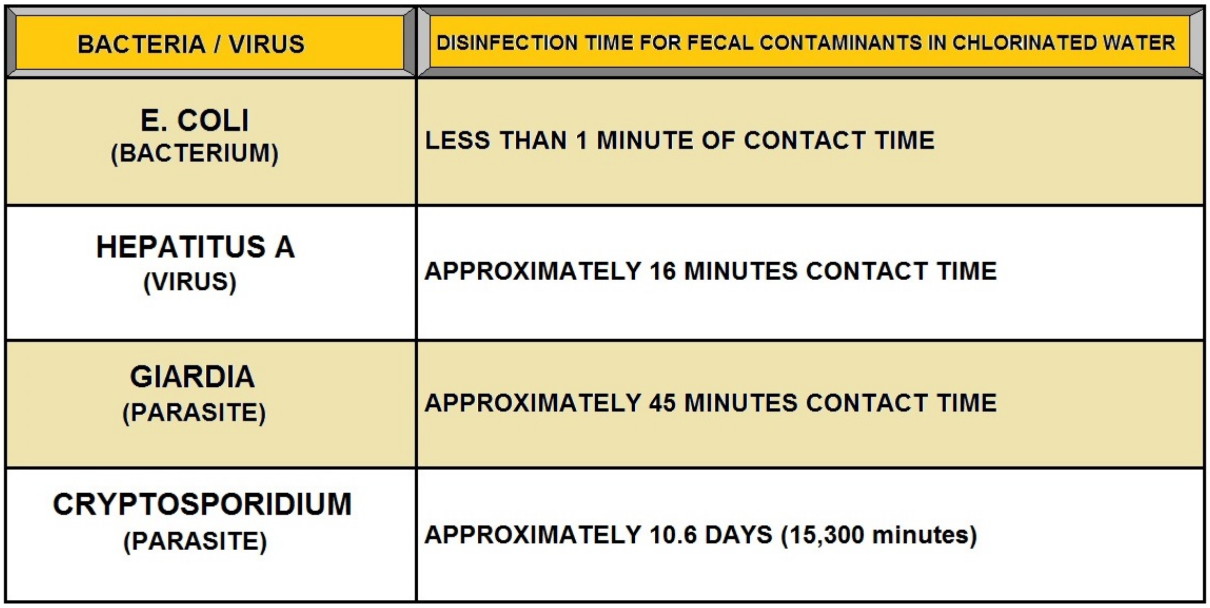
pH & CHLORINE EFFECTS

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 creating 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 significant 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 "*Breakpoint Chlorination*".



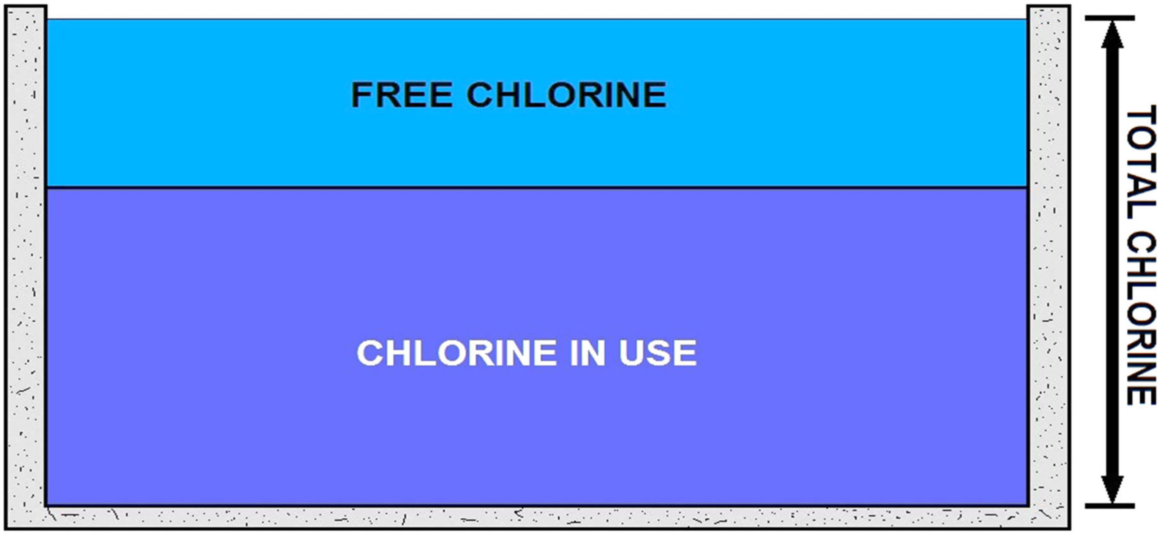
BACTERIA / VIRUS	DISINFECTION TIME FOR FECAL CONTAMINANTS IN CHLORINATED WATER
E. COLI (BACTERIUM)	LESS THAN 1 MINUTE OF CONTACT TIME
HEPATITUS A (VIRUS)	APPROXIMATELY 16 MINUTES CONTACT TIME
GIARDIA (PARASITE)	APPROXIMATELY 45 MINUTES CONTACT TIME
CRYPTOSPORIDIUM (PARASITE)	APPROXIMATELY 10.6 DAYS (15,300 minutes)

CHLORINE TIMETABLE FOR PROPER DISINFECTION

Chlorine Residual Sub-Section

Types of Residual

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.



CHLORINE IN USE + FREE CHLORINE = TOTAL 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.

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 that 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.

Free, Total, and Combined Chlorine

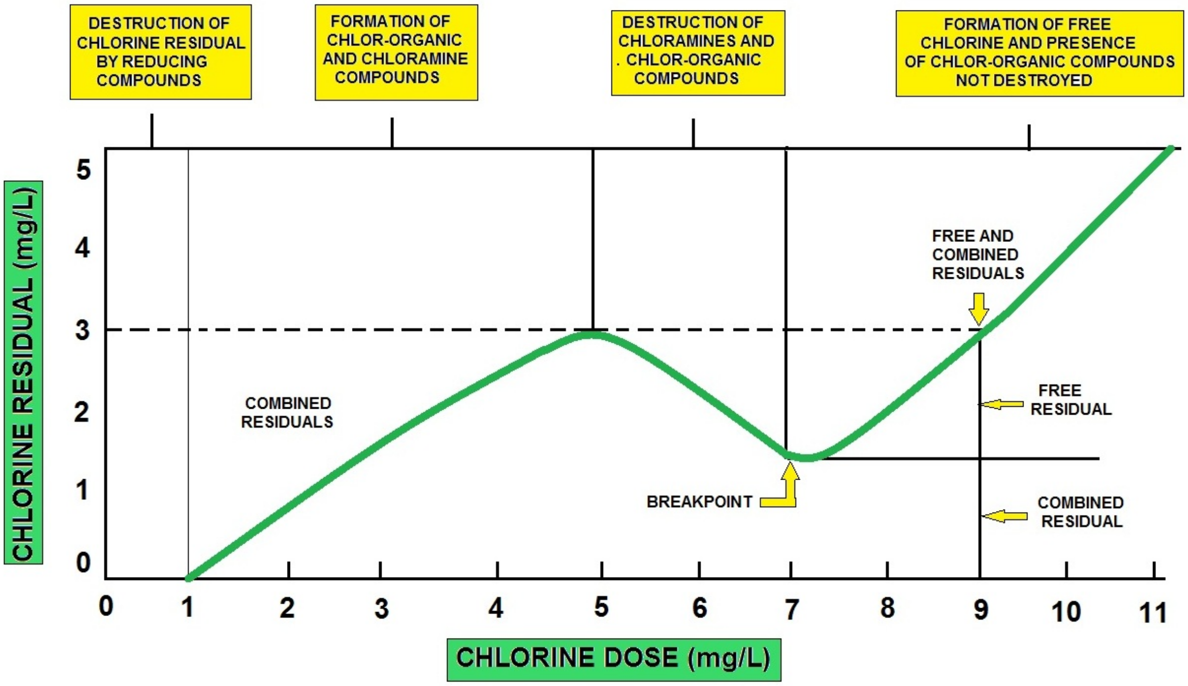
When a chlorine residual test is taken, either a total or a free chlorine residual can be read.

Total residual is all chlorine that is available for disinfection.

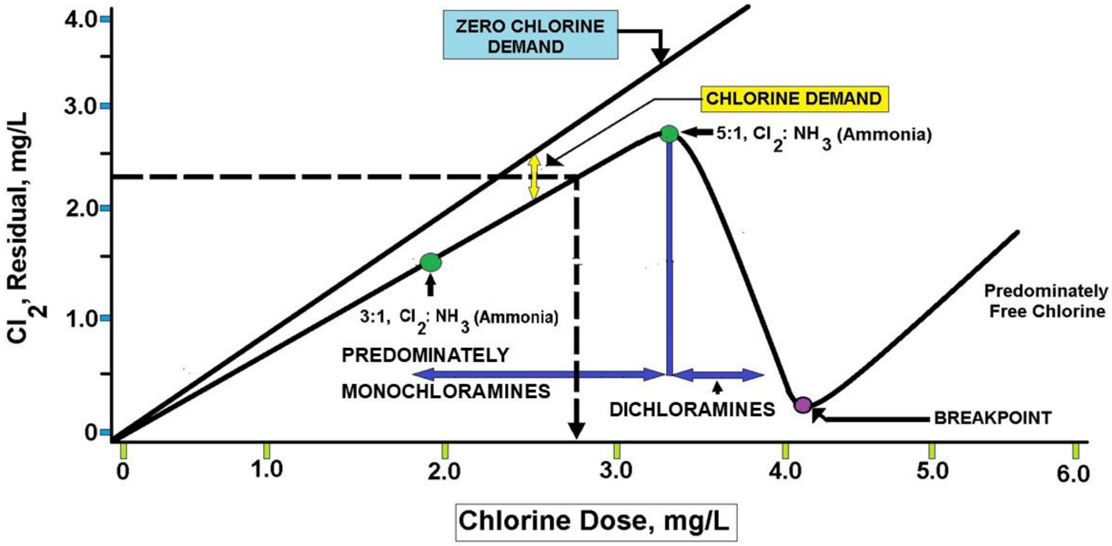
Total chlorine residual = free + combined chlorine residual.

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.***

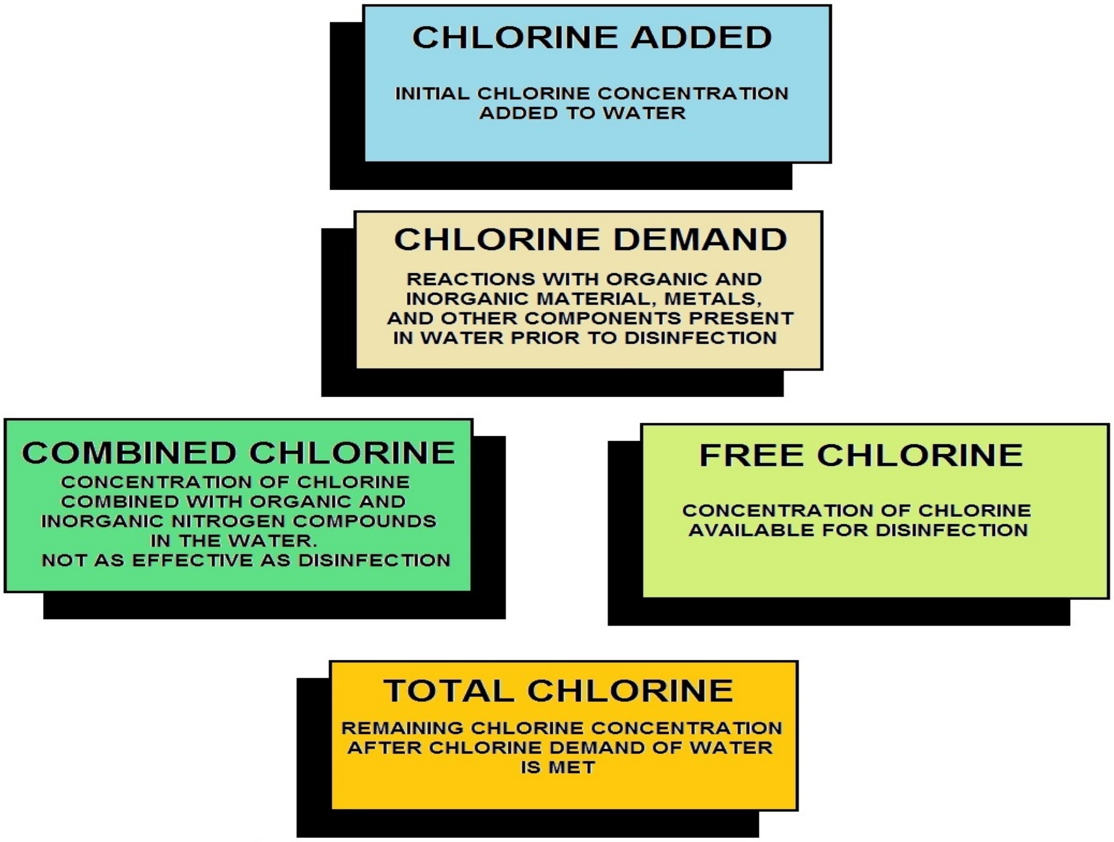


CHLORINE BREAKPOINT CHART #1



Technical Learning College

CHLORAMINATION DOSING CURVE



CHLORINE ADDED

INITIAL CHLORINE CONCENTRATION ADDED TO WATER

CHLORINE DEMAND

REACTIONS WITH ORGANIC AND INORGANIC MATERIAL, METALS, AND OTHER COMPONENTS PRESENT IN WATER PRIOR TO DISINFECTION

COMBINED CHLORINE

CONCENTRATION OF CHLORINE COMBINED WITH ORGANIC AND INORGANIC NITROGEN COMPOUNDS IN THE WATER. NOT AS EFFECTIVE AS DISINFECTION

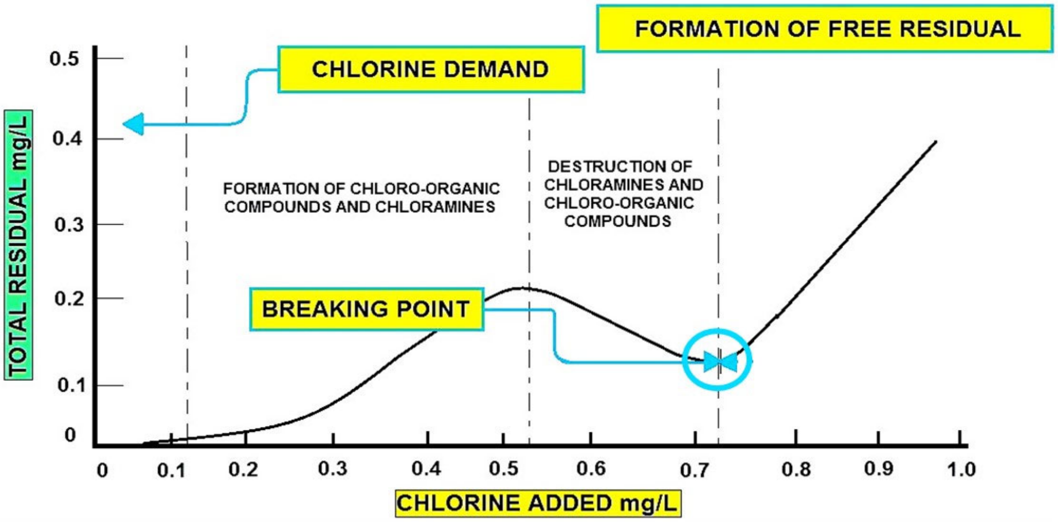
FREE CHLORINE

CONCENTRATION OF CHLORINE AVAILABLE FOR DISINFECTION

TOTAL CHLORINE

REMAINING CHLORINE CONCENTRATION AFTER CHLORINE DEMAND OF WATER IS MET

CHLORINE RESIDUAL ORDER CHART



Technical Learning College

REACTION OF CHLORINE IN WATER

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 (Contact time) = Concentration (mg/L) x Time (Minutes)

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.

BACTERIA / VIRUS	DISINFECTION TIME FOR FECAL CONTAMINANTS IN CHLORINATED WATER
E. COLI (BACTERIUM)	LESS THAN 1 MINUTE OF CONTACT TIME
HEPATITUS A (VIRUS)	APPROXIMATELY 16 MINUTES CONTACT TIME
GIARDIA (PARASITE)	APPROXIMATELY 45 MINUTES CONTACT TIME
CRYPTOSPORIDIUM (PARASITE)	APPROXIMATELY 10.6 DAYS (15,300 minutes)

CHLORINE TIMETABLE FOR PROPER DISINFECTION

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

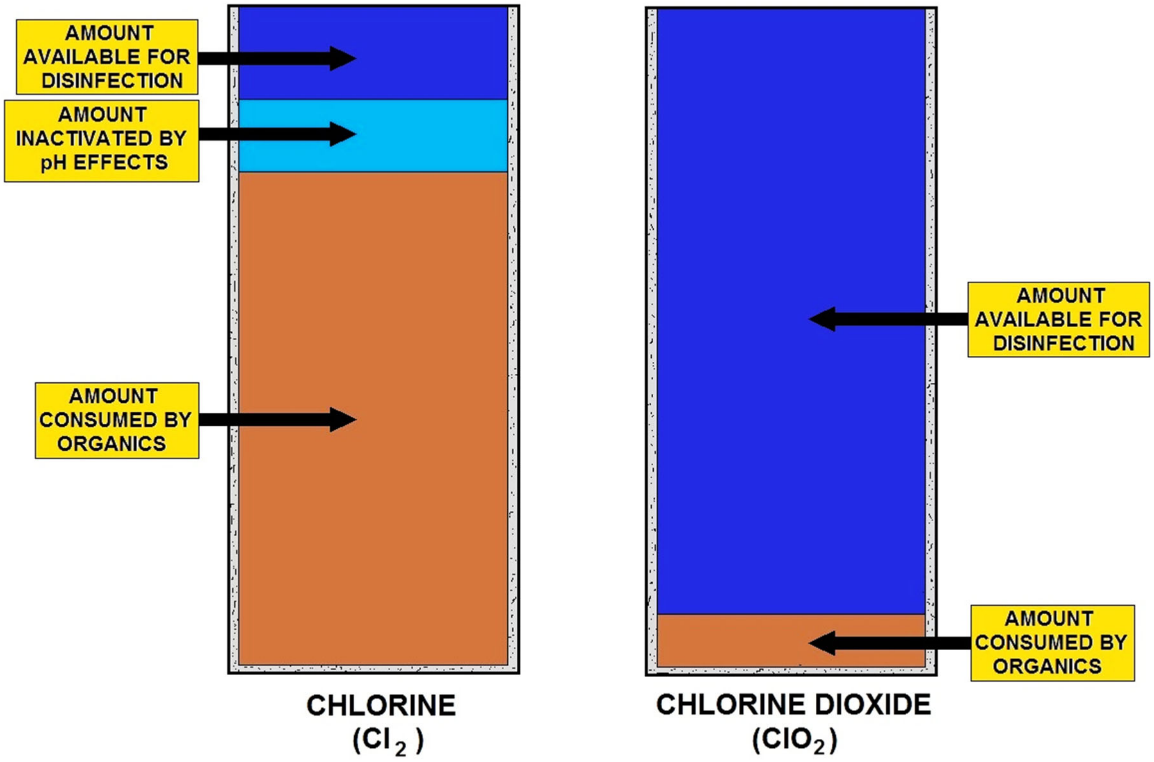
Required CT values are dependent on pH, residual concentration, temperature, and the disinfectant used.

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.

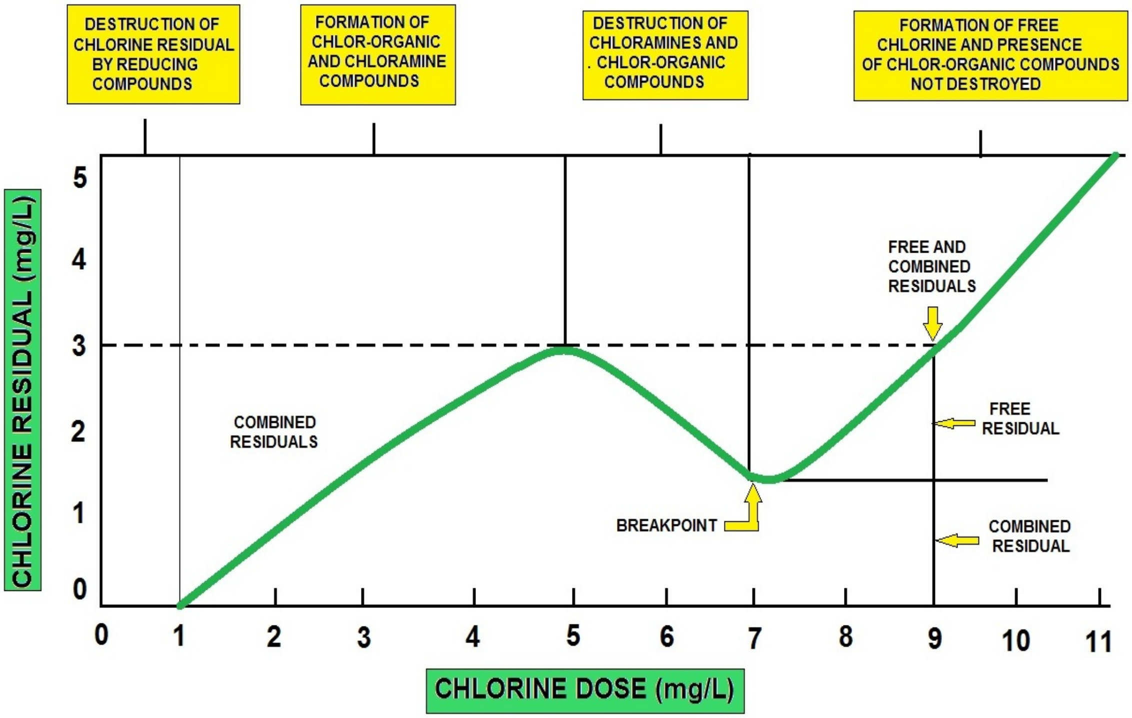
Results shall be reported as a reduction Ratio, along with the appropriate pH, temperature, and disinfectant residual. The reduction Ratio must be greater than 1.0 to be acceptable. Users may also calculate and record actual log reductions.

Reduction Ratio = CT actual ÷ CT required



THE DIFFERENCE IN USING CHLORINE AND CHLORINE DIOXIDE AS A DISINFECTANT

Understanding Chlorine Residual



CHLORINE BREAKPOINT

The amount of available chlorine present in wastewater after a given contact time (20 minutes at peak flow; 30 minutes at average flow), and under specific conditions including pH and temperature. For effective water treatment, the water supply industry has recognized the need for adequate exposure to the disinfectant and sufficient disinfectant dosage for a certain amount of time. In the 1980s, the two functions were combined with the development of the CT values for various disinfectants.

CT represents the combination of the disinfectant dosage and the length of time water has been exposed to a minimum amount of the disinfectant residual.

Mathematically it is represented as CT = concentration x time
concentration = final disinfectant concentration in mg/l
time = minimum exposure time in minutes

In an assessment of disinfection effectiveness, two types of organisms have been chosen as disinfection surrogates – the protozoan Giardia and viruses. CT values established for disinfection of surface waters require treatment plants to achieve a three-log or 99.9% reduction in Giardia and a four-log or 99.99% virus reduction. It is important to recognize that the use of chlorine as the disinfectant is only one part of the treatment process. Equally important is the need for improved filtration to remove organisms.

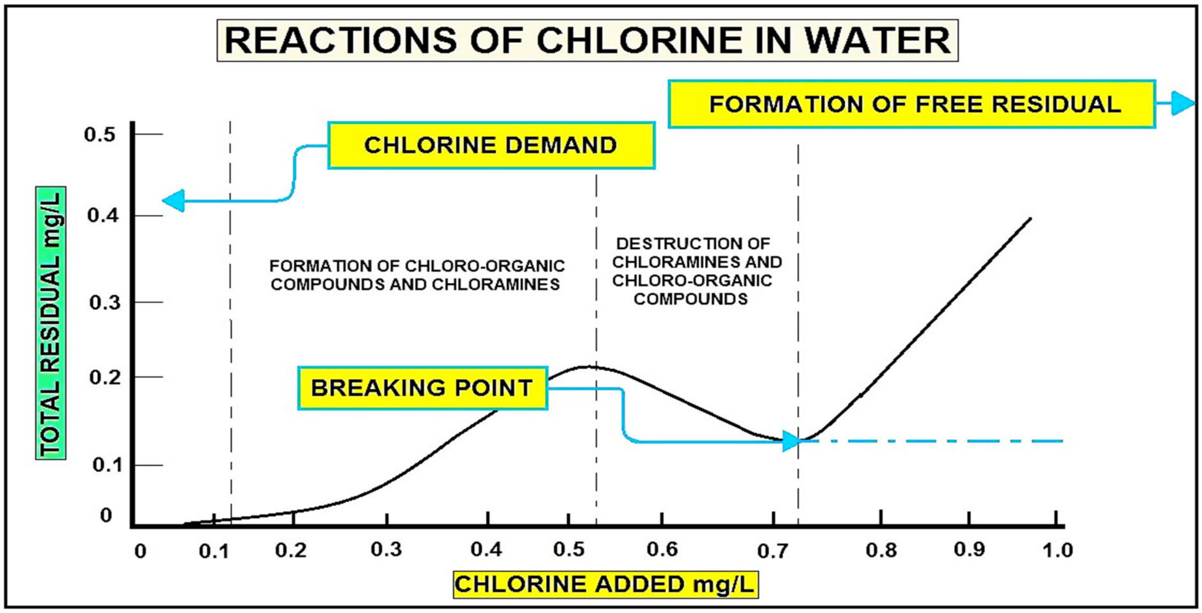
A combination of proper disinfection and filtration is most effective in providing safe drinking water. Recent experiments in controlling Cryptosporidium also suggest the effectiveness of filtration in the water treatment process.

Free residual chlorination involves the application of chlorine to water to produce--either directly or by first destroying any naturally present ammonia--a free available chlorine residual and to maintain this residual through part or all of the water treatment plant and distribution system. Free available residual forms have higher oxidation potentials than combined available chlorine forms and are more effective as disinfectants.

When free available chlorine residuals are desired, the characteristics of the water will determine how this will be accomplished. This may have to be considered:
1. If the water contains no ammonia or other nitrogen compounds, any application of chlorine will yield a free residual once it has reacted with any bacteria, virus and other microorganisms present in the water.
2. If the water contains ammonia, it results in the formation of a combined residual, which must be destroyed by applying an excess of chlorine.

Breakpoint Chlorination

Breakpoint chlorination is the name of the process of adding chlorine to water until the chlorine demand has been satisfied. Chlorine demand equals the amount of chlorine used up before a free available chlorine residual is produced. Further additions of chlorine will result in a chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint. Public water supplies normally chlorinate past the breakpoint.



When chlorine is initially added to water, the following may happen:

1. If the water contains some iron, manganese, organic matter, and ammonia, the chlorine reacts with these materials and no residual is formed, meaning that no disinfection has taken place.
2. If additional chlorine is added at this point, it will react with the organics and ammonia to form chloramines. The chloramines produce a combined chlorine residual. As the chlorine is combined with other substances, it loses some of the disinfection strength. Combined residuals have poor disinfection power and may be the cause of taste and odor problems.
3. With a little more chlorine added, the chloramines and some of the chlororganics are destroyed.
4. With still more chlorine added, a free chlorine residual is formed, free in the sense that it can react quickly.

Free available chlorine is the best residual for disinfection. It disinfects faster and without the swimming-pool odor of combined residual chlorine. The free available residual forms at the breakpoint; therefore, the process is called breakpoint chlorination. The common practice today is to go just beyond the breakpoint to a residual of about .2 to .5 ppm.

A variety of reactions take place during chlorination. When chlorine is added to a water containing ammonia (NH_3), the ammonia reacts with hypochlorous acid (HOCL) to form monochloramine, dichloramine, and trichloramine. The formation of these chloramines depends on the pH of the water and the initial chlorine-ammonia ratio.

Ammonia + Hypochlorous acid ----> Chloramine + Water
NH3 + HOC1------------> NH2C1 + H20 Monochloramine
NH2C1 + HOC1------------ > NHC12 + H20 Dichloramine
NHC12 + HOC1------------ > NC13 + H20 Trichloramine

At the pH of most natural water (pH 6.5 to 7.5), monochloramine and dichloramine exist together. At pH levels below 5.5, dichloramine exists by itself. Below pH 4.0, trichloramine is the only compound found. The monochloramine and dichloramine forms have a definite disinfection power. Dichloramine is a more effective disinfecting agent than monochloramine. However, dichloramine is not recommended as a disinfectant due to the possibility of the formation of taste and odor compounds. Chlorine reacts with phenol and salicylic acid to form chlorophenol, which has an intense medicinal odor. This reaction is much slower in the presence of monochloramines.

Both the chlorine residual and the contact time are essential for effective disinfection. It is important to have complete mixing. The operator also needs to be aware that changes in the pH may affect the ability of the chlorine to disinfect the water. The operator must examine the application and select the best point of feed and the best contact time to achieve the results desired. The operator needs to consider:
1. Whether the injection point and the method of mixing is designed so that the disinfectant is able to get into contact with all of the water to be disinfected. This also depends on whether pre- and/or post-chlorination is being used.
2. Contact time. In situations of good initial mixing, the longer the contact time, the more effective the disinfection.
3. Effectiveness of upstream treatment processes. The lower the turbidity of the water, the more effective the disinfection.
4. Temperature. At higher temperatures the rate of disinfection is more rapid.
5. Dosage and type of chemical. Usually the higher the dose, the quicker the disinfection rate. The form of disinfectant (chloramine or free chlorine) and the type of chemical used influence the disinfection rate.
6. pH. The lower the pH, the better the disinfection.

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. In addition, 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.

Disinfection Information

- 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.

Measuring Chlorine Residual Sub-Section

Amperometric Titration

Amperometric titrations have been successfully used for accurate determination of residual chlorine in water at many plants to maintain regulatory compliance. Different species of chlorine have also been determined, with suitable modification of the method, as free available chlorine, chloramine, chlorine dioxide, and chlorite.

Various dual polarizable electrodes have been used for the amperometric titration of low concentrations of residual chlorine in water. In particular, amperometric (Iodometric) titrations with dual platinum electrodes have gained considerable interest in the determination of total residual chlorine in water. Selective iodometric titrations with dual polarizable electrodes have also been found to be useful for the speciation of chlorine in water, providing the ability to distinguish between free and combined residual chlorine, and between monochloramine and dichloramine in water.

In the amperometric determination of free chlorine, chlorine is titrated with a standard reducing agent such as thiosulfate or phenyl arsine oxide (PAO) at pH 7. As long as the oxidant (free chlorine) is present in the titrated sample, a current flows through the cell.

The standard amperometric sensor design consists of two electrodes (anode and cathode) that measure a change in current caused by the chemical reduction of hypochlorous acid at the cathode. The current that flows because of this reduction is proportional to the chlorine concentration. A membrane and electrolyte help to control the reaction. Flow rate and pressure must be carefully controlled for accurate measurement.

The effect of pH on the disassociation of hypochlorous acid to the hypochlorite ion is quite significant. A standard sensor design is suitable for a constant pH in the range of 6.8-8.0. Calibration of the system enables compensation for the pH of the sample.

Varying pH

For applications with varying pH, or pH values beyond this range, an extended pH range sensor is available using a 4.0 pH electrolyte in the membrane cap. This enables conversion of the hypochlorite ion to hypochlorous acid, enabling accurate chlorine readings in solutions between pH 4.0-12.0.

Time for Measurement

The amount of time to achieve an accurate reading is only 30 seconds for a standard sensor, two minutes for an extended pH range sensor. Flow to the sensor must be consistently controlled in the range of 8-26.4 gal/hr; with a maximum pressure of 1 atm (discharge of sensor must be to atmospheric pressure). Each sensor typically has a required flow cell configuration to enable accurate measurements. During initial start-up, the sensor must be conditioned in the flow stream for 12-24 hours before attempting any calibration.

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.)

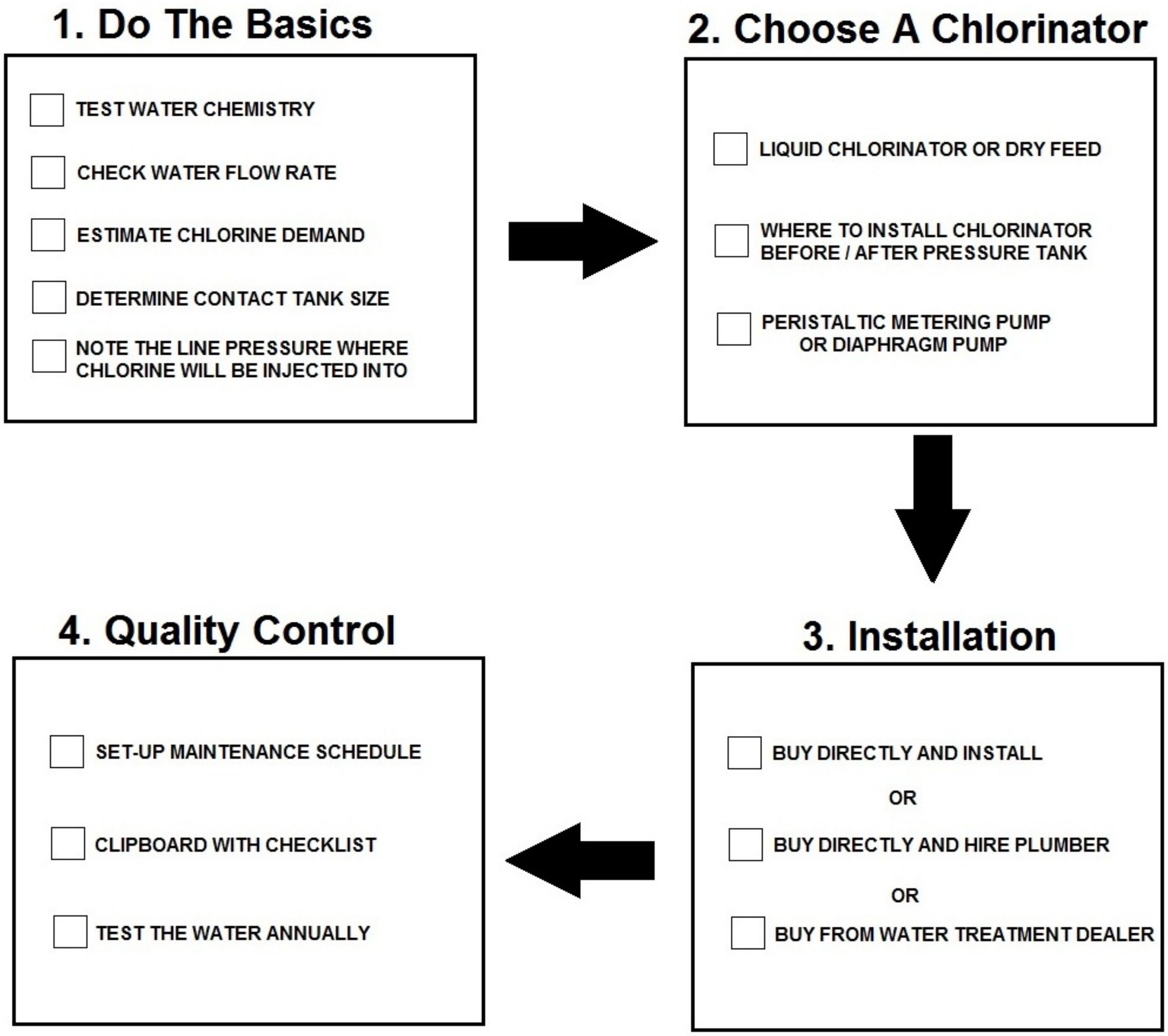
Chlorine test kits are very useful in adjusting the chlorine dose you apply. You can measure what chlorine levels are being found in your system (especially at the far ends).

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 is to use the laboratory amperometric titration method.

Additional Drinking Water Methods (Non-EPA) for Chemical Parameters

Method	**Method Focus**	**Title**	**Location**	**Source**
4500-Cl^- B	Chloride by Silver Nitrate Titration	Standard Methods for the Examination of Water and Wastewater, 18th & 19th Ed.	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-Cl^- D	Chloride by Potentiometric Method	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-Cl D	Chlorine Residual by Amperometric Titration (Stage 1 DBP use SM 19th Ed. only)	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-Cl E	Chlorine Residual by Low Level Amperometric Titration (Stage 1 DBP use SM 19th Ed. only)	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-Cl F	Chlorine Residual by DPD Ferrous Titration (Stage 1 DBP use SM 19th Ed. only)	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-Cl G	Chlorine Residual by DPD Colorimetric Method (Stage 1 DBP use SM 19th Ed. only)	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-Cl H	Chlorine Residual by Syringaldazine (FACTS) Method (Stage 1 DBP use SM 19th Ed. only)	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-Cl I	Chlorine Residual by Iodometric Electrode Technique (Stage 1 DBP use SM 19th Ed. only)	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-ClO_2 C	Chlorine Dioxide by the Amperometric Method I	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-ClO_2 D	Chlorine Dioxide by the DPD Method (Stage 1 DBP use SM 19th Ed. only)	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**
4500-ClO_2 E	Chlorine Dioxide by the Amperometric Method II (Stage 1 DBP use SM 19th Ed. only)	Standard Methods for the Examination of Water and Wastewater, 18th, 19th & 20th Editions	Included in Standard Methods	American Water Works Assn. **(AWWA)**



HOW TO DETERMINE A CHLORINATION SYSTEM

Chlorination Equipment Requirements

For all water treatment facilities, chlorine gas under pressure shall not be permitted outside the chlorine room. The chlorine room is the room 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; the vent line should be run in such a manner that moisture collecting traps are avoided. The vacuum regulating valve(s) shall have positive shutdown in the event of a break in the downstream vacuum lines. As an alternative to chlorine gas, it is permissible to use hypochlorite with positive displacement pumping. Anti-siphon valves shall be incorporated in the pump heads or in the discharge piping.

Capacity

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

Methods of Control

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

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

Standby Provision

As a safeguard against malfunction and/or shutdown, 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. At a minimum, a platform scale shall be provided. Scales shall be of corrosion-resistant material. Read the scales daily and at the same time.

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.

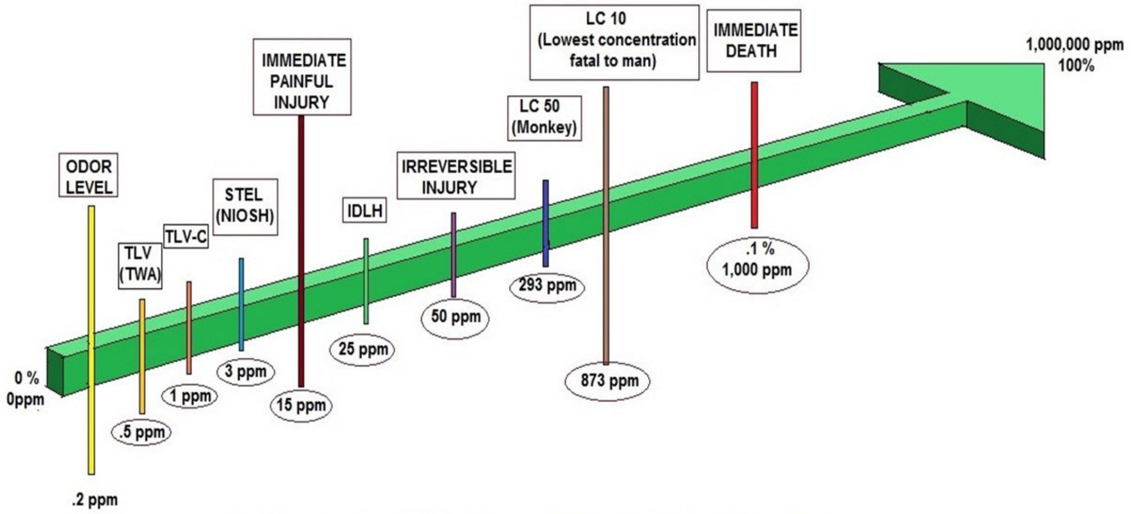
In the photo, we have a 1-ton chlorine gas container and 150-pound Cl_2 gas cylinders. The 1- ton is on a scale. Cylinders stand up-right and containers on their sides.

Here is an operator checking for Cl_2 leaks with Ammonia. If there is a Cl_2 leak, you will be able to see a white smoke. Even if you cannot smell the chlorine, the ammonia will find the leak.

Chlorine measurement devices or Rotameters.

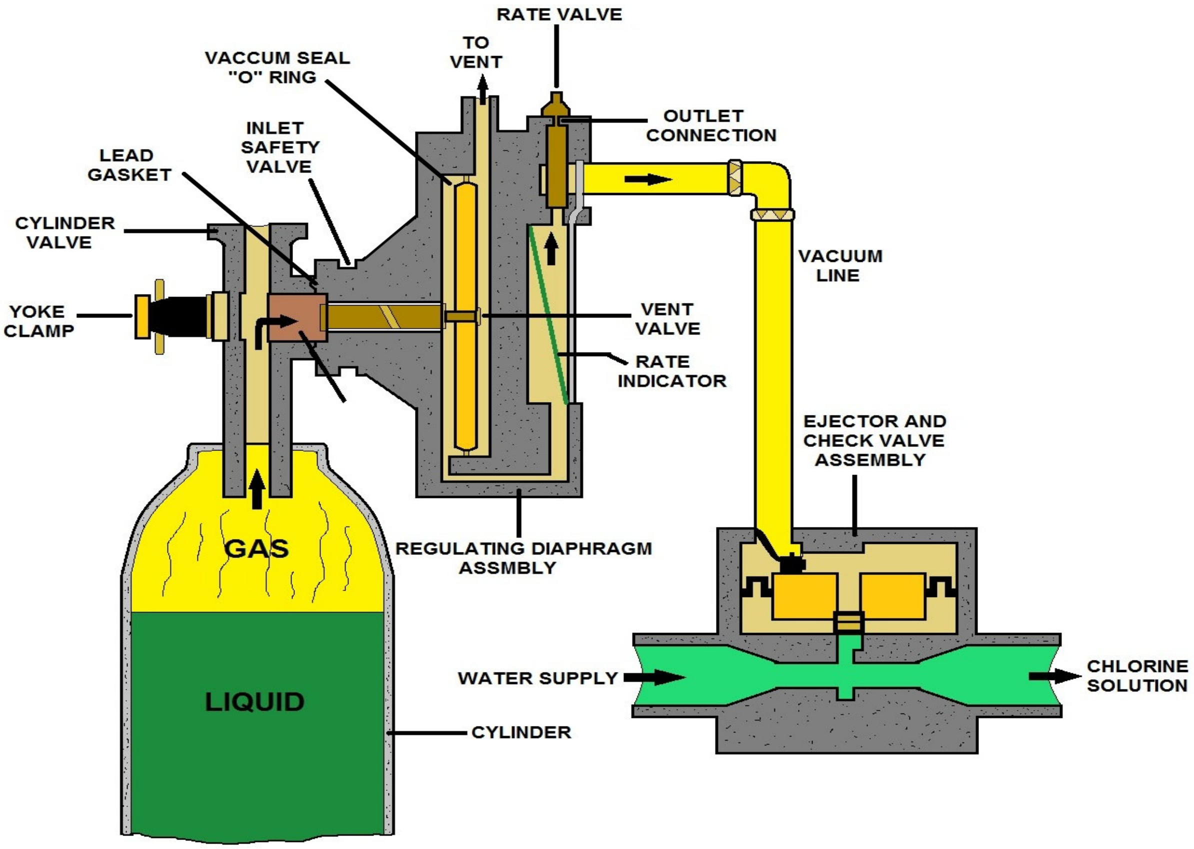
Chlorine is only slightly soluble in water; its maximum solubility is approximately one percent at 49° C. At temperatures below this point it combines with water to form chlorine ice, a crystalline substance. When the water supply to a gas chlorinator is below normal room temperature, it may cool the chlorine gas to the point at which chlorine ice is formed and accumulates on the needle valve and gas outlet tube, resulting in erratic feed results. Because the vapor pressure of chlorine increases with rising temperatures, its solubility also decreases. At 212° F. chlorine is insoluble in water.

Safety Information: There is a fusible plug on every chlorine gas cylinder. 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.



Technical Learning College **LOGARITHMIC SCALE OF CHLORINE EXPOSURE**

Small chlorine storage shed in the foreground; 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.



150 LB SINGLE CHLORINE CYLINDER CHLORINATOR DIAGRAM #1

Cylinder Procedures

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:

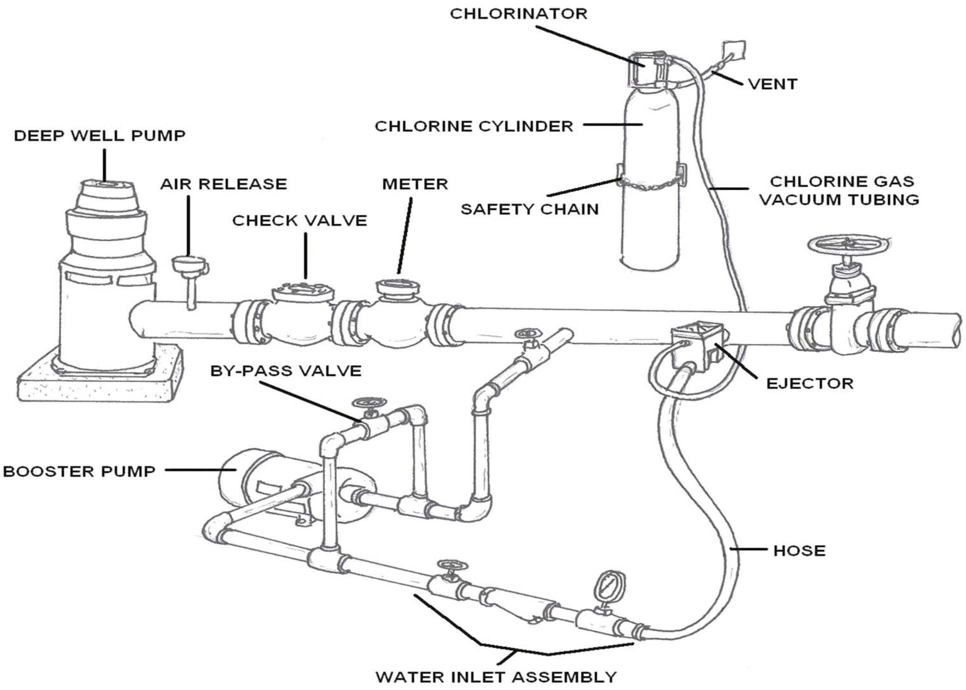
In addition to protective clothing and goggles, chlorine gas should be used only in a well-ventilated area so that any leaking gas cannot concentrate.

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.



150 LB SINGLE CHLORINE CYLINDER CHLORINATOR DIAGRAM #2

Changing 100- and 150-Pound Cylinder Instructions

1. Turn valve stem clockwise to close cylinder valve.
2. Allow float in flow meter to drop to zero. Indicator on front of gas feeder should indicate no gas.
3. Wait about one minute. Float should remain at zero. If the float flutters or does not drop to zero, the valve is not closed tightly. Make sure the valve is closed before proceeding.
4. Turn off ejector, and make certain the gas supply indicator stays in the "No Gas" position by turning the "Reset" knob. If the indicator resets, either gas pressure is still present or there is an air leak in the system. Refer to instruction manual if an air leak is evident.
5. Loosen gas feeder yoke screw. Remove gas feeder from valve.
6. Replace gas cylinder. Be sure to use a chain or cable to secure the new cylinder properly.
7. Remove old lead gasket. Inspect and clean mating surfaces of gas feeder and valve. Install new lead gasket.
8. Position gas feeder on new gas cylinder and tighten yoke screw. Do not tighten excessively.
9. Crack open gas cylinder valve and close quickly.
10. Use ammonia solution to check for leaks. If a white cloud or vapor appears, turn on ejector and repeat steps 2, 3, 4, and correct leaks.
11. After you verify there are no leaks, open gas cylinder valve, about ¼-turn only, and leave cylinder wrench on valve.
12. Turn on the ejector.

Notes:

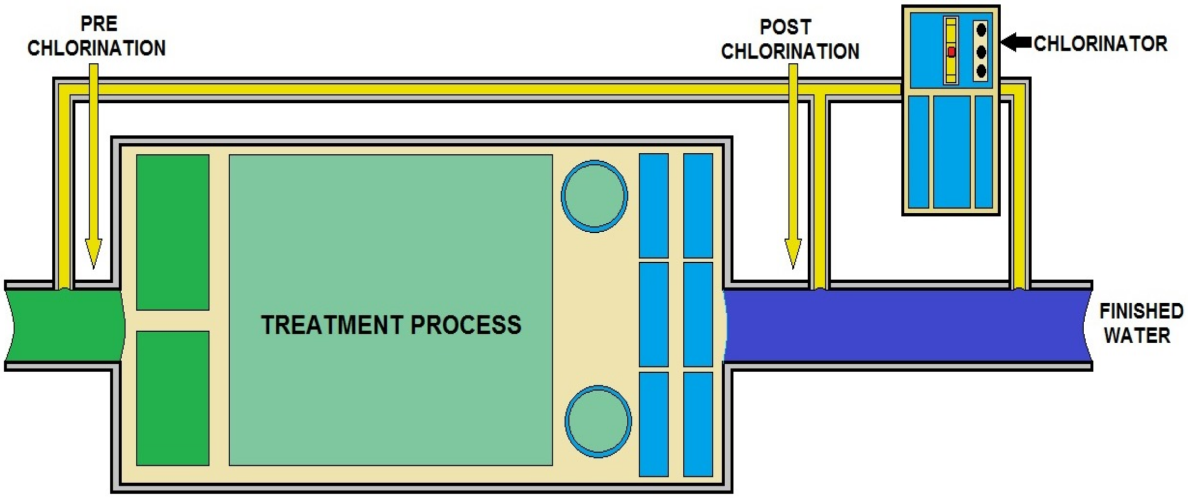
A. See your gas feeder manufacturer's guide for more detailed instructions.
B. Immediately contact your gas supplier if the cylinder valve or cylinder is defective.

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 (i.e., floor area less than 10 feet squared ($3m^2$)). 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, ammonium chloride. Check with OSHA and the chlorine manufacturer for specific information.



CHLORINE FLOW IN A TREATMENT PLANT

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

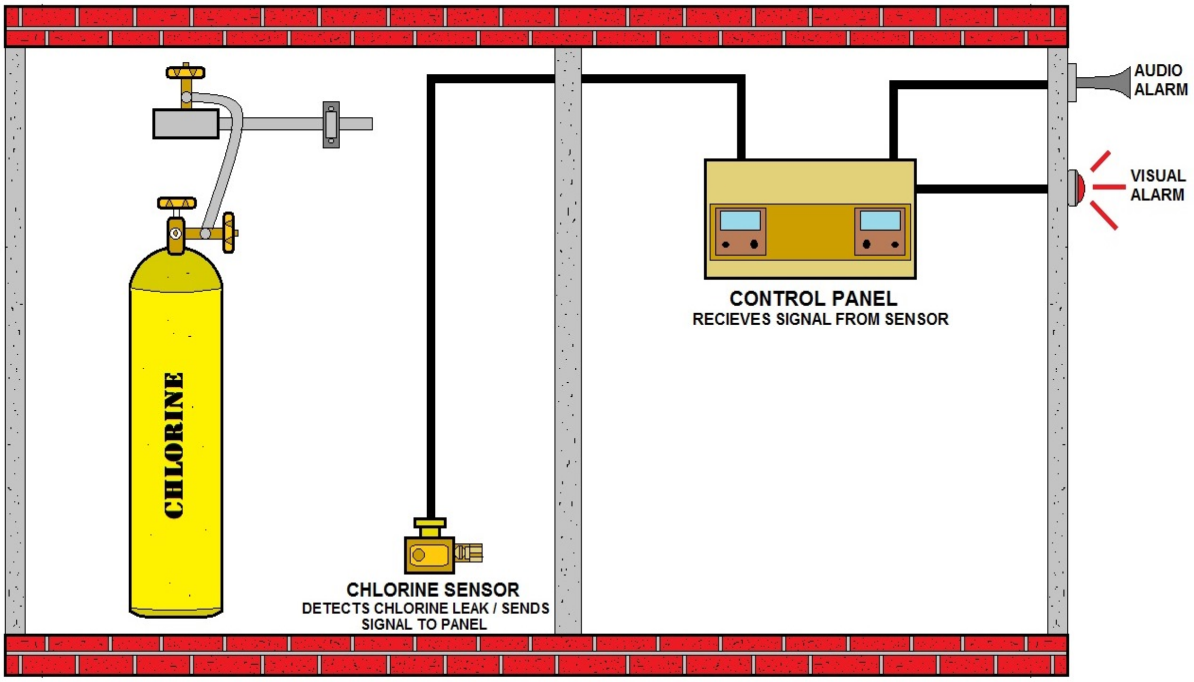
Respiratory equipment shall be provided which has been approved under the Occupational Health and Safety Act, General Safety Regulation - Selection of Respiratory Protective Equipment. Equipment shall be in close proximity to the access door(s) of the chlorine room.

Chlorine Room Design Requirements

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

Ventilation

Gas chlorine rooms shall have entirely separate exhaust ventilation systems capable of delivering one complete air change per minute during periods of chlorine room occupancy only - there shall be no continuous ventilation. The air outlet from the room shall be 6 inches (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.



CHLORINE STORAGE ROOM

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. Check with OSHA and the Chlorine manufacturer for specific information.

Heating

Chlorine rooms shall have separate heating systems, if a forced air system is used to heat the building. 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 60° F or 15°C. Check with OSHA and the Chlorine manufacturer for specific information.

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 2 foot squared (0.20 m^2) 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.

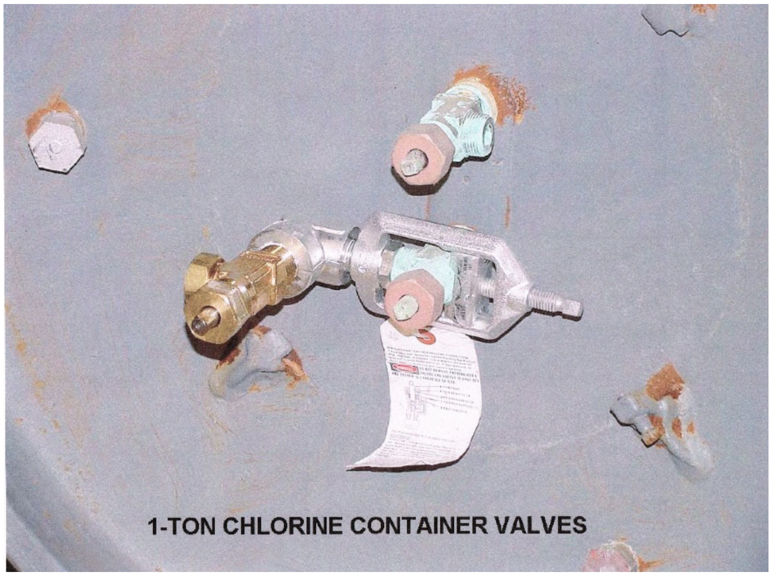
Storage of Chlorine Cylinders/Containers

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/container 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.

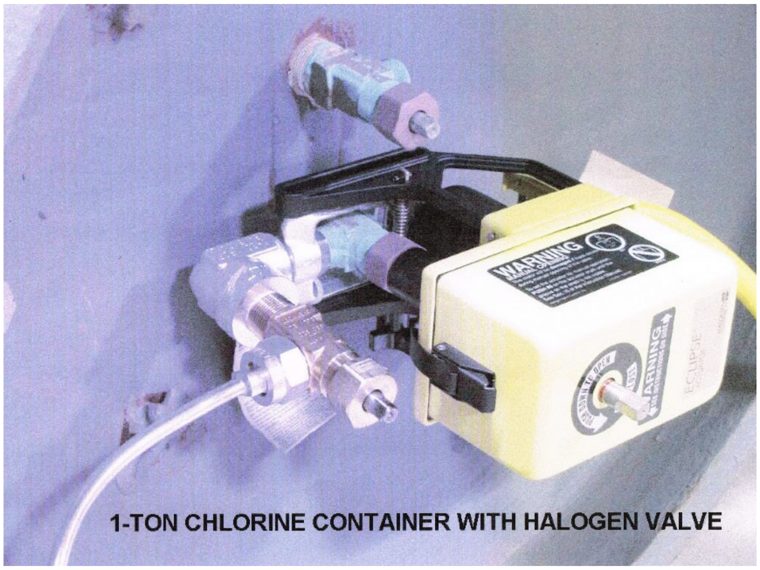
Chlorine gas storage room shall have provision for ventilation at thirty air changes per hour. Viewing glass windows and a panic button on the inside of door should also be provided. In very large facilities, entry into the chlorine rooms may be through a vestibule from outside.

Scrubbers

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



1-TON CHLORINE CONTAINER VALVES



1-TON CHLORINE CONTAINER WITH HALOGEN VALVE

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:
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.

Water Disinfectant Health Cautions

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

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

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

Disinfection Byproducts Section

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 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 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 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 EPA 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.

Health advisories provide additional information on certain contaminants. Health advisories are guidance values based on health effects other than cancer. These values are set for different durations of exposure (e.g., one-day, ten-day, longer-term, and lifetime).

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

EXPOSURE LEVELS (ppm)	EFFECTS OF CHLORINE ON HUMANS
0.2 - 0.4 ppm	ODOR THRESHOLD (VARIES BY INDIVIDUAL)
Less than 0.5 ppm	NO KNOWN ACUTE OR CHRONIC EFFECT
0.5 ppm	ACGIH 8-HOUR TIME WEIGHTED AVERAGE
1.0 ppm	OSHA CEILING LEVEL (PEL) TLV-STEL ERPG - 1
1.0 - 10 ppm	IRRITATION OF THE EYES AND MUCOUS MEMBRANES OF THE UPPER RESPIRATORY TRACT. SEVERITY OF SYMPTOMS DEPENDS ON THE CONCENTRATIONS AND LENGTHS OF EXPOSURE
3 ppm	ERPG-2 (EMERGENCY RESPONSE PLANNING GUIDELINES AS VALUES DEVELOPED BY AIHA) IS THE MAXIMUM AIRBORNE CONCENTRATION BELOW WHICH IT IS BELIEVED THAT NEARLY ALL INDIVIDUALS COULD BE EXPOSED FOR UP TO 1-HOUR WITHOUT EXPERIENCING OR DEVELOPING IRREVERSABLE OR OTHER SERIOUS HEALTH EFFECTS THAT COULD IMPAIR AN INDIVIDUAL'S ABILITY TO TAKE PROTECTIVE ACTION.
10 ppm	NIOSH IDLH (IMMEDIATELY DANGEROUS TO LIFE AND HEALTH)
20 ppm	ERPG-3 IS THE MAXIMUM AIRBORNE CONCENTRATION BELOW WHICH IT IS BELIEVED THAT NEARLY ALL INDIVIDUALS COULD BE EXPOSED FOR UP TO 1-HOUR WITHOUT EXPERIENCING OR DEVELOPING LIFE-THREATENING HEALTH EFFECTS.

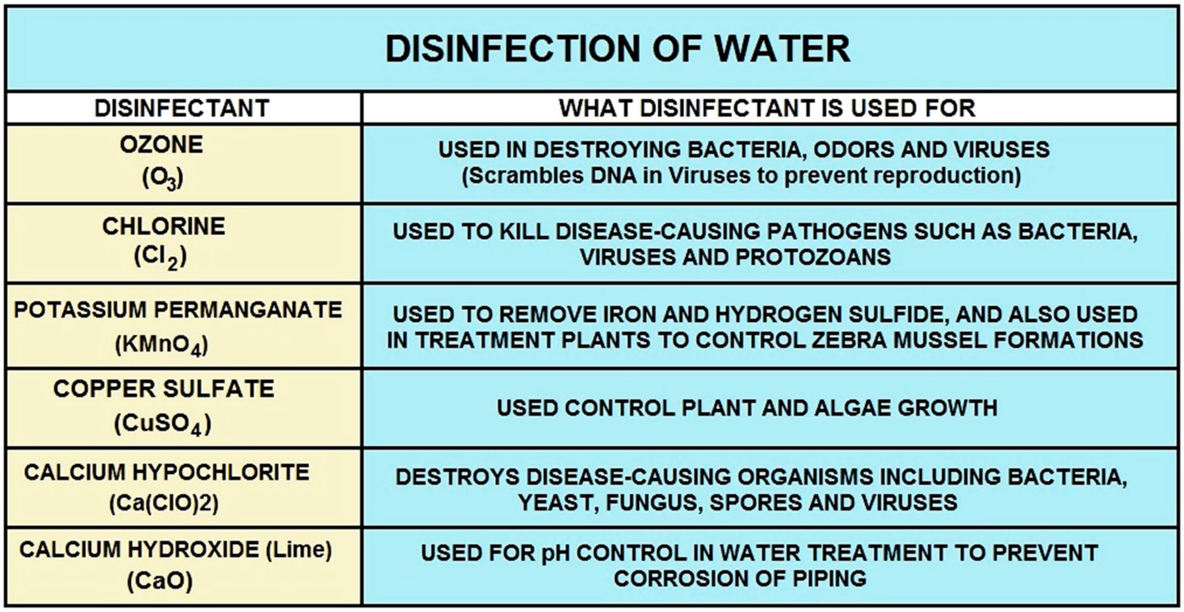
EFFECTS OF CHLORINE EXPOSURE IN PARTS PER MILLION

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 (i.e., bromate).



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

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. Removal of the precursors can be by adsorption on activated carbon beds. It is extremely important that water treatment plants ensure the methods used to control chlorination by-products do not compromise the effectiveness of water disinfection.

Chlorine By-Products

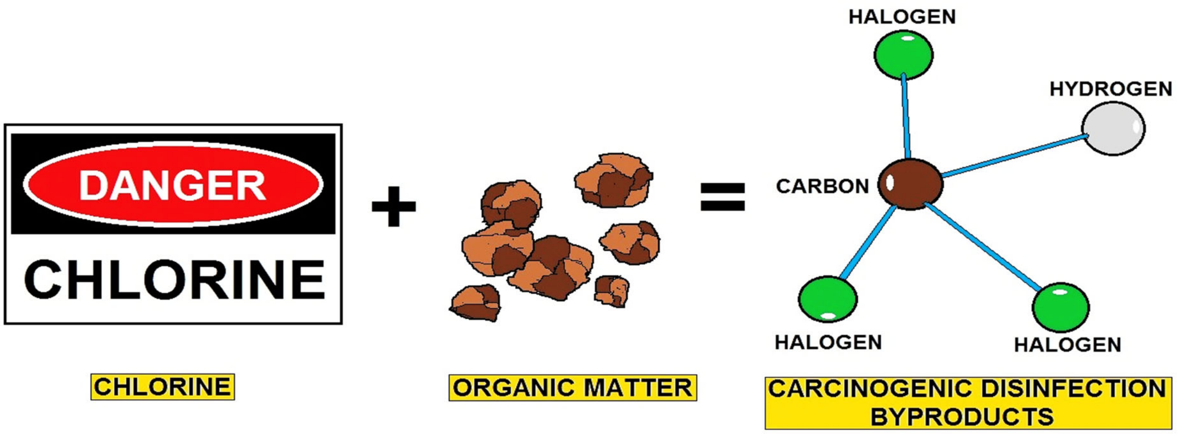
Chlorination by-products are the chemicals formed when the chlorine used to kill disease-causing microorganisms reacts with naturally occurring organic matter (i.e., decay products of vegetation) in the water. The most common chlorination by-products found in U.S. drinking water supplies are the trihalomethanes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



DISINFECTION BYPRODUCT PRODUCTION DIAGRAM

Health Effects

Laboratory animals exposed to very high levels of THMs have shown increased incidences of cancer. In addition, 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.

Haloacetic Acids (HAA5)

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 groundwater public water systems in December 2003.

Bromate is a chemical that is formed when ozone used to disinfect drinking water reacts with naturally occurring bromide found in source water. 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 in December 2003.

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 groundwater 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.

Chemical Oxygen Generation

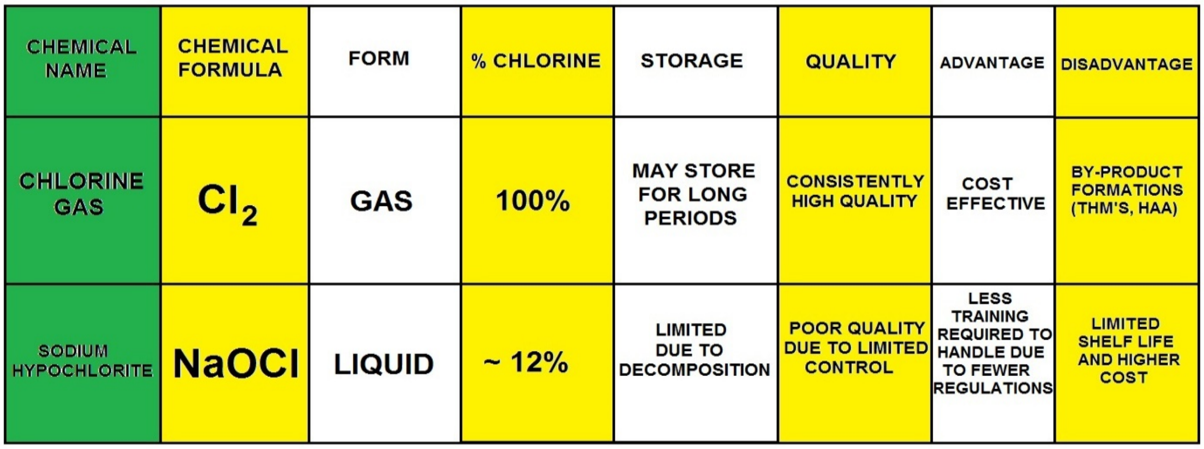
Chemical oxygen generators, such as those in commercial aircraft, provide emergency oxygen to passengers to protect them from drops in cabin pressure by catalytic decomposition of sodium chlorate. The catalyst is normally iron powder.

Barium peroxide (BaO_2) is used to absorb the chlorine which is a minor product in the decomposition. Iron powder is mixed with sodium chlorate and ignited by a charge which is activated by pulling on the emergency mask. The reaction produces more oxygen than is required for combustion. Similarly, the Solidox welding system used pellets of sodium chlorate mixed with combustible fibers to generate oxygen.

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.

Sodium Hypochlorite Sub-Section



CHEMICAL NAME	CHEMICAL FORMULA	FORM	% CHLORINE	STORAGE	QUALITY	ADVANTAGE	DISADVANTAGE
CHLORINE GAS	Cl_2	GAS	100%	MAY STORE FOR LONG PERIODS	CONSISTENTLY HIGH QUALITY	COST EFFECTIVE	BY-PRODUCT FORMATIONS (THM'S, HAA)
SODIUM HYPOCHLORITE	NaOCl	LIQUID	~ 12%	LIMITED DUE TO DECOMPOSITION	POOR QUALITY DUE TO LIMITED CONTROL	LESS TRAINING REQUIRED TO HANDLE DUE TO FEWER REGULATIONS	LIMITED SHELF LIFE AND HIGHER COST

CHLORINE GAS VS. SODIUM HYPOCHLORITE (BLEACH)

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 (Cl_2) 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 muriatic 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 hydrolyzation 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, hydrochloric (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:

$$Cl_2 + 2NaOH \rightarrow NaOCl + NaCl + H_2O$$

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 sulfur hydrogen gas (SH) and ammonia (NH_3). 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:

$$NaOCl + H_2O \rightarrow HOCl + NaOH$$

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

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:

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

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 pollutants (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 pollutants 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.

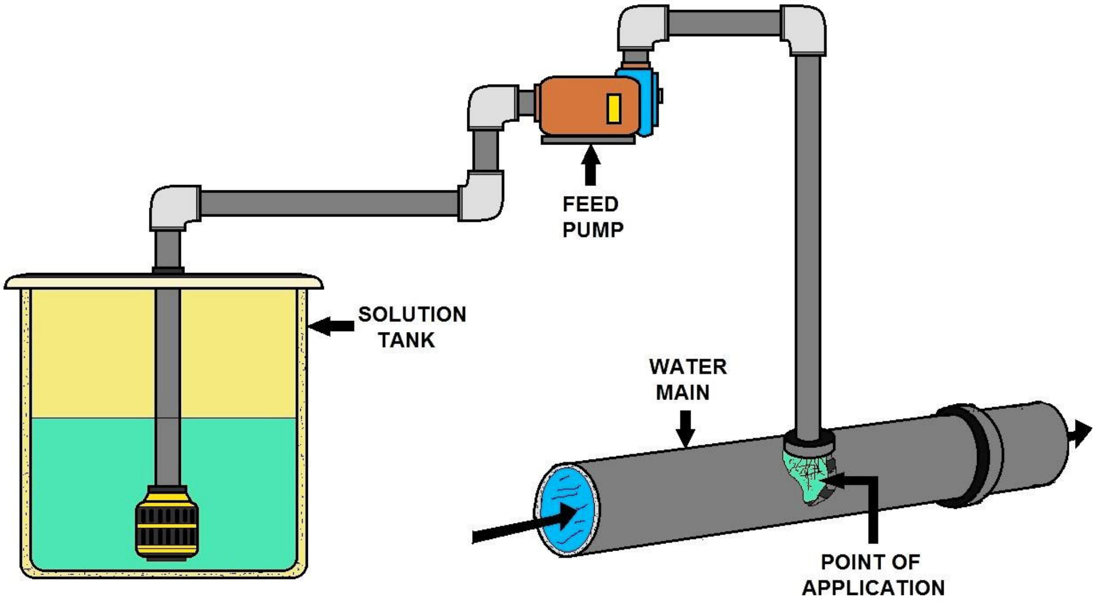
When free chlorine is added to the water, it takes on various forms depending on the pH of the wastewater. It is important to understand the forms of chlorine which are present because each has a different disinfecting capability. The acid form, HOCL, is a much stronger disinfectant than the hypochlorite ion, OCL-.

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 water 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 water 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, and 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.

Sodium Hypochlorite Solutions

Recommendations for Preparing/Handling/Feeding



SODIUM HYPOCHLORITE FEEDING

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.

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 re-primed 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 seal-less 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.

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

Calcium Hypochlorite: Powder and Tablets

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.

Chlorine Facts Review

This information is necessary to pass your post-quiz.

*** 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, it is a noncombustible gas, and a strong oxidizer.

Liquid chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air. Atomic number of chlorine is 17. Cl is the elemental symbol and Cl2 is the chemical formula.

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 both of these species are known as free available chlorine. These 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 **$Cl2 + H_2O \rightarrow H+ + Cl- + HOCl$.** 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, as a safer connection in case the threads on the valve may be worn.

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

On 1-ton chlorine gas 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.

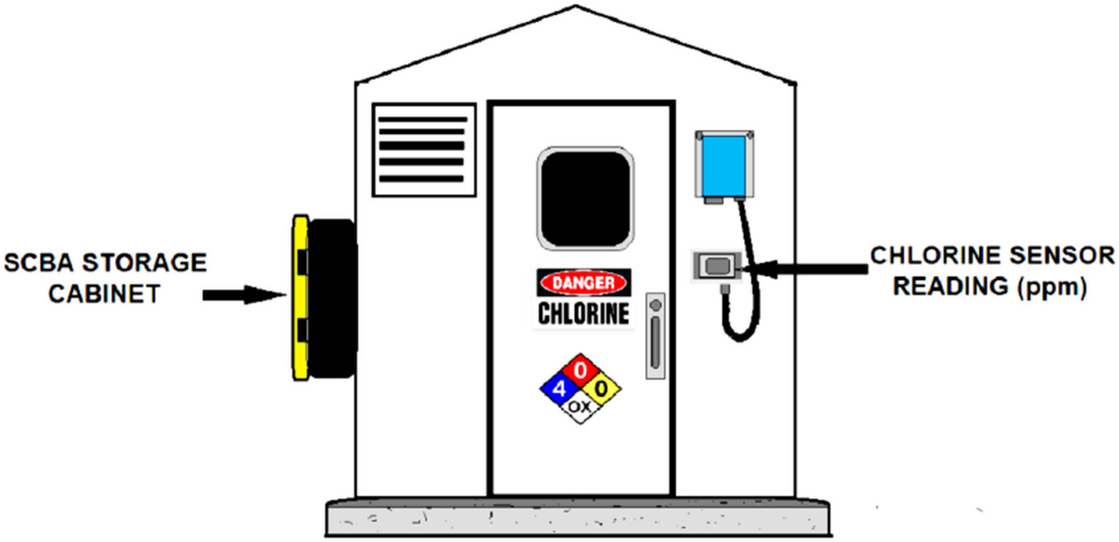
In water treatment, chlorine is added to the effluent before the contact chamber (before the clear well) for complete mixing. One reason for not adding it directly to the chamber is that the chamber has very little mixing due to low velocities.

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, skin blisters and 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.



FIBERGLASS CHLORINE STORAGE SHELTER

Operator and Public Safety
The design of gas chlorine facilities should consider operator and public safety as well as maintaining long-term plant reliability and operation.

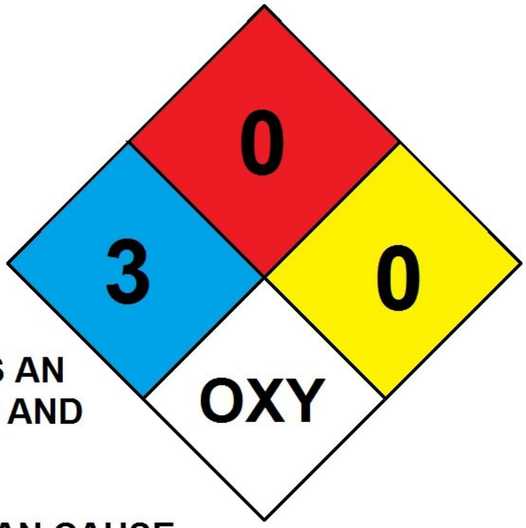
Chlorination facilities are designed such that chlorine gas can be contained in the chlorine storage room. Doors and windows should be gas-tight to minimize escape of gaseous chlorine to the exterior atmosphere or building interior.

Leak detectors should be located 1 foot above the floor of the chlorine storage room and should activate an alarm when a chlorine leak occurs. It is preferable that the detector be capable of differentiating between two or more chlorine concentrations to alert personnel of the severity of the release. This would help determine the appropriate procedure for entrance to the room, ventilation, or other solutions.

Self-contained breathing apparatus (SCBA) should not be located within the chlorine storage room. It is preferable that this equipment be located in a convenient location where personnel can easily access it in the event of an emergency.

Chlorine Health Hazard Sub-Section

- CHLORINE IS EXTREMELY IRRITATING AND CAN BURN THE EYES AND SKIN
- IF INHALED, CHLORINE CAUSES RESPIRATORY DISTRESS, AND POSSIBLY BE FATAL
- LIQUID CHLORINE RELEASE FORMS AN IMMEDIATE CLOUD (FLASH VAPOR) AND COOLS TO -29°F
- EXPOSURE TO CHLORINE LIQUID CAN CAUSE SEVERE FROSTBITE, AS WELL AS CHEMICAL BURNS.



THE HEALTH EFFECTS OF CHLORINE EXPOSURE

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.

Alternative Disinfectants Sub-Section

Chloramine

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 because it limits the formation of DBPs. In the production of chloramines, the ammonia residuals in the finished water, when fed in excess of the 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 ClO_2/chlorite/chlorate allowed in finished water. 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 ($NaClO_2$).

Ozone (O_3)

Ozone is a very effective disinfectant for both Giardia and viruses. Ozone CT values(contact time) 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.

Ultraviolet Radiation

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

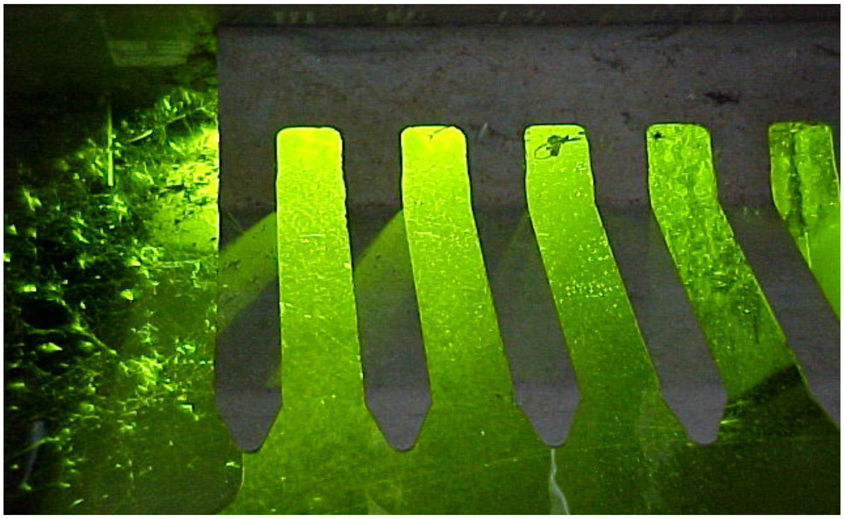
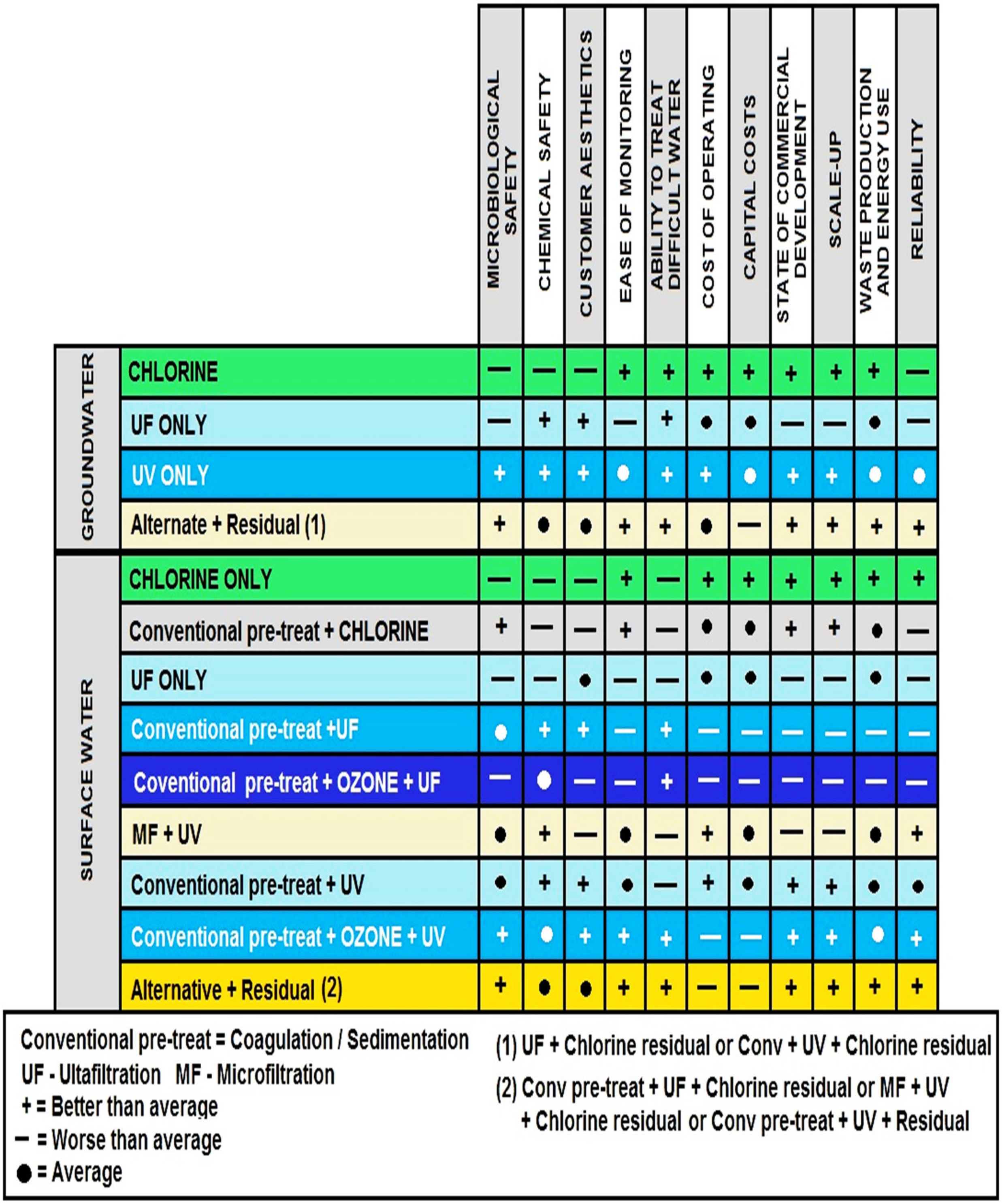


Photo of the green UV light



		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

EFFECTIVE DISNIFECTION ASSESMENT DETERMINATION CHART

Chloramine Breakdown

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 water 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: $NH_2Cl + 2HOCl \rightarrow NHCl2 + 2H_2O$
Trichloramine: $NHCl2 + 3HOCl \rightarrow NHCl_3 + 3H_2O$

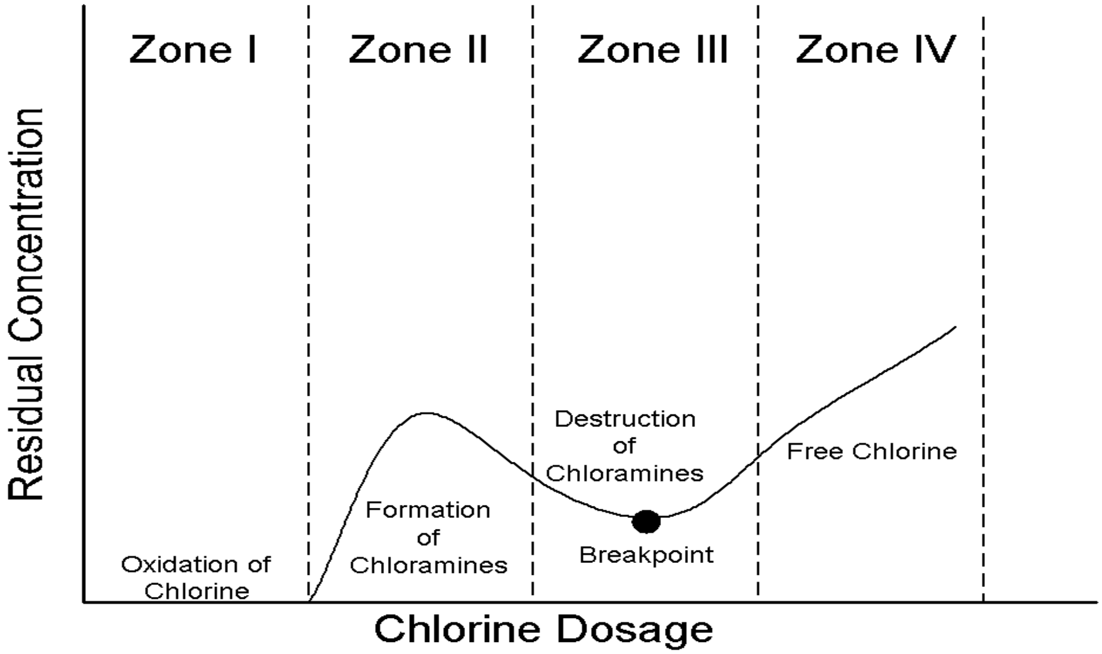
Chloramines are an effective disinfectant against bacteria but not against viruses. As a result, it is necessary to add more chlorine to the water to prevent the formation of chloramines and form other stronger forms of disinfectants.

The final step is that additional free chlorine reacts with the chloramine to produce hydrogen ion, water, and nitrogen gas that will come out of solution. In the case of the monochloramine, the following reaction occurs:

$$\mathbf{2NH_2Cl + HOCl \rightarrow N_2 + 6HCl + H_2O}$$

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, hypochlorous 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.



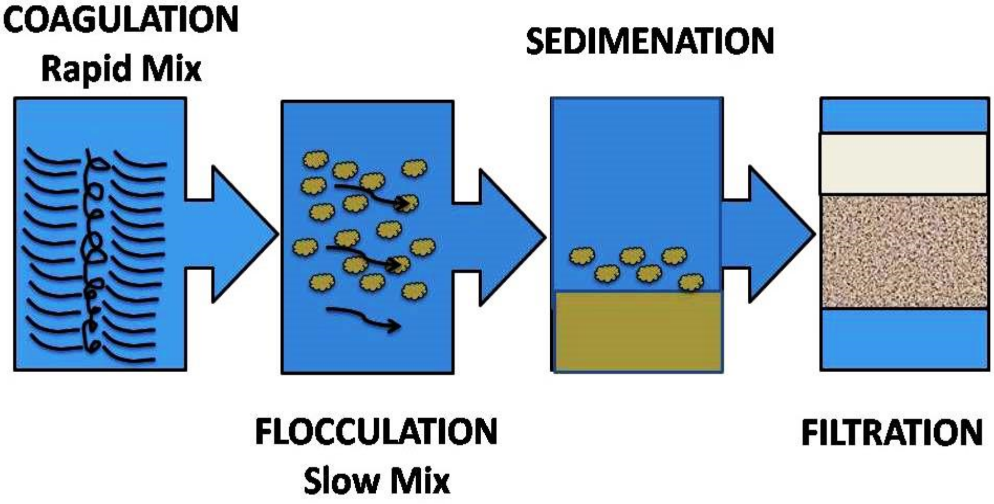
The graph shown on the last page depicts the chlorine residual as a function of increasing chlorine dosage with descriptions of each zone given below (Drawing by Erik Johnston, adapted from Reynolds and Richards, 1996).

· Zone I: Chlorine is reduced to chlorides.
· Zone II: Chloramines are formed.
· Zone III: Chloramines are broken down and converted to nitrogen gas that 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 that results from the water or wastewater's characteristics.

Water Treatment Chlorination Sequence

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.

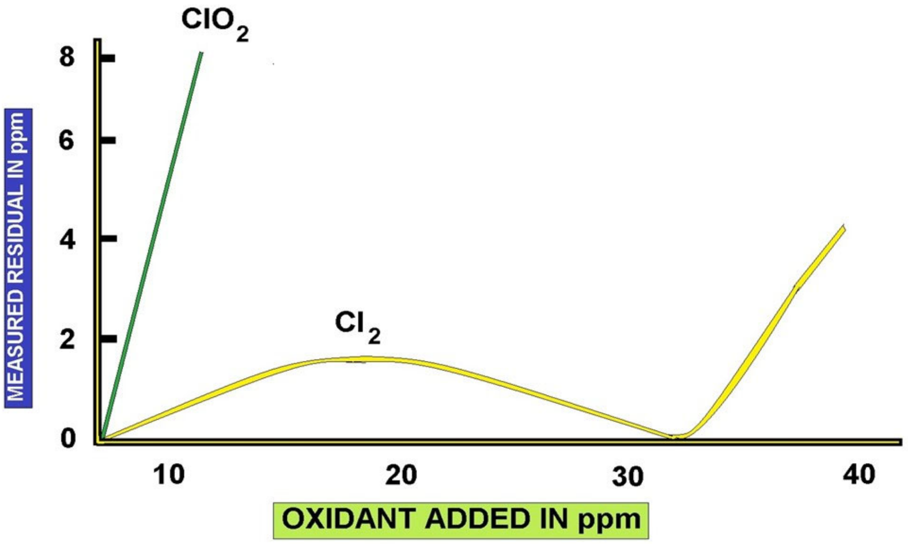
Chlorine is usually added in the rapid mixing chamber and effectively prevents the majority of algal growth. Algae is a problem in water treatment plants because it builds up on the filter media and increases the head which means that the filters need to be backwashed more frequently. In addition, the 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 Dioxide Sub-Section



Technical Learning College

USING CHLORINE DIOXIDE vs CHLORINE

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 bronchospasm 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 Cl2.

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 that 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.

Chlorine Dioxide Methods

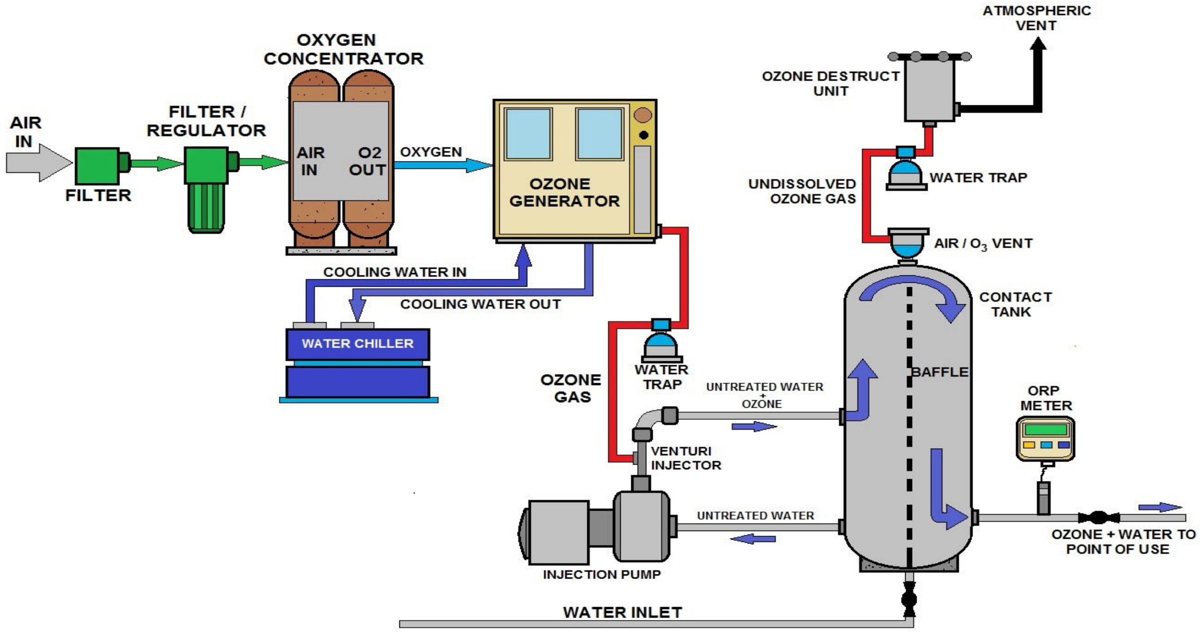
Most tests for chlorine dioxide rely upon its oxidizing properties. Consequently, numerous test kits are readily available that can be adapted to measure chlorine dioxide. In addition, new methods that are specific for chlorine dioxide are being developed. The following are the common analytical methods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

	DPD glycine	**Chlorophenol Red**	**Direct Absorbance**	**Iodometric Titration**	**Amperometric Titration**
Method Type:	Colorimetric	Colorimetric	Colorimetric	Titrimetric	Titrimetric
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

Ozone

Ozone (O_3)

Ozone is a very effective disinfectant for both Giardia and viruses. Ozone CT values(contact time) 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 GENERATION SYSTEM

T10 Value Description

Effective contact time for disinfection, in minutes. The detention time corresponding to the time for which 90% of the water remains in the unit process. For ozone chambers, the T10 value is estimated as follows: If no ozone gas is applied, then T10 = (T50*0.7); else (T50 * 0.1).

Ozone does not provide a system residual and should be used as a primary disinfectant only in conjunction with free and/or combined chlorine.

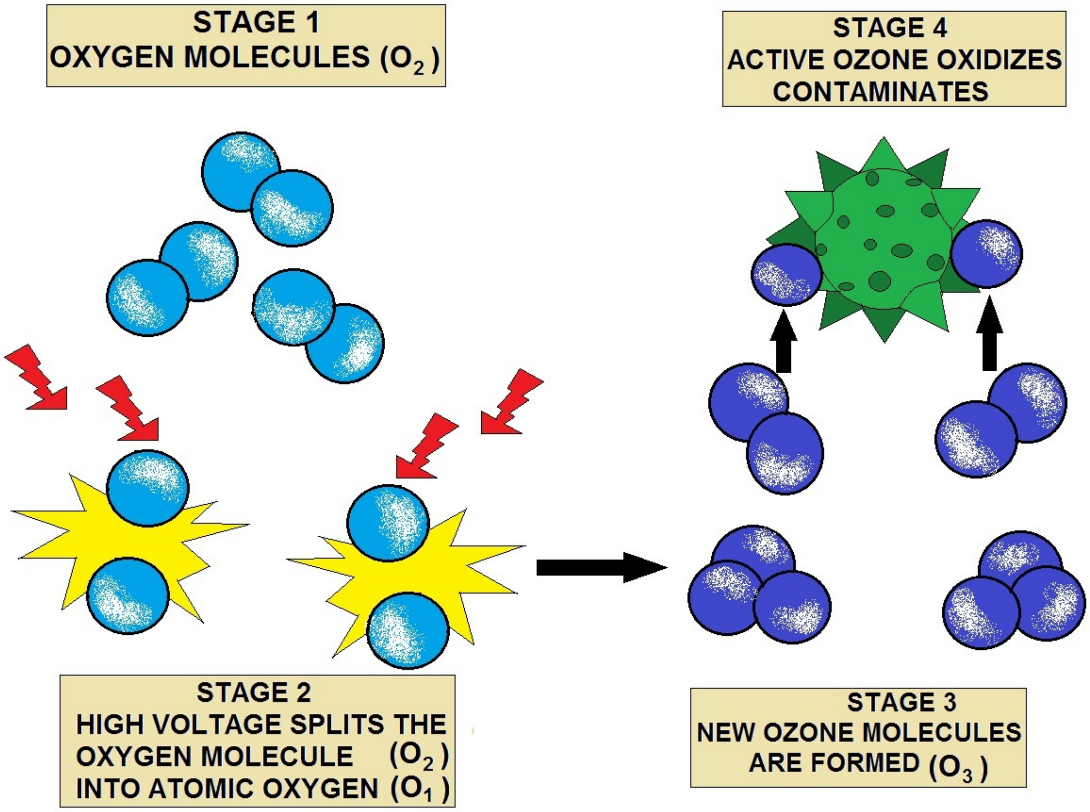
Ozone does not produce chlorinated byproducts (such as trihalomethanes) but it may cause an increase in such byproduct formation if it is fed ahead of free chlorine; ozone may also produce its own oxygenated byproducts such as aldehydes, ketones, or carboxylic acids. Ozone may also be used as an oxidant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

Ozone is probably the strongest oxidizing agent available for water treatment. 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 pungent odor similar to that sometimes noticed during and after heavy electrical storms. In use, ozone breaks down into oxygen and nascent oxygen.

$$O_3 = O_2 + O$$



HOW OZONE IS PRODUCED

It is the nascent unpaired, loose oxygen molecule that produces the high oxidation, 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 in determining ozone demand.

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 other byproducts when followed by chlorination.

Disinfectant Byproducts

Ozone is not practical for complete replacement 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, because it can produce DBPs.

Ultraviolet Radiation

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

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

The lamp itself does not come into direct contact with the water, The lamp is placed inside a quartz tube, and the water is in contact with the outside of the quartz tube. Quartz is used in this case since practically none of the UV rays are absorbed by the quartz, allowing all of the rays to reach the water.

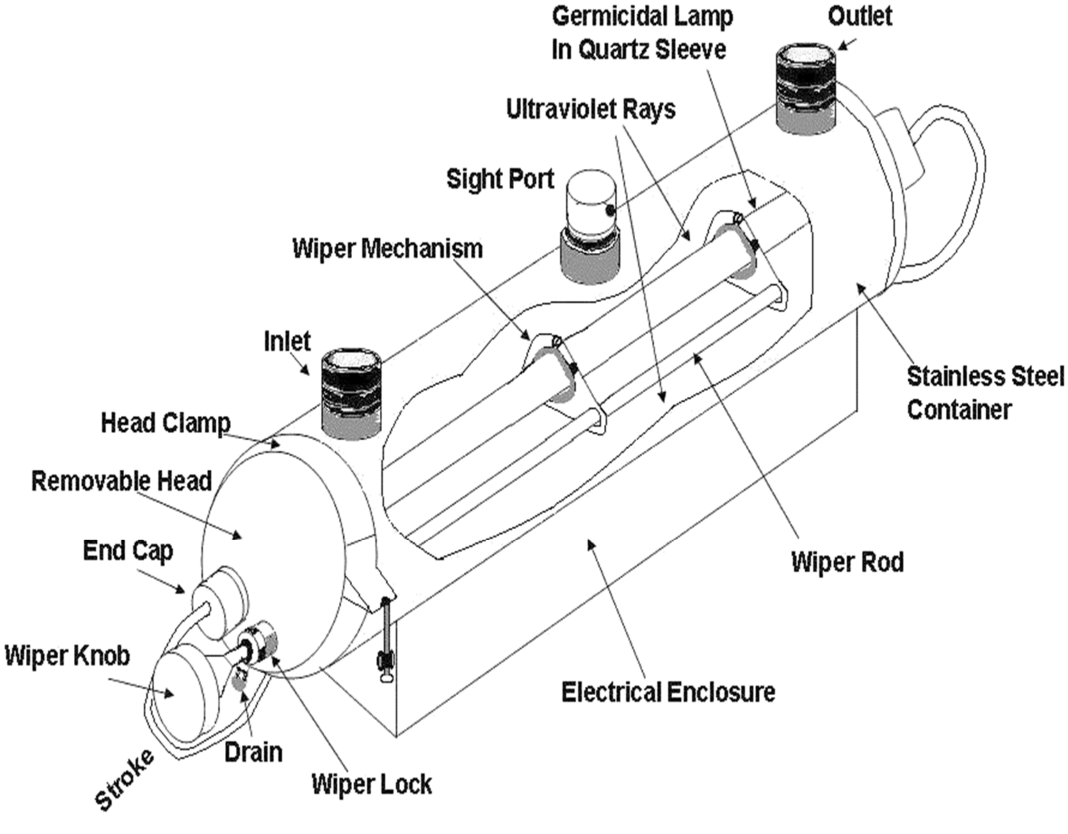
Ordinary glass cannot be used since it will absorb the UV rays, leaving little for disinfection. The water flows around the ultraviolet contactor (quartz tube). The UV sterilizer will consist of a various number of lamps and tubes, depending upon the amount of water to be treated.

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 in 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 the contact or retention time of the water in the unit is not less than 15 seconds. Most manufacturers claim UV lamps have a life of about 7,500 hours, which is about 1 years' time of continuous use.

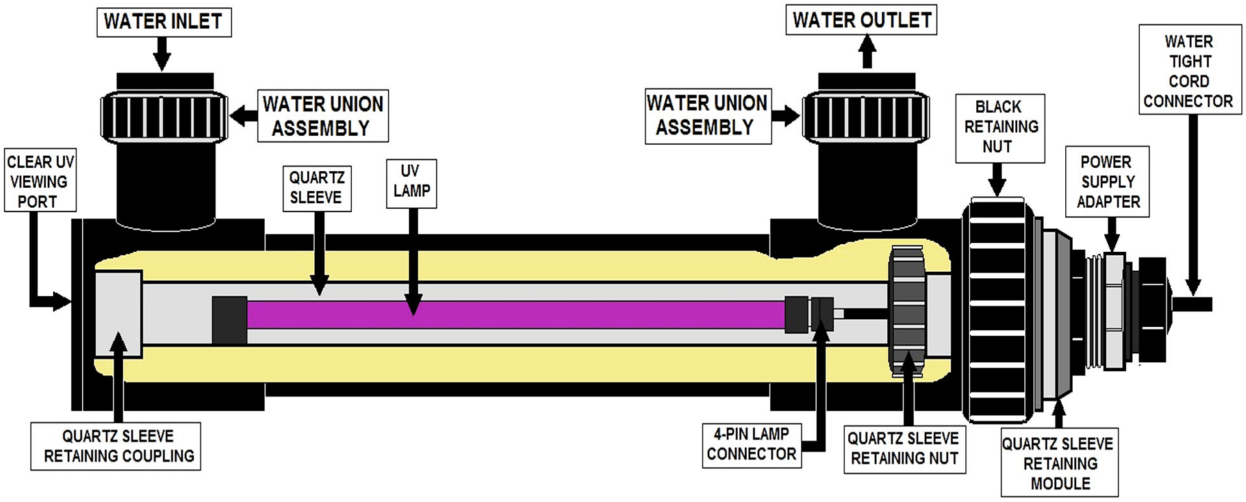
The lamp must be replaced when it loses about 40% to 50% of its UV output; in any installation this is determined by means of a photoelectric cell and a meter that shows the output of the lamp. Each lamp is outfitted with its own photoelectric cell, and an alarm that will be activated when the penetration 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.



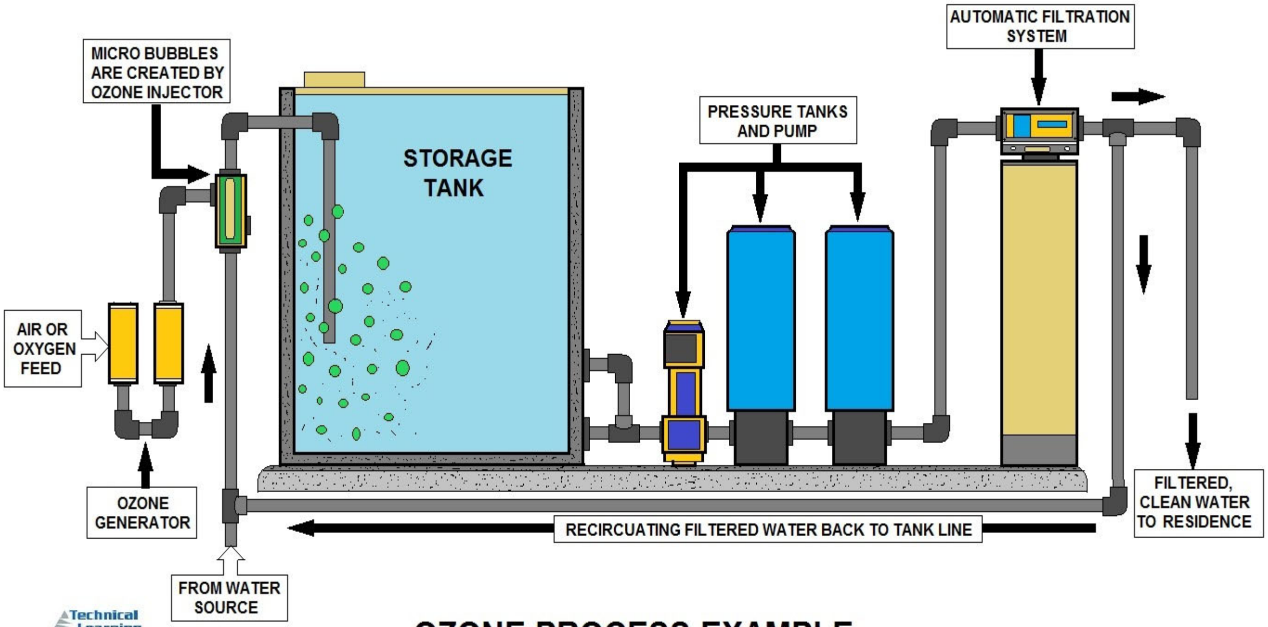
The germicidal effect of UV is thought to be associated with its absorption by various organic components essential to the cell's function. For effective use of ultraviolet, the water to be disinfected must be clean and free of any suspended solids. The water must also be colorless and free of any colloids, iron, manganese, taste, and odor. In addition, although water may appear to be clear, such substances as excesses of chlorides, bicarbonates, and sulfates affect absorption of the ultraviolet rays. The UV unit must be shielded from view for it will cause blindness. 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.

Process Comparison Diagrams



UV LIGHT USED FOR DISINFECTION

Ultraviolet light for disinfection was primarily used in the wastewater industry because of its effectiveness to deactivate microorganisms and not having to dechlorinate the effluent for discharge. In drinking water, UV has become popular because it does not produce trihalomethanes, but there is no residual disinfectant. Another consideration is the cost to operate and maintain the UV unit, which is generally higher than simple chlorination.



OZONE PROCESS EXAMPLE

Potential Water Treatment Disinfectants Health Hazards

Most water suppliers add a disinfectant to drinking water to kill germs such as Giardia and e coli, especially after heavy rainstorms.

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

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

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

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 EPA standards 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 EPA standards over many years may have an increased risk of getting cancer.

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

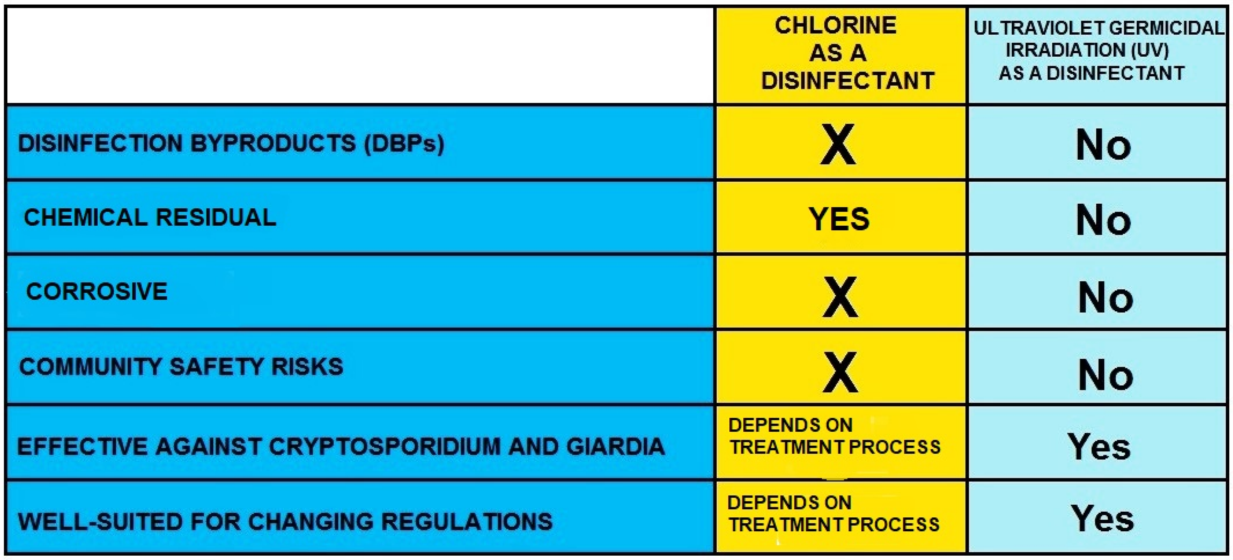
Chlorite
Some infants and young children who drink water containing chlorite in excess of EPA standards could experience nervous system effects. Similar effects may occur in fetuses of pregnant women who drink water containing chlorite in excess of EPA standards. Some people may experience anemia.

Removal of Disinfection By-Products

Disinfectant	***Disinfectant By-product***	***Disinfectant By-product Removal***
Chlorine (HOCl)	Trihalomethane (THM) Chloramine Chlorophenol	Granular Activated Carbon (GAC), resins, controlled coagulation, aeration. GAC-UV GAC
Chloramine (NH_xCl_y)	Probably no THM Others?	GAC UV?
Chlorine dioxide (ClO_2)	Chlorites Chlorates	Use of Fe_2+ in coagulation, RO, ion-exchange
Permanganate ($KMnO_4$)	No THMs	
Ozone (O_3)	Aldehydes, Carboxylics, Phthalates	GAC
Ultraviolet (UV)	None known	

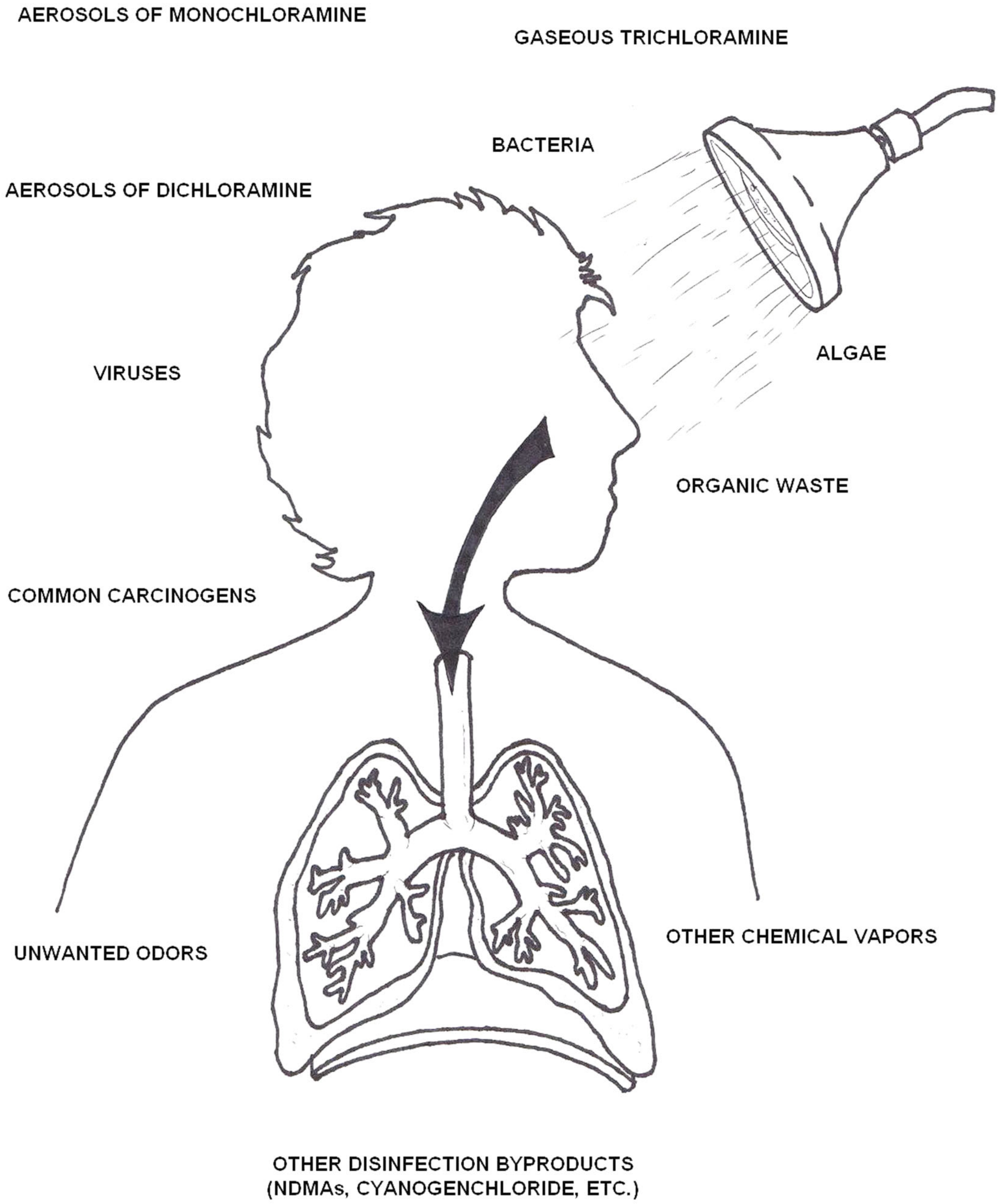
The table indicates that most of the disinfectants will leave a by-product that is or would possibly be harmful to health. This may aid a decision as to whether or not precursors should be removed before these disinfectants are added to water.

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 other processes.



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

CHLORINE vs. UV FOR DISINFECTION



Chloroform Information

Chloroform may be absorbed into the body through ingestion, inhalation, and through the skin. The largest source of human exposure to THMs in the U.S. is from the consumption of chlorinated drinking water. Besides consuming water, other water uses in the home may contribute significantly to total chloroform exposure both from breathing in chloroform vaporized into the air and from it passing through the skin during bathing. Swimming in chlorinated pools will also contribute to the total exposure from the same exposure paths. One study observed that a greater percentage of chloroform passed through the skin when bathing water temperatures were increased. Chloroform does not concentrate in plants; therefore, the contribution from food to total chloroform exposure is small.

Summary

Disinfection

Upon adding chlorine to water, two chemical species, known together as free chlorine, are formed. These species, hypochlorous acid (HOCl, electrically neutral) and hypochlorite ion (OCl-, electrically negative), behave very differently. Hypochlorous acid is not only more reactive than the hypochlorite ion, but is also a stronger disinfectant and oxidant.

The ratio of hypochlorous acid to hypochlorite ion in water is determined by the pH. At low pH (higher acidity), hypochlorous acid dominates while at high pH hypochlorite ion dominates. Thus, the speed and efficacy of chlorine disinfection against pathogens may be affected by the pH of the water being treated. Fortunately, bacteria and viruses are relatively easy targets of chlorination over a wide range of pH. However, treatment operators of surface water systems treating raw water contaminated by the parasitic protozoan Giardia may take advantage of the pH-hypochlorous acid relationship and adjust the pH to be effective against Giardia, which is much more resistant to chlorination than either viruses or bacteria.

Another reason for maintaining a predominance of hypochlorous acid during treatment has to do with the fact that pathogen surfaces carry a natural negative electrical charge. These surfaces are more readily penetrated by the uncharged, electrically neutral hypochlorous acid than the negatively charged hypochlorite ion. Moving through slime coatings, cell walls and resistant shells of waterborne microorganisms, hypochlorous acid effectively destroys these pathogens. Water is made microbiologically safe as pathogens either die or are rendered incapable of reproducing. A typical bacterium has a negatively charged slime coating on its exterior cell wall, which is effectively penetrated by electrically neutral hypochlorous acid, favored by lower pH's.

Chloramines

Chloramines are chemical compounds formed by combining a specific ratio of chlorine and ammonia in water. Because chloramines are relatively weak as a disinfectant, they are almost never used as a primary disinfectant. Chloramines provide a durable residual, and are often used as a secondary disinfectant for long distribution lines and where free chlorine demand is high. Chloramines may also be used instead of chlorine in order to reduce chlorinated byproduct formation and to remove some taste and odor problems.

Advantages

- Reduced formation of THMs, HAAs
- Will not oxidize bromide to bromine forming brominated byproducts
- More stable residual than free chlorine
- Excellent secondary disinfectant, has been found to be better than free chlorine at controlling coliform bacteria and biofilm growth
- Lower taste and odor than free chlorine

Limitations

- Weak disinfectant and oxidant
- Requires shipment and handling of ammonia or ammonia compounds as well as chlorinating chemicals
- Ammonia is toxic to fish, and may pose problems for aquarium owners
- Will cause problems for kidney dialysis if not removed from water

Chlorine Dioxide

Chlorine dioxide (ClO_2) is generated on-site at water treatment facilities. In most generators sodium chlorite and elemental chlorine are mixed in solution, which almost instantaneously forms chlorine dioxide. Chlorine dioxide characteristics are quite different from chlorine.

In solution it is a dissolved gas, which makes it largely unaffected by pH but volatile and relatively easily stripped from solution. Chlorine dioxide is also a strong disinfectant and a selective oxidant. While chlorine dioxide does produce a residual it is only rarely used for this purpose.

Advantages

- ✓ Effective against Cryptosporidium
- ✓ Up to five times faster than chlorine at inactivating Giardia
- ✓ Disinfection is only moderately affected by pH
- ✓ Will not form chlorinated byproducts (THMs, HAAs)
- ✓ Does not oxidize bromide to bromine (can form bromate in sunlight)
- ✓ More effective than chlorine in treating some taste and odor problems
- ✓ Selective oxidant used for manganese oxidation and targeting some chlorine resistant organics

Limitations

- ✓ Inorganic byproduct formation (chlorite, chlorate)
- ✓ Highly volatile residuals
- ✓ Requires on-site generation equipment and handling of chemicals (chlorine and sodium chlorite)
- ✓ Requires a high level of technical competence to operate and monitoring equipment, product and residuals
- ✓ Occasionally poses unique odor and taste problems
- ✓ High operating cost (chlorite chemical cost is high)

Disinfection Section Post 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. Liquid chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air.

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

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 container?

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 Cl_2 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 Cl_2 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 are known collectively as?

Post Quiz Answers

Topic 1- Bacteria Monitoring Post Quiz Answers
1. False, 2. False, 3. True, 4. False, 5. False, 6. True, 7. True, 8. True, 9. True, 10. False

Topic 2- Disnifection Section Post 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. 1.5 -2.5, 5. Scrubbers, 6. Gas chlorine, 7. Secure each cylinder in an upright position. Attach the protective bonnet over the valve. Firmly secure each cylinder, 8. Open chlorine metering orifice slightly. Inspect vacuum lines. Start injector water supply,9. In addition to protective clothing and goggles, chlorine gas should be used only in a well-ventilated area so that any leaking gas cannot concentrate, 10. Chlorine gas forms a mixture of hydrochloric and hypochlorous acids, 11. Because it is too easy to roll, 12. A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber colored liquid, a noncombustible gas, and a strong oxidizer. Chlorine is about 1.5 times heavier than water and gaseous chlorine is about 2.5 times heavier than air, 13. Notify local emergency response team. Warn and evacuate people in adjacent areas, be sure that no one enters the leak area without adequate self-contained breathing equipment,14. Burning of eyes, nose, and mouth; lacrimation and rhinorrhea; Coughing, sneezing, choking, nausea and vomiting; headaches and dizziness; Fatal pulmonary edema; pneumonia; conjunctivitis; keratitis; pharyngitis; burning chest pain; dyspnea; hemoptysis; hypoxemia; dermatitis; and skin blisters, 15. 646 mg/L, 16. Get out of the area of the leak, proceeding upwind, and 2) take only very short breaths through the mouth, 17. 0.195 or also written 19.5%, 18. True, 19. True, 20. True, 21. HOCl and OCl-; free available chlorine

Math Conversion Factors

1 PSI = 2.31 Feet of Water
1 Foot of Water = .433 PSI
1.13 Feet of Water = 1 Inch of Mercury
454 Grams = 1 Pound
2.54 CM =Inch
1 Gallon of Water = 8.34 Pounds
1 mg/L = 1 PPM
17.1 mg/L = 1 Grain/Gallon
1% = 10,000 mg/L
694 Gallons per Minute = MGD
1.55 Cubic Feet per Second = 1 MGD
60 Seconds = 1 Minute
1440 Minutes = 1 Day
.746 kW = 1 Horsepower

LENGTH
12 Inches = 1 Foot
3 Feet = 1 Yard
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 = 1 Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of water
62.38 Pounds = 1 Cubic Foot of water

Dimensions

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

CIRCLE: Area (sq. ft.) = 3.14 X Radius (ft) X Radius (ft)

CYLINDER: Volume (Cu. ft) = 3.14 X Radius (ft) X Radius (ft) X Depth (ft)

PIPE VOLUME: .785 X Diameter^2 X Length = ? To obtain gallons multiply by 7.48

SPHERE: $\frac{(3.14)\quad(\text{Diameter})^3}{(6)}$

Circumference = 3.14 X Diameter

General Conversions

Flowrate

Multiply	—>	to get
to get	**<—**	**Divide**
cc/min	1	mL/min
cfm (ft^3/min)	28.31	L/min
cfm (ft^3/min)	1.699	m^3/hr
cfh (ft^3/hr)	472	mL/min
cfh (ft^3/hr)	0.125	GPM
GPH	63.1	mL/min
GPH	0.134	cfh
GPM	0.227	m^3/hr
GPM	3.785	L/min
oz./min	29.57	mL/min

POUNDS PER DAY= Concentration (mg/L) X Flow (MG) X 8.34
***A.K.A.* Solids Applied Formula** = Flow X Dose X 8.34

PERCENT EFFICIENCY = $\frac{\text{In} - \text{Out}}{\text{In}} \text{ X } 100$

TEMPERATURE: $^{0}\text{F} = (^{0}\text{C X } 9/5) + 32$ $\quad 9/5 = 1.8$

$^{0}\text{C} = (^{0}\text{F} - 32) \text{ X } 5/9$ $\quad 5/9 = .555$

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

FLOW RATE (Q): Q = A X V (**Q**uantity = **A**rea X **V**elocity)

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

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

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

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

N = Manning's Coefficient of Roughness
R = Hydraulic Radius (ft.)
S = Slope of Sewer (ft/ft.)

HYDRAULIC RADIUS (ft) = $\frac{\text{Cross Sectional Area of Flow (ft)}}{\text{Wetted pipe Perimeter (ft)}}$

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

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

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

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

TOTAL HEAD (ft) = Suction Lift (ft) X Discharge Head (ft)

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

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

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

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

SLOPE = $\frac{\text{Rise (ft)}}{\text{Run (ft)}}$ **SLOPE (%)** = $\frac{\text{Rise (ft) X 100}}{\text{Run (ft)}}$

POPULATION EQUIVALENT (PE):
1 PE = .17 Pounds of BOD per Day
1 PE = .20 Pounds of Solids per Day
1 PE = 100 Gallons per Day

LEAKAGE (GPD/inch) = $\frac{\text{Leakage of Water per Day (GPD)}}{\text{Sewer Diameter (inch)}}$

CHLORINE DEMAND (mg/L) = Chlorine Dose (mg/L) – Chlorine Residual (mg/L)

MANNING FORMULA

τQ = Allowable time for decrease in pressure from 3.5 PSI to 2.5 PSI
τq = As below

$\tau Q = (0.022)\ (d_1^2L_1)/Q$ $\tau q = \frac{[\ 0.085]}{q}\ [(d_1^2L1)/(d_1L_1)]$

Q = 2.0 cfm air loss
θ = .0030 cfm air loss per square foot of internal pipe surface
δ = Pipe diameter (inches)
L = Pipe Length (feet)

$V = \frac{1.486}{\nu} R^{2/3} S^{1/2}$

V = Velocity (ft./sec.)
ν = Pipe Roughness
R = Hydraulic Radius (ft)
S= Slope (ft/ft)

HYDRAULIC RADIUS (ft) = $\frac{\text{Flow Area (ft. 2)}}{\text{Wetted Perimeter (ft.)}}$

WIDTH OF TRENCH (ft) = Base (ft) + (2 Sides) X $\frac{\text{Depth (ft 2)}}{\text{Slope}}$

.

Conversion Factors

1 acre = 43,560 square feet
1 cubic foot = 7.48 gallons
1 foot = 0.305 meters
1 gallon = 3.785 liters
1 gallon = 8.34 pounds
1 grain per gallon = 17.1 mg/L
1 horsepower = 0.746 kilowatts
1 million gallons per day = 694.45 gallons per minute
1 pound = 0.454 kilograms
1 pound per square inch = 2.31 feet of water
1% = 10,000 mg/L
Degrees Celsius = (Degrees Fahrenheit - 32) (5/9)
Degrees Fahrenheit = (Degrees Celsius * 9/5) + 32
64.7 grains = 1 cubic foot
1,000 meters = 1 kilometer
1,000 grams = 1 kilogram

REFERENCES

"Alchemy", entry in The Oxford English Dictionary, J. A. Simpson and E. S. C. Weiner, vol. 1, 2nd ed., 1989, ISBN 0-19-861213-3.
"Ancients & Alchemists - Time line of achievement". Chemical Heritage Society.
"Arabic alchemy", Georges C. Anawati, pp. 853–885 in Encyclopedia of the history of Arabic science, eds. Roshdi Rashed and Régis Morelon, London: Routledge, 1996, vol. 3, ISBN 0-415-12412-3.
"California Occupational Guide Number 22: Chemists". Calmis.ca.gov. 1999-10-29.
"Carlsberg Group Company History Page". Carlsberggroup.com.
"Chemical bonding". Britannica. Encyclopædia Britannica.
"Chemistry". Chemistry2011.org.
"General Chemistry Online - Companion Notes: Matter". Antoine.frostburg.edu.
"History - Robert Boyle (1627–1691)".
"History of Acidity". Bbc.co.uk.
"History of Alchemy". Alchemy Lab.
"International Year of Chemistry - The History of Chemistry". G.I.T. Laboratory Journal Europe.
"IUPAC Nomenclature of Organic Chemistry". Acdlabs.com.
"Official SI Unit definitions". Bipm.org.
"Robert Boyle, Founder of Modern Chemistry" Harry Sootin (2011).
"The Lewis Acid-Base Concept". Apsidium.
"What is Chemistry?". Chemweb.ucc.ie.
ACGIH [1991]. Documentation of the threshold limit values and biological exposure indices. 6th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
ACGIH [1994]. 1994-1995 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
Armstrong, James (2012). General, Organic, and Biochemistry: An Applied Approach. Brooks/Cole. p. 48. ISBN 978-0-534-49349-3.
Atkins & de Paula 2009, p. 9.
Atkins, Peter; de Paula, Julio (2009) [1992]. Elements of Physical Chemistry (5th Ed.). New York: Oxford University Press. ISBN 978-0-19-922672-6.
ATS [1987]. Standardization of spirometry -- 1987 update. American Thoracic Society. Am Rev Respir
Barnes, Ruth. Textiles in Indian Ocean Societies. Routledge. p. 1.
Basic Principles of Water Treatment, Littleton, Colorado. Tall Oaks Publishing Inc.
Bates, Roger G. Determination of pH: theory and practice. Wiley, 1973.
Benenson, Abram S., editor. 1990. Control of Communicable Diseases in Man. 15th ed. Baltimore: Victor Graphics, Inc.
Bick, H. 1972. Ciliated protozoa. An illustrated guide to the species used as biological indicators in freshwater biology. World Health Organization, Geneva. 198 pp.
Bick, H. 1972. Ciliated protozoa. An illustrated guide to the species used as biological indicators in freshwater biology. World Health Organization, Geneva. 198 pp.
Bickford, T.M., Lindsey, B.D., and Beaver, M.R., 1996, Bacteriological quality of groundwater used for
Bisson, J.W. and Cabelli, V.J., 1980, Clostridium perfringens as a water pollution indicator: Journal of the Water Pollution Control Federation, v. 52, no. 2, p. 241-248.
Born, Stephen M., Douglas A. Yanggen, and Alexander Zaporozec. A Guide to Groundwater Quality Planning and Management for Local Governments. Wisconsin Geological and Natural History Survey, Madison, WI, 1987.
Born, Stephen M., Douglas A. Yanggen, and Alexander Zaporozec. A Guide to Groundwater Quality Planning and Management for Local Governments. Wisconsin Geological and Natural History Survey, Madison, WI, 1987.
Boyle, Robert (1661). The Sceptical Chymist. New York: Dover Publications, Inc. (reprint). ISBN 0-486-42825-7.
Brenner, K.P., Rankin, C.C., Roybal, Y.R., Stelma, G.R., Scarpino, P.V., and Dufour, A.P., 1993, New medium for simultaneous detection of total coliforms and Escherichia coli in water: Applied and Environmental Microbiology, v. 59, no. 11, p. 3534-3544.

Britton, L.J., and Greeson, P.E., ed., 1989, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A4, 363 p.
Brooks, D., and Cech, I., 1979, Nitrates and bacterial distribution in rural domestic water supplies: Water
*Bunge, M. (1982). "Is chemistry a branch of physics?" Journal for the General Philosophy of Science - Zeitschrift für allgemeine Wissenschaftstheorie **13** (2): 209–223. doi:10.1007/BF01801556.*
Burrows et al. 2008, p. 12. p. 13, p. 16, p. 110.
Burrows, Andrew; Holman, John; Parsons, Andrew; Pilling, Gwen; Price, Gareth (2009). Chemistry^3. Italy: Oxford University Press. ISBN 978-0-19-927789-6.
Butterworth, B.E., Kedderis, G.L., and Conolly, R.B. (1998) The chloroform risk assessment: A mirror of scientific understanding. CIIT Activities,18 no.4.
Cabelli, V.J., 1981, Health effects criteria for marine recreational waters: Cincinnati, Ohio, U.S. Environmental Protection Agency, EPA-600/1-80-031.
Cairns, J., and J.A. Ruthven. 1972. A test of the cosmopolitan distribution of fresh-water protozoans. Hydrobiologia 39:405-427.
Cairns, J., and W.H. Yongue. 1977. Factors affecting the number of species of freshwater protozoan communities. Pages 257-303 in J. Cairns, ed. Aquatic microbial communities. Garland, New York.
Cairns, J., G.R. Lanza, and B.C. Parker. 1972. Pollution related structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa. Proceedings of the National Academy of Sciences 124:79-127.
CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.
Chang, Raymond (1998). Chemistry, 6th Ed. New York: McGraw Hill. ISBN 0-07-115221-0.
Changing States of Matter - Chemforkids.com.
Chemical Reaction Equation- IUPAC Goldbook.
Chemistry is seen as occupying an intermediate position in a hierarchy of the sciences by reductive level between physics and biology. Carsten Reinhardt. Chemical Sciences in the 20th Century: Bridging Boundaries. Wiley-VCH, 2001. ISBN 3-527-30271-9. Pages 1–2.
Chemistry. (n.d.). Merriam-Webster's Medical Dictionary.
Christian, M.S., York, R.G., Hoberman, A.M., Diener, R.M., and Fisher, L.C. (2001b). Oral (drinking water) developmental toxicity studies of bromodichloromethane (BDCM) in rats and rabbits. International Journal of Toxicology, 20, 225-237.
Christian, M.S., York, R.G., Hoberman, A.M., Diener, R.M., Fisher, L.C., and Gates, G.A. (2001a). Biodisposition of dibromoacetic acid (DBA) and bromodichloromethane (BDCM) administered to rats and rabbits in drinking water during range-finding reproduction and developmental toxicity studies. International Journal of Toxicology, 20, 239-253.
Christian, M.S., York, R.G., Hoberman, A.M., Fisher, L.C., and Brown, W.R. (2002a). Oral (drinking water) two-generation reproductive toxicity study of bromodichloromethane (BDCM) in rats. International Journal of Toxicology, 21, 115-146.
Christian, M.S., York, R.G., Hoberman, A.M., Frazee, J., Fisher, L.C., Brown, W.R., and Creasy, D.M. (2002b). Oral (drinking water) two-generation reproductive toxicity study of dibromoacetic acid (DBA) in rats. International Journal of Toxicology, 21, 1-40.
Clayton G, Clayton F [1981-1982]. Patty's industrial hygiene and toxicology. 3rd rev. ed. New York, NY: John Wiley & Sons.
Concern, Inc. Groundwater: A Community Action Guide. Washington, D.C., 1989.
Connell, G.F. (1996). The chlorination/chloramination handbook. Denver: American Water Works Ass.
Coulston, F., and Kolbye, A. (Eds.) (1994). Regulatory Toxicology and Pharmacology, vol. 20, no. 1, pt 2.
*Covington, A. K.; Bates, R. G.; Durst, R. A. (1985). "Definitions of pH scales, standard reference values, measurement of pH, and related terminology" (PDF). Pure Appl. Chem. **57** (3): 531–542. doi:10.1351/pac198557030531.*
Craun, G.F., 1992, Waterborne disease outbreaks in the United States of America—Causes and prevention: World Health Statistician Quarterly, v. 45.
Craun, G.F., and Calderon, R., 1996, Microbial risks in groundwater systems–Epidemiology of waterborne outbreaks, in Under the microscope–Examining microbes in groundwater, Proceedings of the Groundwater Foundation’s 12th Annual Fall Symposium, Sept. 5-6, 1996, Boston, Mass.: Research Foundation of the American Water Works Association.

Craun, G.F., Hauchman, F.S. and Robinson D.E. (Eds.) (2001). Microbial pathogens and disinfection byproducts in drinking water: Health effects and management of risks, Conference Conclusions, (pp.533-545). Washington, D.C.: ILSI Press.

Craun, G.F., Nwachuku, N., Calderon, R.L., and Craun, M.F. (2002). Outbreaks in drinking-water systems, 1991-1998. Journal of Environmental Health, 65, 16-25.

Cross, Brad L and Jack Schulze. City of Hurst (A Public Water Supply Protection Strategy). Texas Water Commission, Austin, TX, 1989.

Curds, C.R. 1992. Protozoa and the water industry. Cambridge University Press, MA. 122 pp.

Curtis, Christopher and Teri Anderson. A Guidebook for Organizing a Community Collection Event: Household Hazardous Waste. Pioneer Valley Planning Commission and Western Massachusetts Coalition for Safe Waste Management, West Springfield, MA, 1984.

Curtis, Christopher, Christopher Walsh, and Michael Przybyla. The Road Salt Management Handbook: Introducing a Reliable Strategy to Safeguard People & Water Resources. Pioneer Valley Planning Commission, West Springfield, MA, 1986.

Davis, J.V., and Witt, E.C., III, 1998, Microbiological quality of public-water supplies in the Ozark Plateaus Aquifer System: U.S. Geological Survey Fact Sheet 028-98, 2 p.

Davy, Humphry (1808). "On some new Phenomena of Chemical Changes produced by Electricity, particularly the Decomposition of the fixed Alkalies, and the Exhibition of the new Substances, which constitute their Bases". Philosophical Transactions of the Royal Society (Royal Society of London.) ***98*** *(0): 1–45. doi:10.1098/rstl.1808.0001.*

DiNovo, F., and Jaffe, M., 1984, Local groundwater protection–Midwest Region: Chicago, Ill., American Planning Association., chap. 2-4, p. 5-40.

DOT [1993]. 1993 Emergency response guidebook, guide 20. Washington, DC: U.S. Department of Transportation, Office of Hazardous Materials Transportation, Research and Special Programs Administration.

Dufour, A.P., 1984, Health effects criteria for fresh recreational waters: Cincinnati, Ohio, U.S. Environmental Protection Agency, EPA-600/1-84-004.

Dumas, J. B. (1837). 'Affinite' (lecture notes), vii, pg 4. "Statique chimique", Paris: Academie des Sciences.

Dutka, B.J., Palmateer, G.A., Meissner, S.M., Janzen, E.M., and Sakellaris, M., 1990, The presence of bacterial virus in groundwater and treated drinking water: Environmental Pollution, v. 63.

Eagle, Cassandra T.; Jennifer Sloan (1998). "Marie Anne Paulze Lavoisier: The Mother of Modern Chemistry". The Chemical Educator (PDF) ***3*** *(5): 1–18. doi:10.1007/s00897980249a.*

Edwards, T.K., and Glysson, G.D., 1988, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C2, 89 p.

Embrey, S.S., 1992, Surface-water-quality assessment of the Yakima River Basin, Washington—Areal distribution of fecal-indicator bacteria, July 1988: U.S. Geological Survey Water-Resources Investigations Report 91- 4073, 33 p.

Feldman, Isaac (1956). "Use and Abuse of pH measurements". Analytical Chemistry ***28*** *(12): 1859. doi:10.1021/ac60120a014.*

Fenchel, T. 1974. Intrinsic rate increase: the relationship with body size. Oecologia 14:317-326.

Fenchel, T., T. Perry, and A. Thane. 1977. Anaerobiosis and symbiosis with bacteria in free-living ciliates. Journal of Protozoology 24:154-163.

Fenchel, T., T. Perry, and A. Thane. 1977. Anaerobiosis and symbiosis with bacteria in free-living ciliates. Journal of Protozoology 24:154-163.

First chemists, February 13, 1999, New Scientist.

Flint, K.P., 1987, The long-term survival of Escherichia coli in river water: Journal of Applied Bact, v. 63.

Foissner, W. 1987. Soil protozoa: fundamental problems, ecological significance, adaptations in ciliates and testaceans, bioindicators, and guide to the literature. Progress in Protistology 2:69-212.

Foissner, W. 1988. Taxonomic and nomenclatural revision of Stádecek's list of ciliates (Protozoa: Ciliophora) as indicators of water quality. Hydrobiologia 166:1-64.

Ford, T.E. and Colwell R.R. (1996). A global decline in microbiological safety of water: A call for action, a report prepared for the American Academy of Microbiology.

Forsberg K, Mansdorf SZ [1993]. Quick selection guide to chemical protective clothing. New York, NY: Van Nostrand Reinhold.

Foster, Laurence, M.D. 1985. "Waterborne Disease - It's Our Job to Prevent It". PIPELINE newsletter, Oregon Health Division, Drinking Water Program, Portland, Oregon 1(4): 1-3.

Foster, Laurence, M.D. 1990. "Waterborne Disease," Methods for the Investigation and Prevention of Waterborne Disease Outbreaks. Ed. Gunther F. Craun. Cincinnati: U.S. Environ Protection Agency.

Francy, D.S. and Darner, R. A., 1998, Factors affecting Escherichia coli concentrations at Lake Erie public bathing beaches: U.S. Geological Survey Water- Resources Investigations Report 98-4241, 42 p.

Francy, D.S., Hart, T.L., and Virosteck, C.M., 1996, Effects of receiving-water quality and wastewater treatment on injury, survival, and regrowth of fecal-indicator bacteria and implications for assessment of recreational water quality: U.S. Geological Survey Water- Resources Investigations Report 96-4199.

Francy, D.S., Helsel, D.L., and Nally, R.A., 2000, Occurrence and distribution of microbiological indicators in groundwater and streamwater: Water Environment Research. v. 72, no. 2., p. 152-161.

Francy, D.S., Jones, A.L., Myers, D.N., Rowe, G.L., Eberle, Michael, and Sarver, K.M., 1998, Quality-assurance/quality-control manual for collection and analysis of water-quality data in the Ohio District, U.S. Geological Survey: U.S. Geological Survey Water-Resources Investigations Report 98-4057, 71 p.

Francy, D.S., Myers, D.N., and Metzker, K.D., 1993, Escherichia coli and fecal-coliform bacteria as indicators of recreational water quality: U.S. Geological Survey Water-Resources Investigations Report 93-4083.

Fujioka, R.S. and Shizumura, L.K., 1985, Clostridium perfringens, a reliable indicator of streamwater quality: Journal of the Water Pollution Control Federation, v. 57, no. 10, p. 986-992.

Gannon, J.T., Manilal, V.B., and Alexander, M., 1991, Relationship between cell surface properties and transport of bacteria through soil: Applied and Environmental Microbiology, v. 57, n. 1, p. 190-193.

Geldreich, E.E., 1976, Fecal coliform and fecal streptococcus density relationships in waste discharges and receiving waters: CRC Critical Reviews in Environmental Control, October 1976, p. 349-369.

Genium [1992]. Safety Data Sheets (SDS) No. 53. Schenectady, NY: Genium Publishing Corporation.

Gerba, C.P., and Bitton, G., 1984, Microbial pollutants—Their survival and transport pattern in ground

Giese, A.C. 1973. Blepharisma. Stanford University Press, CA. 366 pp.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program— Occurrence and distribution water-quality conditions: U.S. Geological Survey Cirr 1112, 33 p.

Glaser, Christopher (1663). Traite de la chymie. Paris. as found in: Kim, Mi Gyung (2003). Affinity, That Elusive Dream - A Genealogy of the Chemical Revolution. The MIT Press. ISBN 0-262-11273-6.

Gold Book Chemical Reaction IUPAC Goldbook.

Gordon, Wendy. A Citizen's Handbook on Groundwater Protection. Natural Resources Defense Council, New York, NY 1984.

Grant WM [1986]. Toxicology of the eye. 3rd ed. Springfield, IL: Charles C Thomas.

Guerra de Macedo, G. (1991). Pan American Health Organization. Ref. No. HPE/PER/CWS/010/28/1.1.

Guerrant, R.L. (1997). Cryptosporidiosis: An emerging, highly infectious threat. Emerging Infectious Diseases, 3, Synopses. [On-Line.] Available: http://www.cdc.gov/ncidod/ied/vol3no1/guerrant.htm

Handzel, T.R., Green. R.M., Sanchez, C., Chung, H., and Sobsey, M.D., 1993, Improved specificity in detecting F-specific coliphages in environmental samples by suppression of somatic phages: Water Science Technology, v. 27, no. 3-4, p. 123-131.

Harrison, Ellen Z. and Mary Ann Dickinson. Protecting Connecticut's Groundwater: A Guide to Groundwater Protection for Local Officials. Connecticut Department of Environmental Protection, Hartford, CT, 1984.

Hathaway GJ, Proctor NH, Hughes JP, and Fischman ML [1991]. Proctor and Hughes' chemical hazards of the workplace. 3rd ed. New York, NY: Van Nostrand Reinhold.

Havelaar, A.H., van Olphen, M., and Drost, Y.C., 1993, F specific bacteriophages are adequate model organisms for enteric viruses in fresh water: Applied and Environmental Microbiology, v. 59, n. 9, p. 2956-2962.

Helsel, D.R. and Hirsch, R.M., 1992, Statistical methods in water resources: New York, Elsevier Science Publishing Company.

Herbst, Eric (May 12, 2005). "Chemistry of Star-Forming Regions". Journal of Physical Chemistry A ***109*** *(18): 4017–4029. doi:10.1021/jp050461c. PMID 16833724.*

Hernandez-Delgado, E.A., Sierra, M.L., and Toranzos, G.A., 1991, Coliphages as alternate indicators of fecal contamination in tropical waters: Environmental Toxicology and Water Quality, v. 6, p. 131-143.

Herwaldt, B.L., Craun, G.F., Stokes, S.L., and Juranek, D.D., 1991, Waterborne-disease outbreaks, 1989-1990: Morbidity and Mortality Weekly Report, Centers for Disease Control, v. 40, no. SS-3, p. 1-13.

Hill, J.W.; Petrucci, R.H.; McCreary, T.W.; Perry, S.S. (2005). General Chemistry (4th ed.). Upper Saddle River, New Jersey: Pearson Prentice Hall. p. 37.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for a national-water quality assessment program: U.S. Geological Survey Circular 1021.

Housecroft & Sharpe 2008, p. 2.

Housecroft, Catherine E.; Sharpe, Alan G. (2008) [2001]. Inorganic Chemistry (3rd Ed.). Harlow, Essex: Pearson Education. ISBN 978-0-13-175553-6.

household supply, Lower Susquehanna River Basin, Pennsylvania and Maryland: U.S. Geological Survey Water-Resources Investigations Report 96-4212.

Howell, J.M., Coyne, M.S., and Cornelius, P., 1995, Fecal bacteria in agricultural waters of the Bluegrass Region of Kentucky: Journal of Environmental Quality, v. 24, p. 411-419.

Hrezo, Margaret and Pat Nickinson. Protecting Virginia's Groundwater A Handbook for Local Government Officials. Virginia Polytechnic Institute and State University, Blacksburg, VA, 1986.

Ihde, Aaron John (1984). The Development of Modern Chemistry. Courier Dover Publications. p. 164. ISBN 0-486-64235-6.

Ijzerman, M.M., and Hagedorn, C., 1992, Improved method for coliphage detection based on □-galactosidase induction: Journal of Virological Methods, v. 40, p. 31-36.

International Association of Water Pollution Research and Control Study Group on Health Related Water Microbiology, 1991, Bacteriophages as model viruses in water quality control: Water Research, v. 25, no. 5, p. 529-545.

International Programme on Chemical Safety (2000). Disinfectants and disinfectant byproducts, Environmental Health Criteria 216.

IUPAC Gold Book Definition.

IUPAC Provisional Recommendations for the Nomenclature of Inorganic Chemistry (2004)

Jaffe, Martin and Frank Dinovo. Local Groundwater Protection. American Planning Association, Chicago, IL, 1987.

Kirmeyer, G.J. (1994). An assessment of the condition of North American water distribution systems and associated research needs. American Water Works Association Research Foundation Project #706.

Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Groundwaterdata-collection protocols and procedures for the National Water-Quality Assessment Program—Collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95-399, 113 p.

Kreier, J.P., and J.R. Baker. 1987. Parasitic protozoa. Allen and Unwin, Boston, MA. 241 pp.

Larson, J.L., Wolf, D.C., and Butterworth, B.E. (1994b). Induced cytotoxicity and cell proliferation in the hepatocarcinogenicity of chloroform in female B6C3F1 mice: comparison of administration by gavage in corn oil vs. ad libitum in drinking water. Fundamentals and Applied Toxicology, 22, 90-102.

Laybourn, J., and B.J. Finlay. 1976. Respiratory energy losses related to cell weight and temperature in ciliated protozoa. Oecologia 44:165-174.

LeChevallier, M.W., Norton, W.D., and Lee, R.G., 1991, Occurrence of Giardia and Cryptosporidium species in surface water supplies: Applied and Environmental Microbiology, v. 57, no. 9, p. 2610-2616.

Lee, C.C., and T. Fenchel. 1972. Studies on ciliates associated with sea ice from Antarctica. II. Temperature responses and tolerances in ciliates from Antarctica, temperate and tropical habitats. Archive für Protistenkunde 114:237-244.

Loomis, George and Yael Calhoon. "Natural Resource Facts: Maintaining Your Septic System." University of Rhode Island, Providence, RI, 1988.

Macozzi, Maureen. Groundwater- Protecting Wisconsin's Buried Treasure. Wisconsin Department of Natural Resources, Madison, WI, 1989.

Maine Ass of Conservation Comm. Groundwater... Maine's Hidden Resource. Hallowell, ME, 1985.

Massachusetts Audubon Society "Local Authority for Groundwater Protection." Groundwater Information Flyer #4. Lincoln, MA, 1984.

Massachusetts Audubon Society. "Groundwater and Contamination: From the Watershed into the Well." Groundwater Information Flyer # 2. Lincoln, MA, 1984.

Massachusetts Audubon Society. "Mapping Aquifers and Recharge Areas." Groundwater Information Flyer # 3. Lincoln, MA, 1984.

Massachusetts Audubon Society. "Road Salt and Groundwater Protection." Groundwater Information Flyer # 9. Lincoln, MA, 1987.

McCann, Alyson and Thomas P Husband. "Natural Resources Facts: Household Hazardous Waste." University of Rhode Island, Providence, RI; 1988.
Miller, David W. Groundwater Cont.: A Special Report. Geraghty & Miller, Inc., Syosset, NY 1982.
Montagnes, D.J.S., D.H. Lynn, J.C. Roff, and W.D. Taylor. 1988. The annual cycle of heterotrophic planktonic ciliates in the waters surrounding the Isles of Shoals, Gulf of Maine: an assessment of their trophic role. Marine Biology 99:21-30.
Mullikin, Elizabeth B. An Ounce of Prevention: A Groundwater Protection Handbook for Local Officials. Vermont Departments of Water Resources and Environmental Engineering, Health, and Agriculture, Montpelier, VT, 1984.
Murphy, Jim. "Groundwater and Your Town: What Your Town Can Do Right Now." Connecticut Department of Environmental Protection, Hartford, CT.
National Research Council. Groundwater Quality Protection: State and Local Strategies. National Academy Press, Washington, D.C., 1986.
New England Interstate Water Pollution Control Commission. "Groundwater: Out of Sight Not Out of Danger." Boston, MA, 1989.
Niederlehner, B.R., K.W. Pontasch, J.R. Pratt, and J. Cairns. 1990. Field evaluation of predictions of environmental effects from multispecies microcosm toxicity test. Archives of Environmental Contamination and Toxicology 19:62-71.
Noake, Kimberly D. Guide to Contamination Sources for Wellhead Protection. Draft. Massachusetts Department of Environmental Quality Engineering, Boston, MA, 1988.
Office of GroundwaterProtection. Guidelines for Delineation of Wellhead Protection Areas. U.S. EPA, Washington, D.C., 1987.
Office of GroundwaterProtection. Survey of State Groundwater Quality Protection Legislation Enacted From 1985 Through 1987. U.S. EPA, Washington, D.C., 1988.
Office of GroundwaterProtection. Wellhead Protection Programs. - Tools for Local Governments. U.S. EPA, Washington, D.C., 1989.
Office of GroundwaterProtection. Wellhead Protection: A Decision-Makers' Guide. U.S. EPA, Washington, D.C., 1987
Office of Pesticides and Toxic Substances. Citizen's Guide to Pesticides. U.S. EPA, Wa, D.C., 1989.
Office of Underground Storage Tanks. Musts for USGS. - A Summary of the New Regulations for Underground Storage Tank Systems. U.S. EPA, Washington, D.C., 1988.
Ohio Environmental Protection Agency. Groundwater. Columbus, OH.
Redlich, Susan. Summary of Municipal Actions for Groundwater Protection in the New England/New York Region. New England Interstate Water Pollution Control Commission, Boston, MA, 1988.
Southern Arizona Water Resources Association. "Water Warnings: Our Drinking Water.... It Takes Everyone to Keep It Clean." Tucson, AZ.
Sponenberg, Torsten D. and Jacob H. Kahn. A Groundwater Primer for Virginians. Virginia Polytechnic Institute and State University, Blacksburg, VA, 1984.
Taylor, W., and R. Sanders. 1991. Protozoa. Pages 37-93 in J.H. Thorp and A.P. Covich, eds. Ecology and classification of North American freshwater invertebrates. Academic Press, New York.
Texas Water Commission. "On Dangerous Ground: The Problem of Abandoned Wells in Texas." Austin, TX, 1989.
Texas Water Commission. The Underground Subject: An Introduction to Groundwater Issues in Texas. Austin, TX, 1989.
U.S. Environmental Protection Agency. Seminar Publication: Protection of Public Water Supplies from GroundwaterContaminants. Center for Environmental Research Information, Cincinnati, OH, 1985.
Waller, Roger M. Groundwater and the Rural Homeowner. U.S. Geological Survey, Reston, VA, 1988.

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

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

Once we grade it, we will email a certificate of completion to you.

Call us if you need any help.

If you need your certificate back within 48 hours, you may be asked to pay a rush service fee of $50.00.

You can download the assignment in Microsoft Word from TLC's website under the Assignment Page. www.abctlc.com

You will have 90 days to successfully complete this assignment with a score of 70% or better. If you need any assistance, please contact TLC's Student Services.