WATER & WASTEWATER SAMPLING COURSE

CONTINUING EDUCATION
PROFESSIONAL DEVELOPMENT COURSE

Technical Learning College

Printing and Saving Instructions

It is recommended that you download this pdf document and assignment 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 on your computer or you can print it out. This course booklet does not have the assignment (the test). Please visit our website and download the assignment (the test).

Printing Instructions: Once you have purchased the program, we will give you permission to print this document. If you are going to print this document, it was designed to be printed double-sided or duplexed but can be printed single-sided.

Hyperlink to Assignment…
http://www.abctlc.com/downloads/PDF/SAMPLING%20ASSIGNMENT.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 Do not solely trust our list for it may be outdated.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 $169.95 plus shipping charges.

All downloads are electronically tracked and monitored for security purposes.

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Do not solely depend on TLC's Approval list for it may be outdated.

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, and 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

Bacteria sample bottles or Bac-Ts. The yellow color indicates that coliform bacteria is present. You can also purchase a blue indicator color instead of yellow.

This course covers 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.

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.

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.

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.)

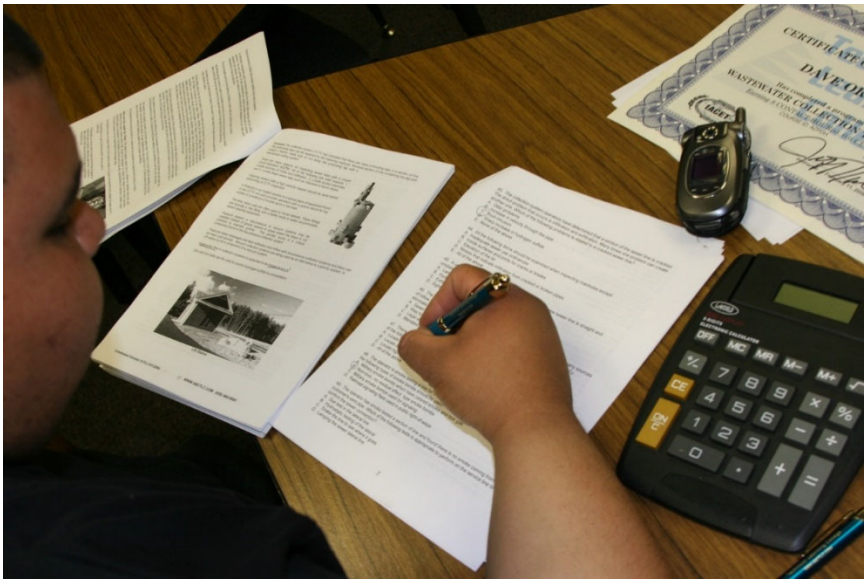
Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling; i.e., 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.

Contact Numbers

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

Important Information about this Manual

This manual has been prepared to assist employees in the general awareness of water and wastewater regulatory sampling and in 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 and wastewater 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.

This manual is a guidance document for employees who are involved with 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.

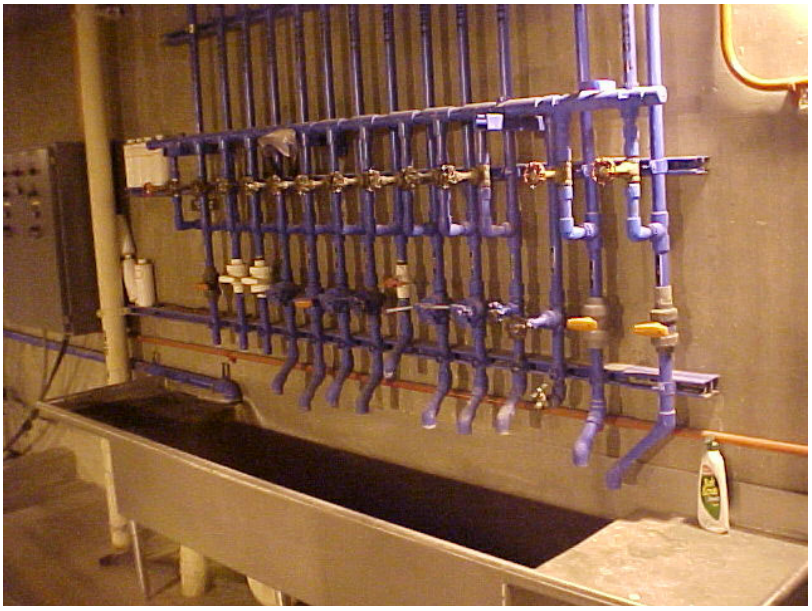
This course manual will provide general guidance and should not be used as a preliminary basis for developing general water/wastewater sampling plans. This document is not a detailed water/wastewater textbook or a comprehensive source book on water/wastewater rules and regulations.

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/wastewater 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, EPA and other appropriate federal, state and local agencies.

Washing laboratory glassware and sample bottles is an everyday experience.

Small ICR Sample Station.



Sample taps inside a Water Treatment Facility

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

CEU Course Description

WATER AND WASTEWATER SAMPLING CEU TRAINING COURSE

Review of Environmental Protection Agency's Rules and Regulation relating to water and wastewater sampling. This course will cover the fundamentals and basic requirements of the federal rule concerning water and wastewater sampling and general laboratory operations.

Attention Wastewater Treatment, Collections, Water Distribution, Well Drillers, Pump Installers, and Water Treatment Operators. The target audience for this course is the person interested in working in a water/wastewater treatment or distribution/collections facility and 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 Water and Wastewater Sampling CEU Training course uses a multiple-choice answer key.

Feedback Mechanism (examination procedures)
Each student will receive a feedback form as part of his or her study packet. You will be able to find this form in the 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 will result in forfeiture of all fees, and the appropriate agency will be notified.

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

Required Texts
The Water and Wastewater Sampling CEU training course comes complete with a short summary of the EPA's Rules and Regulations and drinking water standards. If you need more information or a complete set of Rules, you can download them off the EPA's web page, www.epa.gov or contact your local state environmental agency. You may need to contact a laboratory or state agency for certain sampling information.

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. TLC will not release any records to any party, except to the student self. We will send the required information to the required State for your certificate renewals.

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

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

Educational Mission
The educational mission of TLC is:

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

To provide TLC students 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 18)

Hyperlink to the Glossary and Appendix

http://www.abctlc.com/downloads/PDF/WTGlossary.pdf

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.

Topic Legend

This CEU course covers several different educational topics/functions/purposes/objectives of conventional water treatment, filtration processes, 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 or CWA 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.

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

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

TECH - TECHNICAL: The mechanical or physical treatment process/component. The conventional or microfiltration process including pretreatment processes/ applications/ engineering/ theories. 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.

Common Water Treatment Acronyms

AA - Activated alumina
AC - Activated carbon
ASR - Annual Status Report
As(III) - Trivalent arsenic, common inorganic form in water is arsenite, H_3AsO_3
As(V) - Pentavalent arsenic, common inorganic form in water is arsenate, H_2AsO_4
BDAT - Best demonstrated available technology
BTEX - Benzene, toluene, ethylbenzene, and xylene
CCA - Chromated copper arsenate
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS 3 - CERCLA Information System
CLU-IN - EPA's CLeanUp INformation system
CRAO- Compliance and Regulatory Affairs Office
CWS - Community Water System
cy - Cubic yard
DDT - Dichloro-diphenyl-trichloroethane
DI - De-ionized
DOC - Dissolved organic carbon
DoD - Department of Defense
DOE - Department of Energy
EDTA - Ethylenediaminetetraacetic acid
EPA - U.S. Environmental Protection Agency
EPT - Extraction Procedure Toxicity Test
FRTR - Federal Remediation Technologies Roundtable
ft - feet
gpd - gallons per day
gpm - gallons per minute
HTMR - High temperature metals recovery
MCL - Maximum Contaminant Level (enforceable drinking water standard)
MF - Microfiltration
MHO - Metallurgie-Hoboken-Overpelt
mgd - million gallons per day
mg/kg - milligrams per kilogram
mg/L - milligrams per Liter
NF - Nanofiltration
NPL - National Priorities List
OCLC - Online Computer Library Center
ORD - EPA Office of Research and Development
OU - Operable Unit
PAH - Polycyclic aromatic hydrocarbons
PCB - Polychlorinated biphenyls
P.L. – Public Laws
POTW - Publicly owned treatment works
PRB - Permeable reactive barrier
RCRA - Resource Conservation and Recovery Act
Redox - Reduction/oxidation
RO - Reverse osmosis
ROD - Record of Decision
SDWA - Safe Drinking Water Act

SMZ - Surfactant modified zeolite
SNAP - Superfund NPL Assessment Program
S/S - Solidification/Stabilization
SVOC - Semi-volatile organic compounds
TCLP - Toxicity Characteristic Leaching Procedure
TNT - 2,3,6-trinitrotoluene
TWA - Total Waste Analysis
UF - Ultrafiltration
VOC - Volatile organic compounds
WET - Waste Extraction Test
ZVI - Zero valent iron

Hyperlink to the Glossary and Appendix

http://www.abctlc.com/downloads/PDF/WTGlossary.pdf

Common Water Quality Terms

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Significant Potential Source of Contamination. A facility or activity that stores, uses, or produces chemicals or elements, and that has the potential to release contaminants identified in a state program (contaminants with MCLs plus any others a state considers a health threat)

within a source water protection area in an amount which could contribute significantly to the concentration of the contaminants in the source waters of the public water supply.

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

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

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

State Source Water Petition Program. A state program implemented in accordance with the statutory language at section 1454 of the SDWA to establish local voluntary incentive-based partnerships for SWP and remediation.

State Management Plan (SMP) Program. A state management plan under FIFRA required by the EPA to allow states (i.e. states, tribes and U.S. territories) the flexibility to design and implement approaches to manage the use of certain pesticides to protect ground water.

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

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

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

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

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

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

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

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

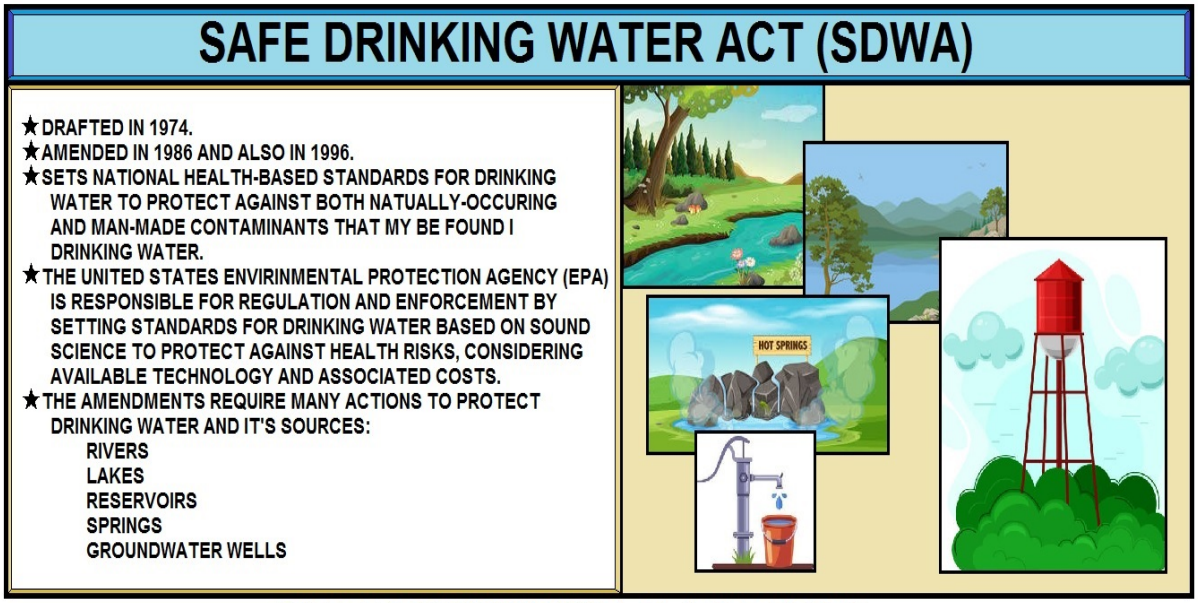
Watershed. A topographic boundary area that is the perimeter of the catchment area of a stream.

Watershed Approach. A watershed approach is a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flow.

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

Wellhead Protection Area (WHPA). The surface and subsurface area surrounding a well or well field, supplying a PWS, through which contaminants are reasonably likely to move toward and reach such water well or well field.

Preface



Safe Drinking Water Act of 1974 Introduction

(Public Law 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

Public law 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.

Water Systems Terminology Introduction

Primary Water Systems
All public water systems must have at least 15 service connections or serve at least 25 people per day for 60 days of the year. Drinking water standards apply to water systems differently based on their type and size:

"COMMUNITY WATER SYSTEM" (CWS): Community Water System (there are approximately 54,000) - A public water system that serves the same people year-round. Most residences including homes, apartments, and condominiums in cities, small towns, and mobile home parks are served by Community Water Systems.

"NON-COMMUNITY WATER SYSTEM" (NCWS): Non-Community Water System - A public water system that serves the public but does not serve the same people year-round. There are two types of noncommunity systems:

"NON-TRANSIENT NON-COMMUNITY WATER SYSTEM" (NTNCWS) Non-Transient Non-Community Water System (there are approximately 20,000) - A noncommunity water system that serves the same people more than six months per year, but not year-round, for example, a school with its own water supply is considered a non-transient system.

"TRANSIENT NON-COMMUNITY WATER SYSTEM" (TNCWS) Transient non-community water system (there are approximately 89,000) - A non-community water system that serves the public but not the same individuals for more than six months, for example, a rest area or campground may be considered a transient water system.

Related Water Systems

"COMBINED DISTRIBUTION SYSTEM" means an interconnected distribution system consisting of the distribution systems of wholesale systems and of the consecutive systems that receive finished water.

"CONSECUTIVE SYSTEM" means a public water system that receives some or all of its finished water from one or more wholesale systems. Delivery may be through a direct connection or through the distribution system of one or more consecutive systems.

"NON-TRANSIENT POPULATION" means the average number of people served per day during the year or normal operating period(s), who do not reside at the place supplied by the system, but have a regular opportunity to consume water produced by the system. Regular opportunity is defined as four or more hours per day, for four or more days per week, for six or more months per year.

"PUBLIC WATER SYSTEM" or "PWS" means a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves an average of at least 25 individuals daily at least 60 days per year. A public water system is either a community water system or a non-community water system. Such term does not include any special irrigation district. Such term includes:
(a) Any collection, treatment, storage, and distribution facilities under control of the supplier of such system and used primarily in connection with such system.

(b) Any collection or pretreatment storage facilities not under such control, which are used primarily in connection with such system.

“PUBLIC WATER SYSTEM THAT HAULS WATER” means a public water system that delivers, by vehicle, finished water through a non-piped conveyance such as a vehicle mounted tank or container.

“SEASONAL SYSTEM” means a non-community water system that is not operated as a public water system on a year-round basis, regardless of whether the system is pressurized or de-pressurized during the off-season.

“SURFACE WATER SYSTEM” means a public water system that uses, in whole or in part, surface water or groundwater under the direct influence of surface water as a source of water.

“TRANSIENT POPULATION” means the average number of individuals served per day during the year or annual operating period(s), who have an opportunity to consume water from the system, but who do not meet the definition of either resident population or non-transient population.

Topic 1 - Water Quality Section

Section Focus: You will learn the basics of the EPA's Safe Water Drinking Act and the reasons why we need to ensure the water means federal standards. At the end of this section, you will be able to describe EPA's Primary and Secondary standards. 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: EPA identifies contaminants to regulate in drinking water to protect public health. The Agency sets regulatory limits for the amounts of certain contaminants in water provided by public water systems. These contaminant standards are required by the Safe Drinking Water Act (SDWA). Drinking water standards may apply differently based on type and size of public water systems.

FACTOR	TYPE	SOURCE(S)	PROBLEM
FECAL COLIFORM BACTERIA	BIOLOGICAL	HUMAN SEWAGE; LIVESTOCK WASTE	POSSIBLE PRESENCE OF PATHOGENIC (DISEASE-CAUSING) ORGANISMS
DISSOLVED OXYGEN (DO)	CHEMICAL	AIR; AQUATIC PLANTS	LOW LEVELS CAN KILL AQUATIC ORGANISMS
NITROGEN AND PHOSPHORUS	CHEMICAL	FERTILIZERS AND DETERGENTS FROM LAWNS AND RUNOFF	EXCESSIVE ALGAE GROWTH CAN LEAD TO LOW DO
ZINC, ARSENIC, LEAD, MERCURY, CADMIUM, NICKEL	CHEMICAL	LANDFILLS; INDUSTRIAL DISCHARGES; RUNOFF	GENETIC MUTATIONS OR DEATH IN FISH & WILDLIFE (HUMAN HEALTH THREATS AS WELL)
SALT	CHEMICAL	SALTWATER INTRUSION (IF NEAR OCEAN)	KILLS FRESHWATER SPECIES OF PLANTS AND ANIMALS
MUD, SAND, OTHER SOLID PARTICLES (TURBIDITY)	PHYSICAL	EROSION AND RUNOFF FROM DEVELOPMENT; AGRICULTURE	REDUCES PHOTOSYNTHESIS IN AQUATIC VEGETATION; INTERFERES WITH RESPIRATION IN AQUATIC ANIMALS

IMPORTANT WATER QUALITY CONCERNS

Common Water Quality Units of Measurement

mg/l = Milligrams per liter. One milligram per liter equals one packet of artificial sweetener sprinkled into 250 gallons of iced tea.
µg/l = Micrograms per liter. One microgram per liter is equal to one packet of artificial sweetener sprinkled into an Olympic-size swimming pool.
NTU = Nephelometric Turbidity Units. A measurement on the cloudiness of the water.
pCi/l = Picocuries per liter. A measure of radioactivity.

Acronyms

Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water.

Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health.

Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water.

Action Level (AL) - The concentration of a contaminant that, if exceeded, triggers treatment or other requirements which a water system must follow.

Federal Water Drinking Water Quality Regulations Timeline

National Interim Primary Drinking Water Regulations (NIPDWR) Promulgated 1975-1981 Contained 7 contaminants, Targeted: Trihalomethanes, Arsenic, and Radionuclides Established 22 drinking water standards.

Phase 1 Standards Promulgated 1987 Contained 8 contaminants, Targeted: VOCs.

Phase 2 Standards Promulgated 1991 Contained 36 contaminants, Targeted: VOCs, SOCs, and IOCs.

Phase 5 Standards Promulgated 1992 Contained 23 contaminants, Targeted: VOCs, SOCs, and IOCs.

Surface Water Treatment Rule (SWTR) Promulgated 1989 Contained 5 contaminants, Targeted: Microbiological and Turbidity.

Stage 1 Disinfectant/Disinfection By-product (D/DBP) Rule Promulgated 1998 Contained 14 contaminants, Targeted: DBPs and precursors.

Interim Enhanced Surface Water Treatment Rule (IESWTR) Promulgated 1998 Contained 2 contaminants, Targeted: Microbiological and Turbidity.

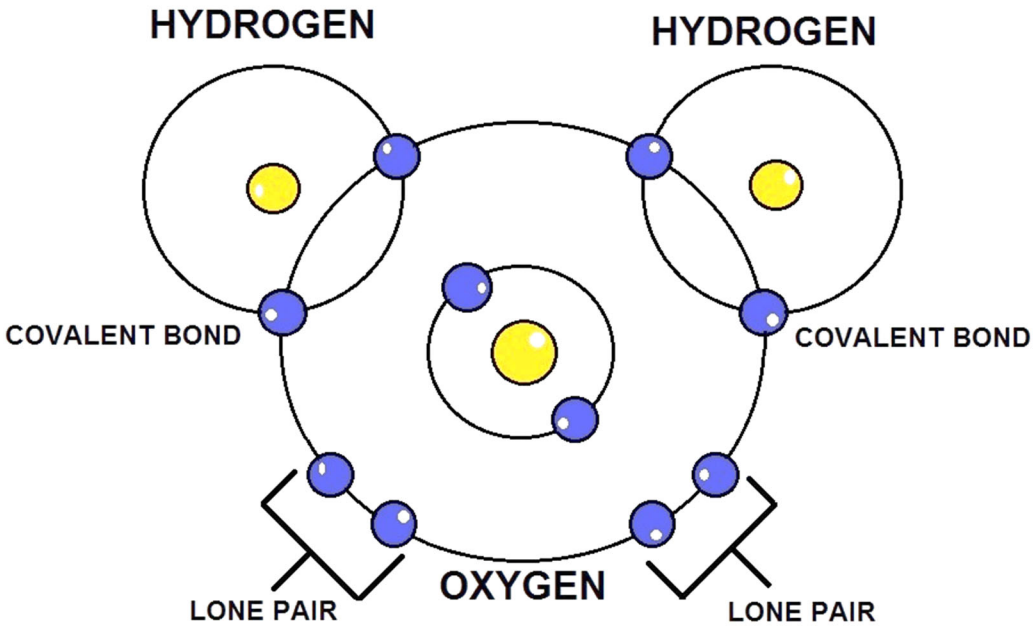
Radionuclide Rule Promulgated 2000 Contained 4 contaminants, Targeted: Radionuclides.

Arsenic Rule Promulgated 2001 Contained 1 contaminant, Targeted: Arsenic.

Filter Backwash Recycling Rule Promulgated 2001 Contained 2 contaminants, Targeted: Microbiological and Turbidity.

What is Water?

Water is the chemical substance with chemical formula H_2O: one molecule of water has two hydrogen atoms covalently bonded to a single oxygen atom. Water is a tasteless, odorless liquid at ambient temperature and pressure, and appears colorless in small quantities, although it has its own intrinsic very light blue hue. Ice also appears colorless, and water vapor is essentially invisible as a gas.

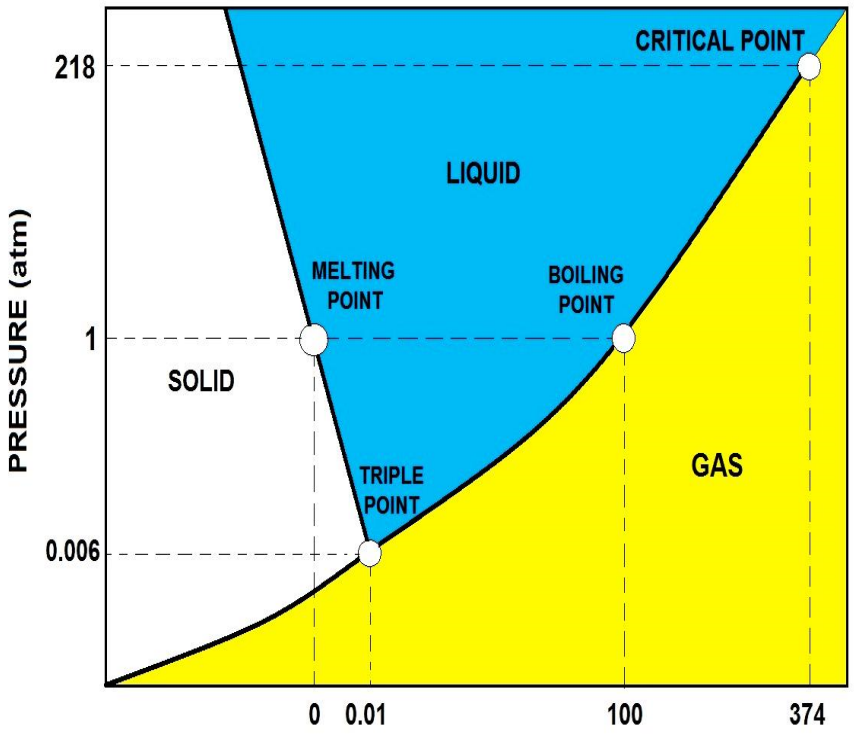


WATER MOLECULE DIAGRAM

Water is primarily a liquid under standard conditions on earth, to other analogous hydrides of the oxygen family in the periodic table, which are gases, such as hydrogen sulfide. The elements surrounding oxygen in the periodic table, nitrogen, fluorine, phosphorus, sulfur and chlorine, all combine with hydrogen to produce gases under standard conditions. The reason that water forms a liquid is that oxygen is more electronegative than all of these elements with the exception of fluorine.

Oxygen attracts electrons much more strongly than hydrogen, resulting in a net positive charge on the hydrogen atoms, and a net negative charge on the oxygen atom. The presence of a charge on each of these atoms gives each water molecule a net dipole moment.

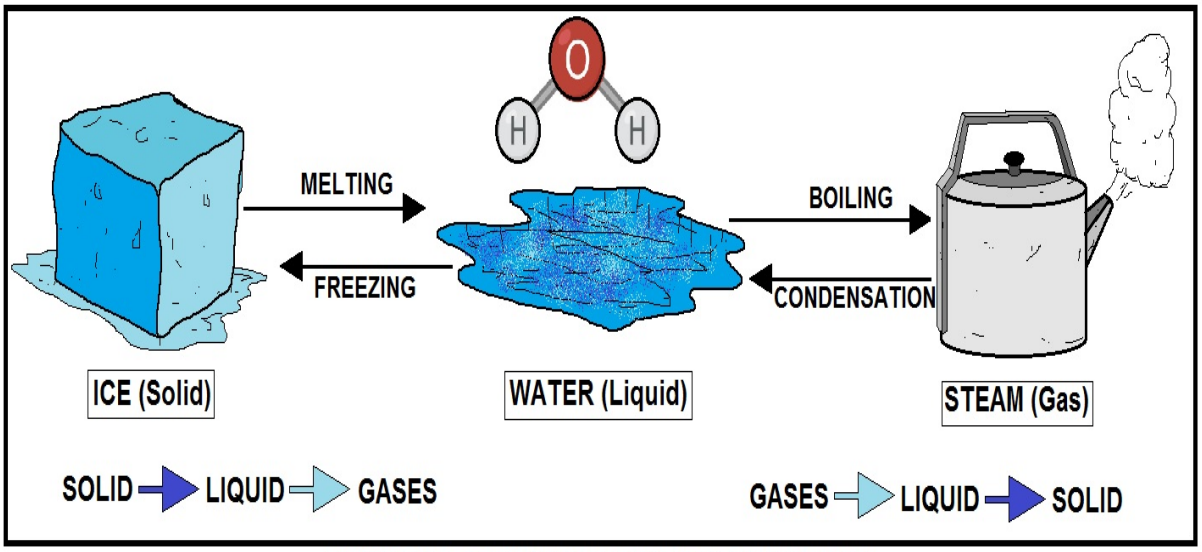
Electrical attraction between water molecules due to this dipole pulls individual molecules closer together, making it more difficult to separate the molecules and therefore raising the boiling point.



TEMPERATURE (^{O}C) WATER PHASE DIAGRAM

Boiling Phase

Once liquid water is heated to 212^{o}F (100^{o}C) it takes a significant amount of energy to change the "phase" of water from a liquid state to a gas state. That is one reason it's easier to heat a pot of water to boiling rather than to evaporate all of it.

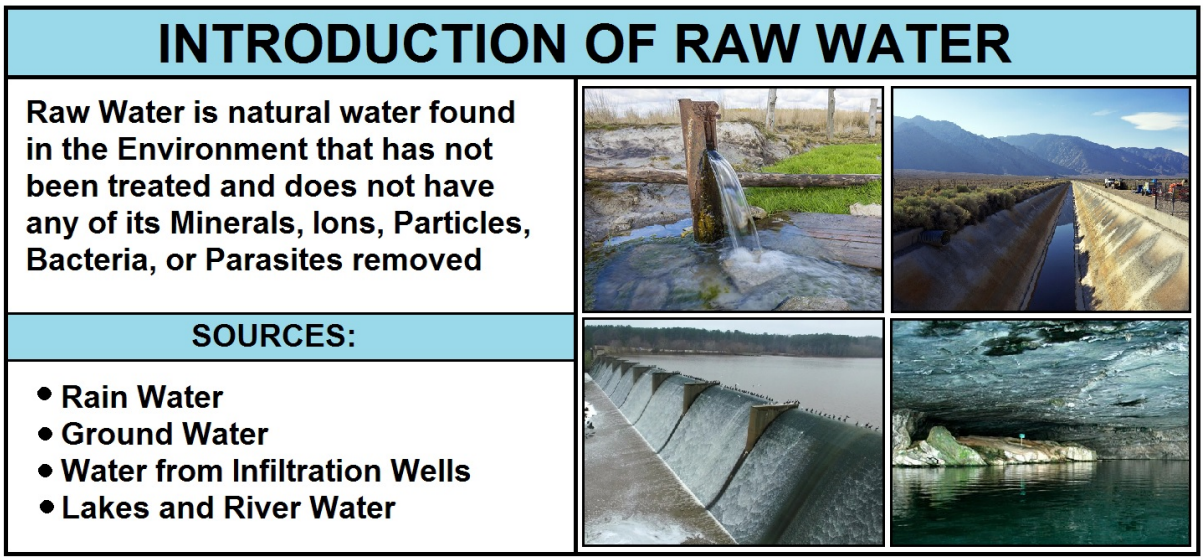


PHYSICAL CHARACTERISTICS OF WATER

Technical Learning College

Surface (Raw) Water Introduction

We will go into greater detail on these concerns in the Water Analysis section.



INTRODUCTION TO RAW WATER

Because raw water (surface water) is never pure of pollution, we need to properly treat it. Most of the earth's water sources obtain their water supplies through precipitation (rain). During precipitation, water passes over (runoff) and through the ground (infiltration), acquiring a wide variety of dissolved or suspended impurities that intensely alters its usefulness. Water has unique physical, chemical and biological properties.

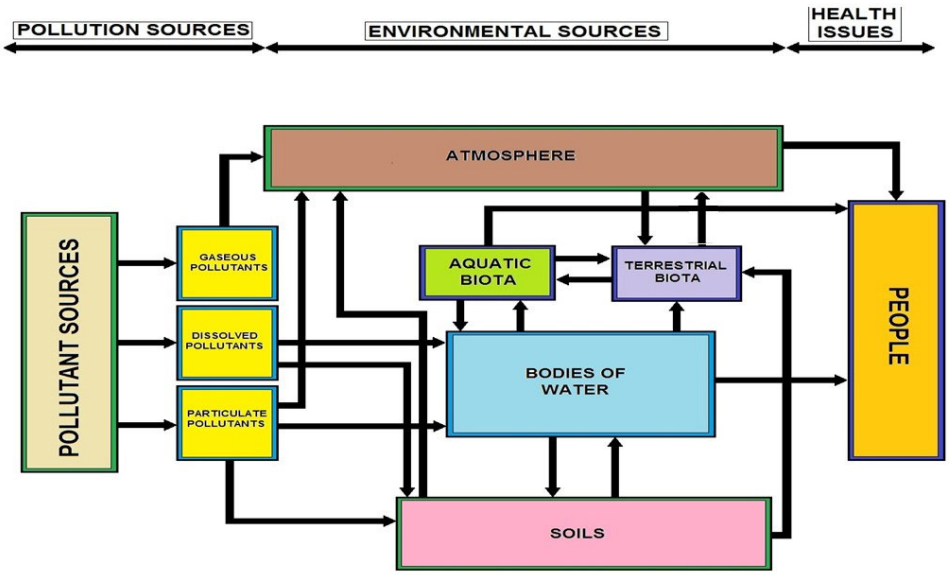
These characteristics have a direct influence on the most effective types of treatment methods and/or chemicals. The improvement of water quality and formation of policy measures (administrative and engineering) revolves around these characteristics.

It is important to remember that raw water will normally contains varying amounts of dissolved minerals including calcium, magnesium, sodium, chlorides, sulfates and bicarbonates, depending on its source.

It is also not uncommon to find traces of iron, manganese, copper, aluminum, nitrates, insecticides and herbicides.

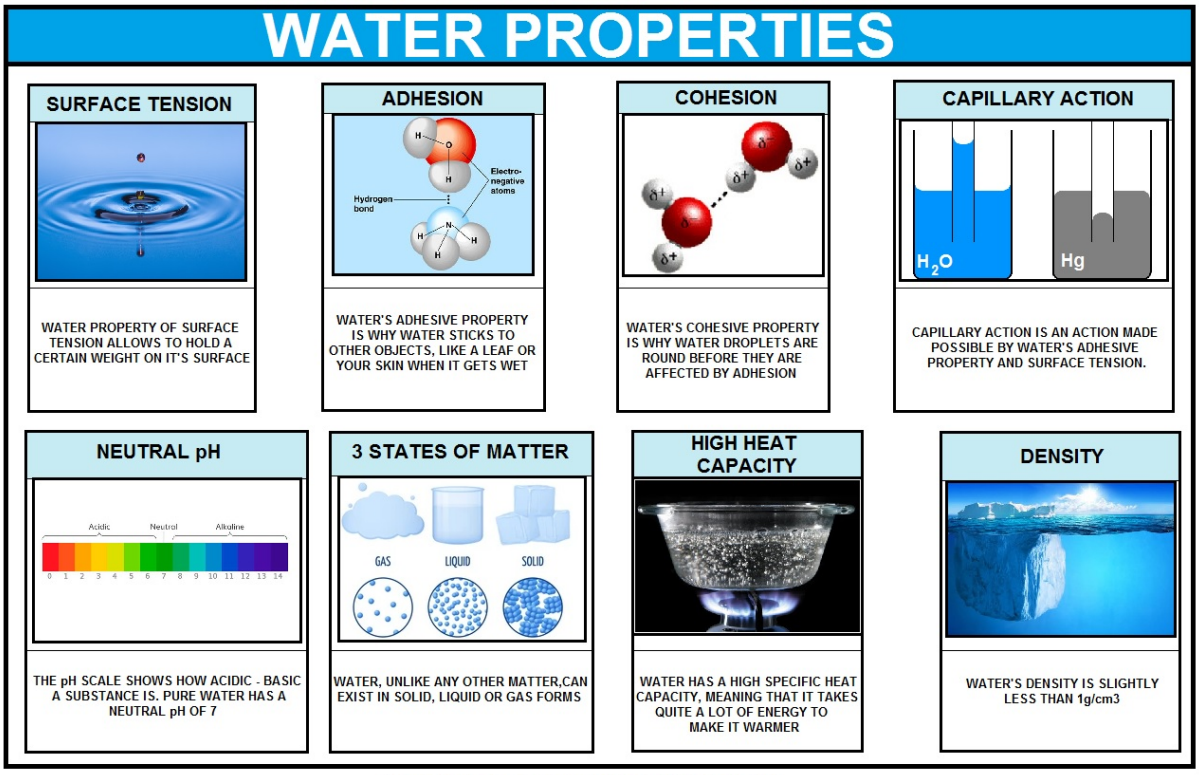
Currently, we also need to deal with contaminants of emerging concern including Pharmaceuticals and Personal Care Products. EPA defines emerging contaminants as: An emerging contaminant (EC) is a chemical or material characterized by a perceived, potential, or real threat to human health or the environment or by a lack of published health standards.

The maximum allowable amounts of all these substances are strictly limited by the regulations (MCLS). These are usually referred to as contaminants and/or pollutants.



Technical Learning College

WATER QUALITY INDICATORS



Technical Learning College

PROPERTIES OF WATER

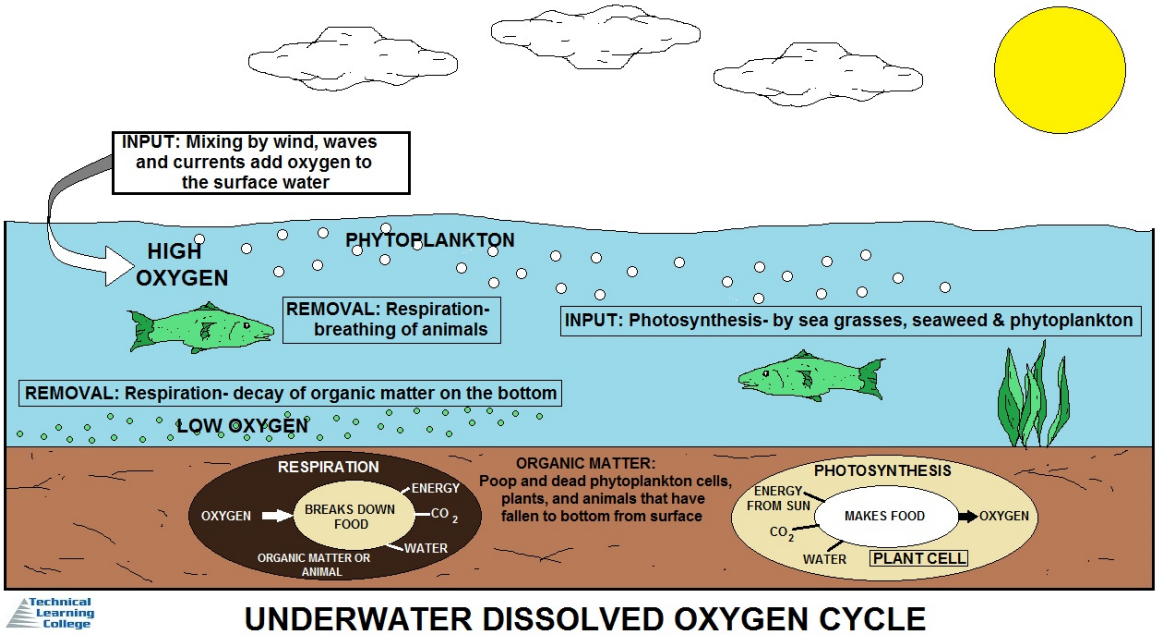
Surface Water Properties

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

Reservoirs are lakes with man-made dams. Surface water is usually contaminated and unsafe to drink.

Depending on the region, some lakes and rivers receive discharge from sewer facilities or defective septic tanks. Runoff could produce mud, leaves, decayed vegetation, and human and animal refuse. The discharge from industry could increase volatile organic compounds. Some lakes and reservoirs may experience seasonal turnover.

Changes in the dissolved oxygen, algae, temperature, suspended solids, turbidity, and carbon dioxide will change because of biological activities.



UNDERWATER DISSOLVED OXYGEN CYCLE

Managing Water Quality at the Source

Depending on the region, source water may have several restrictions of use as part of a Water Shed Management Plan. In some areas, it may be restricted from recreational use, discharge or runoff from agriculture, or industrial and wastewater discharge. Another aspect of quality control is aquatic plants.

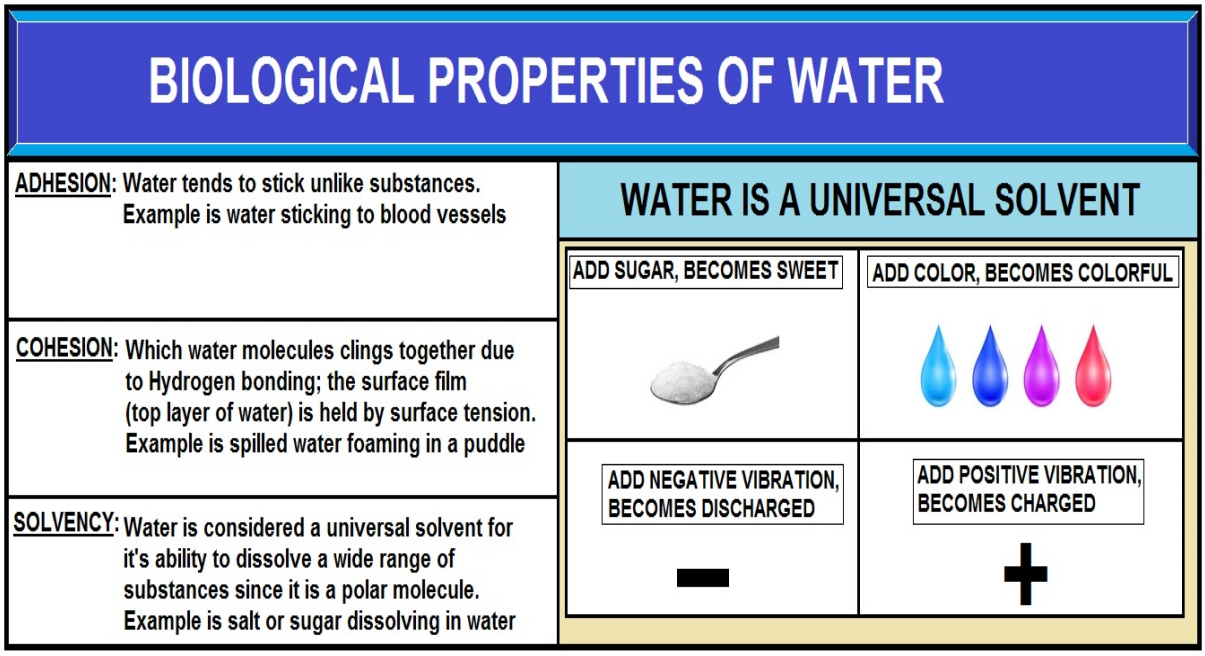
The ecological balance in lakes and reservoirs plays a natural part in purifying and sustaining the life of the lake. For example, algae and rooted aquatic plants are essential in the food chain of fish and birds. Algae growth is the result of photosynthesis. Algae growth is supplied by the energy of the sun. As algae absorbs this energy, it converts carbon dioxide to oxygen.

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

Most treatment plant upsets such as taste and odor, color, and filter clogging is due to algae. The type of algae determines the problem it will cause, for instance slime, corrosion, color, and toxicity. Algae can be controlled in the water supply by using chemicals such as copper sulfate.

Depending on federal regulations and the amount of copper found natural in water, operators have used potassium permanganate, powdered activated carbon and chlorine to control algae blooms. The pH and alkalinity of the water will determine how these chemicals will react.

Many water systems are limiting their chlorine usage because it reacts with the organics in the water to form trihalomethanes. Most treatment plants that do not use chlorine in the disinfection process will still add chlorine for a *residual* in the distribution system.

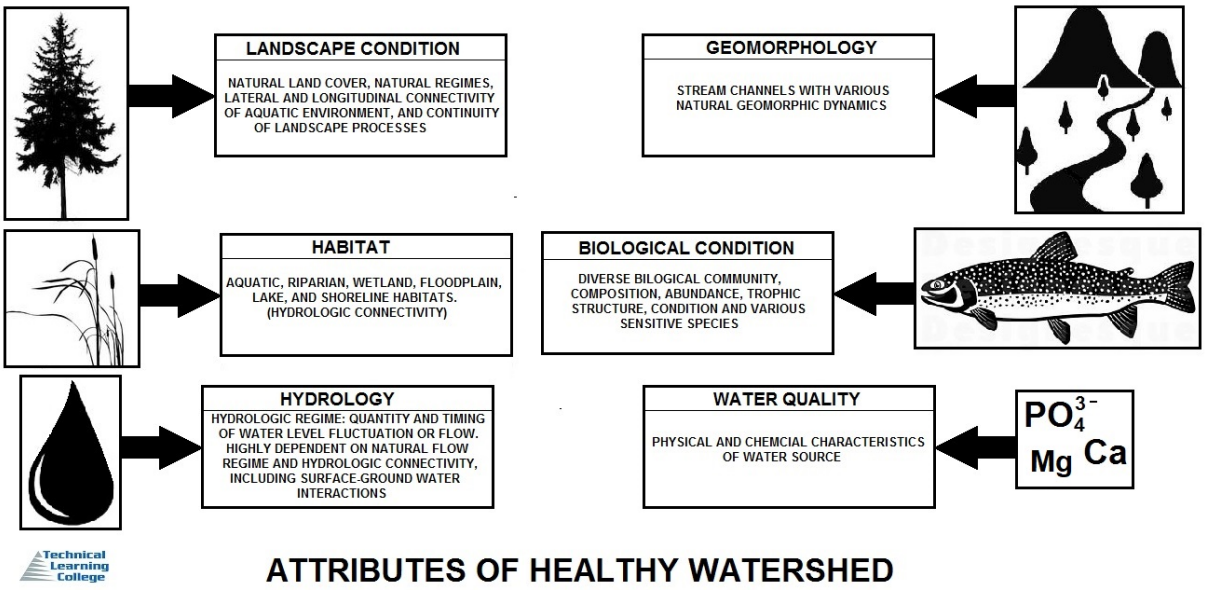


BIOLOGICAL PROPERTIES OF WATER EXAMPLE

Technical Learning College

Physical Characteristics of Water

Physical characteristics such as taste, odor, temperature, pH, TDS, and turbidity; are mostly how the consumer judges how well the provider is treating the water.



ATTRIBUTES OF HEALTHY WATERSHED

Physical characteristics are the elements found that are considered alkali, metals, and non-metals such as carbonates, fluoride, sulfides or acids. The consumer relates it to scaling of faucets or staining. Particles and rust come from the distribution system, the gradual breakdown of the lining of concrete or iron water pipes (mains) or from sediment that has accumulated over the years and is disturbed in some way.

SOLIDS

Solid material in wastewater may be dissolved, suspended, or settled.

Total dissolved solids or TDS (sometimes called filterable residue) is measured as the mass of residue remaining when a measured volume of filtered water is evaporated. The mass of dried solids remaining on the filter is called **total suspended solids** (TSS) or non-filterable residue.

Settleable solids are measured as the visible volume accumulated at the bottom of an Imhoff cone after water has settled for one hour.

Turbidity is a measure of the light scattering ability of suspended matter in the water.

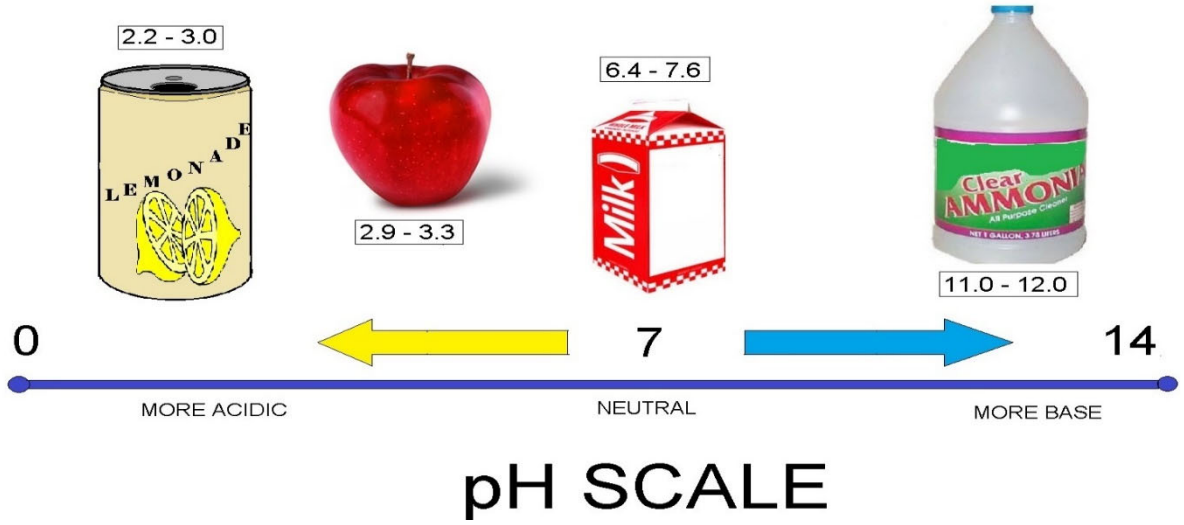
Salinity measures water density or conductivity changes caused by dissolved materials.

Technical Learning College

Total Dissolved Solids (TDS) is not a primary pollutant; it is an indicator of aesthetic water characteristics such as hardness and an indication of an assortment of chemical contaminants which might be present, such as Arsenic. We will cover this in a few more pages.

pH is the negative logarithm of the hydrogen ion concentration, $[H^+]$, a measure of the degree to which a solution is acidic or alkaline. An acid is a substance that can give up a hydrogen ion (H^+); a base is a substance that can accept H^+.

The more acidic a solution the greater the hydrogen ion concentration and the lower the pH; a pH of 7.0 indicates neutrality, a pH of less than 7 indicates acidity, and a pH of more than 7 indicates alkalinity. We will cover this subject further in the Water Analysis/Laboratory Section.

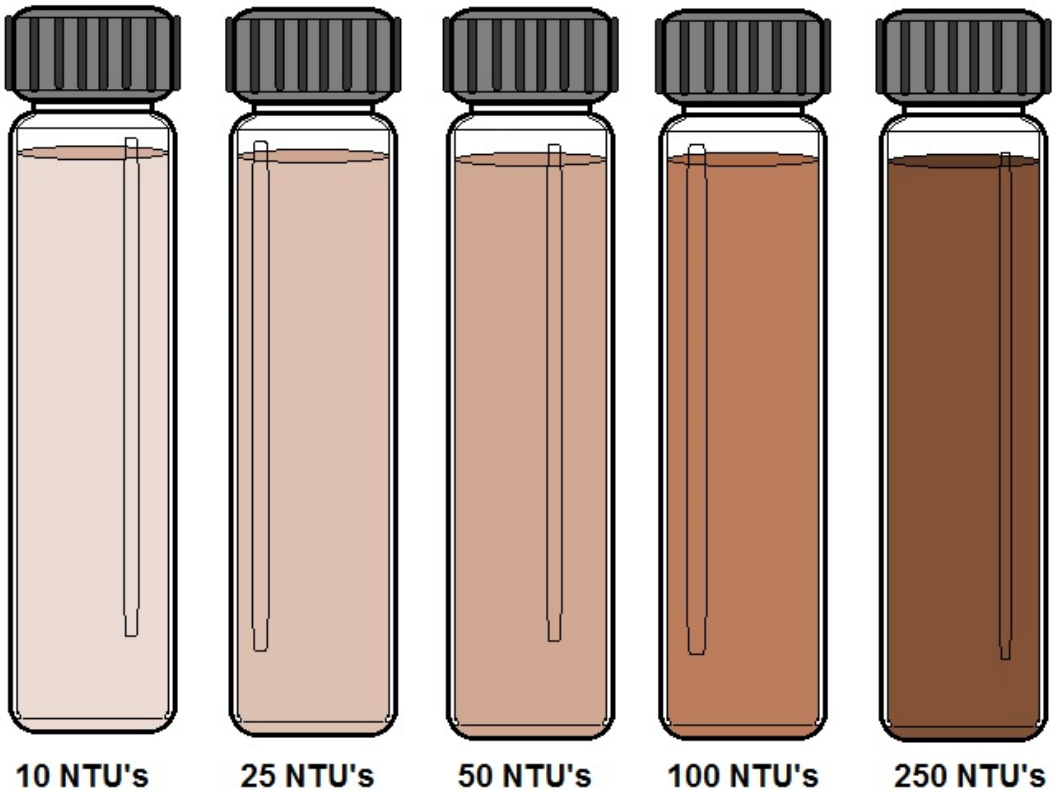


pH SCALE

Alkalinity
Alkalinity of water is its acid-neutralizing capacity. It is the sum of all the titratable bases. The measured value may vary significantly with the end-point pH used. Alkalinity is a measure of an aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known.

Alkalinity is significant in many uses and treatments of natural waters and wastewaters. Because the alkalinity of many surface waters is primarily a function of carbonate, bicarbonate, and hydroxide content, it is taken as an indication of the concentration of these constituents. The measured values also may include contributions from borates, phosphates, silicates or other bases if these are present.

Alkalinity Measurements
Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of water for irrigation. Alkalinity measurements are used in the interpretation and control of water and wastewater treatment processes



TURBIDITY SAMPLES IN NTU's (Neophelometric Turbidity Unit)

Turbidity Introduction

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

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

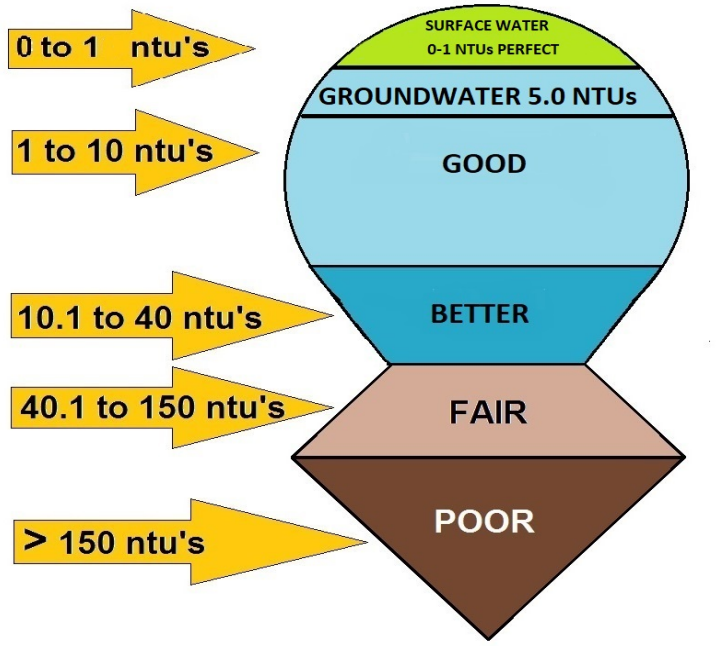
When heavy rains occur, runoff into streams, rivers, and reservoirs occurs, causing turbidity levels to increase. In most cases, the particle sizes are relatively large and settle relatively quickly in both the water treatment plant and the source of supply. However, in some instances, fine, colloidal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

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

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

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

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



TURBIDITY PARAMETERS (NTU) FOR WATER QUALITY

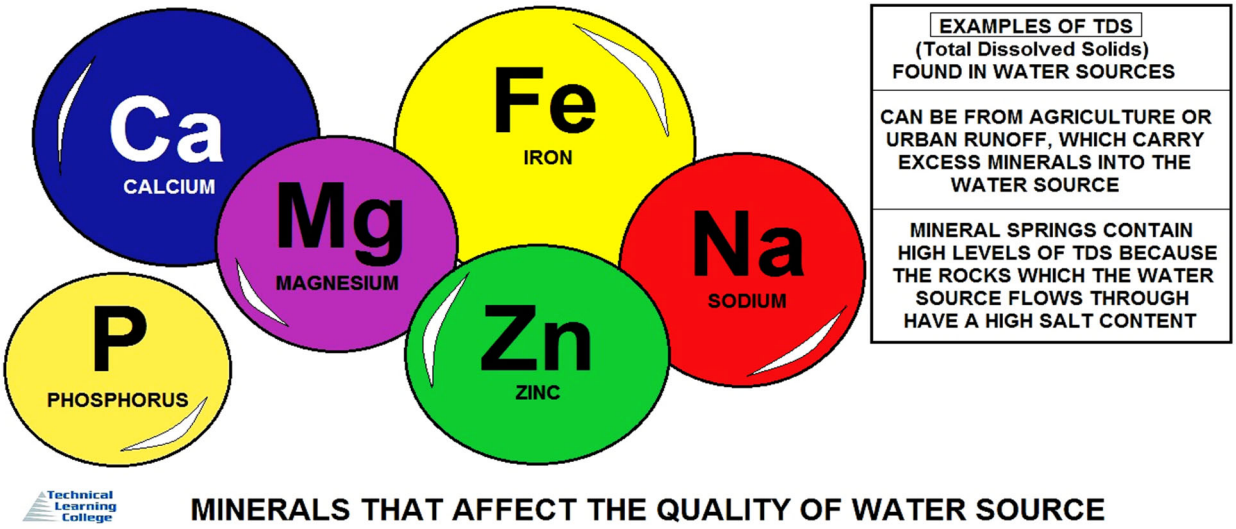
Surface Water System Compliance Information
(Depends on Systems and Rule)

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

Turbidity Key

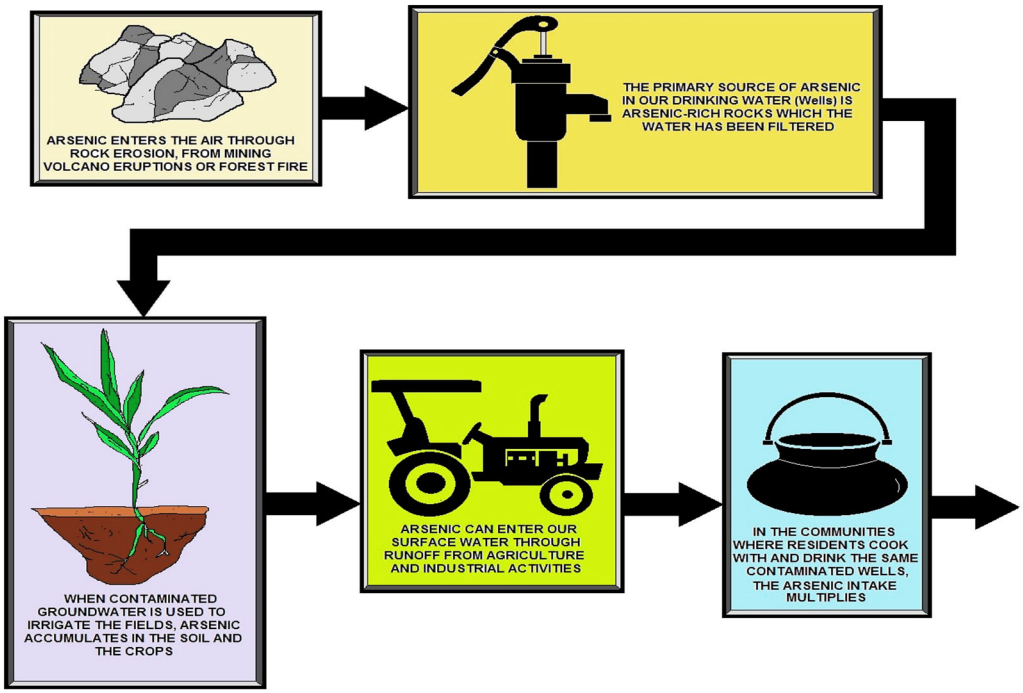
- Turbidity can also be measured in ppm (parts per million) and its size is measured in microns. Turbidity can be particles in the water consisting of finely divided solids, larger than molecules, but not visible by the naked eye; ranging in size from .001 to .150mm (1 to 150 microns).

- 0.34 NTU in 95% of surface water samples, never to exceed 1.0 NTU spike

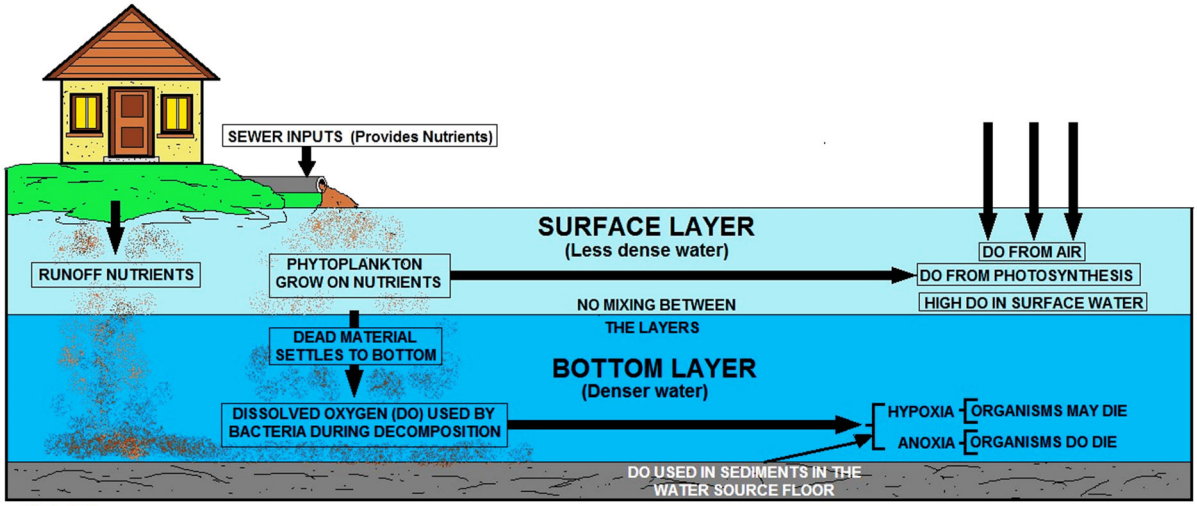


MINERALS THAT AFFECT THE QUALITY OF WATER SOURCE

Lead does not usually occur naturally in water supplies but is derived from lead distribution and domestic pipework and fittings. Water suppliers (distribution systems) have removed most of the original lead piping from the mains distribution system, however many older properties still have lead service pipes and internal lead pipework. The pipework (including the service pipe) within the boundary of the property is the responsibility of the owner of the property, not the water supplier.



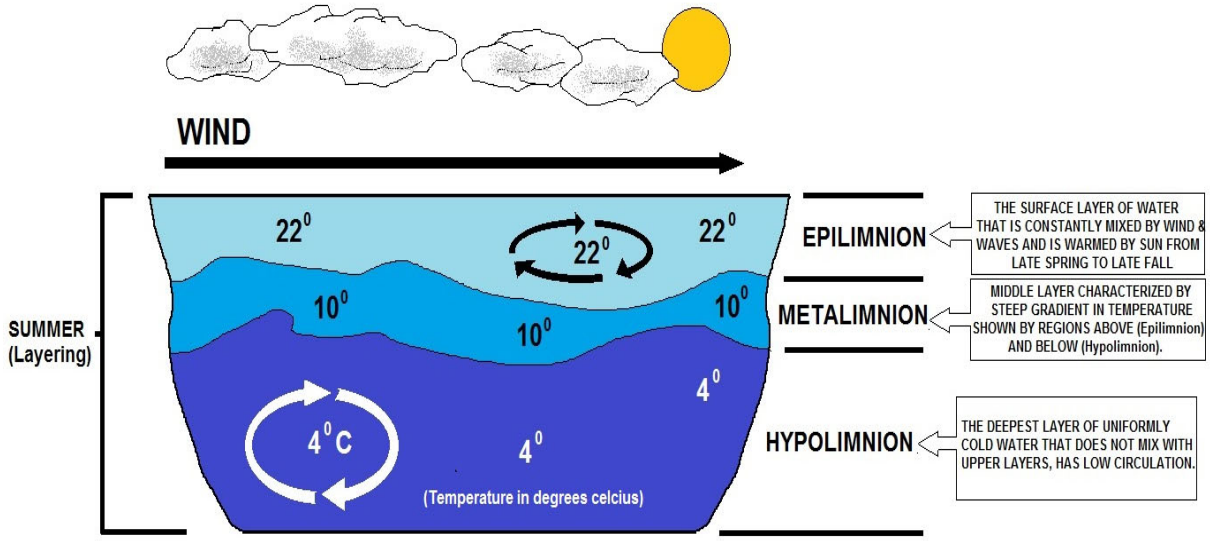
ARSENIC IN DRINKING WATER



DISSOLVED OXYGEN AFFECT IN WATER SOURCES

Dissolved Oxygen

The level of dissolved oxygen in natural waters is often a direct indication of quality, since aquatic plants produce oxygen, while microorganisms generally consume it as they feed on pollutants. At low temperatures the solubility of oxygen is increased, so that in winter, concentrations as high as 20 ppm may be found in natural waters; during summer, saturation levels can be as low as 4 or 5 ppm. Dissolved oxygen is essential for the support of fish and other aquatic life and aids in the natural decomposition of organic matter.



THERMAL STRATIFICATION (Temperature Transition Zones)

Thermal stratification is possible as **water becomes less dense when heated**, meaning water weighs less per unit volume. Therefore, warmer water will be lighter and colder water will be heavier. Due to this, there will always be a level of “self-induced” thermal stratification in a water storage.

Hardness Introduction

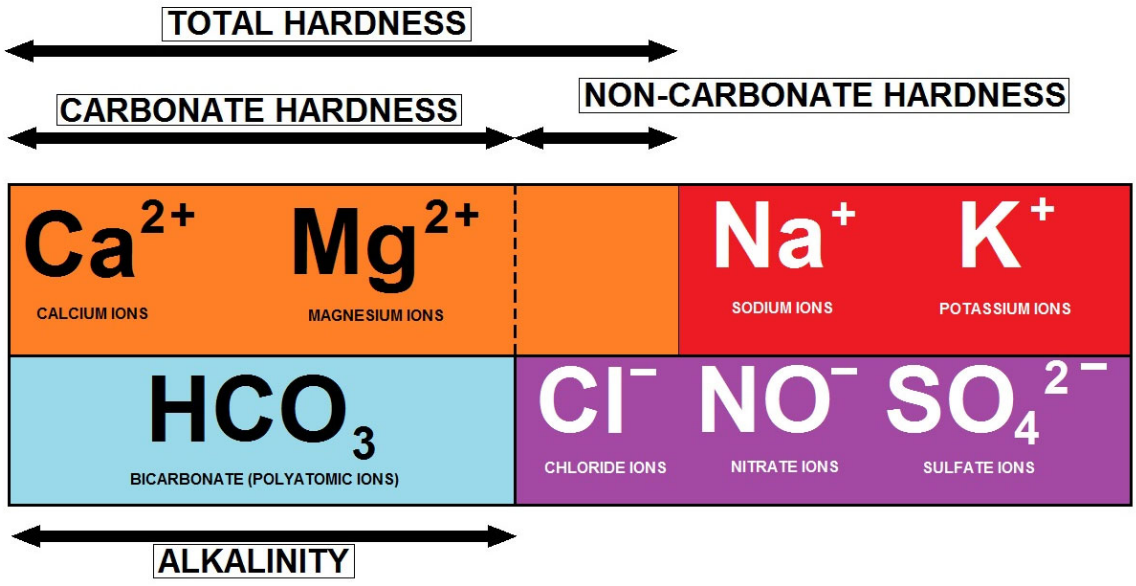
Temporary and Permanent

There are two types of hardness: temporary and permanent. Temporary hardness comes out of the water when it is heated and is deposited as scale and “fur” on kettles, coffee makers and taps and appears as a scum or film on tea and coffee. Permanent hardness is unaffected by heating. We will cover this in the advanced water treatment section

WATER HARDNESS (Salt Types)	
CARBONATE HARDNESS COMPOUNDS	NON-CARBONATE HARDNESS COMPOUNDS
CALCIUM CARBONATE ($CaCO_3$)	CALCIUM SULPHATE ($CaSO_4$)
MAGNESIUM CARBONATE ($MgCO_3$)	MAGNESIUM SULPHATE ($MgSO_4$)
CALCIUM BiCARBONATE ($Ca(HCO_3)_2$)	CALCIUM CHLORIDE ($CaCl_2$)
MAGNESIUM BiCARBONATE ($Mg(HCO_3)_2$)	MAGNESIUM CHLORIDE ($MgCl_2$)
CALCIUM HYDROXIDE ($Ca(OH)_2$)	
MAGNESIUM HYDROXIDE ($Mg(OH)_2$)	

Technical Learning College

CAUSES OF HARDNESS THAT AFFECTS WATER QUALITY

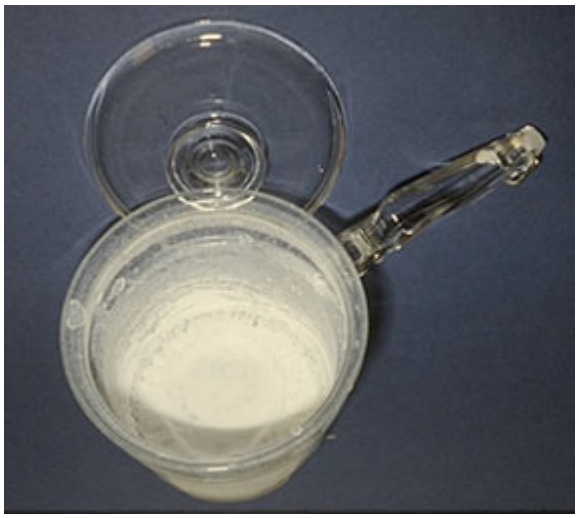


Technical Learning College

CARBONATE HARDNESS CHART

Objections to Hard Water

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



When hard water is heated, scale forms much faster. In particular, when the magnesium hardness is more than about 40 mg/l (as $CaCO_3$), magnesium hydroxide scale will deposit in hot water heaters that are operated at normal temperatures of 140-150°F (60-66°C).

A coating of only 0.04 in. (1 mm) of scale on the heating surfaces of a hot water heater creates an insulation effect that will increase heating costs by about 10 percent.

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

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

Total Dissolved Solids (TDS)

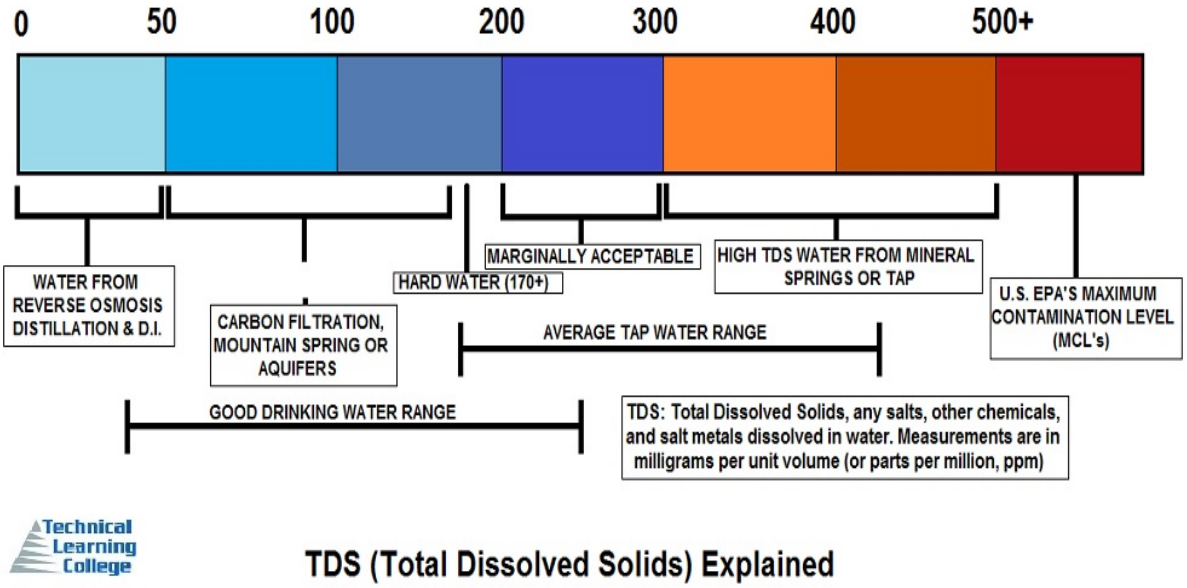
Total dissolved solids (TDS) represents the combined total of all organic and inorganic substances found in drinking water. The total dissolved solids present in water is one of the leading causes of particles and sediments in drinking water, which give water its color, odor, and flavor, and can be a general indicator of water quality.

Organic substances found in drinking water may include:

- Algae
- Bacteria
- Fungi
- Hair
- Pesticides
- Herbicides
- Fertilizers
- Disinfectants
- Pharmaceuticals

Inorganic substances found in drinking water may include:

- Arsenic
- Lead
- Mercury
- Chlorine
- Sodium
- Calcium
- Potassium
- Magnesium
- Fluoride



Secondary Standard

TDS is most often measured in parts per million (ppm) or milligrams per liter of water (mg/L). The normal TDS level ranges from 50 ppm to 1,000 ppm. The Environmental Protection Agency (EPA), which is responsible for drinking water regulations in the United States, has identified TDS as a secondary standard, meaning that it is a voluntary guideline. While the United States set legal standards for many harmful substances, TDS, along with other contaminants that cause aesthetic, cosmetic, and technical effects, has only a guideline.

Levels of TDS (milligrams per litre)	Rating
Less than 300	Excellent
300 - 600	Good
600 - 900	Fair
900 - 1,200	Poor
Above 1,200	Unacceptable

Increased concentrations of dissolved solids can also have technical effects. Dissolved solids can produce hard water, which leaves deposits and films on fixtures and can corrode the insides of hot water pipes and boilers.

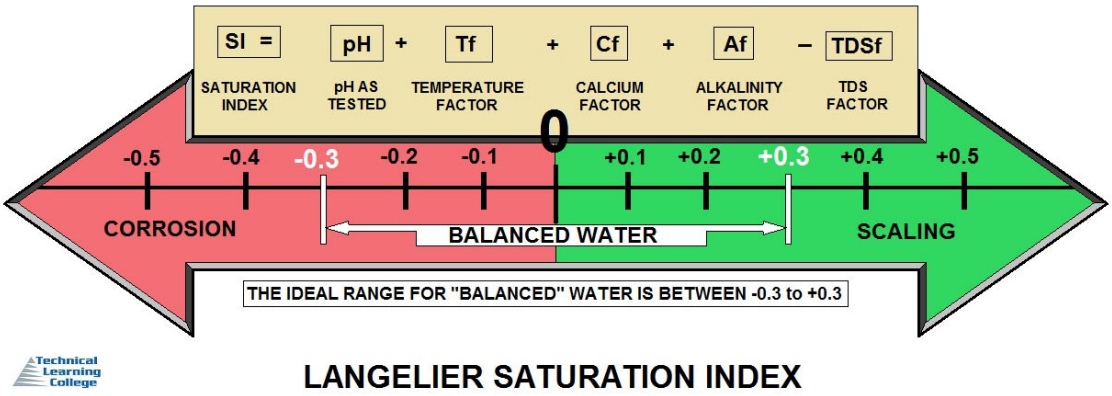
PARAMETERS	CLARITY	TURBIDITY	TOTAL SUSPENDED SOLIDS (TSS)
DEFINITION	HOW FAR LIGHT CAN PASS THROUGH THE WATER COLUMN	MEASURES THE DEGREE TO WHICH WATER LOSES IT'S TRANPARENCY	PARTICLES THAT ARE LARGER THAN 2 MICRONS FOUND IN THE WATER COLUMN
COMMENTS	TURBIDITY AND CLARITY ARE DIRECTLY RELATED. TURBIDITY IS A MEASURE OF THE WATER'S CLARITY High Turbidity = Low Clarity Low Turbidity = High Clarity		WHILE TSS DIRECTLY AFFECTS TURBIDITY, TURBIDITY IS NOT A DIRECT MEASUREMENT OF TOTAL SUSPENDED SOLIDS
WHAT IS MEASURED?	ORGANIC AND INORGANIC SUSPENDED SOLIDS, LIKE CLAY, SILT, SEDIMENT, ALGAE AND BATERIA + DISSOLVED COLORED MATERIALS (Smaller than 2 Microns)		ORGANIC AND INORGANIC SUSPENDED SOLIDS SETTLEABLE SOLIDS (Solids that are moved along the bottom of water by strong flow)
HOW IS IT MEASURED?	DIRECT MEASUREMENT: TURBIDIMETER or TURBIDITY SENSOR INDIRECT MEASUREMENT: SECCHI DISK or TURBIDITY TUBE Indirect Methods are Quick and Expensive but are Dependent on the Visual Acuity of the Observer		TO MEASURE TSS, A WATER SAMPLE IS FILTERED, DRIED AND WEIGHED

TOTAL DISSOLVED SOLIDS / WATER TREATMENT

Technical Learning College

Langelier Saturation Index

The Langelier Saturation index (LSI) is an equilibrium model derived from the theoretical concept of saturation and provides an indicator of the degree of saturation of water with respect to calcium carbonate. It can be shown that the Langelier saturation index (LSI) approximates the base 10 logarithm of the calcite saturation level. The Langelier saturation level approaches the concept of saturation using pH as a main variable. The LSI can be interpreted as the pH change required to bring water to equilibrium.



LANGELIER SATURATION INDEX

Water with a Langelier saturation index of 1.0 is one pH unit above saturation. Reducing the pH by 1 unit will bring the water into equilibrium. This occurs because the portion of total alkalinity present as CO_3^{2-} decreases as the pH decreases, according to the equilibria describing the dissociation of carbonic acid:

$$H_2CO_3 \rightleftarrows HCO_3^- + H^+$$
$$HCO_3^- \rightleftarrows CO_3^{2-} + H^+$$

- If LSI is negative: No potential to scale, the water will dissolve $CaCO_3$
- If LSI is positive: Scale can form and $CaCO_3$ precipitation may occur
- If LSI is close to zero: Borderline scale potential.
- Water quality or changes in temperature, or evaporation could change the index.

The LSI is probably the most widely used indicator of cooling water scale potential. It is purely an equilibrium index and deals only with the thermodynamic driving force for calcium carbonate scale formation and growth. It provides no indication of how much scale or calcium carbonate will actually precipitate to bring water to equilibrium.

It simply indicates the driving force for scale formation and growth in terms of pH as a master variable. In order to calculate the LSI, it is necessary to know the alkalinity (mg/l as $CaCO_3$), the calcium hardness (mg/l Ca^{2+} as $CaCO_3$), the total dissolved solids (mg/l TDS), the actual pH, and the temperature of the water (^oC).

If TDS is unknown, but conductivity is, one can estimate mg/L TDS using a conversion table. LSI is defined as:

$$\mathbf{LSI = pH - pH_s}$$

Where:

pH is the measured water pH

pH_s is the pH at saturation in calcite or calcium carbonate and is defined as:

$$\mathbf{pH_s = (9.3 + A + B) - (C + D)}$$

Where:

$A = (Log_{10}\ [TDS] - 1) / 10$

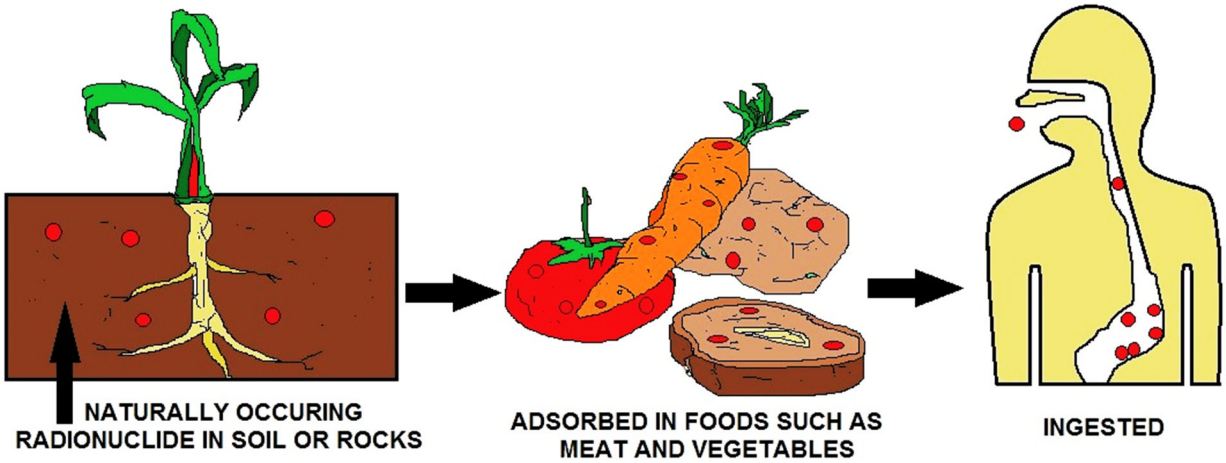
$B = -13.12 \times Log_{10}\ (^oC + 273) + 34.55$

$C = Log_{10}\ [Ca^{2+}\ as\ CaCO_3] - 0.4$

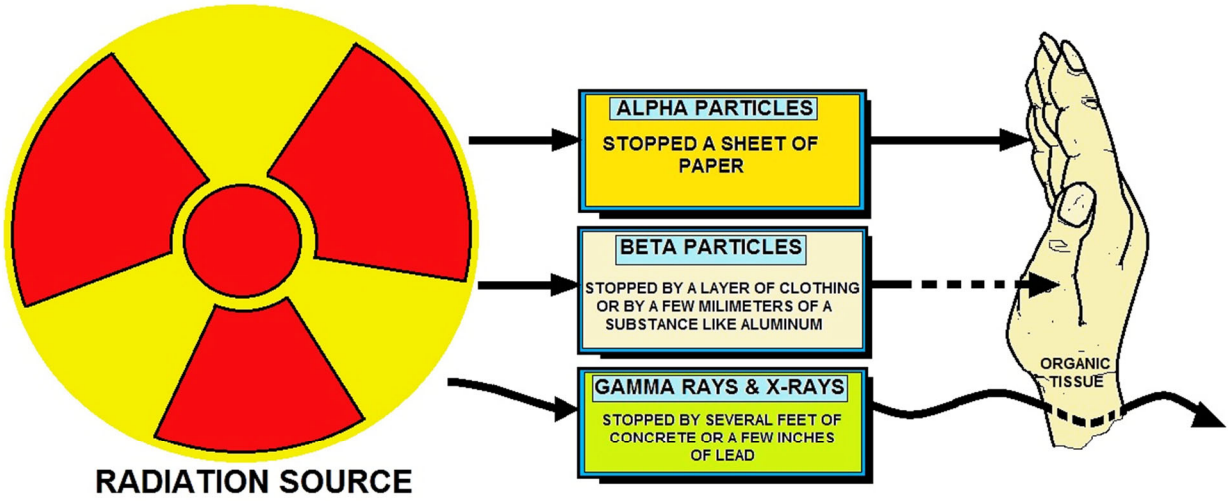
$D = Log_{10}\ [alkalinity\ as\ CaCO_3]$

Radiological Characteristics

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

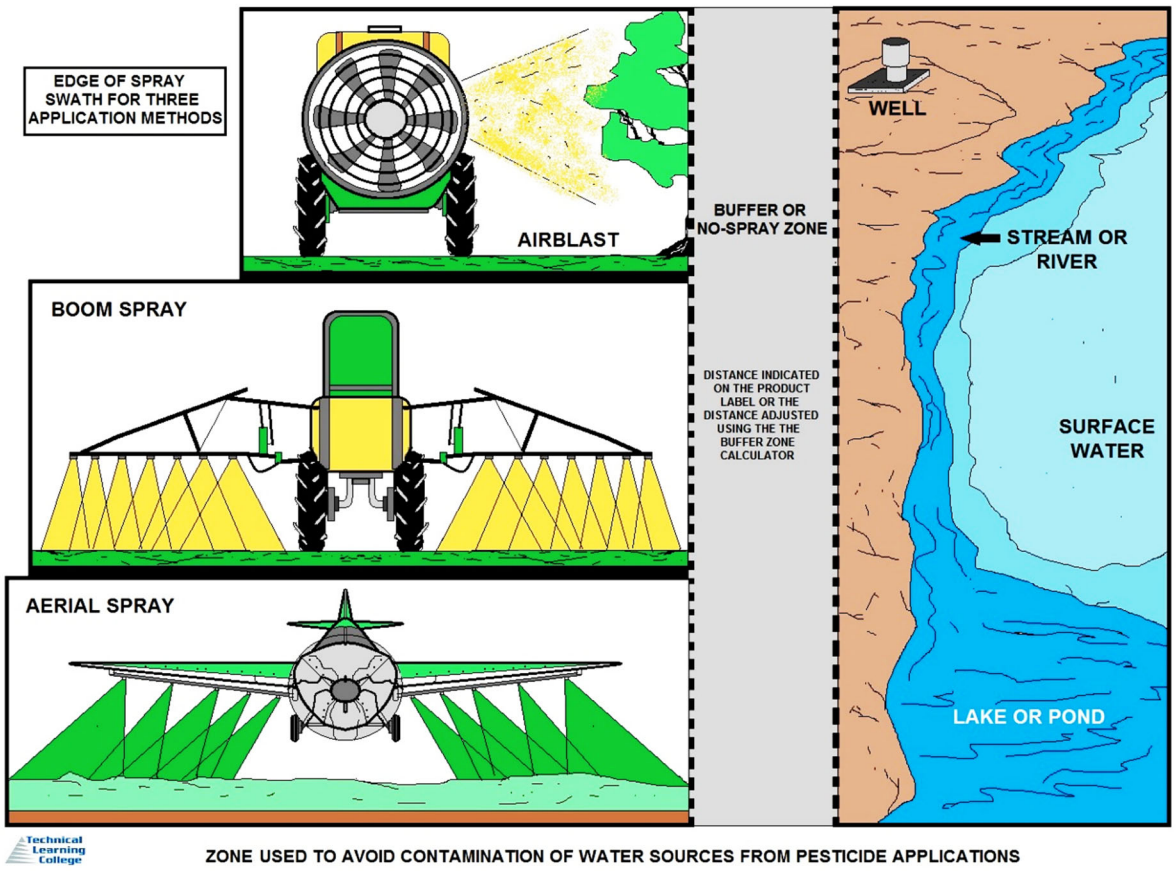


RADIONUCLIDES



PENETRATING POWER OF ALPHA / BETA PARTICLES AND GAMMA RAYS AND X-RAYS

Most of these substances are of natural origin and are picked up as water passes around the water cycle. Some are present due to the treatment processes that are used make the water suitable for drinking and cooking.



Insecticides and Herbicides

Insecticides and herbicides (sometimes referred to as pesticides) are widely used in agriculture, industry, leisure facilities and gardens to control weeds and insect pests and may enter the water cycle in many ways. Aluminum salts are usually added during water treatment to remove color and suspended solids and may reduce any residual insecticides in the water.

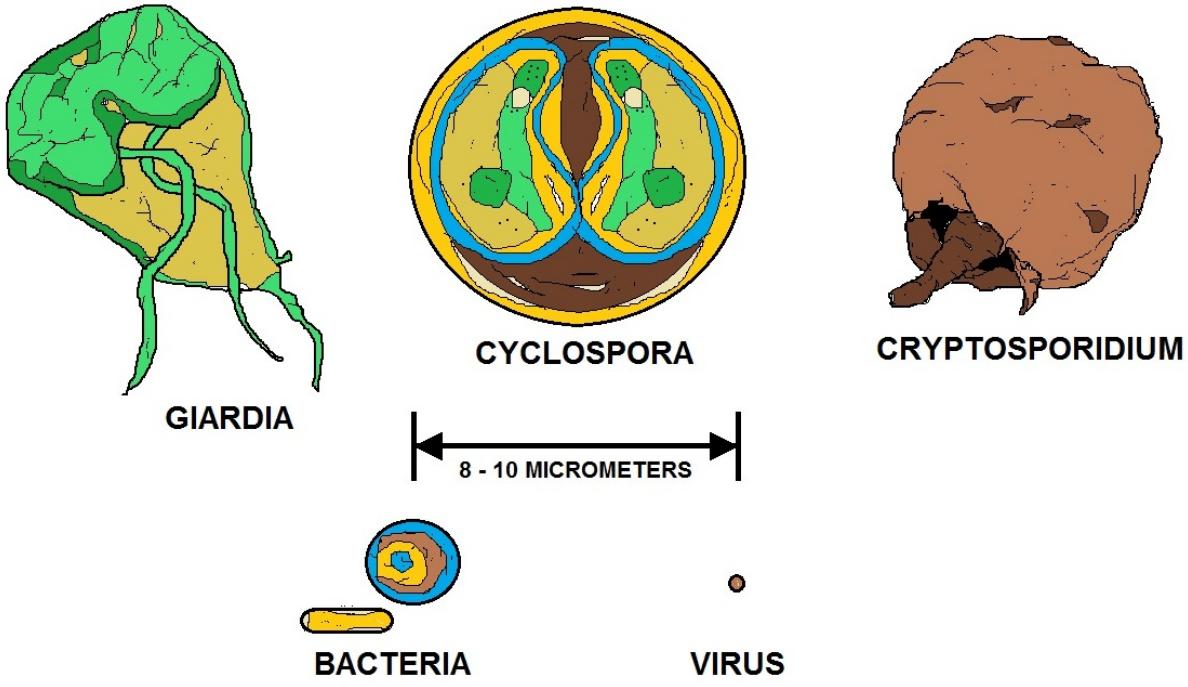
Biological Characteristics of Water

Biological characteristics are the presence of living or dead organisms. Biological characteristics will also interact with the chemical composition of the water. The consumer will become sick or complain about hydrogen sulfide odors, the rotten egg smell. We will cover the Total Coliform Rule in detail in the Water Monitoring Section - Microbiological section and again in the Appendix.

Pathogen Definition
A pathogen is an organism capable of causing disease. Pathogens include parasites, bacteria and viruses.

Biological Parameters

- Biological parameters are important factor that determine quality of drinking water. It is more important than physical and chemical parameters in term of direct effect on human health.
- Some important biological characteristics affecting quality of drinking water includes bacteria, protozoa, virus and algae.



COMPARATIVE SIZES OF PROTOZOAN PARASITES

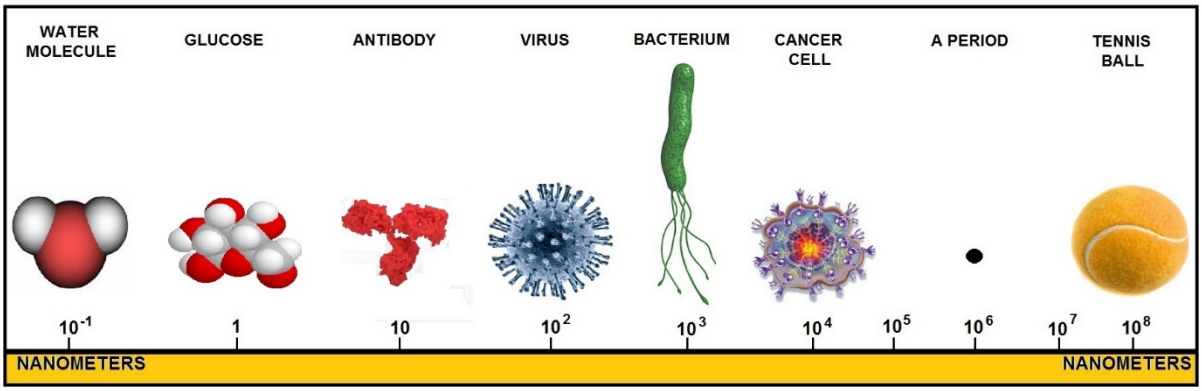
Bacteriological Aspects of Water Pollution

- Human beings and other animals discharge large number of intestinal bacteria into stool and urine. Therefore, bacteria appears in drinking water when water source is contaminated with feces.
- Some intestinal bacteria which are normal flora of intestine are not pathogenic while other bacteria causes serious disease when they are present in drinking water.
- Some pathogenic bacteria includes- *Salmonella, Shigella, Vibrio cholera, Yersinia enterocolitica.*

- These bacteria are only present in drinking water if source of water is contaminated with feces.
- Drinking water must be regularly check to detect intestinal pathogens. However all intestinal pathogens are difficult to cultivate and identify in routine examination. Therefore, presence of pathogenic intestinal bacteria is indirectly checked by detecting intestinal normal flora. Such organism which are routinely checked for quality of water is known as indicator organism for fecal contamination.
- Some indicator organism are fecal coliform (E. *coli*), fecal Streptococci (*Enterococcus*), *Clostridium perfringens*

Cysts

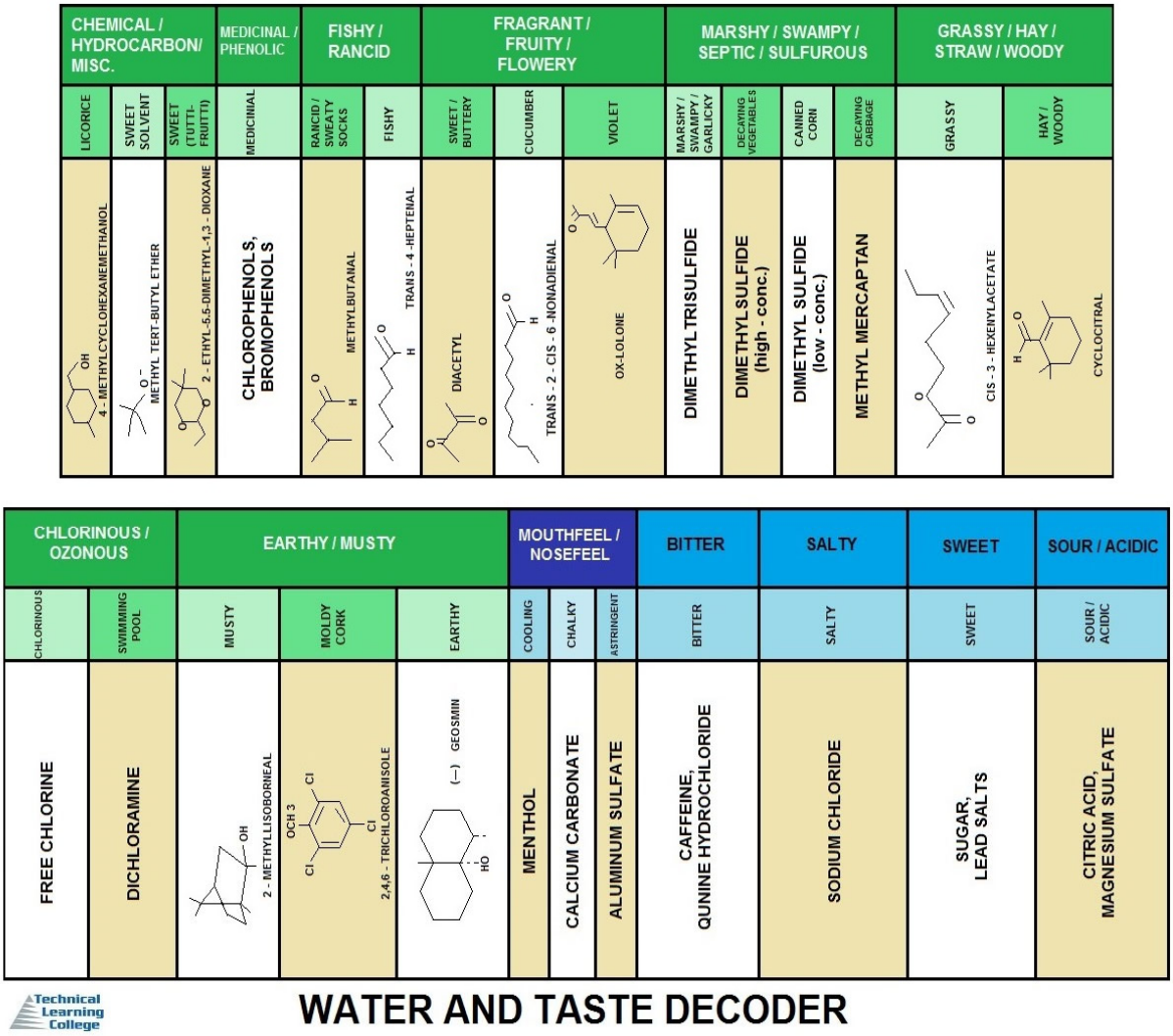
Cysts are associated with the reproductive stages of parasitic microorganisms (protozoans) which can cause acute diarrhea type illnesses; they come from farm animals, wild animals and people. Cysts are very resistant to normal disinfection processes but can be removed by advanced filtration processes installed in water treatment works. Cysts are rarely present in the public water supply. We will cover this area in the water monitoring section.



SIZE COMPARISON
HOW SMALL IS SMALL ?

Drinking Water Tastes and Odors

Health concerns are not the only criteria that we use to judge our drinking water. In fact, often the most noticeable qualities that determine whether water is acceptable to consumers are unpleasant taste or odor, staining, poor reaction with soap, or mineral buildup in pipes and plumbing. These problems result from elevated concentrations of "nuisance" constituents.



Most nuisance constituents occur naturally. These constituents are more likely to occur at nuisance concentrations in groundwater than surface water, because they result from the reaction of groundwater with aquifer rocks and sediments as the water moves underground.

Yellow Water Complaints

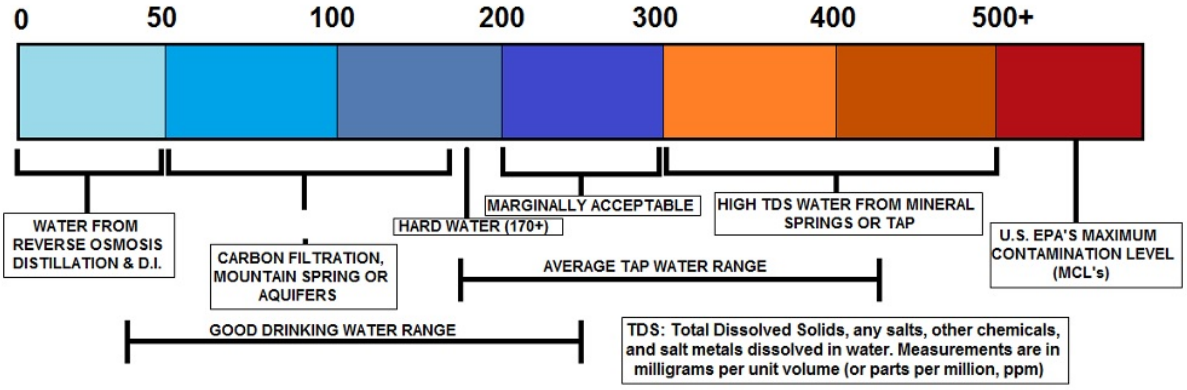
Dissolved iron in groundwater can stain laundry, sinks, bathtubs, and toilets a brownish red, and can degrade plumbing and heating systems. Iron also gives drinking water an unpleasant taste, making it undrinkable for many well owners. Manganese often co-occurs with iron and causes many of the same problems.

Hard Water
Hard water—defined by high concentrations of calcium and magnesium—causes water pipes and fixtures to become coated with scale, limits the ability of soaps and detergents to form suds, and can cause premature failure of plumbing and heating fixtures. pH outside of acceptable ranges can give water a metallic taste and can cause corrosion of pipes. A high dissolved solids concentration—a measure of all dissolved substances in water, also referred to as salinity—makes water taste disagreeably salty.

EPA Guidelines for Nuisance Constituents
The EPA recommends limits, called Secondary Maximum Contaminant Levels (SMCLs), for nuisance constituents in public water supplies. The SMCLs are non-health-based, non-enforceable guidelines for concentrations of 15 constituents in drinking water. These guidelines are designed to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL.

Because they can be smelled, tasted, or seen, nuisance constituents may be more likely to be noticed by consumers than contaminants that actually are a health risk. However, some constituents that have an SMCL also have a higher human-health benchmark. Manganese is one example—the black staining caused by manganese might be just a nuisance or might signal a concentration high enough to be a health risk.

Dissolved Solids
In other situations, the presence of nuisance constituents can signal geochemical conditions that promote high concentrations of other, more harmful contaminants. For example, high concentrations of dissolved solids are considered a nuisance because they cause water to taste salty, but high dissolved solids is not in itself a health concern. However, high dissolved solids can be an indication that there are elevated concentrations of arsenic, uranium, or other trace elements in the groundwater as well. The occurrence of nuisance constituents in drinking water therefore can indicate that testing for a broader range of constituents could be warranted to assess possible risks and to determine options for reducing those risks.



Fluoride Introduction

Some water providers will add fluoride to the water to help prevent cavities in children. Too much fluoride will mottle the teeth.

Chemical Feed
The equipment used for feeding the fluoride to water shall be accurately calibrated before being placed in operation, and at all times shall be capable of maintaining a rate of feed within 5% of the rate at which the machine is set.

The following chemical feed practices apply:
1. Where a dry feeder of the volumetric or gravimetric type is used, a suitable weighing mechanism shall be provided to check the daily amount of chemical feed.
2. Hoppers should be designed to hold a 24 hour supply of the fluoride compound and designed such that the dust hazard to operators is minimized.
3. Vacuum dust filters shall be installed with the hoppers to prevent dust from rising into the room when the hopper is filled.
4. Dissolving chambers are required for use with dry feeders, and the dissolving chambers shall be designed such that at the required rate of feed of the chemical the solution strength will not be greater than 1/4 of that of a saturated solution at the temperature of the dissolving water. The construction material of the dissolving chamber and associated piping shall be compatible with the fluoride solution to be fed.
5. Solution feeders shall be of the positive displacement type and constructed of material compatible with the fluoride solution being fed.
6. The weight of the daily amount of fluoride fed to water shall be accurately determined.
7. Feeders shall be provided with anti-siphon valves on the discharge side. Wherever possible, positive anti-siphon breakers other than valves shall be provided.
8. A "*day tank*" capable of holding a 24 hour supply of solution should be provided.
9. All equipment shall be sized such that it will be operated within the 20 to 80 percent range of their scale, and be capable of feeding over the entire pumpage range of the plant.
10. Alarm signals are recommended to detect faulty operation of equipment; and,
11. The fluoride solution should be added to the water supply at a point where the fluoride will not be removed by any following treatment processes and where it will be mixed with the water. It is undesirable to inject the fluoride compound or solution directly on-line unless there are provisions for adequate mixing.

Metering
Metering of the total water to be fluoridated shall be provided, and the operation of the feeding equipment is to be controlled. Control of the feed rate shall be automatic/ proportional controlled, whereby the fluoride feed rate is automatically adjusted in accordance with the flow changes to provide a constant pre-established dosage for all rates of flow, or (2) automatic/ residual controlled, whereby a continuous automatic fluoride analyzer determines the residual fluoride level and adjusts the rate of feed accordingly, or compound loop controlled, whereby the feed rate is controlled by a flow proportional signal and residual analyzer signal to maintain a constant residual.

Alternate Compounds
Any one of the following fluoride compounds may be used:
1. Hydrofluosilicic acid,
2. Sodium fluoride or,

3. Sodium silicofluoride*.* Other fluoride compounds may be used, if approved by the EPA.

Chemical Storage and Ventilation
The fluoride chemicals shall be stored separately from other chemicals, and the storage area shall be marked "***FLUORIDE CHEMICALS ONLY***". The storage area should be in close proximity to the feeder, kept relatively dry, and provided with pallets (if using bagged chemical) to allow circulation of air and to keep the containers off the floor.

Record of Performance
Accurate daily records shall be kept. These records shall include:
1. The daily reading of the water meter which controls the fluoridation equipment or that which determines the amount of water to which the fluoride is added.
2. The daily volume of water fluoridated.
3. The daily weight of fluoride compound in the feeder.
4. The daily weight of fluoride compound in stock.
5. The daily weight of the fluoride compound fed to the water; and,
6. The fluoride content of the raw and fluoridated water determined by laboratory analysis, with the frequency of measurement as follows:
    (i) treated water being analyzed continuously or once daily, and
    (ii) raw water being analyzed at least once a week.

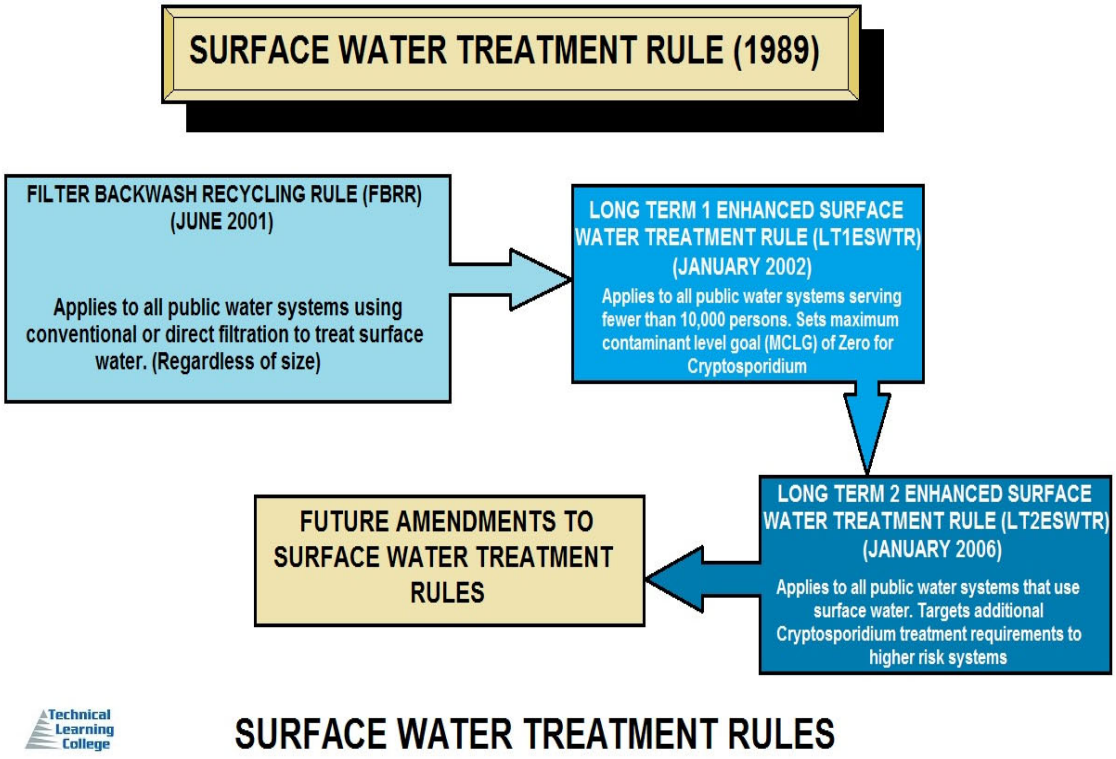
Sampling
In keeping the fluoride records, the following sampling procedures are required:
1. A sample of raw water and a sample of treated water shall be forwarded to an approved independent laboratory for fluoride analysis once a month.
2. On new installations or during start-ups of existing installations, weekly samples of raw and treated water for a period of not less than four consecutive weeks.
3. In addition to the reports required, the EPA may require other information that is deemed necessary.

Fluoride Safety
The following safety procedures shall be maintained:
1. All equipment shall be maintained at a high standard of efficiency, and all areas and appliances shall be kept clean and free of dust. Wet or damp cleaning methods shall be employed wherever practicable.
2. Personal protective equipment shall be used during the clean-up, and appropriate covers shall be maintained over all fluoride solutions.
3. At all installations, safety features are to be considered and the necessary controls built into the installation to prevent an overdose of fluoride in the water. This shall be done either by use of day tanks or containers, anti-siphon devices, over-riding flow switches, sizing of pump and feeders, determining the length and duration of impulses, or other similar safety devices.
4. Safety features shall also be provided to prevent spills and overflows.
5. Individual dust respirators, chemical safety face shields, rubber gloves, and protective clothing shall be worn by all personnel when handling or being exposed to the fluoride dust.
6. Chemical respirators, rubber gloves, boots, chemical safety goggles and acid proof aprons shall be worn where acids are handled.
7. After use, all equipment shall be thoroughly cleaned and stored in an area free of fluoride dusts. Rubber articles shall be washed in water, and hands shall be washed after the equipment is stored; and, all protective devices, whether for routine or emergency use, shall be inspected periodically and maintained in good operating condition.

Safe Drinking Water Act (SDWA) Introduction

On August 6, 1996, President Clinton signed the Reauthorization of the Safe Drinking Water Act, bringing a successful conclusion to years of work on the part of water professionals and a broad range of public interest groups throughout the nation.

This law strikes a balance among federal, state, local, urban, rural, large and small water systems in a manner that improves the protection of public health and brings reason and good science to the regulatory process.



The major elements of this law include:

- The law updates the standard-setting process by focusing regulations on contaminants known to pose greater public health risks.
- It replaces the current law's demand for 25 new standards every three years with a new process based on occurrence, relative risk and cost-benefit considerations.
- It also requires the EPA to select at least five new candidate contaminants to consider for regulation every five years.
- The EPA is directed to require public water systems to provide customers with annual "**Consumer Confidence Reports**" in newspapers and by direct mail.
- The reports must list levels of regulated contaminants along with Maximum Contaminant Levels (**MCLs**) and Maximum Contaminant Level Goals (**MCLGs**), along with plainly worded definitions of both.
- The reports must also include a plainly worded statement of the health concerns for any contaminants for which there has been a violation, describe the utility's sources of

drinking water and provide data on unregulated contaminants for which monitoring is required, including Cryptosporidium and radon.

- The EPA must establish a toll-free hot line customers can call to get additional information.
- The EPA is required to publish guidelines for states to develop water source assessment programs that delineate protection areas and assess contamination risks.
- The EPA is required to identify technologies that are affordable for small systems to comply with drinking water regulations.
- Technical assistance funds and Small System Technical Assistance Centers are authorized to meet the training and technical needs of small systems.
- States are authorized to grant variances for compliance with drinking water regulations for systems serving 3,300 or fewer persons.
- The EPA is required to publish certification guidelines for operators of community and nontransient noncommunity public water systems.
- States that do not have operator certification programs that meet the requirements of the guidelines will lose 20 percent of their SRLF grant.
- A source water petition program for voluntary, incentive-based partnerships among public water systems and others to reduce contamination in source water is authorized.
- The law establishes a new State Revolving Loan Fund (**SRLF**) of $1 billion per year to provide loans to public water systems to comply with the new SDWA.
- It also requires states to allocate 15 percent of the SRLF to systems serving 10,000 or fewer people unless no eligible projects are available for loans.
- It also allows states to jointly administer SDWA and Clean Water Act loan programs and transfer up to 33 percent between the two accounts.
- States must ensure that all new systems have compliance capacity and that all current systems maintain capacity, or lose 20 percent of their SRLF grant.

Although the EPA will continue to provide policy, regulations and guidance, state governments will now have more regulatory flexibility allowing for improved communication between water providers and their local regulators. Increased collaboration will result in solutions that work better and are more fully supported by the regulated community. States that have a source water assessment program may adopt alternative monitoring requirements to provide permanent monitoring relief for public water systems in accordance with EPA guidance.

Risk Assessment

P.L. 104-182 adds risk assessment and communication provisions to SDWA. When developing regulations, the EPA is now required to: (1) use the best available, peer-reviewed science and supporting studies and data; and (2) make publicly available a risk assessment document that discusses estimated risks, uncertainties, and studies used in the assessment. When proposing drinking water regulations, the EPA must publish a health risk reduction and cost analysis. The law permits the EPA to promulgate an interim standard without first preparing a benefit-cost analysis or making a determination as to whether the benefits of a regulation would justify the costs if the EPA determines that a contaminant presents an urgent threat to public health.

New regulations generally become effective 3 years after promulgation. Up to 2 additional years may be allowed if the EPA (or a state in the case of an individual system) determines the time is needed for capital improvements. Section 1412 includes specific provisions for arsenic, sulfate, and radon. The law authorizes states to grant Systems variances from a regulation if raw water quality prevents meeting the standards despite application of the best technology (Section 1415). A new provision authorizes small system variances based on best affordable technology.

States may grant these variances to systems serving 3,300 or fewer persons if the system cannot afford to comply (through treatment, an alternative water source, or restructuring) and the variance ensures adequate protection of public health; states may grant variances to systems serving between 3,300 and 10,000 persons with EPA approval. To receive a small system variance, the system must install a variance technology identified by the EPA. The variance technology need not meet the MCL, but must protect public health. The EPA must identify variance technologies for existing regulations. Variances are not available for microbial contaminants. The Act also provides for exemptions if a regulation cannot be met for other compelling reasons (including costs) and if the system was in operation before the effective date of a standard or treatment requirement (Section 1416). An exemption is intended to give a public water system more time to comply with a regulation and can be issued only if it will not result in an unreasonable health risk. Small systems may receive exemptions for up to 9 years.

State Primacy
The primary enforcement responsibility for public water systems lies with the states, provided they adopt regulations as stringent as the national requirements, adopt authority for administrative penalties, develop adequate procedures for enforcement, maintain records, and create a plan for providing emergency water supplies (Section 1413). Currently, 55 of 57 states and territories have primacy authority. P.L. 104-182 authorizes $100 million annually for EPA to make grants to states to carry out the public water system supervision program. States may also use a portion of their SRF grant for this purpose (Section 1443).

Whenever the EPA finds that a public water system in a state with primary enforcement authority does not comply with regulations, the Agency must notify the state and the system and provide assistance to bring the system into compliance. If the state fails to commence enforcement action within 30 days after the notification, the EPA is authorized to issue an administrative order or commence a civil action.

Nonprimacy State
In a non-primacy state, the EPA must notify an elected local official (if any has jurisdiction over the water system) before commencing an enforcement action against the system (Section 1414). Primacy states may establish alternative monitoring requirements to provide interim monitoring relief for systems serving 10,000 or fewer persons for most contaminants, if a contaminant is not detected in the first quarterly sample. States with approved source water protection programs may adopt alternative monitoring requirements to provide permanent monitoring relief to qualified systems for chemical contaminants (Section 1418).

P.L. 104-182 requires states to adopt programs for training and certifying operators of community and nontransient noncommunity systems. The EPA must publish guidelines specifying minimum standards for operator certification by February 1999. Two years thereafter, the EPA must withhold 20% of a state's SRF grant unless the state has an operator certification program (Section 1419). States are also required to establish capacity development programs based on EPA guidance.

State programs must include: 1) legal authority to ensure that new systems have the technical, financial, and managerial capacity to meet SDWA requirements; and 2) a strategy to assist existing systems that are experiencing difficulties to come into compliance. Beginning in 2001, the EPA is required to withhold a portion of SRF grants from states that do not have compliance development strategies (Section 1420).

Underground Injection Control
Another provision of the Act requires the EPA to promulgate regulations for state underground injection control (**UIC**) programs to protect underground sources of drinking water. These regulations contain minimum requirements for the underground injection of wastes in five well classes to protect underground sources of drinking water and to require that a state prohibit, by December 1977, any underground injection that was not authorized by state permit (Section 1421).

Ground Water Protection Grant Programs
The Act contains three additional ground water protection programs. Added in 1986, Section 1427 established procedures for demonstration programs to develop, implement, and assess critical aquifer protection areas already designated by the Administrator as sole source aquifers. Section 1428, also added in 1986, and established an elective state program for protecting wellhead areas around public water system wells.

If a state established a wellhead protection program by 1989, and the EPA approved the state's program, then the EPA may award grants covering between 50% and 90% of the costs of implementing the program. Section 1429, added by P.L. 104-182, authorizes the EPA to make 50% grants to states to develop programs to ensure coordinated and comprehensive protection of ground water within the states. Appropriations for these three programs and for LYIC state program grants are authorized starting back in FY2003.

Source Water Protection Programs
P.L. 104-182 broadens the pollution prevention focus of the Act to embrace surface water as well as ground water protection. New Section 1453 directs the EPA to publish guidance for states to implement source water assessment programs that delineate boundaries of assessment areas from which systems receive their water, and identify the origins of contaminants in delineated areas to determine systems' susceptibility to contamination. States with approved assessment programs may adopt alternative monitoring requirements to provide systems with monitoring relief under Section 1418.

New Section 1454 authorizes a source water petition program based on voluntary partnerships between state and local governments. States may establish a program under which a community water system or local government may submit a source water quality partnership petition to the state requesting assistance in developing a voluntary partnership to: (1) reduce the presence of contaminants in drinking water; (2) receive financial or technical assistance; and (3) develop a long-term source water protection strategy. This section authorizes $5 million each year for grants to states to support petition programs. Also, states may use up to 10% of their annual SRF capitalization grant for the source water assessment activities or for the petition program.

State Revolving Funds
Section 1452, added by P.L. 104-182 authorizes a State Revolving Loan Fund (**SRF**) program to help systems finance improvements needed to comply with drinking water regulations. The law authorizes the EPA to make grants to states to capitalize SDWA SRFs, which states then use to make loans to public water systems. States must match 20% of the federal grant.

Grants will be allotted to states using the formula for distributing state PWSS grants through FY1997; then, grants will be allotted based on a needs survey. Each state will receive at least 1% of funds.

Drinking water SRFs may be used to provide loan and grant assistance for expenditures that the EPA has determined will facilitate compliance or significantly further the Act's health protection objectives. States must make available 15% of their annual allotment for loan assistance to systems that serve 10,000 or fewer persons. States may use up to 30% of their SRF grant to provide grants or forgive loan principle to help economically disadvantaged communities. Also, states may use a portion of funds for technical assistance, source water protection and capacity development programs, and for operator certification.

Other Provisions

Public water systems must notify customers of violations with potential for serious health effects within 24 hours. Systems must also issue to customers' annual reports on contaminants detected in their drinking water (Section 1414). Section 1417 requires any pipe, solder, or flux used in the installation or repair of public water systems or of plumbing in residential or nonresidential facilities providing drinking water to be "**lead free**" (as defined in the Act).

As of August 1998, it will be unlawful to sell pipes, plumbing fittings or fixtures that are not "**lead free**" or to sell solder or flux that is not lead free (unless it is properly labeled); with the exception of pipes used in manufacturing or industrial processing. P.L. 104-182 sets limits on the amount of lead that may leach from new plumbing fixtures, and allows one year for a voluntary standard to be established before requiring EPA to take regulatory action.

The Administrator has emergency powers to issue orders and commence civil action if a contaminant likely to enter a public drinking water supply system poses a substantial threat to public health and state or local officials have not taken adequate action (Section 1431).

If a chemical necessary for water treatment is not reasonably available, the Administrator can issue a "***certification of need***," in which case the President can order an allocation of the chemical to those needing it (Section 1441).

EPA is provided authority to conduct research, studies, and demonstrations related to the causes, treatment, control, and prevention of diseases resulting from contaminants in water. The Agency is directed to provide technical assistance to the states and municipalities in administering their public water system regulatory responsibilities. The law authorizes annually, $15 million for technical assistance to small systems and Indian Tribes, and $25 million for health effects research (Section 1442). P.L. 104-182 authorizes additional appropriations for drinking water research, not to exceed $26.6 million annually.

The Administrator may make grants to develop and demonstrate new technologies for providing safe drinking water and to investigate health implications involved in the reclamation/reuse of waste waters (Section 1444).

Also, suppliers of water who may be subject to regulation under the Act are required to establish and maintain records, monitor, and provide any information that the Administrator requires to carry out the requirements of the Act (Section 1445).

The Administrator may also enter and inspect the property of water suppliers to enable him/her to carry out the purposes of the Act. Failure to comply with these provisions may result in criminal penalties.

The Act established a National Drinking Water Advisory Council, composed of 15 members (with at least 2 representing rural systems), to advise, consult, and make recommendations to the Administrator on activities and policies derived from the Act (Section 1446).

National Security
Any federal agency having jurisdiction over federally owned and maintained public water systems must comply with all federal, state, and local drinking water requirements, as well as any underground injection control programs (Section 1447). The Act provides for waivers in the interest of national security. Procedures for judicial review are outlined (Section 1448), and provision for citizens' civil actions is made (Section 1449).

Three Types of Public Water Systems

Community Water Systems (CWSs)

- Provide water to the same population year-round (for example: homes, apartment buildings)
- Approximately 52,000 systems serving the majority of the U.S. population

Non-Transient Non-Community Water Systems (NTNCWSs)

- Provide water to the same people at least six months a year, but not all year (for example: schools, factories, churches, office buildings that have their own water system)
- Approximately 85,000 systems

Transient Non-Community Water System (TNCWS)

- Provide water where people do not remain for long periods of time (for example: gas stations, campgrounds)
- Approximately 18,000 systems

SDWA MCLs Introduction

Radionuclides

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

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

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

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

Water Sampling Bottles

These are commonly found examples of various water sampling bottles. VOC and THM bottles are in the front.

You will have to make sure there is absolutely no air inside these tiny bottles. Any air bubble can ruin the sample. There are several ways to get the air out. The best one is slowly overfill the bottle to get a reverse meniscus. Second, is to fill the cap with water before screwing it onto the bottle. The third one is to use a thin copper tube and slowly fill the bottle.

Inorganic Contaminants

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

Inorganic Contaminants

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

Fluoride. Many communities add fluoride to their drinking water to promote dental health. Each community makes its own decision about whether or not to add fluoride. The EPA has set an enforceable drinking water standard for fluoride of 4 mg/L. Some people who drink water-containing fluoride in excess of this MCL level over many years could get bone disease, including pain and tenderness of the bones. The EPA has also set a secondary fluoride standard of 2 mg/L to protect against dental fluorosis.

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

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

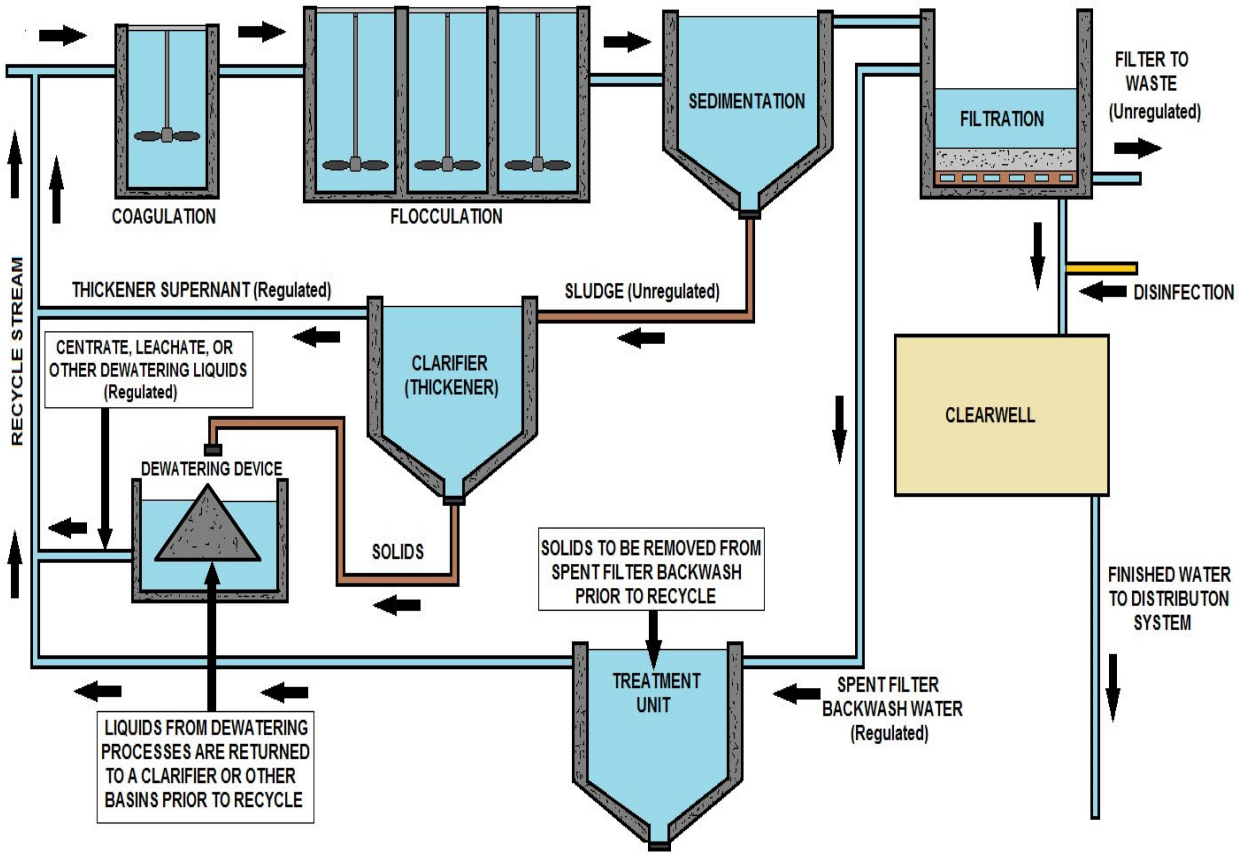
Synthetic Organic Contaminants, including Pesticides & Herbicides

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

Volatile Organic Contaminants

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

Other Related EPA Water Treatment Rules



Filter Backwash Recycling Rule (FBRR)

The Filter Backwash Recycling Rule (FBRR) regulates the recycling of filter backwash water within the treatment process of public water systems. The FBRR requires surface water systems to review their recycle practices and to modify any recycle practices that may compromise microbial control or contribute to violations of the drinking water regulations. Recycle flows can be a source of concentrated microbial pathogens and chemical contaminants.

IESWTR

The Interim Enhanced Surface Water Treatment Rule (IESWTR) builds on the requirements of the Surface Water Treatment Rule. IESWTR specifies treatment requirements to address *Cryptosporidium* and other microbial contaminants in public water systems serving 10,000 or more persons.

The rule balances the need for treatment with potential increases in disinfection by-products. The materials found on this page are intended to assist public water systems and states in the implementation of the IESWTR.

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

To protect human health, an EPA standard limits the amount of arsenic in drinking water. Back in January 2001, the EPA revised the standard from 50 parts per billion (**ppb**), ordering that it fall to 10 ppb in 2006.

After adopting 10 ppb as the new standard for arsenic in drinking water, the EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits. In October 2001, the EPA decided to move forward with implementing the 10 ppb standard for arsenic in drinking water.

More information on the rulemaking process and the costs and benefits of setting the arsenic limit in drinking water at 10 ppb can be found at www.epa.gov/safewater/arsenic.html.

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

Drinking water microbial and disinfection byproduct information collected for the ICR is now available in the EPA's *Envirofacts Warehouse*.

Gas Chromatograph
Used for micro-contaminant water analysis.

Commonly Found Distribution System Water Quality Problems

Turbidity

Turbidity is caused by particles suspended in water. These particles scatter or reflect light rays, making the water appear cloudy. Turbidity is expressed in nephelometric turbidity units (ntu) and a reading in excess of 5 ntu is generally noticeable to water system customers.

Besides the appearance being unpleasant to customers, turbidity in water is significant from a public health standpoint because suspended particles could shelter microorganisms from the disinfectant and allow them to still be viable when they reach the customer.

EPA regulations direct that, for most water systems, the turbidity of water entering the distribution system must be equal or less than 0.5 ntu in at least 95 percent of the measurements taken each month. At no time may the turbidity exceed 5 ntu.

Turbidity changes in the distribution system can indicate developing problems. Increases in turbidity may be caused by changes in velocity or inadequate flushing following main replacement or repairs.

Hardness

Hardness is a measure of the concentration of calcium and magnesium in water. Water hardness usually comes from water contacting rock formations, such as water from wells in limestone formations. Soft ground water may occur where topsoil is thin and limestone formations are sparse or absent. Most surface water is of medium hardness.

Hard and soft water are both satisfactory for human consumption, but customers may object to very hard water because of the scale it forms in plumbing fixtures and on cooking utensils. Hardness is also a problem for some industrial and commercial users because of scale buildup in boilers and other equipment.

Water generally is considered most satisfactory for household use when the hardness is between 75 and 100 mg/L as calcium carbonate ($CaCO_3$). Water with 300 mg/L of hardness usually is considered **hard**. Very soft water of 30 mg/L or less is found in some section of the United States. Soft water usually is quite corrosive, and may have to be treated to reduce the corrosivity.

Iron

Iron occurs naturally in rocks and soils and is one of the most abundant elements. It occurs in two forms. Ferrous iron (Fe^{+2}) is in a dissolved state, and water containing ferrous iron is colorless. Ferric iron (Fe^{+3}) has been oxidized, and water containing it is rust-colored.

Water from some well sources contains significant levels of dissolved iron, which is colorless, but rapidly turns brown as air reaches the water and oxidizes the iron.

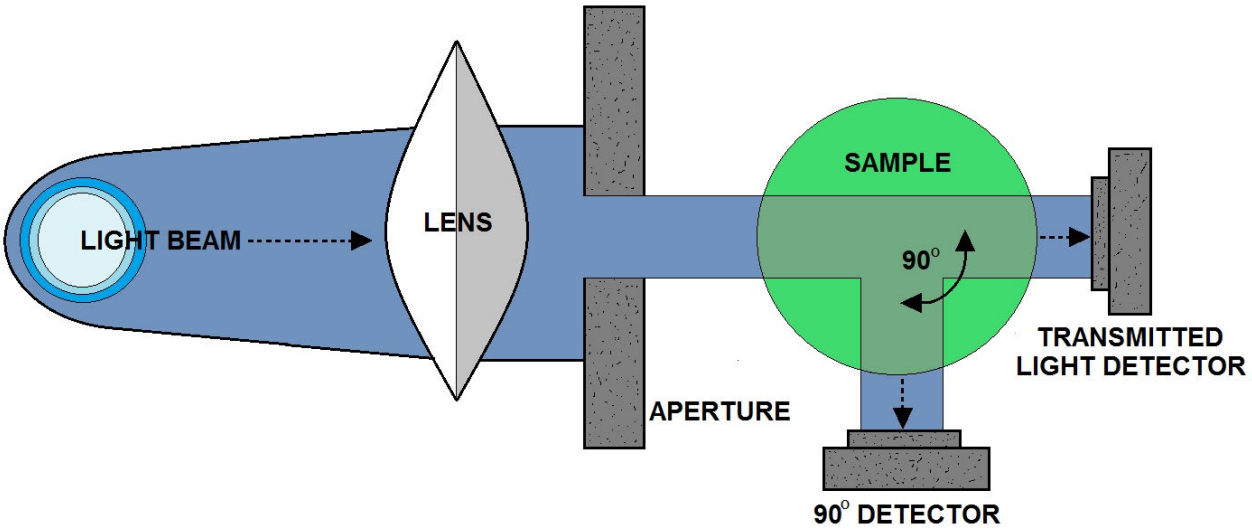
There are no known harmful effects to humans from drinking water containing iron, but NSDWR suggest a limit of 0.5 mg/L. At high levels, the staining of plumbing fixtures and clothing becomes objectionable. Iron also provides nutrient source for some bacteria that grow in distribution systems and wells. Iron bacteria, such as Gallionella, cause red water, tastes and odors, clogged pipes, and pump failure.

Whenever tests on water samples show increased iron concentrations between the point where water enters the distribution system and the consumer's tap, either corrosion, iron bacteria, or both are probably taking place. If the problem is caused by bacteria, flushing mains, shock chlorination, and carrying increased residual chlorine are alternatives to consider.

Manganese
Manganese in ground water creates problems similar to iron. It does not usually discolor the water, but will stain washed clothes and plumbing fixtures black; this is very unpopular with customers. Consumption of manganese has no known harmful effects on humans, but the NSDWR recommend a concentration not to exceed 0.05 mg/L to avoid customer complaints.

Water Quality Safeguards
The **critical** safeguard for water distribution system operations are

- continuous positive pressure in the mains; 20 pounds per square inch (psi) minimum residual pressure is recommended;
- maintenance of chlorine residual;
- cross-connection control; and
- frequent testing.



Technical Learning College

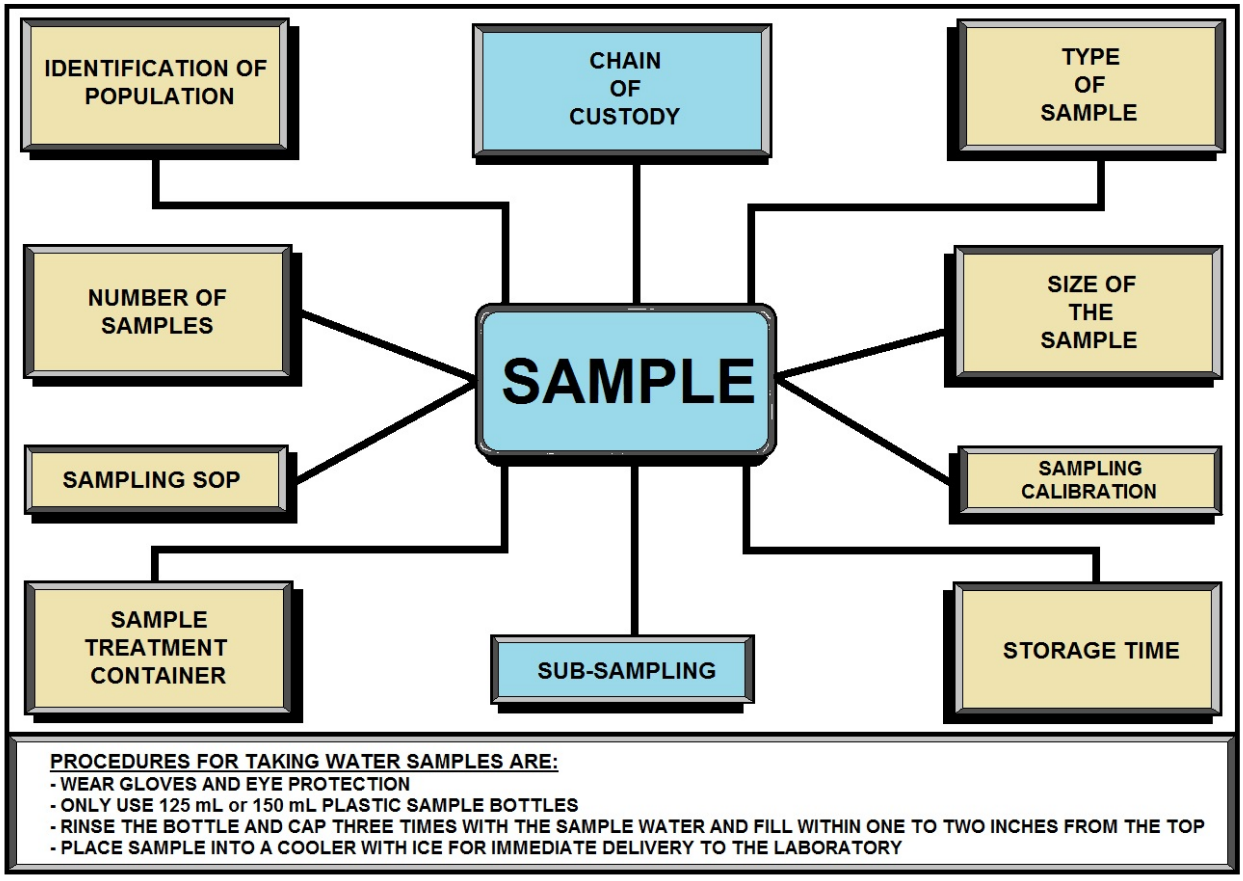
BASICS OF A TURBIDIMETER

Sampling Plan Introduction

A written sampling plan must be developed by the water system. These plans will be reviewed by the Health Department or State Drinking Water agency during routine field visits for sanitary surveys or technical assistance visits. This plan should include:

1. The location of routine sampling sites on a system distribution map. You will need to locate more routine sampling sites than the number of samples required per month or quarter. A minimum of three sites is advised and the sites should be rotated on a regular basis.
2. Map the location of repeat sampling sites for the routine sampling sites. Remember that repeat samples must be collected within five (5) connections upstream and downstream from the routine sample sites.
3. Establish a sampling frequency of the routine sites.
4. Sampling technique, establish a minimum flushing time and requirements for free chlorine residuals at the sites (if you chlorinate continuously).

The sampling sites should be representative of the distribution network and pressure zones. If someone else, e.g., the lab, collects samples for you, you should provide them with a copy of your sampling plan and make sure they have access to all sample sites.



PROPER SAMPLING PROCEDURES (WATER)

WATER TESTING LAB
456 SOMEWHERE ST.
ANYWHERE, AZ 85002

TEST REPORT:

WATER COMPANY
123 ANYWHERE ST.
SOMEWHERE, AZ 85001

DRINKING WATER ANALYSIS RESULTS

FOR MODEL : RO103TDS

NOTE:
ND THIS CONTAMINANT WAS NOT DETECTED AT OR ABOVE OUR STATED DETECTION LEVEL
NBS NO BACTERIA SUBMITTED NBR NO BACTERIA REQUIRED
* THE MCL (Maximum Contaminant Level) OR AN ESTABLISHED GUIDELINE HAS BEEN EXCEEDED FOR THIS CONTAMINANT
** BACTERIA RESULTS MAY BE INVALID DUE TO LACK OF COLLECTION INFORMATION OR BECAUSE SAMPLE HAS EXCEEDED THE 30-HOUR HOLDING TIMES

ANALYSIS PERFORMED: P-PRESENCE A - ABSENCE EP - E.COLI PRESENCE EA - E.COLI ABSENCE NA: NOT ANALYZED

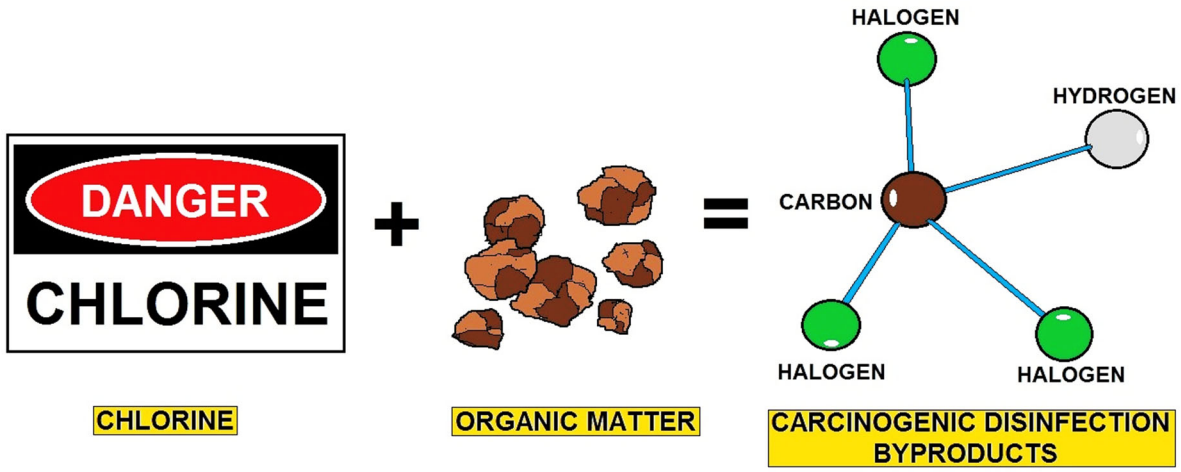
ANALYSIS	MCL (mg/l)	Det. Level	Level Detected
TOTAL COLIFORM	P	P	A
INORGANIC CHEMICALS - Metals			
Aluminum	0.2	0.1	ND
Arsenic	0.05	0.020	ND
Barium	2	0.30	ND
Cadmium	0.005	0.002	ND
Chromium	0.1	0.010	ND
Copper	1.3	0.004	ND
Iron	0.3	0.020	ND
Lead	0.015	0.002	ND
Manganese	0.05	0.004	ND
Mercury	0.002	0.001	ND
Nickel	0.1	0.02	ND
Selenium	0.05	0.020	ND
Silver	0.1	0.02	ND
Sodium	-----	1.0	ND
Zinc	5	0.004	ND
INORGANIC CHEMICALS - Other, and Physical Factors			
Alkalinity (Total as CaCO)	-----	0.1	ND
Chloride	250	5.0	ND
Fluoride	4	0.5	ND
Nitrate as N	10	0.5	ND
Nitrite as N	1	0.5	ND
Sulfate	250	5.0	ND
Hardness (suggested limit - 100)		10	ND
pH (Standard Units)	6.5 - 8.5	-----	7.7
Total Dissolved Solids	500	20	ND
Turbidity (Turbidity Units)	1.0	0.1	ND
ORGANIC CHEMICALS - Trihalomethanes:			
T THMS	0.080	0.004	ND

WATER ANALYSIS REPORT EXAMPLE

Older Stage 1 DBPR Information

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

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



DISINFECTION BYPRODUCT PRODUCTION DIAGRAM

Disinfection byproducts are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts.

Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.

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

The Stage 1 Disinfectant/Disinfection Byproduct Rule standards became effective for trihalomethanes and other disinfection byproducts listed above in December 2001 for large surface water public water systems. Those standards became effective in December 2003 for small surface water and all ground water public water systems.

Trihalomethanes (**THM**) are a group of four chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The trihalomethanes are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The EPA has

published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate total trihalomethanes (TTHM) at a maximum allowable annual average level of 80 parts per billion. This new standard replaced the old standard of a maximum allowable annual average level of 100 parts per billion back in December 2001 for large surface water public water systems. The standard became effective for the first time back in December 2003 for small surface water and all ground water systems.

DISINFECTION TREATMENT	DISINFECTION BYPRODUCTS	HEALTH EFFECTS
CHLORINATION	TRIHALOMETHANES (THM's) HALOACETIC ACIDS (HAA's) CHLORATE	INCREASED RISK OF CANCER; PROBLEMS IN THE KIDNEY, LIVER AND THE CENTRAL NERVOUS SYSTEM. REDUCED ABILITY FOR RED BLOOD CELLS TO CARRY OXYGEN.
CHLORINE DIOXIDE	CHLORATE CHLORITE	REDUCED ABILITY FOR RED BLOOD CELLS TO CARRY OXYGEN. ANEMIA AND NERVOUS SYSTEM EFFECTS (for infants and young children)
CHLORAMINE	CHLORATE	REDUCED ABILITY FOR RED BLOOD CELLS TO CARRY OXYGEN
OZONATION	BROMATE	INCREASED RISK OF CANCER

Technical Learning College

DISINFECTION BYPRODUCT FORMATION AND EFFECTS

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

The regulated haloacetic acids, known as HAA5, are: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid. EPA has published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate HAA5 at 60 parts per billion annual average.

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

Drinking water standards may apply differently based on type and size of public water systems.

Disinfection Rules Stages 1 & 2 DBPR Introduction

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

Stage 2 DBPR

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

General Requirements

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

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

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

– 0.080 mg/L (80 ppb) for total trihalomethanes (TTHM), and

– 0.060 mg/L (60 ppb) for five haloacetic acids (HAA5).

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

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

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

Compliance Timeline

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

• If your system **is** part of a combined distribution system, you must comply with the revised MCLs by the same date as required for the largest system in your combined distribution system.
Example: if your system serves 8,000 people, but you purchase water from a system that serves 250,000 people, you must comply by the dates shown in Schedule 1.
• If your system **is not** part of a combined distribution system, compliance dates are based on the population served by your system.

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

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

Note: You are on the same schedule for Stage 2 DBPR compliance as you were on for the IDSE.

The timeline on the next page shows important dates for the Stage 2 DBPR as well as periods for *Cryptosporidium* and *E. coli* required under the LT2ESWTR.

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

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

Where do DBPs come from?
Chlorine and other chemical disinfectants have been widely used by public water systems (along with filtration) to protect the public from microbial pathogens in drinking water. DBPs are formed when certain disinfectants react with DBP precursors (organic and inorganic materials) in source waters. In most cases, natural organic matter (NOM) is an important factor that affects the levels of DBPs that form NOM is usually measured as Total Organic Carbon (TOC).

The levels of DBPs in drinking water can vary significantly from one point in a distribution system to another, as many continue to form in the distribution system. DBP levels are generally higher in surface water systems because surface water usually contains higher DBP precursor levels and requires stronger disinfection.

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

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

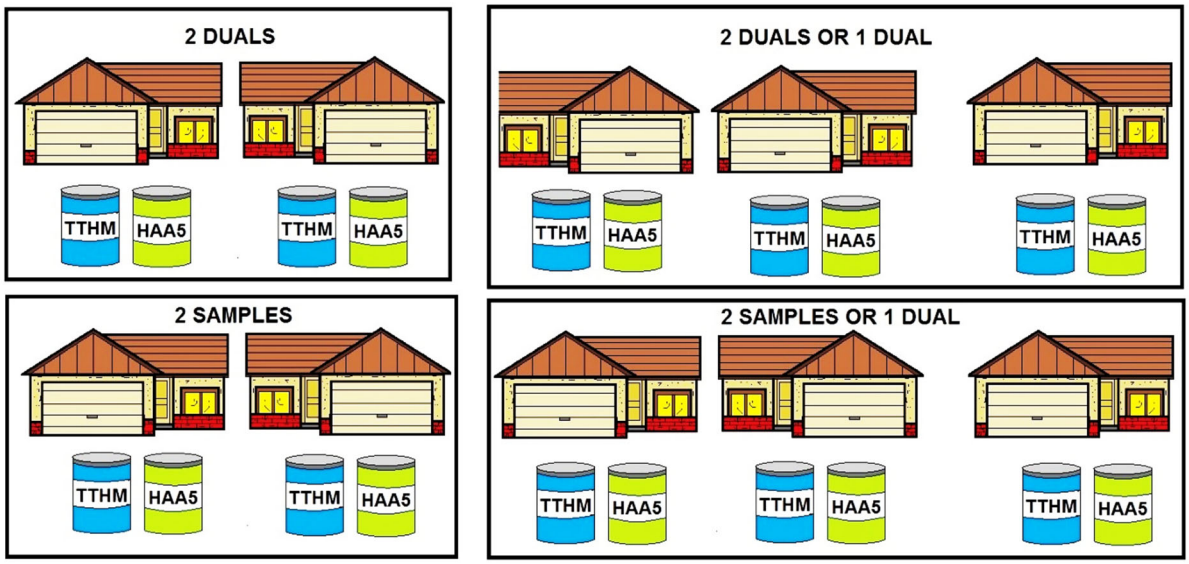
- Making operational improvements at the plant or in the distribution system
- Modifying current treatment operations to remove more DBP precursors or form lower levels of DBPs
- Upgrading or installing a new treatment technology

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

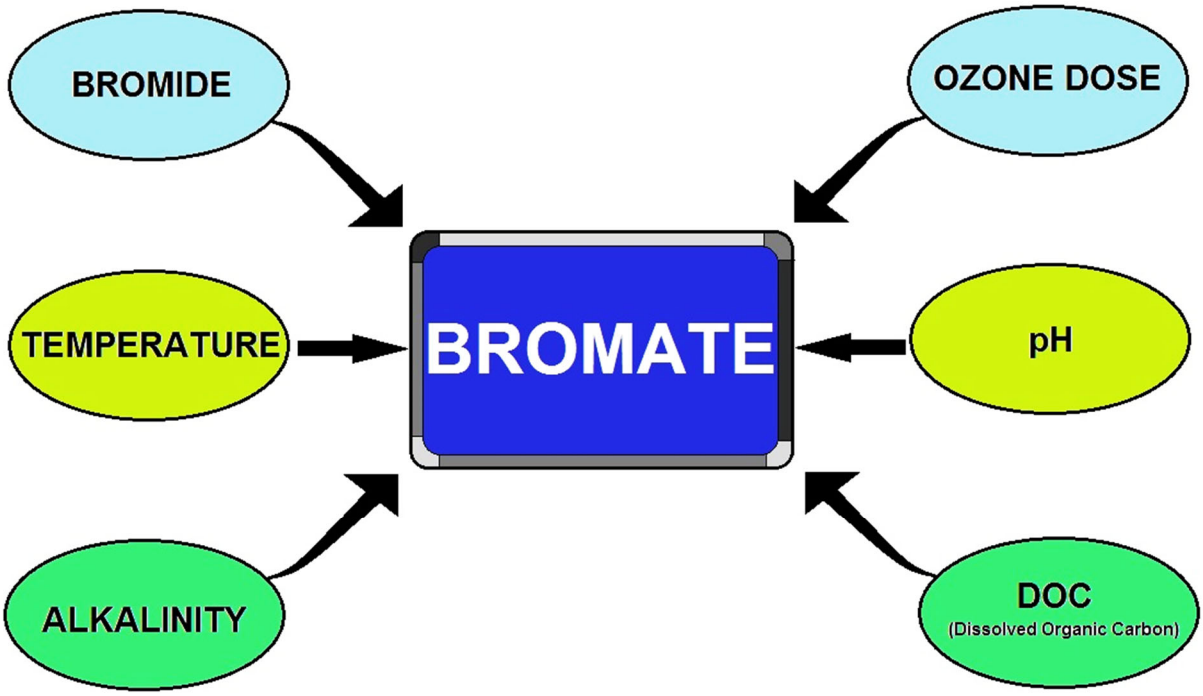
With population-based monitoring, there are five categories of small systems under the Stage 2 DBPR:

- Subpart H systems that serve fewer than 500 people.
- Subpart H systems that serve 500 to 3,300 people.
- Subpart H systems that serve 3,301 to 9,999 people.
- Ground water systems that serve fewer than 500 people.
- Ground water systems that serve 500 to 9,999 people.

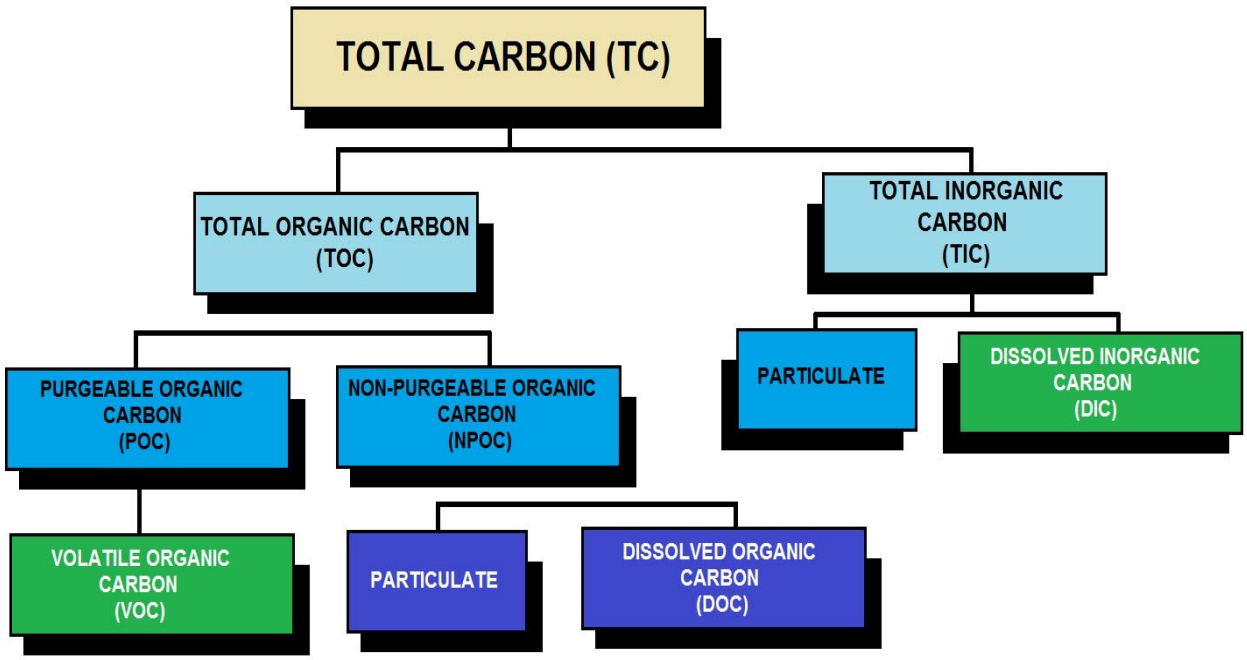
If you do not know what type of system you are, you should contact your State to confirm this information.



STAGE 2 DISINFECTION BYPRODUCT RULE
REPEAT (TRIGGERED) SAMPLING DIAGRAM



BROMATE FORMATION FACTORS



Technical Learning College

TOTAL CARBON BREAKDOWN

More on the Stage 2 DBP Rule

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

The Stage 2 DBP rule is one part of the Microbial and Disinfection Byproducts Rules (MDBPs), which are a set of interrelated regulations that address risks from microbial pathogens and disinfectants/disinfection byproducts.

The Stage 2 DBP rule focuses on public health protection by limiting exposure to DBPs, specifically total trihalomethanes (TTHM) and five haloacetic acids (HAA5), which can form in water through disinfectants used to control microbial pathogens. This rule will apply to all community water systems and nontransient noncommunity water systems that add a primary or residual disinfectant other than ultraviolet (UV) light or deliver water that has been disinfected by a primary or residual disinfectant other than UV.

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

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

What is the Stage 2 DBPR?

The Stage 2 Disinfection Byproducts Rule will reduce potential cancer and reproductive and developmental health risks from disinfection byproducts (DBPs) in drinking water, which form when disinfectants are used to control microbial pathogens. Over 260 million individuals are exposed to DBPs. This final rule strengthens public health protection for customers in the US by tightening compliance monitoring requirements for two groups of DBPs, trihalomethanes (TTHM) and haloacetic acids (HAA5). The rule targets systems with the greatest risk and builds incrementally on existing rules. This regulation will reduce DBP exposure and related potential health risks and provide more equitable public health protection. The Stage 2 DBPR is being promulgated simultaneously with the Long Term 2 Enhanced Surface Water Treatment Rule to address concerns about risk tradeoffs between pathogens and DBPs.

What does the rule require?

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

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

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

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

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

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

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

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

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

More on Evolving Disinfection Rules

In the past 40 years, the Safe Drinking Water Act (SDWA) has been highly effective in protecting public health and has also evolved to respond to new and emerging threats to safe drinking water. Disinfection of drinking water is one of the major public health advances in the 20th century. One hundred years ago, typhoid, dysentery and cholera epidemics were common through American cities; disinfection was a major factor in reducing these epidemics.

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

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

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

All living organisms have carbon as an essential element in their cells. When trees shed their leaves, the leaves start decomposing and are ultimately broken down by bacteria into carbon-containing compounds. Similarly, dead animals on land and fish and other aquatic life decompose and disintegrate into compounds that contain carbon as an essential element. Hence, all surface water and groundwater contain varying amounts of carbon-containing compounds called organic matter (primarily humic and fulvic acids).

The EPA Surface Water Treatment Rule (SWTR) requires systems using public water supplies from either surface water or groundwater under the direct influence of surface water to disinfect. In addition, since some disinfectants produce chemical by-products, the dual objective of disinfection is to provide the required level of organism destruction and remain within the maximum contaminant level (MCL) for the SWTR disinfection set by EPA. An MCL is set for Total Trihalomethanes and additional disinfection byproducts.

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

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

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

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

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2) rule applies to all water systems using surface water, groundwater under the influence of a surface water, as well as groundwater/surface water blends. The LT2 requirements began in 2006 with the characterization of raw water Cryptosporidium and E.coli levels. Systems serving <10,000 monitor for E.coli only every two weeks for one year. Compliance with the LT2 requirements begin in April 2013.

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

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

The Stage 1 Disinfectants and Disinfection Byproducts Rule and Interim Enhanced Surface Water Treatment Rule, announced in December 1998, are the first of a set of rules under the 1996 SDWA Amendments. This fact sheet focuses on the Stage 1 Disinfectants and Disinfection Byproducts Rule. A separate fact sheet focuses on the Interim Enhanced Surface Water Treatment Rule (EPA 815-F-98-009).

Public Health Concerns

While disinfectants are effective in controlling many microorganisms, they react with natural organic and inorganic matter in source water and distribution systems to form DBPs. Results from toxicology studies have shown several DBPs (e.g., bromodichloromethane, bromoform, chloroform, dichloroacetic acid, and bromate) to be carcinogenic in laboratory animals.

Other DBPs (e.g., chlorite, bromodichloromethane, and certain haloacetic acids) have also been shown to cause adverse reproductive or developmental effects in laboratory animals.

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

Disinfection Byproduct Research and Regulations Summary

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

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

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

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

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

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

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

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

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

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

The IPCS (IPCS 2000, p. 375) reached similar conclusions:
Disinfection is unquestionably the most important step in the treatment of water for drinking water supplies. The microbial quality of drinking water should not be compromised because of concern over the potential long-term effects of disinfectants and DBPs. The risk of illness and death resulting from exposure to pathogens in drinking water is very much greater than the risks from disinfectants and DBPs.

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

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

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

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

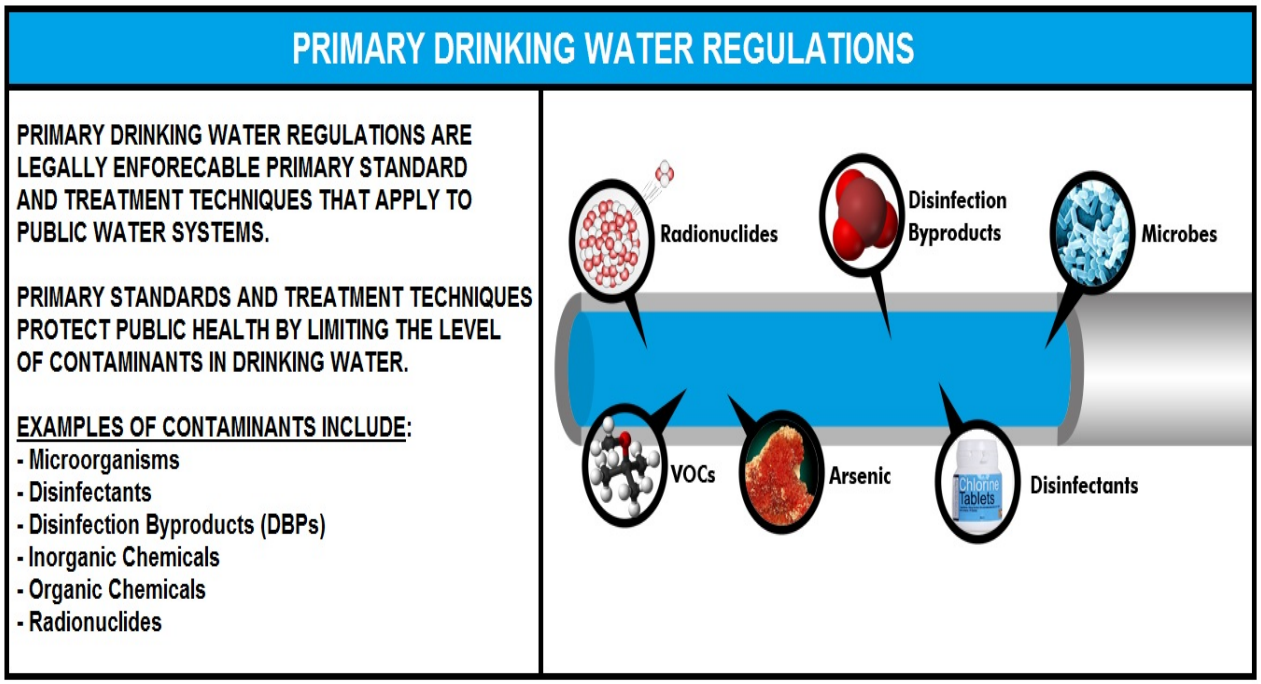
3. Membrane Technology
Membranes, used historically to desalinate brackish waters, have also demonstrated excellent removal of natural organic matter. Membrane processes use hydraulic pressure to force water through a semi-permeable membrane that rejects most contaminants. Variations of this technology include reverse osmosis (RO), nanofiltration (low pressure RO), and microfiltration (comparable to conventional sand filtration).

Other conventional methods of reducing DBP formation include changing the point of chlorination and using chloramines for residual disinfection. EPA predicted that most water systems will be able to achieve compliance with new DBP regulations through the use of one or more of these relatively low cost methods (EPA, 1998). Water system managers may also consider switching from chlorine to alternative disinfectants to reduce formation of THMs and HAAs.

National Primary Drinking Water Regulations

Inorganic Chemicals	MCLG [1] (mg/L) [4]	MCL[2] or TT[3] (mg/L) [4]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood glucose	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	none[5]	0.010	Skin damage; circulatory system problems; increased risk of cancer	Discharge from semiconductor manufacturing; petroleum refining; wood preservatives; animal feed additives; herbicides; erosion of natural deposits
Asbestos (fiber >10 micrometers)	7 million fibers per Liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Some people who use water containing chromium well in excess of the MCL over many years could experience allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	Action Level= 1.3; TT[6]	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. Those with Wilson's Disease should consult their personal doctor if their water systems exceed the copper action level.	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth.	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	Action Level= 0.015; TT[6]	Infants and children: Delays in physical or mental development. Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits

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



PRIMARY DRINKING WATER REGULATIONS / STANDARDS

Organic Chemicals	MCLG [1] (mg/L) [4]	MCL [2] or TT [3] (mg/L) [4]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Acrylamide	zero	TT[7]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system problems; reproductive difficulties	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood or nervous system; reproductive difficulties.	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharger from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1-1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1, 2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from pharmaceutical and chemical factories
1-2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl)adipate	0.4	0.4	General toxic effects or reproductive difficulties	Leaching from PVC plumbing systems; discharge from chemical factories
Di(2-ethylhexyl)phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories

Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Nervous system effects	Residue of banned insecticide
Epichlorohydrin	zero	TT[7]	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from industrial chemical factories; added to water during treatment process
Ethylbenzene	0.7	0.7	Liver or kidney problems	Discharge from petroleum refineries
Ethelyne dibromide	zero	0.00005	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased risk of cancer	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, and circulatory problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Total Trihalomethanes (TTHMs)	none[5]	0.10	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide

1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.20	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from petroleum refineries
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories
Radionuclides	**MCLG [1] (mg/L) [4]**	**MCL[2] or TT[3] (mg/L) [4]**	**Potential Health Effects from Ingestion of Water**	**Sources of Contaminant in Drinking Water**
Beta particles and photon emitters	none[5]	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits
Gross alpha particle activity	none[5]	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits
Radium 226 and Radium 228 (combined)	none[5]	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
Microorganisms	**MCLG [1] (mg/L) [4]**	**MCL[2] or TT[3] (mg/L) [4]**	**Potential Health Effects from Ingestion of Water**	**Sources of Contaminant in Drinking Water**
Giardia lamblia	zero	TT[8]	Giardiasis, a gastroenteric disease	Human and animal fecal waste
Heterotrophic plate count	N/A	TT[8]	HPC has no health effects, but can indicate how effective treatment is at controlling microorganisms.	n/a
Legionella	zero	TT[8]	Legionnaire's Disease, commonly known as pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and *E. Coli*)	zero	5.0%[9]	Used as an indicator that other potentially harmful bacteria may be present[10]	Human and animal fecal waste
Turbidity	N/A	TT[8]	Turbidity has no health effects but can interfere with disinfection and provide a medium for microbial growth. It may indicate the presence of microbes.	Soil runoff
Viruses (enteric)	zero	TT[8]	Gastroenteric disease	Human and animal fecal waste

Common water sample bottles for distribution systems.

Radiochems, VOCs, (Volatile Organic Compounds), TTHMs, Total Trihalomethanes), Nitrate, Nitrite.

Most of these sample bottles will come with the preservative already inside the bottle.

Some bottles will come with a separate preservative (acid) for the field preservation.

Slowly add the acid or other preservative to the water sample; not water to the acid or preservative.

Drinking water standards may apply differently based on type and size of public water systems.

National Secondary Drinking Water Regulations

National Secondary Drinking Water Regulations (NSDWRs or secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

The EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

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

Notes

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

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

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

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

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

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

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

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

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

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

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

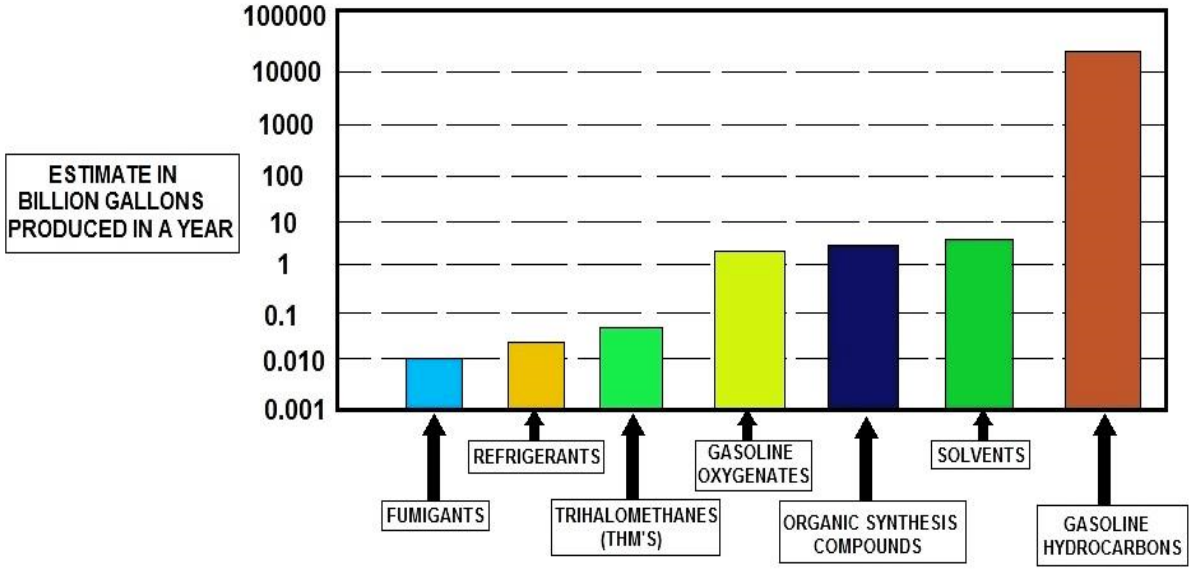
[10] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms.

Chemical Monitoring Sub-Section

The final federal rules regarding Phase II and V contaminants were promulgated by the U.S. EPA in 1992 and initial monitoring began in January 1993. This group of contaminants consists of Inorganic Chemicals (IOC), Volatile Organic Chemicals (VOC) and Synthetic Organic Chemicals (SOC) and the rule applies to all community and non-transient non-community public water systems.

The monitoring schedule for these contaminants is phased in by water system population size according to a "standardized monitoring framework" established by the U.S. EPA. This standardized monitoring framework establishes nine-year compliance cycles consisting of three 3-year compliance periods.

The first compliance cycle began back in January 1993 and ended December 31, 2001, with subsequent compliance cycles following the nine-year timeframe. The three-year compliance period of each cycle is the standard monitoring period for the water system.



VOLATILE ORGANIC COMPOUNDS FOUND IN GROUNDWATER CHART

Turbidity Monitoring
Monitoring for turbidity is applicable to all public water systems using surface water sources or ground water sources under the direct influence of surface water in whole or part. Check with your state drinking water section or health department for further instructions.

The maximum contaminant level for turbidity for systems that provide filtration treatment:
1. Conventional or direct filtration: less than or equal to 0.5 NTU in at least 95% of the measurements taken each month. Conventional filtration treatment plants should be able to achieve a level of 0.1 NTU with proper chemical addition and operation.
2. Slow sand filtration, cartridge and alternative filtration: less than or equal to 1 NTU in at least 95% of the measurements taken each month. The turbidity levels must not exceed 5 NTU at any turbidity measurements must be performed on representative samples of the filtered water every

four (4) hours that the system serves water to the public. A water system may substitute continuous turbidity monitoring for grab sample monitoring if it validates the continuous measurement for accuracy on a regular basis using a protocol approved by the Health or Drinking Water Agency, such as confirmation by a bench top turbidimeter. For systems using slow sand filtration, cartridge, or alternative filtration treatment the Health or Drinking Water Agency may reduce the sampling frequency to once per day if it determines that less frequent monitoring is sufficient to indicate effective filtration performance.

Inorganic Chemical Monitoring

All systems must monitor for inorganics. The monitoring for these contaminants is also complex with reductions, waivers and detections affecting the sampling frequency. Please refer to the monitoring schedules provided by your state health or drinking water sections for assistance in determining individual requirements. All transient non-community water systems are required to complete a one-time inorganic chemical analysis. The sample is to be collected at entry points (**POE**) to the distribution system representative of each source after any application of treatment.

Nitrates

Nitrate is an inorganic chemical that occurs naturally in some groundwater but most often is introduced into ground and surface waters by man. The most common sources are from fertilizers and treated sewage or septic systems.

At high levels (over 10 mg/l) it can cause the "**blue baby**" syndrome in young infants, which can lead to serious illness and even death. It is regarded as an "**acute health risk**" because it can quickly cause illness.

Every water system must test for ***Nitrate*** at least yearly. Systems that use ground water only must test yearly. Systems that use surface water and those that mix surface and ground water must test every quarter. A surface water system may go to yearly testing if community and nontransient noncommunity water must do quarterly monitoring whenever they exceed 5 mg/l in a test. After 4 quarters of testing and if the results show that the nitrate level has not exceeded 5 mg/L, they may go back to yearly testing.

Radiological Contaminants

All community water systems shall monitor for gross alpha activity every four years for each source. Depending on your state rules, compliance will be based on the annual composite of 4 consecutive quarters or the average of the analyses of 4 quarterly samples. If the average annual concentration is less than one half the MCL, an analysis of a single sample may be substituted for the quarterly sampling procedure.

Total Trihalomethanes (TTHM)

All community water systems serving a population of 10,000 or more and which add a disinfectant in any part of the drinking water treatment process shall monitor for total trihalomethanes (**TTHM**). The MCL is 0.08 mg/l (80 ppb) and consists of a calculation of the running average of quarterly analyses of the sum of the concentrations of bromodichloromethane, di-bromochloromethane, bromoform and chloroform.

Lead and Copper Rule
The Lead and Copper Rule was promulgated by the U.S. EPA on June 7, 1991, with monitoring to begin in January 1992 for larger water systems. This rule applies to all community and nontransient, noncommunity water systems and establishes action levels for these two contaminants at the consumer's tap. Action levels of 0.015 mg/l for lead and 1.3 mg/l for copper have been established.

This rule establishes maximum contaminant level goals (**MCLGs**) for lead and copper, treatment technique requirements for optimal corrosion control, source water treatment, public education and lead service line replacement. Whenever an action level is exceeded, the corrosion control treatment requirement is triggered. This is determined by the concentration measured in the 90th percentile highest sample from the samples collected at consumers' taps.

Sample results are assembled in ascending order (lowest to highest) with the result at the 90th percentile being the action level for the system. For example, if a water system collected 20 samples, the result of the 18th highest sample would be the action level for the system.

The rule also includes the best available technology (**BAT**) for complying with the treatment technique requirements, mandatory health effects language for public notification of violations and analytical methods and laboratory performance requirements.

Initial monitoring began in January 1992 for systems with a population of 50,000 or more, in July 1992 for medium-sized systems (3,300 to 50,000 population) and in July 1993 for small-sized systems (less than 3,300 population),

One-liter tap water samples are to be collected at high-risk locations by either water system personnel or residents.

Generally, high-risk locations are homes with lead-based solder installed after 1982 or with lead pipes or service lines. If not enough of these locations exist in the water system, the rule provides specific guidelines for selecting other sample sites.

The water must be allowed to stand motionless in the plumbing pipes for at least six (6) hours and collected from a cold water tap in the kitchen or bathroom. It is a first draw sample, which means the line is not to be flushed prior to sample collection.

The number of sampling sites is determined by the population of the system and sample collection consists of two, six-month monitoring periods; check with your state rule or drinking water section for more information.

Sampling Sites by Population

System size - No. of sites (no. of persons served)	*No. of sites (standard monitoring)*	*No. of sites (reduced monitoring)*
>100,000	100	50
10,001-100,000	60	30
3,301 to 10,000	40	20
501 to 3,300	20	10
101 to 500	10	5
< 100	5	5

If a system meets the lead and copper action levels or maintains optimal corrosion control treatment for two consecutive six-month monitoring periods, then reduced monitoring is allowed and sampling frequency drops to once per year.

After three consecutive years of reduced monitoring, sample frequency drops to once every three years. In addition to lead and copper testing, all large water systems and those medium- and small-sized systems that exceed the lead or copper action levels will be required to monitor for the following water quality parameters: pH, alkalinity, calcium, conductivity, orthophosphate, silica and water temperature.

These parameters are used to identify optimal corrosion control treatment and determine compliance with the rule once treatment is installed.

The sampling locations for monitoring water quality parameters are at entry points and representative taps throughout the distribution system.

Coliform sampling sites can be used for distribution system sampling. The number of sites required for monitoring water quality during each six-month period is shown below.

Number of Water Quality Parameters per Population

System size # (no. of persons served) no. of sites for water quality parameters

>100,000	25
10,001-100,000	10
3,301 to 10,000	3
501 to 3,300	2
101 to 500	1
<100	1

Water systems which maintain water quality parameters reflecting optimal corrosion control for two consecutive six-month monitoring periods qualify for reduced monitoring. After three consecutive years, the monitoring frequency can drop to once per year.

All large water systems must demonstrate that their water is minimally corrosive or install corrosion control treatment regardless of lead and copper sampling results.

Quality Assurance /Quality Control Measures - Introduction

In addition to standard samples, the field technicians collect equipment blanks (**EB**), field cleaned equipment blanks (**FB**), split samples (**SS**), and field duplicate samples (**FD**).

Overall care must be taken in regards to equipment handling, container handling/storage, decontamination, and record keeping. Sample collection equipment and non-preserved sample containers must be rinsed three times with sample water before the actual sample is taken. Exceptions to this are any pre-preserved container or bac-t type samples.

If protective gloves are used, they shall be clean, new and disposable. These should be changed upon arrival at a new sampling point. Highly contaminated samples shall never be placed in the same ice chest as environmental samples. It is good practice to enclose highly contaminated samples in a plastic bag before placing them in ice chests. The same is true for wastewater and drinking water samples.

Ice chests or shipping containers with samples suspected of being highly contaminated shall be lined with new, clean, plastic bags. If possible, one member of the field team should take all the notes, fill out labels, etc., while the other member does all of the sampling.

Preservation of Samples
Proper sample preservation is the responsibility of the sampling team, not the lab providing sample containers. The best reference for preservatives is Standard Methods or your local laboratory.

It is the responsibility of the field team to assure that all samples are appropriately preserved.

Follow the preservative solution preparation instructions.

Always use strong safety precautions when diluting any acid.

Slowly add the acid or other preservative to the water sample; not water to the acid or preservative.

Put a new label on the dispensing bottle with the current date.

Wait 3-4 hours for the preservative to cool most samples down to 4 degrees Celsius.

Most preservatives have a shelf life of one year from the preparation date.

When samples are analyzed for TKN, TP, NH_4 and NOx 1 mL of 50% Trace Metal grade sulfuric acid is added to each discrete auto sampler bottles/bags in the field lab before sampling collection. The preservative maintains the sample at 1.5<pH<2 after collection. To meet maximum holding time for these preserved samples (28 days), pull and ship samples every 14 days.

Narrow range pH paper (test strips) can be used to test an aliquot of the preserved sample.

Place the pH paper into the container and compare the color with the manufacturer's color chart.

FINISHED WATER REPORT	UNITS OF MEASURE
FINISHED WATER TURBIDITY	NTU Neophelometric Turbidity Unit
FINSHED WATER TEMPERATURE	Deg. C Degrees Celcius
FINISHED WATER pH	SU Standard Units
FINISHED WATER ALKALINITY	mg/l Milligrams per Liter
FINISHED WATER HARDNESS	mS/cm Millisiemens per Centimeter
FINISHED WATER CONDUCTIVITY	mg/l Milligrams per Liter
FINISHED WATER TOTAL DISSOLVED SOLIDS	mg/l Milligrams per Liter
FINISHED WATER FLUORIDE	mg/l Milligrams per Liter
FINISHED WATER IRON	mg/l Milligrams per Liter
FINISHED WATER MANGANESE	mg/l Milligrams per Liter
FINISHED WATER PHOSPHATE	mg/l Milligrams per Liter
HARDNESS PER GALLON	GRAINS

WATER QUALITY REPORT INCLUDING UNITS OF MEASUREMENT

FINISHED WATER REPORTING INFO	UNITS OF MEASUREMENT
FINSIHED WATER TURBIDITY	NTU – NEOPHELOMETRIC TURBIDITY UNIT
FINISHED WATER TEMPERATURE	DEGREES CELCIUS
FINISHED WATER pH	SU – STANDARD UNITS
FINISHED WATER ALKALINITY	PPM or GRAINS PER GALLON
FINISHED WATER HARDNESS	Degrees of general hardness (dGH or °GH) Milligrams of $CaCO_3$ per Liter
FINISHED WATER CONDUCTIVITY	Millimhos per Centimeter [mmho/cm]
FINISHED WATER TOTAL DISSOLVED SOLIDS	Mg/L - Milligrams per Liter
FINISHED WATER FLUORIDE	Mg/L - Milligrams per Liter
FINISHED WATER IRON	Mg/L - Milligrams per Liter
FINISHED WATER MANGANESE	Mg/L - Milligrams per Liter
FINISHED WATER PHOSPHATE	Mg/L - Milligrams per Liter
HARDNESS PER GALLON	GRAINS PER GALLON

Water quality reports are used not only to satisfy state and federal compliance. It is a great reference tool for evaluating changes to source water due to human influence and unforeseen weather changes.

Since the Lead and Copper rule was enacted by EPA water systems analyze the water to see if it will leach the metals from the pipe, causing corrosion, or chemicals will precipitate out causing scaling in pipes and industrial processes such as boilers.

Drinking Water Sampling - Analysis Charts

ANALYSIS	METHOD	HOLDING TIME
Inorganic Compounds (IOC) Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Silver, Sodium, Thallium, Zinc, Hardness, Conductivity, Turbidity, Color, Chloride, Cyanide, Fluoride, Nitrate, Nitrite, Sulfate, and Total Dissolved Solids.	**(various)**	**48 hours**
Primary Pollutants (Short IOC) Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver, Sodium, Thallium, Turbidity, Fluoride, Cyanide, Nitrate, and Nitrite.	**(various)**	**48 hours**
Municipal Testing		
Lead and Copper	**EPA 200.9 for Pb** **EPA 200.7 for Cu**	**14 days**
Public or Individual Water Source Testing		
Nitrate	**SM-4500 NO3 D**	**48 hours**
Total Coliform & E. Coli	**SM-9223 B**	**30 Hours**
Metals Analysis on Drinking Water (per element)		
GFAA **(As, Pb, Sb, Se, Tl)**	**EPA 200.9**	**6 months**
ICP (Ag, Al, B, Ba, Be, Cd, Cr, Cu, Fe, Mn, Mo, Na, Ni, Zn)	**EPA 200.7**	**6 months**
CVAA (Hg)	**EPA 245.1**	**6 months**
Primary Pollutant Metals	**GFAA/ICP/CVAA**	**6 months**
Drinking Water Analysis		
PH	**EPA 150.1**	
Acidity	**SM-2310 B (4b)**	**14 days**
Alkalinity (Bicarbonate & Carbonate)	**SM-2320 B (4a)**	**14 days**
BOD	**SM-5210 B**	**48 hours**
Calcium	**EPA 200.7**	**6 months**
Chloride	**SM-4500 Cl**	**8 days**
Chlorine, total	**SM-4500 Cl**	**5 hours**
Color	**SM-2120 B**	**8 hours**
COD	**EPA 410.4 (7.3)**	**28 days**
Cyanide	**EPA 335.2 (8.7)**	**28 days**
Dissolved Oxygen	**SM-4500 O C**	**8 hours**
Fluoride	**SM-4500 F C**	**28 days**
Hardness	**SM-2340 B**	**6 months**

Magnesium	**EPA 200.7**	**6 months**
Nitrogen, ammonia	**SM-4500 NH3 E** **SM-4500 NH3 H**	**28 days**
Nitrogen, nitrate	**SM-4500 NO3 D**	**48 hours**
Nitrogen, nitrite	**SM-4500 NO2**	**48 hours**
Nitrate + Nitrite	**SM-4500 NO3 E**	**48 hours**
Nitrogen, TKN	**EPA 351.4**	**28 days**
Odor	**SM-2150**	**6 days**
Phosphorous, ortho	**EPA 200.7**	**48 hours**
Phosphorous, total	**SM-4500 P**	**28 days**
Solids, settle able	**SM-2540**	**7 days**
Solids, suspended	**SM-2540 D**	**7 days**
Drinking Water Analysis		
Solids, total dissolved	**SM-2540 B**	**7 days**
Solids, volatile	**SM-2540 E**	**7 days**
Specific Conductance	**SM-2510 B**	**28 days**
Sulfate	**SM-4500 SO-4 E**	**28 days**
Sulfide	**SM-4500 S-2 D**	**28 days**
Sulfite	**EPA 377.1**	**28 days**
Silica	**SM-4500 SI E**	**28 days**
Total Organic Carbon	**EPA 415.1**	**28 days**
Turbidity	**SM- 2130 B**	**48 hours**

ORGANICS		
Semi-volatile Organics in Water (SOC)*	**(various)**	**7 days**
Volatile Organics in Water*	**(various)**	**7 days**
Trihalomethanes*	**EPA 501.1**	**7 days**
Gross Alpha & Bata (Radionuclides)*	**(various)**	**7 days**
BOD	**SM-5210 B**	**48 hours**
COD	**EPA 410.4(7.3)**	**28 days**
Oil and Grease	**EPA 413.1(1.2)**	**28 days**
Hardness W/digestion	**SM-2340 B**	**6 months**
Nitrogen, TKN	**EPA 351.4**	**28 days**
Nitrogen, ammonia	**SM-4500 NH3 F**	**28 days**
Nitrogen, Total Organic	**SM-4500 NorgNH3**	**28 days**
Nitrogen, nitrate	**SM-4500 NO3 D**	**48 hours**
Nitrogen, nitrite	**SM-4500 NO2 B**	**48 hours**
Phosphorous, ortho	**SM-4500 P E**	**48 hours**
Sulfate	**SM-4500 SO4 E**	**28 days**
Solids, dissolved	**SM-2540**	**7 days**
Solids, settle able	**SM-2540 F**	**7 days**
Solids, suspended	**SM-2540 D**	**7 days**
Solids, total	**SM-2540 B**	**7 days**
Solids, volatile	**SM-2540 E**	**7 days**
Total Organic Carbon	**EPA 415.1**	**28 days**
PH	**EPA 150.1**	
Metals (per element)		

ICP **(Ag, Al, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Sb, V, Zn)**	**EPA 200.7**	**6 months**
GFAA **(As, Pb, Ba, Se, Tl)**	**EPA 200.9**	**6 months**
CVAA (Hg)	**EPA 245.1**	**6 months**

Definitions:

Action level - the concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.

Maximum Contaminant Level - the "Maximum Allowed" (MCL) is the highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLGs as feasible using the best available treatment technology.

Maximum Contaminant Level Goal - the "Goal" (MCLG) is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety.

Non-Detects (ND) - laboratory analysis indicates that the constituent is not present.

Parts per million (ppm) or Milligrams per liter (mg/L) - one part per million corresponds to one minute in two years or a single penny in $10,000.

Parts per billion (ppb) or Micrograms per liter (ug/L) - one part per billion corresponds to one minute in 2,000 years, or a single penny in $10,000,000.

Picocuries per liter (pCi/L) - picocuries per liter is a measure of the radioactivity in water.

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.

SAMPLE CONTAINERS and PRESERVATION

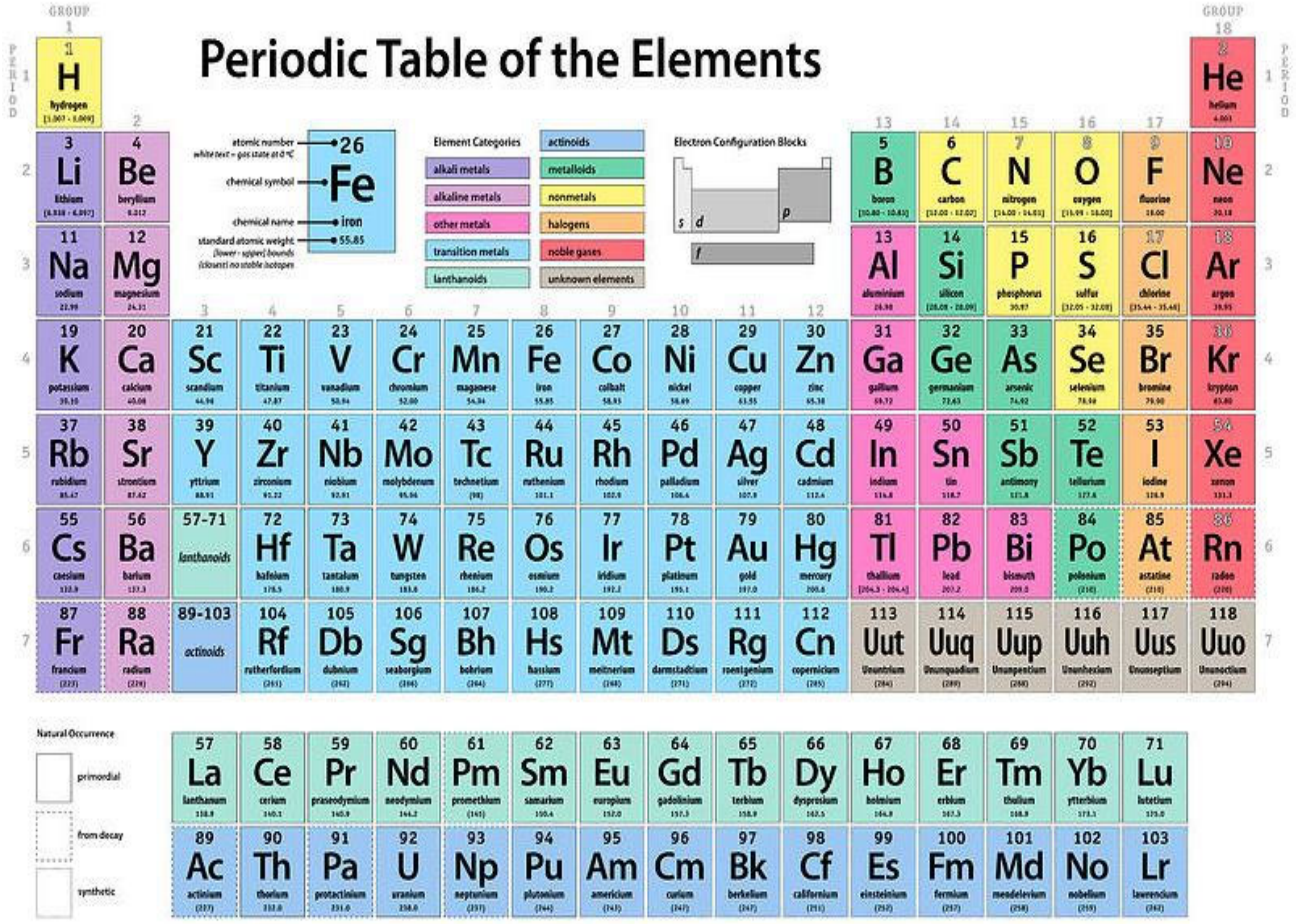
Methods used by the laboratory usually specify what type of container and how much sample is required to run an analysis. The following table provides a summary of the sample handling and preservation requirements for some of the most common tests.

Parameter	Bottle Type	Minimum Sample Size	Maximum Holding Time	Storage & Preservation
Acidity	P or G[B]	100ml	24 hrs/14 days	refrigerate
Alkalinity	P or G	200ml	24 hrs/14 days	refrigerate
BOD (5 day)	P or G	1L	6 hrs/48 hrs	refrigerate
Boron	P	100ml	28 days/6 months	
Chloride	P or G	250ml	28 days	
Chlorine, residual	P or G	500ml	0.5 hr/stat	analyze on site ASAP
COD	P or G	500ml	28 days/28 days	analyze on site ASAP
Color	P or G	500ml	48 hrs/48 hrs	refrigerate
Coliform, Total	P or G	125ml	30 hrs	refrigerate
Conductivity	P or G	500ml	48 hrs/48 hrs	refrigerate
Cyanide, Total	P or G	500ml	28 days/28 days	add NaOH to pH>12
				refrigerate in dark
Fluoride	P	300ml	28days/ 28 days	
Hardness	P or G	100ml	6 months/6 months	add HNO_3 to pH<2
Metals, general	P[A] or G[A]	250ml	6 months/6 months	add HNO_3 to pH<2
Furnace	P[A] or G[A]	250ml	6 months/6 months	
Flame	P[A] or G[A]	250ml	6 months/6 months	
Mercury	P[A] or G[A]	500ml	28 days/28 days	add HNO_3 to pH<2
Nitrogen *Ammonia*	P or G	500ml	7 days/ 28 days	ASAP or add H_2SO_4 to pH<2 & refrigerate
Nitrate	P or G	100ml	48 hrs/48 hrs	ASAP & refrigerate
Nitrate + Nitrite	P or G	200ml	48 hrs/28 days	ASAP & refrigerate
Nitrite	P or G	100ml	none/48 hrs	ASAP & refrigerate

TKN	P or G	500ml	7 days/28 days	add H_2SO_4 to pH<2
Oxygen, dissolved	G (BOD)	300ml		
Electrode			0.5 hrs/stat	ASAP on site
Winkler			8hrs/8 hrs	ASAP on site
pH	P or G	50ml	2 hrs/stat	ASAP on site
Phosphate,	G^A			
Ortho		100ml	48hrs	filter ASAP refrigerate
Total		100ml	28 days/28 days	refrigerate
Solids,	P or G			
Dissolved		250ml	7 days	refrigerate
Settleable		1L	48 hrs	refrigerate
Suspended		250ml	7 days	refrigerate
Total		250ml	7 days	refrigerate
Volatile		250ml	7 days	refrigerate
Silica	P	200ml	28 days/28 days	refrigerate
Sulfate	P or G	100ml	28 days/28 days	refrigerate
Turbidity	P or G	100ml	24 hrs/48 hrs	ASAP/refrigerate, store in dark up to 24 hrs

Refrigerate = storage at 4 degrees C, in the dark. P = plastic (polyethylene or equivalent); G = glass, G^A or P^A = rinsed with 1:1 HNO_3; G^B = glass, borosilicate, G^S = glass rinsed with organic solvents; NS = not stated in cited reference; stat = no storage allowed; analyze immediately.

Inorganic Compound (IOC) Section



Inorganic Compound
Inorganic Contaminants (IOCs) are elements or compounds found in water supplies and may be natural in the geology or caused by activities of man through mining, industry or agriculture. An inorganic compound is typically a chemical compound that lacks Carbon-Hydrogen bonds, that is, a compound that is not an organic compound, but the distinction is not defined or even of particular interest. Some simple compounds that contain carbon are often considered inorganic.

Examples include many toxic or poisonous compounds like:
carbon monoxide, carbon dioxide, carbonates, cyanides, cyanates, carbides, and thiocyanates. Many of these are normal parts of mostly organic systems, including organisms, which means that describing a chemical as inorganic does not obligatory mean that it does not occur within living things.

It is common to have trace amounts of many Inorganic Contaminants in water supplies. Amounts above the Maximum Contaminant Levels may cause a variety of damaging effects to the liver, kidney, nervous system circulatory system, blood, gastrointestinal system, bones, or skin depending upon the inorganic contaminant and level of exposure.

IOC Sample Collection – Things to Remember

Sample instructions should be supplied with the sample containers from the laboratory. If the laboratory fails to include sample instructions, contact the laboratory and request sample instructions.

Some general practices to remember:

• Samples should be collected at the entry point to the distribution system after all treatment (finished water)

• Select a sampling faucet that does NOT have an aerator (sampling must be done with minimum aeration

• Run the water until the temperature is as cold as it gets (except for Pb and Cu samples.)

• Just before sample collection, adjust to a very low flow. Do not change the flow while collecting the sample

• Routine nitrate and nitrite samples should be collected on a Monday or a Tuesday

• When filling sample bottle, tip bottle slightly so that water flows down the side wall of the container. Bring bottle to an upright position as it fills

• Call the laboratory if bottles are received broken (or break while collecting samples)

• The owner or operator of a water supply must maintain chemical analysis reports (results) or a summary of those reports for at least 10 years

Inorganic Chemicals

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0[7]	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	TT[7]; Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits

Inorganic Chemicals

Contaminant	MCLG[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	zero	TT[7]; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (measured as Nitrogen)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines

Synthetic Organic Chemicals (SOCs) Section

SOC/VOC bottles are the smaller, thin bottles with the septum tops. Be careful not to get any air bubbles in the SOC/VOC bottles. It may take a few weeks to learn to collect a proper sample.

SOC

Synthetic Organic Chemicals (SOCs) are organic (carbon based) chemicals that are less volatile than Volatile Organic Compounds (VOCs). SOCs are used as pesticides, defoliants, fuel additives and as ingredients for other organic compounds. They are all man made and do not naturally occur in the environment. Some of the more well-known SOCs are Atrazine, 2,4-D, Dioxin and Polychlorinated Biphenyls (PCBs).

SOCs most often enter the natural environment through application of pesticide (including runoff from areas where they are applied), as part of a legally discharged waste stream, improper or illegal waste disposal, accidental releases or as a byproduct of incineration. Some SOCs are very persistent in the environment, whether in soil or water.

SOCs are generally toxic and can have substantial health impacts from both acute (short-term) and chronic (long-term) exposure. Many are known carcinogens (cancer causing). EPA has set Maximum Contaminant Levels (MCL) for 30 SOCs under the Safe Drinking Water Act.

The Safe Drinking Water Act requires that all water sources of all public water systems be periodically monitored for regulated SOCs. The monitoring frequency can be adjusted through a waiver if SOCs are not detected.

EPA established Maximum Contaminant Levels (MCL), Maximum Contaminant Level Goals (MCLG), monitoring requirements and best available technologies for removal for 65 chemical contaminants over a five-year period as EPA gathered and analyzed occurrence and health effects data. This series of rules are known as the Chemical Phase Rules and they define regulations for three contaminant groups:

- ✓ Inorganic Chemicals (IOC),
- ✓ Synthetic Organic Chemicals (SOC), and
- ✓ Volatile Organic Chemicals (VOC).

The Chemical Phase rules provide public health protection through the reduction of chronic risks from:

- ✓ cancer;
- ✓ organ damage; and
- ✓ circulatory,
- ✓ nervous, and
- ✓ reproductive system disorders.

They also help to reduce the occurrence of Methemoglobinemia or "blue baby syndrome" from ingestion of elevated levels of nitrate or nitrite. All public water systems must monitor for Nitrate and Nitrite.

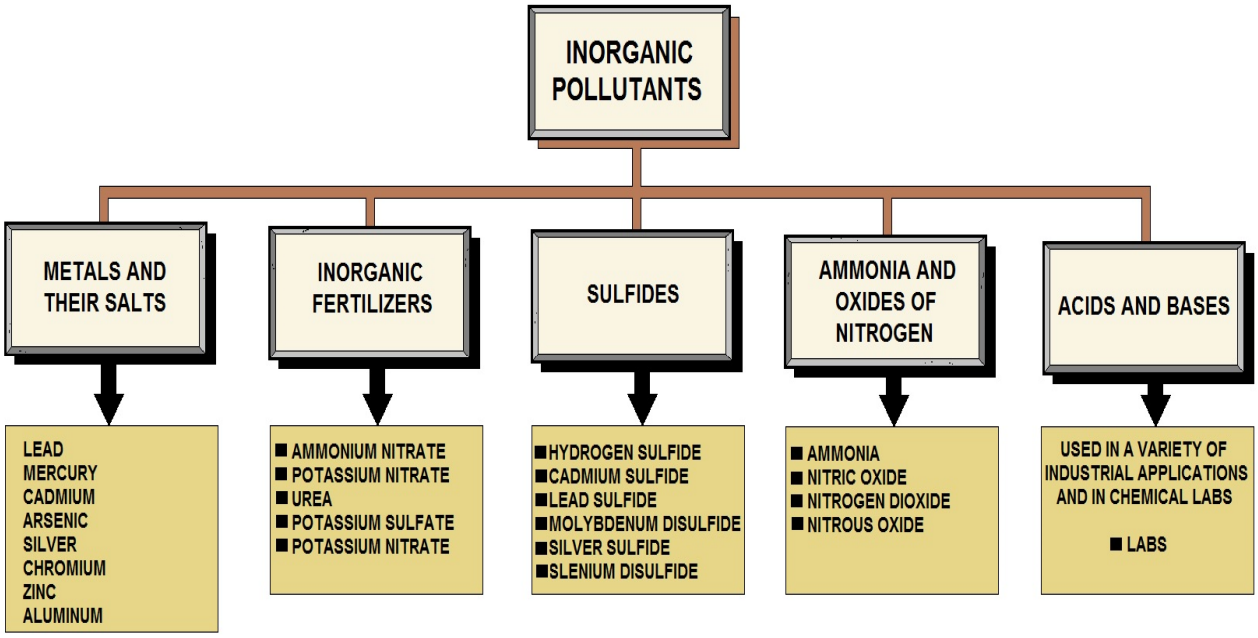
Community water systems and Non-transient non-community water systems must also monitor for IOCs, SOCs, and VOCs.

These lists of the organic chemicals—which include pesticides, industrial chemicals, and disinfection by-products—that are tested for in public water systems (those that provide water to the public), along with the maximum standard for the contaminant, and a brief description of the potential health effects associated with long-term consumption of elevated levels of the contaminants.

The federal standard for most contaminants is listed as a Maximum Contaminant Level (MCL), the lowest concentration at which that particular contaminant is believed to represent a potential health concern. Unless otherwise noted, the MCL is expressed as parts per billion (ppb).

Also, because of technological limitations or other factors, it is not possible to test for some contaminants in a reliable fashion. Instead, public water systems are required to use specific Treatment Techniques (TT) that are designed to remove these particular contaminants from the water.

Unregulated Chemicals
In addition to the chemicals listed, monitoring is done for approximately 60 organic chemicals for which MCLs have not been established. If unacceptable levels are found of these “unregulated” contaminants—based on established state health standards and an assessment of the risks they pose—the response is the same as if an MCL has been exceeded: the public water system must notify those served by the system.



INORGANIC CONTAMINANTS OF WATER EXAMPLES

Synthetic Organic Chemicals	MCL (ppb)	Potential Health Effects
Acrylamide	TT	Cancer, nervous system effects
Alachlor	2	Cancer
Aldicarb	3	Nervous system effects
Aldicarb sulfoxide	4	Nervous system effects
Aldicarb sulfone	2	Nervous system effects
Atrazine	3	Liver, kidney, lung, cardiovascular effects; possible carcinogen
Benzo(a)pyrene (PAHs)	0.2	Liver, kidney effects, possible carcinogen
Carbofuran	40	Nervous system, reproductive system effects
Chlordane	2	Cancer
2,4-D	70	Liver, kidney effects
Di(2-ethylhexyl) adipate	400	Reproductive effects
Di(2-ethylhexyl) phthalate	6	Cancer
Dibromochloro-propane (DBCP)	0.2	Cancer
Dinoseb	7	Thyroid, reproductive effects
Diquat	20	Ocular, liver, kidney effects
Endothall	100	Liver, kidney, gastrointestinal effects
Endrin	2	Liver, kidney effects
Epichlorohydrin	TT	Cancer
Ethylene dibromide (EDB)	0.05	Cancer
Glyphosate	700	Liver, kidney effects
Heptachlor	0.4	Cancer
Heptachlor epoxide	0.2	Cancer
Hexachlorobenzene	1	Cancer
Hexachlorocyclopentadiene (HEX)	50	Kidney, stomach effects

Lindane	0.2	Liver, kidney, nervous system, immune system, circulatory system effects
Methoxychlor	40	Developmental, liver, kidney, nervous system effects
Oxamyl (Vydate)	200	Kidney effects
Pentachlorophenol	1	Cancer
Picloram	500	Kidney, liver effects
Polychlorinated biphenyls (PCBs)	0.5	Cancer
Simazine	4	Body weight and blood effects, possible carcinogen
2,3,7,8-TCDD (Dioxin)	0.00003	Cancer
Toxaphene	3	Cancer
2,4,5-TP (Silvex)	50	Liver, kidney effects

Volatile Organic Compounds (VOCs)

Definitions

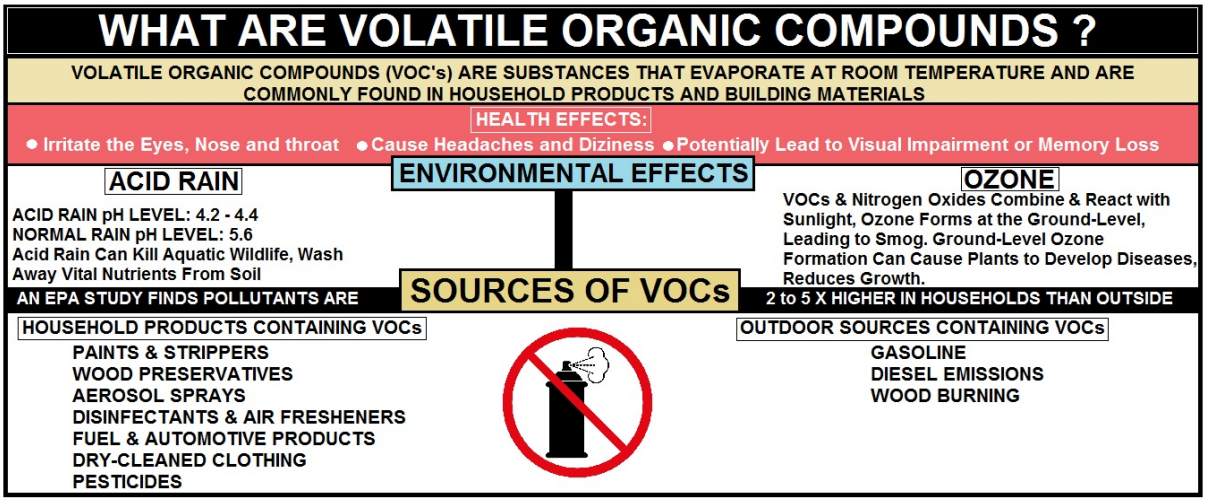
Volatile Organic Compounds (VOCs) – "VOCs are ground-water contaminants of concern because of very large environmental releases, human toxicity, and a tendency for some compounds to persist in and migrate with ground-water to drinking-water supply well … In general, VOCs have high vapor pressures, low-to-medium water solubilities, and low molecular weights. Some VOCs may occur naturally in the environment, other compounds occur only as a result of manmade activities, and some compounds have both origins." - Zogorski and others, 2006

Volatile Organic Compounds (VOCs) – "Volatile organic compounds released into the atmosphere by anthropogenic and natural emissions which are important because of their involvement in photochemical pollution." - Lincoln and others, 1998

Volatile Organic Compounds (VOCs) – "Hydrocarbon compounds that have low boiling points, usually less than 100ºC, and therefore evaporate readily. Some are gases at room temperature. Propane, benzene, and other components of gasoline are all volatile organic compounds." - Art, 1993

Volatile Organic Compounds (VOCs) – "VOCs are organic compounds that can be isolated from the water phase of a sample by purging the water sample with inert gas, such as helium, and, subsequently, analyzed by gas chromatography.

Many VOCs are human-made chemicals that are used and produced in the manufacture of paints, adhesives, petroleum products, pharmaceuticals, and refrigerants. They often are compounds of fuels, solvents, hydraulic fluids, paint thinners, and dry-cleaning agents commonly used in urban settings. VOC contamination of drinking water supplies is a human-health concern because many are toxic and are known or suspected human carcinogens." - U.S. Geological Survey, 2005



VOLATILE ORGANIC COMPOUNDS (VOCs)

Technical Learning College

VOCs *Explained*

Volatile organic compounds (VOCs) are organic chemicals that have a high vapor pressure at ordinary, room-temperature conditions. Their high vapor pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air. An example is formaldehyde, with a boiling point of –19 °C (–2 °F), slowly exiting paint and getting into the air.

VOCs are numerous, varied, and ubiquitous. They include both human-made and naturally occurring chemical compounds. Most scents or odors are of VOCs. VOCs play an important role in communication between plants. Some VOCs are dangerous to human health or cause harm to the environment.

Anthropogenic VOCs are regulated by law, especially indoors, where concentrations are the highest. Harmful VOCs are typically not acutely toxic, but instead have compounding long-term health effects. Because the concentrations are usually low and the symptoms slow to develop, research into VOCs and their effects is difficult.

Specific Components

Paints and Coatings

A major source of man-made VOCs are coatings, especially paints and protective coatings. Solvents are required to spread a protective or decorative film. Approximately 12 billion liters of paints are produced annually. Typical solvents are aliphatic hydrocarbons, ethyl acetate, glycol ethers, and acetone. Motivated by cost, environmental concerns, and regulation, the paint and coating industries are increasingly shifting toward aqueous (water-based) solvents.

Chlorofluorocarbons and Chlorocarbons

Chlorofluorocarbons, which are banned or highly regulated, were widely used cleaning products and refrigerants. Tetrachloroethene is used widely in dry cleaning and by industry. Industrial use of fossil fuels produces VOCs either directly as products (e.g., gasoline) or indirectly as byproducts (e.g., automobile exhaust).

Benzene

One VOC that is a known human carcinogen is benzene, which is a chemical found in environmental tobacco smoke, stored fuels, and exhaust from cars in an attached garage. Benzene also has natural sources such as volcanoes and forest fires. It is frequently used to make other chemicals in the production of plastics, resins, and synthetic fibers. Benzene evaporates into the air quickly and the vapor of benzene is heavier than air allowing the compound to sink into low-lying areas. Benzene has also been known to contaminate food and water and if digested can lead to vomiting, dizziness, sleepiness, rapid heartbeat, and at high levels, even death may occur.

Methylene Chloride

Methylene chloride is another VOC that is highly dangerous to human health. It can be found in adhesive removers and aerosol spray paints and the chemical has been proven to cause cancer in animals. In the human body, methylene chloride is converted to carbon monoxide and a person will suffer the same symptoms as exposure to carbon monoxide. If a product that contains methylene chloride needs to be used the best way to protect human health is to use the product outdoors. If it must be used indoors, proper ventilation is essential to keeping exposure levels down.

Perchloroethylene
Perchloroethylene is a volatile organic compound that has been linked to causing cancer in animals. It is also suspected to cause many of the breathing related symptoms of exposure to VOC's. Perchloroethylene is used mostly in dry cleaning.

Studies show that people breathe in low levels of this VOC in homes where dry-cleaned clothes are stored and while wearing dry-cleaned clothing. While dry cleaners attempt to recapture perchlorothylene in the dry cleaning process to reuse it in an effort to save money, they can't recapture it all. To avoid exposure to perchlorothylene, if a strong chemical odor is coming from clothing when picked up from the dry cleaner, do not accept them and request that less of the chemical be used as well as a complete drying of the garments

MTBE
MTBE was banned in the US around 2004 in order to limit further contamination of drinking water aquifers primarily from leaking underground gasoline storage tanks where MTBE was used as an octane booster and oxygenated-additive.

Formaldehyde
Many building materials such as paints, adhesives, wall boards, and ceiling tiles slowly emit formaldehyde, which irritates the mucous membranes and can make a person irritated and uncomfortable. Formaldehyde emissions from treated wood are in the range of 0.02 – 0.04 ppm. Relative humidity within an indoor environment can also affect the emissions of formaldehyde. High relative humidity and high temperatures allow more vaporization of formaldehyde from wood materials.

Health Risks
Respiratory, allergic, or immune effects in infants or children are associated with man-made VOCs and other indoor or outdoor air pollutants. Some VOCs, such as styrene and limonene, can react with nitrogen oxides or with ozone to produce new oxidation products and secondary aerosols, which can cause sensory irritation symptoms. Unspecified VOCs are important in the creation of smog.

Health Effects Include:
Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans. Key signs or symptoms associated with exposure to VOCs include conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness.

The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effects. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed.

Routes of Entry
Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics. At present, not much is known about what health effects occur from the levels of organics usually found in homes.

Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.

Reducing Exposure
To reduce exposure to these toxins, one should buy products that contain Low-VOC's or No VOC's. Only the quantity which will soon be needed should be purchased, eliminating stockpiling of these chemicals. Use products with VOC's in well ventilated areas. When designing homes and buildings, design teams can implement the best possible ventilation plans, call for the best mechanical systems available, and design assemblies to reduce the amount of infiltration into the building.

These methods will help improve indoor air quality, but by themselves they cannot keep a building from becoming an unhealthy place to breathe. While proper building ventilation is a key component to improving indoor air quality, it cannot do the job on its own. As stated earlier, awareness is the key component to improving air quality, when choosing building materials, furnishings, and decorations. When architects and engineers implement best practices in ventilation and mechanical systems, the owner must maintain good air quality levels thereafter.

Chemical Fingerprinting
The exhaled human breath contains a few hundred volatile organic compounds and is used in breath analysis to serve as a VOC biomarker to test for diseases such as lung cancer. One study has shown that "volatile organic compounds ... are mainly blood borne and therefore enable monitoring of different processes in the body." And it appears that VOC compounds in the body "may be either produced by metabolic processes or inhaled/absorbed from exogenous sources" such as environmental tobacco smoke. Research is still in the process to determine whether VOCs in the body are contributed by cellular processes or by the cancerous tumors in the lung or other organs.

Volatile Organic Chemicals	MCL (ppb)	Potential Health Effects
Benzene	5	Cancer
Carbon tetrachloride	5	Liver effects, cancer
Chlorobenzene	100	Liver, kidney, nervous system effects
o-Dichlorobenzene	600	Liver, kidney, blood cell effects
para-Dichlorobenzene	175	Kidney effects, possible carcinogen
1,2-Dichloroethane	5	Cancer
1,1-Dichloroethylene	7	Liver, kidney effects, possible carcinogen
cis-1,2-Dichloroethylene	70	Liver, kidney, nervous system, circulatory system effects
trans-1,2-Dichloroethylene	100	Liver, kidney, nervous system, circulatory system effects
1,2-Dichloropropane	5	Cancer
Ethylbenzene	700	Liver, kidney, nervous system effects
Methylene chloride	5	Cancer
Styrene	100	Liver, nervous systems effects, possible carcinogen
Tetrachloroethylene (PCE)	5	Cancer
Toluene	1,000	Liver, kidney, nervous system, circulatory system effects
Total trihalomethanes Chloroform Bromoform Bromodichloromethane Chlorodibromomethane	100	Cancer
1,2,4-Trichlorobenzene	70	Liver, kidney effects
1,1,1-Trichloroethane	200	Liver, nervous system effects
1,1,2-Trichloroethane	5	Kidney, liver effects, possible carcinogen
Trichloroethylene (TCE)	5	Cancer
Vinyl chloride	2	Nervous system, liver effects, cancer

Xylenes (total)	10,000	Liver, kidney, nervous system effects

Disinfection By-products	MCL (ppb)	Potential Health Effects
Bromate	10	Cancer
Chlorate	1,000	Anemia, nervous system effects
Haloacetic Acids (HAA5)*	60	Cancer
Total trihalomethanes (TTHMs)**	80	Cancer

*Haloacetic acids consist of monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid.

**Total trihalomethanes consist of chloroform, bromoform, bromodichloromethane, and chlorodibromomethane.

Safe Drinking Water Act (SDWA) Summary

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

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

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

Current EPA Research –Barriers to Contamination
Although water treatment and disinfection techniques are quite effective at microbe reduction, finished drinking water is not sterile. Survival and regrowth of microorganisms in drinking water distribution systems can lead to the deterioration of water quality and even noncompliance of a supply.

Regrowth has largely been associated with heterotrophic bacteria (i.e., those bacteria – including pathogens – that require preformed organic compounds as carbon and energy sources).

Bacterial growth occurs on the walls of the distribution system (referred to as “biofilms”) and in the water either as free living cells or cells attached to suspended solids. A multi-faceted phenomenon, bacterial regrowth is influenced primarily by temperature, residence time in mains and storage units, the efficacy of disinfection, and nutrients.

Assimilable Organic Carbon (AOC)
Assimilable organic carbon (AOC) is the portion of the total organic carbon (TOC) dissolved in water that is easily used by microorganisms as a carbon source (i.e., nutrients). Researchers are currently investigating treatment processes to control AOC.

One promising process is biologically active filtration wherein bacterial communities are intentionally established in the filters to use up, or biodegrade, the AOC as it passes through. This treatment process must be employed before final disinfection so that bacteria escaping from the filter can be properly controlled.

Most water utilities do not disinfect with chlorine until late in the treatment train. This limits the formation of disinfection by-products (i.e., those compounds like chloroform produced when chlorine reacts with naturally occurring organic carbon).

To accomplish disinfection earlier in treatment, some water utilities employ ozonation. While ozone is a very strong disinfectant, it also converts a portion of the TOC into AOC. Researchers are examining the advantages (e.g., disinfection of bacteria, viruses and protozoan cysts, control of color, control of taste and odor, enhancement of coagulation, and partial oxidation of the naturally occurring organic carbon that reacts with chlorine) and disadvantages of ozone (e.g., enhancement of AOC, conversion of bromide to bromate, and formation of its own disinfection byproducts like formaldehyde).

EPANET
The project entitled “EPANET” involves the development and testing of a water quality model for drinking water distribution systems. The EPANET model is a computer program that performs extended period simulation of hydraulic and water quality behavior within water distribution networks. It tracks the flow of water in each pipe, the pressure at each pipe junction, the height of water in each tank, and the concentration of a contaminant throughout the network during a multiple time period simulation. Water age and source tracing can also be simulated.

EPANET can be useful for analyzing the loss of disinfectant residual, designing water quality sampling programs, performing drinking water exposure risk assessments, and calibrating network hydraulic models. It can provide insight into how changes in water source utilization, pumping water storage levels, use of satellite treatment and targeted pipe cleaning and replacement would affect drinking water quality. In support of small community and non-community (less than 3,300 people) drinking water treatment systems, researchers are designing, modifying and testing “Hybrid Drinking Water Treatment Package Plants.”

These package plants are factory-built, skid-mounted, and ready to be operated in the field with minimal site preparation. They exhibit lower capital cost than custom designed facilities built onsite and can incorporate any drinking water treatment process. Promising technologies being considered for incorporation include membranes, advanced oxidation, bag filters, and photocatalytic oxidation.

By merging, modifying, and adapting conventional treatment trains with innovative treatment technologies, a broader variety of contaminants (including pathogens) can be removed and SDWA compliance can be facilitated. Concern has recently mounted over the ability of certain pathogenic protozoan (*Cryptosporidium)* cysts to survive treatment processes and enter the distribution system.

Topic 1- Water Quality Post Quiz

Internet Link to Assignment…

http://www.abctlc.com/downloads/PDF/SAMPLING%20ASSIGNMENT.pdf

The answers for the post quiz are located in the rear before the References.

1. What is the substance or compound manufactured from aluminum hydroxide by dehydroxylating it in a way that produces a highly porous material?

2. Define TDS?

3. What is the substance or compound forms especially strong complexes with Mn(II), Cu(II), Fe(III), Pb (II) and Cr(III)?

4. Which compound/element can dissolve and accumulate in underground water sources, such as wells, and in the air in your home?

5. The EPA set a standard limit or the amount of what element in drinking water to 10 ppb?

6. Which compound/element/substance is a chemical that occurs naturally in the earth's crust. When rocks, minerals, and soil erode, they release this compound/element/substance into water supplies?

ICR

7. The EPA has collected data required by the Information Collection Rule (ICR) to support future regulation of *Microbial contaminants*, disinfectants, and disinfection byproducts. True or False

8. The rule is intended to provide EPA with information on chemical byproducts that form when disinfectants used for microbial control react with chemicals already present in source water (disinfection byproducts (DBPs)); *Disease-causing microorganisms (pathogens)*, including Cryptosporidium; and engineering data to control these contaminants. True or False

Stage 2 DBP Rule Federal Register Notices

9. Which rule is one part of the Microbial and Disinfection Byproducts Rules, which are a set of interrelated regulations that address risks from microbial pathogens and disinfectants/disinfection byproducts?

10. Which rule focuses on public health protection by limiting exposure to DBPs, specifically total trihalomethanes and five haloacetic acids, which can form in water through disinfectants used to control microbial pathogens?

11. There are specific microbial pathogens, such as_____, which can cause illness, and are highly resistant to traditional disinfection practices.

12. Which rule and the Long Term 2 Enhanced Surface Water Treatment Rule are the second phase of rules required by Congress?

13. Which rule is being promulgated simultaneously with the Long Term 2 Enhanced Surface Water Treatment Rule to address concerns about risk tradeoffs between pathogens and DBPs?

14. Which term requires systems to conduct an evaluation of their distribution systems, known as an Initial Distribution System Evaluation?

Filter Backwash Recycling Rule (FBRR)

15. The Filter Backwash Recycling Rule (FBRR) regulates the chlorination within the treatment process of public water systems. True or False

16. The FBRR requires surface water systems to review their recycle practices and to modify any recycle practices that may compromise microbial control or contribute to violations of the drinking water regulations. Recycle flows can be a source of concentrated microbial pathogens and chemical contaminants.
True or False

IESWTR

17. The Interim Enhanced Surface Water Treatment Rule (IESWTR) builds on the requirements of the Surface Water Treatment Rule. True or False

18. IESWTR specifies treatment requirements to address *fluoride* in public water systems serving 10,000 or more persons. True or False

Topic 2- 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 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.

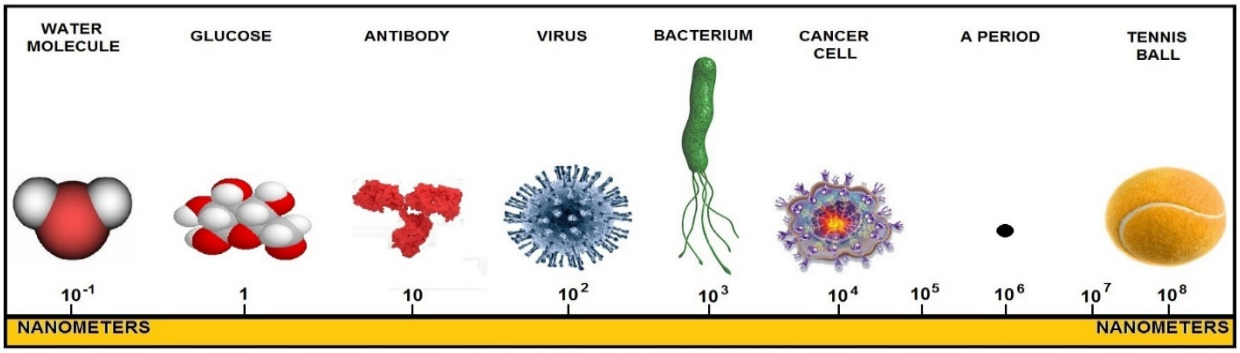
Scope/Background: The Environmental Protection Agency (EPA) published the Revised Total Coliform Rule (RTCR) in the Federal Register (FR) on February 13, 2013 (78 FR 10269) and minor corrections on February 26, 2014 (79 FR 10665). The RTCR is the revision to the 1989 Total Coliform Rule (TCR) and is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

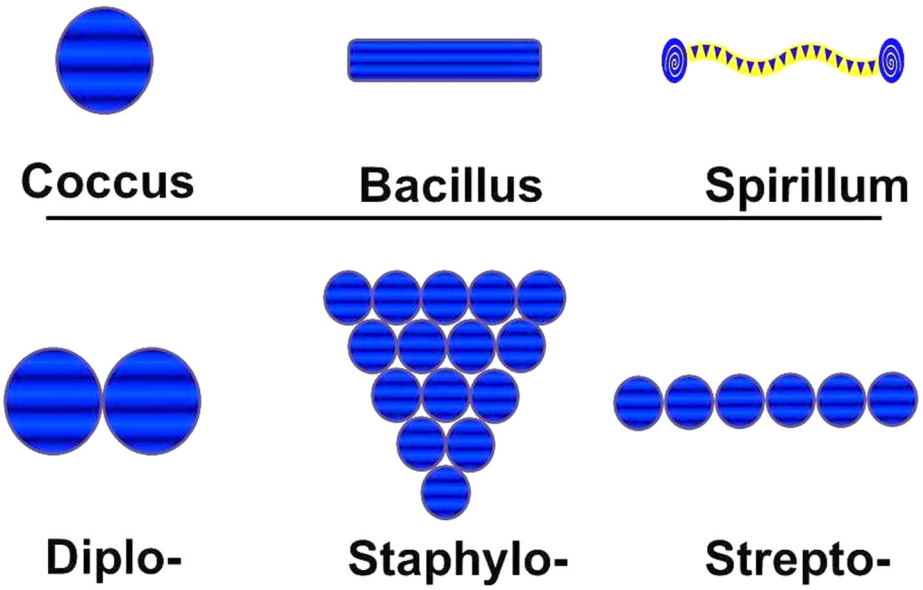
Bacteria are highly designed creatures formed in a variety of shapes. The simplest shape is a round sphere or ball.

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

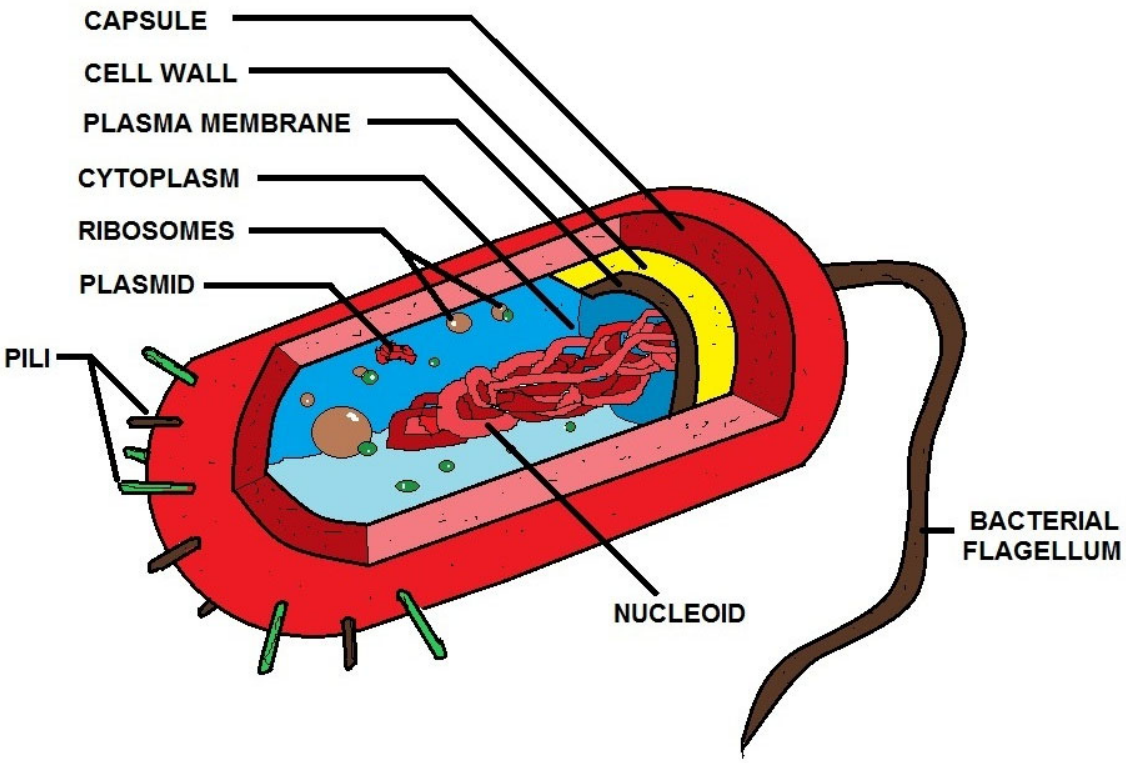


BASIC BACTERIA SHAPES DIAGRAM

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



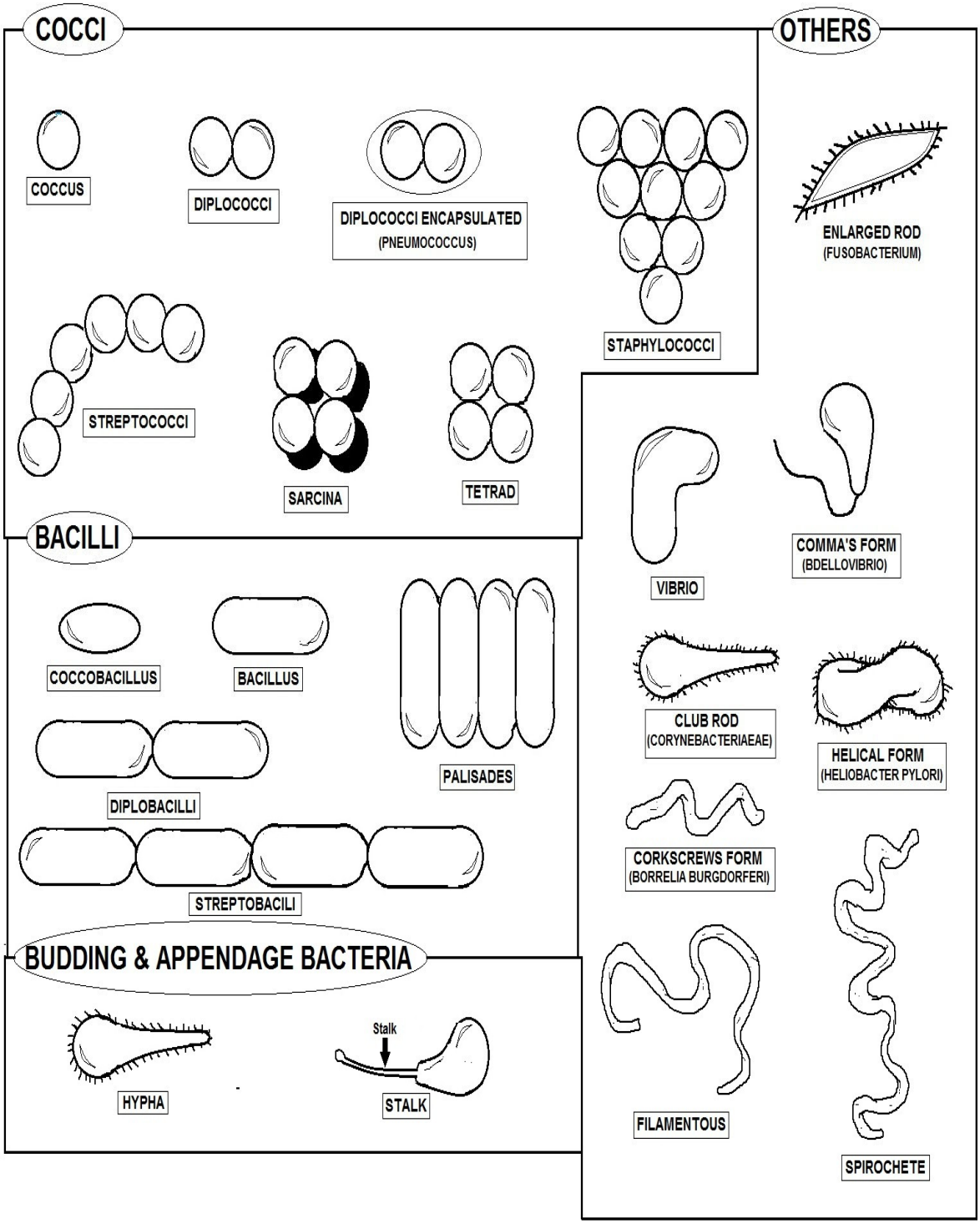
PROKARYOTIC CELL

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:

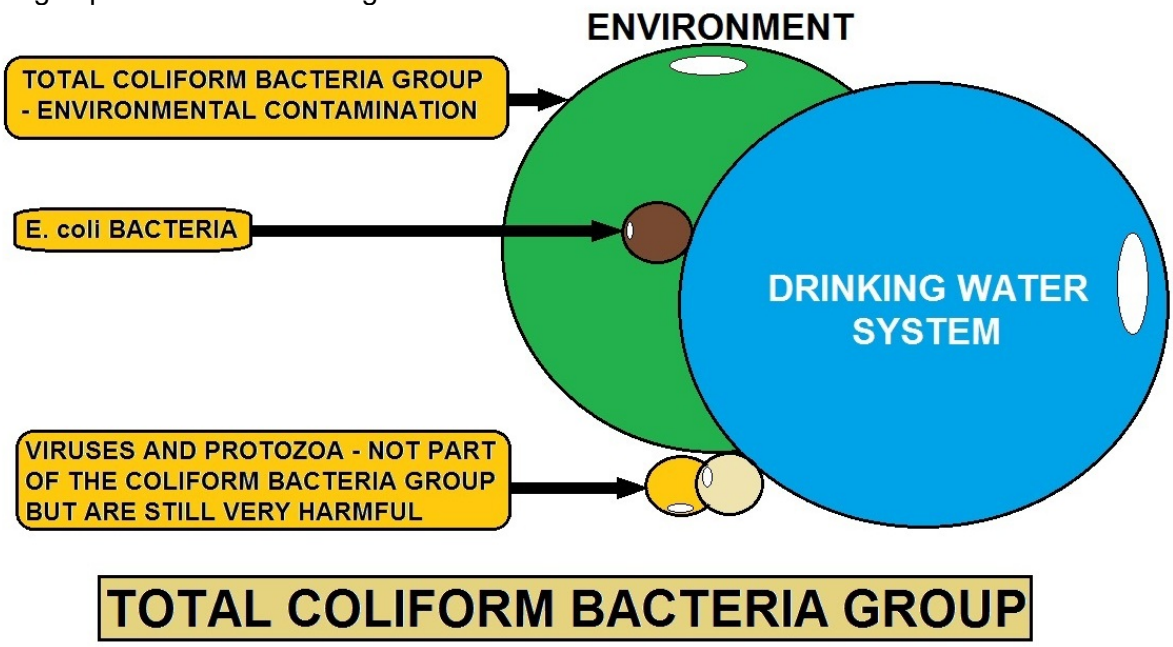
Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife;

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.



Background

Coliform bacteria and chlorine residual are the only routine sampling and monitoring requirements for small ground water systems with chlorination. The coliform bacteriological sampling is governed by the Total Coliform Rule (**TCR**) of the SDWA. Although there is presently no requirement for chlorination of groundwater systems under the SDWA, State regulations require chlorine residual monitoring of those systems that do chlorinate the water.

TCR

The TCR requires all Public Water Systems (PWS) to monitor their distribution system for coliform bacteria according to the written sample sitting plan for that system. The sample sitting plan identifies sampling frequency and locations throughout the distribution system that are selected to be representative of conditions in the entire system.

Coliform contamination can occur anywhere in the system, possibly due to problems such as; low pressure conditions, line breaks, or well contamination, and therefore routine monitoring is required. A copy of the sample sitting plan for the system should be kept on file and accessible to all who are involved in the sampling for the water system.

Number of Monthly Samples
The number of samples to be collected monthly depends on the size of the system. The TCR specifies the minimum number of coliform samples collected, but it may be necessary to take more than the minimum number in order to provide adequate monitoring.

This is especially true if the system consists of multiple sources, pressure zones, booster pumps, long transmission lines, or extensive distribution system piping. Since timely detection of coliform contamination is the purpose of the sample-sitting plan, sample sites should be selected to represent the varying conditions that exist in the distribution system. The sample sitting plan should be updated as changes are made in the water system, especially the distribution system.

Sampling Procedures
The sample-sitting plan must be followed and all operating staff must be clear on how to follow the sampling plan. In order to properly implement the sample-sitting plan, staff must be aware of how often sampling must be done, the proper procedures and sampling containers to be used for collecting the samples, and the proper procedures for identification, storage and transport of the samples to an approved laboratory. In addition, proper procedures must be followed for repeat sampling whenever a routine sample result is positive for total coliform.

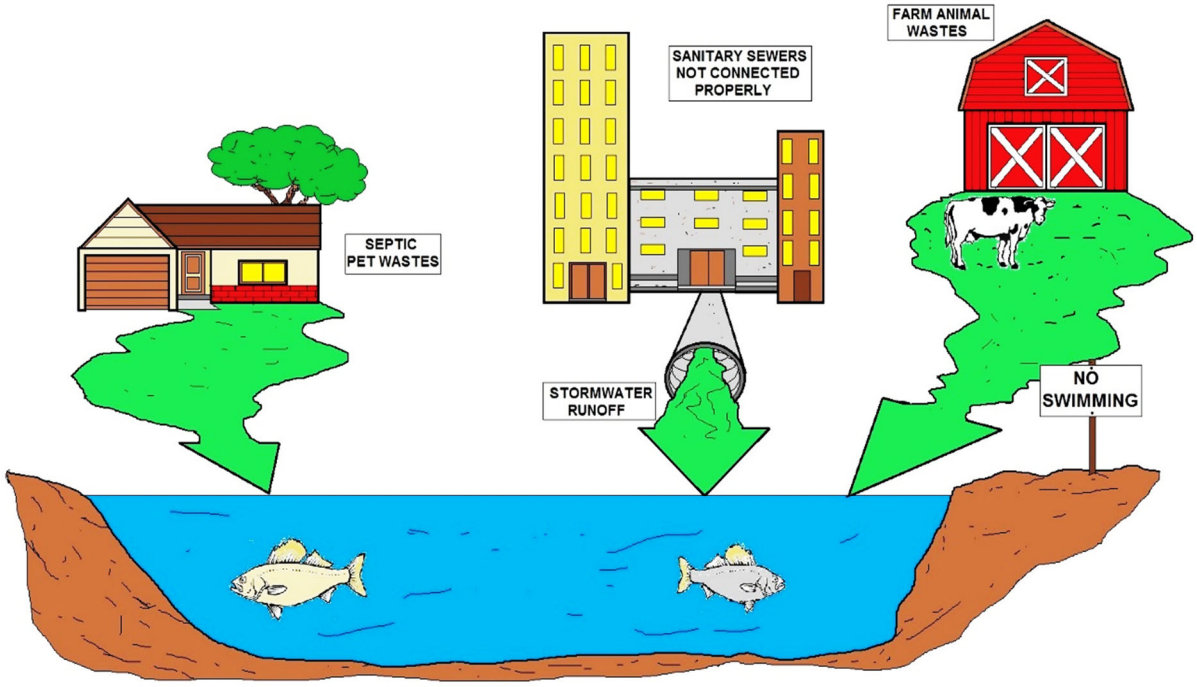
Routine Sampling Requirements
Total coliform samples must be collected by PWSs at sites which are representative of water quality throughout the distribution system according to a written sample siting plan subject to state review and revision.

For PWSs collecting more than one sample per month, collect total coliform samples at regular intervals throughout the month, except that ground water systems serving 4,900 or fewer people may collect all required samples on a single day if the samples are taken from different sites.

Each total coliform-positive (TC+) routine sample must be tested for the presence of E. coli.
► If any TC+ sample is also E. coli-positive (EC+), then the EC+ sample result must be reported to the state by the end of the day that the PWS is notified.
► If any routine sample is TC+, repeat samples are required. – PWSs on quarterly or annual monitoring must take a minimum of three additional routine samples (known as additional routine monitoring) the month following a TC+ routine or repeat sample.
► Reduced monitoring may be available for PWSs using only ground water and serving 1,000 or fewer persons that meet certain additional PWS criteria.

Coliform Bacteria Introduction

Total coliforms are a group of related bacteria that are (with few exceptions) not harmful to humans. A variety of bacteria, parasites, and viruses, known as pathogens, can potentially cause health problems if humans ingest them. EPA considers total coliforms a useful indicator of other pathogens for drinking water because they are easier to measure and associate with water contamination.



SOURCES OF FECAL COLIFORM BACTERIA

Total coliforms are used to determine the adequacy of water treatment and the integrity of the distribution system.

All bacteriological samples are analyzed for the coliform group; however, a positive reaction to these coliform analyses may be from sources other than fecal. In order to differentiate between these sources, all samples that are total coliform positive must be analyzed again to determine if fecal coliform or *E. coli* are present.

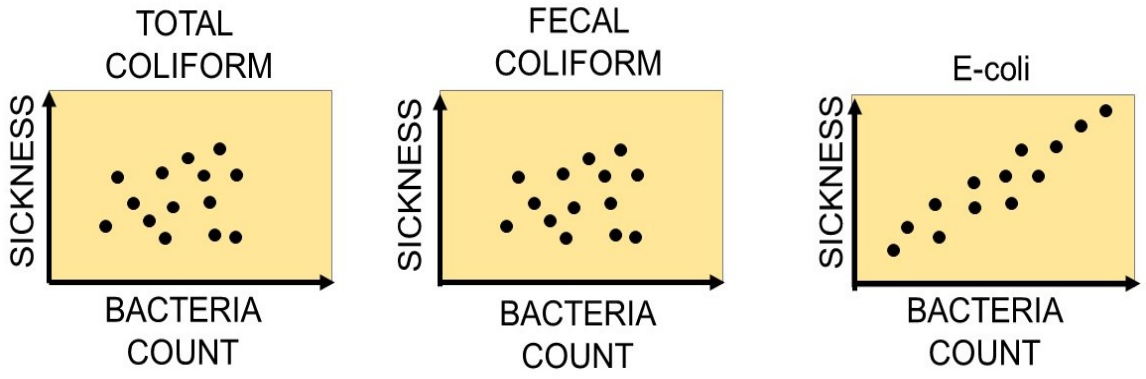
Key provisions of the RTCR include:

- Setting a maximum contaminant level goal (MCLG) and maximum contaminant level (MCL) for E. coli for protection against potential fecal contamination.
- Setting a total coliform treatment technique (TT) requirement.
- Requirements for monitoring total coliforms and E. coli according to a sample siting plan and schedule specific to the PWS.
- Provisions allowing PWSs to transition to the RTCR using their existing Total Coliform Rule (TCR) monitoring frequency, including PWSs on reduced monitoring under the existing TCR.

- Requirements for seasonal systems (such as Non-Community Water Systems not operated on a year-round basis) to monitor and certify the completion of a state-approved start-up procedures.
- Requirements for assessments and corrective action when monitoring results show that PWSs may be vulnerable to contamination.
- Public notification (PN) requirements for violations.
- Specific language for CWSs to include in their Consumer Confidence Reports (CCRs) when they must conduct an assessment or if they incur an E. coli MCL violation.

TCR Key Provisions

- To comply with the monthly MCL for total coliforms (TC), PWSs must not find coliforms in more than five percent of the samples they take each month to meet EPA's standards. If more than five percent of the samples contain coliforms, PWS operators must report this violation to the state and the public.
- If a sample tests positive for TC, the system must collect a set of repeat samples located within 5 or fewer sampling sites adjacent to the location of the routine positive sample within 24 hours.
- When a routine or repeat sample tests positive for total coliforms, it must also be analyzed for fecal coliforms or E. coli, which are types of coliform bacteria that are directly associated with feces. A positive result for fecal coliforms or E. coli can signify an acute MCL violation, which necessitates rapid state and public notification because it represents a direct health risk.
- At times, an acute violation due to the presence of fecal coliform or E. coli may result in a "boil water" notice. The system must also take at least 5 routine samples the next month of operation if any sample tests positive for total coliforms.



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.

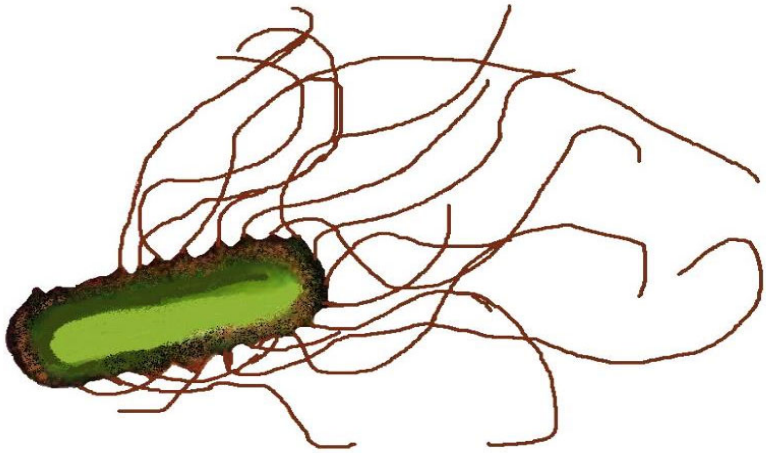
Dangerous Waterborne Microbes

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***.

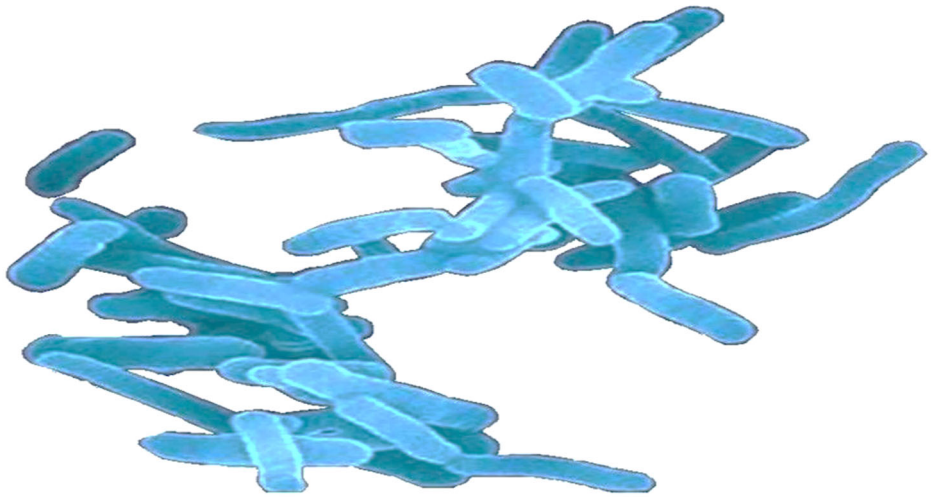
Giardia lamblia is a parasite that enters lakes and rivers through sewage and animal waste. It causes gastrointestinal illness (e.g. diarrhea, vomiting, and cramps).



PERITRICHOUS SHAPED BACTERIA EXAMPLE

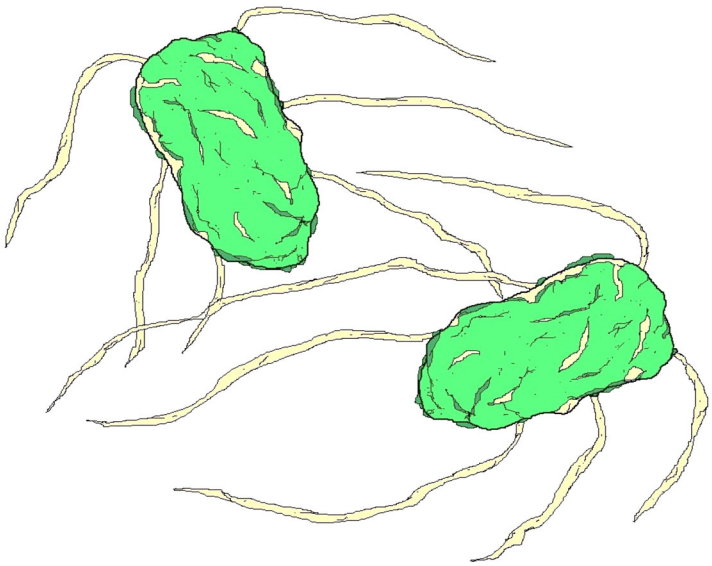
Microbiologists broadly classify bacteria according to their shape: spherical, rod-shaped, and spiral-shaped. Pleomorphic bacteria can assume a variety of shapes. Bacteria may be further classified according to whether they require oxygen (aerobic or anaerobic) and how they react to a test with Gram's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



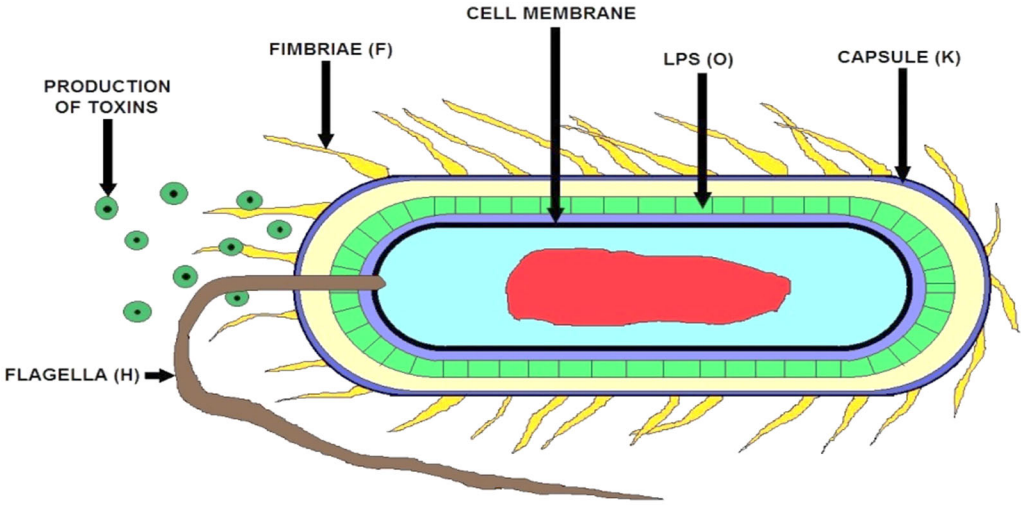
SHIGELLA DYSENTARIAE EXAMPLE

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

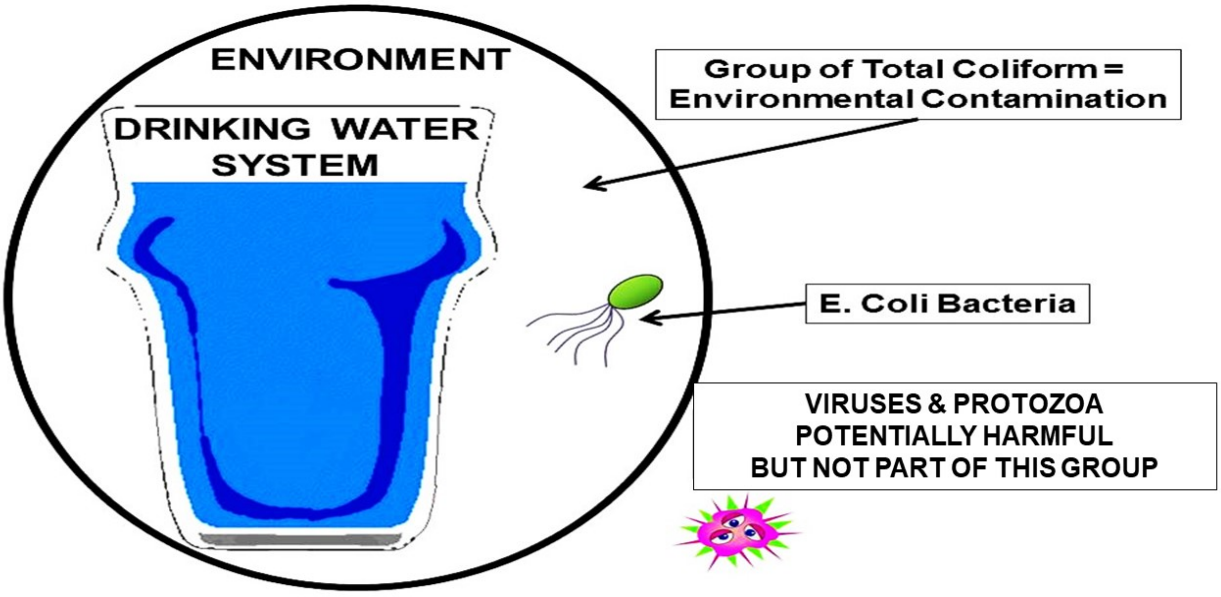
Salmonellae usually do not ferment lactose; most of them produce hydrogen sulfide that in media containing ferric ammonium citrate reacts to form a black spot in the center of the creamy colonies.



E. COLI

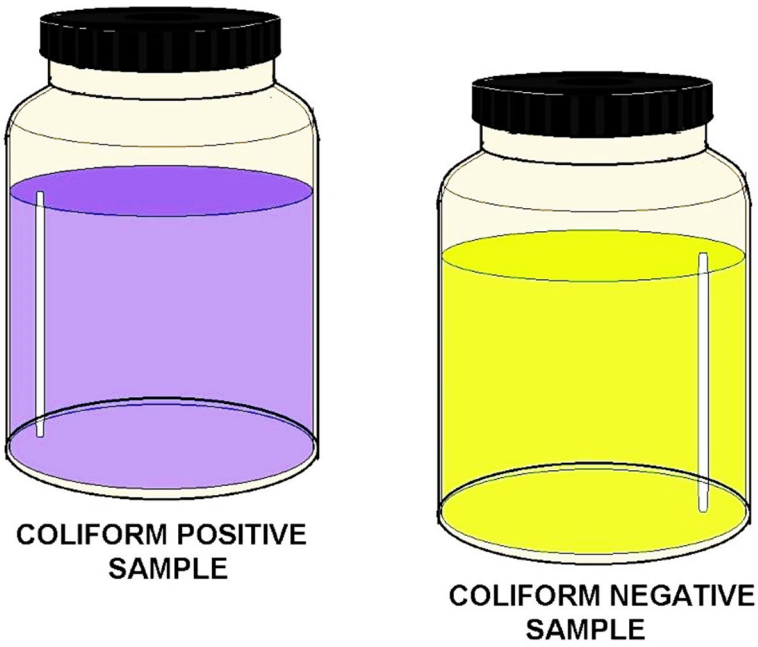
Fecal Coliform Bacteria

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.

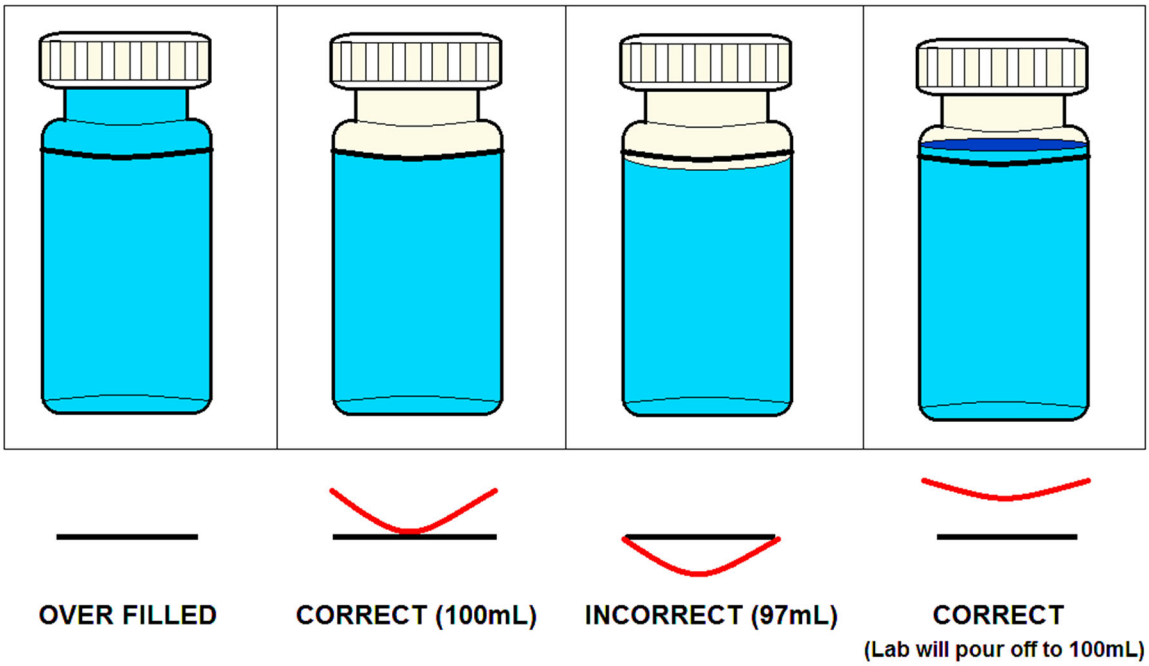


Technical Learning College

GROUP OF TOTAL COLIFORM BACTERIA



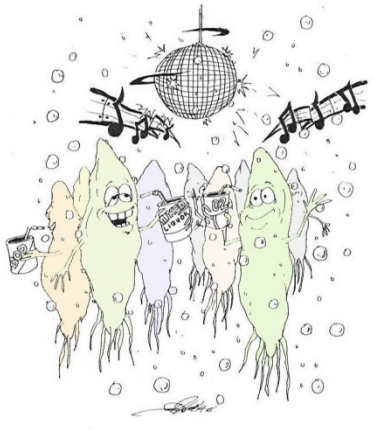
COLIFORM BACTERIA PRESENCE TEST EXAMPLE



BAC-T SAMPLE BOTTLE DIAGRAM

Bacteriological Monitoring Introduction

Most waterborne diseases and illnesses have been related to the microbiological quality of drinking water. The routine microbiological analysis of your water is for coliform bacteria. The coliform bacteria group is used as an indicator organism to determine the biological quality of your water. The presence of an indicator or pathogenic bacteria in your drinking water is an important health concern. Indicator bacteria signal possible fecal contamination, and therefore, the potential presence of pathogens. They are used to monitor for pathogens because of the difficulties in determining the presence of specific disease-causing microorganisms.



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

Bacteria Sampling - 1 Example
Water samples for bacteria tests must always be collected in a sterile container. Take the sample from an outside faucet with the aerator removed. Sterilize by spraying a 5% Household beach or alcohol solution or flaming the end of the tap with a propane torch. Run the water for five minutes to clear the water lines and bring in fresh water. Do not touch or contaminate the inside of the bottle or cap. Carefully open the sample container and hold the outside of the cap. Fill the container and replace the top. Refrigerate the sample and transport it to the testing laboratory within six hours (in an ice chest). Many labs will not accept bacteria samples on Friday so check the lab's schedule. Mailing bacteria samples is not recommended because laboratory analysis results are not as reliable. Iron bacteria forms an obvious slime on the inside of pipes and fixtures. A water test is not needed for identification. Check for a reddish-brown slime inside a toilet tank or where water stands for several days.

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

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

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

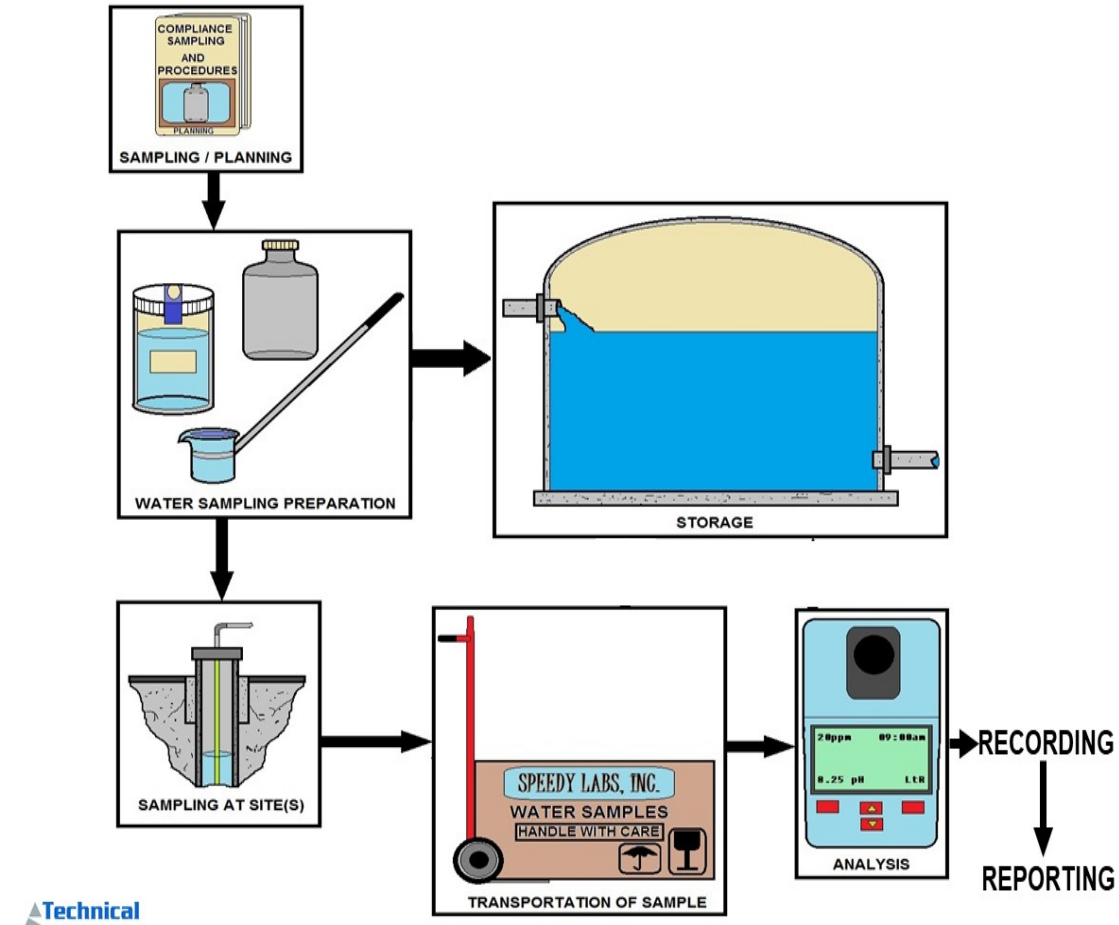
Methods

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

Microbial Regulations

One of the key regulations developed and implemented by the United States Environmental Protection Agency (USEPA) to counter pathogens in drinking water is the Surface Water Treatment Rule.

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



WATER SAMPLING FLOW CHART

Basic Types of Water Samples

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

The three (3) 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.

4. **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

5. **Trigger: Level 2 Assessment** is triggered if any one of the following occurs:
► A PWS incurs an E. coli MCL violation.
► A PWS has a second Level 1 Assessment within a rolling 12-month period.
► A PWS on state-approved annual monitoring has a Level 1 Assessment trigger in 2 consecutive years.

Routine Coliform Sampling
The number of routine samples and frequency of collection for community public water systems is shown in Table 3-1 below.

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

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

No. of Samples per System Population

Persons served - Samples per month

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

Repeat Sampling Introduction

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

1. If only one routine sample per month or quarter is required, four (4) repeat samples must be collected.
2. For systems collecting two (2) or more routine samples per month, three (3) repeat samples must be collected.
3. Repeat samples must be collected from:

a. The original sampling location of the coliform present sample.
b. Within five (5) service connections upstream from the original sampling location.
c. Within five (5) service connections downstream from the original sampling location.
d. Elsewhere in the distribution system or at the wellhead, if necessary.

4. If the system has only one service connection, the repeat samples must be collected from the same sampling location over a four-day period or on the same day.
5. All repeat samples are included in the MCL compliance calculation.
6. If a system which normally collects fewer than five (5) routine samples per month has a coliform present sample, it must collect five (5) routine samples the following month or quarter regardless of whether an MCL violation occurred or if repeat sampling was coliform absent.

Positive or Coliform Present Results

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

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

After you have contacted an agency for assistance, you will be instructed as to the proper repeat sampling procedures and possible corrective measures for solving the problem. It is very important to initiate the repeat sampling immediately as the corrective measures will be based on those results.

Some examples of typical corrective measures to coliform problems are:

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

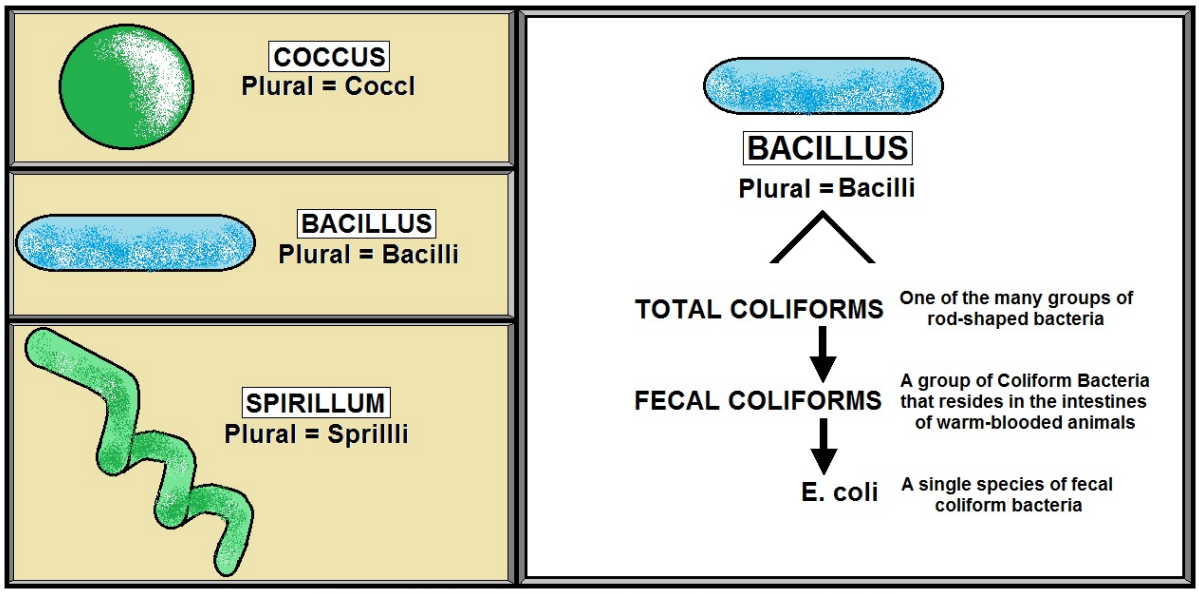
This list provides some basic operation and maintenance procedures that could help eliminate potential bacteriological problems, check with your state drinking water section or health department for further instructions.

Maximum Contaminant Levels (MCLs)

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

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

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



COLIFORM BACTERIA EXAMPLE

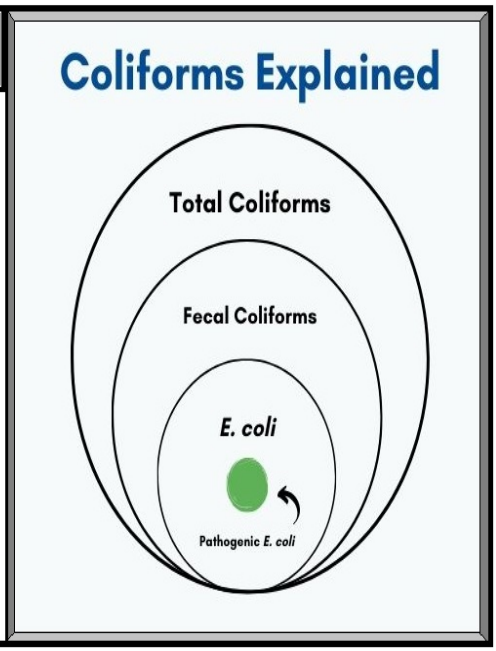
TOTAL COLIFORM RULE (TCR) REVISIONS

REVISED TOTAL COLIFORM RULE (RTCR)

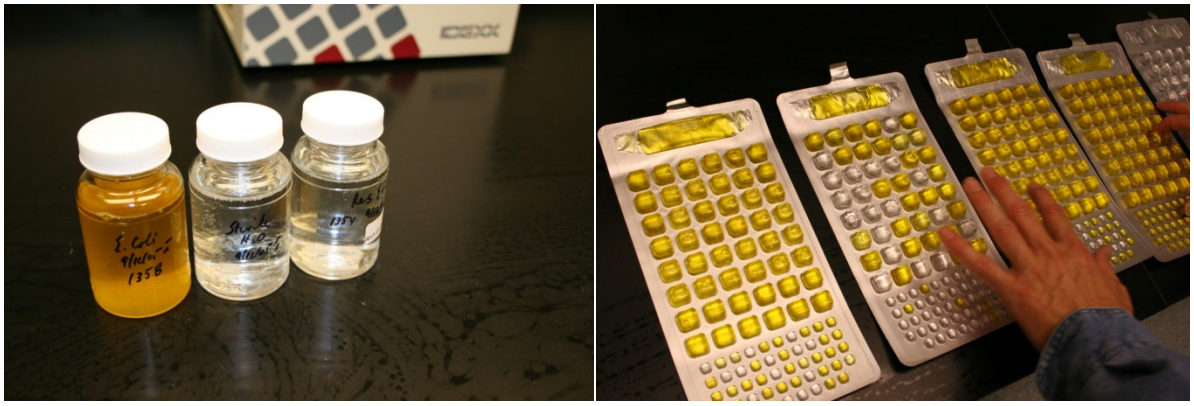
THIS REVISES THE 1989 TOTAL COLIFORM RULE (TCR) AND IS INTENDED TO IMPROVE PUBLIC HEALTH PROTECTION. THIS ESTABLISHED A "FIND-AND-FIX" APPROACH FOR INVESTIGATING AND CORRECTING CAUSES OF COLIFORM PROBLEMS WITHIN WATER DISTRIBUTION SYSTEMS.

THE MAXIMUM CONTAMINANT LEVEL (MCL) FOR BACTERIA IN DRINKING WATER IS ZERO TOTAL COLIFORM COLONIES PER 100 MILLILITERS OF WATER.

BEGINNING JULY 1st, 2021, ALL RESAMPLES SUBMITTED IN RESPONSE TO A PREVIOUS POSITIVE COLIFORM RESULT MUST BE ANALYZED TO DETERMINE COLIFORM AND E.coli DENSITY



TOTAL COLIFORM RULE (TCR) REVISIONS

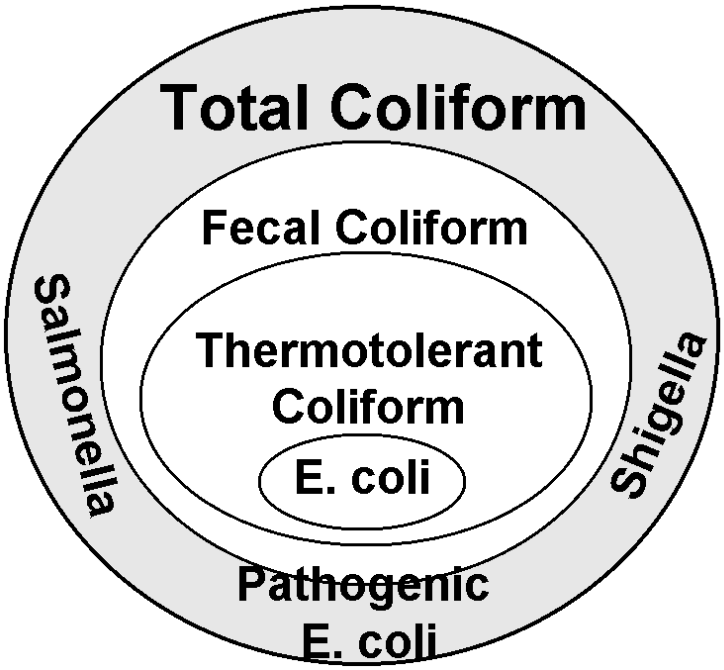


Looking under a black light to identify the presence of E. coli.

Colilert tests simultaneously detect and confirms coliform and E. coli in water samples in 24 hours or less.

Simply add the Colilert reagent to the sample, incubate for 24 hours, and read results.

Colilert is easy to read, as positive coliform samples turn yellow or blue, and when E. coli is present, samples fluoresce under UV light.



FECAL COLIFORM BACTERIA COLONIES
(Per 100 Milliliters)

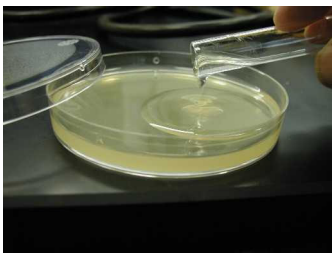
Heterotrophic Plate Count - Introduction

Heterotrophic organisms utilize organic compounds as their carbon source (food or substrate). In contrast, autotrophic organisms use inorganic carbon sources. The Heterotrophic Plate Count provides a technique to quantify the bacteriological activity of a sample. The R2A agar provides a medium that will support a large variety of heterotrophic bacteria. After an incubation period, a bacteriological colony count provides an estimate of the concentration of heterotrophs in the sample of interest.

Heterotrophic Plate Count (**HPC**) --- formerly known as the standard plate count, is a procedure for estimating the number of live heterotrophic bacteria and measuring changes during water treatment and distribution in water or in swimming pools. Colonies may arise from pairs, chains, clusters, or single cells, all of which are included in the term "*colony-forming units*" (**CFU**).

Method:

There are three methods for standard plate count:



1. **Pour Plate Method**
The colonies produced are relatively small and compact, showing less tendency to encroach on each other than those produced by surface growth. On the other hand, submerged colonies often are slower growing and are difficult to transfer.

2. **Spread Plate Method**
All colonies are on the agar surface where they can be distinguished readily from particles and bubbles. Colonies can be transferred quickly, and colony morphology can be easily discerned and compared to published descriptions. See next page

3. **Membrane Filter Method**
This method permits testing large volumes of low-turbidity water and is the method of choice for low-count waters.

Material

i) Apparatus
- Glass rod
- Erlenmeyer flask
- Graduated Cylinder
- Pipette
- Petri dish
- Incubator

ii) Reagent and sample
- Reagent-grade water
- Nutrient agar
- Sample

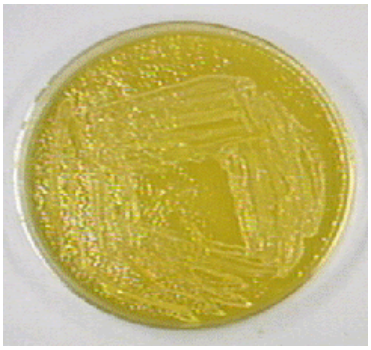
Procedure*

1. Boil mixture of nutrient agar and nutrient broth for 15 minutes, then cool for about 20 minutes.
2. Pour approximately 15 ml of medium in each Petri dish, let medium solidify.

3. Pipette 0.1 ml of each dilution onto surface of pre-dried plate, starting with the highest dilution.
4. Distribute inoculum over surface of the medium using a sterile bent glass rod.
5. Incubate plates at 35°C for 48h.
6. Count all colonies on selected plates promptly after incubation, consider only plates having 30 to 300 colonies in determining the plate count.
*Duplicate samples

Computing and Reporting
Compute bacterial count per milliliter by the following equation:
CFU/ml = colonies counted / actual volume of sample in dish a)If there is no plate with 30 to 300 colonies, and one or more plates have more than 300 colonies, use the plate(s) having a count nearest 300 colonies.
b) If plates from all dilutions of any sample have no colony, report the count as less than 1/actual volume of sample in dish estimated CFU/ml.
c) Avoid creating fictitious precision and accuracy when computing CFU by recording only the first two left-hand digits.

Heterotrophic Plate Count (Spread Plate Method)



Laboratory Equipment Needed
100 x 15 Petri Dishes
Turntable
Glass Rods: Bend fire polished glass rod 45 degrees about 40 mm from one end. Sterilize before using.
Pipette: Glass, 1.1 mL. Sterilize before using.
Quebec Colony Counter
Hand Tally Counter

Reagents
1) R2A Agar: Dissolve and dilute 0.5 g of yeast extract, 0.5 g of proteose peptone No. 3, 0.5 g of casamino acids, 0.5 g of glucose, 0.5 g of soluble starch, 0.3 g of dipotassium hydrogen phosphate, 0.05 g of magnesium sulfate heptahydrate, 0.3 g of sodium pyruvate, 15.0 g of agar to 1 L. Adjust pH to 7.2 with dipotassium hydrogen phosphate **before adding agar.** Heat to dissolve agar and sterilize at 121 C for 15 minutes.

2) Ethanol: As needed for flame sterilization.

Preparation of Spread Plates
Immediately after agar sterilization, pour 15 mL of R2A agar into sterile 100 x 15 Petri dishes; let agar solidify. Pre-dry plates inverted so that there is a 2 to 3 g water loss overnight with the lids on. Use pre-dried plates immediately or store up to two weeks in sealed plastic bags at 4°C.

Sample Preparation
Mark each plate with sample type, dilution, date, and any other information before sample application.

Prepare at least duplicate plates for each volume of sample or dilution examined.
Thoroughly mix all samples by rapidly making about 25 complete up-and-down movements.

Sample Application
Uncover pre-dried agar plate. Minimize time plate remains uncovered. Pipette 0.1 or 0.5 mL sample onto surface of pre-dried agar plate.

Record Volume of Sample Used.
Using a sterile bent glass rod, distribute the sample over surface of the medium by rotating the dish by hand on a turntable. Let the sample be absorbed completely into the medium before incubating. Put cover back on Petri dish and invert for duration of incubation time. Incubate at 28°C for 7 days. Remove Petri dishes from incubator for counting.

Counting and Recording
After incubation period, promptly count all colonies on the plates. To count, uncover plate and place on Quebec colony counter. Use a hand tally counter to maintain count. Count all colonies on the plate, regardless of size. Compute bacterial count per milliliter by the following equation:

$$\text{CFU} \Big/ \text{mL} = \frac{\text{colonies counted}}{\text{actual volume of sample in dish, mL}}$$

To report counts on a plate with no colonies, report the count as less than one (<1) divided by the sample volume put on that plate (remember to account for any dilution of that sample).

If plates of all dilutions for a sample have no colonies, report the count as less than one (<1) divided by the largest sample volume used. Example: if 0.1 mL of a 100:1 and 10000:1 dilution of a sample both turned up with no colonies formed, the reported result would be <1 divided by the largest sample volume 0.001 mL (0.1 mL divided by 100). The final reported result for the sample is <1000 CFU per mL.

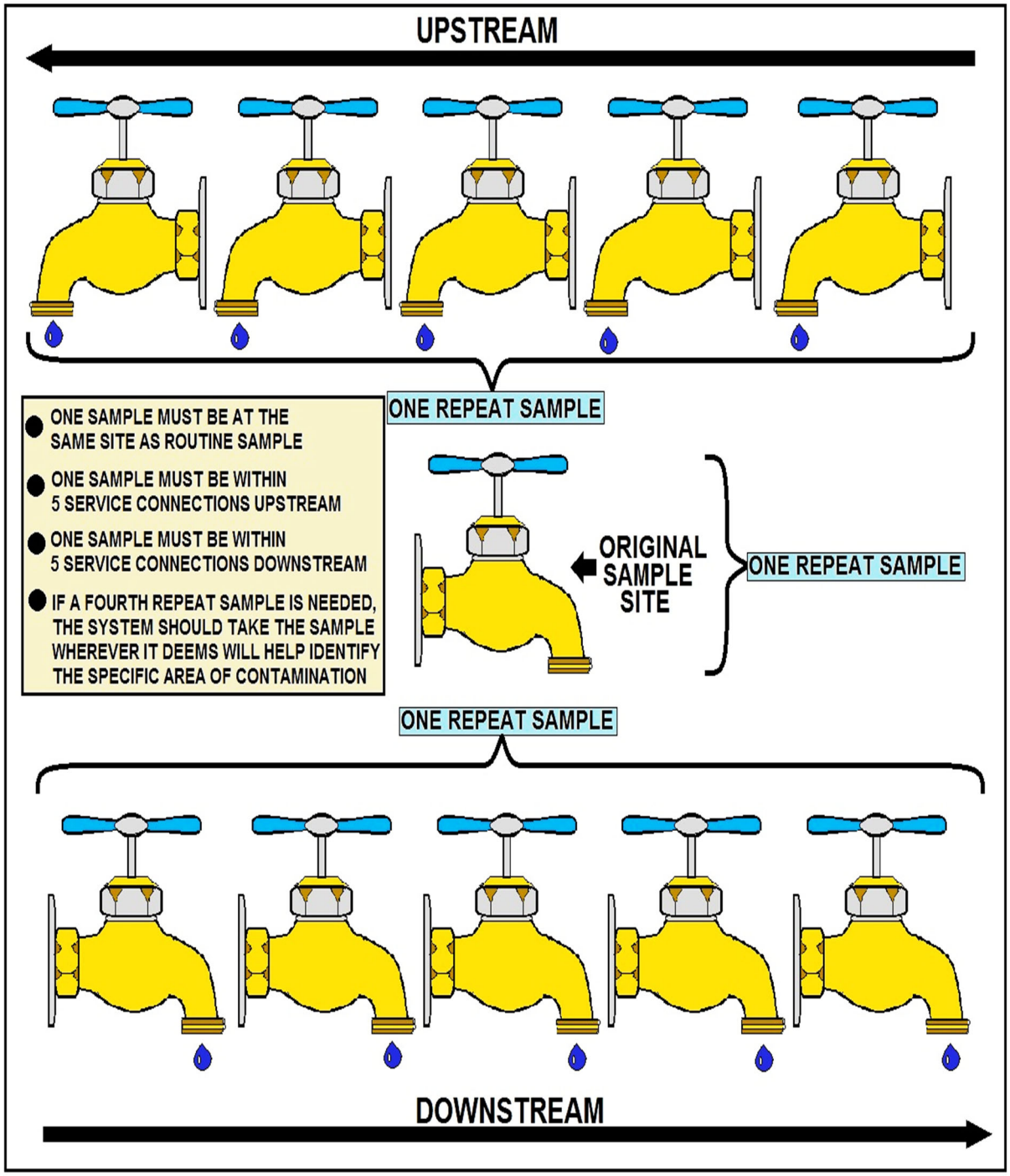
Assignment

1. Report the number of colony forming units (**CFU**) found on each plate.
2. Calculate the **CFU** per mL for each plate.
3. The aim of diluting samples is to produce a plate having 30 to 300 colonies, which plates meet these criteria. If no sample produces a plate with a count in this range, use the plate(s) with a count closest to 300. Based on these criteria, use your calculated results to report the CFU per mL for each sample.

In the conclusion of your lab report, comment on your final results for each sample type as well as the quality of your application of this analysis technique. Feel free to justify your comments using statistical analysis. Also, comment on the general accuracy of this analytical technique and the factors that affect its accuracy and or applicability.

Data Table for Samples

Sample ID	Volume of Sample, mL	Colonies Counted per plate



EXAMPLE OF WHAT HAS TO BE DONE IF A PRESENCE OF COLIFORMS ARE DETECTED WHEN CONDUCTING ROUTINE SAMPLES AT DESIGNATED SAMPLE SITES

Total Coliforms

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

For systems which collect 40 or more samples per month, no more than five (5) percent may be positive. Check with your state drinking water section or health department for further instructions.

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

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

1. A routine analysis shows total coliform present and is followed by a repeat analysis which indicates fecal coliform or E. coli present.

2. A routine analysis shows total and fecal coliform or E. coli present and is followed by a repeat analysis which indicates total coliform present.

An acute health risk violation requires the water system to provide public notice via radio and television stations in the area. This type of contamination can pose an immediate threat to human health and notice must be given as soon as possible, but no later than 24 hours after notification from your laboratory of the test results.

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

Public Notice

A public notice is required to be issued by a water system whenever it fails to comply with an applicable MCL or treatment technique, or fails to comply with the requirements of any scheduled variance or permit. This will inform users when there is a problem with the system and give them information.

A public notice is also required whenever a water system fails to comply with its monitoring and/or reporting requirements or testing procedure.

Each public notice must contain certain information, be issued properly and in a timely manner and contain certain mandatory language. The timing and place of posting of the public notice depends on whether an acute risk is present to users. Check with your state drinking water section or health department for further instructions.

The following are Acute Violations

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

Sim Plate Method

IDEXX's SimPlate for HPC method is used for the quantification of heterotrophic plate count (HPC) in water.

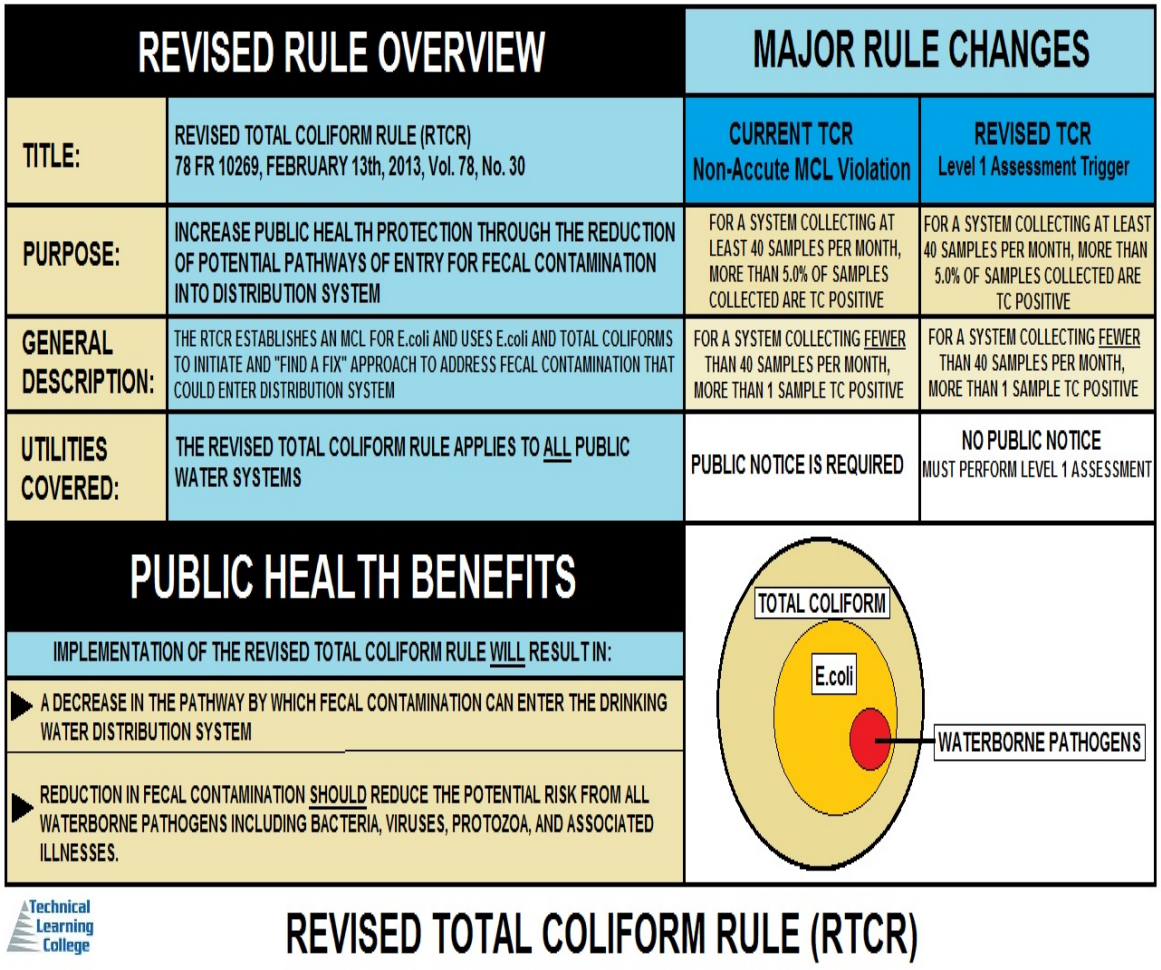
It is based on the Multiple Enzyme Technology which detects viable bacteria in water by testing for the presence of key enzymes known to be present in these little organisms.

This technique uses enzyme substrates that produce a blue fluorescence when metabolized by waterborne bacteria. The sample and media are added to a SimPlate Plate, incubated and then examined for fluorescing wells.

The number of wells corresponds to a Most Probable Number (MPN) of total bacteria in the original sample.

The MPN values generated by the SimPlate for HPC method correlate with the Pour Plate method using the Total Plate Count Agar, incubated at 35^{o}C for 48 hours as described in *Standard Methods for the Examination of Water and Wastewater, 19th Edition.*

Revised Total Coliform Rule (RTCR) Summary



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

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

Why revise the 1989 TCR?
The 1996 amendments to the Safe Drinking Water Act [Section 1412(b) (9)] require the Administrator to review and revise, as appropriate, each national primary drinking water regulation not less often that every six years. EPA published its decision to revise the TCR in July 2003 as part of its National Primary Drinking Water Regulation (NPDWR) review.

The RTCR:

- Upholds the purpose of the 1989 TCR to protect public health by ensuring the integrity of the drinking water distribution system and monitoring for the presence of microbial contamination.

- Requires public water systems (PWSs) to meet a legal limit for E. coli, as demonstrated by required monitoring.
- Specifies the frequency and timing of required microbial testing based on population served, public water system type and source water type: ground water or surface water.

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

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

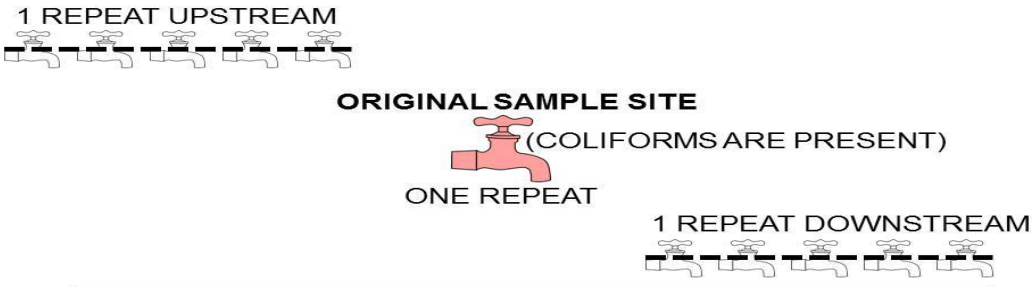
Minor Corrections to the Revised Total Coliform Rule (RTCR)
Minor corrections to the final RTCR became effective on April 28, 2014. No comments were received on the Direct Final Rule published on February 26, 2014 and the corrections therefore became effective without further notice. See the **Direct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

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

The RTCR:

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

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



ONE AT THE SAME SITE AS THE ROUTINE SAMPLE.
ONE WITHIN 5 SERVICE CONNECTIONS UPSTREAM.
ONE WITHIN 5 SERVICE CONNECTIONS DOWNSTREAM.

IF A FOURTH REPEAT SAMPLE IS REQUIRED THE SYSTEM SHOULD TAKE THE SAMPLE WHEREVER IT FEELS IT WILL HELP IDENTIFY THE AREA OF CONTAMINATION.

REPEAT SAMPLING PROCEDURES

RTCR Key Provisions *Most of this section comes from the USEPA.*

Provision Category	Key Provisions
Contaminant Level	Addresses the presence of total coliforms and E. coli in drinking water. For E. coli (EC), the Maximum Contaminant Level Goal (MCLG) is set at zero. The Maximum Contaminant Level (MCL) is based on the occurrence of a condition that includes routine and repeat samples. For total coliforms (TC), PWSs must conduct a Level 1 or Level 2 assessment of their system when they exceed a specified frequency of total coliform occurrences. An MCL violation or failure to take repeat samples following a routine total coliform-positive sample will trigger a Level 1 or Level 2 assessment. Any sanitary defect identified during a Level 1 or Level 2 assessment must be corrected by the PWS. These are the treatment technique requirements of the RTCR.
Monitoring	Develop and follow a sample-siting plan that designates the PWS's collection schedule. This includes location of routine and repeat water samples. Collect routine water samples on a regular basis (monthly, quarterly, annually). Have samples tested for the presence of total coliforms by a state certified laboratory. Analyze all routine or repeat samples that are total coliform positive (TC+) for E. coli. Collect repeat samples (at least 3) for each TC+ positive routine sample. For PWSs on quarterly or annual routine sampling, collect additional routine samples (at least 3) in the month after a TC+ routine or repeat sample.

RTCR Key Provisions *Most of this section comes from the USEPA.*	
	Seasonal systems must monitor and certify the completion of a state-approved start-up procedures.
Level 1 and Level 2 Assessments and Corrective Actions	PWSs are required to conduct a Level 1 or Level 2 assessment if conditions indicate they might be vulnerable to contamination. PWSs must fix any sanitary defects within a required timeframe.
Reporting and Recordkeeping	PWSs are required to report certain items to their states. These reporting and recordkeeping requirements are essentially the same as under TCR. The addition to the Requirements is the Level 1 and Level 2 requirements.
Violations, Public Notification (PN) and Consumer Confidence Report (CCR)	PWSs incur violations if they do not comply with the requirements of the RTCR. The violation types are essentially the same as under the TCR with few changes. The biggest change is no acute or monthly MCL violation for total coliform positive samples only. PN is required for violations incurred. Within required timeframes, the PWS must use the required health effects language and notify the public if they did not comply with certain requirements of the RTCR. The type of PN depends on the severity of the violation. Community water systems (CWSs) must use specific language in their CCRs when they must conduct an assessment or if they incur an E. coli MCL violation.

Disinfection Key

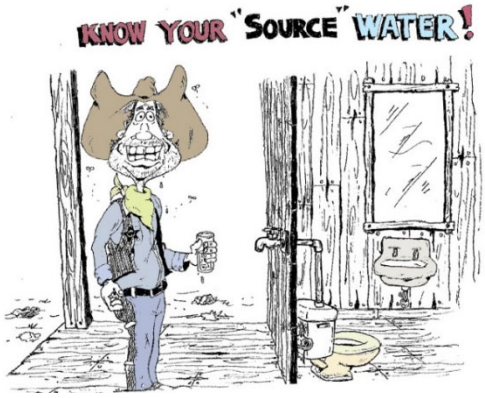
- Contact time is required
  - 99% or 2 log inactivation of crypto
  - 99.9% or 3 log inactivation of giardia lamblia cysts
  - 99.99% or 4 log inactivation of enteric viruses
- CT = Concentration of disinfectant x contact time

The chlorine residual leaving the plant must be = or > 0.2 mg/L and measurable throughout the system

Troubleshooting Table for Bacteriological Monitoring

Problems

1. Positive Total Coliform.
2. Chlorine taste and odor.
3. Inability to maintain an adequately free chlorine residual at the furthest points of the distribution system or at dead end lines.

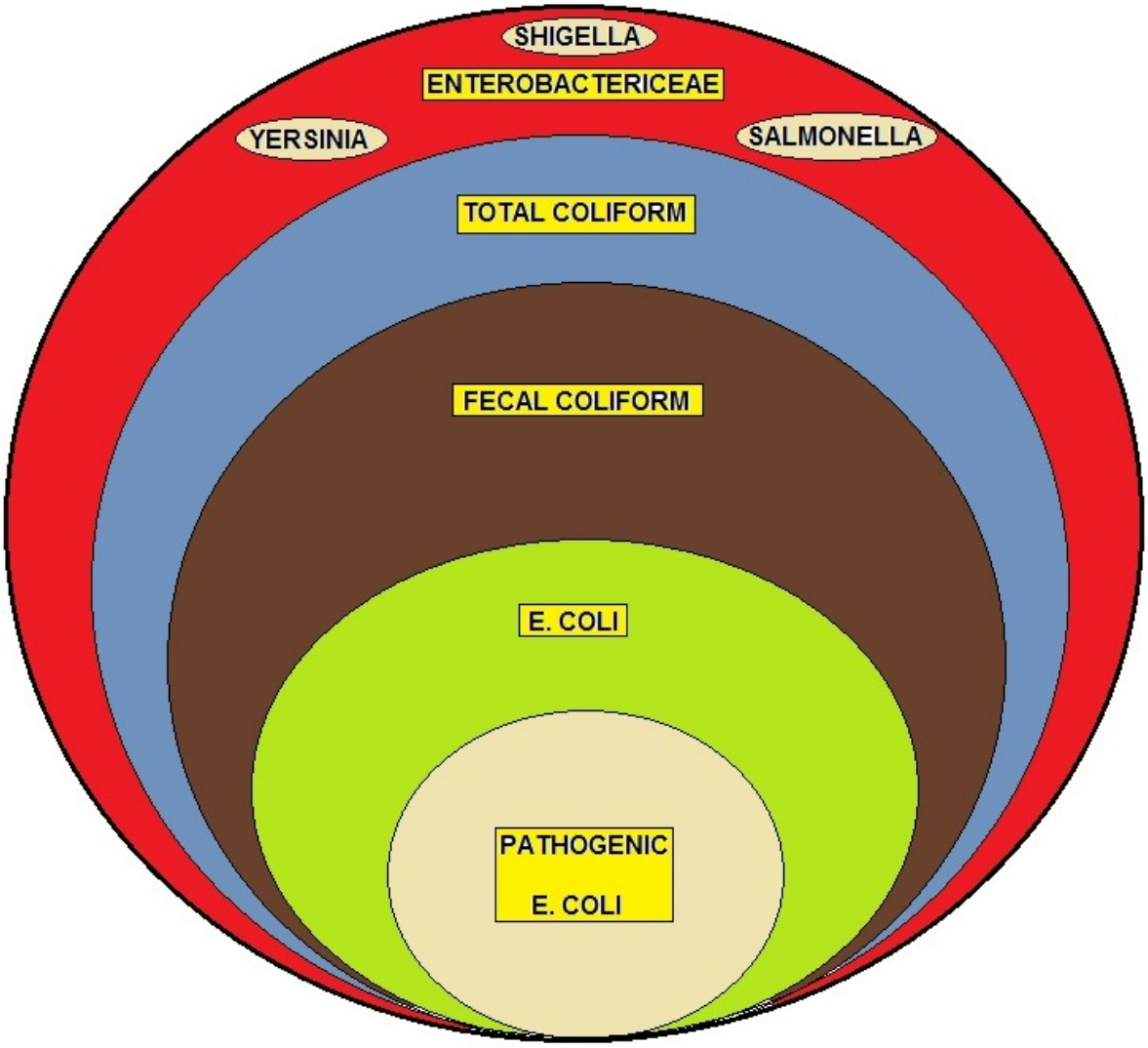


Possible Causes

1A. Improper sampling technique.
1B. Contamination entering distribution system.
1C. Inadequate chlorine residual at the sampling site.
1D. Growth of biofilm in the distribution system.
2A. High total chlorine residual and low free residual.
3A. Inadequate chlorine dose at treatment plant.
3B. Problems with chlorine feed equipment.
3C. Ineffective distribution system flushing program.
3D. Growth of biofilm in the distribution system.

Possible Solutions

1A/ Check distribution system for low-pressure conditions, possibly due to line breaks or excessive flows that may result in a backflow problem.
1B. Insure that all staff are properly trained in sampling and transport procedures as described in the TCR.
1C. Check the operation of the chlorination feed system. Refer to issues described in the sections on pumps and hypochlorination systems. Insure that residual test is being performed properly.
1D. Thoroughly flush effected areas of the distribution system. Superchlorination may be necessary in severe cases.
2A. The free residual should be at least 85% of the total residual. Increase the chlorine dose rate to get past the breakpoint in order to destroy some of the combined residual that causes taste and odor problems. Additional system flushing may also be required.
3A. Increase chlorine feed rate at point of application.
3B. Check operation of chlorination equipment.
3C. Review distribution system flushing program and implement improvements to address areas of inadequate chlorine residual.
3D. Increase flushing in area of biofilm problem.



COLIFORM BACTERIA SUB-SET #1
INDICATOR ORGANISMS

Waterborne Pathogen Section - Introduction

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

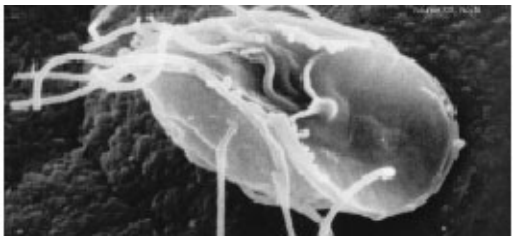
Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral (or feces-to-mouth) route. Pathogens may get into water and spread when infected humans or animals pass the bacteria, viruses, and protozoa in their stool. For another person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

Waterborne pathogens are different from other types of pathogens such as the viruses that cause influenza (the flu) or the bacteria that cause tuberculosis. Influenza virus and tuberculosis bacteria are spread by secretions that are coughed or sneezed into the air by an infected person.

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

Only proper treatment and a safe distribution system can ensure eliminating the spread of waterborne disease. In addition to water, other methods exist for spreading pathogens by the fecal-oral route. The foodborne route is one of the more common methods. A frequent source is a food handler who does not wash his hands after a bowel movement and then handles food with “unclean” hands. The individual who eats feces-contaminated food may become infected and ill. It is interesting to note the majority of foodborne diseases occur in the home, not restaurants.

Day care centers are another common source for spreading pathogens by the fecal-oral route. Here, infected children in diapers may get feces on their fingers, then put their fingers in a friend’s mouth or handle toys that other children put into their mouths. You will usually be asked to sample for Giardia at these facilities.



Giardia

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

Chain of Transmission
This chain lists the events that must occur for the transmission of disease via drinking water. By breaking the chain at any point, the transmission of disease will be prevented. Water is contaminated with feces. This contamination may be of human or animal origin. The feces must contain pathogens (disease-causing bacteria, viruses or protozoa). If the human or animal source is not infected with a pathogen, no disease will result.

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

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

Emerging Waterborne Pathogens
Emerging waterborne pathogens constitute a major health hazard in both developed and developing nations. A new dimension to the global epidemiology of cholera-an ancient scourge-was provided by the emergence of Vibrio cholerae O139. Also, waterborne enterohemorrhagic Escherichia coli (E. coli O157:H7), although regarded as a problem of the industrialized west, has recently caused outbreaks in Africa.

Outbreaks of chlorine-resistant Cryptosporidium in the US have motivated water authorities to reassess the adequacy of current water-quality regulations. Of late, a host of other organisms, such as hepatitis viruses (including hepatitis E virus), Campylobacter jejuni, microsporidia, cyclospora, Yersinia enterocolitica, calciviruses and environmental bacteria like Mycobacterium spp, aeromonads, Legionella pneumophila and multidrug-resistant Pseudomonas aeruginosa have been associated with water-borne illnesses.

The protection and enhancement of our nation's water quality remains a chief concern of the U.S. Environmental Protection Agency. The Office of Research and Development is committed, through the extensive waterborne disease research efforts earlier described, to ensure that the most effective and efficient methods are developed to identify, detect, and inactivate/remove pathogens that may be present in our drinking water supplies.

Life cycles, mechanisms of infection, protective or dormant states, emergence of disinfection resistant variants, optimal pathogen removal techniques, regrowth in distribution lines…all are areas that must be investigated and understood to afford the water quality safeguards that are so often taken for granted. The successes and failures of these research efforts, relayed to the public and appropriate federal, state, and local agencies, have helped to ensure safe drinking water.

More on this subject in the Microorganism Appendix. **Hyperlink to the Glossary and Appendix** *http://www.abctlc.com/downloads/PDF/WTGlossary.pdf*

Primary Waterborne Diseases Section - Alphabetical Order

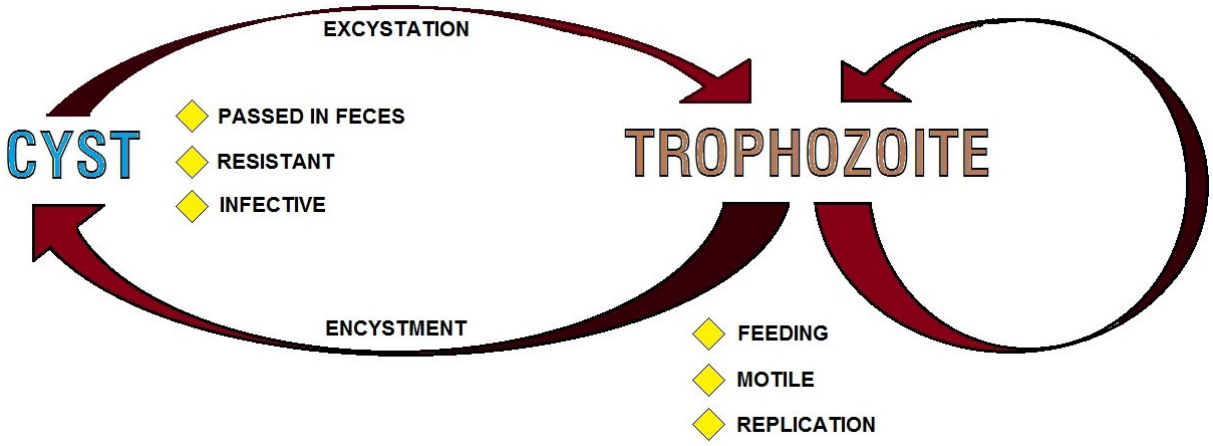
Campylobacter
Campylobacter, the basics. It is a bacterium. It causes diarrheal illness. Campylobacter is primarily associated with poultry, animals, and humans.

Campylobacter prevention: Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.

Cryptosporidium
Cryptosporidium, the basics. It is a parasite. It causes diarrheal illness known as cryptosporidiosis. It is typically associated with animals and humans, and it can be acquired through consuming fecally contaminated food, contact with fecal contaminated soil and water.

Cryptosporidium, prevention: Prevention strategies for this pathogen include source protection. A CT value of 9,600 is required when dealing with fecal accidents. CT equals a concentration, in parts per million, while time equals a contact time in minutes. Cryptosporidium can also be prevented or eliminated by boiling water for one minute.

Filtration with an "*absolute*" pore size of one micron or smaller can eliminate Cryptosporidium, and reverse osmosis is known to be effective as well.



TYPICAL FECAL-ORAL LIFE CYCLE DIAGRAM

E-Coli Section
Escherichia coli. Escherichia coli O157:H7, the basics. It's a bacteria. There are several pathogenic strains of Escherichia coli, which are classified under enterovirulent E. coli. They are enterohemorrhagic, enteroinvasive, enterotoxigenic, enteropathogenic, and enteroaggregative causes diarrheal illness, and it's classified as an enterohemorrhagic E. coli. In its most severe form, it can cause hemorrhagic colitis. The reservoir for this bacteria are cattle, deer, goats, and sheep. Humans can also be a reservoir. It is typically associated with contaminated food and water.

E. coli O157:H7 prevention: Prevention strategies for this pathogen include source protection, halogenation of water, or boiling water for one minute.

Giardia
Giardia, the basics. It is a parasite. It causes diarrheal illness known as giardiasis. It is typically associated with water. It is the most common pathogen in waterborne outbreaks. It can also be found in soil and food, and humans and animals are the reservoir for this pathogen.

Giardia prevention: Prevention strategies for this pathogen include source protection; filtration, coagulation, and halogenation of drinking water.

Hepatitis A
Hepatitis A, the basics. It is a virus. It causes inflammation of the liver, and the reservoir for Hepatitis A virus is humans.

Hepatitis A, Prevention: Prevention strategies for this pathogen include source protection and adequate disinfection. Fecal matter can protect Hepatitis A virus from chlorine. Additionally, Hepatitis A virus is resistant to combined chlorines, so it is important to have an adequate free chlorine residual.

Legionella
Legionella, the basics. It is a bacterium. It causes a respiratory illness known as Legionellosis. There are two illnesses associated with Legionellosis: the first, Legionnaire's disease, which causes a severe pneumonia, and the second, Pontiac fever, which is a non-pneumonia illness; It is typically an influenza-like illness, and it's less severe. Legionella is naturally found in water, both natural and artificial water sources.

Legionella, prevention: Maintaining hot water systems at or above 50 degrees Centigrade and cold water below 20 degrees Centigrade can prevent or control the proliferation of Legionella in water systems. Hot water in tanks should be maintained between 71 and 77 degrees Centigrade.

Proper recreational water system maintenance and disinfection can prevent the proliferation of Legionella in recreational water systems. It is important to prevent water stagnation. This can be accomplished by eliminating dead ends in distribution systems and in recreational water systems. Additionally, preventing biofilm development is important to control this particular pathogen in water systems.

Norovirus
Norovirus, the basics. It is a virus. It causes diarrheal illness, and humans are the reservoir for this virus.

Norovirus, prevention: Prevention strategies for this pathogen include source protection.

Pseudomonas
Pseudomonas, the basics. It is a bacterium. It is caused by dermal contact with water. It can cause dermatitis, which is an inflammation of the skin, or it can cause otitis, which is an infection of the ear. Pseudomonas is typically associated with soil and water.

Pseudomonas prevention: Proper maintenance and disinfection of recreational water systems is important in preventing Pseudomonas.

Salmonella Typhi
Salmonella typhi, the basics. It is a bacterium. It causes diarrheal illness, also known as typhoid fever. Humans are the reservoir for this pathogen. Salmonella species, the basics. It is a bacterium. It causes diarrheal illness known as salmonellosis.

Humans and animals are the reservoir, and it has typically associated with contaminated food and water. Salmonella species, prevention. Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.

Salmonella typhi, prevention: Prevention strategies for this pathogen include source protection, chlorination or halogenation of water, and boiling water for one minute.

Schistosomatidae
Schistosomatidae, the basics. It is a parasite. It is acquired through dermal contact, cercarial dermatitis. It is commonly known as swimmer's itch. The reservoir for this pathogen are aquatic snails and birds.

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

Shigella Species
Shigella species, the basics. It is a bacterium. It causes diarrheal illness known as shigellosis. Humans and primates are the reservoir for this pathogen. Shigella species, in the United States two-thirds of the shigellosis in the U.S. is caused by Shigella sonnei, and the remaining one-third is caused by Shigella flexnieri. In developing countries, Shigella dysenteriae is the primary cause of illness associated with this pathogen.

Shigella species prevention: Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.

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

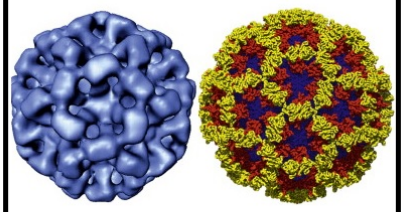
Vibrio cholerae prevention: Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.

MICROBIOLOGICAL CONTAMINANTS FOUND IN WATER

THESE ARE OFTEN OF FECAL NATURE RELATED TO HUMANS, DOMESTIC ANIMALS OR WILDLIFE

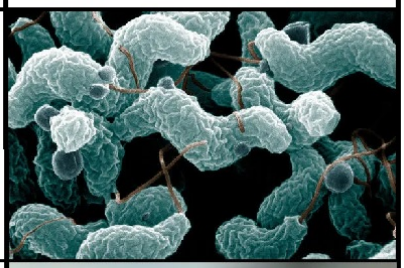
CALIVIVIRUS:

SIGNS OF THIS VIRUS INCLUDE SNEEZING, NASAL DISCHARGE, OCULAR DISCHARGE, CONJUNCTIVITUS, ULCERATION OF THE TONGUE, LETHARGY, INAPPENTENCE (Lack of Appetite) AND FEVER



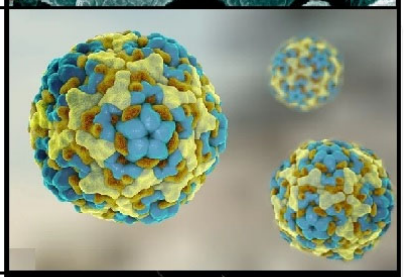
CAMPYLOBACTOR JEJUNI:

THIS IS ONE OF THE MOST COMMON CAUSES OF FOOD POISIONING. IT IS CHARACTERIZED BY DIARRHEA, ABDOMINAL PAIN, FEVER, NAUSEA AND SOMETIMES VOMITING



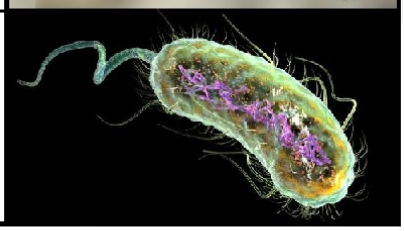
ENTEROVIRUS:

SYMPTOMS OF THIS VIRUS INFECTION MAY INCLUDE FEVER, RUNNY NOSE, SNEEZING, COUGH, SKIN RASH, MOUTH BLISTERS, AND BODY AND MUSCLE ACHES



ESCHERICHIA COLI:

NORMALLY LIVES IN THE INTESTINES OF HEALTHY PEOPLE AND ANIMALS. MOST E.Coli ARE HARMLESS OR RELATIVELY BRIEF DIARRHEA. SOME E.Coli CAN CAUSE SEVERE STOMACH CRAMPS, BLOODY DIARRHEA AND VOMITING

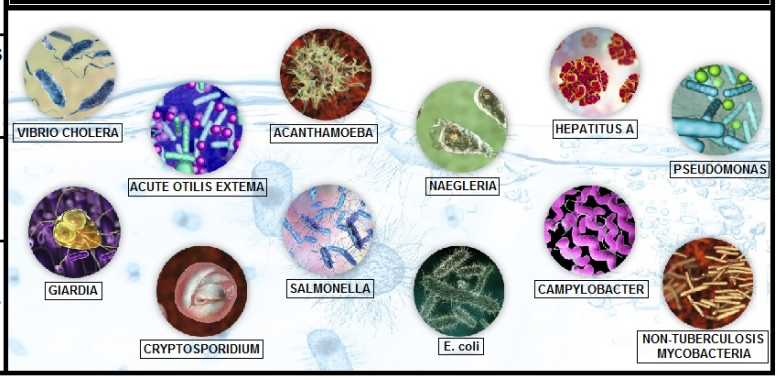


Technical Learning College

MICROBIOLOGICAL CONTAMINANTS

PRESENCE OF PATHOGENS IN WATER
THE PRESENCE OF COLIFORM BACTERIA CAN INDICATE THERE MAY BE HARMFUL BACTERIA PATHOGENS IN THE WATER
THE PRINCIPAL REMOVAL PROCESSES ARE THOSE LIKELY USED TO REMOVE THE MAJORITY OF THE MICROBES IN WATER BEING TREATED
THE REMOVAL PROCESSES BEING UTILIZED ARE SEDIMENTATION, FLOTATION AND THE USE OF HIGH RATE GRANULAR MEDIA FILTRATION
DISINFECTION WITH IODINE OR CHLORINE IS THE MOST EFFECTIVE AT KILLING VIRUSES FOUND IN WATER.

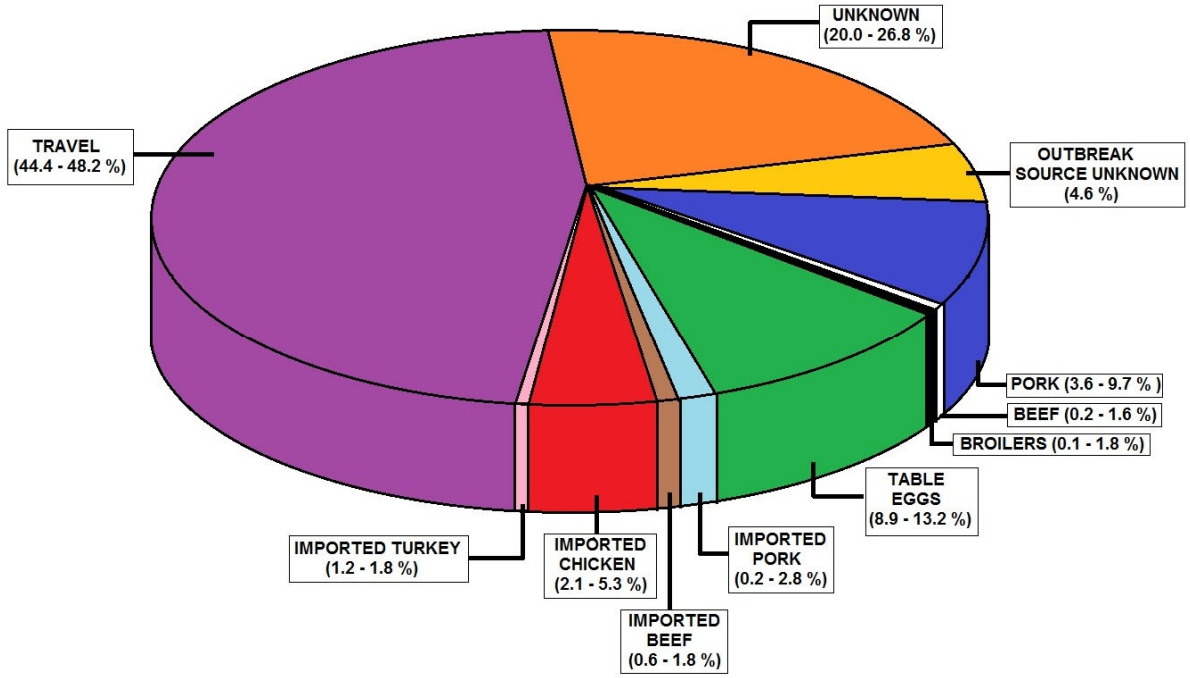
TYPES OF PATHOGENS FOUND IN WATER



Technical Learning College

PATHOGENS FOUND IN WATER SUPPLIES

Waterborne Bacterial Diseases



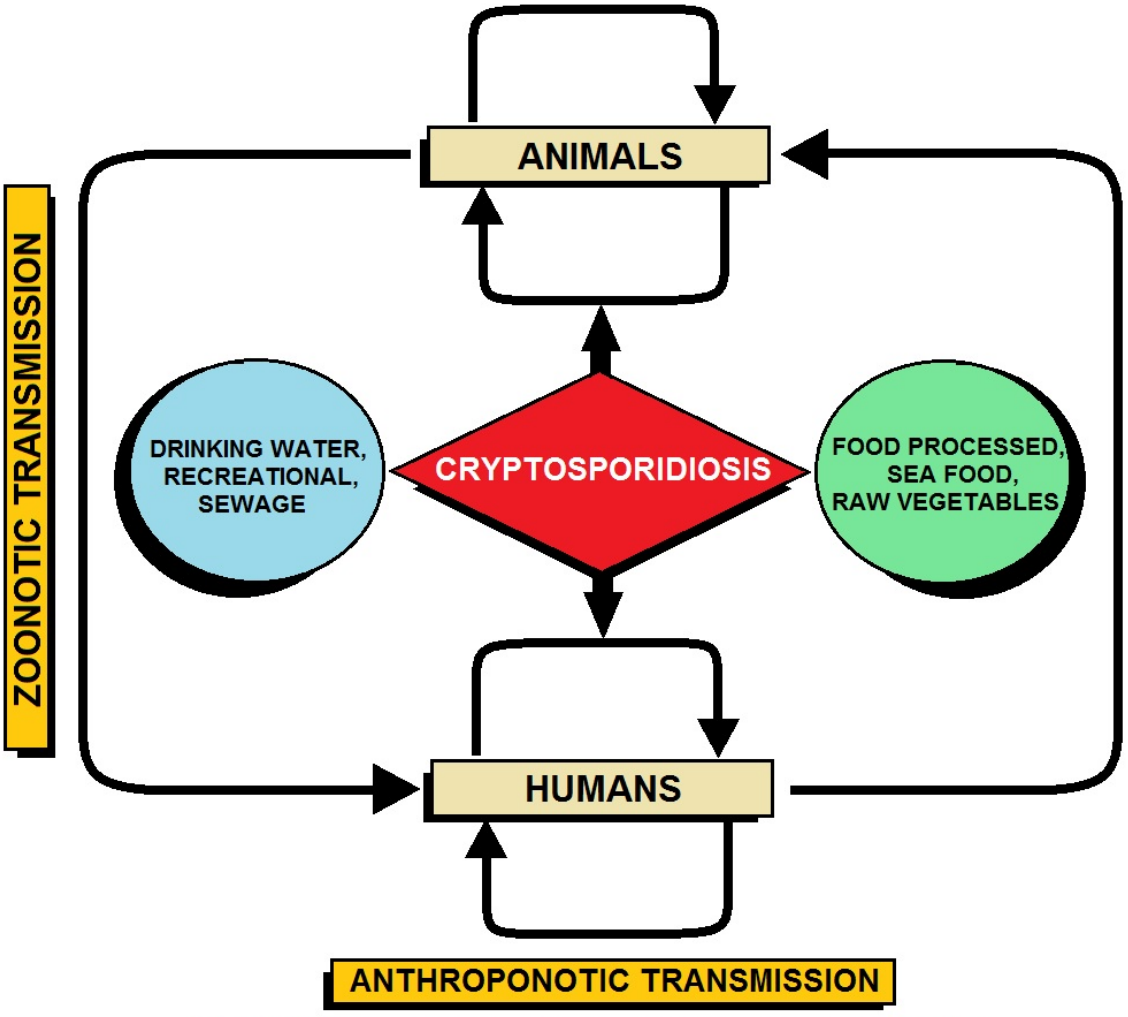
COURSES OF SAMONELLA PIE CHART

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.

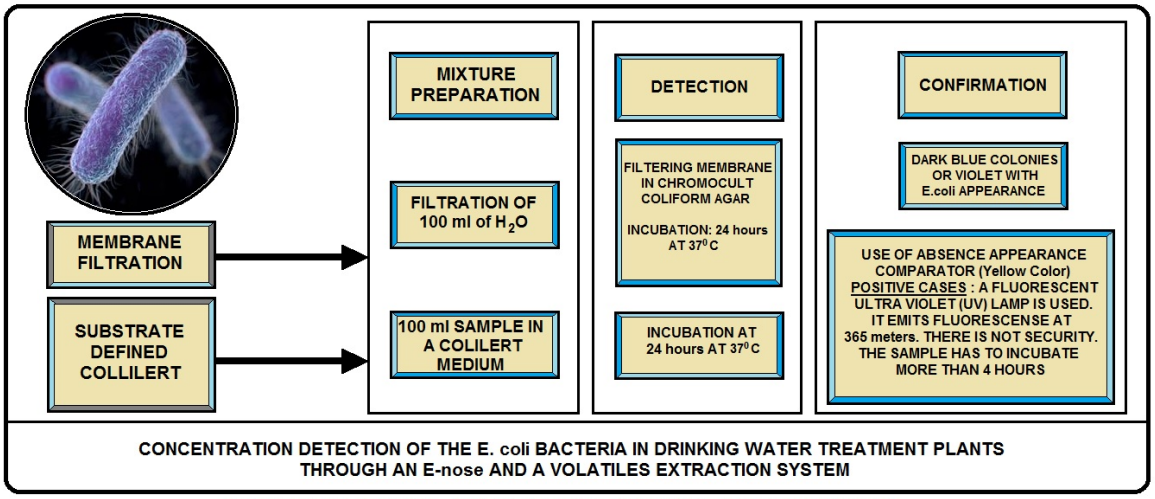
Campylobacteriosis outbreaks have most often been associated with food, especially chicken and un-pasteurized milk, as well as un-chlorinated water. These organisms are also an important cause of "**travelers' diarrhea**." Medical treatment generally is not prescribed for campylobacteriosis because recovery 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.



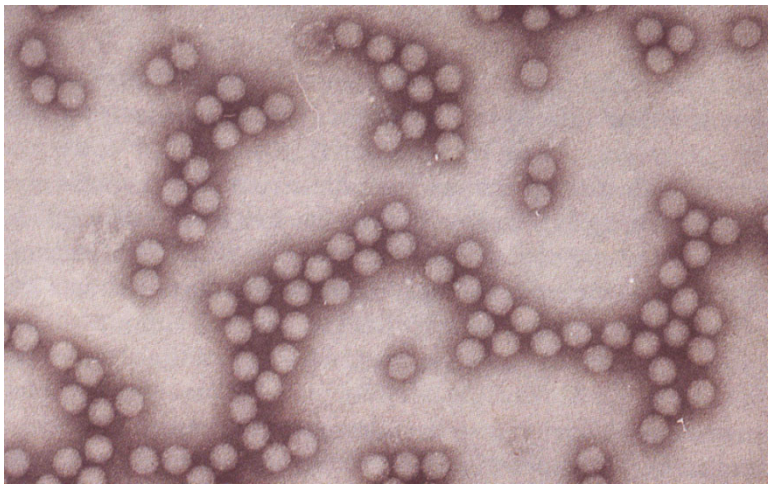
TRANSMISSION OF CRYPTOSPORIDIOSIS



CONVENTIONAL BACTERIOLOGICAL MONITORING

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.

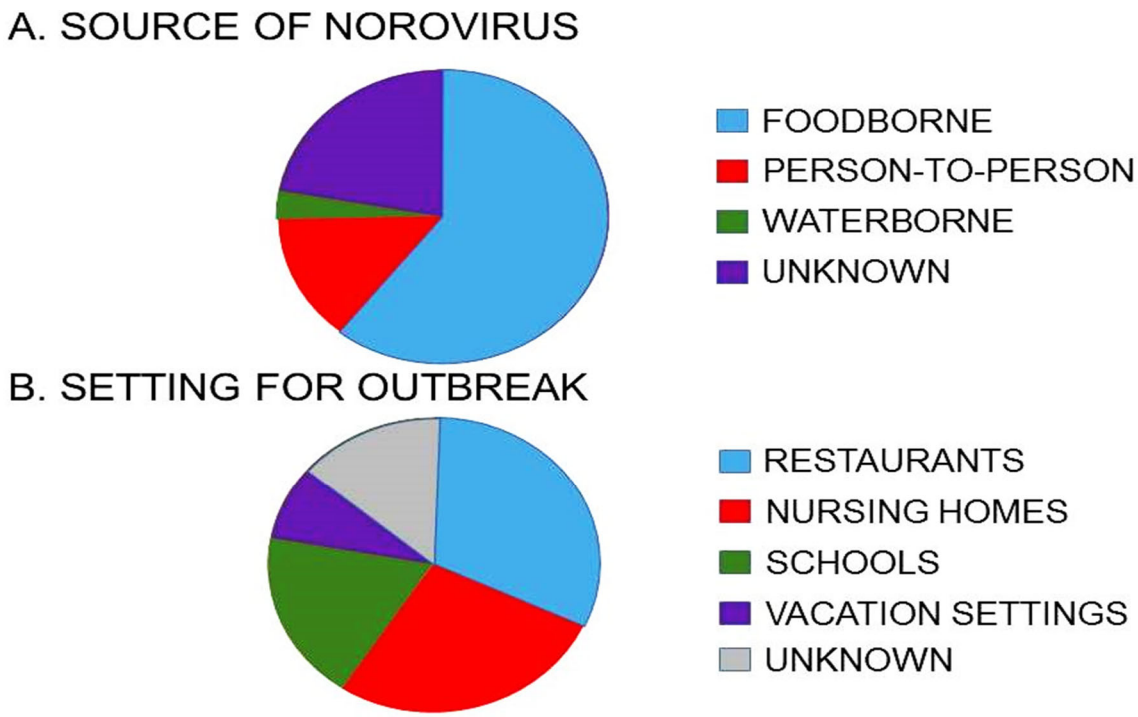
The virus is usually spread by the fecal–oral route. This may be through contaminated food or water or person-to-person contact. It may also spread via contaminated surfaces or through air from the vomit of an infected person. Risk factors include unsanitary food preparation and sharing close quarters.

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

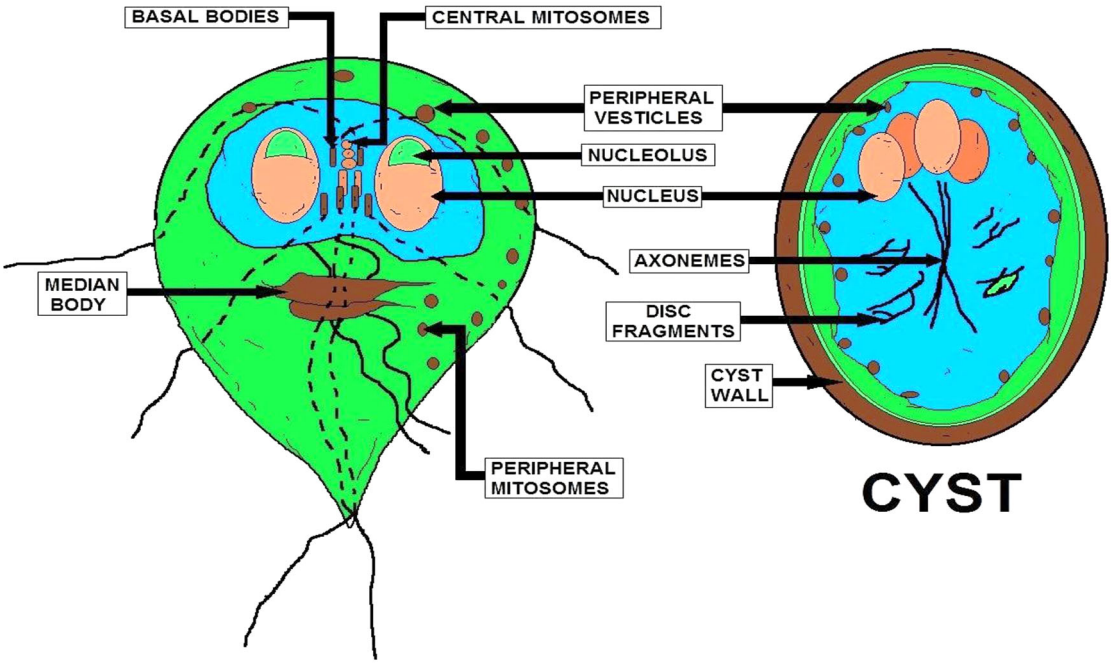
Protozoan pathogens are larger than bacteria and viruses, but still microscopic. They invade and inhabit the gastrointestinal tract. Some parasites enter the environment in a dormant form, with a protective cell wall called a "**cyst**." The cyst can survive in the environment for long periods of time 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.

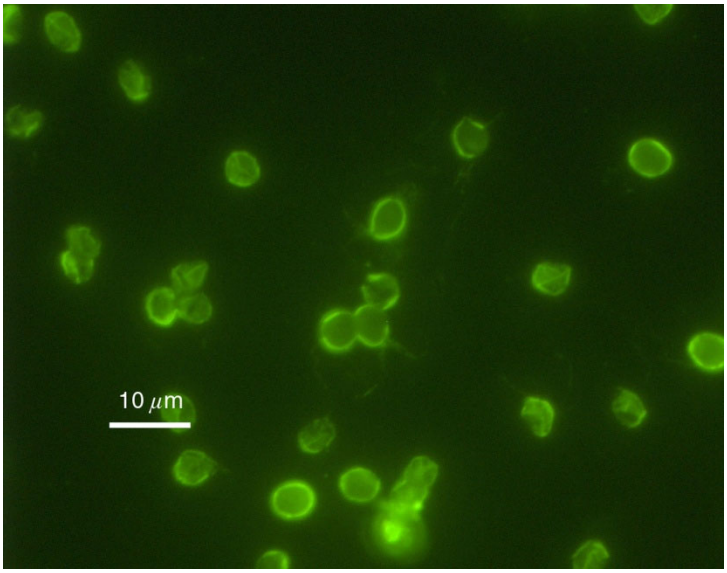
Many infections are asymptomatic (no symptoms). Giardiasis occurs worldwide. Waterborne outbreaks in the United States occur most often in communities receiving their drinking water from streams or rivers without adequate disinfection or a filtration system.

- 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.

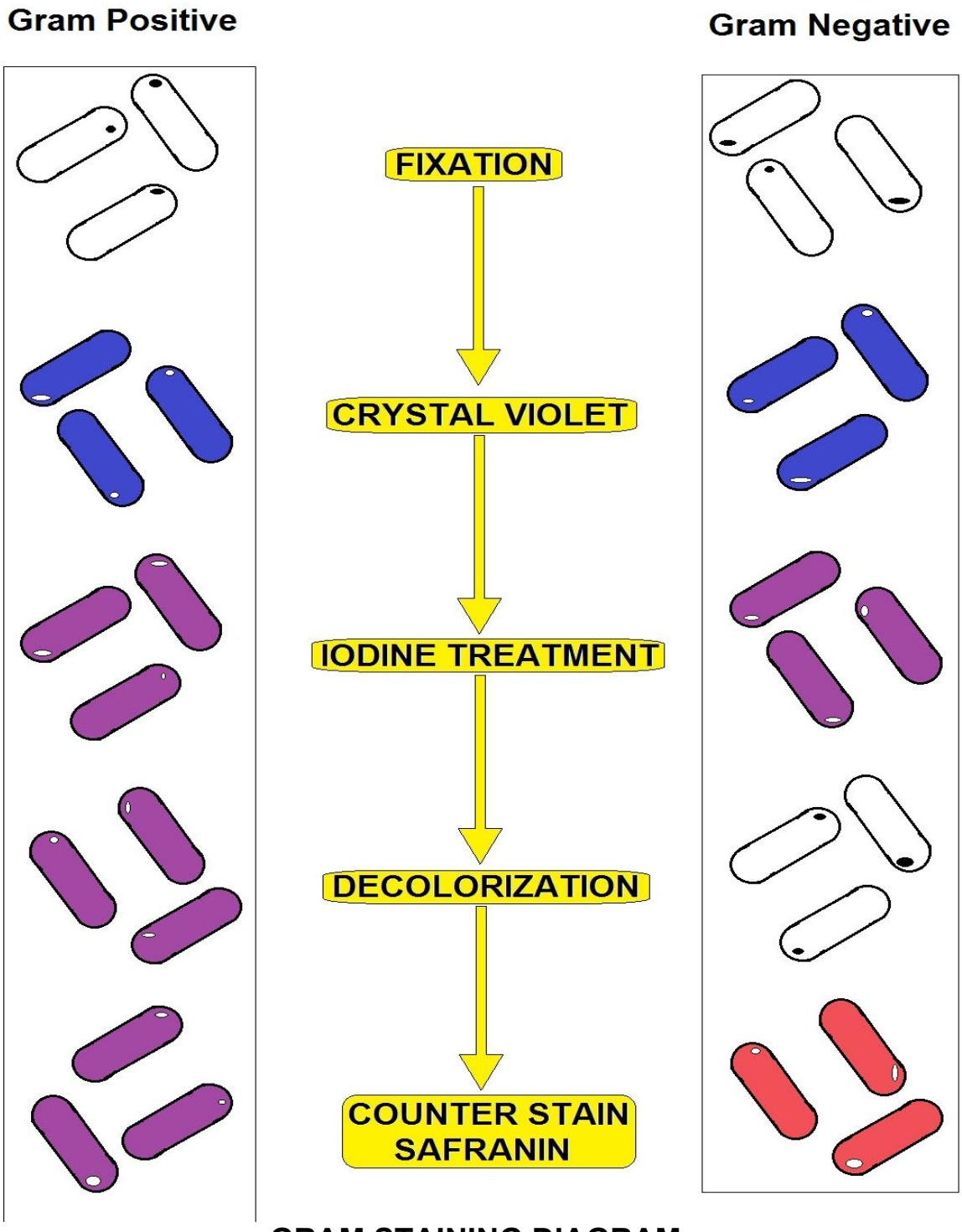
For those who operate water systems with inadequate source protection or treatment facilities, the potential risk of a waterborne disease outbreak is real. For those operating systems that currently provide adequate source protection and treatment, operating and maintaining the system at a high level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



GRAM STAINING DIAGRAM

Sampling 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 Ground Water 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 / Ammonia	VOC / THM's	Semi Volital Organics (625)	Chloride		Cyanide	Florida	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: Yes No

Received Intact: Yes No

Received Cold: Yes No

Temperature:

PRIORITY:

RELINQUISHED BY:

Signature: Time:

Printed Name: Date:

Company

RELINQUISHED BY:

Signature: Time:

Printed Name: Date:

Company

SAMPLED RECEIVED BY:

Signature: Time:

Printed Name: Date:

SAMPLED RECEIVED BY:

Signature: Time:

Printed Name: Date:

Company

Chain of Custody Example.

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

Collection of Surface Water Samples- 1 Example

Most of this section comes from the USEPA.

Representative samples may be collected from rivers, streams and lakes if certain rules are followed:

1. Watch out for flash floods! If a flooding event is likely and samples must be obtained, always go in two-person teams for safety. Look for an easy route of escape.
2. Select a sampling location at or near a gauging station, so that stream discharge can be related to water-quality loading. If no gauging station exists, then measure the flow rate at the time of sampling, using the streamflow method described below.
3. Locate a straight and uniform channel for sampling.
4. Unless specified in the sampling plan, avoid sampling locations next to confluences or point sources of contamination.
5. Use bridges or boats for deep rivers and lakes where wading is dangerous or impractical.
6. Do not collect samples along a bank, as they may not be representative of the surface water body as a whole.
7. Use appropriate gloves when collecting the sample.

Streamflow Measurement

Before collecting water quality samples, record the stream's flow rate at the selected station. The flow rate measurement is important for estimating contaminant loading and other impacts.

The first step in streamflow measurement is selecting a cross-section. Select a straight reach where the stream bed is uniform and relatively free of boulders and aquatic growth. Be certain that the flow is uniform and free of eddies, slack water and excessive turbulence.

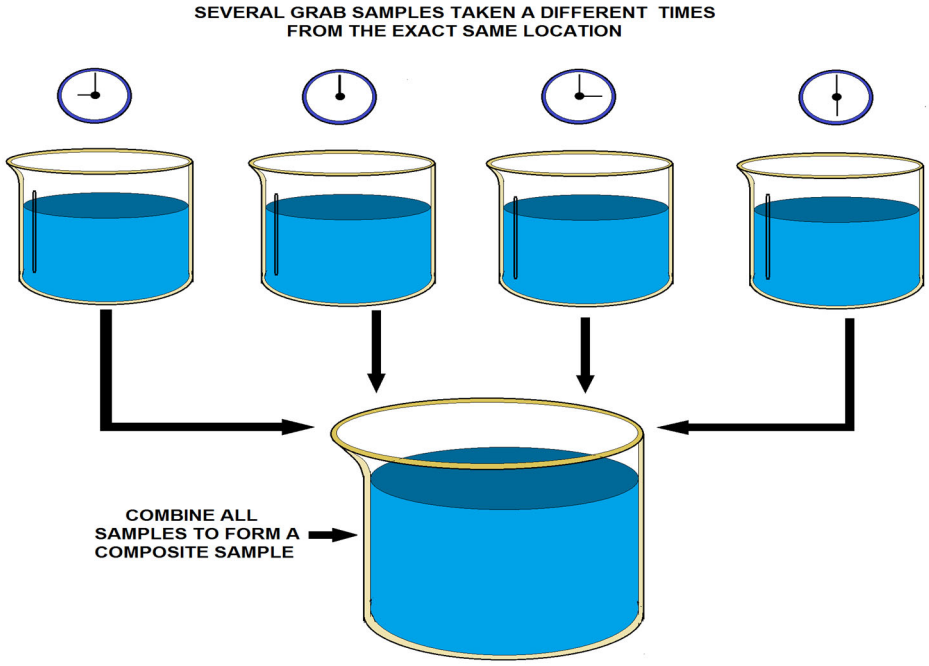
After the cross-section has been selected, determine the width of the stream by stringing a measuring tape from bank-to-bank at right angles to the direction of flow. Next, determine the spacing of the verticals. Space the verticals so that no partial section has more than 5 per cent of the total discharge within it.

At the first vertical, face upstream and lower the velocity meter to the channel bottom, record its depth, then raise the meter to 0.8 and 0.2 of the distance from the stream surface, measure the water velocities at each level, and average them. Move to the next vertical and repeat the procedure until you reach the opposite bank.

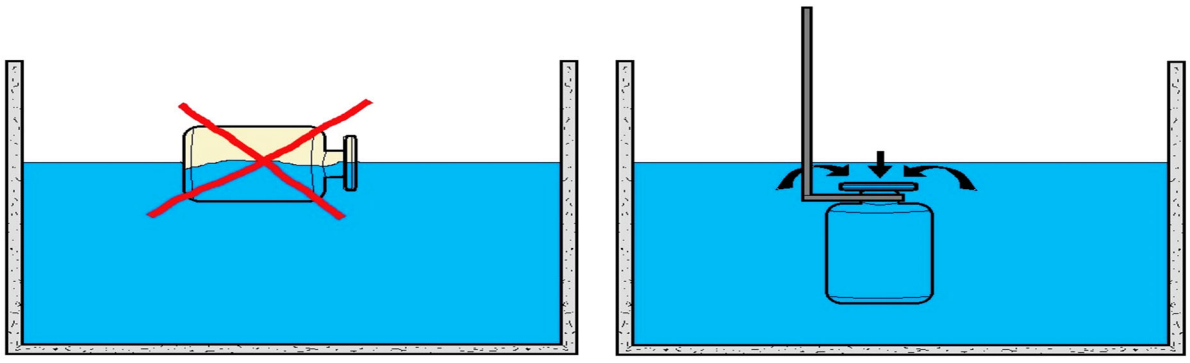
Once the velocity, depth and distance of the cross-section have been determined, the mid-section method can be used for determining the stream’s discharge rate. Calculate the discharge in each increment by multiplying the averaged velocity in each increment by the increment width and averaged depth.

(Note that the first and last stations are located at the edge of the waterway and have a depth and velocity of zero.) Add up the discharges for each increment to calculate the total stream discharge rate. Record the flow in liters (or cubic feet) per second in your field book.

Composite Sampling
Composite sampling is intended to produce a water quality sample representative of the total stream discharge at the sampling station. If your sampling plan calls for composite sampling, use an automatic type sampler, ideally located mid-stream.



MAKING A COMPOSITE SAMPLE FROM GRAB SAMPLES DIAGRAM



PROPER MATHOD OF TAKING IMMERSE TYPE WATER SAMPLES.

Note: Both of these sampling methods are not correct for taking Bac-T or disinfection byproduct sampling.

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).

Topic 2- Bacteriological Monitoring Section Post Quiz

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.

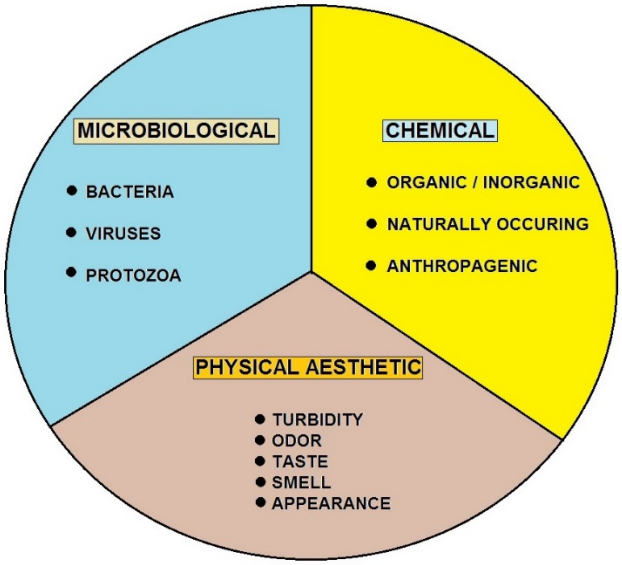
9. A coliform sample site plan is a list of sites by street address, lot number, or other permanent description, that identifies all the approved locations where your routine (monthly) coliform samples may be collected. The list of sites must be plotted on a map of your service area.

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

Topic 3 - Water Laboratory Analysis Section

Section Focus: You will learn the basics of the water laboratory and related water quality analysis/procedures. At the end of this section, you will be able to describe water analytical methodologies, i.e., pH, DO, turbidity, Jar Testing, etc. and related lab reports. 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: Laboratory analysis of water quality refers primarily to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to compliance or process control requirements. Laboratory analysis is frequently used by reference to a set of standards against which compliance, generally achieved through treatment of the water, can be assessed



WATER QUALITY BROKEN DOWN INTO 3 BROAD CATEGORIES

Quality of Water Primary Factors – Review

If you classified water by its characteristics and could see how water changes as it passes on the surface and below the ground, it would be in these four categories:

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

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

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

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

FACTOR	TYPE	SOURCE(S)	PROBLEM
FECAL COLIFORM BACTERIA	BIOLOGICAL	HUMAN SEWAGE; LIVESTOCK WASTE	POSSIBLE PRESENCE OF PATHOGENIC (DISEASE-CAUSING) ORGANISMS
DISSOLVED OXYGEN (DO)	CHEMICAL	AIR; AQUATIC PLANTS	LOW LEVELS CAN KILL AQUATIC ORGANISMS
NITROGEN AND PHOSPHORUS	CHEMICAL	FERTILIZERS AND DETERGENTS FROM LAWNS AND RUNOFF	EXCESSIVE ALGAE GROWTH CAN LEAD TO LOW DO
ZINC, ARSENIC, LEAD, MERCURY, CADMIUM, NICKEL	CHEMICAL	LANDFILLS; INDUSTRIAL DISCHARGES; RUNOFF	GENETIC MUTATIONS OR DEATH IN FISH & WILDLIFE (HUMAN HEALTH THREATS AS WELL)
SALT	CHEMICAL	SALTWATER INTRUSION (IF NEAR OCEAN)	KILLS FRESHWATER SPECIES OF PLANTS AND ANIMALS
MUD, SAND, OTHER SOLID PARTICLES (TURBIDITY)	PHYSICAL	EROSION AND RUNOFF FROM DEVELOPMENT; AGRICULTURE	REDUCES PHOTOSYNTHESIS IN AQUATIC VEGETATION; INTERFERES WITH RESPIRATION IN AQUATIC ANIMALS

WATER QUALITY FACTORS

SECONDARY DRINKING WATER REGULATIONS / STANDARDS (EPA)

SECONDARY REGULATIONS / STANDARDS ARE MORE RECOMMENDATIONS THAN RULES. IT IS MEANT TO TAKE A BROADER LOOK AT WHAT MAKES PUBLIC WATER APPEALING AND ACCESSIBLE TO THE PUBLIC EXAMPLE EFFECTS INCLUDE:

AESTHETIC EFFECTS:
THESE AFFECT THE TASTE, ODOR AND SMELL OF DRINKING WATER, BUT POSE NO HEALTH-RISK PROPERTIES.
EXAMPLES INCLUDE: Iron, Manganese, Copper, Zinc and certain Sulfates.

COSMETIC EFFECTS:
THE MOST PREVALENT COSMETIC EFFECT IS TOOTH SPOTTING OR DISCOLORATION, OFTEN SEEN IN CHILDREN DUE TO FLUORIDE OVEREXPOSURE DURING FORMATIVE TOOTH DEVELOPMENT.

TECHNICAL EFFECTS:
THIS EFFECT IS NOT NECESSARILY THE WATER ITSELF, BUT RATHER THE POSSIBILITY OF DAMAGED OR MALFUNCTIONING WATER EQUIPMENT AS WELL AS FORMS OF PURIFICATIONS METHODS NOT WORKING PROPERLY

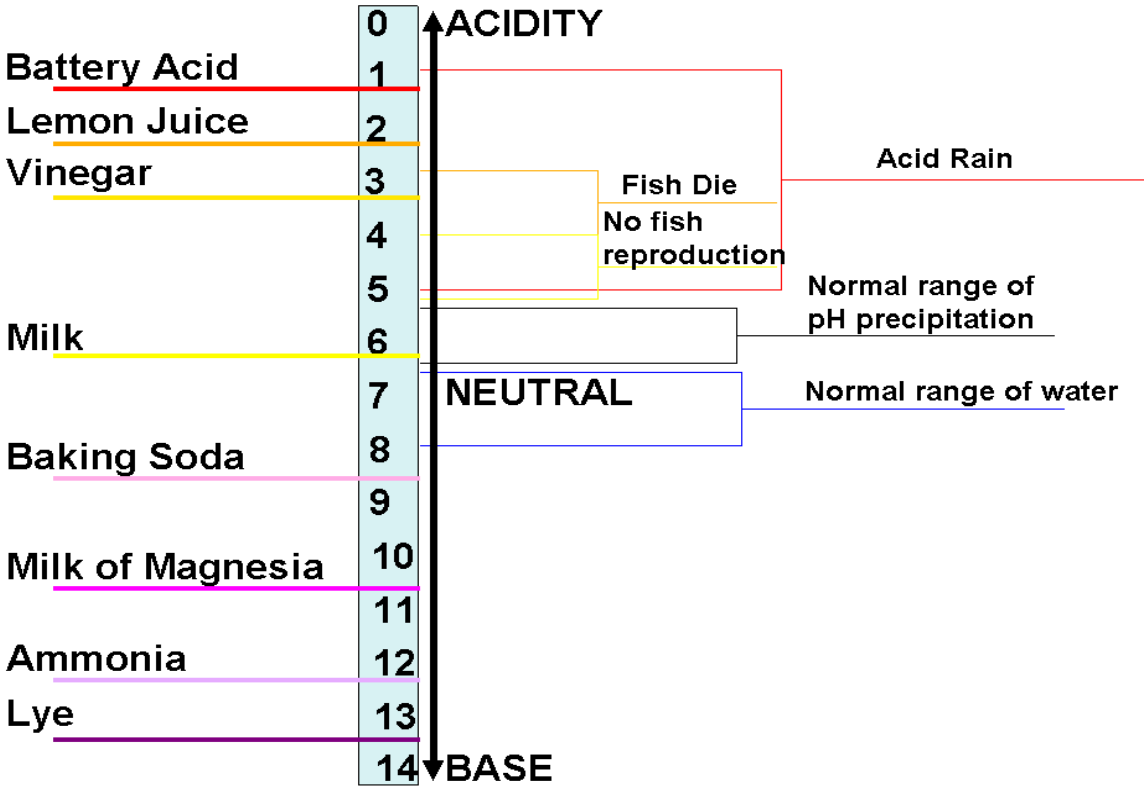
SECONDARY DRINKING WATER STANDARDS (EPA)

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

Technical Learning College

EPA SECONDARY DRINKING WATER REGULATIONS / STANDARDS

pH Section



Basics

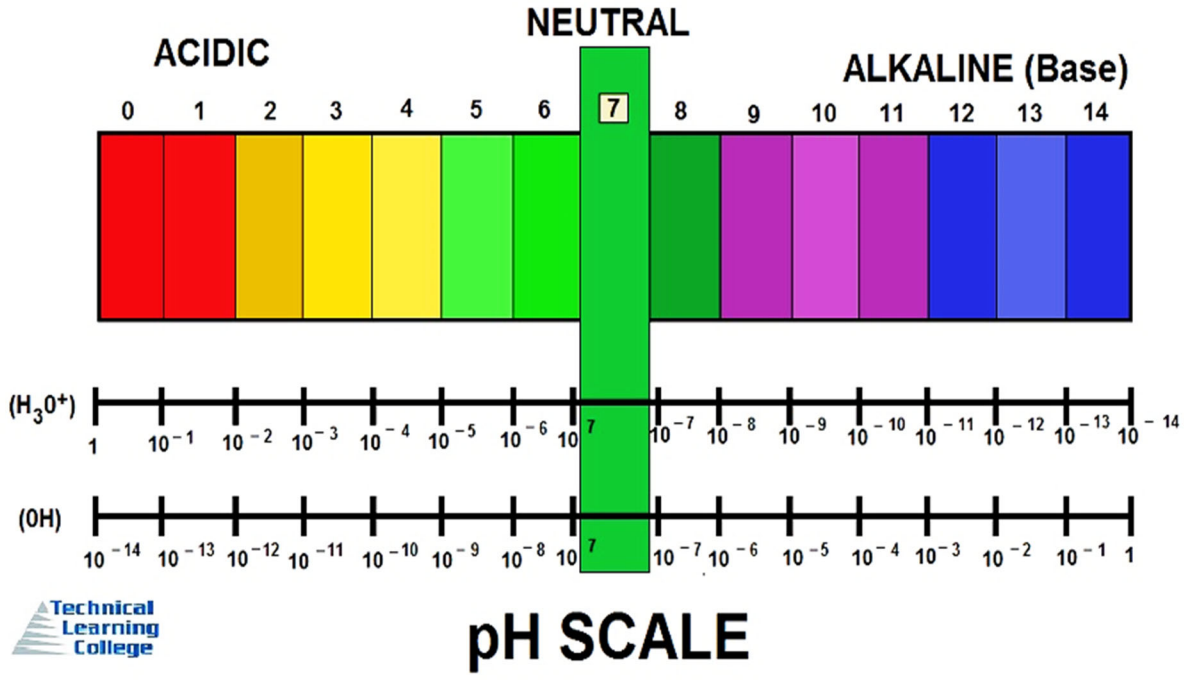
pH: A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid-point or neutral.
A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity.

A pH of 7, there are an equal amount or number of hydroxyl (OH-) and Hydrogen (H+) ions in the solution.

A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. Normal rain has a pH of **5.6** – slightly acidic because of the carbon dioxide picked up in the earth's atmosphere by the rain.

pH = (**Power of Hydroxyl Ion Activity**).
The acidity of a water sample is measured on a pH scale. This scale ranges from **0** (maximum acidity) to **14** (maximum alkalinity). The middle of the scale, **7**, represents the neutral point. The acidity increases from neutral toward **0**.

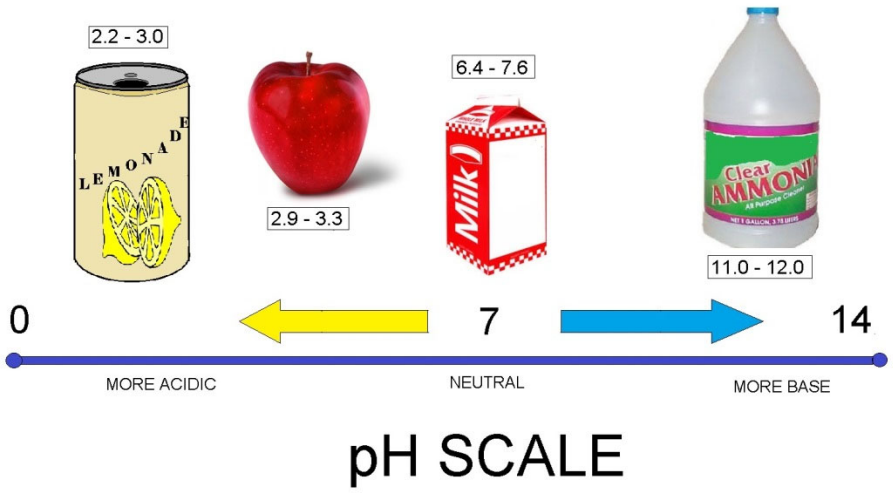
Because the scale is logarithmic, a difference of one pH unit represents a tenfold change. For example, the acidity of a sample with a pH of **5** is ten times greater than that of a sample with a pH of **6**. A difference of 2 units, from **6** to **4**, would mean that the acidity is one hundred times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



Hydrogen Ion pH Comparison Chart

pH	Hydrogen Ion Concentration, mmol/L
14	0.00000000000001
13	0.0000000000001
12	0.000000000001
11	0.00000000001
10	0.0000000001
9	0.000000001
8	0.00000001
7	0.0000001
6	0.000001
5	0.00001
4	0.0001
3	0.001
2	0.01
1	0.1

pH Testing Section



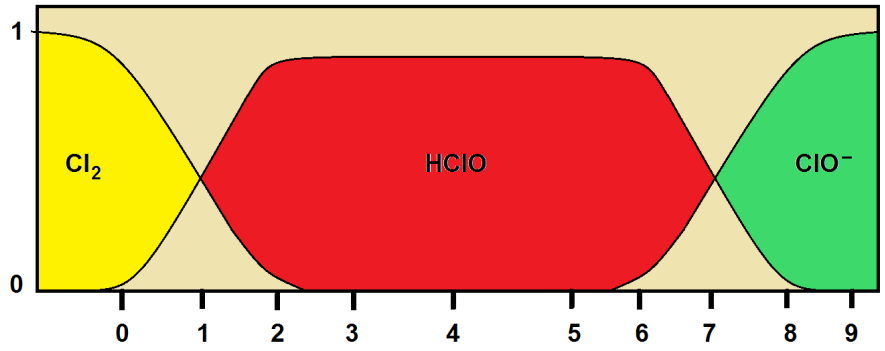
pH SCALE

As a water treatment operator, you will need to master pH sampling and testing. pH measurements are important in water and wastewater processes (sampling) but also in medicine, biology, chemistry, agriculture, forestry, food science, environmental science, oceanography, civil engineering, chemical engineering, nutrition, and many other applications.

In water and wastewater processes, **pH** is a measure of the acidity or basicity of an aqueous solution.

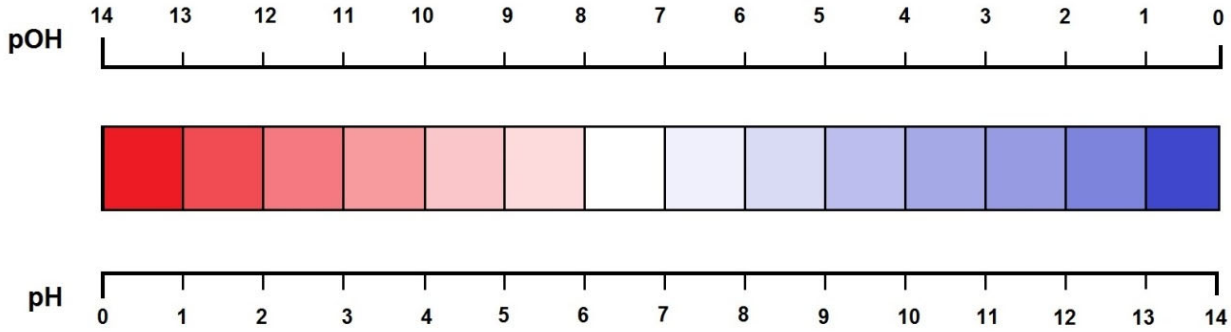
The pH scale is traceable to a set of standard solutions whose pH is established by international agreement.

Primary pH standard values are determined using a concentration cell with transference, by measuring the potential difference between a hydrogen electrode and a standard electrode such as a silver chloride electrode. Measurement of pH for aqueous solutions can be done with a glass electrode and a pH meter, or using indicators like strip test paper.



pH VALUES CHANGE WITH THE ADDITION OF DIFFERENT TYPES OF CHLORINE

Mathematically, pH is the measurement of hydroxyl ion (H+) activity and expressed as the negative logarithm of the activity of the (solvated) hydronium ion, more often expressed as the measure of the hydronium ion concentration.



RELATIONSHIP BETWEEN p(OH^-) & p (H^+)
red = ACIDIC / blue = BASIC)

History
The scientific discovery of the p[H] concept was first introduced by Danish chemist Søren Peder Lauritz Sørensen at the Carlsberg Laboratory back in 1909 and revised to the modern pH in 1924 to accommodate definitions and measurements in terms of electrochemical cells. In the first papers, the notation had the "H" as a subscript to the lowercase "p", as so: pH.

Alkalinity
Alkalinity is the quantitative capacity of an aqueous solution to neutralize an acid. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. It is one of the best measures of the sensitivity of the stream to acid inputs. There can be long-term changes in the alkalinity of rivers and streams in response to human disturbances.

Reference. Bates, Roger G. Determination of pH: theory and practice. Wiley, 1973.

pH Definition and Measurement

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

pH Scale

Technical Definition of pH

In technical terms, pH is defined as the decimal logarithm of the reciprocal of the hydrogen ion activity, *a*H+, in a solution.

$$pH = -\log_{10}(a_{H^+}) = \log_{10}\left(\frac{1}{aH+}\right)$$

Ion-selective electrodes are often used to measure pH, respond to activity.

In this calculation of electrode potential, *E*, follows the Nernst equation, which, for the hydrogen ion can be written as

$$E = E^0 + \frac{RT}{F} In\,(a_H +) = E^0 - \frac{2.303RT}{F} pH$$

where *E* is a measured potential, E^0 is the standard electrode potential, *R* is the gas constant, *T* is the temperature in kelvin, *F* is the Faraday constant. For H^+ number of electrons transferred is one. It follows that electrode potential is proportional to pH when pH is defined in terms of activity.

International Standard ISO 31-8 is the standard for the precise measurement of pH as follows: A galvanic cell is set up to measure the electromotive force (EMF) between a reference electrode and an electrode sensitive to the hydrogen ion activity when they are both immersed in the same aqueous solution.

The reference electrode may be a silver chloride electrode or a calomel electrode. The hydrogen-ion selective electrode is a standard hydrogen electrode.

Reference electrode | concentrated solution of KCl || test solution | H_2 | Pt

Firstly, the cell is filled with a solution of known hydrogen ion activity and the emf, E_S, is measured. Then the emf, E_X, of the same cell containing the solution of unknown pH is measured.

$$pH(X) = pH(S) + \frac{E_S - E_x}{Z}$$

The difference between the two measured emf values is proportional to pH. This method of calibration avoids the need to know the standard electrode potential. The proportionality constant, *1/z* is ideally equal to $\frac{1}{2.303RT/F}$ the "Nernstian slope".

If you were to apply this practice the above calculation, a glass electrode is used rather than the cumbersome hydrogen electrode. A combined glass electrode has an in-built reference electrode. It is calibrated against buffer solutions of known hydrogen ion activity. IUPAC has proposed the use of a set of buffer solutions of known H^+ activity.

Two or more buffer solutions should be used in order to accommodate the fact that the "slope" may differ slightly from ideal.

The electrode is first immersed in a standard solution and the reading on a pH meter is adjusted to be equal to the standard buffer's value, to implement the proper calibration. The reading from a second standard buffer solution is then adjusted, using the "slope" control, to be equal to the pH for that solution. Further details, are given in the IUPAC recommendations.

When more than two buffer solutions are used the electrode is calibrated by fitting observed pH values to a straight line with respect to standard buffer values. Commercial standard buffer solutions usually come with information on the value at 25 °C and a correction factor to be applied for other temperatures. The pH scale is logarithmic and pH is a dimensionless quantity.

pH Indicators
Visual comparison of the color of a test solution with a standard color chart provides a means to measure pH accurate to the nearest whole number. Indicators may be used to measure pH, by making use of the fact that their color changes with pH.

More precise measurements are possible if the color is measured spectrophotometrically, using a colorimeter of spectrophotometer. Universal indicator consists of a mixture of indicators such that there is a continuous color change from about pH 2 to pH 10. Universal indicator paper is made from absorbent paper that has been impregnated with universal indicator.

pOH
pOH is sometimes used as a measure of the concentration of hydroxide ions, OH^-, or alkalinity. pOH values are derived from pH measurements. The concentration of hydroxide ions in water is related to the concentration of hydrogen ions by

$$[\mathrm{OH^-}] = \frac{K_W}{[\mathrm{H^+}]}$$

where K_W is the self-ionization constant of water. Taking logarithms

$$\mathrm{pOH} = \mathrm{pK_W} - \mathrm{pH}$$

At room temperature pOH ≈ 14 − pH. However, this relationship is not strictly valid in other circumstances, such as in measurements of soil alkalinity.

Extremes of pH
Measurement of pH below about 2.5 (ca. 0.003 mol dm^{-3} acid) and above about 10.5 (ca. 0.0003 mol dm^{-3} alkali) requires special procedures because, when using the glass electrode, the Nernst law breaks down under those conditions.

Extreme pH measurements imply that the solution may be concentrated, so electrode potentials are affected by ionic strength variation. At high pH the glass electrode may be affected by "alkaline error", because the electrode becomes sensitive to the concentration of cations such as Na^+ and K^+ in the solution. Specially constructed electrodes are available which partly overcome these problems. Runoff from industrial outfalls, restaurant grease, mines or mine tailings can produce some very low pH values.

Applications
Water has a pH of $pK_w/2$, so the pH of pure water is about 7 at 25 °C; this value varies with temperature. When an acid is dissolved in water, the pH will be less than that of pure water. When a base, or alkali, is dissolved in water, the pH will be greater than that of pure water.

A solution of a strong acid, such as hydrochloric acid, at concentration 1 mol dm^{-3} has a pH of 0. A solution of a strong alkali, such as sodium hydroxide, at concentration 1 mol dm^{-3}, has a pH of 14. Thus, measured pH values will lie mostly in the range 0 to 14, though negative pH values and values above 14 are entirely possible. Since pH is a logarithmic scale, a difference of one pH unit is equivalent to a tenfold difference in hydrogen ion concentration.

The pH of an aqueous solution of pure water is slightly different from that of a salt such as sodium chloride even though the salt is neither acidic nor basic. In this case, the hydrogen and hydroxide ions' activity is dependent on ionic strength, so K_w varies with ionic strength.

The pH of pure water decreases with increasing temperatures. One example is the pH of pure water at 50 °C is 6.55.

Seawater
The pH of seawater plays an important role in the ocean's carbon cycle, and there is evidence of ongoing ocean acidification caused by human caused carbon dioxide emissions. pH measurement can be complicated by the chemical properties of seawater, and several distinct pH scales exist in chemical oceanography.

These solutions have a relatively low ionic strength (~0.1) compared to that of seawater (~0.7), and, as a consequence, are not recommended for use in characterizing the pH of seawater, since the ionic strength differences cause changes in electrode potential. To resolve this problem, an alternative series of buffers based on artificial seawater was developed. This new series resolves the problem of ionic strength differences between samples and the buffers. The newest pH scale is referred to as the **total scale**, often denoted as $\mathbf{pH_T}$. The bottom line: do not use a fresh water pH meter to measure the pH of seawater.

Calculation of pH
The calculation of the pH of a solution containing acids and/or bases is an example of a chemical speciation calculation, that is, a mathematical procedure for calculating the concentrations of all chemical species that are present in the solution. The complexity of the procedure depends on the nature of the solution.

If the pH of a solution contains a weak acid requires the solution of a quadratic equation.

If the pH of a solution contains a weak base may require the solution of a cubic equation.

For strong acids and bases no calculations are necessary except in extreme situations.

The general case requires the solution of a set of non-linear simultaneous equations.

A complicating factor is that water itself is a weak acid and a weak base. It dissociates according to the equilibrium

$$2H_2O \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

with a dissociation constant, K_w defined as

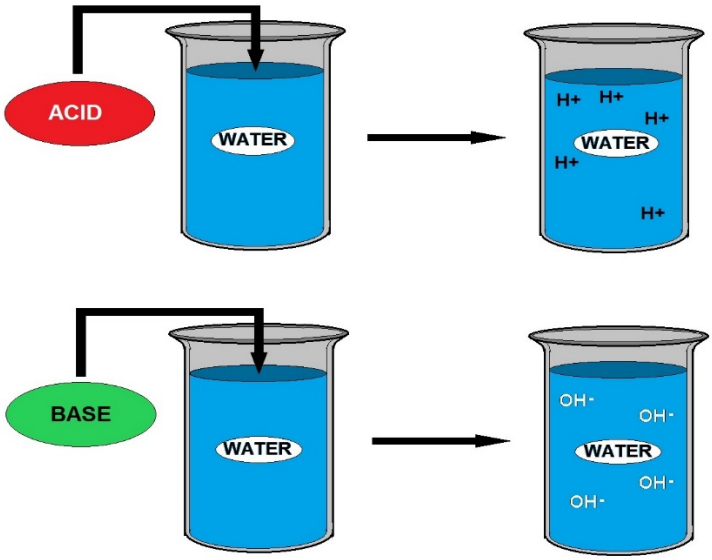
$$K_w = [H^+][OH^-]$$

where $[H^+]$ represents for the concentration of the aquated hydronium ion and $[OH^-]$ stands for the concentration of the hydroxide ion.

K_w has a value of about 10^{-14} at 25 °C, so pure water has a pH of approximately 7.

This equilibrium needs to be considered at high pH and when the solute concentration is extremely low.

Strong Acids and Bases



Strong Acids and Bases

Strong acids and bases are compounds that, for practical purposes, are completely dissociated in water. Under normal circumstances, this means that the concentration of hydrogen ions in acidic solution can be taken to be equal to the concentration of the acid. The pH is then equal to minus the logarithm of the concentration value.

Hydrochloric acid (HCl) is an example of a strong acid. The pH of a 0.01M solution of HCl is equal to $-\log_{10}(0.01)$, that is, pH = 2.

Sodium hydroxide, NaOH, is an example of a strong base. The p[OH] value of a 0.01M solution of NaOH is equal to $-\log_{10}(0.01)$, that is, p[OH] = 2.

From the definition of p[OH] above, this means that the pH is equal to about 12. For solutions of sodium hydroxide at higher concentrations, the self-ionization equilibrium must be taken into account.

Weak Acids and Bases

A weak acid or the conjugate acid of a weak base can be treated using the same formalism.

Acid: $HA \rightleftharpoons H^+ + A^-$

Base: $HA^+ \rightleftharpoons H^+ + A$

First, an acid dissociation constant is defined as follows. Electrical charges are omitted from subsequent equations for the sake of generality

$$K_a = \frac{[H][A]}{[HA]}$$

and its value is assumed to have been determined by experiment. This being so, there are three unknown concentrations, [HA], $[H^+]$ and $[A^-]$ to determine by calculation. Two additional equations are needed.

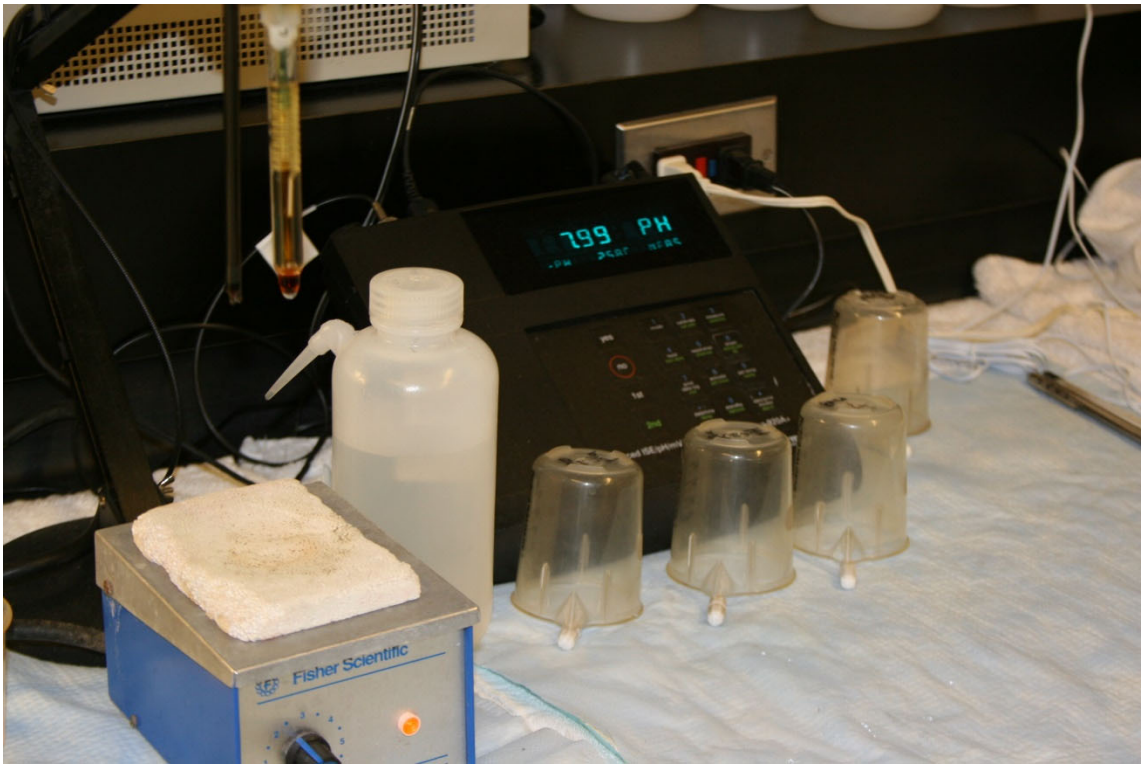
One way to provide them is to apply the law of mass conservation in terms of the two "reagents" H and A.

$$C_A = [A] + [HA]$$
$$C_H = [H] + [HA]$$

C stands for analytical concentration. In some texts one mass balance equation is replaced by an equation of charge balance. This is satisfactory for simple cases like this one, but is more difficult to apply to more complicated cases as those below.

Together with the equation defining K_a, there are now three equations in three unknowns. When an acid is dissolved in water $C_A = C_H = C_a$, the concentration of the acid, so [A] = [H]. After some further algebraic manipulation an equation in the hydrogen ion concentration may be obtained.

$$[H]^2 + K_a[H] - K_aC_a = 0$$



Digital pH Meter

Alkalinity Sub-Section

Introduction

Alkalinity of water is its acid-neutralizing capacity. It is the sum of all the titratable bases. The measured value may vary significantly with the end-point pH used. Alkalinity is a measure of an aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known.

Alkalinity and pH Adjustment

Adjusting pH and alkalinity is the most common corrosion control method because it is simple and inexpensive. pH is a measure of the concentration of hydrogen ions present in water; alkalinity is a measure of water's ability to neutralize acids.

Generally, water pH less than 6.5 is associated with uniform corrosion, while pH between 6.5 and 8.0 can be associated with pitting corrosion. Some studies have suggested that systems using only pH to control corrosion should maintain a pH of at least 9.0 to reduce the availability of hydrogen ions as electron receptors. However, pH is not the only factor in the corrosion equation; carbonate and alkalinity levels affect corrosion as well.

Generally, an increase in pH and alkalinity can decrease corrosion rates and help form a protective layer of scale on corrodible pipe material.

Chemicals commonly used for pH and alkalinity adjustment are hydrated lime ($CaOH_2$ or calcium hydroxide), caustic soda (NaOH or sodium hydroxide), soda ash (Na_2CO_3 or sodium carbonate), and sodium bicarbonate ($NaHCO_3$, essentially baking soda).

Care must be taken, however, to maintain pH at a level that will control corrosion but not conflict with optimum pH levels for disinfection and control of disinfection by-products.

Corrosion Inhibitors

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

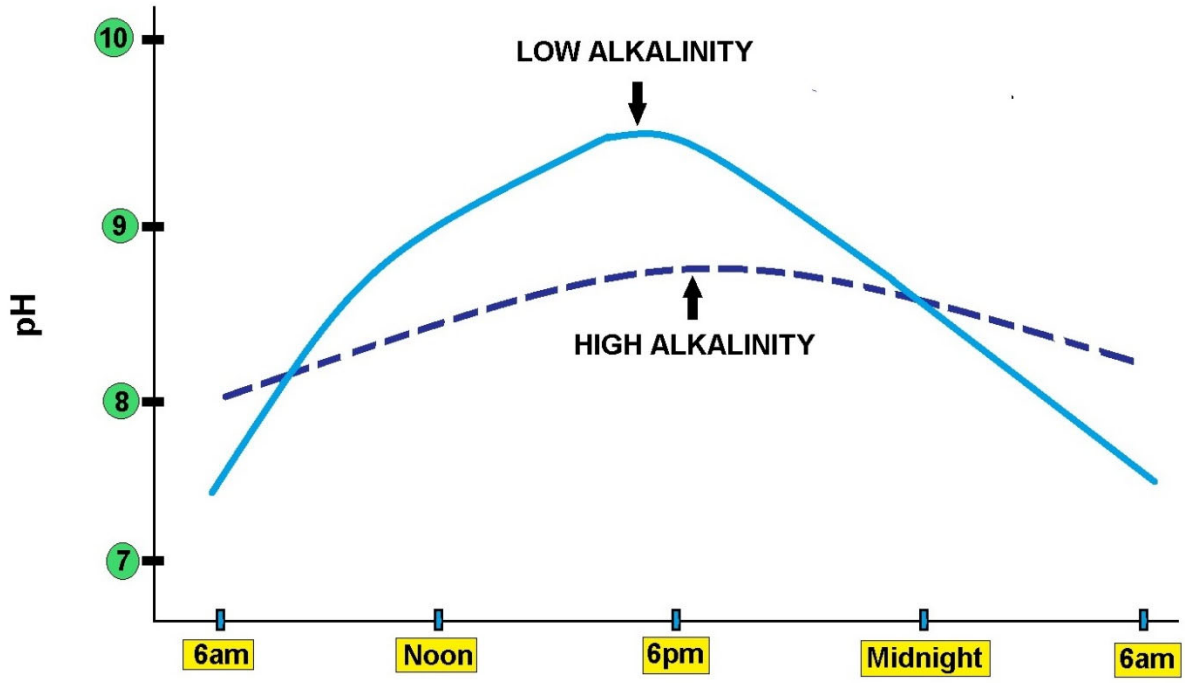
The phosphates used as corrosion inhibitors include polyphosphates, orthophosphates, glassy phosphates and bimetallic phosphates. In some cases, zinc is added in conjunction with orthophosphates or polyphosphates.

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

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

Sodium silicates are particularly effective for systems with high water velocities, low hardness, low alkalinity and a pH of less than 8.4.

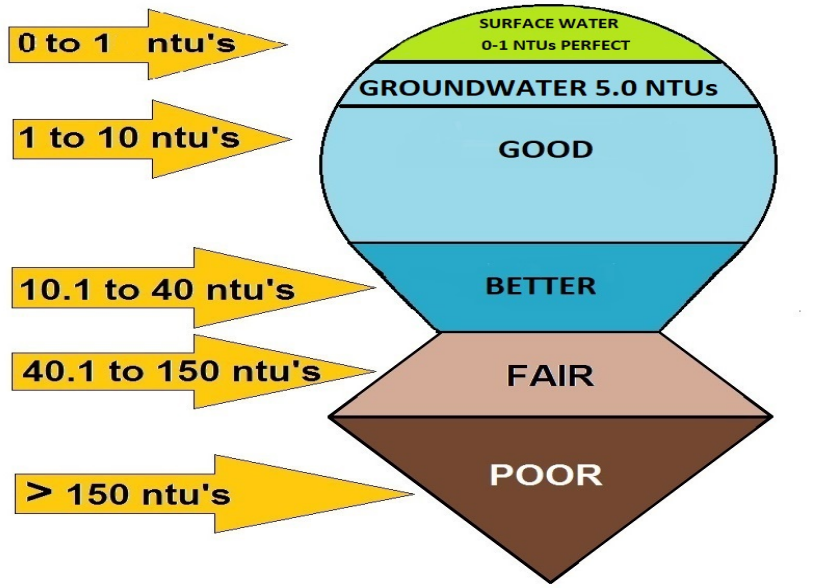
Typical coating maintenance doses range from 2 to 12 mg/1. They offer advantages in hot water systems because of their chemical stability. For this reason, they are often used in the boilers of steam heating systems.



ALKALINITY CAN CHANGE THROUGHOUT THE DAY DIAGRAM

Turbidity Testing Sub-Section

Suspension of particles in water interfering with passage of light is called turbidity. Turbidity is caused by wide variety of suspended matter that range in size from colloidal to coarse dispersions, depending upon the degree of turbulence, and ranges from pure inorganic substances to those that are highly organic in nature. Turbid waters are undesirable from an aesthetic point of view in drinking water supplies. Turbidity is measured to evaluate the performance of water treatment plants.



TURBIDITY PARAMETERS (NTU) FOR WATER QUALITY

Surface Water (SW) System Compliance

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

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.

Turbidity Key

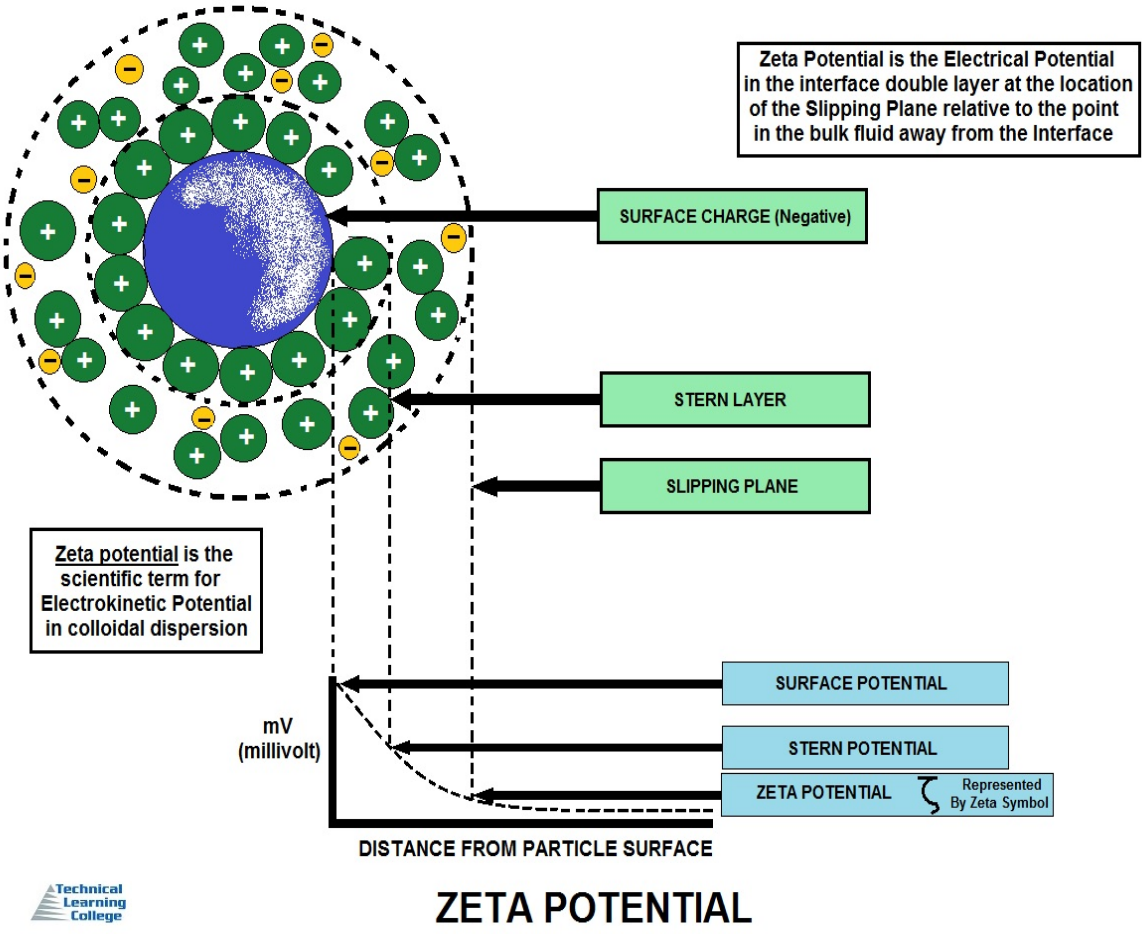
- Turbidity can also be measured in ppm (parts per million) and its size is measured in microns. Turbidity can be particles in the water consisting of finely divided solids, larger than molecules, but not visible by the naked eye; ranging in size from .001 to .150mm (1 to 150 microns).

- 0.34 NTU in 95% of surface water samples, never to exceed 1.0 NTU spike

Cloudy Water

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

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



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

Repulsive Force

An electrostatic force called the **"Zeta Potential**" - $$\zeta = \frac{4 \pi q d}{D}$$

Where:

ζ = Zeta Potential
q = charge per unit area of the particle
d = thickness of the layer surrounding the shear surface through which the charge is effective
D = dielectric constant of the liquid

Attractive force

Force due to van der Waals forces

Van der Waals forces are weak forces based on a polar characteristic induced by neighboring molecules. When two or more nonpolar molecules, such as He, Ar, H_2, are in close proximity, the nucleus of each atom will weakly attract electrons in the counter atom resulting, at least momentarily, in an asymmetrical arrangement of the nucleus.

This force, van der Waals force, is inversely proportional to the sixth power of the distance ($1/d^6$) between the particles. As can clearly be seen from this relationship, decay of this force occurs exponentially with distance.

Ways to Measure Turbidity

1.) Jackson Candle Test
2.) Secchi Disk - a black and white disk divided like a pie in 4 quadrants about 6" in diameter. This device is lowered by a rope into the water until it cannot be seen and then the rope is measured.
3.) Turbidimeter - Light is passed through a sample. A sensitive photomultiplier tube at a 90^o angle from the incident light beam detects the light scattered by the particles in the sample. The photomultiplier tube converts the light energy into an electrical signal, which is amplified and displayed on the instrument. The reading is expressed in Nephelometric Turbidity Unit (NTU) or Formazin Turbidity Unit (FTU).

How to Treat Turbidity

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

By introducing aluminum (Al_3^+) into the water in the form of Alum ($Al_2(SO_4)_3 \bullet nH_20$) we can accomplish the supercharging of the water. This is the *coagulation* part of the coagulation/flocculation process; flocculation follows coagulation.

During the *flocculation* process the particles join together to form flocs; the larger the flocs, the faster they will settle within a clarifier.

Other chemical coagulants used are Ferric Chloride and Ferrous Sulfate.

Alum works best in the pH range of natural waters, 5.0 - 7.5. Ferric Chloride works best at lower pH values, down to pH 4.5.

Ferrous Sulfate works well through a range of pH values, 4.5 to 9.5.

During the coagulation process, charged hydroxy-metallic complexes are formed momentarily (i.e. $Al(OH)_2^+$, $Al(OH)_2^{1+}$ etc.). These complexes are charged highly positive, and therefore upset the stable negative charge of the target particles, thereby momentarily displacing the water layer surrounding the charged particle. This upset decreases the distance "d," in turn decreasing the Zeta potential.

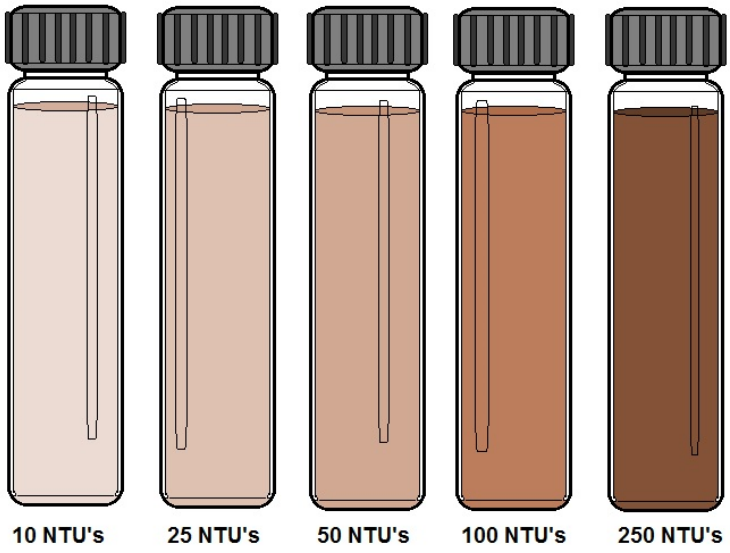
The particles are then able to get close enough together for van der Waals forces to take over and the particles begin to flocculate. The chemical reaction continues until the aluminum ions (Al^+_3) reach their final form, $Al(OH)_3$ (s), and settle out (note – the flocculated particles settle out separately from the precipitated $Al(OH)_3$ (s)).

If too much alum is added, then the opposite effect occurs--the particles form sub complexes with the Al^+_3 and gain a positive charge about them, and the particles re-stabilize.

The final key to obtaining good flocs is the added energy put into the system by way of rotating paddles in the flocculator tanks. By *"pushing"* (adding energy) the particles together we can aid in the flocculation process, forming larger flocs.

It is important to understand that too much energy, i.e. rotating the paddles too fast, would cause the particles to shear (breakup), thereby reducing the size of the particles and increasing the settling time in the clarifier.

Turbidity Analysis



TURBIDITY SAMPLES IN NTU's (Neophelometric Turbidity Unit)

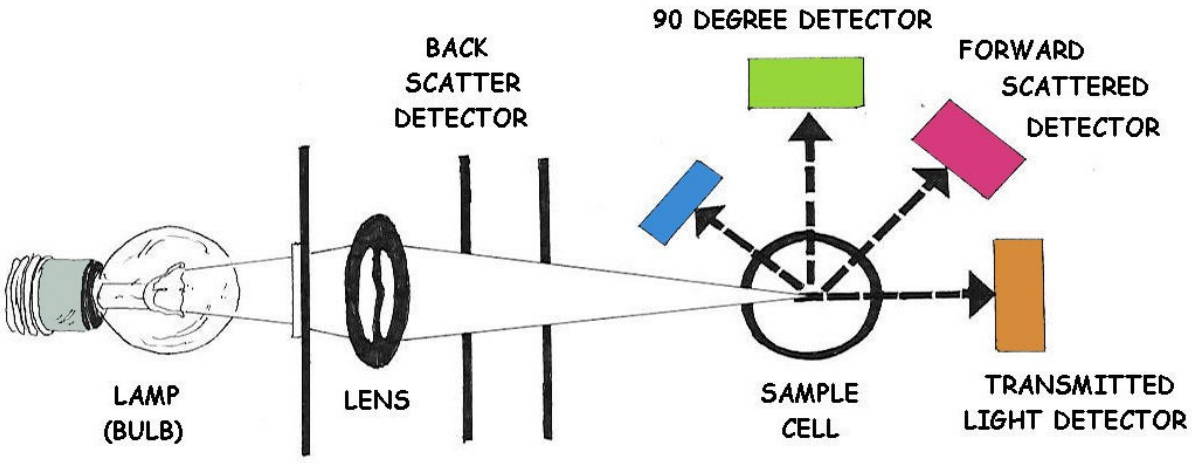
Principle
Turbidity can be measured either by its effect on the transmission of light, which is termed as Turbidimetry, or by its effect on the scattering of light, which is termed as Nephelometry. A Turbidimeter can be used for samples with moderate turbidity and a Nephelometer for samples with low turbidity. The higher the intensity of scattered light, the higher the turbidity.

Interference
Color is the main source of interference in the measurement of turbidity.

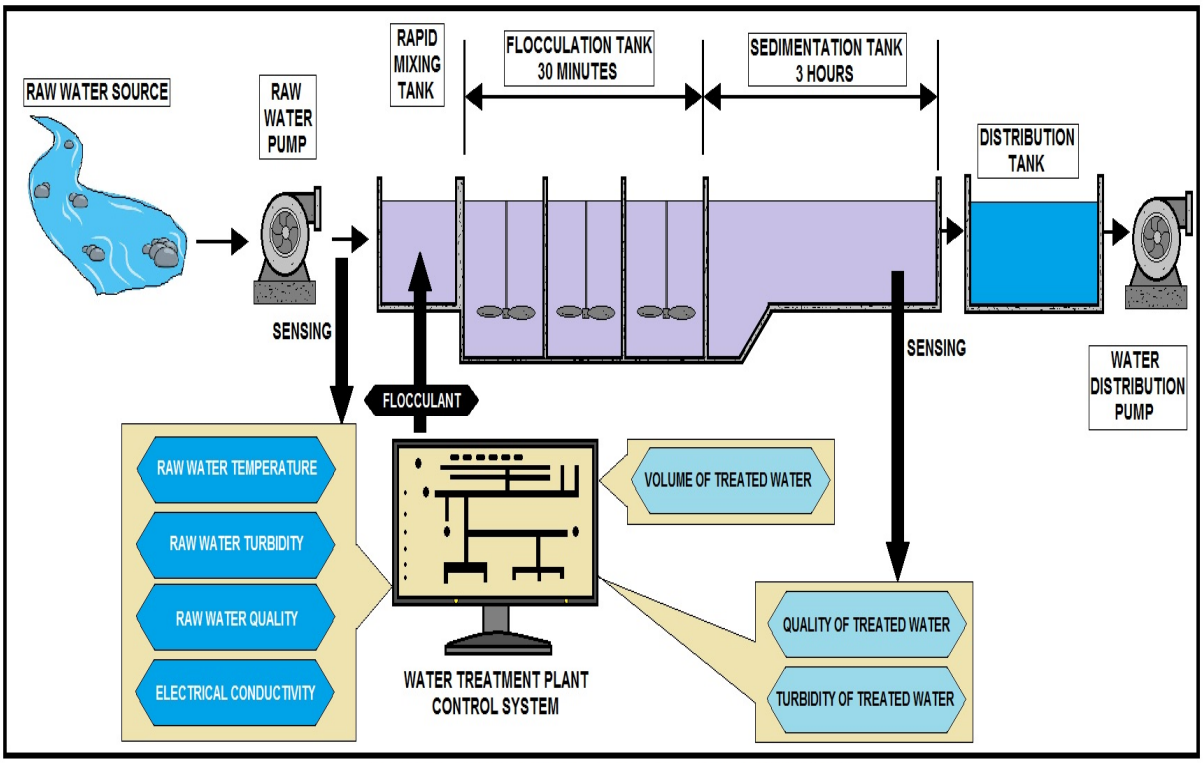
Apparatus Necessary: Turbidimeter or Nephelometer.

Reagents
1. Solution I: Dissolve 1.0 gm Hydrazine Sulfate and dilute to 100 mL.
2. Solution II: Dissolve 10.0 gm Hexamethylene tetramine and dilute to 100 mL.
3. Mix 5 mL of I with 5 mL of II. Allow to stand for 24 hrs. at 25 $\pm$ 3°C and dilute to 100 mL. This solution (III) will have turbidity of 400 units (N.T.U.)
4. Standard turbidity suspension: Dilute 10 mL of solution III as prepared above to 100 mL to have solution of the turbidity of 40 units. (N.T.U.)

Procedure
1. Prepare calibration curve in the range of 0-400 units by carrying out appropriate dilutions of solutions III and IV above taking readings on turbidimeter.
2. Take sample or a suitably diluted aliquot and determine its turbidity either by visual comparison with the diluted standards or by reading on turbidimeter.
3. Read turbidity from the standard curves and apply correction due to dilution, if necessary.
4. Report the readings in turbidity units.



HOW AN TURBIDIMETER WORKS



RAW WATER TURBIDITY MONITORING

Jar Testing Sub-Section

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

Instructions
The jar test, as with any coagulant test, will only provide accurate results when properly performed. Because the jar test is intended to simulate conditions in your plant, developing the proper procedure is very important. Take time to observe what happens to the raw water in your plant after the chemicals have been added, then simulate this during the jar test. The RPM of the stirrers and the minutes to complete the test depend on the conditions/parameters of your plant.

If, for instance, your plant does not have a static or flash mixer, starting the test at high rpm would provide misleading results. This rule applies to flocculator speed, length of settling time and floc development. Again, operate the jar test to simulate conditions in your plant.

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

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

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

Key Equations

$$Al_2(SO_4)_3 \bullet 14.3H_2O + 6H_2O \rightarrow 2Al(OH)_3(s) + 14.3H_2O + 3H_2SO_4 \quad (2)$$

$$Al_2(SO_4)_3 \bullet 14.3H_2O + 6Na(HCO_3) \rightarrow 2Al(OH)_3(s) + 3Na_2SO_4 + 14.3H_2O + 6CO_2 \quad (3)$$

$$Al_2(SO_4)_3 \bullet 14.3H_2O + 6Na(OH) \rightarrow 2Al(OH)_3(s) + 3Na_2SO_4 + 14.3H_2O \quad (4)$$

Apparatus
- Jar Test Apparatus
- 6 1500 mL Beakers
- pH meter
- Pipettes
- Conductivity Meter
- Turbidimeter

Procedure #1

- Make up a 10-g/L solution of alum.
- Make up a 0.1 N solution of NaOH (buffer). (Na^{+1} = 23 mg/mmol, O^{-2} = 16 mg/mmol, H^{+} = 1 mg/mmol)
- Fill each of the six 1500 mL beakers with one-liter of river water.
- Measure the temperature and conductivity.
- Measure the initial pH
- Add alum and NaOH solutions in equal portions as specified by instructor.
- Mixing protocol: Alter to match plant conditions
    - rapid mix - 1 minute (100 rpm)
    - slow mix - 15 minutes (20 rpm)
    - off, settling - 30 minutes
- Measure final turbidity. Take the sample from the center, about 2" down for each one-liter sample. Be careful not to disturb the flocs that have settled.
- Measure final pH

Jar Testing Procedure Step # 2

Jar testing is a useful tool that **helps water plant operators determine the most effective chemical source-water treatment**. By simulating coagulation and flocculation that occurs at full scale in the plant, jar testing can inform quick and effective treatment process adjustments.

Jar tests are conducted on a four- or six-place gang stirrer, which can be utilized to simulate mixing and settling conditions in a clarifier. Jars (beakers) with different treatment programs or the same product at different dosages are run side-by-side, and the results compared to an untreated jar, or one treated with the current program.

The general procedure for jar testing is as follows [a]:
1. Fill the appropriate number of (matched) 1000 mL square transparent jars [b] with well-mixed test water, using a 1000 mL graduate.
2. Place the filled jars on the gang stirrer, with the paddles positioned identically in each beaker.
3. Mix the beakers at 40 – 50 rpm for 30 seconds. Discontinue mixing until polymer addition is completed.
4. Leave the first beaker as a blank [a], and add increasing dosages of the first polymer to subsequent beakers. Inject polymer solutions as quickly as possible, below the liquid level and about halfway between the stirrer shaft and beaker wall.
5. Increase the mixing speed to 100-125 rpm for 15-60 seconds (rapid mix).
6. Reduce the mixing to 40 rpm and continue the slow mix for twice the duration of the rapid mix. Note relative floc sizes.
7. Turn the mixer off and allow settling to occur. Note relative rates of settling.
8. After settling for a period of time (typically 10 or 15 min.), note supernatant appearance. If desired, the latter may be quantified using a turbidimeter or clarity wedge (for turbidity), or determined gravimetrically (for suspended solids).
9. Remove the jars from the gang stirrer, empty the contents and thoroughly clean the beakers.
10. Repeat the procedure from Step 1, but substituting for the Blank the dosage selected as providing the desired level of performance in the first series of test. If the currently used product is available, the first series of tests consists of a dosage curve of that product: test dosages are selected so as to bracket the plant dosage.

Legend

a. If the current program is unknown or samples are unavailable, or if there is no product in use, the first step is to determine an approximate minimum dosage of flocculant. This is accomplished by slowly stirring 100 or 200 mL of the substrate in a beaker and adding the polymer solution in 1 mL increments until flocculation begins to occur. This will be the starting dosage of jar testing.
b. It is preferable to used square jars or beakers to provide more turbulent mixing and insure good distribution of the polymer. Alternatively, use 1-liter plastic laboratory bottles from which the tops have been cut off.)
c. Inorganic or organic coagulants may require longer rapid mix times, perhaps as much as 5 min.
d. Some plants, especially water prep facilities, have mixing regimes which they feel duplicate plant conditions. Mixing times may also be substantially greater in these plants.

Information to be Recorded

Initial Turbidity = NTU Alum - g/L Buffer - 0.1 N

Beaker	Alum (ml)	Buffer (ml)	Turbidity (NTU)	pH-Before	pH-After	Temp. °C

Preparing Polymers for the Jar Test

A successful Jar Test is very reliant upon the proper preparation of the polymers being tested. Dilution technique *("make down")* is especially critical, since it involves compactly coiled large molecules in emulsions, prior to activation. The polymer must be uncoiled to provide maximum contact with the colloidal particles to be flocculated. If the following procedures are not followed, the Jar Test results will be very unreliable.

Required Equipment:

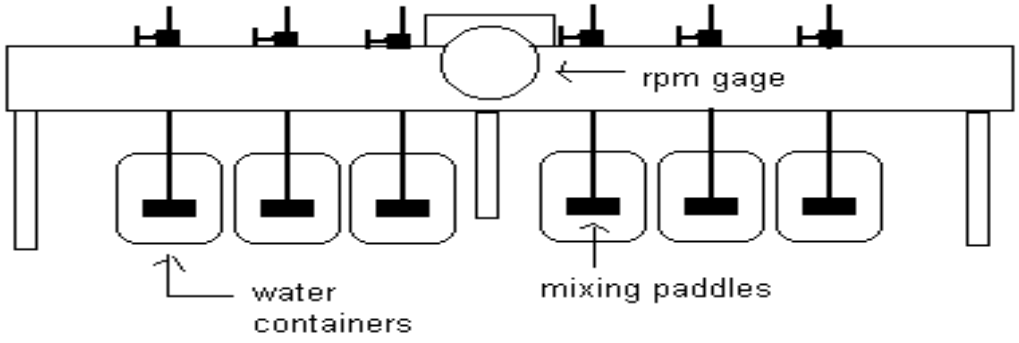
- 250 mL bottles with lids.
- High speed hand mixer (for emulsion polymers).
- Syringes (1cc, 5cc, 10cc).
- 250 and 500 mL beakers.
- Water (it is recommended that the make-down water from the plant be used).
- Graduated cylinder (100 mL).

Emulsion Polymers (Prepare 1.0% solution.)

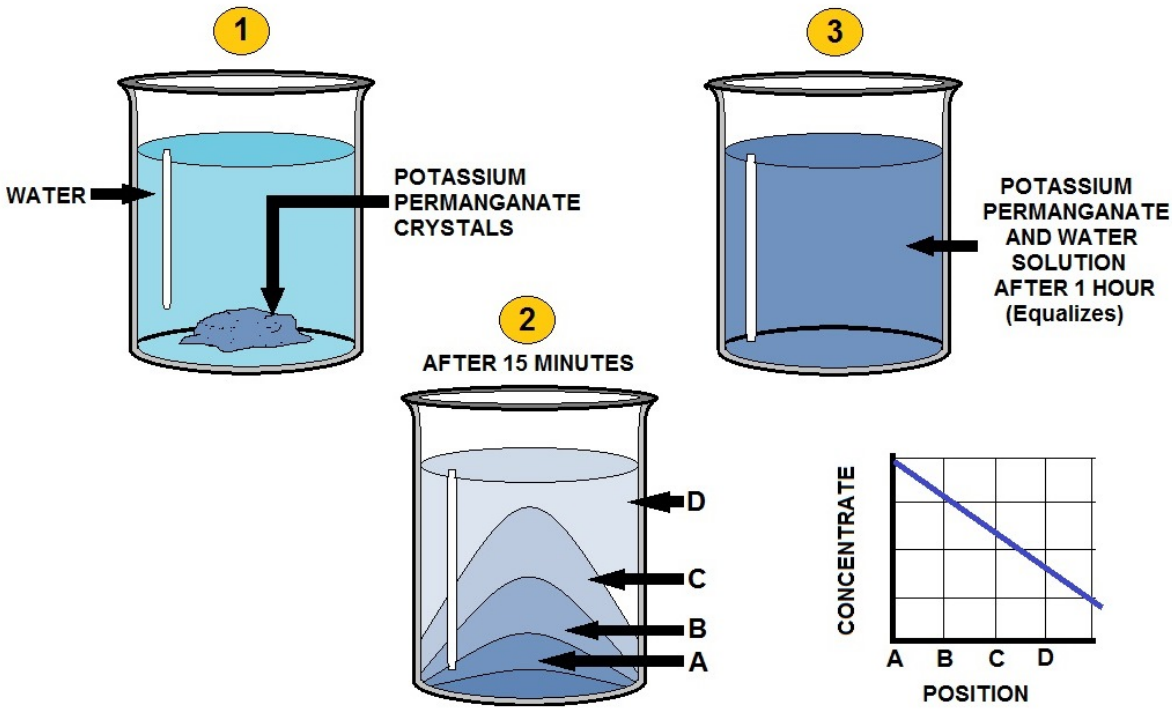
- Add 198 mL of water to a beaker.
- Insert Braun mixer into water and begin mixing.
- Using a syringe, inject 2 mL of neat polymer into vortex.
- Mix for 20 seconds. Do not exceed 20 seconds!
- Allow dilute polymer to age for at least 20 minutes, but preferably overnight. Prepare 0.1% solution.
- Add 180 mL of water to 250 mL bottle.
- Add 20 mL of 1.0% polymer solution.
- Shake vigorously for at least one minute.

Solution Polymers and Inorganics (Prepare a 1.0% solution.)

- Add 198 mL of water to 250 mL bottle.
- Using a syringe, add 2 mL of neat product to bottle.
- Shake vigorously for at least 1 minute.
- Prepare 0.1% solution.
- Add 180 mL to 250 mL bottle.
- Add 20 mL of 1 % solution.
- Shake vigorously for at least one minute.



JAR TESTING APPARATUS



DIFFUSION OF POTASSIUM PERMANGANATE IN WATER

Creation of Potassium Permanganate

Potassium permanganate is produced industrially from manganese dioxide (MnO_2), which also occurs as the mineral pyrolusite. The MnO_2 is fused with potassium hydroxide and heated in air or with a source of oxygen, like potassium nitrate or chlorate.

This process gives potassium manganate, which upon electrolytic oxidation in alkaline media, or by boiling the manganate solution in the presence of carbon dioxide until all the green color is discharged, gives potassium permanganate.

$$2\ MnO_2 + 4\ KOH + O_2 \rightarrow 2\ K_2MnO_4 + 2\ H_2O$$
$$2\ MnO_4^{2-} + Cl_2 \rightarrow 2\ MnO_4^{-} + 2\ Cl^{-}$$

or:

$$3\ K_2MnO_4 + 2\ CO_2 \rightarrow 2\ KMnO_4 + 2\ K_2CO_3 + MnO_2$$

In which the potassium permanganate is separated by filtering the insoluble manganese dioxide, evaporating the solution to 1/3 and recrystallizing it.

Potassium Permanganate Jar Test

Potassium Permanganate has been used for a number of years in both water and wastewater treatment. $KMnO_4$ is a strong oxidizer that can be used to destroy many organic compounds of both natural and man-made origin. $KMnO_4$ is also used to oxidize iron, manganese and sulfide compounds and other taste and odor producing substances usually due to the presence of very small quantities of secretions given off by microscopic algae, which develop on the surface waters and on beds of lakes and rivers under certain conditions of temperature and chemical composition.

$KMnO_4$ must be used with caution, as this material produces an intense purple color when mixed with water. As the permanganate ion is reduced during its reaction with compounds that it oxidizes, it changes color from purple, to yellow or brown. The final product formed is manganese dioxide (MnO_2), an insoluble precipitate that can be removed by sedimentation and filtration.

All $KMnO_4$ applied must be converted to manganese dioxide (MnO_2) prior to filtration. If it is not all converted and is still purple or pink, it will pass through the filter into the clearwell or distribution system. This may cause the customer to find pink tap water, or the reaction may continue in the system and the same conditions as exist with naturally occurring manganese may cause staining of the plumbing fixtures.

Stock Solutions
Strong Stock Solution
5 grams potassium permanganate dissolved in 500 ml distilled water.

Test Stock Solution
A. 4 ml strong stock solution thoroughly mixed in 100 ml distilled water.
B. Each 5 ml of the test stock solution added to a 2000 ml sample equals 1 mg/l.

Jar Testing - Example 1
If you have a six position stirrer:
Using a graduated cylinder, measure 2000 ml of the sample to be tested into each of the six beakers. Dose each beaker to simulate plant practices in pre-treatment, pH adjustment, coagulant,- etc. Do not add carbon or chlorine. Using a graduated pipette, dose each beaker with the test stock solution in the following manner.

Jar #	$KMnO_4$ml	KMnO4 mg/l	Color
1	0.50	0.10	no pink
2	0.75	0.15	no pink
3	1.00	0.20	no pink
4	1.25	0.25	no pink
5	1.50	0.30	pink
6	1.75	0.35	pink

Stir the beakers to simulate the turbulence where the $KMnO_4$ is to be added and observe the color change.

As the iron and manganese begin to oxidize, the sample will turn varying shades of brown, indicating the presence of oxidized iron and or manganese. Samples which retain a brown or yellow color indicate that the oxidation process is incomplete and will require a higher dosage of $KMnO_4$.

The end point has been reached when a pink color is observed and remains for at least 10 minutes. In the preceding table a pink color first developed in beaker #5 which had been dosed with 1.5 ml/ 0.3 mg/l. If the first jar test does not produce the correct color change, continue with increased dosages.

When applying potassium permanganate to raw water, care must be taken not to bring pink water to the filter unless you have "*greensand*" filter media. Also, permanganate generally reacts more quickly at pH levels above 7.0.

Quick Test
In this example a quick way to check the success of a $KMnO_4$ application is by adding 1.25 ml of the test stock solution to 1000 ml finished water. If the sample turns brown, there is iron or manganese remaining in the finished water. If the sample remains pink, oxidation is complete.

With proper application, potassium permanganate is an extremely useful chemical treatment.

As well as being a strong oxidizer for iron and manganese, $KMnO_4$ used as a disinfectant in pre-treatment could help control the formation of trihalomethanes by allowing chlorine to be added later in the treatment process or after filtration. Its usefulness also extends to algae control, as well as many taste/odor problems.

To calculate the dosage of $KMnO_4$ for iron and manganese removal, here is the formula to use, based on the amount of iron and manganese in the water:

$KMnO_4$ Dose, mg/l = 0.6(iron, mg/l) + 2.0(Manganese, mg/l)

Example:
Calculate the $KMnO_4$ dose in mg/l for a water with 0.4 of iron. The manganese concentration is 1.2 mg/l.

Known Unknown
Iron, mg/l = 0.4 mg/l $KMnO_4$ Dose, mg/l
Manganese, mg/l = 1.2 mg/l

Calculate the $KMnO_4$ dose in mg/l.

$KMnO_4$ Dose, mg/l = 0.6(Iron, mg/l) + 2.0(Manganese, mg/l)
= 0.6(0.4 mg/l) + 2.0(1.2 mg/l)
= 2.64 mg/l

Note: The calculated 2.64 mg/l KMnO4 dose is the minimum dose. This dose assumes there are no oxidizable compounds in the raw water. Therefore, the actual dose may be higher. Jar testing should be done to determine the required dose.

Alkalinity Test

Alkalinity (Total)
References: ASTM D 1067-92, Acidity or Alkalinity of Water.
APHA Standard Methods, 19th ed., p. 2-26, method 2320B (1995).
EPA Methods for Chemical Analysis of Water and Wastes, method 310.1 (1983).

The alkalinity of water is a measurement of its buffering capacity or ability to react with strong acids to a designated pH. Alkalinity of natural waters is typically a combination of bicarbonate, carbonate, and hydroxide ions. Sewage and wastewaters usually exhibit higher alkalinities either due to the presence of silicates and phosphates or to a concentration of the ions from natural waters.

Alkalinity inhibits corrosion in boiler and cooling waters and is therefore a desired quality which must be maintained. It is also measured as a means of controlling water and wastewater treatment processes or the quality of various process waters.

In natural waters, excessive alkalinity can render water unsuitable for irrigation purposes and may indicate the presence of industrial effluents. *The Titrimetric Method.* CHEMetrics' tests determine total or "M" alkalinity using an acid titrant and a pH indicator. The end point of the titration occurs at pH 4.5. Results are expressed as ppm (mg/L) $CaCO_3$.

Titration Method
a. Principle
Hydroxyl ions present in a sample, as a result of dissociation or hydrolysis of solutes react with additions of standard acid. Alkalinity thus depends on the end-point pH used.

b. Reagents
i) Standard Hydrochloric Acid – 0.02 N.
ii) Methyl Orange Indicator – Dissolve 0.1 g of methyl orange in distilled water and dilute to 1 liter.
iii) Sodium carbonate solution, 0.02 N: Dry 3 to 5 g primary standard Na_2CO_3 at 250°C for 4 h and cool in a desiccator. Weigh 1.03 gm.
(to the nearest mg), transfer to a 1-L volumetric flask, fill flask to the mark with distilled water, dissolve and mix reagent. Do no keep longer than 1 week.

c. Procedure
Titrate over a white surface 100 ml of the sample contained in a 250-ml conical flask with standard hydrochloric acid using two or three drops of methyl orange Indicator.
(**NOTE** – If more than 30 ml of acid is required for the titration, a smaller suitable aliquot of the sample shall be taken.)

d. Calculation
Total alkalinity (as $CaCO_3$), mg/l = 10 V or NxVx50x1000

$$\text{T.A. (as } CaCO_3) = \frac{\text{NxVx50x1000}}{\text{Sample Amount}}$$

Where N = Normality of HCl used
V = volume in ml of standard hydrochloric acid used in the titration.

Alkalinity to Phenolphthalein
The sample is titrated against standard acid using phenolphthalein indicator.

a. Reagents
i) Phenolphthalein Indicator Solution :
Dissolve 0.1 g of phenolphthalein in 60 ml of ETHANOL and dilute with Distilled water to 100 ml.
ii) Standard hydrochloric Acid – 0.02 N.

b. Procedure
Add 2 drops of phenolphthalein indicator solution to a sample of suitable size, 50 or 100 ml, in a conical flask and titrate over a while surface with standard hydrochloric acid.

c. Calculation

$$\textbf{Alkalinity to phenolphthalein (as } \mathbf{CaCO_3}\textbf{)}, \text{ mg/l} = \frac{1000\ V_1}{V_2}$$

Where
V_1 = volume in ml of standard hydrochloric acid used in the titration , and
V_2 = Volume in ml of the sample taken for the test.

Caustic Alkalinity

a. General
Caustic alkalinity is the alkalinity corresponding to the hydroxides present in water and is calculated from total alkalinity (T) and alkalinity to phenolphthalein (P).

b. Procedure Determine total alkalinity and alkalinity to phenolphthalein and calculate caustic alkalinity as shown in Table below. Result of Titration Caustic Alkalinity or Hydroxide Alkalinity as $CaCO_3$ Carbonate Alkalinity as $CaCO_3$ Bicarbonate Concentration as $CaCO_3$ **Result of Titration**	**Caustic Alkalinity or Hydroxide Alkalinity as $CaCO_3$**	**Carbonate Alkalinity as $CaCO_3$**	**Bicarbonate Concentration as $CaCO_3$**
P=0	0	0	0
P<1/2T	0	2P	T-2P
P=1/2T	0	2P	0
P>1/2T	2P-T	2(T-P)	0
P=T	T	0	0

The alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity of natural water is due to the salts of carbonate, bicarbonate, borates, silicates and phosphates along with the hydroxyl ions in free state. However, the major portion of the alkalinity in natural waters is caused by hydroxide, carbonate, and bicarbonates which may be ranked in order of their association with high pH values.

Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes, particularly in coagulation and softening.

Hardness (Calcium)

Reference: West, T. S., DSC, Ph.D., Complexometry with EDTA and Related Reagents, 3rd ed., p. 46, 164 (1969).

Originally described as water's capacity to precipitate soap, hardness is one of the most frequently determined qualities of water. It is a composite of the calcium, magnesium, strontium, and barium concentrations in a sample. The current practice is to assume total hardness refers to the calcium and magnesium concentrations only.

Completely de-hardened water, resulting from sodium zeolite or other suitable ion exchange treatment, is required for various processes-including power generation, printing and photo finishing, pulp and paper manufacturing, and food and beverage processing.

Hard water can cause scale formation on heat exchange surfaces, resulting in decreased heat transfer and equipment damage.

The Titrimetric Method. This method is specific for calcium hardness. The EGTA titrant in alkaline solution is employed with zincon indicator. Results are expressed as ppm (mg/L) $CaCO_3$. Although the reagent itself is stable, the end-point indicator has a limited shelf-life. We recommend stocking quantities that will be used within 7 months.

Hardness (Total)

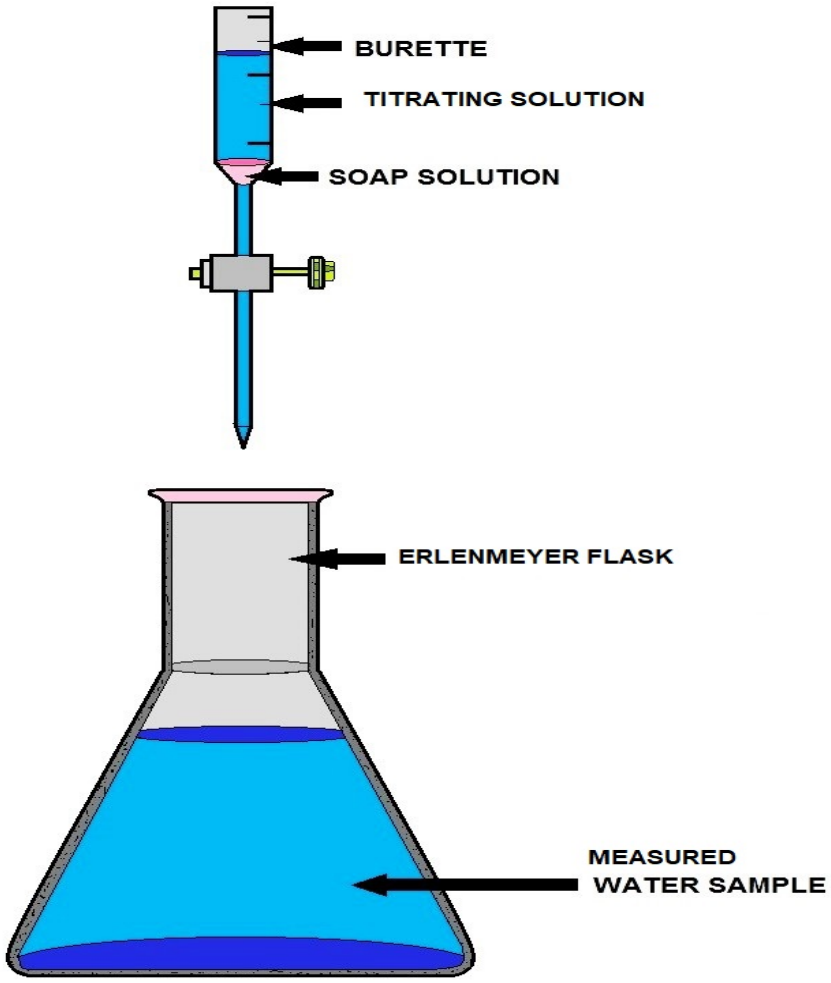
References: Colorimetric-Calcichrome chemistry--Method developed by CHEMetrics, Inc. Titrimetric--APHA Standard Methods, 19th ed., p. 2-36, method 2340 C (1995). EPA Methods for Chemical Analysis of Water and Wastes, method 130.1 (1983).

The Colorimetric Method

The colorimetric method is applicable to monitoring boiler feedwater and other industrial waters. The titrimetric method is applicable to drinking, surface, and brine waters. CHEMetrics developed the sensitive Calcichrome reagent, which is a dark purple color. It reacts to form a light purple color at the lower end of the range, and forms a light blue color at the end of the range. Results are expressed as ppm (mg/L) or ppb (µg/L) $CaCO_3$. *The Titrimetric Method.*

The EDTA titrant is employed in alkaline solution with a calmagite indicator. This method determines the combined calcium and magnesium concentration of a sample. If no magnesium is present, the end point of the titration normally appears sluggish.

However, the reagent has been specially formulated to ensure a sharp end point, regardless of the presence of magnesium. Results are expressed as ppm (mg/L) $CaCO_3$.



TESTING FOR THE HARDNESS OF WATER

WATER HARDNESS (Salt Types)	
CARBONATE HARDNESS COMPOUNDS	NON-CARBONATE HARDNESS COMPOUNDS
CALCIUM CARBONATE ($CaCO_3$)	CALCIUM SULPHATE ($CaSO_4$)
MAGNESIUM CARBONATE ($MgCO_3$)	MAGNESIUM SULPHATE ($MgSO_4$)
CALCIUM BiCARBONATE ($Ca(HCO_3)_2$)	CALCIUM CHLORIDE ($CaCl_2$)
MAGNESIUM BiCARBONATE ($Mg(HCO_3)_2$)	MAGNESIUM CHLORIDE ($MgCl_2$)
CALCIUM HYDROXIDE ($Ca(OH)_2$)	
MAGNESIUM HYDROXIDE ($Mg(OH)_2$)	

Technical Learning College

CAUSES OF HARDNESS THAT AFFECTS WATER QUALITY

Iron (Total)

Reference: J. A. Tetlow and A. L. Wilson, "Determination of Iron in Boiler Feedwater", Analyst, 1958. See discussion under Iron (total & soluble). CHEMetrics' colorimetric method for determining total iron uses thioglycolic acid to dissolve particulate iron and to reduce any iron from the ferric to the ferrous state. Ferrous iron then reacts with PDTS in acid solution to form a purple-colored chelate. Results are expressed as ppm (mg/L) Fe.

Manganese

Reference: APHA Standard Methods, 14th ed., p. 227, method 314C (1975).
Manganese can act as an oxidizing or reducing agent, depending on its valence state. In various forms, it is used as a pigment or a bleaching agent. Manganese concentrations in potable water should not exceed 0.05 mg/L.

Concentrations greater than 0.1 mg/L will impart a foul taste to water and discolor laundry and porcelain surfaces. Generally speaking, surface and ground waters rarely contain more than 1 mg/L of soluble or suspended manganese. Levels higher than 1 mg/l in surface waters can result from mining operations or excessive discharging from domestic waste treatment facilities or industrial plants.

CHEMetrics' tests measure soluble manganese compounds but do not differentiate the various valence states. Manganese is oxidized in the presence of periodate to form a deep-red reaction product. Reducing agents will interfere. Results are expressed as ppm (mg/L) Mn.

Fluorides

Fluoride ions have dual significance in water supplies. High concentration of F- causes dental fluorisis (disfigurement of the teeth). At the same time, a concentration less than 0.8 mg/l results in `dental caries'. Hence, it is recommended to maintain the F- conc. between 0.8 to 1.0 mg/L in drinking water. Among the many methods suggested for the determination of fluoride ion in water, the colormetric method (SPADNS) & the ion selective electrode method are the most satisfactory and applicable to a variety of samples. Because all of the colorimetric methods are subject to errors due to the presence of interfering ions, it may be necessary to distill the sample before making the fluoride estimation.

The addition of the prescribed buffer frees the electrode method from the interference, caused by such relatively common ions as aluminum hexametaphosphate and orthophosphate which adversely affect the colorimetric methods. However, samples containing fluoroborate ion (BF_4), must be subject to a preliminary distillation step in either of the methods. Both the methods and the preliminary distillation step are discussed below.

1. SPADNS METHOD

Principle

Under acid condition fluorides (**HF**) react with zirconium SPADNS solution and the `Lake' (color of SPADNS reagent) gets bleached due to formation of ZrF_6. Since bleaching is a function of fluoride ions, it is directly proportional to the concentration of F. It obeys Beer's law in a reverse manner.

Interference

Alkalinity 5000 mg/L, aluminum 0.1 mg/L, chlorides 7000 mg/L, Fe 10 mg/L, PO_4 16 mg/L, SO_4 200 mg/L, and hexametaphosphate 1.0 mg/L interfere in the bleaching action. In presence of these interfering radicals distillation of the sample is recommended.

Apparatus

1. Distillation apparatus
2. Colorimeter for use at 570 nm.
3. Nessler's tubes cap. 100 ml.

Reagents

1. Sulfuric acid H_2SO_4 concentration.
2. Silver Sulfate Ag_2SO_4 crystals.
3. SPADNS solution: Dissolve 958 mg SPADNS and dilute to 500 ml.
4. Ziroconyl acid reagent: Dissolve 133 mg $ZrOCl_2$ $8H_2O$ in 25 ml water. Add 350 ml. conc. HCl and dilute to 500 ml.
5. Mix equal volume of 3 and 4 to produce a single reagent. Protect from direct light.

6**. Reference solution:** Add 10 ml SPADNS solution to 100 ml distilled water. Dilute 7 ml concentration HCl to 10 ml and add to diluted SPADNS solution.
7. **Sodium arsenite solution:** Dissolve 5.0 g $NaAsO_2$ and dilute to 1000 ml.
8. **Stock F- solution:** Dissolve 221.0 mg anhydrous NaF and dilute to 1000 ml. 1 ml = 100 mg F-.
9**. Standard F :** Dilute stock solution 10 times to obtain 1 ml = 10mg F.

A. Preliminary Distillation Step
Place 400 ml distilled water in the distilling flask and carefully add 200 ml conc. H_2SO_4. Swirl until the flask contents are homogenous, add 25 to 30 glass beads and connect the apparatus. Begin heating slowly at first and then rapidly until the temperature of the flask reaches exactly 180°C. Discard the distillate. This process removes fluoride contamination and adjusts the acid-water ratio for subsequent distillations.

After cooling the acid mixture remaining after the above step or previous distillation to 120°C or below add 300 ml of sample, mix thoroughly, and distill as before until the temperature reaches 180°C. Do not heat above 180°C to prevent Sulfate carryover.

Add Ag_2SO_4 to distilling flask at the rate of 5 mg/mg Cl when high chloride samples are distilled. Use the sulfuric acid solution in the flask repeatedly until the contaminants from the samples accumulate to such an extent that recovery is affected or interferences appear in the distillate. After the distillation of high fluoride samples, flush the still with 300 ml. distilled water and combine the two fluoride distillates. After periods of inactivity, similarly flush the still, and discard the distillate.

B. Procedure
1. Prepare standard curve in the range 0.0 to 1.40 mg/L by diluting appropriate volume of standard F solution to 50 ml in Nessler's tubes.
2. Add 10.0 mL mixed reagent prepared as in 5 above to all the samples, mix well and read optical density of bleached color at 570 nm using reference solution for setting zero absorbance.
3. Plot conc. Vs. % transmission or absorbance.
4. If sample contains residual chlorine, remove it by adding 1 drop (0.05ml) $NaAsO_2$ solution 0.1 mg Cl_2 and mix. $NaAsO_2$ conc. should not exceed 1300 mg/L to avoid error due to $NaAsO_2$. Take suitable aliquot & dilute it to 50 mL.

5. Add acid Zirconia - SPADNS reagent 10 ml; Mix well and read % transmission or absorbance.
6. Take suitable aliquots of sample either direct or after distillation in Nessler's tubes. Follow the step 5.
7. Calculate the mg F present in the sample using standard curve.

2. Ion Selective Electrode Method
Principle
The fluoride sensitive electrode consists of a lanthanum fluoride crystal, it forms a cell in combination with a reference electrode, normally the calomel electrode. The crystal contacts the sample solution at one face and an internal reference solution at the other. A potential is established by the presence of fluoride ions across the crystal, which is measured by a device called ion meter, or by a digital pH meter having an expanded millivolt scale.

The fluoride ion selective electrode can be used to measure the activity or concentration of fluoride in an aqueous sample by use of an appropriate calibration curve. However, fluoride activity depends on the total ionic strength of the sample. The electrode does not respond to bound or complex fluoride. Addition of a buffer solution of high total ionic strength containing a chelate to complex aluminum preferentially overcomes these difficulties.

Interference
Polyvalent cations such as Al (III), Fe (III) and Si (IV) will complex fluoride ions. However, the addition of CDTA (Cyclohexylene diamine tetra acetic acid) preferentially will complex concentrations of aluminum up to 5 mg/L. Hydrogen ion forms complex with fluoride, while hydroxide ion interferes with electrode response. By adjusting the pH between 5 to 8 no interference occurs.

Apparatus
1. Ion meter (field / laboratory model) or pH/mV meter for precision laboratory measurements.
2. Reference electrode (calomel electrode)
3. Fluoride sensitive electrode.
4. Magnetic stirrer.
5. Plastic labware (Samples and standards should always be stored in plastic containers as fluoride reacts with glass).

Reagents
1. Standard fluoride solution prepared as directed in SPADNS method.
2. Total Ionic strength adjustment buffer (TISAB).

Place approximately 500 ml distilled water in a 1 - L beaker add 57 mL glacial acetic acid, 58 gm NaCl and 4.0 gm 1, 2 cyclohexylene diamine tetraacetic acid. Stir to dissolve.

Place beaker in a cool water bath and add slowly 6 N NaOH (About 125 ml) with stirring, until pH is between 5 and 5.5. Transfer to a 1 - L volumetric flask and make up the volume to the mark.

Procedure
1. For connecting the electrodes to meter, and for further operation of the instrument, follow the instruction manual supplied by the manufacturer.
2. Check the electrode slope with the ion meter (59.16 mV for monovalent ions and 29.58 mV for divalent ions at 25^{o}C)
3. Take 50 ml of each 1 ppm and 10 ppm fluoride standard. Add 50 ml TISAB (or 5 ml if conc. TISAB is used) and calibrate the instrument.
4. Transfer 50 to 100 ml of sample to a 150 ml plastic beaker. Add TISAB as mentioned in (3).
5. Rinse electrode, blot dry and place in the sample. Stir thoroughly and note down the steady reading on the meter.
6. Recalibrate every 1 or 2 hours.
7. Direct measurement is a simple procedure for measuring a large number of samples. The temperature of samples and standard should be the same and the ionic strength of standard and samples should be made the same by addition of TISAB to all solutions.
8. Direct measurement results can be verified by a known addition procedure. The known addition procedure involves adding a standard of known concentration to a sample solution. From the change in electrode potential before and after addition, the original sample concentration is determined.

Fluoride SPADNS Method

References:
APHA Standard Methods, 20th ed., p. 4-82, method 1500 F-(1998).
EPA Methods for Chemical Analysis of Water and Wastes, method 340.1 (1974,1978).
Thomas and Chamberlain, 1974, Colorimetric Analytical Methods, pp 186-193.

The Fluoride Vacu-vials® test method is based on the reaction between fluoride and a red zirconium-dye lake that has been formed with SPADNS.

The loss of color resulting from the reaction of the fluoride with the dye lake is a function of the fluoride concentration. Results are expressed in ppm (mg/Liter) F-.

This method is approved by the EPA for NPDES and NPDWR reporting purposes when the samples have been distilled from an acid solution.

Seawater and wastewater samples must be pre-distilled. Distillation removes most contaminating interferences except chlorine. Sodium Arsenite has been added to remove up to 5 mg/L chlorine.

Oxygen (Dissolved)

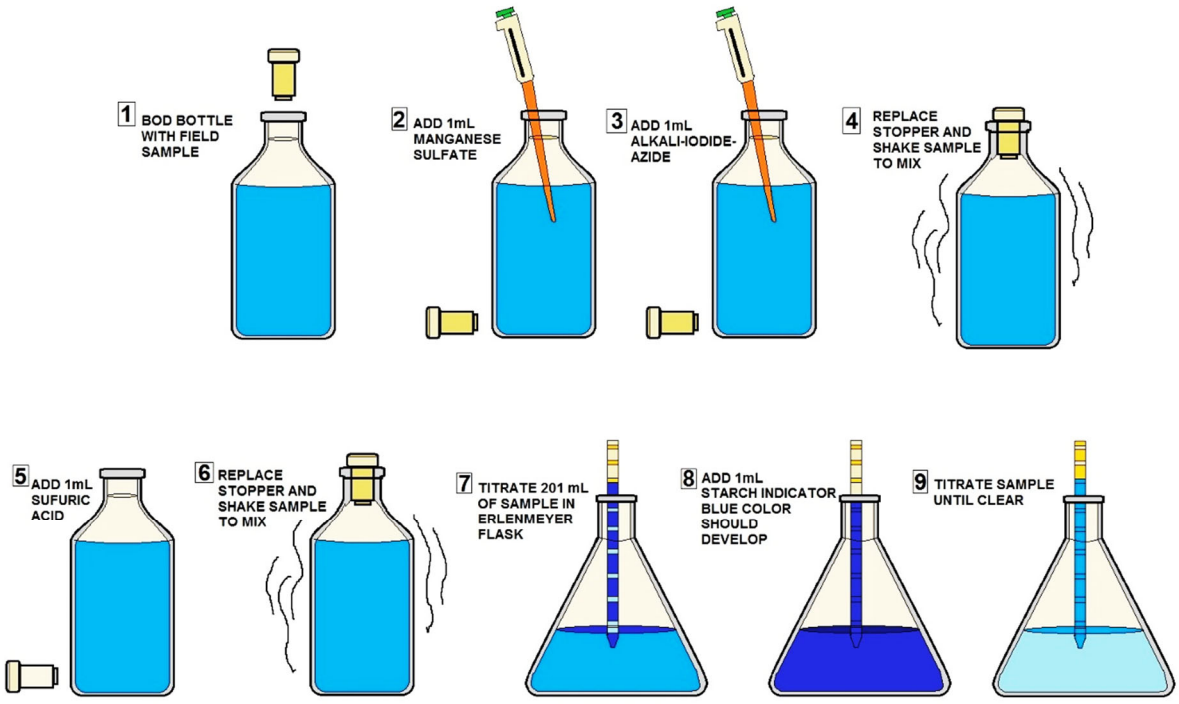
References: Indigo Carmine--ASTM D 888-87, Colorimetric Indigo Carmine, Test Method A. Gilbert, T.W., Behymer, T.D., Castaneda, H.B., "Determination of Dissolved Oxygen in Natural and Wastewaters," *American Laboratory*, March 1982, pp. 119-134.
Rhodazine D method--(Method developed by CHEMetrics, Inc.) Power Plant Manual, First ed., p. 169 (1984).

Corrosive Element
At elevated temperatures, oxygen is highly corrosive to metals, causing *"pitting"* in ferrous systems such as high-pressure boilers and deep well oil recovery equipment. To prevent costly corrosion damage, the liquids in contact with the metal surfaces must be treated, usually by a combination of physical and chemical means. De-aeration can reduce the dissolved oxygen concentration of boiler feedwater from several ppm to a few ppb. Chemical reducing agents such as hydrazine or sodium sulfite are sometimes used instead of de-aeration, but more often are used to react with residual oxygen which remains after the de-aeration process.

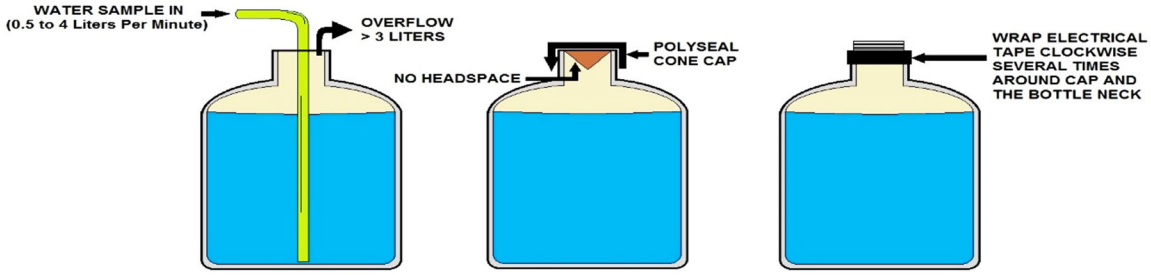
The Colorimetric Methods
Test kits for environmental and drinking water applications (ppm range) employ the indigo carmine method. The reduced form of indigo carmine reacts with D.O. to form a blue product. The indigo carmine methodology is not subject to interferences from temperature, salinity or dissolved gases such as sulfide, which can affect users of D.O. meters. Results are expressed as ppm (mg/L) O_2.

The dissolved oxygen products provide fast, accurate colorimetric oxygen determination. Test kit K-7512 is used to monitor surface waters. ULR CHEMets™ ampoules detect oxygen to 1 ppb. Test kit K-7540 is widely used to monitor boiler feedwater.

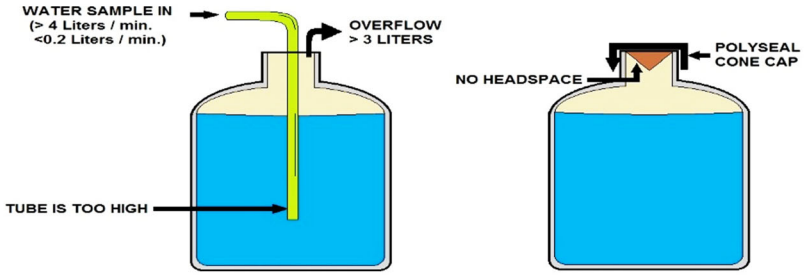
Probe Method
Reliable and accurate D.O. probes are available that can be fitted to 300 ml BOD bottles or other containers for suitable water.



HOW TO MEASURE DISSOLVED OXYGEN IN A WATER SAMPLE
DO NOT ALLOW THE PIPPETTES TO TOUCH THE WATER



WILL PRODUCE GOOD RESULTS



DO NOT DO THIS. WILL PRODUCE INACCURATE RESULTS

WATER SAMPLING PROCEDURES

Total Dissolved Solids TDS (Filterable)

The dissolved (Filterable) solids can be determined from the difference between the residue on evaporation and total suspended solids, but if the dissolved solids content is low and the suspended solids high, a direct determination is better.

It is preferable to adopt the centrifugal method of separating suspended matter in order that a sufficiently large volume of separated liquid is available for the determination.

Principle
A known volume of filtered sample is evaporated and dried in a weighed dish at 105^{o}C to constant weight; the increase in weight over the empty dish represents the dissolved solids.

Apparatus
1. Evaporating dishes, 50, 100 mL capacity (Preferably porcelain or silica).
2. Pipettes 25, 50 ml capacity
3. Water bath & Oven
4. Balance to weigh up to 4th decimal.

Procedure
The known volume (V) of filtered sample in a previously ignited and weighed basin (W_1).

Evaporate to dryness on a steam bath and further dry at 105^{o}C for one or two hours in an oven.

Cool in desiccator and weight (W_2).

Repeat by further heating for 15 minutes and cooling until successive results do not differ by more than about 0.4 mg.

Calculation

$$\text{Dissolved solids mg/L} = \frac{(W_2 - W_1) \times 1000}{V}$$

Where
W_2 = Weight of residue and dish
W_1 = Weight of empty and dry dish
V = Weight of sample

Ozone Analysis

Reference:
DDPD method: Developed by CHEMetrics, Inc.
Indigo method: Bader, H. and Hoigne, J., "Determination of Ozone in Water by the Indigo Method," Water Research, Vol. 15, 449-456, 1981. APHA Standard Methods, 20th ed., p. 4-137, Method 4500-03 B (1998).

Ozone is a strong oxidizing agent. Ozonation is used as an alternative biocide and disinfectant to chlorination of drinking water. Ozone is used to remove odor, decolorize, and to control algae and other aquatic growths. Because ozone is unstable in water, monitoring ozone residuals is important to ensure that proper treatment levels are maintained.

The Colorimetric Methods

The DDPD chemistry employs a methyl substituted form of the DPD reagent. The A-7400 activator solution (potassium iodide) is added to the sample before analysis. Ozone reacts with the iodide to liberate iodine.

The iodine then reacts with the reagent to give a blue-violet color. Various free halogens and halogenating agents produce color with the reagent. Chromate in test samples below 25 ppm will not interfere with results.

Results are expressed as ppm (mg/L) O_3.The new ozone method employs the indigo trisulfonate reagent, which reacts instantly and quantitatively with ozone, bleaching the blue color in direct proportion to the amount of ozone present.

Malonic acid is included in the formulation to prevent interference from chlorine. Results are expressed as ppm (mg/L) O_3.

Examples of Water Sampling Letters and Forms

June 18, 2022

Wyatt Curtiss
1718 West Van Buren Street
Sunflower, AZ 85007

Dear Mr. Curtiss:

The City of Sunflower initially responded to your water quality concerns on May 19, 2015. We found insufficient chlorine in the drinking water at your business. We proceeded to flush and redirect the water in your area.

We resampled your area on two additional dates:

	May 28, 2016		July 25, 2016	
Address	Chlorine (mg/L)	CFU	Chlorine (mg/L)	CFU
310 N. 17th Dr.	O.3	780	0.8	<1
1708 W. Van Buren St.	0.2	305	0.6	8

Currently our results indicate good conditions in your area. According to our testing method, a CFU (Colony Forming Units) count of bacteria below 500 is considered adequately disinfected (passing). Other evidence of good water quality is the absence of Total Coliform and the *Escherichia coli* bacteria. This is indicated by the "-" (negative) results in the "Total Coliform" and the "E. Coli" columns of the Bacteriological Analysis Form.

Quality control is documented on the bottom of the Bacteriological Analysis Form. The results are normal and indicate that the incubator was kept at the correct temperature and that we were looking for the correct organisms.

All tests indicate that the drinking water being provided is safe. Should you have any questions regarding drinking water quality in the City of Sunflower, please contact me at 474-8888. Our office hours are 8:00 a.m. to 5:00 p.m., Monday through Friday.

Sincerely,

Bill Fields
Water Quality Inspector

<DATE>

<NAME>
<ADDRESS>

Dear <NAME>:

Thank you for collecting drinking water samples from your home for the City of Sunflower's Lead and Copper monitoring program. You will be receiving the test results soon -- if you haven't already.

Our tests show there is essentially no lead or copper in water coming to you from our water treatment plants. But we also need to know if our drinking water leaches lead or copper from your household plumbing. The only way we can learn this information is to analyze samples from inside your home.

Thanks again for your help. With the information we gain we can do an even better job of making sure your tap water meets all federal and state health and safety regulations.

Sincerely,

Chris Binder
Mayor

August 24, 2022

Doc Curtiss
1008 East Northern Avenue
Sunflower, Arizona 85020

Dear Mr. Curtiss:

The City of Sunflower responded to your water quality concerns on 11/27/15. We collected a bacteriological sample and checked the chlorine level at your home. The results are recorded on our worksheet, the Bacteriological Analysis Form, and are attached to this letter.

Our results indicate excellent conditions with 10 Colony Forming Units (CFU) per site. According to our testing method, a CFU count below 500 is considered adequately disinfected (passing). Other evidence of good water quality is the absence of Total Coliform and the Escherichia Coli bacteria. This is indicated by the "-" (negative) results in the Total Colif. and the E. Coli columns of the Bacteriological Analysis Form.

Quality control is documented on the bottom of the Bacteriological Analysis Form. The results are normal and indicate that the incubator was kept at the correct temperature and that we were looking for the correct organisms.

The chlorine level was checked at the same sampling site. The chlorine level was adequate with a reading of 0.7 mg/L.

All tests indicate that the drinking water being provided is safe. Should you have any questions, please contact me at 232-9508. Our office hours are 8:00 a.m. to 5:00 p.m., Monday through Friday.

Sincerely,

Bill Fields
Water Quality Inspector

Facts about Water Taste and Odor

Musty or earthy odors are something common to water systems that use surface water (rivers, streams and lakes) as a source of their drinking water. These odors are natural and are usually the result of algae growth. The growth is most common when air and water temperatures begin to drop in the fall as a result of changes in the weather. A certain temperature range makes algae grow more quickly in the surface water. The odor may occur intermittently through January.

Some people find the odor objectionable and/or a nuisance, but it represents no health hazard. The odor affects only the aesthetic quality of the water.

The Water Services Department treats water at treatment plants to ensure it meets all health and safety standards. We add chlorine to the water to protect against harmful organisms. The department regularly tests the drinking water for about 150 different compounds.

If you experience a musty odor in the water you drink, try the following:

- First, fill a water bottle and leave it uncapped on the counter for 30 to 60 minutes.
- Then, refrigerate the water for a few hours.
- If there still is some odor, try running the tap for 15 to 30 seconds before filling the water jug.
- Finally, inexpensive carbon filters can be added at the faucet to help eliminate the odors. However, remember to follow directions concerning maintenance such as cleaning or replacing the filter.

During seasonal changes, our water often contains 10-15 parts per trillion of the natural compound that creates the musty odor. Some people can detect the odor when there is as little as five parts per trillion in the water. For purposes of comparison, five parts per trillion is comparable to five seconds in 32,000 years.

Remember, the odor is seasonal and is not a health hazard. It usually occurs in the fall and disappears sometime during the winter.

Topic 3 - Water Laboratory Analysis Section

1. pH is a measure of the _____ or _____of an aqueous solution.

2. Primary pH standard values are determined using a concentration cell with transference, by measuring the potential difference between a hydrogen electrode and a standard electrode such as a silver chloride electrode.
True or False

3. Measurement of pH for aqueous solutions can be done with a glass electrode and a pH meter, or using indicators like_____.

4. Alkalinity is the quantitative capacity of an aqueous solution to neutralize a base.
True or False

5. There can be long-term changes in the _____of rivers and streams in response to human disturbances.

pH Indicators

6. Universal indicator consists of a mixture of indicators such that there is a continuous color change from about pH _____ to pH _____. Universal indicator paper is made from absorbent paper that has been impregnated with universal indicator.

Strong Acids and Bases

7. Strong acids and bases are _____that, for practical purposes, are completely dissociated in water.

8. pH is a measure of the concentration of _____ions present in water; alkalinity is a measure of water's ability to neutralize acids.

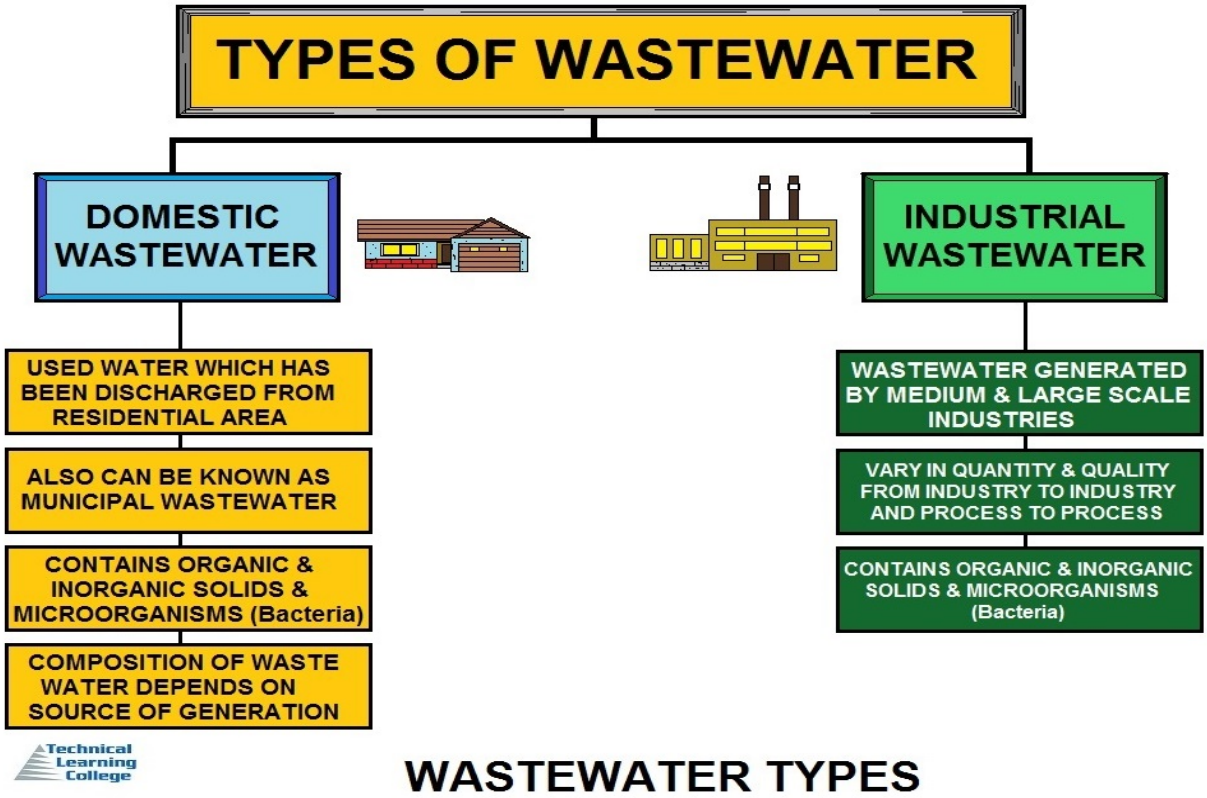
9. pH is not the only factor in the corrosion equation; _____and alkalinity levels affect corrosion as well.

10. Generally, an increase in pH and alkalinity can decrease corrosion rates and help form a protective layer of _____ on corrodible pipe material.

Topic 4 – Wastewater Section - Introduction

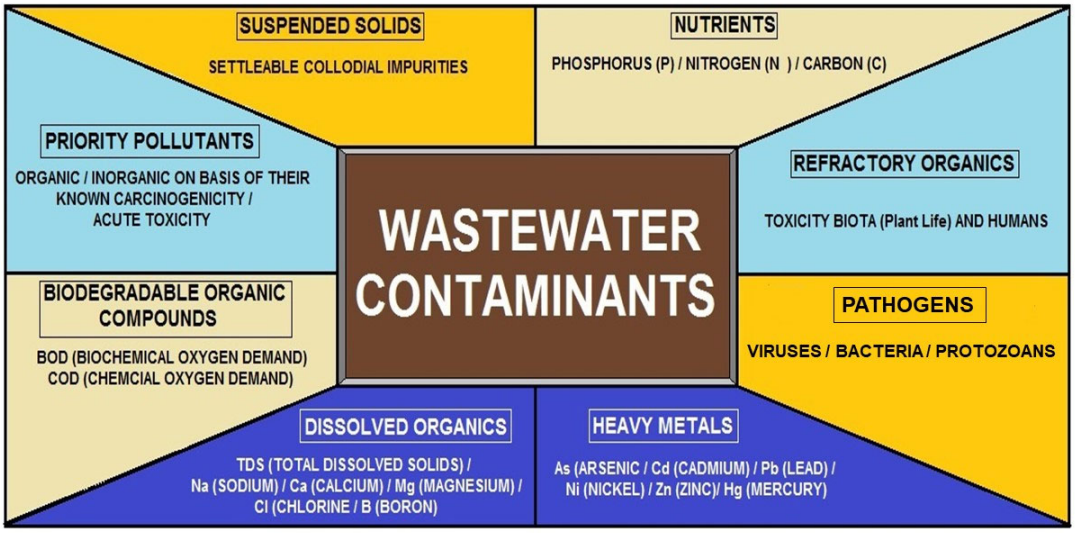
Section Focus: You will learn the basics of the Clean Water Act, the need for wastewater treatment and common wastewater constituents. At the end of this section, you will be able to describe the need for wastewater treatment and the composition/components of wastewater. There is a post quiz at the end of this section to review your comprehension and a final examination in the Assignment for your contact hours.

Scope/Background: Under the CWA, EPA has implemented pollution control programs such as setting wastewater standards for industry. EPA has also developed national water quality criteria recommendations for pollutants in surface waters.



The diagram above shows the difference between domestic wastewater and industrial wastewater. Not all communities have industrial waste and if they do, the plant generally treats a high volume of flow.

Always follow your NPDES permit for proper sampling and laboratory procedures.



Technical Learning College

TYPES OF WASTEWATER CONTAMINANTS

Above are the common wastewater contaminants that we must deal with correctly to achieve our permit requirements.

Domestic wastewater is typically composed of more than 99% water and only a small portion of the 1% may include components that endanger public health or the environment. Other materials make up only a small portion of wastewater, but can be present in large enough quantities to endanger public health and the environment.

Common Wastewater Compliance Terms

Acronym	Full Phrase
AA	Approval Authority
AO	Administrative Order
BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollutant Control Technology
BMP	Best Management Practices
BMR	Baseline Monitoring Report
BOD5	5-day Biochemical Oxygen Demand Test
BPJ	Best Professional Judgment
BPT	Best Practicable Control Technology Currently Available
CA	Control Authority
CFR	Code of Federal Regulations
CIU	Categorical Industrial User
CSO	Combined Sewer Overflow
CWA	Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972) Pub. L. 92-500, as amended by Pub. L. 95-217, Pub. L. 95-576, Pub. L. 96-483, Pub. L. 97-117, and Pub. L. 100-4, 33 U.S.C. 1251 et seq.
CWF	Combined Wastestream Formula
CWT	Centralized Waste Treater
DMR	Discharge Monitoring Report
DSE	Domestic Sewage Exclusion
DSS	Domestic Sewage Study
ELG	Effluent Limitations Guideline
EPA	Environmental Protection Agency
EPCRA	Emergency Preparedness and Community Right to Know Act
ERP	Enforcement Response Plan
FOG	Fats, Oils and Grease
FDF	Fundamentally Different Factors
FR	Federal Register
FWA	Flow Weighted Average
GPD	Gallons per Day
HABS	Harmful Algae Blooms
IU	Industrial User
LEL	Lower Explosive Limit
MAHL	Maximum Allowable Headworks Loading
MAIL	Maximum Allowable Industrial Loading
MGD	Million Gallons per Day
MPN	Most Probable Number
MSDS	Material Safety Data Sheet –Replaced By SDS, Safety Data Sheet
NAICS	North American Industry Classification System (replaces SIC 1998)
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council

NSPS	New Source Performance Standard
O&G	Oil and Grease
O&M	Operations and Maintenance
OCPSF	Organic Chemicals, Plastics, and Synthetic Fibers
P2	Pollution Prevention
PCA	Federal Water Pollution Control Act
PCI	Pretreatment Compliance Inspection
PCS	Permit Compliance System
PIRT	Pretreatment Implementation Review Task Force
POTW	Publicly Owned Treatment Works
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
SIC	Standard Industrial Classification
SIU	Significant Industrial User
SPCC	Spill Prevention Control and Countermeasures
SNC	Significant Noncompliance
SSO	Sanitary Sewer Overflow
SUO	Sewer Use Ordinance
TCLP	Toxicity Characteristic Leaching Procedure
TIE	Toxicity Identification Evaluation
TOMP	Toxic Organic Management Program
TRE	Toxicity Reduction Evaluation
TRI	Toxic Release Inventory
TSS	Total Suspended Solids
TTO	Total Toxic Organics
USC	United States Code
UST	Underground Storage Tank
WET	Whole Effluent Toxicity
WWTP	Wastewater Treatment Plant
µ	Micron

Wastewater Treatment Introduction

Wastewater treatment is the process of cleaning used water and sewage so it can be returned safely to our environment. Wastewater treatment is the last line of defense against water pollution. If you envision the water cycle as a whole, you can clean water produced by wastewater treatment is the same water that eventually ends up back in our lakes and rivers, where we get our drinking water.

Why Are Wastewater Treatment Plants Important?
Wastewater treatment plants are vital to our communities. They protect public health by eliminating disease-causing bacteria from water. By protecting water quality, wastewater treatment plants make it possible for us to safely enjoy the recreational use of clean oceans, lakes, streams and rivers.

33 U.S.C. s/s 1251 et seq. (1977)
The Clean Water Act (CWA) is a 1977 amendment to the Federal Water Pollution Control Act (PCA) of 1972, which set the basic structure for regulating discharges of pollutants to waters of the United States.

The law gave the EPA the authority to set effluent standards on an industry basis (technology-based) and continued the requirements to set water quality standards for all contaminants in surface waters. The CWA makes it unlawful for any person to discharge any pollutant from a point source into navigable waters unless a permit (NPDES) is obtained under the act.

The 1977 amendments focused on toxic pollutants. In 1987, the PCA was reauthorized and again focused on toxic substances, authorized citizen suit provisions, and funded sewage treatment plants (POTW's) under the Construction Grants Program.

The CWA provides for the delegation by the EPA of many permitting, administrative, and enforcement aspects of the law to state governments. In states with the authority to implement CWA programs, the EPA still retains oversight responsibilities.

In 1972, Congress enacted the first comprehensive national clean water legislation in response to growing public concern for serious and widespread water pollution. The Clean Water Act is the primary federal law that protects our nation’s waters, including lakes, rivers, aquifers, and coastal areas.

Lake Erie was dying. The Potomac River was clogged with blue-green algae blooms that were a nuisance and a threat to public health. Many of the nation's rivers were little more than open sewers and sewage frequently washed up on shore. Fish kills were a common sight. Wetlands were disappearing at a rapid rate.

Today, the quality of our waters has improved dramatically as a result of a cooperative effort by federal, state, tribal and local governments to implement the pollution control programs established in 1972 by the Clean Water Act.

The Clean Water Act's primary objective is to restore and maintain the integrity of the nation's waters. This objective translates into two fundamental national goals:

- eliminate the discharge of pollutants into the nation's waters, and
- achieve water quality levels that are fishable and swimmable.

The Clean Water Act focuses on improving the quality of the nation’s waters. It provides a comprehensive framework of standards, technical tools and financial assistance to address the many causes of pollution and poor water quality. This includes municipal and industrial wastewater discharges, polluted runoff from urban and rural areas, and habitat destruction.

For example, the Clean Water Act requires major industries to meet performance standards to ensure pollution control; charges states, and tribes with setting specific water quality criteria appropriate for their waters and developing pollution control programs to meet them; provides funding to states and communities to help them meet their clean water infrastructure needs; protects valuable wetlands and other aquatic habitats through a permitting process that ensures development, and other activities are conducted in an environmentally sound manner. After 48 years, the act continues to provide a clear path for clean water and a solid foundation for an effective national water program.

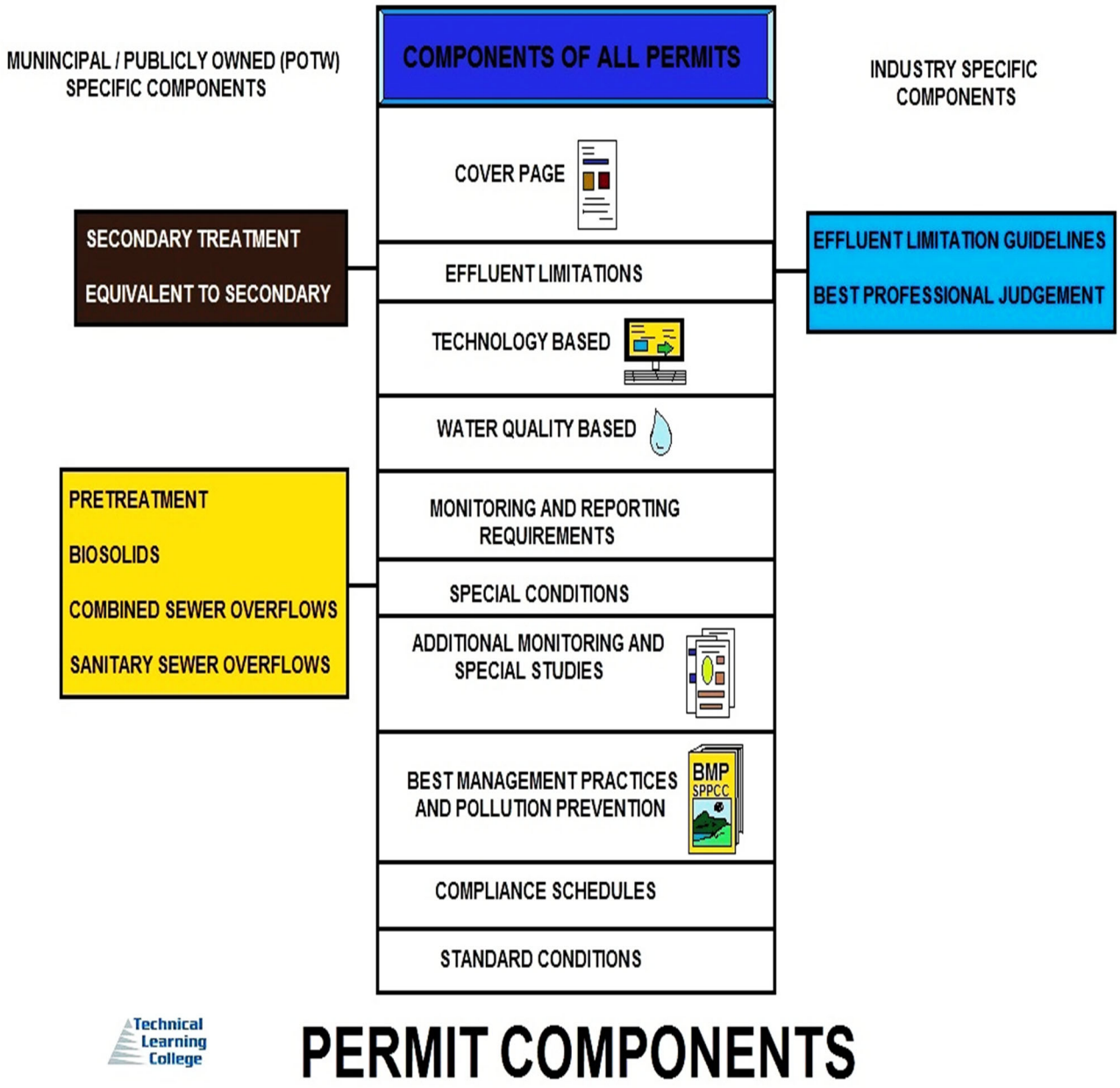
In 1972
Only a third of the nation's waters were safe for fishing and swimming. Wetlands losses were estimated at about 460,000 acres annually.

Agricultural runoff resulted in the erosion of 2.25 billion tons of soil and the deposit of large amounts of phosphorus and nitrogen into many waters. Sewage treatment plants served only 85 million people.

Today
Two-thirds of the nation's waters are safe for fishing and swimming. The rate of annual wetlands losses is estimated at about 70,000-90,000 acres according to recent studies.

The amount of soil lost due to agricultural runoff has been cut by one billion tons annually, and phosphorus and nitrogen levels in water sources are down. Modern wastewater treatment facilities serve 173 million people.

The Future
All Americans will enjoy clean water that is safe for fishing and swimming. We will achieve a net gain of wetlands by preventing additional losses and restoring hundreds of thousands of acres of wetlands. Soil erosion and runoff of phosphorus and nitrogen into watersheds will be minimized, helping to sustain the nation's farming economy and aquatic systems. The nation's waters will be free of effects of sewage discharges.



NPDES Permit Foreword

Once a wastewater plant is designed and built, state or federal agencies will determine the type of permit required using the information illustrated above. You will need to understand that this discharge permit is your legal standard for proper sampling, treatment and discharging. You must abide by your permit requirements and not deviate from them based on information presented in this course.

Clean Water Act Secondary Treatment Standards (40 CFR § 133.102)

The following paragraphs describe the minimum level of effluent quality attainable by secondary treatment in terms of the parameters - BOD5, SS and pH. All requirements for each parameter shall be achieved except as provided for in §§ 133.103 and 133.105.
(a) *BOD*5.
(1) The 30-day average shall not exceed 30 mg/l.
(2) The 7-day average shall not exceed 45 mg/l.
(3) The 30-day average percent removal shall not be less than 85 percent.
(4) At the option of the NPDES permitting authority, in lieu of the parameter BOD5 and the levels of the effluent quality specified in paragraphs (a)(1), (a)(2) and (a)(3), the parameter CBOD5 may be substituted with the following levels of the CBOD5 effluent quality provided:
(i) The 30-day average shall not exceed 25 mg/l.
(ii) The 7-day average shall not exceed 40 mg/l.
(iii) The 30-day average percent removal shall not be less than 85 percent.

(b) *SS.* (1) The 30-day average shall not exceed 30 mg/l.
(2) The 7-day average shall not exceed 45 mg/l.
(3) The 30-day average percent removal shall not be less than 85 percent.

(c) *pH.* The effluent values for pH shall be maintained within the limits of 6.0 to 9.0 unless the publicly owned treatment works demonstrates that: (1) Inorganic chemicals are not added to the waste stream as part of the treatment process; and (2) contributions from industrial sources do not cause the pH of the effluent to be less than 6.0 or greater than 9.0.

Terms used in this part are defined as follows:
(a) *7-day average.* The arithmetic mean of pollutant parameter values for samples collected in a period of 7 consecutive days.
(b) *30-day average.* The arithmetic mean of pollutant parameter values of samples collected in a period of 30 consecutive days.
(c) *Act.* The Clean Water Act (33 U.S.C. 1251 *et seq.,* as amended).
(d) *BOD.* The five day measure of the pollutant parameter biochemical oxygen demand (BOD).
(e) *CBOD*5. The five day measure of the pollutant parameter carbonaceous biochemical oxygen demand (CBOD5).
(f) *Effluent concentrations consistently achievable through proper operation and maintenance.* (1) For a given pollutant parameter, the 95th percentile value for the 30-day average effluent quality achieved by a treatment works in a period of at least two years, excluding values attributable to upsets, bypasses, operational errors, or other unusual conditions, and (2) a 7-day average value equal to 1.5 times the value derived under paragraph (f)(1) of this section.

Wastewater Treatment Process Preface

During the early days of our nation's history, people living in both the cities and the countryside used cesspools and privies to dispose of domestic wastewater. Cities began to install wastewater collection systems in the late nineteenth century because of an increasing awareness of waterborne disease and the popularity of indoor plumbing and flush toilets.

The use of sewage collection systems brought dramatic improvements to public health, further encouraging the growth of metropolitan areas. In the year 2000, approximately 208 million people in the U.S. were served by centralized collection systems.

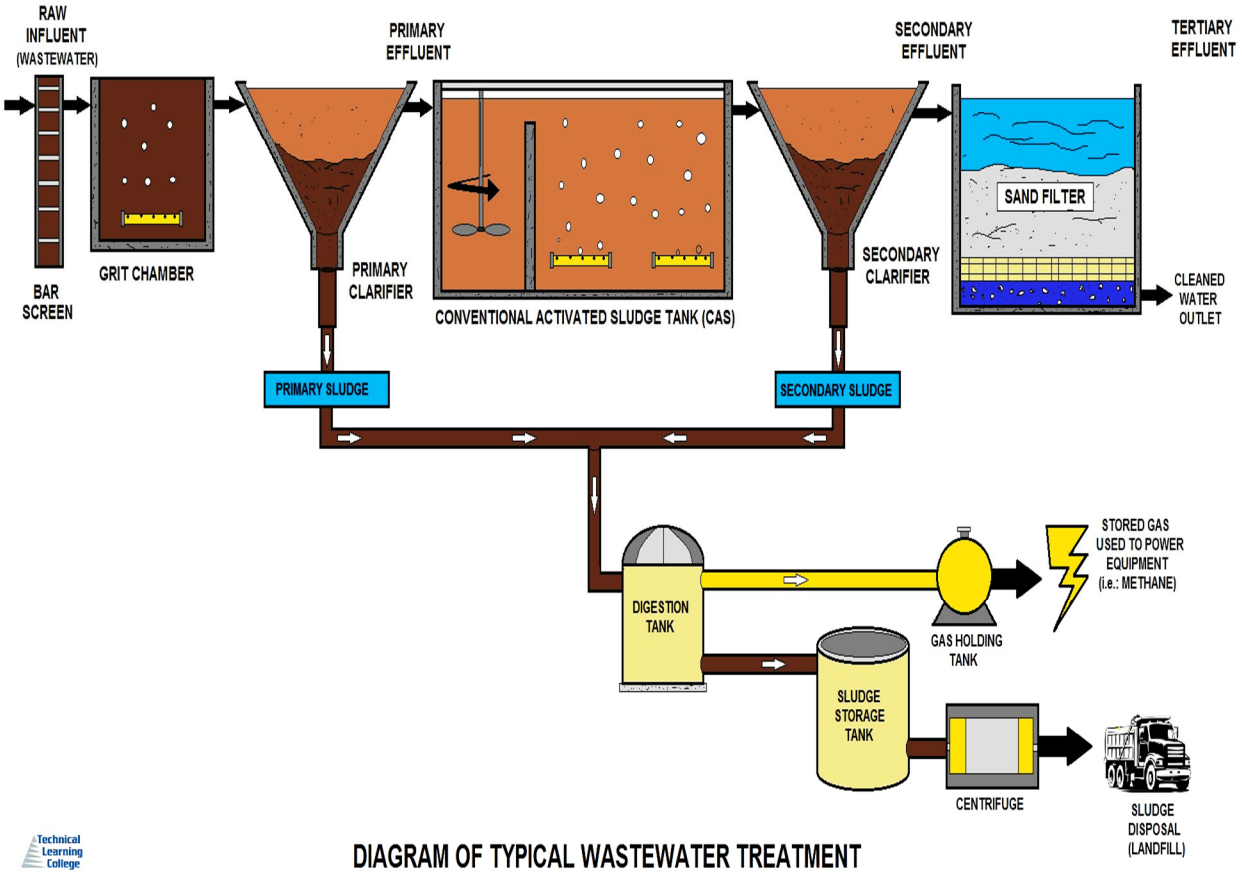


DIAGRAM OF TYPICAL WASTEWATER TREATMENT

Physical, Biological or Chemical Wastewater Treatments

There are two wastewater treatment processes namely chemical or physical treatment, and biological wastewater treatment or a mixture of the two processes. Biological waste treatment plants use biological matter and bacteria to break down waste matter. Physical waste treatment plants use chemical reactions as well as physical processes to treat wastewater. Biological treatment systems are ideal for treating wastewater from households and business premises.

Primary Treatment
As sewage enters a plant for treatment, it flows through a screen, which removes large floating objects such as rags and sticks that might clog pipes or damage equipment. After sewage has been screened, it passes into a grit chamber, where cinders, sand, and small stones settle to the bottom. A grit chamber is particularly important in communities with combined sewer systems where sand or gravel may wash into sewers along with storm water. After screening is completed and grit has been removed, sewage still contains organic and inorganic matter along with other suspended solids.

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

Biosolids are usually removed from tanks by pumping, after which it may be further treated for use as a fertilizer, or disposed of in a land fill or incinerated. Over the years, primary treatment alone has been unable to meet many communities' demands for higher water quality. To meet them, cities and industries normally treat to a secondary treatment level, and in some cases, also use advanced treatment to remove nutrients and other contaminants.

Secondary Treatment
The secondary stage of treatment removes about 85 percent of the organic matter in sewage by making use of the bacteria in it. The principal secondary treatment techniques used in secondary treatment are the trickling filter and the activated sludge process. After effluent leaves the sedimentation tank in the primary stage it flows or is pumped to a facility using one or the other of these processes. A trickling filter is simply a bed of stones from three to six feet deep through which sewage passes.

More recently, interlocking pieces of corrugated plastic or other synthetic media have also been used in trickling beds. Bacteria gather and multiply on these stones until they can consume most of the organic matter. The cleaner water trickles out through pipes for further treatment. From a trickling filter, the partially treated sewage flows to another sedimentation tank to remove excess bacteria. The trend today is towards the use of the activated sludge process instead of trickling filters.

The activated sludge process speeds up the work of the bacteria by bringing air and sludge heavily laden with bacteria into close contact with sewage. After the sewage leaves the settling tank in the primary stage, it is pumped into an aeration tank, where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. During this time, the bacteria break down the organic matter into harmless by-products.

The sludge, now activated with additional billions of bacteria and other tiny organisms, can be used again by returning it to the aeration tank for mixing with air and new sewage. From the aeration tank, the partially treated sewage flows to another sedimentation tank for removal of excess bacteria. To complete secondary treatment, effluent from the sedimentation tank is usually disinfected with chlorine before being discharged into receiving waters. Chlorine is fed into the water to kill pathogenic bacteria, and to reduce odor.

What Exactly is in Wastewater?

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

Domestic Wastewater Quality Characteristics

Typical Composition of Untreated Domestic Wastewater -Table 1

CONTAMINANTS	UNITS	LOW STRENGTH	MEDIUM STRENGTH	HIGH STRENGTH
Solids, total (TS)	mg/L	390	720	1220
Dissolved, total (TDS)	mg/L	270	500	860
Fixed	mg/L	160	300	520
Volatile	mg/L	110	200	340
Suspended solids, total (TSS)	mg/L	120	210	400
Fixed	mg/L	25	50	85
Volatile	mg/L	95	160	315
Settleable solids	mg/L	5	10	20
Biochemical Oxygen Demand				
5-d, 20°C (BOD_5 20°C)	mg/L	110	190	350
Total organic carbon	mg/L	80	140	260
Chemical oxygen demand (COD)	mg/L	250	430	800
Nitrogen (total as N)	mg/L	20	40	70
Organic	mg/L	8	15	25
Free ammonia	mg/L	12	25	45
Nitrites	mg/L	0	0	0
Nitrates	mg/L	0	0	0
Phosphorus (total as P)	mg/L	4	7	12
Organic	mg/L	1	2	4
Inorganic	mg/L	3	5	10
Chlorides	mg/L	30	50	90
Sulfate	mg/L	20	30	50
Oil and Grease	mg/L	50	90	100
Volatile organic compounds (VOCs)	mg/L	<100	100-400	>400
Total coliform	No./100 mL	10^6-10^8	10^7-10^9	10^7-10^{10}
Fecal Coliform	No./100 mL	10^3-10^5	10^4-10^6	10^5-10^8
Cryptosporidium oocysts	No./100 mL	10^{-1} – 10^0	10^{-1}-10^1	10^{-1}-10^2
Giardia lamblia cysts	No./100 mL	10^{-1}-10^1	10^{-1}-10^2	10^{-1}-10^3

Source: Metcaff & Eddy. "Wastewater Engineering Treatment and Reuse. 4th ed. Boston: McGraw –Hill, 2003 (p.186)

Typical Composition of Untreated Domestic Wastewater -Table 2

PARAMETER	UNIT[3]	CONCENTRATED	MODERATE	DILUTED	VERY DILUTED
Biochemical oxygen demand (BOD)	g O_2/m^3				
Infinite BOD	g O_2/m^3	530	380	230	150
7-day BOD	g O_2/m^3	400	290	170	115
5-day BOD	g O_2/m^3	350	250	150	100
Dissolved BOD	g O_2/m^3	140	100	60	40
Dissolved BOD Very Easily Degradable	g O_2/m^3	70	50	30	20
After 2 hours of settling	g O_2/m^3	250	175	110	70
Total nitrogen	g N/m^3	80	50	30	20
Ammonium nitrogen[1]	g N/m^3	50	30	18	12
Nitrite nitrogen	g N/m^3	0.1	0.1	0.1	0.1
Nitrate nitrogen	g N/m^3	0.5	0.5	0.5	0.5
Organic nitrogen	g N/m^3	30	20	12	8
Kjeldahl nitrogen[2]	g N/m^3	80	50	30	20
Total phosphorus	g P/m^3	14	10	6	4
Orthophosphate	g P/m^3	10	7	4	3
Polyphosphate	g P/m^3	0	0	0	0
Organic phosphate	g P/m^3	4	3	2	1

Legend
[1] $NH_3+NH_4^+$
[2] org-$(N+NH_3 + NH4^+)$
[3] g/m3 = mg/L =ppm

Reference: Henze, Mogens, Paul Harremoes, Jes la Cour Jansen, and Eric Arvin, "Wastewater Treatment, Biological and Chemical Processes." Third Edition. Berlin. Springer-Verlag 2002. Specially, the data is from Table 1.7, Typical organic matter in domestic wastewater (p. 28) and Table 1.8 Typical content of nutrients in domestic wastewater (p. 29)

Conventional Wastewater Treatment Processes

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

Biological or Secondary Treatment
In nature, bacteria in water consume organic matter to grow and reproduce. Aerobic bacteria near the water surface, where oxygen is present, produce carbon dioxide as a by-product. Anaerobic bacteria in or near the bottom sediments, where there is little or no oxygen, produce methane and smaller amounts of other gases as a byproduct. The bacteria normally present in water must have oxygen to do their part in breaking down the sewage.

In the 1920s, scientists observed that these natural processes could be contained and accelerated in systems to remove organic material from wastewater.

With the addition of oxygen to wastewater, masses of microorganisms grew and rapidly metabolized organic pollutants.

Any excess microbiological growth could be removed from the wastewater by physical processes. Activated Sludge is a suspended growth process for removing organic matter from sewage by saturating it with air and microorganisms that can break down the organic matter. Advanced Treatment involves treatment levels beyond secondary treatment.

The mass of bacteria in an aeration tank came to be called “mixed liquor”. Here, floating bacteria stick to organic matter forming small clumps called “floc”. Floc is slightly denser than water so once the mixed liquor flows into a tank not being agitated by the addition of oxygen, it settles to the bottom. From here, some is returned to the head of the aeration tank to maintain the bacterial population. This is called returned activated sludge (RAS). Excess is removed (or “wasted”) from the system. This is waste activated sludge (WAS). Part of the job of a wastewater plant operator is to adjust the waste and return rates to maintain the optimum ratio of bacteria to the fluctuating amount of organic matter arriving as primary tank effluent. If there are too few bacteria, they won’t remove enough organics to meet permit requirements. If there are too many, they will not have enough to eat, and their removal efficiency will decline.

Chemical
Chemicals can be used to create changes in pollutants that increase the removal of these new forms by physical processes. Simple chemicals such as alum, lime or iron salts can be added to wastewater to cause certain pollutants, such as phosphorus, to floc or bunch

together into large, heavier masses which can be removed faster through physical processes.

Over the past 30 years, the chemical industry has developed synthetic inert chemicals known as polymers to further improve the physical separation step in wastewater treatment. Polymers are often used at the later stages of treatment to improve the settling of excess microbiological growth or biosolids.

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

Bacteria and other microorganisms are particularly plentiful in wastewater and accomplish most of the treatment. Most wastewater treatment systems are designed to rely in large part on biological processes. We will cover this area in greater detail later in the course.

Pathogens
Many disease-causing viruses, parasites, and bacteria also are present in wastewater and enter from almost anywhere in the community. These pathogens often originate from people and animals that are infected with or are carriers of a disease.

Graywater and blackwater from typical homes contain enough pathogens to pose a risk to public health. Other likely sources in communities include hospitals, schools, farms, and food processing plants.

Some illnesses from wastewater-related sources are relatively common.

Gastroenteritis can result from a variety of pathogens in wastewater, and cases of illnesses caused by the parasitic protozoa Giardia lambia and Cryptosporidium are not unusual in the U.S.

Other important wastewater-related diseases include hepatitis A, typhoid, polio, cholera, and dysentery.

Outbreaks of these diseases can occur as a result of drinking water from wells polluted by wastewater, eating contaminated fish, or recreational activities in polluted waters. Some illnesses can be spread by animals and insects that come in contact with wastewater.

Even municipal drinking water sources are not completely immune to health risks from wastewater pathogens.

Drinking water treatment efforts can become overwhelmed when water resources are heavily polluted by wastewater. For this reason, wastewater treatment is as important to public health as drinking water treatment. We will cover this area in greater detail later in the course.

Primary Wastewater Components and Constituents

Important Wastewater Characteristics

In addition to the many substances, (liquids, inorganics-solids, trash, contaminants) found in wastewater, there are other characteristics system engineers and operators use to evaluate wastewater. For example, the color, temperature, pH, odor, DO, Total Solids and turbidity of wastewater give clues about the amount and type of pollutants present and treatment necessary. We will examine these characteristics, which can affect public health and the environment, as well as the design, cost, and effectiveness of treatment.

Essential Wastewater Treatment Terms

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

Aerobic Bacteria (Aerobes) – bacteria which will live and reproduce only in an environment containing oxygen. Oxygen combined chemically, such as in water molecules (H_2O), cannot be used for respiration by aerobes.

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

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

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

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

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

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

Organic Matter

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

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

ORGANIC LOADING RATE

Organic loading rate is defined as the application of soluble and particulate organic matter. It is typically expressed on an area basis as pounds of BOD5 per unit area per unit time, such as pounds of BOD5 per square foot per day (lb/ft^2/day). The concept of using **organic loading rates** to size an infiltration surface is based on the currently allowable hydraulic loading rates and typical organic concentrations of residential septic tank effluent (STE).

Technical Learning College

Large amounts of biodegradable materials are dangerous to lakes, streams, and oceans, because organisms use dissolved oxygen in the water to break down the wastes. This can reduce or deplete the supply of oxygen in the water needed by aquatic life, resulting in fish kills, odors, and overall degradation of water quality. This is called eutrophication.

The amount of oxygen organisms need to break down wastes in wastewater is referred to as the biochemical oxygen demand (BOD) and is one of the measurements used to assess overall wastewater strength. Some organic compounds are more stable than others and cannot be quickly broken down by organisms, posing an additional challenge for treatment. This is true of many synthetic organic compounds developed for agriculture and industry.

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

Fats, Oil and Grease (Scum)

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

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

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

FAT AND GREASE REMOVAL

In some larger plants, **fat and grease** are removed by passing the sewage through a small tank where skimmers collect the fat floating on the surface. Air blowers in the base of the tank may also be used to help recover the fat as a froth. Many plants, however, use primary clarifiers with mechanical surface skimmers for fat and grease removal.

Volatile Fatty Acid
Volatile fatty acid **(VFA)** analysis forms an important means of assessing the effectiveness of the digestion process within a wastewater treatment plant. This new analytical technique provides wastewater treatment plant operators with a much improved means of being able to optimize the operation of the digesters in the wastewater treatment plants.

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

Large amounts of many inorganic substances can contaminate soil and water. Some are toxic to animals and humans and may accumulate in the environment. For this reason, extra treatment steps are often required to remove inorganic materials from industrial wastewater sources. For example, heavy metals which are discharged with many types of industrial wastewaters are difficult to remove by conventional treatment methods. Although acute poisonings from heavy metals in drinking water are rare in the U.S., potential long-term health effects of ingesting small amounts of some inorganic substances over an extended period of time are possible.

Nutrient Introduction ***(we will return to this subject in detail later.)***
Wastewater often contains large amounts of the nutrients nitrogen and phosphorus in the form of nitrate and phosphate, which promote plant growth. Organisms only require small amounts of nutrients in biological treatment, so there normally is an excess available in treated wastewater.

In severe cases, excessive nutrients in receiving waters cause algae and other plants to grow quickly depleting oxygen in the water. Water deprived of oxygen, fish and other aquatic life die, emitting foul odors.

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

NUTRIENTS

Nutrients are components in foods that an organism uses to survive and grow. Macronutrients provide the bulk energy an organism's metabolic system needs to function while micronutrients provide the necessary cofactors for metabolism to be carried out. Both types of nutrients can be acquired from the environment.

Technical Learning College

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

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

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

The release of large amounts of nutrients, primarily phosphorus but occasionally nitrogen, causes nutrient enrichment which results in excessive growth of algae.

Uncontrolled algae growth blocks out sunlight and chokes aquatic plants and animals by depleting dissolved oxygen in the water at night. The release of nutrients in quantities that exceed the affected waterbody’s ability to assimilate them results in a condition called eutrophication or cultural enrichment.

Because nutrients are very essential to the process, we will cover this in several different sections.

Gases

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

Solids Sub-Section - Introduction

Wastewater contains nutrients of every type; phosphorus, nitrogen, sodium, potassium, iron, calcium and compounds such as fats, sugars and proteins. Microorganisms use these substances as a “food” source for energy, for the synthesis of cell components and to maintain life processes.

Many types of microorganisms can be found in the wastewater treatment system. However, the types of organisms that will dominate will be the ones that are best suited to the “environment” or conditions in the system.

Organic and/or Inorganic Materials

Solid materials in wastewater can consist of organic and/or inorganic materials and organisms. *Much more information on this subject in the Laboratory section*.

Organic and/or Inorganic Materials

Solid materials in wastewater can consist of organic and/or inorganic materials and organisms. The solids must be significantly reduced by treatment or an excessive amount of BOD will be discharged to receiving waters. Solids are removed because they provide places for microorganisms to escape disinfection. They also can clog soil absorption fields in onsite systems.

Settleable Solids

Certain substances, such as sand, grit, and denser than water organic and inorganic materials settle out from the rest of the wastewater collection system or stream during the primary treatment tanks. On the bottom of settling tanks and ponds, organic material makes up a biologically active layer of sludge that aids in treatment. During normal plant operation, only small amounts of settable solids are discharged.

Suspended Solids

Materials that resist settling may remain suspended in wastewater, especially if the wastewater is moving. Suspended solids needs to be reduced to a low level to not interfere with disinfection systems or lower the water quality of the receiving water. Suspended solids in wastewater must be treated, or they will clog soil absorption systems or reduce the effectiveness of disinfection systems.

Dissolved Solids

Small particles of certain wastewater materials can dissolve, like salt in water. Some dissolved materials are consumed by microorganisms in wastewater.

Others dissolved solids, such as heavy metals, are difficult to remove by conventional treatment. Excessive amounts of dissolved solids in wastewater can have adverse effects on the environment.

Total Suspended Solids (TSS)

Total suspended solids (TSS) is the dry-weight of suspended particles that are not dissolved, in a sample of water that can be trapped by a filter that is analyzed using a filtration apparatus. It is a water quality parameter used to assess the quality of a specimen of any type of water or water body, ocean water for example, or wastewater after treatment

in a wastewater treatment plant. It is listed as a conventional pollutant in the U.S. Clean Water Act.

Total dissolved solids is another parameter acquired through a separate analysis which is also used to determine water quality based on the total substances that are fully dissolved within the water, rather than undissolved suspended particles.

Types of Solids on Wastewater

ACRONYM	COMMON TERM	EXPLANATION
TSS	Total Suspended Solids	Solids that cannot pass through a 1.2-µm filter.
TVSS	Total Volatile Suspended Solids	Solids that cannot pass through a 1.2 - µm filter and are burned away when placed in a furnace at 550^{o} C.
TDS	Total Dissolved Solids	Solids that are small enough to pass through a 1.2 - µm filter. The sample must be dried completely before the dissolved solids can be seen with the naked eye.
TS	Total Solids	All of the solid material in a sample. This includes both organic and inorganic solids. TS = TSS + TDS
TVS	Total Volatile Solids	All of the solids in a sample that are burned away when placed in a furnace at 550^{o} C

Hydrogen Sulfide and Ammonia Sub-Section

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

Hydrogen sulfide or H_2S problems are very common in the collection and wastewater system. There are many chemicals used to help or treat this problem.

The best method of controlling hydrogen sulfide is to eliminate its habitat or growth area by keeping sewers cleaner, this will harbor fewer slime bacteria. Here are some important statements regarding the reduction of hydrogen sulfide: Salts of zinc and iron may precipitate sulfides, lime treatments can also kill bacteria that produce hydrogen sulfide, but this creates a sludge disposal problem and chlorination is effective at reducing the bacteria which produce hydrogen sulfide. Hydrogen sulfide conditions occur in the sewer system because of the lack of oxygen.

HYDROGEN SULFIDE

Hydrogen sulfide is the chemical compound with the chemical formula **H_2S**. It is a colorless gas with the characteristic foul odor of rotten eggs. It is very poisonous, corrosive, and flammable. **Hydrogen sulfide** is often produced from the microbial breakdown of organic matter in the absence of oxygen gas, such as in swamps and sewers; this process is commonly known as anaerobic digestion that is done by sulfate-reducing microorganisms.

Technical Learning College

ODORS

Odors emitted by sewage treatment are typically an indication of an anaerobic or "septic" condition. Early stages of processing will tend to produce foul-smelling gases, with hydrogen sulfide being most common in generating complaints.

Large process plants in urban areas will often treat the odors with carbon reactors, a contact media with bio-slimes, small doses of chlorine, or circulating fluids to biologically capture and metabolize the noxious gases. Other methods of odor control exist, including addition of iron salts, hydrogen peroxide, calcium nitrate, etc. to manage hydrogen sulfide levels.

Technical Learning College

Nutrient Introduction

Influent wastewater contains the micronutrients nitrogen, potassium and phosphorus as well as trace nutrients like iron and manganese. Nitrogen is present in many compounds in wastewater influent including urea or urine, organically bound nitrogen (proteins and other compounds), and ammonia. Organically bound nitrogen can be soluble or particulate, whereas ammonia is only present as soluble. Phosphorus is found in particulate or dissolved forms. Phosphorus is present in proteins, urine and detergents. *Much more information on this subject in the Nutrient section.*

WASTEWATER ANALYTICAL CATEGORIES	
ORGANICS	BOD (Biological Oxygen Demand COD (Chemical Oxygen Demand TOC (Total Organic Carbon) O&G (Oil and Grease)
SOLIDS	TS (Total Solids) TVS (Total Volatile Solids) TSS (Total Suspended Solids)
PHYSICAL PROPERTIES	pH (0 to 14 pH Scale) Temperature Turbidity Color & Odor
NUTRIENTS	NH (Nihonium) TKN (Total Kjeldahl Nitrogen) N-N (Nitrate to Nitrite) TP (Total Phosphorus)

Technical Learning College

INTERACTION OF WASTEWATER ANALYTICAL CATEGORIES AND LAB TESTS

Biological Components Sub-Section Introduction

Biochemical Oxygen Demand or BOD Introduction
Wastewater is composed of a variety of inorganic and organic substances.

Organic substances refer to molecules that are based on carbon and include fecal matter as well as detergents, soaps, fats, greases and food particles (especially where garbage grinders are used). These large organic molecules are easily decomposed by bacteria in POTW or the septic system.

However, oxygen is required for this process of breaking large molecules into smaller molecules and eventually into carbon dioxide and water.

The amount of oxygen required for this process is known as the biochemical oxygen demand or BOD.
The five-day BOD, or BOD_5 lab test, is measured by the quantity of oxygen consumed by microorganisms or bacteria under controlled conditions during a five-day period, and is the most common measure of the amount of biodegradable organic material in, or strength of, sewage.

We will cover this area in detail in several different areas of this course. We will cover this area in about ten more pages and again in the Microorganism and Laboratory Sections at the end of the course. Please make notes on this difficult subject.

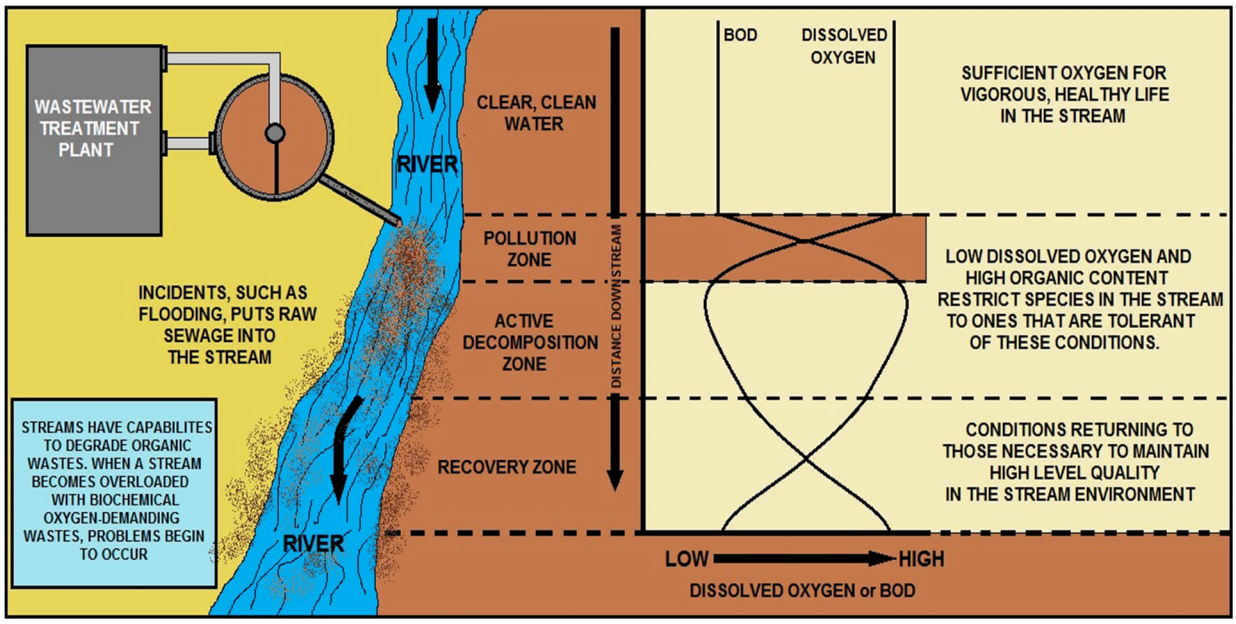
Biochemical Oxygen Demand
Biochemical Oxygen Demand (**BOD or BOD5**) is an indirect measure of biodegradable organic compounds in water, and is determined by measuring the dissolved oxygen decrease in a controlled water sample over a five-day period.

During the five-day period, **aerobic** bacteria (oxygen-consuming) decompose organic matter in the sample and consumes dissolved oxygen in proportion to the amount of organic material that is present. Then what happens is a high BOD concentration of substance can be biologically degraded, thus consuming oxygen and possibly resulting in low dissolved oxygen in the receiving water.

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

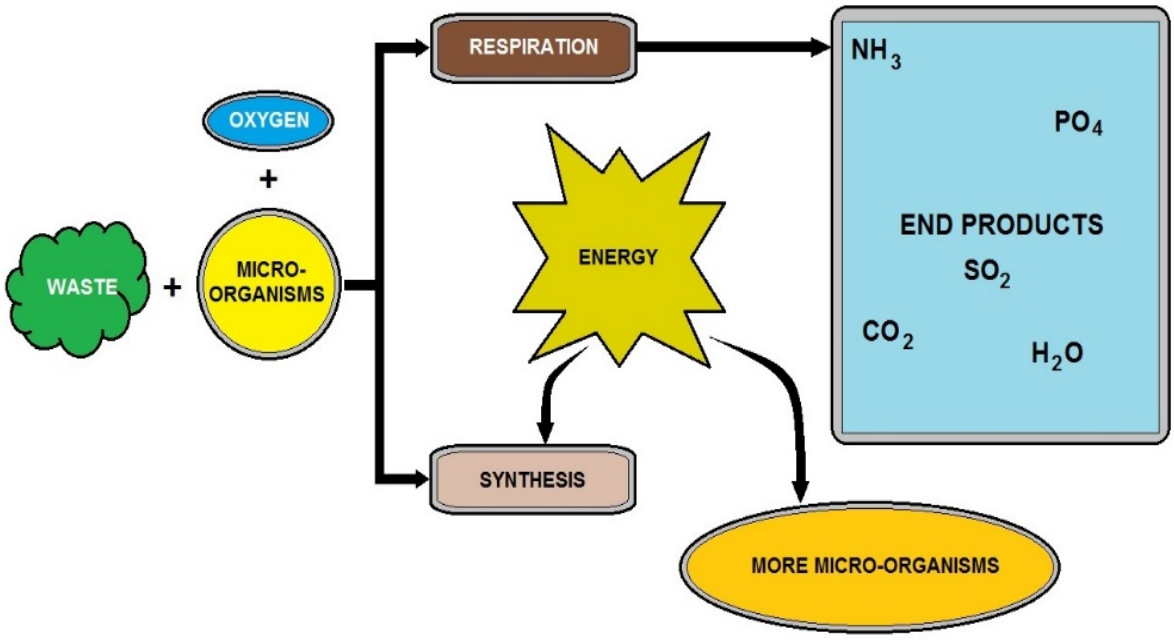
Organic Carbon
Most organic carbon in water occurs as partly degraded plant and animal materials, some of which are resistant to microbial degradation.

Organic carbon is important in the estuarine food web and is incorporated into the ecosystem by photosynthesis of green plants, then consumed as carbohydrates and other organic compounds by higher animals. In another process, formerly living tissue containing carbon is decomposed as detritus by bacteria and other microbes.



Technical Learning College

EFFECTS OF BOD ON WATER QUALITY



BASICS OF WASTEWATER MICROORGANISMS BREAKDOWN

Chemical Reaction Introduction

There are thousands of chemical reactions involved in the metabolism of a bacterium this diagram identifies three major processes that are relevant to the biological treatment of wastewater. These are Ingestion, Respiration, Growth and division.

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

Clarification
A process to reduce the concentration of suspended matter in water. In the activated sludge treatment process, the removal of suspended solids from wastewater is usually through gravity separation in a clarifier.

Waste Activated Sludge
The activated sludge (excess biomass or cell mass) removed from the secondary treatment process. For most treatment plants, this will be a portion of the Return Activated Sludge (RAS) flow stream.

Return Activated Sludge
The settled activated sludge (biomass) that is collected in a secondary clarifier and returned to the secondary treatment process to mix with incoming wastewater. This returns a concentrated population of microorganisms back into the aeration basin.

Sludge Volume Index
A numerical expression of the settling characteristics of activated sludge in the final clarifier. SVI is expressed as the ratio of the volume in milliliters of activated sludge settled from a 1,000-mL sample in 30 minutes divided by the concentration of mixed liquor in milligrams per liter multiplied by 1,000. A good settling sludge (textbook value) is 100, but can commonly be between 80-150.

CHEMICAL OXYGEN DEMAND

Oxidizable chemicals (such as reducing chemicals) introduced into a natural water will similarly initiate chemical reactions (such as shown above). Those chemical reactions create what is measured in the laboratory as the **chemical oxygen demand (COD).**

Technical Learning College

B.O.D.

Biochemical Oxygen Demand (**BOD**, also called **Biological Oxygen Demand**) is the amount of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The **BOD** value is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water.

Technical Learning College

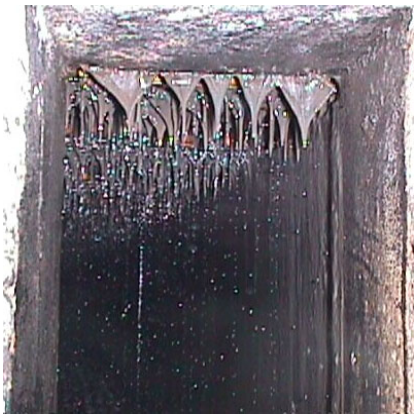
BOD and COD Reduction

Wastewater treatment plants (POTWs) are designed to reduce the BOD and COD in the effluent discharged to receiving or natural waters. The goal is to meet state and federal discharge criteria and protect the environment. It has been said that wastewater treatment plants are designed to function as "microbiology farms," where bacteria and other microorganisms are fed oxygen and organic waste. Wastewater plant operators are farmers striving to create optimum conditions for their crop of bacteria. Pretreatment inspectors protect this bacteria crop.

Treatment of wastewater usually involves biological processes such as the activated sludge system in the secondary stage after preliminary screening to remove coarse particles and primary sedimentation that settles out suspended solids. These secondary treatment steps are generally considered environmental biotechnologies that harness natural self-purification processes contained in bioreactors for the biodegradation of organic matter and bioconversion of soluble nutrients in the wastewater.

Application Specific Microbiology

Each wastewater stream is unique, and so too are the community of microorganisms that process it. This "application-specific microbiology" is the preferred methodology in wastewater treatment affecting the efficiency of biological nutrient removal. The right laboratory prepared bugs are more efficient in organics removal if they have the right growth environment.



Draining Biofilm

This efficiency is multiplied if microorganisms are allowed to grow as a layer of biofilm on specifically designed support media. In this way, optimized biological processing of a waste stream can occur. To reduce the start-up phase for growing a mature biofilm one can also purchase "application specific bacterial cultures" from appropriate microbiology vendors.

Aeration is often used to refresh the wastewater flow at the influent channel.

Pollutants - Oxygen-Demanding Substances

CONVENTIONAL POLLUTANTS

POTWs are designed to treat typical household wastes and biodegradable commercial and biodegradable industrial wastes. The Clean Water Act defines the contaminants from these sources as **conventional pollutants**. **Conventional pollutants** are biological oxygen demand (BOD), total suspended solids (TSS), fecal coliform, oil and grease, and pH**.**

Technical Learning College

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

Oxygen-demanding substances are contributed by domestic sewage and agricultural and industrial wastes of both plant and animal origin, such as those from food processing, paper mills, tanning, and other manufacturing processes.

These substances are usually destroyed or converted to other compounds by bacteria if there is sufficient oxygen present in the water, but the dissolved oxygen needed to sustain fish life is used up in this break down process. *Much more information on this subject in the Laboratory section.*

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

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

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

TEMPERATURE AND GROWTH RATES

All biological and chemical reactions are affected by temperature. Microorganisms growth and reaction rates are slow at cold temperatures and much faster at warmer temperatures. Most microorganisms do best under moderate temperatures (10-25ºC). Aeration basin temperatures should be routinely measured and recorded.

Technical Learning College

Thermal Effects
Heat reduces the capacity of water to retain oxygen. In some areas, water used for cooling is discharged to surface water / streams at elevated temperatures from power plants and industries.

Even discharges from wastewater treatment plants and storm water retention ponds affected by summer heat can be released at temperatures above that of the receiving water, and elevate the stream temperature. Unchecked discharges of waste heat can seriously alter the ecology of a lake, a stream, or estuary.

Wastewater Temperature
The maximum temperature of the wastewater entering a biological reactor should be < 95°F (35°C). It is to be understood that many wastewater treatment systems cannot maintain their wastewater at or below this temperature. Nonetheless, the literature seems to be consistent in setting 95°F as the upper limit, beyond which the operation of the biological system and solids settling in the clarifiers will begin to suffer.

Temperatures in Celsius and Fahrenheit Chart

Reference Point	Degrees in Celsius	Degrees in Fahrenheit
Water Freeing Point Sea Level	**0**	**32**
Typical Winter Wastewater Temperature	**10**	**50**
Room Temperature *	**20**	**68**
Body Temperature (Human)	**37**	**98.6**
Boiling Point of Water at Sea Level	**100**	**212**

Because of the importance of temperature, it will be discussed in other chapters of this course.

NPDES Permit Information

INTERFERENCE

Interference: a discharge from an industrial user that, alone or in conjunction with other sources a) inhibits or disrupts a POTW plant, its treatment processes or operations, or its sludge processes, use, or disposal, and b) therefore causes a violation including increasing a violation's magnitude or duration of any permit or rule that controls release of pollutants from the POTW.

Technical Learning College

PASS-THROUGH

Pass-through: a POTW has a violation of its limits caused by an industrial users discharge that **passes through** the public facility without being adequately treated. The pollutant limit violated must be a pollutant discharged by the industrial user, but it's not necessary to demonstrate impact on the POTW operation.

Technical Learning College

Secondary Treatment Standards

SAMPLE	30-Day Average, mg/L	7 –Day Average, mg/L	Minimum Percent Removal
BOD 5	30	45	85%
CBOD 5	25	40	85%
TSS	30	45	85%
pH	Instantaneous 6.0 to 9.0 S.U.		

Sampling Influent and Industrial Waste

Industrial Waste

Industrial waste is a killer of activated sludge bugs. In the photograph, the Inspector or Sampler is shaking the sample to make sure that the sample is mixed-up before pouring off a smaller sample into the smaller sample bottles on the ground. Normally, these Inspectors or Samplers will work in pairs. These professionals need to get used to having wastewater and/or industrial waste/odors all over your clothes. But other than that, spiders, grease, confined spaces, irate customers, the interesting odors and dangerous Hydrogen Sulfide gas; this is a good job to have, a secure and well-paying job.

Temperature

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

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

pH

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

Wastewater Priority Pollutants

The concentrations of various wastewater pollutants in dissolved, colloidal, and suspended form are typically low but can vary considerably. EPA Priority Pollutants refer to a list of 129 pollutants that includes

heavy metals and specific organic chemicals. They were assigned a high priority for development of water quality criteria and effluent limitation guidelines because they are frequently found in wastewater. The EPA has published analytical test methods for all of them. Priority Pollutants are a subset of "*Toxic Pollutants*" as defined in the CWA. There are hundreds of *toxic pollutants*. There is no analytical test for the group as a whole, nor is it currently practical to regulate or test for all of these compounds in wastewater.

*Each POTW w*ith an approved pretreatment program must develop local limits for arsenic, cadmium, chromium, copper, cyanide, lead, mercury, nickel, silver and zinc. The POTW must also identify all *other pollutants of concern* and evaluate the need for limits for these pollutants.

The priority pollutant scans performed periodically by POTWs with approved pretreatment programs are useful in identifying *Pollutants of concern.* Many POTWs have surcharge programs for excess *Conventional pollutants.* A POTW should set absolute upper limits for *Conventional pollutants* in its sewer use ordinance (SUO) or industrial user (IU) permits, based on total plant capacity.

Excess Nutrients
Excess nutrients can stimulate the growth of algae and other aquatic plants. When these plants die and decompose, they may reduce the amount of *Oxygen* in the water.

Nutrients can also get into wastewater from industrial discharges, common household detergents and cleaners, runoff from streets and lawns and air pollutants that fall to the ground. Treatment plants cannot remove all *nutrients* from the wastewater.

"Heavy Metals" refers to dense, *metallic elements* that generally occur at trace levels in wastewater. Many heavy metals are toxic at low concentrations and most tend to accumulate.

Typical pesticides and herbicides include DDT, Aldrin, Chlordane, Endosulfan, Endrin, Heptachlor, and Diazinon. Surprisingly, concentrations of pesticides in urban runoff may be equal or greater than the pesticides in agricultural runoff. DDT is still present in stormwater.

PAHs spilled or released petroleum products (from oil spills or discharge of oil production brines) and combustion products that are found in urban runoff.

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

The Priority Pollutants are a set of *Chemical pollutants* EPA regulates, and for which EPA has published analytical test methods. *Priority Pollutant* list is more practical for testing and for regulation in that chemicals are described by their individual chemical names.

The list of toxic pollutants contains hundreds of compounds; there is no test for the group as a whole, nor is it practical to regulate or test for all of these compounds.

Appendix A to 40 CFR, Part 423--126 Priority Pollutants

001 Acenaphthene
002 Acrolein
003 Acrylonitrile
004 Benzene
005 Benzidine
006 Carbon tetrachloride (tetrachloromethane)
007 Chlorobenzene
008 1,2,4-trichlorobenzene
009 Hexachlorobenzene
010 1,2-dichloroethane
011 1,1,1-trichloreothane
012 Hexachloroethane
013 1,1-dichloroethane
014 1,1,2-trichloroethane
015 1,1,2,2-tetrachloroethane
016 Chloroethane
018 Bis(2-chloroethyl) ether
019 2-chloroethyl vinyl ether (mixed)
020 2-chloronaphthalene
021 2,4, 6-trichlorophenol
022 Parachlorometa cresol
023 Chloroform (trichloromethane)
024 2-chlorophenol
025 1,2-dichlorobenzene
026 1,3-dichlorobenzene
027 1,4-dichlorobenzene
028 3,3-dichlorobenzidine
029 1,1-dichloroethylene
030 1,2-trans-dichloroethylene
031 2,4-dichlorophenol
032 1,2-dichloropropane
033 1,2-dichloropropylene (1,3-dichloropropene)
034 2,4-dimethylphenol
035 2,4-dinitrotoluene
036 2,6-dinitrotoluene
037 1,2-diphenylhydrazine
038 Ethylbenzene
039 Fluoranthene
040 4-chlorophenyl phenyl ether
041 4-bromophenyl phenyl ether
042 Bis(2-chloroisopropyl) ether
043 Bis(2-chloroethoxy) methane
044 Methylene chloride (dichloromethane)
045 Methyl chloride (dichloromethane)
046 Methyl bromide (bromomethane)
047 Bromoform (tribromomethane)
048 Dichlorobromomethane
051 Chlorodibromomethane
052 Hexachlorobutadiene
053 Hexachloromyclopentadiene
054 Isophorone
055 Naphthalene
056 Nitrobenzene
057 2-nitrophenol
058 4-nitrophenol
059 2,4-dinitrophenol
060 4,6-dinitro-o-cresol
061 N-nitrosodimethylamine
062 N-nitrosodiphenylamine
063 N-nitrosodi-n-propylamin
064 Pentachlorophenol
065 Phenol
066 Bis(2-ethylhexyl) phthalate
067 Butyl benzyl phthalate
068 Di-N-Butyl Phthalate
069 Di-n-octyl phthalate
070 Diethyl Phthalate
071 Dimethyl phthalate
072 1,2-benzanthracene (benzo(a) anthracene
073 Benzo(a)pyrene (3,4-benzo-pyrene)
074 3,4-Benzofluoranthene (benzo(b) fluoranthene)
075 11,12-benzofluoranthene (benzo(b) fluoranthene)
076 Chrysene
077 Acenaphthylene
078 Anthracene
079 1,12-benzoperylene (benzo(ghi) perylene)
080 Fluorene
081 Phenanthrene
082 1,2,5,6-dibenzanthracene (dibenzo(,h) anthracene)
083 Indeno (,1,2,3-cd) pyrene (2,3-o-pheynylene pyrene)
084 Pyrene
085 Tetrachloroethylene
086 Toluene
087 Trichloroethylene
088 Vinyl chloride (chloroethylene)
089 Aldrin
090 Dieldrin
091 Chlordane (technical mixture and metabolites)
092 4,4-DDT
093 4,4-DDE (p,p-DDX)
094 4,4-DDD (p,p-TDE)
095 Alpha-endosulfan
096 Beta-endosulfan
097 Endosulfan sulfate
098 Endrin
099 Endrin aldehyde
100 Heptachlor
101 Heptachlor epoxide (BHC-hexachlorocyclohexane)
102 Alpha-BHC
103 Beta-BHC
104 Gamma-BHC (lindane)
105 Delta-BHC (PCB-polychlorinated biphenyls)
106 PCB-1242 (Arochlor 1242)
107 PCB-1254 (Arochlor 1254)
108 PCB-1221 (Arochlor 1221)
109 PCB-1232 (Arochlor 1232)
110 PCB-1248 (Arochlor 1248)
111 PCB-1260 (Arochlor 1260)
112 PCB-1016 (Arochlor 1016)
113 Toxaphene
114 Antimony
115 Arsenic
116 Asbestos
117 Beryllium
118 Cadmium
119 Chromium
120 Copper
121 Cyanide, Total
122 Lead
123 Mercury
124 Nickel
125 Selenium
126 Silver
127 Thallium
126 Silver
128 Zinc
129 2,3,7,8-tetrachloro-dibenzo-p-dioxin (TCDD)

Wastewater Sampling Information
Required Containers, Preservation Techniques, and Holding Times
40 CFR 136.3

Table II-Required Containers, Preservation Techniques, and Holding Times

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
Bacterial Tests:			
Coliform, total, fecal, and *E. coli*	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5]	8 hours.[22,23]
Fecal streptococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5]	8 hours.[22]
Enterococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5]	8 hours.[22]
Salmonella	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5]	8 hours.[22]
Inorganic Tests:			
Acidity	P, FP, G	Cool, ≤6 °C[18]	14 days.
Alkalinity	P, FP, G	Cool, ≤6 °C[18]	14 days.
Ammonia	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.
Biochemical oxygen demand	P, FP, G	Cool, ≤6 °C[18]	48 hours.
Boron	P, FP, or Quartz	HNO_3 to pH<2	6 months.
Bromide	P, FP, G	None required	28 days.
Biochemical oxygen demand, carbonaceous	P, FP G	Cool, ≤6 °C[18]	48 hours.
Chemical oxygen demand	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.
Chloride	P, FP, G	None required	28 days.
Chlorine, total residual	P, G	None required	Analyze within 15 minutes.
Color	P, FP, G	Cool, ≤6 °C[18]	48 hours.
Cyanide, total or available (or CATC) and free	P, FP, G	Cool, ≤6 °C[18], NaOH to pH>10[5,6]; reducing agent if oxidizer present	14 days.
Fluoride	P	None required	28 days.
Hardness	P, FP, G	HNO_3 or H_2SO_4 to pH<2	6 months.
Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes.
Kjeldahl and organic N	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.
—Metals—:[7]			
Chromium VI	P, FP, G	Cool, ≤6 °C[18], pH = 9.3–9.7[20]	28 days.
Mercury (CVAA)	P, FP, G	HNO_3 to pH<2	28 days.
Mercury (CVAFS)	FP, G; and FP-lined cap[17]	5 mL/L 12N HCl or 5 mL/L BrCl[17]	90 days.[17]
Metals, except boron, chromium VI, and mercury	P, FP, G	HNO_3 to pH<2, or at least 24 hours prior to analysis[19]	6 months.
Nitrate	P, FP, G	Cool, ≤6 °C[18]	48 hours.
Nitrate-nitrite	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.
Nitrite	P, FP, G	Cool, ≤6 °C[18]	48 hours.
Oil and grease	G	Cool to ≤6 °C[18], HCl or H_2SO_4 to pH<2	28 days.
Organic Carbon	P, FP, G	Cool to ≤6 °C[18], HCl, H_2SO_4, or H_3PO_4 to pH<2	28 days.
Orthophosphate	P, FP, G	Cool, ≤6 °C[18,24]	Filter within 15 minutes; Analyze within 48 hours.
Oxygen, Dissolved Probe	G, Bottle and top	None required	Analyze within 15 minutes.
Phenols	G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.
Phosphorous (elemental)	G	Cool, ≤6 °C[18]	48 hours.
Phosphorous, total	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days.
Residue, total	P, FP, G	Cool, ≤6 °C[18]	7 days.
Residue, Filterable	P, FP, G	Cool, ≤6 °C[18]	7 days.

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
Residue, Nonfilterable (TSS)	P, FP, G	Cool, ≤6 °C[18]	7 days.
Residue, Settleable	P, FP, G	Cool, ≤6 °C[18]	48 hours.
Residue, Volatile	P, FP, G	Cool, ≤6 °C[18]	7 days.
Silica	P or Quartz	Cool, ≤6 °C[18]	28 days.
Specific conductance	P, FP, G	Cool, ≤6 °C[18]	28 days.
Sulfate	P, FP, G	Cool, ≤6 °C[18]	28 days.
Sulfide	P, FP, G	Cool, ≤6 °C[18], add zinc acetate plus sodium hydroxide to pH>9	7 days.
Sulfite	P, FP, G	None required	Analyze within 15 minutes.
Surfactants	P, FP, G	Cool, ≤6 °C[18]	48 hours.
Temperature	P, FP, G	None required	Analyze.
Turbidity	P, FP, G	Cool, ≤6 °C[18]	48 hours.
—Organic Tests—[6]			
Purgeable Halocarbons	G, FP-lined septum	Cool, ≤6 °C[18], 0.008% $Na_2S_2O_3$[5]	14 days.
Adsorbable Organic Halides (AOX)	G	Cool, ≤6 °C[18], 0.008% $Na_2S_2O_3$[5], HNO_3 to pH <2	Hold at least 3 days but not more than 6 months
Purgeable aromatic hydrocarbons	G, FP-lined septum	Cool, ≤6 °C[18], 0.008% $Na_2S_2O_3$[5], HCl to pH 2[9]	14 days.[9]
Acrolein and Acrylonitrile	G, FP-lined septum	Cool, ≤6 °C[18], 0.008% $Na_2S_2O_3$[5], pH to 4–5[10]	14 days.[10]
Phenols[11]	G, FP-lined cap	Cool, ≤6 °C[18], 0.008% $Na_2S_2O_3$[5]	7 days until extraction, 40 days after extraction.
Benzidines[11,12]	G, FP-lined cap	Cool, ≤6 °C[18], 0.008% $Na_2S_2O_3$[5]	7 days until extraction.[13]
Phthalate esters[11]	G, FP-lined cap	Cool, ≤6 °C[18]	7 days until extraction, 40 days after extraction.
Nitrosamines[11,14]	G, FP-lined cap	Cool, ≤6 °C[18], store in dark, 0.008% $Na_2S_2O_3$[5]	7 days until extraction, 40 days after extraction.
PCBs[11]	G, FP-lined cap	Cool, ≤6 °C[18]	1 year until extraction, 1 year after extraction.
Nitroaromatics and Isophorone[11]	G, FP-lined cap	Cool, ≤6 °C[18], store in dark, 0.008% $Na_2S_2O_3$[5]	7 days until extraction, 40 days after extraction.
Polynuclear aromatic hydrocarbons[11]	G, FP-lined cap	Cool, ≤6 °C[18], store in dark, 0.008% $Na_2S_2O_3$[5]	7 days until extraction, 40 days after extraction.
Haloethers[11]	G, FP-lined cap	Cool, ≤6 °C[18], 0.008% $Na_2S_2O_3$[5]	7 days until extraction, 40 days after extraction.
Chlorinated hydrocarbons[11]	G, FP-lined cap	Cool, ≤6 °C[18]	7 days until extraction, 40 days after extraction.
Pesticides[11]	G, FP-lined cap	Cool, ≤6 °C[18], pH 5–9[15]	7 days until extraction, 40 days after extraction.

[1]"P" is polyethylene; "FP" is fluoropolymer (polytetrafluoroethylene (PTFE; Teflon®;), or other fluoropolymer, unless stated otherwise in this Table II; "G" is glass; "PA" is any plastic that is made of a sterilizable material (polypropylene or other autoclavable plastic); "LDPE" is low density polyethylene.

[2]Except where noted in this Table II and the method for the parameter, preserve each grab sample within 15 minutes of collection. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), refrigerate the sample at ≤6 °C during collection unless specified otherwise in this Table II or in the method(s). For a composite sample to be split into separate aliquots for preservation and/or analysis, maintain the sample at ≤6 °C, unless specified otherwise in this Table II or in the method(s), until collection, splitting, and preservation is completed. Add the preservative to the sample container prior to sample collection when the preservative will not compromise the integrity of a grab sample, a composite sample, or an aliquot split from a composite sample; otherwise, preserve the grab sample, composite sample, or aliquot split from a composite sample within 15 minutes of collection. If a composite measurement is required but a composite sample would compromise sample integrity, individual grab samples must be collected at prescribed time intervals (e.g., 4 samples over the course of a day, at 6-hour intervals). Grab samples must be analyzed separately and the concentrations averaged. Alternatively, grab samples may be collected in the field and composited in the laboratory if the compositing procedure produces

results equivalent to results produced by arithmetic averaging of the results of analysis of individual grab samples. For examples of laboratory compositing procedures, see EPA Method 1664A (oil and grease) and the procedures at 40 CFR 141.34(f)(14)(iv) and (v) (volatile organics).

[3]When any sample is to be shipped by common carrier or sent via the U.S. Postal Service, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4]Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before the start of analysis and still be considered valid. Samples may be held for longer periods only if the permittee or monitoring laboratory has data on file to show that, for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under §136.3(e). For a grab sample, the holding time begins at the time of collection. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), the holding time begins at the time of the end of collection of the composite sample. For a set of grab samples composited in the field or laboratory, the holding time begins at the time of collection of the last grab sample in the set. Some samples may not be stable for the maximum time period given in the table. A permittee or monitoring laboratory is obligated to hold the sample for a shorter time if it knows that a shorter time is necessary to maintain sample stability. See §136.3(e) for details. The date and time of collection of an individual grab sample is the date and time at which the sample is collected. For a set of grab samples to be composited, and that are all collected on the same calendar date, the date of collection is the date on which the samples are collected. For a set of grab samples to be composited, and that are collected across two calendar dates, the date of collection is the dates of the two days; e.g., November 14–15. For a composite sample collected automatically on a given date, the date of collection is the date on which the sample is collected. For a composite sample collected automatically, and that is collected across two calendar dates, the date of collection is the dates of the two days; e.g., November 14–15.

[5]ASTM D7365-09a specifies treatment options for samples containing oxidants (e.g.,chlorine). Also, Section 9060A of Standard Methods for the Examination of Water and Wastewater (20th and 21st editions) addresses dechlorination procedures.

[6]Sampling, preservation and mitigating interferences in water samples for analysis of cyanide are described in ASTM D7365-09a. There may be interferences that are not mitigated by the analytical test methods or D7365-09a. Any technique for removal or suppression of interference may be employed, provided the laboratory demonstrates that it more accurately measures cyanide through quality control measures described in the analytical test method. Any removal or suppression technique not described in D7365-09a or the analytical test method must be documented along with supporting data.

[7]For dissolved metals, filter grab samples within 15 minutes of collection and before adding preservatives. For a composite sample collected with an automated sampler (e.g., using a 24-hour composite sampler; see 40 CFR 122.21(g)(7)(i) or 40 CFR Part 403, Appendix E), filter the sample within 15 minutes after completion of collection and before adding preservatives. If it is known or suspected that dissolved sample integrity will be compromised during collection of a composite sample collected automatically over time (e.g., by interchange of a metal between dissolved and suspended forms), collect and filter grab samples to be composited (footnote 2) in place of a composite sample collected automatically.

[8]Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9]If the sample is not adjusted to pH 2, then the sample must be analyzed within seven days of sampling.

[10]The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11]When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity (i.e., use all necessary preservatives and hold for the shortest time listed). When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to ≤6 °C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6–9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (regarding the requirement for thiosulfate reduction), and footnotes 12, 13 (regarding the analysis of benzidine).

[12]If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0 ± 0.2 to prevent rearrangement to benzidine.

[13]Extracts may be stored up to 30 days at < 0 °C.

[14]For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7–10 with NaOH within 24 hours of sampling.

[15]The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

[16]Place sufficient ice with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, it is necessary to immediately measure the temperature of the samples and confirm that the preservation temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature cannot be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature. Aqueous samples must not be frozen. Hand-delivered samples used on the day of collection do not need to be cooled to 0 to 6 °C prior to test initiation.

[17]Samples collected for the determination of trace level mercury (<100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. A sample collected for dissolved trace level mercury should be filtered in the laboratory within 24 hours of the time of collection. However, if circumstances preclude overnight shipment, the sample should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. If sample integrity will not be maintained by shipment to and filtration in the laboratory, the sample must be filtered in a designated clean area in the field within the time period necessary to maintain sample integrity. A sample that has been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

[18]Aqueous samples must be preserved at ≤6 °C, and should not be frozen unless data demonstrating that sample freezing does not adversely impact sample integrity is maintained on file and accepted as valid by the regulatory authority. Also, for purposes of NPDES monitoring, the specification of "≤ °C" is used in place of the "4 °C" and "< 4 °C" sample temperature requirements listed in some methods. It is not necessary to measure the sample temperature to three significant figures (1/100th of 1 degree); rather, three significant figures are specified so that rounding down to 6 °C may not be used to meet the ≤6 °C requirement. The preservation temperature does not apply to samples that are analyzed immediately (less than 15 minutes).

[19]An aqueous sample may be collected and shipped without acid preservation. However, acid must be added at least 24 hours before analysis to dissolve any metals that adsorb to the container walls. If the sample must be analyzed within 24 hours of collection, add the acid immediately (see footnote 2). Soil and sediment samples do not need to be preserved with acid. The allowances in this footnote supersede the preservation and holding time requirements in the approved metals methods.

[20]To achieve the 28-day holding time, use the ammonium sulfate buffer solution specified in EPA Method 218.6. The allowance in this footnote supersedes preservation and holding time requirements in the approved hexavalent chromium methods, unless this supersession would compromise the measurement, in which case requirements in the method must be followed.

[21]Holding time is calculated from time of sample collection to elution for samples shipped to the laboratory in bulk and calculated from the time of sample filtration to elution for samples filtered in the field.

[22]Sample analysis should begin as soon as possible after receipt; sample incubation must be started no later than 8 hours from time of collection.

[23]For fecal coliform samples for sewage sludge (biosolids) only, the holding time is extended to 24 hours for the following sample types using either EPA Method 1680 (LTB–EC) or 1681 (A–1): Class A composted, Class B aerobically digested, and Class B anaerobically digested.

[24]The immediate filtration requirement in orthophosphate measurement is to assess the dissolved or bio-available form of orthophosphorus (*i.e.*, that which passes through a 0.45-micron filter), hence the requirement to filter the sample immediately upon collection (*i.e.*, within 15 minutes of collection).

[38 FR 28758, Oct. 16, 1973]

Topic 4 – Wastewater Section – Introduction Post Quiz

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

1. Ammonia is an important component of the nitrogen cycle and because it is oxidized in the environment by microorganisms (i.e., nitrification), it is a large source of available nitrogen in the environment.
True or False

2. Ammonia is a nutrient that contains nitrogen and sulfur.
True or False

3. Un-ionized ammonia refers to all forms of ammonia in water with the exception of the ammonium ion (NH4+). Ionized ammonia refers to the ammonium ion.
True or False

4. Indicators of low dissolved-oxygen conditions include substantial presence of high dissolved-oxygen filamentous bacteria in the activated sludge, non- turbid effluent, or dark gray or black-colored mixed liquor (often with a pleasant odor).
True or False

5. Carbon, ammonia, and copper are essential to living organisms and are the chief nutrients present in natural water.
True or False

6. The best temperatures for wastewater treatment probably range from 77 to 95 degrees Fahrenheit.
True or False

7. In general, biological treatment activity accelerates in cold temperatures and slows in warm temperatures, but extreme hot or cold can stop treatment processes altogether.
True or False

8. The acidity or alkalinity of wastewater affects both treatment and the environment.
True or False

9. Low pH indicates increasing acidity while a high pH indicates increasing alkalinity (a pH of 7 is low). The pH of wastewater needs to remain between 4 and 5 to protect organisms. True or False

10. Inorganic minerals, metals, and compounds, such as sodium, potassium, calcium, magnesium, cadmium, copper, lead, nickel, and zinc are not common in wastewater. True or False

11. Heavy metals which are discharged with many types of industrial wastewaters are easy to remove by conventional treatment methods. True or False

12. Although acute poisonings from heavy metals in drinking water are rare - potential long-term health effects of ingesting small amounts of some inorganic substances over an extended period of time are possible. True or False

13. The solids must be significantly reduced by treatment or they can increase BOD when discharged to receiving waters and provide places for microorganisms to escape disinfection. They also can clog soil absorption fields in onsite systems. True or False

14. Certain substances, such as sand, grit, and heavier organic and inorganic materials settle out from the rest of the wastewater stream during the preliminary stages of treatment. True or False

15. Excessive amounts of dissolved solids in wastewater cannot have adverse effects on the environment. True or False

Topic 5 -Wastewater Sampling Section

Section Focus: You will learn the basics of the wastewater sampling program, rules, and sampling procedures. At the end of this section, you will be able to understand and describe various sampling regulations and sampling procedures. 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 sampler should be thoroughly familiarized with existing safety guidelines and follow your permit and proper sampling procedures, guidelines and practices for any analyte of particular interest. The sampler must always be alert to the possibility of danger, especially in dealing with unknown sites, situations or possible contaminants. Legal samples are necessary for process control and for when there is evidence an individual or company has not complied with wastewater regulatory requirements and there is a potential for laying charges. Legal sampling is conducted under the following circumstances: Any known or suspected violation, Spills or environmental accidents, Previous knowledge about compliance history does not exist or it is unknown. From the standing point of objectivity, continuity of evidence and quality of the results, the collection, handling, transport, analysis, storage and disposal of the legal samples must be defensible.

WASTEWATER CHARACTERISTICS & SPECIFIC SOURCES	
PHYSICAL	
SOLIDS	Domestic - Industrial Wastes / Soil Erosion / Inflow, etc.
COLOR	Industrial - Domestic Wastes / Natural Decaying of Organic Matter
ODOR	Industrial Wastes / Decomposition of Wastewater
CHEMICAL	
PHENOLS	Industrial Wastes
pH	Industrial Wastes
TOXIC COMPOUNDS	Industrial Wastes
HEAVY METALS	Industrial Wastes
PESTICIDES	Run-Off From Agriculture
BIOLOGICAL	/ Open Water Courses / Treatment Units, etc

CHART IDENTIFYING BASIC SOURCES AND CHARACTERISTICS OF WASTEWATER

Collecting Wastewater Samples

The purpose of this section is to understand both general and specific sampling procedures, methods and considerations to be used and observed when collecting wastewater samples for field screening or laboratory analysis.

For more detailed information on sampling frequencies, consult the EPA's 2017 *Industrial User Inspection and Sampling Manual for POTW*s.

Parameter	Sample type	Container	Preservative	Holding time
pH	Grab	Polyethylene or Glass	N/A	analyze immediately 15 minutes
BOD	Composite	Polyethylene or Glass	chilled to 4°C	48 hours
TSS	Composite	Polyethylene or Glass	chilled to 4°C	7 days
NH 3 as N	Composite	Polyethylene or Glass	chilled to 4°C, H2 SO_4 to pH<2	28 days
Oil and Grease	Grab	Glass	chilled to 4°C, HCl or H_2SO_4 to pH<2	28 days
Cyanide, total	Grab	Polyethylene or Glass	chilled to 4°C, NaOH to a pH >12, and 0.6g of ascorbic acid if residual chlorine is present	14 days
Metals (total) excl. Cr $^{+6}$ B, and Hg	Composite	Polyethylene or Glass	HNO3 to pH<2	6 months
624 (volatiles organics)	Grab	Amber glass, w/ Teflon septum lid and zero headspace	chilled to 4°C (additional laboratory preservation required)	7 or 14 days, depending on specific organic
625 (semi-volatile organics)	Composite	Amber glass w/ Teflon lined lid	chilled to 4°C (additional laboratory preservation required)	7 days for sample prep; 40 days for extract

Compliance WWT & Pretreatment Sampling Introduction

Sampling is the most appropriate method for verifying compliance with pretreatment standards. Monitoring location(s) are designated by the Control Authority and must be such that compliance with permitted discharge limits can be determined. Where possible, the Control Authority should not designate monitoring locations that are confined spaces or difficult to access or difficult to place automated sampling equipment.

Monitoring locations should:

- be appropriate for waste stream conditions;
- be representative of the discharge;
- have no bypass capabilities; and
- allow for unrestricted access at all times.

Control Authorities should measure flow to allow for collection of flow-proportioned composite samples, which are required, unless flow-proportional sampling is not feasible. Flow-proportional composite samples are preferred over time composite samples particularly where the monitored discharge is intermittent or variable.

Desired analyses dictate the preparation protocols, equipment, and collection bottles to be used to avoid contamination of samples or loss of pollutants through improper collection. Sampling for such pollutants as pH, cyanide, oil and grease, flashpoint, and volatile organic compounds require manual collection of grab samples.

Similar to composite samples, grab samples must be representative of the monitored discharge and are to be collected from actively mixed holding tanks or flowing wastestreams. Fluctuations in flow or the nature of the discharge may require collection of and hand-composting of more than one grab sample to accurately assess compliance.

To ensure defensibility of data, Control Authorities should develop and implement standard operating procedures and policies detailing sample collection and handling protocols in accordance with 40 CFR Part 136.

Adherence to proper sample collection and handling protocols, 40 CFR Part 136 approved analytical methodologies, and record-keeping requirements [40 CFR §403.12(o)(1)] can be verified through review of field measurement records, chain of custodies, and lab reports. Field measurement records may require information regarding sample location, condition of and programmed settings for sampling equipment, wastewater meter readings, and information for such parameters as pH and temperature which require analysis in the field.

Chain of custody forms serve as a link between field personnel and the laboratory and contain information regarding sample matrix, type, and handling. Lab reports should contain the minimum information specified in 40 CFR §403.12(o)(1)(ii-iv) as well as any additional information necessary to demonstrate compliance with 40 CFR Part 136 requirements (e.g., analytical methodology, sample preparation date and time, and time of analysis).

Use of standardized forms which prompt recording of information necessary for demonstrating compliance with applicable requirements will aid in ensuring it can be used as admissible evidence in enforcement proceedings or in judicial actions.

Compliance Sampling Evaluation

Wastewater sampling/analysis is an integral part of the National Pollutant Discharge Elimination System (NPDES) Compliance Monitoring Program. NPDES permits contain specific and legally enforceable effluent limitations and monitoring requirements.

Objectives and Requirements
When evaluating the permittee sampling program, the inspector should:

- Verify that the permittee's sampling program complies with the permit.
- Verify that the permittee's sampling program complies with:
  - Title 40 of the *Code of Federal Regulations* (CFR), sections 136.1 to 136.6 and Appendices A, B, and C (Guidelines for Establishing Test Procedures for the Analysis of Pollutants) for wastewater samples; and 40 CFR Part 503.
- Document potential violations to support enforcement action.

In addition, specific objectives of the sampling conducted by inspectors include the following:

- Verify compliance with effluent limitations.
- Verify accuracy of reports and program self-monitoring.
- Support enforcement action.
- Support permit development reissuance and/or revision.
- Determine the quantity and quality of effluent.

Sampling, analysis, preservation technique, sample holding time, and sample container requirements are provided under 40 CFR Part 136 as authorized by section 304(h) of the Clean Water Act (CWA). For all NPDES permittees the inspector should perform a review of sampling procedures and quality control measures the facility uses to ensure the integrity of sample data.
To evaluate sampling procedures, assess the following eight areas:

- Sample site locations
- Sample collection techniques
- Field measurements
- Sample labeling (including locations) and documentation
- Sample preservation and holding time
- Transfer of custody and shipment of samples
- Quality control
- Data handling and reporting

Types of WWT Samples *(Credit USEPA)*

General
There are four types of routine samples that are collected by the POTW's Sampling Section: grab, time proportional composites, flow proportional composites, and hand composites. The sampling method used depends largely on the types of analyses to be run, and the nature of the wastestream being sampled. Each sampling method is described in this section.

Most POTW's will define the sampling methods which must be used by industrial users (IUs) to obtain representative samples to show compliance with their permits:

Example

(1) A grab sample is an individual sample collected in less than 15 minutes without regard for flow or time of day. pH, cyanide, oil and grease, sulfide, and volatile organics must be collected as grab samples.

(2) 24-hour flow proportional composite samples where feasible. The POTW may waive this requirement if the IU demonstrates that this method is not feasible. Samples would then be taken by means of time proportional composite sampling methods, or by hand composite where the IU can demonstrate that this will provide a representative sample of the effluent being discharged.

The volume of sample to be collected by any of these methods is dependent on the number and types of analyses that must be performed.

Grab Samples
Grab samples are individual samples collected in less than 15 minutes without regard to flow or time of day. Grab samples are normally taken manually, but can be pumped. Oil and grease samples and purgeable organics are exceptions and must be taken manually.

The collection of a grab sample is appropriate when a sample is needed to:

- Represent an effluent that does not discharge on a continuous basis.
- Provide information about instantaneous concentrations of pollutants at a specific time.
- Allow collection of a variable sample volume.
- Corroborate composite samples.
- Monitor parameters not amenable to compositing (e.g., pH, temperature, dissolved oxygen, chlorine, purgeable organics, oil and grease, coliform bacteria, and others specified by the NPDES permit, which may include phenols, sulfites, and hexavalent chromium).

Grab Sample

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

EPA Sample Identification Methods

Identify each sample accurately and completely. Use labels or tags to identify the samples that are moisture-resistant and able to withstand field conditions. If moisture-resistant labels are not available, place a piece of tape over each label to prevent water damage. Use a waterproof pen to complete the labels or tags. A numbered label or tag associated with a field sample data sheet containing detailed information on the sample is preferable to using only a label or tag for information.

The information for each sample should include the following:

- Facility name/location
- Sample site location
- Sample number
- Name of sample collector
- Date and time of collection
- Indication of grab or composite sample with appropriate time and volume information
- Identification of parameter to be analyzed
- If the sample is preserved and, if so, the preservative used

Various Composite Sampling Techniques (Credit EPA)

The four primary methods of composite sample collection are time compositing, flow proportion compositing, sequential compositing, and continuous compositing. Table 5-1 lists the advantages and disadvantages of these methods. The permit may specify which type of composite sample to use. Composite samples are collected either manually by combining multiple grab samples or by using automatic sampling equipment. Inspectors should consider variability in wastestream flow rate, parameter concentrations and the approved EPA methods when choosing compositing methods, sampling equipment (tubing and containers), and quality assurance procedures. The compositing methods are as follows:

• **Time Composite Sample**: This method requires discrete sample aliquots collected in one container at constant time intervals. This method is appropriate when the flow of the sampled stream is constant (flow rate does not vary more than ±10 percent of the average flow rate) or when flow monitoring equipment is not available.

• **Flow-Proportional Composite Sample**—in one method, a constant sample volume is collected at varying time intervals proportional to stream flow (e.g., 200 milliliters sample collected for every 5,000 gallons of flow). In the other method (which has two variations, see Table 5-1), the sample is collected by increasing the volume of each aliquot as the flow increases, while maintaining a constant time interval between the aliquots.

• **Sequential Composite Sample**—this method requires discrete samples collected in individual containers at constant time intervals or discharge increments; for example, samples collected every 15 minutes, composited into separate containers each hour. The discrete samples can then be manually flow-proportioned to form the composite sample. Alternatively, a constant sample volume is collected at constant discharge volume increments measured with a flow totalizer.

• **Continuous Composite Sample**—collect this sample continuously from the wastestream. The sample may be constant volume, or the volume may vary in proportion to the flow rate of the wastestream.

Influent Sample Collection
Document and take influent samples at points of high turbulence flow to ensure good mixing. In some instances, the most desirable location may not be accessible. Ensure sampling points are located prior to any internal facility return lines, and sampling equipment should be placed so that it does not interfere with flow measuring devices. The preferred sampling points for raw wastewater are at the most downstream location from the collection lines, but prior to preliminary treatment:

- Waste flowing from the last process in a manufacturing operation, for an industrial user.
- Pump wet well (if turbulent).
- Upstream collection lines, tank, or distribution box following pumping from the wet well or sump.
- Flume throat.
- Aerated grit chamber.
- Upstream siphon following the comminutor (in absence of grit chamber). If it is not possible to sample at a preferred point, choose an alternative location and document the basis for choosing that location.

Table 5-1. Compositing Methods			
Method	**Advantages**	**Disadvantages**	**Comments**
Time Composite			
Constant sample volume, constant time interval between samples.	Minimal manual effort; requires no flow measurement.	May lack representativeness for highly variable flows.	Widely used in both automatic and manual sampling.
Flow-Proportional Composite			
Constant sample volume, time interval between samples proportional to stream flow.	Minimal manual effort.	Requires accurate flow measurement reading equipment; manual compositing from flowchart.	Widely used in automatic as well as manual sampling.
Constant time interval between samples, sample volume proportional to total stream flow at time of sampling.	Minimal instrumentation.	Manual compositing from flowchart in absence of prior information on the ratio of minimum to maximum flow; chance of collecting too small or too large individual discrete samples for a given composite volume.	Used in automatic samplers and widely used as manual method.
Constant time interval between samples, sample volume proportional to total stream flow since last sample.	Minimal instrumentation.	Manual compositing from flow chart in absence of prior information on the ratio of minimum to maximum flow; chance of collecting too small or too large individual discrete samples for a given composite volume.	Not widely used in automatic samplers but may be done manually.
Sequential Composite			
Series of short period composites, constant time intervals between samples.	Useful if fluctuations occur and the time history is desired.	Requires manual compositing of aliquots based on flow.	Commonly used; however, manual compositing is labor intensive.
Series of short period composites, aliquots taken at constant discharge increments.	Useful if fluctuations occur and the time history is desired.	Requires flow totalizer; requires manual compositing of aliquots based on flow.	Manual compositing is labor intensive.
Continuous Composite			
Constant sample volume.	Minimal manual effort, requires no flow measurement highly variable flows.	Requires large sample capacity; may lack representativeness for highly variable flows.	Practical but not widely used.
Sample volume proportional to stream flow.	Minimal manual effort, most representative especially for highly variable sample volume, variable pumping capacity and power.	Requires accurate flow measurement equipment, large sample volume, variable pumping capacity, and power.	Not widely used.

Effluent Sample Collection
Collect effluent samples at the location specified in the NPDES permit. Occasionally, municipal plant permits may specify sampling prior to chlorination. For these plants, monitor all parameters at the upstream location except fecal coliforms, pH, and total residual chlorine. Collect wastewater for use in bioassays at the location specified in the facility's NPDES permit. Collect samples either manually (grab or composite) or with automatic samplers (continuous or composite).

The following general guidelines apply when taking samples:

- Take samples at a location specified in the NPDES permit and/or at a location selected to yield a representative sample.
- Use the sampling method (grab, composite, continuous) specified in the permit. Some parameters that must be collected as an individual grab sample are dissolved oxygen, total residual chlorine, oil and grease, coliform bacteria, purgeable organics, sulfides, cyanide, and total phenols. • Avoid collecting large nonhomogeneous particles and objects.
- Collect the sample facing upstream to avoid contamination.
- Do not rinse sample container with sample when collecting oil and grease and microbiological samples, but fill the container directly to within 2.5 to 5 cm from the top.
- Fill the container completely if the sample is to be analyzed for purgeable organics, oxygen, ammonia, hydrogen sulfide, free chlorine, pH, hardness, sulfite, ammonium, ferrous iron, acidity, or alkalinity.
- Collect sufficient volume to allow for quality assurance testing. (see EPA's website https://www.epa.gov/cwa-methods for a listing of all approved sampling methods. Each sampling method will indicate the required sampling equipment, sampling containers and sampling volume, but additional volumes may be necessary for quality assurance testing.

The following general guidelines apply when using automatic samplers:

- Collect samples where the wastewater is well mixed. Collect the sample near the center of the flow channel at 0.4 to 0.6 depth (mid-depth).
- Obtain a sufficient volume of sample to perform all required analyses plus any additional amount for quality control. Individual portions of a composite sample should be at least 100 milliliters to minimize sampler solids bias.
- For automatic samplers that use a peristaltic pump, obtain adequate flow rates in the sampler tubing to effectively transport the suspended solids. To avoid solids bias, the velocity of the wastewater in sample tubing should be at least 2 feet per second (fps) and the tubing diameter should be at least 0.25 inch.
- Time of sample collection begins when the last aliquot is dispensed into the composite sample container.

Sample Volume
The volume of sample collected depends on the type and number of analyses needed, as reflected in the parameters to be measured. Obtain the volume of the sample sufficient for all the required analyses plus an additional amount to provide for any split samples or repeat analyses.

EPA approved sampling methods provide a guide to sample volumes required for determining the constituents in wastewater (available at https://www.epa.gov/cwa-methods).

Consult the laboratory receiving the sample for any specific volume required. EPA's Methods for Chemical Analysis of Water and Wastes (EPA, 1979a) and Handbook for Sampling and Sample Preservation of Water and Wastewater (EPA, 1982), and the current EPA-approved edition of Standard Methods for the Examination of Water and Wastewater (American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF), 2013) contain specific recommended minimum sample volumes for different pollutant parameters.

Sample Containers
The regulations at 40 CFR Part 136 describe required sample containers, sample preservation, and sample holding time. EPA approved sampling methods indicate appropriate sample containers for each analysis It is essential that the sample containers be made of chemically resistant material unaffected by the concentrations of the pollutants measured. In addition, sample containers must have a closure that will protect the sample from contamination. Collect wastewater samples for chemical analysis in plastic (polyethylene) containers. Exceptions to this general rule are oil and grease samples, pesticides, phenols, polychlorinated biphenyls (PCBs), and other organic pollutant samples.

Collect these in properly cleaned glass jars or bottles and seal. Collect bacteriological samples in properly sterilized plastic or glass containers. Collect samples that contain constituents that will oxidize when exposed to sunlight (such as iron cyanide complexes) in dark containers. Ensure sample containers are clean and uncontaminated. Check analytical procedures to determine if they specify container cleaning procedures. Use precleaned and sterilized disposable containers (e.g., polyethylene cubitainers).

If these are not used or if the analytical method does not specify procedures, use the following procedures for cleaning sample containers:

- Wash with hot water and detergent.
- Rinse with acid (e.g., nitric for metals).
- Rinse with tap water, then rinse three or more times with organic-free water.
- Rinse glass containers with an interference-free, redistilled solvent (such as acetone or methylene chloride for extractable organics.
- Dry in contaminant-free area.

EPA Sample Identification Procedures
Identify each sample accurately and completely. Use labels or tags to identify the samples that are moisture-resistant and able to withstand field conditions. If moisture-resistant labels are not available, place a piece of tape over each label to prevent water damage.

Use a waterproof pen to complete the labels or tags. A numbered label or tag associated with a field sample data sheet containing detailed information on the sample is preferable to using only a label or tag for information.

The information for each sample should include the following:

- Facility name/location
- Sample site location
- Sample number
- Name of sample collector
- Date and time of collection
- Indication of grab or composite sample with appropriate time and volume information
- Identification of parameter to be analyzed • If the sample is preserved and, if so, the preservative used

Wastewater Sample Preservation and Holding Time Introduction

In most cases, wastewater samples contain one or more unstable pollutants that require immediate (e.g., within 15 minutes) preservation and/or analysis. Provide appropriate chemical preservation before transferring samples to the laboratory. EPA approved sampling methods indicate appropriate sample preservation for each analysis (sampling methods are available at https://www.epa.gov/cwa-methods).

Procedures used to preserve samples include cooling, pH adjustment, and chemical treatment. For some parameters, such as cyanide and phenols, add preservatives to sample bottles prior to or immediately following sample collection.

For many samples, if preservatives are not appropriately used, bacteria can quickly degrade certain constituents (such as phenols and phosphorus). Other constituents may volatilize (such as volatile organics and sulfides) or may react to form different chemical species (hexavalent chromium, for example).

Proper preservation and holding times are essential to ensure sample integrity (see 40 CFR Part 136). Analysis of samples within one day ensures against error from sample deterioration. However, such prompt analysis is not feasible for composite samples in which portions may be stored for as long as 24 hours.

Where possible, provide sample preservation during compositing, usually by refrigeration to 6°C (or icing). If using an automatic sampler with ice, replace the ice as necessary to maintain low temperatures. This is a limitation of automatic samplers used during the summer when ice must be frequently replaced. Table II of 40 CFR 136.3(e) indicates maximum sample holding times. Times listed are the maximum holding times between sample collection and analysis that are allowed for the sample to be considered valid. Unless otherwise specified in the method, holding time limitations begin upon combination of the last aliquot in a sample. When use of an automatic sampler makes it impossible to preserve each aliquot, the chemical samples may be preserved by maintaining at 6°C until compositing and sample splitting is completed (40 CFR 136.3(e)).

Transfer and Custody of Samples
To ensure the validity of the permit compliance sampling data in court, written records must accurately trace the custody of each sample through all phases of the monitoring program (EPA Order 5360.1). The primary objective of this chain-of-custody is to create an accurate written record (see an example chain-of-custody form in Appendix M) that can be used to trace the possession and handling of the sample from the moment of its collection through its analysis and introduction as evidence.

The following procedures are appropriate for the transfer of custody and shipment of samples:

- Use sample seals to protect the sample's integrity from the time of collection to the time it is opened in the laboratory, including the time the sample is within an automatic sampling apparatus, thus the automatic sampler should be sealed on the outside. The seal should indicate the collector's name, the date and time of sample collection, and sample identification number. For automatic samplers, seals should indicate the sample time at which the apparatus began sampling, as the sample container is subsequently sealed in the apparatus.
- Pack samples properly to prevent breakage. Seal or lock the shipping container to readily detect any evidence of tampering. Use of tamper-proof evidence tape is recommended.
- Place samples on ice or synthetic ice substitute that will maintain sample temperature at 6°C throughout shipment.
- The responsibility for proper packaging, labeling, and transferring of possession of the sample lies with the inspector. Accompany every sample with a sample tag and a chain-of-custody record that has been completed, signed, and dated. The chain-of-custody record should include the names of

sample collectors, sample identification numbers, date and time of sample collection, location of sample collection, and names and signatures of all persons handling the sample in the field and in the laboratory.
• The originator retains a copy of the chain of custody forms. Also, the originator must retain all receipts associated with the shipment.
• EPA Inspectors with the responsibility of working with hazardous materials that are placed in commerce (transporting/shipping) must have hazardous materials training as required by the Department of Transportation (see Appendix N).
• When transferring possession of samples, the transferee must sign and record the date and time on the chain-of-custody record (use the currently approved record). In general, custody transfers are made for each sample, although samples may be transferred as a group, if desired. For each sample being transferred, the transferee should list the sample and their name on the custody record. Each person who takes custody must fill in the appropriate section of the chain-of-custody record. Both the transferee and person who takes custody of the sample(s) must sign the custody record.
• Pack and ship samples in accordance with applicable International Air Transportation Association (IATA) and/or DOT regulations.

Quality Control
Conduct control checks during the actual sample collection to determine the performance of sample collection techniques. In general, the most common monitoring errors usually are improper sampling methodology, improper preservation, inadequate mixing during compositing and splitting, and excessive sample holding time. In addition, collect and analyze the following samples to check sample collection techniques:

Blanks
Trip blank
Trip blanks are vial(s) filled at the laboratory with deionized water. The blank(s) follows the same handling and transport procedures as the samples collected during the event. The blank(s) functions as a check on sample contamination originating from sample transport, shipping and from site conditions. Note: Expose the trip blank vial(s), to the same environmental conditions (light, temperature, etc.) of the sample vial(s) but do not open until it is time for analysis.

Field blank/field reagent blank
Field blanks are similar to trip blanks except they are prepared in the field with deionized water exactly as the sample(s) that are collected. Field blanks are used to check for analytical artifacts and/or background introduced by sampling and analytical procedures.

Temperature blank.
A temperature blank is a small sample bottle filled with distilled water that is placed in each cooler prior to shipment. Upon arrival at the laboratory the temperature of the sample bottle is measured to evaluate if samples were adequately cooled during sample shipment.

Equipment/rinsate blank
Collect an equipment/rinsate blank when using an automatic sampler or other non-dedicated equipment during the sampling process. The blank is a check of the equipment cleanliness. For automatic samplers, prepare blanks prior to collecting samples, by pumping deionized organic free water (rinsate) through the sampler and collecting the discharge purge water in a sample container for analysis for the constituents of concern.

Field Duplicate
Collect a field duplicate sample simultaneously from the same source at selected stations on a random timeframe by grab samples or from two sets of field equipment installed at the site. Duplicate samples check analytical precision as well as evaluate the “representativeness” of the sample aliquot.

Split Samples
Split samples are samples that have been divided into two containers for analysis by separate laboratories. These samples provide an excellent means of identifying discrepancies in the permittee’s analytical techniques and procedures. When filling split samples from a single composite jug, shake the composited sample well and half fill the EPA sample container, then shake the composite again and fill half of the permittee’s container. Repeat the procedure for each parameter collected. The laboratories performing the sample analyses should also use the following control measures:

Prep/Reagent Blank
A prep/reagent blank is a sample consisting of reagent(s), without the target analyte or sample matrix, introduced into the analytical procedure at the appropriate point and carried through all subsequent steps to determine the contribution of the reagents and to aid in identifying errors in the observed value that may result from the analytical steps.

Quality Control Sample
A quality control sample is an uncontaminated sample matrix spiked with known amounts of analytes from a source independent from the calibration standards. Use this sample to establish intra-laboratory or analyst specific precision and bias or to assess the performance of all or a portion of the measurements’ system.

Matrix Spike/Matrix Spike Duplicate (MS/MSD)
A matrix spike/matrix spike duplicate sample is three times the normal volume required for a specific chemical analysis to which a known quantity of analyte has been added prior to all sample preparation. The laboratory utilizes the MS/MSD samples as part of their Quality Assurance/Quality Control Program.

- Use a matrix spike to verify accuracy of the analytical procedures.
- A matrix spike duplicate is a duplicate of a matrix spike sample. It measures the precision of the analysis in terms of relative percent difference.

Table 5-2 indicates quality control procedures for field analyses and equipment. Quality control is discussed in greater detail in Chapter 7 EPA's NPDES

Collecting Procedure for Water/Wastewater Grab Samples

1. Lower dipper or mouth of the bottle into water just below surface. Note sampling time and any other relevant information to the previously applied sampling label.

2. Retrieve or move the collected sample to a clean processing area.

3. If a bottle was used to collect the sample, rinse the bottle 3 times to remove any contaminants.

4. Pour the sample into the required laboratory bottle.

5. You may need to filter the sample; this is true with some water and wastewater samples. Filtering (for ortho-P and NOx samples).

6. Bottles supplied by an independent laboratory often come pre-loaded with preservative. Otherwise, preservative can be added in the POTW's lab. Bringing bulk preservatives, often strong acids and bases, into the field is not practical.

7. Secure sample container caps tightly.

8. Place the sample containers in an iced cooler before storage.

Timed Composites
Timed samples are usually taken in instances where the intention is to characterize the wastes over a period of time without regard to flow, or where the flow is fairly constant.

Timed composite samples consist of a series of equal volume grab samples taken at regular intervals. A typical interval is 15 minutes, with a maximum sampling duration of 24 hours.

The sample volume and sampling interval need to be calculated, and calibrated, so as to not overfill the collection bottle.

Samplers are available which can hold 24 separate bottles, each of which can receive multiple samples. Samplers can also be fitted with a single composite bottle, typically having a 2.5-gallon capacity. They provide space around the bottle for ice to cool the sample.

Flow Proportional Composites
Flow proportional composite samples consist of: a series of grab samples whose volumes are equal in size, taken each time a specified amount of flow has been measured. For example, a flow measuring device sends readings to a controller which then sends a signal to the sampler every time 1,000 gallons of flow are recorded. A flow measuring device must be used in conjunction with the automatic sampler.

This sampling method is used for all sampling activities except for instances where grab samples are required or time proportional sampling is more expedient and can provide the same accuracy as flow proportional sampling (i.e., constant flow levels or level of contaminants).

Hand Compositing
When sampling a batch discharge tank, hand compositing can be done. If the tank contents are homogenous, and remain so by active mixing, a grab sample provides the same results as a flow proportional composite sample.

If one is not certain that the contents of a batch tank are homogenous, taking four or more discharge grab samples of equal volume at evenly spaced time intervals over the course of the discharge will produce a more representative sample.

For multiple batch discharges in a day, the results of the hand composites can be averaged, considering differences in the volume of the batches.

The results of one, or the proportional average of multiple batch discharges, are the equivalent of a 24-hour flow proportional sampling at a facility with a continuous discharge. The sampling data would be compared with the average daily categorical standards or local limits where applicable.

Pre-Sampling Procedures
To ensure acceptable analytical results, numerous steps must be followed before a sampling program can be initiated:

To ensure that sampling goes smoothly, a considerable amount of preparation is required.
(1) All sampling equipment shall be clean and be in good working order.
(2) Fully charge needed batteries and backups.
(3) Select approved sampling location or equivalent.
(4) Determine what analyses are needed. Be sure the method selected Is sensitive enough to provide results in the range of the permit limit.
(5) Order sample bottles if not enough are in stock.
(6) Label sample containers with available information.
(7) Pack extra sample containers and labels to replace any that break while sampling.
(8) Gather enough ice chests to hold all the samples with room for ice/ice packs.
(9) Prepare PPE and, if needed, traffic control and/or confined space entry equipment.
(10) Arrange for the additional staff required for traffic control or confined space entry.
(11) Prepare Chain of Custody forms.

Sampling Equipment Example
Most pretreatment programs have one or more dedicated vehicles. These are loaded with equipment that is routinely needed for sampling. This typically includes equipment for confined space entry (support frame, winch, harnesses, gas detector, blowers, etc.) traffic diversion (cones, reflective vests, flags, etc.), manhole cover removal, flow measurement, PPE, and, of course, sampling.

There are many types and brands of automatic composite samplers. Most use a battery for remote placement and power from an outlet when available. If more than a few grabs for pH and temperature are needed, probes linked to a local or remote data logger are used for “sampling”.

The equipment that is kept in the sampling vehicle is dependent on the types of sampling activities planned each week, while the equipment stored in the storeroom is for back-up needs and future sampling demands.

Each sampling vehicle should be equipped with at least one sampler and one flow meter more than is needed for the particular sampling period. For example, three scheduled flow proportionate sampling sites would require a vehicle to be equipped with four samplers and four flow meters.

At least one spare battery for each type of equipment taken into the field should also be placed in the sampling vehicle.

Auxiliary equipment, such as supports, harnesses, blowers, etc., to be carried in each vehicle will depend on the nature of the sampling location.

In order to keep the equipment in good working order, the equipment should be maintained, cleaned and inspected on a regular basis. Routine maintenance and cleaning procedures should be written into your standard operating procedures.

Sampling Equipment Maintenance - Example

Basic maintenance for samplers includes: periodic calibration and general equipment checking, and replacement of the internal desiccant and fuses. Routine cleaning or replacement of tubing and other parts should be done following the manufactures guidelines or according to your SOP.

Basic maintenance of the flow meters includes: periodic replacement of the internal desiccant, plotter paper, ribbon, fuses, and any broken re-roll spool assemblies. Note: Some flow meters have two tabs on the sides which are extremely thin and easily broken.

The NiCad and Gel Cell batteries need to be recharged on a regular basis. Any battery that reads less than 12.50 when checked should not be installed or left on any of the sampling equipment. At the battery charging station, areas are set aside for batteries that need to be charged and batteries already charged.

To prolong battery life, NiCad batteries should be fully discharged before recharging for a maximum of 24 hours, in accordance with the procedures described in the manufacturer's operations and maintenance manuals. Always bring a second set or back-up set of batteries with you.

It is important to note that charged NiCad batteries, if left unused for a long time, are nevertheless slowly discharging. Gel cell batteries are generally more stable. Voltage readings should be taken before the charged batteries are taken into the field to be sure that they still have a full charge.

When a sampler, flow meter, or ancillary equipment needs more specific repairs, the manufacturer representative should be contacted and arrangements made for repair or replacement of the equipment.

Compliance Sampling Evaluation

Wastewater sampling/analysis is an integral part of the National Pollutant Discharge Elimination System (NPDES) Compliance Monitoring Program. NPDES permits contain specific and legally enforceable effluent limitations and monitoring requirements.

Objectives and Requirements
When evaluating the permittee sampling program, the inspector should:

- Verify that the permittee's sampling program complies with the permit.
- Verify that the permittee's sampling program complies with:
  - Title 40 of the *Code of Federal Regulations* (CFR), sections 136.1 to 136.6 and Appendices A, B, and C (Guidelines for Establishing Test Procedures for the Analysis of Pollutants) for wastewater samples; and 40 CFR Part 503.
- Document potential violations to support enforcement action.

In addition, specific objectives of the sampling conducted by inspectors include the following:

- Verify compliance with effluent limitations.
- Verify accuracy of reports and program self-monitoring.
- Support enforcement action.
- Support permit development reissuance and/or revision.
- Determine the quantity and quality of effluent.

Sampling, analysis, preservation technique, sample holding time, and sample container requirements are provided under 40 CFR Part 136 as authorized by section 304(h) of the Clean Water Act (CWA). For all NPDES permittees the inspector should perform a review of sampling procedures and quality control measures the facility uses to ensure the integrity of sample data.
To evaluate sampling procedures, assess the following eight areas:

- Sample site locations
- Sample collection techniques
- Field measurements
- Sample labeling (including locations) and documentation
- Sample preservation and holding time
- Transfer of custody and shipment of samples
- Quality control
- Data handling and reporting

Common Wastewater Sample Bottles

625/608, 1657, TTO/Organics, TPH/Oil/Grease,
Thin vials-TOCs, VOCs, 601/602 and 502.2
Be careful not to get air in the VOC/SVOC bottles.

NO_2/NO_3, Fluoride, Sulfide, Metals, BOD-TDS-TSS
Wide-mouth Sludge/Metals bottle

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

Sample Receipt

No. Containers:

Project Number

Custody Seals: Yes No

Received Intact: Yes No

Field Measurements:

Received Cold: Yes No

Temperature:

PRIORITY:

pH:

Temp:

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

Wastewater Sampling Information

Required Containers, Preservation Techniques, and Holding Times
40 CFR 136.3

Parameter number/name	Container 1	Preservation 2, 3	Maximum holding time 4
Table IA - Bacterial Tests			
1-4. Coliform, total, fecal, & E. coli	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ 5	8 hours.22 23
5. Fecal streptococci	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ 5	8 hours.22
6. Enterococci	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ 5	8 hours.22
7. Salmonella	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ 5	8 hours.22
Table IA - Aquatic Toxicity Tests			
8-11. Toxicity, acute & chronic	P, FP, G	Cool, ≤6 °C 16	36 hours.
Table IB - Inorganic Tests			
1. Acidity	P, FP, G	Cool, ≤6 °C 18	14 days.
2. Alkalinity	P, FP, G	Cool, ≤6 °C 18	14 days.
4. Ammonia	P, FP, G	Cool, ≤6 °C 18, H_2SO_4 to pH <2	28 days.
9. Biochemical oxygen dem&	P, FP, G	Cool, ≤6 °C 18	48 hours.
10. Boron	P, FP, or Quartz	HNO_3 to pH <2	6 months.
11. Bromide	P, FP, G	None required	28 days.
14. Biochemical oxygen dem &, carbonaceous	P, FP G	Cool, ≤6 °C 18	48 hours.
15. Chemical oxygen dem&	P, FP, G	Cool, ≤6 °C 18, H_2SO_4 to pH <2	28 days.
16. Chloride	P, FP, G	None required	28 days.
17. Chlorine, total residual	P, G	None required	Analyze within 15 minutes.
21. Color	P, FP, G	Cool, ≤6 °C 18	48 hours.
23-24. Cyanide, total or available (or CATC) & free	P, FP, G	Cool, ≤6 °C 18, NaOH to pH >10 5 6, reducing agent if oxidizer present	14 days.
25. Fluoride	P	None required	28 days.
27. Hardness	P, FP, G	HNO_3 or H_2SO_4 to pH <2	6 months.
28. Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes.
31, 43. Kjeldahl & organic N	P, FP, G	Cool, ≤6 °C 18, H_2SO_4 to pH <2	28 days.
Table IB - Metals 7			
18. Chromium VI	P, FP, G	Cool, ≤6 °C 18, pH = 9.3-9.7 20	28 days.
35. Mercury (CVAA)	P, FP, G	HNO_3 to pH <2	28 days.
35. Mercury (CVAFS)	FP, G; & FP-lined cap 17	5 mL/L 12N HCl or 5 mL/L BrCl 17	90 days.17
Metals, except boron, chromium VI, & mercury 3, 5-8, 12, 13, 19, 20, 22, 26, 29, 30, 32-34, 36, 37, 45, 47, 51, 52, 58-60, 62, 63, 70-72, 74, 75.	P, FP, G	HNO_3 to pH <2, or at least 24 hours prior to analysis 19	6 months.
38. Nitrate	P, FP, G	Cool, ≤6 °C 18	48 hours.
39. Nitrate-nitrite	P, FP, G	Cool, ≤6 °C 18, H_2SO_4 to pH <2	28 days.
40. Nitrite	P, FP, G	Cool, ≤6 °C 18	48 hours.
41. Oil & grease	G	Cool to ≤6 °C 18, HCl or H_2SO_4 to pH <2	28 days.
42. Organic Carbon	P, FP, G	Cool to ≤6 °C 18, HCl, H_2SO_4, or H_3PO_4 to pH <2	28 days.
44. Orthophosphate	P, FP, G	Cool, to ≤6 °C 18 24	Filter within 15 minutes; Analyze within 48 hours.
46. Oxygen, Dissolved Probe	G, Bottle & top	None required	Analyze within 15 minutes.
47. Winkler	G, Bottle & top	Fix on site & store in dark	8 hours.
48. Phenols	G	Cool, ≤6 °C 18, H_2SO_4 to pH <2	28 days.
49. Phosphorus (elemental)	G	Cool, ≤6 °C 18	48 hours.
50. Phosphorus, total	P, FP, G	Cool, ≤6 °C 18, H_2SO_4 to pH <2	28 days.
53. Residue, total	P, FP, G	Cool, ≤6 °C 18	7 days.
54. Residue, Filterable (TDS)	P, FP, G	Cool, ≤6 °C 18	7 days.
55. Residue, Nonfilterable (TSS)	P, FP, G	Cool, ≤6 °C 18	7 days.

56. Residue, Settleable	P, FP, G	Cool, ≤6 °C 18	48 hours.
57. Residue, Volatile	P, FP, G	Cool, ≤6 °C 18	7 days.
61. Silica	P or Quartz	Cool, ≤6 °C 18	28 days.
64. Specific conductance	P, FP, G	Cool, ≤6 °C 18	28 days.
65. Sulfate	P, FP, G	Cool, ≤6 °C 18	28 days.
66. Sulfide	P, FP, G	Cool, ≤6 °C 18, add zinc acetate plus sodium hydroxide to pH >9	7 days.
67. Sulfite	P, FP, G	None required	Analyze within 15 minutes.
68. Surfactants	P, FP, G	Cool, ≤6 °C 18	48 hours.
69. Temperature	P, FP, G	None required	Analyze within 15 minutes.
73. Turbidity	P, FP, G	Cool, ≤6 °C 18	48 hours.

Table IC - Organic Tests 8

Purgeable Halocarbons 13, 18-20, 22, 24, 25, 27, 28, 34-37, 39-43, 45-47, 56, 76, 104, 105, 108-111, 113.	G, FP-lined septum	Cool, ≤6 °C 18, 0.008% Na2S2O3 5, HCl to pH 2 9	14 days.9
26. 2-Chloroethylvinyl ether	G, FP-lined septum	Cool, ≤6 °C 18, 0.008% $Na_2S_2O_3$ 5	14 days.
Purgeable aromatic hydrocarbons 6, 57, 106.	G, FP-lined septum	Cool, ≤6 °C 18, 0.008% $Na_2S_2O_3$ 5, HCl to pH 2 9	14 days.9
3, 4. Acrolein & acrylonitrile	G, FP-lined Septum	Cool, ≤6 °C 18, 0.008% $Na_2S_2O_3$, pH to 4-5 10	14 days. 10
Phenols 11 23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112.	G, FP-lined cap	Cool, ≤6 °C 18, 0.008% $Na_2S_2O_3$	7 days until extraction, 40 days after extraction.
7, 38. Benzidines 11 12	G, FP-lined cap	Cool, ≤6 °C 18, 0.008% $Na_2S_2O_3$ 5	7 days until extraction.13
Phthalate esters 11 14, 17, 48, 50-52.	G, FP-lined cap	Cool, ≤6 °C 18	7 days until extraction, 40 days after extraction.
82-84. Nitrosamines 11 14	G, FP-lined cap	Cool, ≤6 °C 18, store in dark, 0.008% $Na_2S_2O_3$ 5	7 days until extraction, 40 days after extraction.
88-94. PCBs 11	G, FP-lined cap	Cool, ≤6 °C 18	1 year until extraction, 1 year after extraction.
54, 55, 75, 79. Nitroaromatics & isophorone 11	G, FP-lined cap	Cool, ≤6 °C 18, store in dark, 0.008% $Na_2S_2O_3$ 5	7 days until extraction, 40 days after extraction.
Polynuclear aromatic hydrocarbons 11 1, 2, 5, 8-12, 32, 33, 58, 59, 74, 78, 99, 101.	G, FP-lined cap	Cool, ≤6 °C 18, store in dark, 0.008% $Na_2S_2O_3$ 5	7 days until extraction, 40 days after extraction.
15, 16, 21, 31, 87. Haloethers 11	G, FP-lined cap	Cool, ≤6 °C 18, 0.008% $Na_2S_2O_3$ 5	7 days until extraction, 40 days after extraction.
Chlorinated hydrocarbons 11 29, 35-37, 63-65, 73, 107.	G, FP-lined cap	Cool, ≤6 °C 18	7 days until extraction, 40 days after extraction.
CDDs/CDFs 11 60-62, 66-72, 85, 86, 95-97, 102, 103.	G	See footnote 11	See footnote 11.
Aqueous Samples: Field & Lab Preservation	G	Cool, ≤6 °C 18, 0.008% $Na_2S_2O_3$ 5, pH <9	1 year.
Solids & Mixed-Phase Samples: Field Preservation	G	Cool, ≤6 °C 18	7 days.
Tissue Samples: Field Preservation	G	Cool, ≤6 °C 18	24 hours.
Solids, Mixed-Phase, & Tissue Samples: Lab Preservation	G	Freeze, ≤−10 °C	1 year.
114-118. Alkylated phenols	G	Cool, <6 °C, H2SO4 to pH <2	28 days until extraction, 40 days after extraction.
119. Adsorbable Organic	G	Cool, <6 °C, 0.008% $Na_2S_2O_3$,	Hold at least 3 days, but

Halides (AOX)		HNO_3 to pH <2	not more than 6 months.
120. Chlorinated Phenolics	G, FP-lined cap	Cool, <6 °C, 0.008% $Na_2S_2O_3$, H_2SO_4 to pH <2	30 days until acetylation, 30 days after acetylation.
Table ID - Pesticides Tests			
1-70. Pesticides 11	G, FP-lined cap	Cool, ≤6 °C 18, pH 5-9 15	7 days until extraction, 40 days after extraction.
Table IE - Radiological Tests			
1-5. Alpha, beta, & radium	P, FP, G	HNO_3 to pH <2	6 months.
Table IH - Bacterial Tests			
1, 2. Coliform, total, fecal	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ 5	8 hours.22
3.E. coli	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ 5	8 hours.22
4. Fecal streptococci	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ 5	8 hours.22
5. Enterococci	PA, G	Cool, <10 °C, 0.008% $Na_2S_2O_3$ 5	8 hours.22
Table IH - Protozoan Tests			
6. Cryptosporidium	LDPE; field filtration	1-10 °C	96 hours.21
7. Giardia	LDPE; field filtration	1-10 °C	96 hours.21

Polyethylene (P) or glass (G). For microbiology, plastic sample containers must be made of sterilizable materials (polypropylene or other autoclavable plastic).

Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4 degrees C until compositing and sample splitting is completed.

When any sample is to be shipped by common carrier or sent through the United States Mails, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under Sec. 136.**3**(e). Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show that this is necessary to maintain sample stability. See Sec. 136.**3**(e) for details. The term ``analyze immediately'' usually means within 15 minutes or less of sample collection. Should only be used in the presence of residual chlorine.

Maximum holding time is 24 hours when sulfide is present. Optionally all samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

Samples should be filtered immediately on-site before adding preservative for dissolved metals.

Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

Sample receiving no pH adjustment must be analyzed within seven days of sampling.

The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within **3** days of sampling.

When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4 deg. C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; Samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re the requirement for thiosulfate reduction of residual chlorine), and footnotes 12, 13 (re the analysis of benzidine).

If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0<plus-minus>0.2 to prevent rearrangement to benzidine.

Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.

For the analysis of diphenylnitrosamine, add 0.008% $NA_2S_2O_3$ and adjust pH to 7-10 with NaOH within 24 hours of sampling.

The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $NA_2S_2O_3$.

Sufficient ice should be placed with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, it is necessary to immediately measure the temperature of the samples and confirm that the 4^0C temperature maximum has not been exceeded.

In the isolated cases where it can be documented that this holding temperature cannot be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature.

Metals Sampling *(Example Procedure)*

Metals sampling will encompass a variety of individual samples within a sample, i.e., nickel, zinc, silver and others. As a general rule, metals samples need to be collected as a composite and preserved with 1:1 nitric acid to pH < 2.

If ICP (inductively coupled plasma) laboratory analysis will be used, a 500 ml sample is sufficient. ICP is used for a general scan; if more stringent detection limits are needed then furnace analysis is used.

If additional analysis is required, i.e., furnace method analysis, collect a 2 liter bottle of sample (instead of the 500 ml sample) and preserve with nitric acid.

Ice is not necessary for preservation, but it won't jeopardize the sample, either.

PARAMETER	CONTAINER	PRESERVATIVE	MAX. HOLDING TIME
Metals	P	HNO_3 to pH < 2	6 months

This course contains general EPA's CWA federal rule requirements. Please be aware that each state implements wastewater/safety/environmental /building regulations that may be more stringent than EPA's regulations. Check with your state environmental agency for more information. These rules change frequently and are often difficult to interpret and follow. Be careful to not be in non-compliance and do not follow this course for proper compliance.

Wastewater Treatment Plant Sampling *(Example Procedure)*

POTW samples are collected in accordance with the National Pollutant Discharge Elimination System (NPDES) permit that sets discharge limits for certain pollutants and specifies sampling frequencies and sample types.

Depending on the POTW, laboratory personnel, operators, or a combination of these are responsible to prepare sample bottles and trip blanks, program composite samplers, and collect grab samples. It is common to collect samples for operational parameters along with permit required samples.

Plant Sampling Procedure *(Example Procedure)*
Ideally, set up two samplers at the plant influent channel and two samplers at the plant effluent channel. Two samplers are used to provide sufficient sample quantity and to minimize the impact of a sampler failure. All sampling equipment must be prepared and cleaned as established in your POTW's SOP's procedures. Teflon hose is required. Sampling locations or sites are specified in each plant's NPDES permit.

Collect the following composite samples at both sites.

(1) **Metals Sample** - (one 2-liter plastic bottle)

Preserve with 1:1 nitric acid to a pH < 2. Store sample at 4°C.

(2) **Cyanide Sample** – (one 2-liter plastic bottle)

Collect the cyanide sample as a composite in accordance with NPDES permit. Check the sample for chlorine. If Cl_2 is present, use ascorbic acid to eliminate it. Add NaOH to a pH > 12. Store samples at 4°C.

(3) EPA Test Method 608 and 625 samples are informational samples only. These results are used for local limits data.

608 and 625 samples are collected as composite samples. From the well-mixed influent channel composite jug: Pour one 1-liter amber glass bottle of each sample (608, 625). Check samples for chlorine. At the effluent channel: Collect and pour one 4-liter amber glass bottle of each sample (608, 625). Check samples for chlorine. If Cl_2 is present in the samples, use sodium thiosulfate ($Na_2S_20_3$) to eliminate it. Store samples on ice at 4°C.

(4) **625/Phenols** are collected as a grab sample. Collect one 4-liter amber glass bottle at the effluent channel only. Check the sample for chlorine. If Cl_2 is present, use sodium thiosulfate ($Na_2S_20_3$) to eliminate it. Store sample at 4°C.

Bio-Solids Sampling *(Example Procedure)*

Bio-solids (dried sludge) samples are collected at POTWs.

Normally, bio-solid samples will be collected from the final storage area for dry sludge. The location of the dried bio-solids may vary based on the individual plants. Sampling frequency will be determined on an as needed basis and to comply with the EPA requirements.

Grab samples are useful for bio-solids. Care should be taken to avoid contamination. All samples are collected using a sterile plastic scoop in order to avoid any contamination.

The following is a list of samples to be collected:

PARAMETER	CONTAINER
Helminth Ova & Enteric Virus	1 Qt Plastic Bag (Ziploc)
Metals +	500 ml Plastic Bottle
Nitrogen (total)	4 oz Glass Bottle
TOC (Total Organic Carbon)	4 oz Glass Bottle
Fecal Coliform	500 ml Plastic Bottle

Sample Scheduling
An active file is maintained on each sampling location which contains historical data including past process discharge flow readings, water meter readings, sampling dates, and conditions of sampling site. A calendar of upcoming sampling events should be maintained.

River Sampling Activities *(Example Procedure)*
To judge the impact of a POTW's discharge to a river, it may be necessary to sample the river above and below the plant's outfall. When developing a sampling plan for river sampling, the following considerations must be observed:

(1) Sampling sites must meet the objectives of the program or study.
(2) At the sampling sites the river must be flowing freely and the sample must be as representative as possible of river flow at that site. Consideration of all safety factors must be observed.
(3) Samples must be collected midstream of the main channel at approximately two-thirds of the depth unless specific depths have been requested.
(4) All safety precautions must be observed during sampling which includes the use of harnesses, waterproof boots and other equipment.

Sewers *(Example Procedure)*
Sewer system and user rate sampling are conducted in manholes. General guidelines for selection of sampling locations include the following:

(1) Samples should be taken at points of high turbulent flow to ensure good mixing and prevent the deposition of solids.
(2) The sample location should be easily accessible and free of any major safety hazards.
(3) Sample lines should not be located where there is surface scum.

(4) If a flow study or a flow/proportional sampling event is required, make sure that the sewer pipe does not have a curve, a drop in the line or any obstructions. These would cause false flow readings.

Cleaning Automatic Samplers *(Example Procedure)*
Samplers, sample jars, grab beakers, and all other equipment used in collecting samples must be cleaned between their use at each site, to avoid the possibility of cross contamination. Latex or nitrile gloves should be worn to protect against infections and chemical burns. The following steps should be taken to ensure the proper cleaning of the sampling equipment.

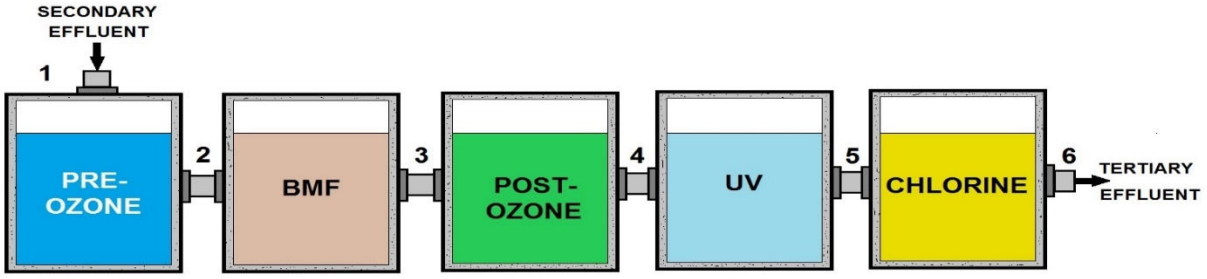
Follow the manufactures recommended procedures for cleaning your automatic samplers. Clean composite jugs and caps separately from the samplers, following your labs SOP.

You may also want to read an EPA Operating Procedure [https://www.epa.gov/sites/default/files/2016-01/documents/field_equipment_cleaning_and_decontamination_at_fec206_af.r3_1.pdf].

Many state environmental departments have their own cleaning procedures for field samplers.

Cleaning often includes the following steps:

(1) Disassemble the sampler into its component parts.
(2) Add laboratory soap to a bucket and immerse the parts to be cleaned. Use a bottle brush to thoroughly scrub the inside and outside of parts, focusing on areas that sample comes in contact with.
(3) Sometimes tubing (suction, peristaltic, or discharge) is so contaminated or worn that replacement is a better option than cleaning. Keep extra tubing in stock.
(4) A dilute acid is sometimes used to remove stubborn contaminants.
(5) A disinfectant is sometimes called for.
(6) Lab water is most commonly used for the final rinse before drying. Sometimes a solvent like acetone is used instead.
(7) Once dry, reassemble the sampler. Return it to your sampling vehicle or storage area. Leave the lid loose so moisture won't be trapped inside.



TERTIARY TREATMENT PROCESS SAMPLING POINTS

Selection of Sampling Site
In order to ensure the collection of valid samples, a representative sampling site must be selected. For industrial sampling, the sites are designated in the permit.

QA/QC Field Procedures for Plant Sampling *(Example Procedure)*

Duplicate Sampling Procedure

The purpose of Duplicate Samples is to check the laboratory's ability to reproduce analytical results. Duplicate Samples are to be collected using these steps:

1. Determine amount of sample needed. If a flow proportion sample is required, then base the amount of sample needed on the current flow reading. If a flow-proportion sample is not required, then use the predetermined amount for the sampling site.
2. Collect sample using a grab type sampler or a sampling head.
3. Measure the amount determined in Step 1 using a graduated cylinder or other accurate measuring device.
4. Pour measured sample into sample container that is not marked as the Duplicate Sample.
5. Measure same amount as in Step 1.
6. Pour second measured quantity into sample container marked for Duplicate Sample.
7. Process both samples using standard procedures and submit both samples to laboratory.

Split Sampling Procedure

The purpose of Split Samples is to check analytical procedures by having the samples analyzed by two different laboratories. Collect Split Samples following the procedure used for Duplicate Sampling. The only difference is that the Split Sample is sent to a different lab.

Trip Blank Procedure

The purpose of Trip Blanks is to determine if the purge bottles for the volatile organic samples have been adequately cleaned, and if sample contamination occurs between the time sample bottles leave the laboratory to the time that samples are returned to the lab.

Using a purge vile from the same source as the ones to be used for sampling, fill it with DI water in the laboratory. If purge bottles with a preservative are called for, use one of them for the trip blank.

Note the time of Trip Blank sample collection on the COC form. Place the trip blank(s) in the ice chest with the purge bottles to be used for sampling. The Blank remains there for the sampling event and is processed with the other samples for testing.

Industrial Users - Permitted/Nonpermitted Sampling *(Example Procedure)*

The sampling points within an industry vary with each industry, depending on the nature of the process and location of pretreatment facilities. Therefore, exact locations must be identified on a case by case basis. However, the following general principles apply in all cases:

(1) SUOs should give permit writers the ability to require industries to install a sampling vault at a specified location. Depending on the specific site, a special sampling vault may or may not be needed.
(2) The sampling location should be easily accessible and relatively free of safety hazards.
(3) The specific location of all sampling points should be part of any permit. It is common to include a map and/or photos to help identify sampling locations.
(4) If a sampling location can no longer provide access to a representative sample, the permit needs to be modified to identify a location that works.
(5) When sampling a categorical process or pretreatment system effluent, there should be, if possible, no discharge present other than that from the regulated process. If other wastestreams are combined with the regulated wastestream prior to the sampling location, the combined wastestream formula will need to be utilized. The sampling crew must be aware of lower limits to correctly show analysis on chain of custody.
(6) When filling out chain of custody forms, be sure to specify a test method sensitive enough to provide concentration results below the limit.
(7) If mass limitations are to be applied, some means of determining process flow must be available.
(8) The local limit sampling location needs to be after all flows (industrial and domestic) have combined and before discharge to the public sewer.

Sample Volume -Type and Analyses
Typical sample volumes are required for various analyses. Each laboratory has developed their own standard volumes for routine analyses performed on industrial waste samples. If you are not getting sample bottles from a lab, be sure to ask what volumes they require.

Typical volumes:

(1) BOD/COD/TSS (1000-2000 ml, plastic)
(2) Heavy metals (500-2000 ml, plastic)
(3) Cyanide (2000 ml, plastic)
(4) Oil and grease (1000 ml, level-one glass)

Selection and Preparation of Sample Containers
The selection of a sample container is based on the parameter to be measured and the volumetric needs of the lab. The primary variables are material, diameter of the opening, and volume. The inspector should be familiar with the type of sampling containers and preservatives that are needed.

It is essential that the sample containers be made of chemically resistant material, and do not affect the concentrations of the pollutants to be measured. In addition, sample containers should have a closure (i.e., leak proof/resistant, Teflon lined) that protects the sample from contamination and should be properly labeled before leaving the sampling site.

Sample Preservation

Wastewater usually contains one or more unstable pollutants that require immediate analysis or preservation until an analysis can be made. Sample preservation is needed for composite samples, for example, which may be stored for as long as 24 hours prior to transferring them to the laboratory. Recommended preservatives and holding times that should be used for specific pollutants are presented at the start of this Chapter.

Chain of Custody (COC)
Documentation of all pertinent data concerning the collection, preservation and transportation of samples is critical to the overall success of the Wastewater Sampling Program. If sampling is performed for the Pretreatment program, any sampling data may be used as evidence in court proceedings against a noncompliant industrial user. In this case, documentation becomes critical. The COC form is a legal document and is of major importance in a court hearing.

Specific procedures with regard to chain of custody are outlined below:

(1) The sampling crew takes a sufficient supply of prenumbered Industrial Waste Lab Reports, (custody forms) and sample containers into the field.

It is generally possible to fill out much of the form ahead of time, with the notable exceptions of the time of collection and the change in custody signatures.

a) TURN-AROUND TIME: Check box to indicate if results are needed on a rush basis or in standard turn-around time.
b) PROJECT #/NAME: The ID # or name assigned for the sampling event.
c) SITE ID #/NAME: For each sampling location.
d) DATE SAMPLED: From - Date sampling began. To - Date sample is pulled. If it is a grab sample, only the date the sample was taken will be entered with the other line crossed out.
e) COLLECTED: Date and Time. For a composite sample, the start, end, and total times are recorded.
f) MATRIX: Wastewater, DI water, etc.
g) SAMPLE TYPE: Grab or Composite (hand, flow, or time proportional).
h) SAMPLE BOTTLE: Material & Size
i) NUMBER OF CONTAINERS: Used for this sample.
j) PARAMETER: For example: Metals, Cyanide, O&G, VOC, etc. and,
k) TEST METHOD: Respectively: EPA 200.7, 4500-CN E, EPA 1664A, EPA 624, etc.
l) PRESERVATIVE: Codes for each preservative may be specified on the COC form.
m) NOTES to LAB: Includes any special notes to the lab, such as special analysis required of the sample, a letter code which is assigned to the entity being tested, the amount of flow if sample is flow proportional, grab sample pH and temperature, and/or actual sample temperature.
n) NOTES (Other): Should include the results of any field tests including pH and temperature.
o) COLLECTED BY: for the samplers initials and, if needed, the vehicle ID #.
p) RELINQUISHED BY: Signature w/Date & Time.
q) RECEIVED BY: Signature w/Date & Time.

(2) When a sample is taken the crew records the time of collection on the COC form.

Quality Assurance/Quality Control (*Example*)
Quality Assurance/Quality Control (QA/QC) measures taken by the sampling crew include equipment blanks, trip blanks, split samples and duplicate samples. Equipment blanks and trip blanks are routine QA/QC measures.

Split samples are taken for Local Limits sampling and when requested by an industry.

Split samples requested by an industry are analyzed by their lab at their expense.

Duplicate samples are run when requested by a Project Leader.

According to the EPA, the primary purpose of blanks is to trace sources of artificially introduced contamination. There are five types of blanks used to trace where contamination is introduced, three of which are used in the field and two are used the laboratory. https://www.epa.gov/sites/default/files/2015-06/documents/blanks.pdf

In addition, temperature blanks are sometimes used. Either laboratory staff or the sampling crew prepare the travel, trip, and/or temperature blanks needed for a sampling event.

Any contamination detected in the blanks would result from field exposure which could in turn affect collected samples.

Field Equipment (Rinsate) Blank Procedure *((Example Procedure)*

The purpose of Field Equipment Blanks, also known as Rinsate Blanks is to test the procedure for cleaning the sample measuring container to determine if cross contamination between sample sites has occurred. These Blanks are needed only at sites where flow-proportion samples are taken. Follow these steps when collecting a Field Equipment Blank(also see QA/QC check list example:

1. Collect Field Equipment Blank **AFTER** collecting a sample and **BEFORE** moving to the next sampling location.
2. Open a sealed bottle of High Purity Water.
3. After collecting a sample, triple rinse the sample measuring container, usually a graduated cylinder, using High Purity water.
4. Pour the High Purity Water into the sample measuring container that was just rinsed.
5. Pour the High Purity water from sample measuring device into sample bottles labeled for the Field Equipment Blanks.
6. Repeat Steps 3 through 5 until all Field Equipment Blank sample bottles have been filled.
7. Process samples using standard procedures and submit to laboratory.

An equipment blank is high purity water which has been collected in a composite sample bottle or a series of discrete bottles from an automatic sampler. Equipment blanks are used to evaluate the reliability of composite samples collected in the field. The data produced from the equipment blank indicates the performance of the sample collection system, which involves the cleaning of sampling equipment, and accessories, preservation techniques, and handling of samples. The objective is to demonstrate that the samples are not contaminated by inadequate cleaning of equipment, contaminated preservation additives or sample collection techniques, and to provide documented records on Quality Assurance Practices.

Procedures to be followed in collecting the equipment blanks are outlined below. (Also see QA/QC check list, example).

(1) The sampler is to be assembled completely in the manner determined by the parameters the crew will be sampling (i.e. if sampling for organics, Teflon suction tubing must be used at that site). The composite jar inside the sampler must always be rinsed out thoroughly with high purity water.

(2) Program the sampler to collect the proper amount of high purity water that is representative of the sample parameters that will be collected at that site. Grab samples are excluded. Pump high purity water through the strainer and intake tubing prior to filling the sampler bottle. Then, place the strainer into as many fresh, uncontaminated bottles of high purity water as needed to collect the necessary volume of sample.

(3) If the sampler is set up in the discrete mode, the crew must then transfer the collected samples into the field composite bottle and shake to mix thoroughly.

(4) Transfer the sample from the field composite bottle into its respective lab sample bottles. Test and preserve the samples as appropriate for the parameters being analyzed.

(5) Follow the chain of custody procedures outlined in SOP for turning the samples in to the laboratory. All paperwork must be completed at this time, and all bottles must be marked accordingly. Custody seals must be used. The crew must note the sampling activity in a logbook that is kept specifically for documenting preparation of equipment blanks and/or any other QA activities.

Sampling Techniques *(Example)*

General Guidelines

In general, the following guidelines should be observed in conducting sampling activities:

(1) Samples being collected must be representative of the wastestream being tested.

(2) Samples shall be collected in uncontaminated containers and preserved properly.

(3) Samples should be of sufficient volume for the required analyses.

(4) Samples should be stored in a manner which does not alter the properties of the sample prior to chain of custody transfer.

(5) Samples should be properly and completely identified by labeling them with the proper information.

(6) Sample lines should be as short as possible and the smallest practical diameter to facilitate purging, reduce lag time, and give adequate consideration to maximum transport velocity. Also, they should have sufficient strength to prevent structural failure.

(7) Sample lines should be pitched downward at least 10 percent to prevent settling or separation of solids contained by the sample.

(8) Samples should be delivered as quickly as possible to the laboratory.

Specific Techniques

Sampling techniques in addition to the above general guidelines must also recognize differences in sampling methodology, preservation, and analytical methods.

The following sections specify techniques that differ by pollutant group and discuss such factors as sampling methodology (e.g., composite, grab, etc.), type of container, preservation and holding time.

Sampling Techniques for Volatile Organics *(Example Procedure)*

Volatile organics are analyzed in accordance with EPA methods 601, 602, 603 and 624.

Due to the volatility of these compounds, only grab samples can be used. If a composite sample is needed, individual grab samples must be collected and composited in the laboratory prior to analysis.

The procedures that must be followed in taking these samples are outlined below.

NOTE: Gloves, clothing, face, and eye protection must be worn when handling volatile organics. In addition, the sampling crew must thoroughly clean those parts of the body that have been exposed to these materials.

(1) For each sampling date, the lab should also provide two additional bottles to be used as a backup in case of breakage. These sampling vials are only good for one week. If any are unused, they must be returned to the lab for disposal.

(2) The lab will provide one sample trip blank per sampling date. This bottle is to be kept on ice until the samples are submitted to the lab. At least one day prior to sampling, go to the lab and request the sample bottles (40 ml vials) for the specific sampling site, as indicated by the sampling plan. The laboratory will arrange to have the appropriate number of sample bottles prepared, based on the number of analyses to be performed. The sampling crew should make sure that all bottles are provided for these samples by the lab technicians.

(3) Collect the sample in a clean glass beaker. Test for chlorine with the Hach test kit. If there is any chlorine residual, neutralize the chlorine with sodium thiosulfate ($Na_2S_2O_3$) and retest for chlorine. Repeat until there is no chlorine residual. Make notes on chain of custody sheet if extra amounts of sodium thiosulfate are required for neutralization.

(4) Remove the vials from the ice. There will be two empty vials for the 601 sample and two vials with HCl for the 602. The HCl will already have been measured into the vials by the lab personnel.

(5) Fill the vial so that the sample is higher than the rim. Surface tension causes this bulge to exist. This is accomplished by pouring the sample from the beaker into the vial along the side of the vial to minimize the possibility of entrapping air in the sample. Do not rinse out or overfill the vials, this will wash out the preservative in the vial.

(6) Seal the vial so that no air bubbles are entrapped in it. Remember to put the Teflon side of the cap facing down onto the vial.

(7) To be sure there are no air bubbles, turn the vial upside down and tap it against the palm of the hand. Check to see if there are air bubbles along the sides or bottom of the vial. If there are bubbles, unseal the vial, top off the vial, and reseal. Check the vial again for the presence of bubbles.

(8) All samples must be maintained at 4°C from the time of collection until the time of extraction. Custody seals must be placed on all samples, and all paper work must be filled out properly.

(9) Return the sample bottles and QA/QC bottles to the laboratory the same day the sample is collected.

Common wastewater sample bottles

Radionuclides, VOCs, (Volatile Organic Compounds), TTHMs, (Total Trihalomethanes), Nitrate, Nitrite.

Most of these sample bottles will come with the preservative already inside the bottle.

Some bottles will come with a separate preservative (acid) for the field preservation.

Slowly add the acid or other preservative to the water sample; not water to the acid or preservative.

SECONDARY TREATMENT STANDARDS

The biological treatment component for a municipal wastewater treatment plant is termed **secondary treatment**, and is usually preceded by simple settling (primary treatment). Secondary treatment standards have been established by U.S. EPA for publicly-owned treatment works (POTWs) and reflect the performance of secondary wastewater treatment plants. These technology-based regulations apply to all municipal wastewater treatment plants and represent the minimum level of effluent quality attainable by **secondary treatment**, as reflected in terms of 5-day biochemical oxygen demand (BOD5) and total suspended solids (TSS) removal.

Technical Learning College

METHOD DETECTION LIMIT OR MDL

The **Method Detection Level (MDL)** is the basic measure of whether a pollutant or parameter has been detected. It's the minimum concentration at which we can be confident that the effluent concentration is greater than zero. The **MDL** is dependent upon the analytical method used for the pollutant. A sensitive analytical method will typically have a lower **MDL** and can provide more accurate results. In general, if the reported pollutant concentration is less than three times the magnitude of the **MDL**, the accuracy or reliability of these results is questionable, and permit decisions using data in this range should be avoided if possible.

Technical Learning College

Synthetic Organic Chemicals (SOC) Sub-Section

Common wastewater sampling bottles. SOC/VOC bottles are the smaller, thin bottles with the septum tops. Be careful not to get any air bubbles in the SOC/VOC bottles

SOC Introduction

Synthetic Organic Chemicals (SOCs) are organic (carbon based) chemicals that are less volatile than Volatile Organic Compounds (VOCs). SOCs are used as pesticides, defoliants, fuel additives and as ingredients for other organic compounds. They are all man made and do not naturally occur in the environment. Some of the more well-known SOCs are Atrazine, 2,4-D, Dioxin and Polychlorinated Biphenyls (PCBs).

SOCs most often enter the natural environment through application of pesticide (including runoff from areas where they are applied), as part of a legally discharged waste stream, improper or illegal waste disposal, accidental releases or as a byproduct of incineration. Some SOCs are very persistent in the environment, whether in soil or water.

SOCs are generally toxic and can have substantial health impacts from both acute (short-term) and chronic (long-term) exposure. Many are known carcinogens (cancer causing). EPA has set Maximum Contaminant Levels (MCL) for 30 SOCs under the Safe Drinking Water Act.

SDWA Act

The Safe Drinking Water Act requires that all water sources of all public water systems be periodically monitored for regulated SOCs. The monitoring frequency can be adjusted through a waiver if SOCs are not detected.

EPA established Maximum Contaminant Levels (MCL), Maximum Contaminant Level Goals (MCLG), monitoring requirements and best available technologies for removal for 65 chemical contaminants over a five year period as EPA gathered and analyzed occurrence and health effects data. This series of rules are known as the Chemical Phase Rules and they define regulations for three contaminant groups:

- Inorganic Chemicals (IOC),
- Synthetic Organic Chemicals (SOC), and
- Volatile Organic Chemicals (VOC).

The Chemical Phase rules provide public health protection through the reduction of chronic risks from:

- cancer;
- organ damage; and
- circulatory,
- nervous, and
- reproductive system disorders.

They also help to reduce the occurrence of Methemoglobinemia or "blue baby syndrome" from ingestion of elevated levels of nitrate or nitrite. All public water systems must monitor for Nitrate and Nitrite. Community water systems and Non-transient non-community water systems must also monitor for IOCs, SOCs, and VOCs.

This is a list of the organic chemicals—which include pesticides, industrial chemicals, and disinfection by-products—that are tested for in public water systems (those that provide water to the public), along with the maximum standard for the contaminant, and a brief description of the potential health effects associated with long-term consumption of elevated levels of the contaminants.

The federal standard for most contaminants is listed as a Maximum Contaminant Level (MCL), the lowest concentration at which that particular contaminant is believed to represent a potential health concern.

Unless otherwise noted, the MCL is expressed as parts per billion (ppb). Also, because of technological limitations or other factors, it is not possible to test for some contaminants in a reliable fashion. Instead, public water systems are required to use specific Treatment Techniques (TT) that are designed to remove these particular contaminants from the water.

In addition to the chemicals listed, monitoring is done for approximately 60 organic chemicals for which MCLs have not been established. If unacceptable levels are found of these “unregulated” contaminants—based on established state health standards and an assessment of the risks they pose—the response is the same as if an MCL has been exceeded: the public water system must notify those served by the system.

Volatile Organic Compounds (VOCs) Sub-Section

Definitions
Volatile Organic Compounds (VOCs) – "VOCs are groundwater contaminants of concern because of very large environmental releases, human toxicity, and a tendency for some compounds to persist in and migrate with groundwater to drinking-water supply well … In general, VOCs have high vapor pressures, low-to-medium water solubilities, and low molecular weights. Some VOCs may occur naturally in the environment, other compounds occur only as a result of manmade activities, and some compounds have both origins." - Zogorski and others, 2006

40 CFR 51.100(s) - Definition - Volatile organic compounds (VOC)
(s) "Volatile organic compounds (VOC)" means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions.

VOCs Explained

Volatile organic compounds (VOCs) are organic chemicals that have a high vapor pressure at ordinary, room-temperature conditions. Their high vapor pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air. An example is formaldehyde, with a boiling point of –19 °C (–2 °F), slowly exiting paint and getting into the air.

VOCs are numerous, varied, and ubiquitous. They include both human-made and naturally occurring chemical compounds. Most scent or odors are composed of VOC molecules. Industrial use of fossil fuels produces VOCs either directly as products (e.g., gasoline) or indirectly as byproducts (e.g., vehicle exhaust). Some VOCs are dangerous to human health or cause harm to the environment. Anthropogenic VOCs are regulated by law, especially indoors, where concentrations are the highest. Harmful VOCs are typically not acutely toxic, but instead have compounding long-term health effects. Because the concentrations are usually low and the symptoms slow to develop, research into VOCs and their effects is difficult.

Specific Sources of Select VOCs
Paints and Coatings
A major source of man-made VOCs are coatings, especially paints and protective coatings. Solvents are required to spread a protective or decorative film. Approximately 12 billion liters of paints are produced annually.

Typical paint solvents are aliphatic hydrocarbons, ethyl acetate, glycol ethers, and acetone. Motivated by cost, environmental concerns, and regulation, the paint and coating industries are increasingly shifting toward aqueous solvents.

Chlorofluorocarbons and Chlorocarbons
Chlorofluorocarbons, which are banned or highly regulated, were widely used cleaning products and refrigerants. Tetrachloroethene is used widely in dry cleaning and by industry. Industrial use of fossil fuels produces VOCs either directly as products (e.g., gasoline) or indirectly as byproducts (e.g., automobile exhaust).

Benzene
One common VOC that is a known human carcinogen is benzene, which is a chemical found in environmental tobacco smoke, stored fuels, and exhaust from cars in an attached garage. Benzene also has natural sources such as volcanoes and forest fires. It is frequently used to make other chemicals in the production of plastics, resins, and synthetic fibers.

Benzene evaporates into the air quickly and the vapor of benzene is heavier than air allowing the compound to sink into low-lying areas. Benzene has also been known to contaminate food and water and if digested can lead to vomiting, dizziness, sleepiness, rapid heartbeat, and at high levels, even death may occur.

Methylene Chloride
Methylene chloride is another VOC that is highly dangerous to human health. It can be found in adhesive removers and aerosol spray paints and the chemical has been proven to cause cancer in animals. In the human body, methylene chloride is converted to carbon monoxide and a person will suffer the same symptoms as exposure to carbon monoxide. If a product that contains methylene chloride needs to be used the best way to protect human health is to use the product outdoors. If it must be used indoors, proper ventilation is essential to keeping exposure levels down.

Perchloroethylene
Perchloroethylene is another VOC that has been linked to causing cancer in animals. It is also suspected to cause many of the breathing related symptoms of exposure to VOC's. Perchloroethylene is used mostly in dry cleaning. Studies show that people breathe in low levels of this VOC in homes where dry-cleaned clothes are stored and while wearing dry-cleaned clothing. While dry cleaners attempt to recapture perchlorothylene in the dry cleaning process to reuse it in an effort to save money, they can't recapture it all. To avoid exposure to perchlorothylene, if a strong chemical odor is coming from clothing when picked up from the dry cleaner, do not accept them and request that less of the chemical be used as well as a complete drying of the garments

MTBE
MTBE was used as an octane booster and oxygenated-additive. It was banned in the US around 2004 in order to limit further contamination of drinking water aquifers primarily from leaking underground gasoline storage tanks.

Formaldehyde
Many building materials such as paints, adhesives, wall boards, and ceiling tiles slowly emit formaldehyde, which irritates the mucous membranes and can make a person irritated and uncomfortable. Formaldehyde emissions from wood are in the range of 0.02 – 0.04 ppm. Relative humidity within an indoor environment can also affect the emissions of formaldehyde. High relative humidity and high temperatures allow more vaporization of formaldehyde from wood-materials.

Health Risks
Respiratory, allergic, or immune effects in infants or children are associated with man-made VOCs and other indoor or outdoor air pollutants. Some VOCs, such as styrene and limonene, can react with nitrogen oxides or with ozone to produce new oxidation products and secondary aerosols, which can cause sensory irritation symptoms. Unspecified VOCs are important in the creation of smog. VOCs are one category of hazardous air pollutants (HAPs) that are known or suspected to cause cancer, birth defects, and seriously impact the environment. Along with regulating air emissions, the EPA, through the Clean Water Act, regulates wastewater discharges of these, and other, pollutants from many categories of industries.

Health effects include:
Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans.

Key signs or symptoms associated with exposure to VOCs include conjunctival irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness.

The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effects. As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed. Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics. At present, not much is known about what health effects occur from the levels of organics usually found in homes. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.

Reducing Exposure
To reduce exposure to these toxins, one should buy products that contain Low-VOC's or No VOC's. Only the quantity which will soon be needed should be purchased, eliminating stockpiling of these chemicals. Use products with VOC's in well ventilated areas. When designing homes and buildings, design teams can implement the best possible ventilation plans, call for the best mechanical systems available, and design assemblies to reduce the amount of infiltration into the building. These methods will help improve indoor air quality, but by themselves they cannot keep a building from becoming an unhealthy place to breathe.

While proper building ventilation is a key component to improving indoor air quality, it cannot do the job on its own. As stated earlier, awareness is the key component to improving air quality, when choosing building materials, furnishings, and decorations. When architects and engineers implement best practices in ventilation and mechanical systems, the owner must maintain good air quality levels thereafter.

40 CFR 51.100(s) - Definition - Volatile organic compounds (VOC)

(1) This includes any such organic compound other than the following, which have been determined to have negligible photochemical reactivity:

- methane
- ethane
- methylene chloride (dichloromethane)
- 1,1,1-trichloroethane (methyl chloroform)
- 1,1,2-trichloro-1,2,2-trifluoroethane (CFC-113)
- trichlorofluoromethane (CFC-11)
- dichlorodifluoromethane (CFC-12)
- chlorodifluoromethane (HCFC-22)
- trifluoromethane (HFC-23)
- 1,2-dichloro 1,1,2,2-tetrafluoroethane (CFC-114)
- chloropentafluoroethane (CFC-115)
- 1,1,1-trifluoro 2,2-dichloroethane (HCFC-123)
- 1,1,1,2-tetrafluoroethane (HFC-134a)
- 1,1-dichloro 1-fluoroethane (HCFC-141b)
- 1-chloro 1,1-difluoroethane (HCFC-142b)
- 2-chloro-1,1,1,2-tetrafluoroethane (HCFC-124)
- pentafluoroethane (HFC-125)
- 1,1,2,2-tetrafluoroethane (HFC-134)
- 1,1,1-trifluoroethane (HFC-143a)
- 1,1-difluoroethane (HFC-152a)
- parachlorobenzotrifluoride (PCBTF)

- cyclic, branched, or linear completely methylated siloxanes
- acetone
- perchloroethylene (tetrachloroethylene)
- 3,3-dichloro-1,1,1,2,2-pentafluoropropane (HCFC-225ca)
- 1,3-dichloro-1,1,2,2,3-pentafluoropropane (HCFC-225cb)
- 1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC 43-10mee)
- difluoromethane (HFC-32)
- ethylfluoride (HFC-161)
- 1,1,1,3,3,3-hexafluoropropane (HFC-236fa)
- 1,1,2,2,3-pentafluoropropane (HFC-245ca)
- 1,1,2,3,3-pentafluoropropane (HFC-245ea)
- 1,1,1,2,3-pentafluoropropane (HFC-245eb)
- 1,1,1,3,3-pentafluoropropane (HFC-245fa)
- 1,1,1,2,3,3-hexafluoropropane (HFC-236ea)
- 1,1,1,3,3-pentafluorobutane (HFC-365mfc)
- chlorofluoromethane (HCFC-31)
- 1-chloro-1-fluoroethane (HCFC-151a)
- 1,2-dichloro-1,1,2-trifluoroethane (HCFC-123a)
- 1,1,1,2,2,3,3,4,4-nonafluoro-4-methoxy-butane ($C_4F_9OCH_3$ or HFE-7100)
- 2-(difluoromethoxymethyl)-1,1,1,2,3,3,3-heptafluoropropane ($(CF_3)_2CFCF_2OCH_3$)
- 1-ethoxy-1,1,2,2,3,3,4,4,4-nonafluorobutane ($C_4F_9OC_2H_5$ or HFE-7200)
- 2-(ethoxydifluoromethyl)-1,1,1,2,3,3,3-heptafluoropropane ($(CF_3)_2CFCF_2OC_2H_5$)
- methyl acetate
- 1,1,1,2,2,3,3-heptafluoro-3-methoxy-propane (n-$C_3F_7OCH_3$ or HFE-7000)
- 3-ethoxy-1,1,1,2,3,4,4,5,5,6,6,6-dodecafluoro-2-(trifluoromethyl) hexane (HFE-7500)
- 1,1,1,2,3,3,3-heptafluoropropane (HFC 227ea)
- methyl formate ($HCOOCH_3$)
- 1,1,1,2,2,3,4,5,5,5-decafluoro-3-methoxy-4-trifluoromethyl-pentane (HFE-7300)
- dimethyl carbonate
- propylene carbonate
- and perfluorocarbon compounds which fall into these classes:
  - (i) cyclic, branched, or linear, completely fluorinated alkanes,
  - (ii) cyclic, branched, or linear, completely fluorinated ethers with no unsaturations,
  - (iii) cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations, and
  - (iv) sulfur containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine.

(2) For purposes of determining compliance with emissions limits, VOC will be measured by the test methods in the approved State implementation plan (SIP) or 40 CFR Part 60, Appendix A, as applicable. Where such a method also measures compounds with negligible photochemical reactivity, these negligibly-reactive compounds may be excluded as VOC if the amount of such compounds is accurately quantified, and such exclusion is approved by the enforcement authority.

Toxic - Heavy Metals Sub-Section

Heavy metals, also known as trace metals, are one of the most persistent pollutants in wastewater. The discharge of high amounts of heavy metals into water bodies leads to several environmental and health impacts. The exposure of humans to heavy metals can occur through a variety of routes, which include inhalation as dust or fume, vaporization and ingestion through food and drink. Some negative impacts of heavy metals to aquatic ecosystems include death of aquatic life, algal blooms, habitat destruction from sedimentation, debris, increased water flow, other short and long term toxicity from chemical contaminants.

Abundant amounts of heavy metals present in soils cause reduction in quality and quantity of food preventing plants' growth, uptake of nutrients, physiological and metabolic processes. Severe effects on animals may include reduced growth and development, cancer, organ damage, nervous system damage, and in extreme cases, death. To help mitigate the negative impacts of heavy metals on the health of humans, animals and the environment, a variety of remediation processes exists. These remediation processes are broadly classified into chemical and biological, although the latter is advocated in recent years.

Biological remediation processes (microbial remediation and phytoremediation) are indicated to be very effective in the treatment of heavy metal pollutants in wastewater. Microbial remediation is the restoration of the environment and its quality using microorganisms, such as bacteria, fungi, protozoan and algae while phytoremediation is the use of plants to degrade or accumulate toxic metals, thereby leading to a reduction in the bioavailability of the contaminant in the soil or water.

Heavy metal concentrations from industrial wastewater pollution such as zinc, copper, nickel and chrome, has sparked major environmental compliance initiatives. For this purpose, government agencies established industry compliance standards for metal-contaminated wastewater discharge into municipal sewage treatment plants, and hazardous metal waste solids into landfills.

Industrial metal pollutants that include, but are not limited to:

- Aluminum
- Antimony (a metalloid)
- Arsenic is a metalloid
- Barium
- Beryllium
- Cadmium
- Copper
- Ferric (Iron / Iron Oxide)
- Hexavalent & Trivalent Chrome
- Lead
- Mercury - mercury poisoning
- Molybdenum
- Nickel / Electroless Nickel
- Osmium
- Selenium
- Silver
- Thallium
- Vanadium
- Zinc / Zinc Phosphate

Radioactive metals:

- Actinium
- Thorium
- Uranium
- Radium
- The transuraniums, such as plutonium, americium, etc.
- Polonium
- Radioactive isotopes of metallic elements not otherwise strongly toxic, e.g. cobalt-60 and strontium-90.

Aluminum

Aluminum has no biological role and its classification into toxic metals is controversial. Significant toxic effects and accumulation to tissues have been observed in renally impaired patients. However, individuals with healthy kidneys can be exposed to large amounts of aluminum with no ill effects. Thus, aluminum is not considered dangerous to persons with normal elimination capacity.

Trace Elements with Toxicity

- Chromium as hexavalent Cr(VI)
- Nickel – nickel salts are carcinogenic
- Copper – copper toxicity
- Zinc - zinc toxicity
- Iron – iron poisoning
- Fluorine-fluoride poisoning

Non-metals

Some heavy nonmetals may be erroneously called "metals", because they have some metallic properties.

- Selenium – a nonmetal; essential element
- Tellurium

Atomic Spectrometry

Atomic spectrometry converts each metal in the water sample to a particulate emission that can then be weighed. Extrapolations are made to determine each metal concentration in each water sample taken. The complicated analysis requires preserving the sample with acid, heating the sample to convert to a particulate emission and then identifying each metal and its weight.

A simple analogy is to capture the steam from a pot of water, separate every atom in the steam, identify each atom, weigh each atom and then apply these numbers back to the original volume of water contained in the pot. The result is an accurate picture of what is in the water.

Heavy Metals in Water

High heavy metals concentrations can be naturally occurring. Every geologic formation contains a certain amount of heavy metal. Mine operations extract and process these metals in areas with the highest concentrations. Water in these areas may have high metal concentrations due to the combination of naturally occurring deposits and mine waste.

Water samples are usually taken randomly within a contaminated area and offsite to identify the source of contamination and the pathway it travels, into the drinkable groundwater system or away from potable water sources. Accurate determination of heavy metal contamination is important to identify cumulative risks to people drinking water derived from these areas.

Sampling Techniques for Heavy Metals *(Example)*

(1) Generally, all metal samples collected are to be composite samples, i.e., flow/composite, time/composite, or hand composite.

(2) For composite sampling, place the lid on the bottle and agitate the bottle to completely mix the composite sample.

(3) Transfer the required amount from the composite container to either a 500 ml or 2000 ml clean plastic bottle. Check the pH of the sample.

Note: For inductively coupled plasma (ICP) metal analysis, a 500 ml clean plastic bottle is required. For extra metals or metals by furnace, a 2000 ml clean plastic bottle is required.

(4) Add nitric acid (1:1 solution) to the sample to reduce the pH to below 2.0. Usually, 2 ml/500 ml is sufficient. Recheck the pH to be sure it is below 2.0. Make a note on the lab sheet if more than two ml of acid is required to bring the pH below 2.0.

(5) Label the sample bottle with the corresponding IW number and proper analysis code letter. Attach the custody seal to the sample, then store in the ice chest until transferred to the laboratory. Fill out the IW lab sheet with all the pertinent information, being careful to include all required parameters and the type of analysis required, e.g., ICP/furnace.

(6) When a grab sample is necessary, rinse out the receiving sample bottle with an aliquot of the wastewater flow or sample stream at least three times. Then fill the sample bottle and proceed with steps two through four described above.

(7) When a split sample is requested (i.e., one for the samplers and one for the user), the composite sample is prepared as described in item one. Providing there is sufficient sample, a portion is transferred into the bottle provided by the user.

(8) If more than one site is sampled per day, a clean composite container (i.e., two and one half-gallon glass jar), must be used at each site.

(9) If a discrete sampler is being used, at the time of collection combine all the samples that have been collected into a single clean composite bottle. Then follow the preceding steps one through four, and refer to step six if a split is requested.

Acid/Base/Neutral Extractable Organics and Pesticides

Acid extractable organics are analyzed in accordance with EPA methods 604 and 625. Base/neutral extractable organics are analyzed in accordance with EPA method 625, or individual methods for various groups of compounds including EPA methods 605, 606, 607, 609, 611, and 612. Pesticides are analyzed in accordance with EPA method 608.

The procedures that must be followed in taking these samples are outlined below.

(1) Samples must be collected in certified clean one-gallon amber glass bottles with Teflon lids.

(2) No travel blanks or QA/QC bottles are required with the samples.

(3) Grab samples must be collected in amber glass bottles. They do not have to be completely filled, but must be a minimum of 1/3 to 1/2 full. Bottles should not be prewashed with samples prior to filling.

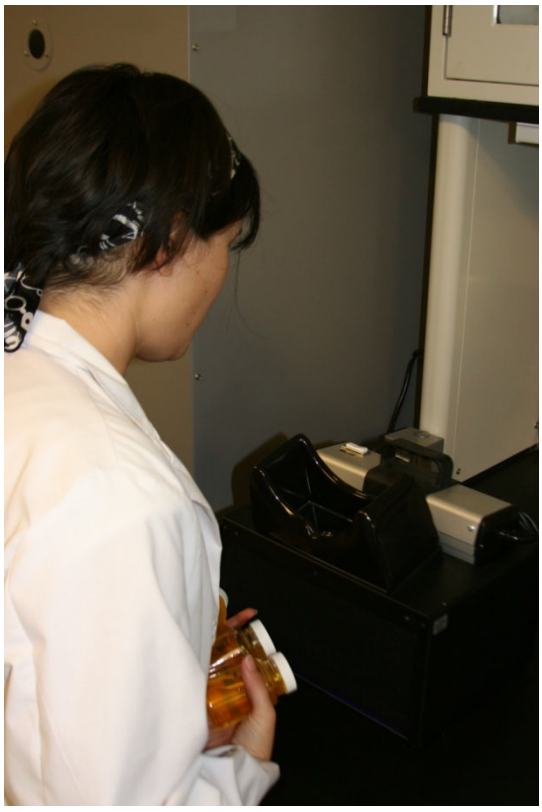
(4) For composite sampling, glass composite bottles must be used and precleaned. Teflon tubing must be used for the suction piping. The pump tubing must be medium grade silicone rubber.

(5) The composite bottle in the sampler must be kept refrigerated (putting ice in the sampler) at 4°C. If amber glass is not used (i.e. 2 1/2-gallon clear composite sampler bottle), the sample must be protected from the light during collection and compositing. The compositing must be done in the field (i.e. when discrete sampling has been used).

(6) All samples must be iced at 4°C from the time of collection until extraction.

(7) The sample should be checked for the presence of chlorine using field test kits that provide results in accordance with EPA methods 330.4 and 330.5. If chlorine is determined to be present, 80 mg of sodium thiosulfate should be added to each bottle. The sample must be retested for chlorine. This procedure must be repeated until there is no residual of chlorine shown. The amount of sodium thiosulfate added must be noted on the chain of custody if in excess of 80 mg.

(8) All necessary paperwork must be completed at sampling site. All bottles must be properly labeled, and have custody seals.



Cyanide *(Procedure Example)*

To assure that the sample can be analyzed for cyanide, no chlorine can be present in the sample. Procedures for taking cyanide samples are as follows:

(1) This sample is normally a grab sample. The cyanide sample is a composite sample when collected as part of Priority Pollutants or Plant Sampling at the POTW.

(a) In the sampling file, check the industries' wastewater discharge permit and locate all cyanide (CN) sampling sites. If the sampling sites are located in a confined space, follow Confined Space procedures before collecting the sample or samples.

(b) Collect 2000 ml (maximum), 1000 ml (minimum), of CN sample into a plastic bottle.

NOTE: 2000 ml is the standard, but for batch dischargers 1000 ml is adequate.

(c) Test the cyanide sample for pH and temperature with the pH meter. Record the results on the custody sheet (Industrial Waste (IW) lab sheet).

(d) Test for chlorine with a Total Chlorine Test Kit (the instructions are located in the kit)

(e) If chlorine is present in the CN sample, neutralize it with Ascorbic Acid ($C_6H_8O_6$). For ascorbic acid neutralization, add $C_6H_8O_6$, a few crystals at a time, until five mls of sample in the test tube produces no color. Then add an additional 0.06 g of $C_6H_8O_6$ for each liter of sample volume.

(f) Once all Cl_2 has been neutralized, preserve the sample with Sodium Hydroxide (NaOH) and raise the pH to >12. Verify the >12 pH with a pH meter or pH test strips.

(g) Mark on the side of the CN sample bottle the COC sheet number (using a water proof marker), and place a corresponding custody seal across the sample bottle tightened cap. Place a Cyanide label on the bottle if cyanide is suspected of being present in the sample.

(h) Cool and store the CN sample at 4°C and transport it to the laboratory.

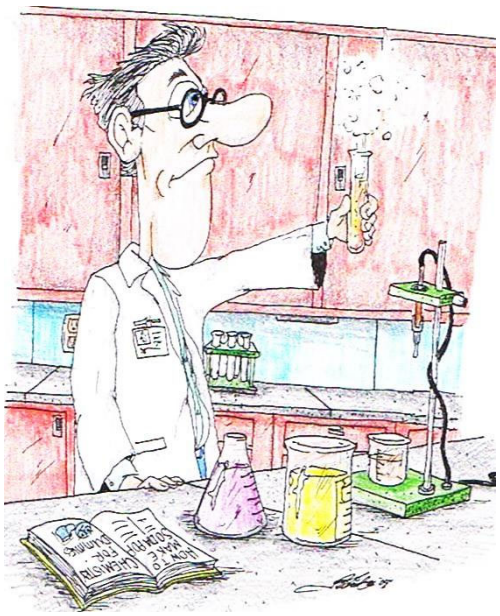
Total Sulfides *(Example)*

(1) The Total Sulfide sample is collected as a grab sample only. Use a clean 500 ml plastic bottle to collect the sample. This sample may be pumped into the sample container or collected directly from the discharge side of the sampling device.

(2) Preserve the sample with 1 ml of 2N Zinc Acetate ($C_4H_6O_4Zn$) and then add Sodium Hydroxide (NaOH) to raise the pH > 9.

(3) Label and seal the sample with a custody seal. Cool to 4°C.

Oil and Grease/TPH *(Procedure Example)*



EPA Method 1664A
Extraction of Oil and Grease from Water Samples Using Solid-Phase Extraction (SPE) Disk Configuration

Oil and Grease Disc Configuration Method
Acidify each 1L sample to pH < 2 using 6 M of HCl.

Place required number of samples (1–6) in the sample vial rack. Insert sample lines into each sample bottle.

Collection
Label the collection vials (1–6) and place these into the collection rack. Position the solvent bottles on the left side of the Dionex AutoTrace instrument.

Solvents
Add methanol to solvent bottle
1. Water (pH 2) to solvent bottle
2. Hexane/THF (1:1) to solvent bottle
3. Hexane to solvent bottle
4. And water to solvent bottle
5. Place these solvent bottles to the left side of the Dionex AutoTrace instrument and insert the solvent lines into the corresponding bottle (up to five different solvents can be used with the Dionex AutoTrace instrument). SPE Media Insert SPE disks onto the Dionex AutoTrace instrument (see Dionex (now part of Thermo Scientific) AutoTrace 280 Operation Manual for details1) and secure the disk into place using the disk holder. The green LED will be illuminated when the disk is locking into place.

METHOD 413.1 (Oil and Grease). Is no longer a valid procedure.

BOD/COD/SS *(Example)*

(1) 24-hour composite sampling is always used for this test. Agitate the bottle to completely mix the composite sample. Do not allow the solids to settle out before you pour off the sample.

(2) When more than one sample is being taken from a composite bottle, the BOD/COD/SS is taken first. The lab needs 1000 ml if the sample is cloudy or has solids. If the sample is clear, you must collect 2000 ml. Transfer the appropriate volume to the sample bottle.

(3) Take the pH/temperature of the sample with either pH paper and a thermometer, or the pH meter carried on the sampling trucks.

(4) Label the sample bottle and place a custody seal over the lid. Store at 4°C.

(5) Should split samples be requested, they are only supplied when it is sure there is enough sample for POTW's requirements. Users must provide their own sample containers and allow POTW's staff to pour off samples.

More on these samples in the Laboratory Analysis Chapter located in the rear of this course.

Virus Sampling *(Procedure Example)*

Viruses are microbiological organisms which can cause infectious diseases. Wastewater recharge and sewage disposal into the environment may contribute to the occurrence of viruses in surface water and groundwater. Viruses are the most mobile and infectious of the waterborne pathogens. Large volumes of water must be filtered to detect viruses. This involves passing the water samples through a cartridge filter by use of a gasoline driven pump.

(1) **Equipment Needed**
Most of the equipment required for virus sampling is available on the sampling trucks. However, some equipment is virus sampling specific. The needed equipment is as follows:

(a) Gasoline/oil powered water pump
(b) Hoses - intake (supplied with pump) and discharge (garden type, with female connectors at both ends)
(c) Two 55-gallon plastic containers
(d) Filter apparatus
(e) Cartridge filters
(f) Sodium thiosulfate (two 500 gram bottles/site)
(g) Gasoline can with gas/oil mixture
(h) Hach total chlorine test kit
(i) Large plastic Zip-lock bags (supplied with cartridges)
(j) Chain of custody sheets
(k) Thermometer
(l) Water-proof marker
(m) Latex gloves
(n) Liquid bleach
(o) Cooler with blue ice
(p) pH meter

(2) **Sampling Procedure**
Check the pump for gas/oil prior to starting (do not fill while it is running). Make sure the gas/oil mixture is correct by checking the mixing instructions on the side of the two-cycle pump oil can. Latex gloves should be worn for protection, and to prevent contamination of the filters.

Connect the hoses and filter housing (with no filter) to the pump, and run the effluent through it for one to two minutes to flush the system. Next, pump effluent into the two 55-gallon drums and rinse them out. (Note: If disinfection was not possible after the last sampling, then 50-100 gallons of effluent should be pumped through the entire equipment set up prior to placing the filter in the housing.)

Pump effluent almost to the top (just above the handles) of both containers. While the drums are filling, check the water in the drums for chlorine using a Hach test kit and record the results and the temperature on the custody sheet. If chlorine is present and needs to be eliminated, add 500 grams of sodium thiosulfate to each container to eliminate it. After visual observation has determined that all the sodium thiosulfate has dissolved, retest to make sure there is a <0.1 ppm chlorine residual.

If chlorine was removed, take the hose from the channel, allow it to drain, and reprime the pump with the dechlorinated water.

Pump this water through the system to flush it, and adjust the flow to fill a one-gallon jug in about 15-20 seconds. Don't waste too much water, as the flow can be adjusted after the filter is inserted. Install the filter into the blue holder, being very careful not to touch it with your hands (wear clean latex gloves).

There are two black washers that go with the filter, one on the bottom and the other on the top. Make sure these are aligned with the filter housing to prevent leaking. Screw the holder and filter onto the apparatus.

Refuel the pump, restart it, and adjust the water flow so that it is close to 15-20 seconds per gallon. Make sure the housing doesn't leak.

Try to keep this amount of flow, since too great a flow will cause pass-through in the filter. Pump the water from both containers until they are empty. Stop the pump, remove the filter (wear clean latex gloves), and place it in its original zip-lock bag. The washers do not need to go with the filter, but if they fall into the bag it is better to leave them than take the chance of contaminating the filter trying to remove them.

Fill in the information area on the zip-lock bag with a marker, indicating the plant being sampled and the date, and put it in the cooler with the blue ice provided. The blue ice keeps the temperature at 4°C to prevent significant die-off of the viruses.

While at the site, or later at the plant, mix a half-gallon of bleach to 10 gallons of clean water. Pump it through the flow system and the containers. Rinse everything with fresh water and drain it so it is ready for the next time.

Let the pump cool before storing it. Store the gas/oil mixture in the warehouse flammable storage cabinet.

Parasitology Sampling

Parasitology sampling utilizes the same equipment and techniques as in the virus sampling described above. However, a different type of filter, which is provided by the Lab, is used.

Dissolved Oxygen Testing Sub-Section

Dissolved oxygen (**DO**) in water is not considered a contaminant. However, the (DO) level is important because too much or not enough dissolved oxygen can create unfavorable conditions. Generally, a lack of (DO) in natural waters creates anaerobic conditions. Anaerobic means without air. Certain bacteria thrive under these conditions and utilize the nutrients and chemicals available to exist. *Under anaerobic conditions the reaction is:*

Anaerobic:

Organics → intermediates + CO_2 + H_2O + energy

Where the intermediates are butyric acid, mercaptans and hydrogen sulfide gas. At least two general forms of bacteria act in balance in a wastewater digester: Saprophytic organisms and Methane Fermenters. The saprophytes exist on dead or decaying materials. The methane fermenters live on the volatile acids produced by these saprophytes. The methane fermenting bacteria require a pH range of 6.6 to 7.6 to be able to live and reproduce. Aerobic conditions indicate that dissolved oxygen is present. Aerobic bacteria require oxygen to live and thrive. When aerobes decompose organics in the water, the result is carbon dioxide and water.

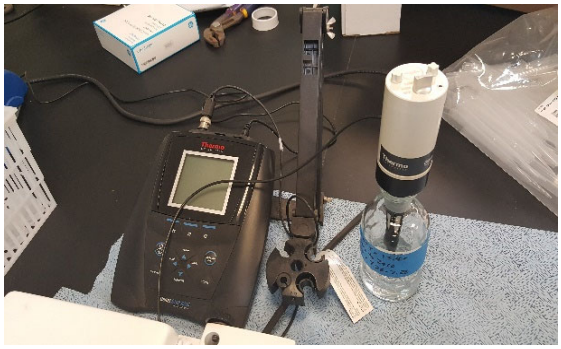
Aerobic:

Organics + Oxygen → CO_2 + H_2O + energy

Dissolved Oxygen in a water sample can be detrimental to metal pipes in high concentrations because oxygen helps accelerate corrosion. Oxygen is an important component in water plant operations. Its primary value is to oxidize iron and manganese into forms that will precipitate out of the water. It also removes excess carbon dioxide. The amount of dissolved oxygen in a water sample will affect the taste of drinking water also.

Methods of Determination

There are two methods that we will be using in the lab. The membrane electrode method procedure is based on the rate of diffusion of molecular oxygen across a membrane. The other is a titrimetric procedure (Winkler Method) based on the oxidizing property of the (DO). Many factors determine the solubility of oxygen in a water sample. Temperature, atmospheric pressure, salinity, biological activity and pH all have an effect on the (DO) content.



Iodometric Test

The Iodometric (titration) test is very precise and reliable for (DO) analysis of samples free from particulate matter, color and chemical interferences. Reactions take place with the addition of certain chemicals that liberate iodine equivalent to the original (DO) content. The iodine is then measured to the starch iodine endpoint. We then calculate the dissolved oxygen from how much titrate we use. Certain oxidizing agents can liberate iodine from iodides (positive interference), and some reducing agents reduce iodine to iodide (negative interferences).

The alkaline Iodide-Azide reagent effectively removes interference caused by nitrates in the water sample, so a more accurate determination of (DO) can be made.

Methods of analysis are highly dependent on the source and characteristics of the sample. The membrane electrode method involves an oxygen permeable plastic membrane that serves as a diffusion barrier against impurities.

Only molecular oxygen passes through the membrane and is measured by the meter. This method is excellent for field testing and continuous monitoring. Membrane electrodes provide an excellent method for (DO) analysis in polluted, highly colored turbid waters and strong waste effluents.

These interferences could cause serious errors in other procedures. Prolonged usage in waters containing such gases as H_2S tends to lower cell sensitivity. Frequent changing and calibrating of the electrode will eliminate this interference. Samples are taken in BOD bottles where agitation or contact with air is at a minimum. Either condition can cause a change in the gaseous content. Samples must be determined immediately for accurate results.

The dissolved oxygen test is the one of the most important analyses in determining the quality of natural waters. The effect of oxidation wastes on streams, the suitability of water for fish and other organisms and the progress of self-purification can all be measured or estimated from the dissolved oxygen content. In aerobic sewage treatment units, the minimum objectionable odor potential, maximum treatment efficiency and stabilization of wastewater are dependent on maintenance of adequate dissolved oxygen. Frequent dissolved oxygen measurement is essential for adequate process control.

Term Review

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

Aerobic Bacteria (aerobes) – bacteria which will live and reproduce only in an environment containing oxygen. Oxygen combined chemically, such as in water molecules (H_2O), cannot be used for respiration by aerobes.

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

Anaerobic Bacteria (anaerobes) – bacteria that thrive without the presence of oxygen.

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

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

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

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

Procedure for Dissolved Oxygen Determination

Meter Probe Method
Collect a water sample in the clean 300-ml glass stoppered BOD bottle for two or three minutes to make sure there are no air bubbles trapped in the bottle. Do one Tap water sample and one DI water sample. Mark the BOD bottles.

Insert the DO probe from the meter into your BOD bottles. Record the DO for Tap and DI water. Now continue with the Winkler Burette method.

Winkler Burette Method
Add the contents of one MANGANESE SULFATE powder pillow and one ALKALINE IODIDE-AZIDE reagent powder pillow to each of your BOD bottles (TAP and DI)

1. Immediately insert the stoppers so that no air is trapped in the bottles and invert several times to mix. A flocculent precipitate will form. It will be brownish-orange if dissolved oxygen is present or white if oxygen is absent.

2. Allow the samples to stand until the floc has settled and leaves the solution clear (about 10 minutes). Again invert the bottles several times to mix and let stand until the solution is clear.

3. Remove the stoppers and add the contents of one SULFAMIC ACID powder pillow to each bottle. Replace the stoppers, being careful not to trap any air bubbles in the bottles, and invert several times to mix. The floc will dissolve and leave a yellow color if dissolved oxygen is present.

4. Measure 200 ml of the prepared solution by filling a clean 250-ml graduated cylinder to the 200-ml mark. Pour the solutions into clean 250-ml Erlenmeyer flasks. Save the last 100 mls for a duplicate.

5. Titrate the prepared solutions with PAO Titrant, 0.025N, to a pale yellow color. Use a white paper under the flask.

6. Add two droppers full of Starch Indicator Solution and swirl to mix. A dark blue color will develop.

7. Continue the titration until the solution changes from dark blue to colorless (end point). Go Slow- drop by drop. Record the burette reading to the nearest 0.01mls.

8. The total number of ml of PAO Titrant used is equal to the mg/L dissolved oxygen.

Dissolved Oxygen Results

Meter Results

1. De-ionized water _____mg/L

2. Tap water _____mg/L

3. What is the meter procedure measuring?

4. What factors would determine which the best method to use is?

5. What are two forms of bacteria present in a wastewater digester?

Wrinkler Method Results

1. **De-ionized Water**

200ml final Burette reading-
Sample initial Burette reading- -_____ = _____mg/L

100ml final Burette reading-
duplicate initial Burette reading- -_____dup=_____mg/L
mls x 2

2. **Tap water**

200ml final Burette reading-
Sample initial Burette reading- -_____=_____mg/L
mls

100ml final Burette reading
Sample initial Burette reading- -_____=_____mg/L
mls x 2

3. What are some factors that can alter the (DO) content prior to testing?

4. Were your samples anaerobic or aerobic?

5. Why is it important to monitor the (DO) content of water and wastewater?

Be specific and give a detailed explanation.

Biochemical Oxygen Demand (BOD) Sub-Section

In the BOD test, microorganisms are charged with eating all the organics (food). In a BOD bottle, organics from a sample are added to dilution water containing nutrients, oxygen, and microorganisms, then capped and incubated at 20^{o}C for 5 days. Initially the microorganism level is fairly low, but the environmental growing conditions are excellent, so the microorganisms quickly enter the log growth reproduction phase and begin to consume the organics.

The lack of food causes a slowing in the reproduction rate as well as a decrease in the amount of oxygen used. With the high microorganism population, the remaining organics are quickly consumed and the microorganism enter the endogenous phase. During the endogenous phase, the microorganisms utilize internal food reserves, and many die (endogenous phase).

Microorganisms are Hungry
If everything is okay, most of the microorganisms are hungry, but alive and there is still sufficient oxygen left in the bottle to be measured. The amount of oxygen that has been consumed over the 5 days is proportional to the amount of organics (BOD) consumed.

Carbonaceous Demand and Nitrogenous Demand
The test measures the oxygen required for the biochemical degradation of organic material (carbonaceous demand) and the oxygen used to oxidize inorganic material such as sulfides and ferrous iron. It may also measure the oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand) unless their oxidation is prevented by an inhibitor

The method consists of placing a sample in a full, airtight bottle and incubating the bottle under specified conditions for a specific time. Dissolved oxygen (DO) is measured initially and after incubation. The BOD is calculated from the difference between the initial and final DO.

English Legend
Normally a 5-day BOD test period (English legend has it that 5 days was the time period taken between sewage entering a river and reaching the ocean) is used where samples are incubated in the dark (to restrict algal growth) at 20^{o}C (the temperature believed to be reasonably representative of field conditions).

Most wastewaters contain more oxygen demanding materials than the amount of DO available in air-saturated water. Therefore, it is necessary to dilute certain samples before incubation to bring the oxygen demand and supply into appropriate balance.

Bacterial growth requires nutrients such as nitrogen, phosphorus and trace metals. These are added to dilution water, which is buffered to ensure that the pH of the incubated sample remains in a range suitable for bacterial growth.

General Materials Illustration

1. BOD nutrient buffer pillows
2. Nitrification inhibitor
3. D(+)Glucose
4. L-Glutamic acid
5. Purified water or equivalent
6. BOD dilution water container
7. BOD dilution water aerator
8. BOD bottles
9. DO meter and electrode
10. Water bath (20 to 30^{o}C)
11. Balance (4 decimal places)
12. Weighing boats
13. Porcelain crucibles
14. Dessicator
15. Spatula
16. Magnetic stirrer
17. Incubator (20^{o}C +/- 1^{o}C)
18. Oven (103^{o}C)
19. Volumetric flask (1000mL)
20. Graduated cylinders (10 to 1000mL volume)
21. Parafilm
22. Pasteur pipettes
23. Gloves
24. Marker Pen
25. Scissors

Preservation Method

If more than a 2-hour delay before analysis of grab sample(s) takes place the sample(s) should be kept at or below 4^{o}C from the time of collection and analysis should begin within 6 hours of collection. If this is not possible store sample(s) at or below 4^{o}C and report length and temperature of storage with the results.

In no case start analysis more than 24 hours after grab sample collection. Keep composite samples at or below 4^{o}C during composting.

Limit composting period to 24 hours. Use the same criteria as for storage of grab samples, starting the measurement of holding time from the end of the composting period.

State storage time and conditions as part of the results.

Preparation of BOD Dilution Water

1. Place a desired volume of purified water in a BOD dilution water container.
2. Place a BOD aerator in the BOD dilution water
3. Aerate the BOD dilution water overnight.
4. Add a BOD nutrient buffer pillow to the BOD dilution water.
5. Continue aeration of the BOD dilution water until sample dilution is ready to take place.

Preparation of 2% Glucose-Glutamic Acid Solution (Prepare immediately before use)

1. Dry D(+)Glucose and L-Glutamic acid at 103^{o}C for 1 hour.
2. Add 0.150g of D(+)Glucose and 0.150g of L-Glutamic acid to a 1000mL volumetric flask containing purified water, mix thoroughly and make up to the mark with purified water.
3. Prepare a 1:50 (2%) dilution of the Glucose-Glutamic Acid solution using BOD dilution water.

BOD Determination

1. Prepare dilutions, where appropriate, of the sample(s) to be tested. Dilutions that result in a residual DO of at least 1mg/L and a DO uptake of at least 2mg/L after 5 days incubation provide the most reliable results.
2. Transfer the diluted or undiluted sample(s) to a corresponding glass stoppered BOD bottle(s).
3. Bring the diluted or undiluted sample(s) to 20^{o}C.
4. Measure the DO_o of the sample(s) in mg/L using a DO meter and electrode. The DO should be approximately 9.2mg/L at 20^{o}C.
5. Add an appropriate quantity of nitrification inhibitor to the sample(s).
6. Stopper the BOD bottle.
7. Treat a BOD blank, containing BOD dilution water instead of sample in the same manner as the sample.
8. Treat the 2% Glucose-Glutamic Acid Solution in the same manner as the sample.
9. Incubate the sample(s), blank and Glucose-Glutamic Acid Solution at 20±1oC for 5 days.
10. Measure the DO_5 of the sample(s), blank and Glucose-Glutamic Acid solution and determine their BOD_5 according to the formula in section 6:0.

The DO uptake of the blank after 5 days should not be more than 0.2 mg/L and preferably not more than 0.1 mg/L. If the oxygen depletion exceeds 0.2 mg/L obtain satisfactory water by improving purification or from another source balance.

The BOD_5 of the Glucose-Glutamic Acid solution should be 200±37mg/L. If it is outside this range reject any BOD determinations made with the BOD dilution water and seek the cause of the problem balance.

If more than one sample dilution meets the criteria of a residual DO of at least 1mg/L and a DO depletion of at least 2mg/L and there is no evidence of toxicity at higher sample concentrations or the existence of an obvious anomaly, average results in the acceptable range.

BOD Formula

BOD formula when sample dilution is less than 1:10

$$BOD_5 = \frac{[(DO_o - DO_5) - (X-1/X)(DO_o - DO_5)]}{\text{Sample Blank}} \times X$$

X = Dilution factor

BOD formula when sample dilution is 1:10 or greater than 1:10

$$BOD_5 = \frac{[(DO_o - DO_5) - (DO_o - DO_5)]}{\text{Sample Blank}} \times X$$

X = Dilution factor

BOD formula when sample is undiluted

$$BOD_5 = \frac{(DO_o - DO_5)}{\text{Sample}}$$

Specific Oxygen Uptake Rate (SOUR) Sub-Section

This laboratory activity explores the Specific Oxygen Uptake Rate analysis (SOUR) and its use in measuring the metabolic activity of organisms in aquatic systems.

Focus
Microorganisms use oxygen as they consume food in an aerobic aquatic system. The rate at which they use oxygen is an indicator of the biological activity of the system and is called the Oxygen Uptake Rate (OUR).

High oxygen uptake rates indicate high biological activity; low oxygen uptake rates indicate low biological activity. In biological waste treatment facilities, oxygen uptake rates are used to monitor performance of process units. The analysis is based on a series of dissolved oxygen (DO) measurements taken on a sample over a period of time. The test is most valuable for plant operations when combined with volatile suspended solids data.

Combining oxygen uptake and volatile suspended solids data yields a value called the Specific Uptake Rate (SOUR). Specific Uptake Rates (SOUR) describe the amount of oxygen used by the microorganisms to consume one gram of food and is reported as mg/L of oxygen used per gram of organic material per hour.

The specific uptake rate is valuable when comparing one aquatic system with another or if a single system is to be charted over time. The performance of one aeration basin can be compared with another or the biological activity in a stream can be studied and compared both above and below a waste outfall. Furthermore, toxic or high organic loads can often be detected before severe deterioration of effluent quality occurs. Changes in the SOUR on effluent samples will indicate changes in loading.

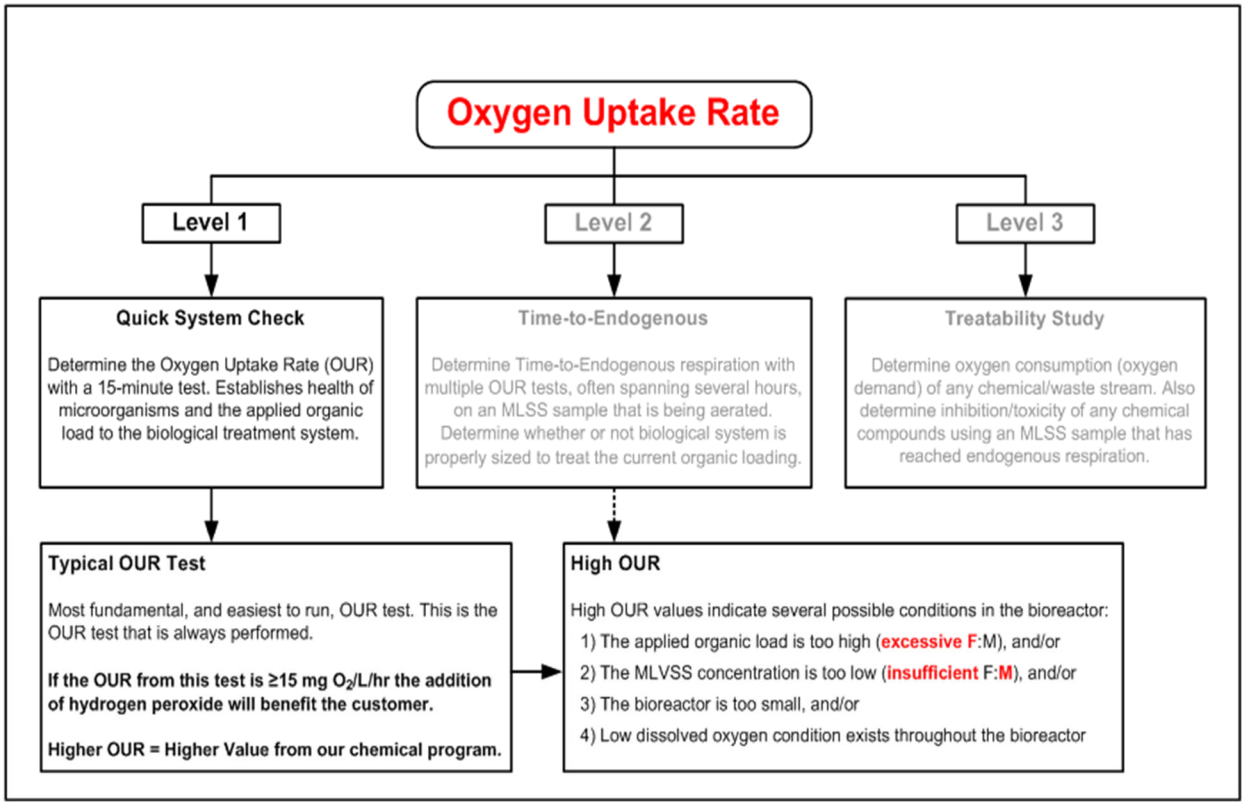
Significance of SOUR Values **Values (mg/hr/g VSS)**	**Rate of Oxygen Consumption**	**Significance**
>20	High	Not enough solids for the BOD loading
12-20	Normal	Good BOD removal and sludge settling
<12	Low	Too many solids or presence of toxicity

Typical Ranges of Specific Oxygen Uptake Rates (SOUR) for Various Modifications of the Activated Sludge Process at Aeration Tank Effluent

Process Modification SOUR Range (mg/hr/g VSS)
Conventional 8-20
Step aeration 8-20
Extended aeration 3-12
Contact stabilization 5-15

Reason for Testing
Biological waste treatment in the activated sludge process is based on the ability of the microorganisms to utilize dissolved oxygen in breaking down soluble organic substances. The oxygen uptake test is a means of measuring the respiration rate of the organisms in the activated sludge process. Since it measures the oxygen used in the process, it is a useful tool in the evaluation of process performance, aeration equipment and biodegradability of the waste. So that comparisons can be made between various plants, it is usually expressed as the SOUR (specific uptake rate); i.e. the amount of oxygen in mg utilized by one gram of the volatile suspended solids in the activated sludge.

$$\text{SOUR, (mg/g)/hr} = \frac{\text{OUR, mg } O_2\text{/L/min} \times \frac{60 \text{ min}}{1\ hr}}{VSS\ (mg/L) \times \frac{1\ g}{1000\ mg}}$$



Total Dissolved Solids (TDS) Sub-Section

Water is a good solvent and picks up impurities easily. Pure water is tasteless, colorless, and odorless and is often called the universal solvent. Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and some small amounts of organic matter that are dissolved in water.

TDS in drinking-water originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing. In the United States, elevated TDS has been due to natural environmental features such as: mineral springs, carbonate deposits, salt deposits, and sea water intrusion, but other sources may include: salts used for road de-icing, anti-skid materials, drinking water treatment chemicals, stormwater and agricultural runoff, and point/non-point wastewater discharges.

In general, the total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Therefore, the total dissolved solids test provides a qualitative measure of the amount of dissolved ions, but does not tell us the nature or ion relationships.

In addition, the test does not provide us insight into the specific water quality issues, such as: Elevated Hardness, Salty Taste, or Corrosiveness. Therefore, the total dissolved solids test is used as an indicator test to determine the general quality of the water.

Total Solids

The term "total solids" refers to matter suspended or dissolved in water or wastewater, and is related to both specific conductance and turbidity.

Total solids (also referred to as total residue) are the term used for material left in a container after evaporation and drying of a water sample.

Total Solids includes both total suspended solids, the portion of total solids retained by a filter and total dissolved solids, the portion that passes through a filter (American Public Health Association, 1998).

Total solids can be measured by evaporating a water sample in a weighed dish, and then drying the residue in an oven at 103 to 105° C.

The increase in weight of the dish represents the total solids. Instead of total solids, laboratories often measure total suspended solids and/or total dissolved solids.

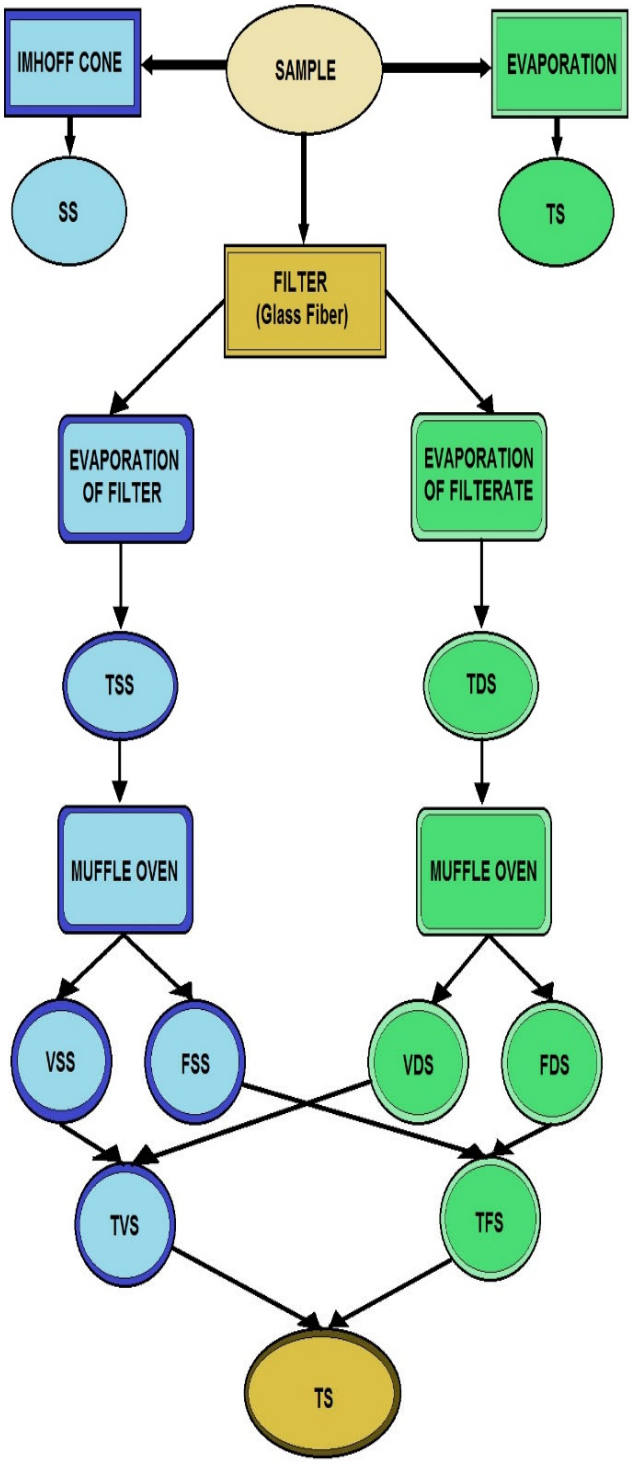
Types of Solids on Wastewater

ACRONYM	COMMON TERM	EXPLANATION
TSS	Total Suspended Solids	Solids that cannot pass through a 1.2- µm filter.
TVSS	Total Volatile Suspended Solids	Solids that cannot pass through a 1.2 - µm filter and are burned away when placed in a furnace at 550° C.
TDS	Total Dissolved Solids	Solids that are small enough to pass through a 1.2 - µm filter. The sample must be dried completely before the dissolved solids can be seen with the naked eye.
TS	Total Solids	All of the solid material in a sample. This includes both organic and inorganic solids. TS = TSS + TDS
TVS	Total Volatile Solids	All of the solids in a sample that are burned away when placed in a furnace at 550° C

Total Suspended Solids (TSS)

Total suspended solids (TSS) is the dry-weight of suspended particles that are not dissolved, in a sample of water that can be trapped by a filter that is analyzed using a filtration apparatus. It is a water quality parameter used to assess the quality of a specimen of any type of water or water body, ocean water for example, or wastewater after treatment in a wastewater treatment plant. It is listed as a conventional pollutant in the U.S. Clean Water Act.

Total dissolved solids is another parameter acquired through a separate analysis which is also used to determine water quality based on the total substances that are fully dissolved within the water, rather than undissolved suspended particles.



FSS: Fixed Suspended Solids
TDS: Total Dissolved Solids
VDS: Volatile Dissolved Solids
FDS: Fixed Dissolved Solids
TVS: Total Volatile Solids
TFS: Total Fixed Solids

EQUIPMENT USED TO MEASURE AND DETERMINE TYPES OF SOLIDS

Technical Learning College

DETERMINATION OF DIFFERENT TYPES OF SOLIDS

1. 

Lab tech removing filter for TSS analysis.

Total Suspended Solids (TSS) Sub-Section

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis causes less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills.

Sampling downstream from a wastewater plant's discharge point.

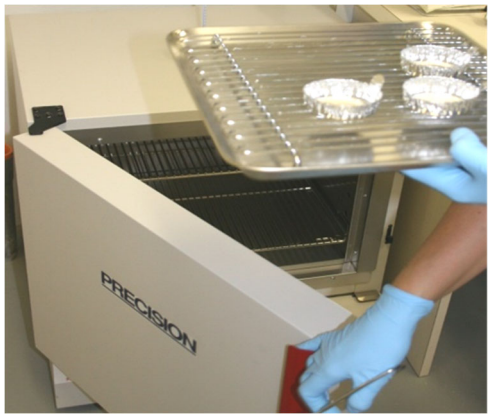
High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further (because warmer waters can hold less DO), and can harm aquatic life in many other ways, as discussed in the temperature section. (The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food.

Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development. When suspended solids settle to the bottom of a water body, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks which could have been used by aquatic organisms for homes.

Dead fish in lake using reclaimed water.

High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles on the land and be carried into water bodies with storm water. In the water, the pollutants may be released from the sediment or travel farther downstream. High TSS can cause problems for industrial use, because the solids may clog or scour pipes and machinery.

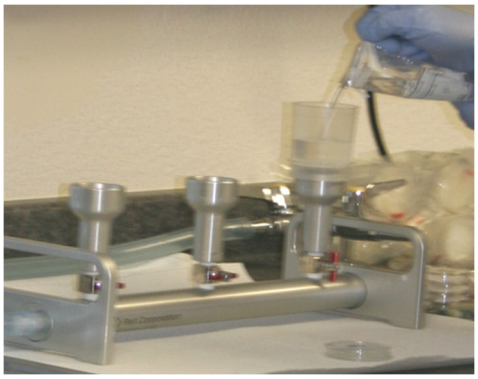
Measurement of Total Suspended Solids



To measure TSS, the water sample is filtered through a pre-weighed filter. The residue retained on the filter is dried in an oven at 103 to 105° C until the weight of the filter no longer changes. The increase in weight of the filter represents the total suspended solids. TSS can also be measured by analyzing for total solids and subtracting total dissolved solids.

Total Dissolved Solids (TDS) are solids in water that can pass through a filter (usually with a pore size of 0.45 micrometers). TDS is a measure of the amount of material dissolved in water.

This material can include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, organic ions, and other ions. A certain level of these ions in water is necessary for aquatic life.



Changes in TDS concentrations can be harmful because the density of the water determines the flow of water into and out of an organism's cells (Mitchell and Stapp, 1992). However, if TDS concentrations are too high or too low, the growth of many aquatic lives can be limited, and death may occur.

Similar to TSS, high concentrations of TDS may also reduce water clarity, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature.

TDS is used to estimate the quality of drinking water, because it represents the amount of ions in the water. Water with high TDS often has a bad taste and/or high water hardness, and could result in a laxative effect.

The TDS concentration of a water sample can be estimated from specific conductance if a linear correlation between the two parameters is first established. Depending on the chemistry of the water, TDS (mg/l) can be estimated by multiplying specific conductance (micromhos/cm) by a factor between 0.55 and 0.75. TDS can also be determined by measuring individual ions and adding them up.

Settleometer Test

A simple procedure called the Settleometer Test is used to determine the settling characteristics of mixed liquor. The test requires a settleometer, which is typically a clear plastic cylinder with a capacity of 2 liters. Graduations on the cylinder range from 100 to 1000 cubic centimeters (or milliliters) of settled sludge per liter.

A sample of mixed liquor should be obtained from the discharge end of the aeration tank, being careful not to include scum in the sampling container. Do not allow the sample to set for more than a few minutes before the settling test is performed. Determine the MLSS concentration in milligrams per liter on a portion of this sample.

Mix the sample well, and fill the settleometer to the 1000 graduation. Immediately start a timer and at the end of 30 minutes record the settled sludge volume in the settleometer.

It is a good idea to occasionally record the settled sludge volume every 5 minutes while the solids are settling and prepare a graph of settled sludge volume versus minutes. This allows the operator to see whether the solids are settling too quickly or slowly. Solids that settle too quickly may be an indication of an old sludge that will probably leave straggler floc in the effluent, while solids that settle too slowly or do not compact well may be washed out of the clarifier during times of high hydraulic load.

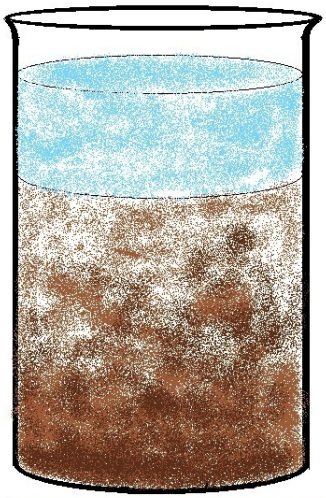
Denitrification
It is also a good practice to allow the sample to set in the settleometer for an additional 30 to 60 minutes after the settling test. Watch for tiny bubbles that form in the settled sludge. These nitrogen bubbles form as nitrate is reduced to nitrogen gas (denitrification) under anoxic conditions.

As the bubbles rise, they attach themselves to floc particles and float them to the surface. A small amount of denitrification occurring in the secondary clarifier will cause a scum to form on the surface, while a large amount of denitrification may float a significant portion of the biomass to the top of the clarifier. The settleometer test may give the operator the first warning that this may become a problem.

Volume of the Biomass
Two main factors determine the settled sludge volume in the settleometer at the end of the 30 minutes. The first, solids compaction indicates how much volume the biomass will occupy. But the operator must recognize the influence of the second factor, MLSS concentration, in settled sludge volume. As long as the MLSS does not change, settleometer test results can be compared from one day to the next.

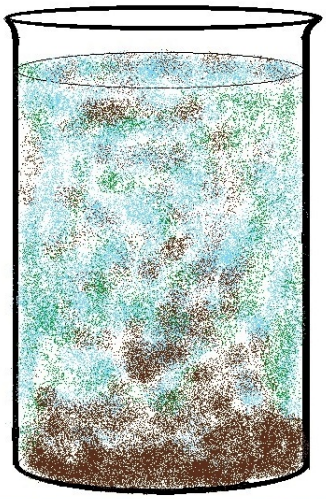
Nevertheless, as the MLSS increases, the settled sludge volume in the settleometer will increase. Since we use the settleometer test mainly to indicate how well the mixed liquor compacts, we must account for the concentration of the biomass in the settleometer. This allows the operator to track changes in sludge quality even though the MLSS concentration changes.

SETTLING TEST OBSERVATION / LOOKING FOR BULKING SLUDGE

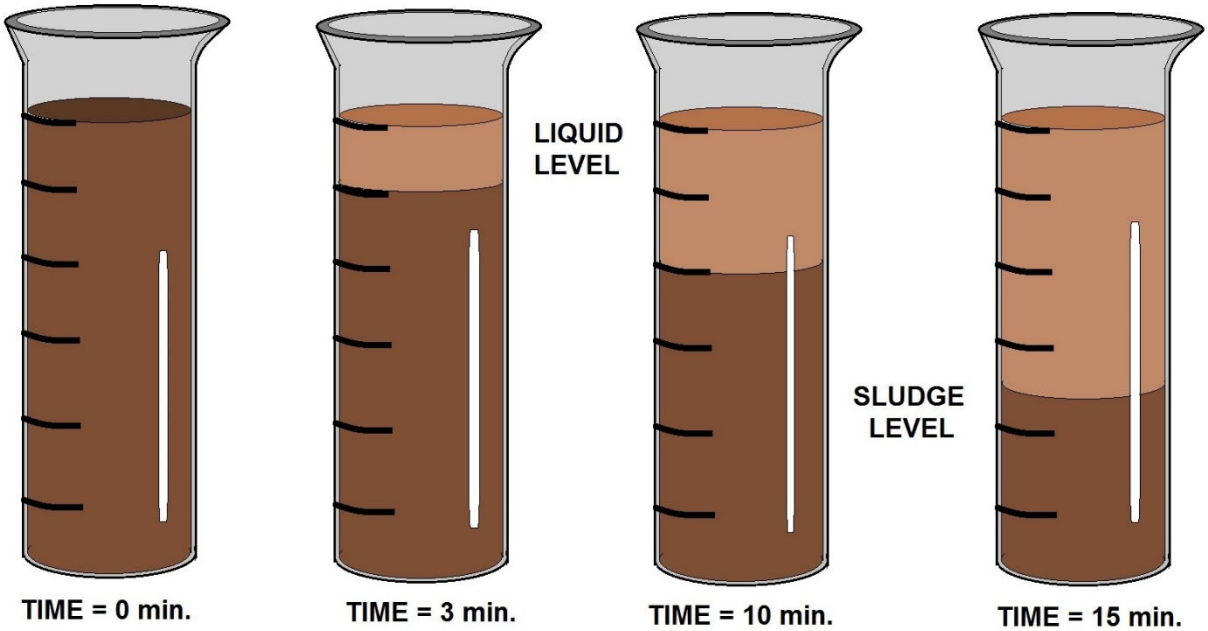


SUPERNATANT VERY CLEAR

60 MINUTES

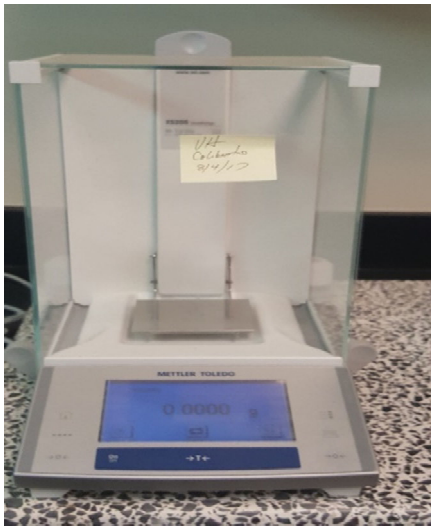


SUPERNATANT CLOUDY



Suspended Matter for Mixed Liquor and Return Sludge (MLSS)

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



Apparatus

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

Procedure

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

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

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

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

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

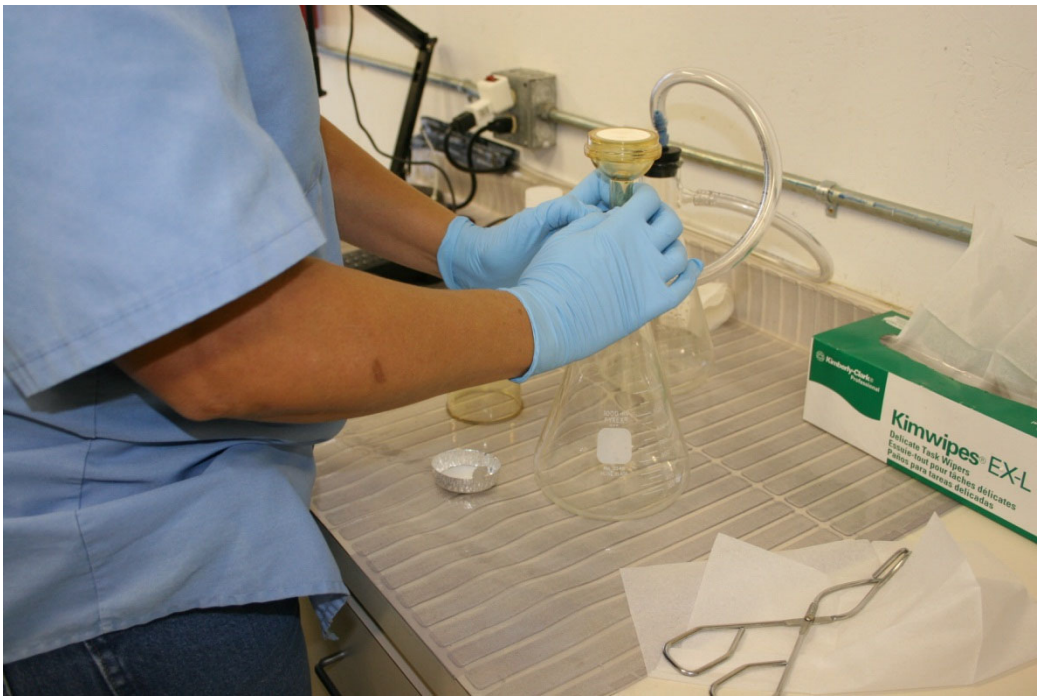
6. Remove the filter paper with tweezers. Dry in a 103^0 c oven for 30 minutes. Remove and desiccate. Reweigh the filter paper (W_2) to the nearest 0.01g.

Calculation:

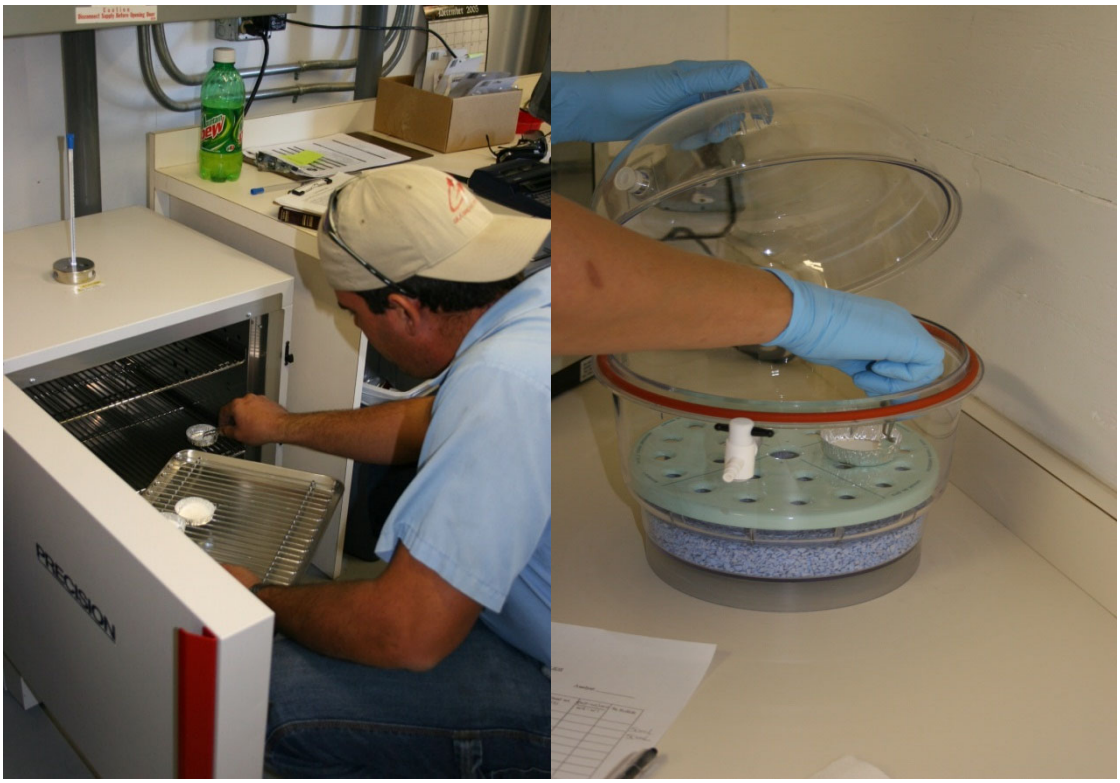
mg/L Suspended Matter

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

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



Total dissolved solids - The weight per unit volume of all volatile and non-volatile solids dissolved in a water or wastewater after a sample has been filtered to remove colloidal and suspended solids.



Top left, filters being baked at 105ºC. Right photograph, filters in desiccant.

Sludge Volume Index (SVI) Formula

SVI is used by operators to determine and compare mixed liquor settleability. It mathematically relates settled sludge volume in the settleometer to MLSS concentration. The definition for SVI is: The volume in milliliters occupied by one gram of activated sludge that has settled for 30 minutes. Note that SVI relates sludge volume in milliliters to MLSS concentration in grams per liter.

A simple formula for SVI is:

$$\textbf{SVI} = \frac{\textbf{mls Settled in 30 min}}{\textbf{MLSS Conc, grams/L}} \quad \textbf{or} \quad \textbf{SVI} = \frac{\textbf{mls Settled}}{\textbf{MLSS, mg/l / 1000}}$$

Sludge Density Index (SDI)
SDI is another way to express sludge compaction, makes use of the same information as SVI, but expresses it as sludge density (weight per volume rather than volume per weight). The definition for SDI is: The grams of activated sludge which occupies a volume of 100 ml after 30 minutes of settling. The formula for SDI is:

$$\textbf{SDI} = \frac{\textbf{grams/L of MLSS}}{\textbf{mls settled in 30 min / 100}} \quad \textbf{or} \quad \frac{\textbf{MLSS, mg/L / 1000}}{\textbf{mls settled in 30 min / 100}}$$

Consider the example given above where MLSS is 2400 mg/L and after 30 minutes of settling the sludge occupies a volume of 260 ml. The SDI is calculated as follows:

$$\textbf{SDI} = \frac{\textbf{2400 mg/l / 1000}}{\textbf{260 ml / 100}} = \frac{\textbf{2.4}}{\textbf{2.6}} = \textbf{0.92}$$

Oxygen Uptake Rate (OUR) and Specific Oxygen Uptake Rate (SOUR)
Oxygen Uptake Rate **(OUR)** is an important wastewater control parameter for activated sludge process carried out using dissolved oxygen analyzer that measures the amount of oxygen used up by the microorganisms expressed in unit time of **mg/L (ppm) per hour**.

Conducting the Level 1 OUR Test
The OUR test is easily performed by recording a series of dissolved oxygen measurements in one minute increments over a 15 minute time period from a mixed liquor suspended solids (MLSS) sample **collected from the discharge of a bioreactor**. It should be noted that high organic loading conditions will result in oxygen depletion in the MLSS sample in less than 15 minutes.

Sludge Volume Index (SVI) Procedure

1. Pour sample of mixed liquor from the process into a 2 liter settlometer.

2. Allow it to settle for 30 minutes

3. After the time period, read the marking to determine the volume occupied by the settled sludge and the reading is expressed in terms of mL/L and this is figure is known as the sludge volume SV value.

4. Next, for MLSS, there are actually two approaches to get the value. A conventional standard approach is by filtering the sludge, drying it and then weigh the second portion of the mixed liquid. However, this can be time consuming and a faster way is by using MLSS meter.

.

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

Calculation:

SVI = $\frac{\text{sludge volume SV}}{\text{MLSS}} \times 1000$

SETTLEABILITY TEST

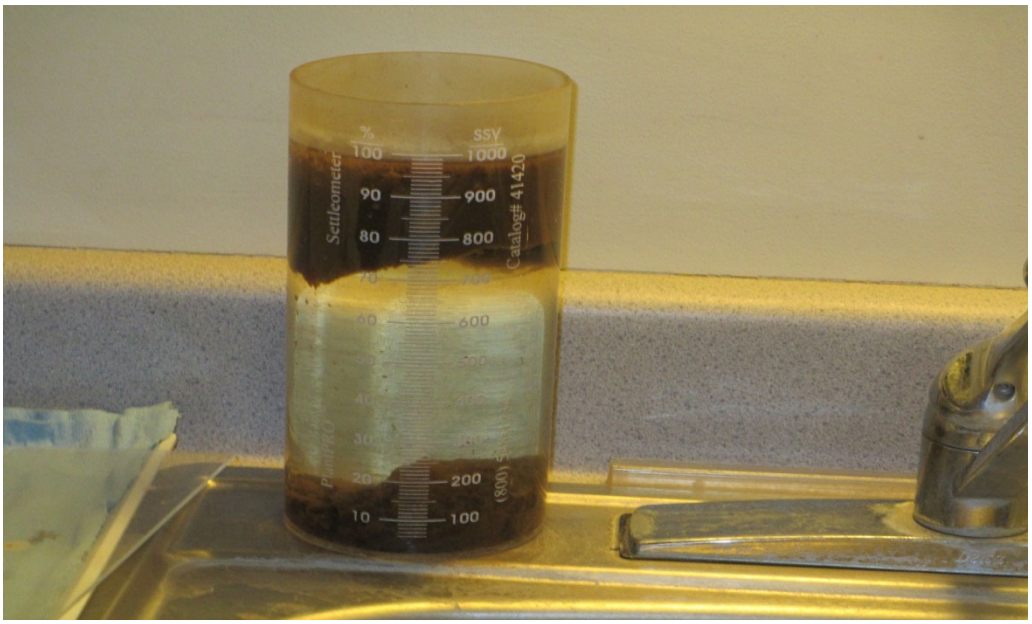
The settleability test is an analysis of the settling characteristics of the activated sludge mixed liquor suspended solids (MLSS). This analysis is often referred to as "running a settleometer." The analysis is normally done within the treatment plant rather than a certified laboratory.

This analysis includes five basic items:

1. A clear container to hold the MLSS
2. A timing device or clock to track elapsed time
3. A paddle or other mixing device
4. A clip board, or place to record the readings
5. Operator patience, attentiveness and diligence

Technical Learning College

The settleometer is a great tool for operators. It indicates how the solids will settle in the clarifier and the density of the sludge.



During the settleometer test, operators not only check how the solids settle out they can also determine the rate of denitrification in the clarifier.

Sludge Volume Index Lab Report Worksheet

Suspended Mater Calculations:

(W_1) = _____ mg Duplicate (W_1) = _____ mg

(W_2) = _____ mg (W_2) = _____ mg

mls Sample = _____ mls Sample = _____ .

mg/L suspended matter = _____ dup. _____ .

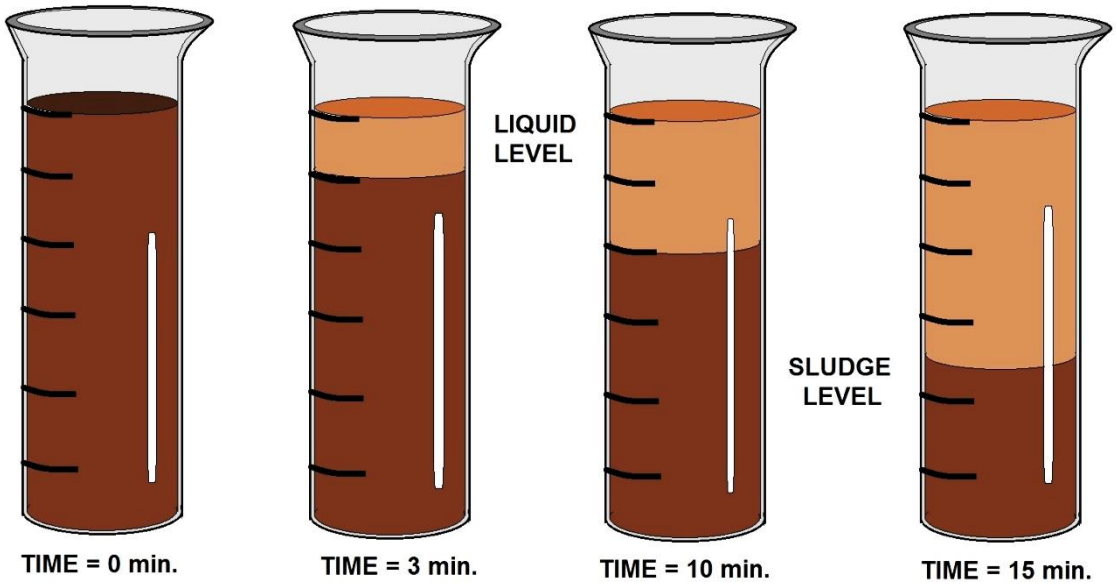
Settleability Calculations:

% settled sludge = _____

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

Sludge Volume Index Calculations:

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



MIXED LIQUOR DEFINITION

Mixed liquor suspended solids (MLSS) is the concentration of suspended solids, in an aeration tank during the activated sludge process, which occurs during the treatment of wastewater. The units MLSS is primarily measured in are milligrams per liter (mg/L). Mixed liquor is a combination of raw or unsettled wastewater and activated sludge within an aeration tank.

Technical Learning College

MLSS

Mixed Liquor Suspended Solids (**MLSS**) is a test for the total suspended solids in a sample of mixed liquor. This test is essentially the same as the test you performed for **TSS** in the last lab, except for the use of mixed liquor as the water sample. In addition, the concentration of suspended solids found in the mixed liquor is typically much greater than that found in the raw or treated water. **MLSS** concentrations are often greater than 1,000 mg/L, but should not exceed 4,000 mg/L.

Technical Learning College

MLVSS

Mixed Liquor Volatile Suspended Solids is generally defined as the microbiological suspension in the aeration tank of an activated-sludge biological wastewater treatment plant.

The biomass solids in a biological waste water reactor are usually indicated as **total suspended solids (TSS)** and **volatile suspended solids (VSS).** The mixture of solids resulting from combining recycled sludge with influent wastewater in the bioreactor is termed **mixed liquor suspended solids (MLSS)** and **mixed liquor volatile suspended solids (MLVSS).** The solids are comprised of biomass, **nonbiodegradable volatile suspended solids (nbVSS),** and inert **inorganic total suspended solids (iTSS).**

Technical Learning College

MIXED LIQUOR CALCULATION

MLSS (g/L) = SV [mL/L]/SVI [mL/g]

Where:
SVI = sludge volume index (mL/g)
SV = Volume of settled solids per 1 litre after 30 minutes
SVI is a calculation from two analyses: SV30 and MLSS.
$0=(Q+Q_r)(X')-(Q_rX'_r+Q_wX'_r)$

Where:
Q = wastewater flow rate (m^3/d)
Q_r = return sludge flow rate (m^3/d)
X' = MLSS (kg/m^3)
X'_r = return sludge concentration (kg/m^3)
Q_w = sludge wasting flow rate (m^3/d)

Technical Learning College

MIXED LIQUOR ADJUSTMENT

If content is too high
1. The process is prone to bulking of solids and the treatment system can become overloaded.
2. This can cause the dissolved oxygen content to drop; this may reduce the efficiency of nitrification and the settleability of the sludge.
3. Excessive aeration will be required, which wastes electricity.
4. It will create thick foam on upper layer.

If content is too low
1. The process may not remove sufficient organic matter from the wastewater.
2. The sludge age may be too low to enable nitrification.

The typical control band for the concentration of MLSS is 2 to 4 g/L for conventional activated sludge, or up to 15 g/l for membrane bioreactors.

Technical Learning College

Fecal Coliform Analysis Sub-Section

FECAL TESTING CONCEPT

A sample is collected and analyzed using aseptic (sterile) technique. A measured volume of sample is filtered through a sterile 0.45µ membrane filter, transferred to an absorbent pad containing m-FC broth, then incubated at 44.5°C for 24 hours. Blue/blue gray colonies are counted and reported as colony forming units (cfu) per 100 ml of sample. The method is limited by turbidity in the sample. Excessive turbidity will reduce fecal coliform recovery, requiring the MPN method to be used instead of the membrane filter method.

Technical Learning College

Sample Collection
Fecal coliform must be collected in a clean, sterile borosilicate glass or plastic bottle containing sodium thiosulfate. Pre-sterilized bags or bottles containing sodium thiosulfate can also be used. Sodium thiosulfate is added to remove residual chlorine which will kill fecal coliforms during transit. 0.1 ml of 10% sodium thiosulfate is added to a 120 ml sample bottle prior to sterilization. The minimum bottle size should be 120 ml to allow enough head space (1") for proper sample mixing.

Collection Procedure
Select a site that will provide a representative sample. Fecal coliform samples are always grab samples and should be drawn directly from the flow stream without using collection other devices. We do not want to cross contaminate the sample. Keep the sample bottle lid closed tightly until it is to be filled.

Remove the cap and do not contaminate the inner surface of the bottle, neck, threads or cap. Fill the container without rinsing, being sure to leave ample air space to allow mixing. Rinsing will remove the dechlorinating agent. All samples should be labeled properly with date and time of collection, sampler's name, and sample collection location. Leaking sample bottles allow for contamination of the sample and should be discarded and the sampling repeated.

Preservation
Fecal coliform samples should be analyzed as soon as possible after collection to prevent changes to the microorganism population. Fecal coliforms must be transported on ice, if they cannot be analyzed within 1 hour of collection. Fecal coliforms transported at ambient temperature may reproduce and higher bias to the numbers than desired or they may be killed off resulting in lower numbers, if handled poorly such as transport in sunlight. Fecal coliform samples should be stored by the laboratory in a refrigerator until time of analysis. The maximum holding time for state or federal permit reporting purposes is 6 hours.

Phase microscopes are used to see indicator bugs and other MO's microorganisms. This examination is used so that the operator knows how well the process is working.

This is a filter used for the coliform test.

Pass-Through /Emerging Wastewater Contaminants Sub-Section

This section provides a brief background on emerging contaminants and key findings from studies on the co-removal of emerging contaminants by nutrient removal technologies.

The term “emerging contaminants” refers broadly to those synthetic or naturally occurring chemicals, or to any microbiological organisms, that have not been commonly monitored in the environment but which are of increasing concern because of their known or suspected adverse ecological or human health effects.

Some chemicals that we use in our everyday lives including medicines (such as prescription and non-prescription drugs), personal hygiene products (for example, soaps, disinfectants, …) and their chemical additives (such as preservatives) are present in the environment and associated with various sources such as municipal wastewater treatment plants, runoff from agricultural and urban land surfaces, and septic systems. These contaminants are referred to collectively as “contaminants of emerging concern” and represent a shift in traditional thinking as many are produced industrially yet are dispersed to the environment from domestic uses.

This investigation identifies and quantifies the environmental sources, presence, and magnitude of environmental contaminants with the underlying theme of understanding the contaminants from their source to a “receptor organism.” The goal of the investigation is to understand the actual versus the perceived health risks to humans or wildlife due to low-level exposures from understudied chemical contaminants in the environment.

Background on Emerging Contaminants
Emerging contaminants can fall into a wide range of groups defined by their effects, uses, or by their key chemical or microbiological characteristics. Two groups of emerging contaminants that are of particular interest and concern at present are endocrine disrupting chemicals (EDCs) and pharmaceutical and personal care products (PPCPs). These compounds are found in the environment, often as a result of human activities.

EDCs may interfere with the endocrine systems by damaging hormone-producing tissues, changing the processes by which hormones are made or metabolized, or mimicking hormones.

In addition to natural and synthetic forms of human hormones that are released into the environment, there are a multitude of synthetic organic compounds that are able to disrupt the endocrine system. Public concern about EDCs in the environment has been rapidly increasing since the 1990s when researchers reported unusual sexual characteristics in wildlife. A report by the USGS, found that fish in many streams had atypical ratios of male and female sex hormones (Goodbred et al., 1997).

In England, researchers found that male trout kept in cages near WWTP outfalls were developing eggs on their testes and had increased levels of the protein that is responsible for egg production (vitellogenin) (Sumpter, 1995; Kaiser, 1996). Follow-up laboratory studies showed that synthetic forms of estrogen (17α-ethynylestradiol (EE2)) could increase vitellogenin production in fish at levels as low as 1-10 ng/L, with positive responses seen down to the 0.1-0.5 ng/L level (Purdom et al., 1994).

Human estrogens have the ability to alter sexual characteristics of aquatic species at trace concentrations as low as 1 ng/L (Purdom et al., 1994).

WWTP effluents have been identified as a primary source for EDCs in the environment, with the bulk of their endocrine disrupting activity resulting from human estrogen compounds (Desbrow et al., 1998, Snyder et al., 2001). The synthetic estrogen, EE2, and the natural estrogens, estrone (E1) and 17β-estradiol (E2), are the greatest contributors to endocrine disrupting activity in WWTP effluent (Johnson et al., 2001) with EE2 showing the greatest recalcitrance in WWTPs (Joss et al., 2004). Influent concentrations range from below detection to 70 ng/L for EE2, 670 ng/L for E1 and 150 ng/L for E2 (Vethaak et al., 2005, Clara et al., 2005b). Other EDCs include tributyl tin, which was previously used in paints to prevent marine organisms from sticking to ships, nonylphenol (a surfactant), and bisphenol A (platicizer and preservative).

PPCPs encompass a wide variety of products that are used by individuals for personal health or cosmetic reasons, and include certain agricultural and veterinary medicine products.

PPCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the counter therapeutic drugs, veterinary drugs, fragrances, sun-screen products, vitamins, and cosmetics. Many of these products, notably the pharmaceuticals for human or animal use, are specifically designed to be biologically active, and some PPCPs may also fall into the category of EDCs described previously.

Estrogens of Concern

Name	***Chemical Structure***	***Name***	***Chemical Structure***
E1	Estrone		$C_{18}H_{22}O_2$
E2	17β-estradiol		$C_{18}H_{24}O_2$
E3	Estriol		$C_{18}H_{24}O_3$
EE2	17α-ethynylestradiol		$C_{20}H_{24}O_2$

Currently, municipal sewage treatment plants are engineered to remove conventional pollutants such as solids and biodegradable organic material but are not specifically designed for PPCP removal or for other unregulated contaminants. Wastewater treatment commonly consists of primary settling followed by biological treatment, secondary settling, and disinfection. This treatment can remove more than 90 percent of many of the most commonly known or suspected EDCs found in wastewater influent; however, low concentrations of some suspected EDCs may remain in the wastewater treatment sludge or effluent (WERF, 2005).

Removal of Emerging Contaminants by Nutrient Removal Technologies

Several studies have examined the effectiveness of current wastewater treatment technologies in the removal of emerging contaminants. Some of these studies are discussed below and their major findings are organized under three subsections: role of activated sludge SRT in removal efficiency, role of nitrifying bacteria in biodegradation, and use of RO to improve removal efficiencies. Details regarding the study design, such as evaluated treatments and contaminants, and a summary of major study findings are provided at the end of this section.

Examples of Wastewater Forms

Field Sampling Log for SIUs Wastewater *Example*

DATE/TIME	GRAB		COMPOSITE	
COMPANY NAME:			SITE #:	
	pH: ______ TEMP: ______	CL_2: ______	pH: ______ TEMP: ______	CL_2: ______
COMPANY NAME:			SITE #:	
	pH: ______ TEMP: ______	CL_2: ______	pH: ______ TEMP: ______	CL_2: ______
COMPANY NAME:			SITE #:	
	pH: ______ TEMP: ______	CL_2: ______	pH: ______ TEMP: ______	CL_2: ______
COMPANY NAME:			SITE #:	
	pH: ______ TEMP: ______	CL_2: ______	pH: ______ TEMP: ______	CL_2: ______
COMPANY NAME:			SITE #:	
	pH: ______ TEMP: ______	CL_2: ______	pH: ______ TEMP: ______	CL_2: ______

Example
Sampling Requirements for NPDES Permit for a Water Treatment Plant.

1. Outfall Sampling

Parameter	Frequency*	Type of sample**	Comments
Flow	Continuous	Continuous	
TSS	Once/day	Composite over 24-hrs	
pH	Once/day	Grab	
Arsenic	Once/month	Composite over 24-hrs	
Barium	Once/month	Composite over 24-hrs	
Cadmium	Once/month	Composite over 24-hrs	
Chromium	Once/month	Composite over 24-hrs	
Lead	Once/month	Composite over 24-hrs	
Magnesium	Once/month	Composite over 24-hrs	
Mercury	Once/month	Composite over 24-hrs	
THMs	Once/month Once/month	Composite over 24-hrs Grab	Grab sample is a city initiative.

* One sample/day is based on continuous discharge. That is defined as discharging at least once a day. Under intermittent discharge conditions, a minimum of twice the number of samples is required. See Section C.2. of the permit for more details.

** Composite sample is collected based on a flow or volume weighted samples collected at a frequency of 15-minute intervals for the duration of discharge.

2. **Influent (upstream) Sampling**

Parameter	Frequency*	Type of sample**	Comments
Flow	None	N/A	No monitoring required
TSS	Once/day	Composite over 24-hrs	
pH	None	N/A	
Arsenic	Once/month	Grab	
Barium	Once/month	Grab	
Cadmium	None	N/A	
Chromium	None	N/A	
Lead	Once/month	Grab	
Magnesium	None	N/A	
Mercury	None	N/A	
THMs	None	N/A	

* One sample/day is based on continuous discharge. That is defined as discharging at least once a day. Under intermittent discharge conditions, a minimum of twice the number of samples is required. See Section C.2. of the permit for more details.

** Composite sample is collected based on a flow or volume weighted samples collected at a frequency of 15-minuteintervals for the duration of intake.

Mixing Zone Sampling

Parameter	Frequency*	Type of sample**	Comments
Flow	Continuous	N/A	No monitoring required
TSS	Once/day	Composite over 24-hrs	
pH	Once/day	Grab	
Arsenic	Once/month	Grab	
Barium	Once/month	Grab	
Cadmium	None	N/A	
Chromium	None	N/A	
Lead	Once/month	Grab	
Magnesium	None	N/A	
Mercury	None	N/A	
THMs	Once/month	Grab	

* One sample/day is based on continuous discharge. That is defined as discharging at least once a day. Under intermittent discharge conditions, a minimum of twice the number of samples is required. See Section C.2. of the permit for more details.

** Composite sample is collected based on a flow or volume weighted samples collected at a frequency of 15-minute intervals for the duration of discharge .

*** Sample shall be collected approximately 69 minutes after start of discharge. Composite sampling shall continue for the duration of discharge but not less than 2-hours.

Section References

California State University – Sacramento. Operation of Wastewater Treatment Plants - Volumes I, II, III. Sacramento, California.

International Air Transport Authority (IATA). Dangerous Goods Regulations, Most Recent Version

Metcalf and Eddy, Inc. 2003. Wastewater Engineering: Treatment, Disposal, and Reuse. 4th Edition, McGraw-Hill Book Co., New York, NY

SESD Operating Procedure for Control of Records, SESDPROC-002, Most Recent Version

SESD Operating Procedure for Equipment Inventory and Management (SESDPROC-104, Most Recent Version)

SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205, Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination at the FEC, SESDPROC-206, Most Recent Version

SESD Operating Procedure for Field pH Measurement, SESDPROC-100, Most Recent Version

SESD Operating Procedure for Field Sampling Quality Control, SESDPROC-011, Most Recent Version

SESD Operating Procedure for Field Specific Conductance Measurement, SESDPROC101, Most Recent Version

SESD Operating Procedure for Field Temperature Measurement, SESDPROC-102, Most Recent Version

SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version

SESD Operating Procedure for Packaging, Marking, Labeling and Shipping of Environmental and Waste Samples, SESDPROC-209, Most Recent Version

SESD Operating Procedure for Sample and Evidence Management, SESDPROC-005, Most Recent Version

SESD Operating Procedure for Surface Water Sampling (SESDPROC-201), Most Recent Version

SESD Operating Procedure for Wastewater Flow Measurement, SESDPROC-109, Most Recent Version

Title 40 Code of Federal Regulations (CFR), Part 136.3, Table II, Most Recent Version

US EPA. 1977. Process Control Manual: Aerobic Biological Treatment Facilities MD-14. EPA 430/09-77-006, Office of Water, Washington, D.C.

US EPA. 2000. Activated Sludge Process Control Testing. ESD, Water Compliance Unit, Athens, GA

US EPA. 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual. Region 4 Science and Ecosystem Support Division (SESD), Athens, GA

Topic 5 -Wastewater Sampling Section Post Quiz

True or False

1. Grab samples indicate the condition of the wastewater at that specific time and always represent the normal conditions. True or False

2. Grab samples are required when the analysis change rapidly. For instance, grab samples are required for certain tests such as temperature, pH, D.O. (dissolved oxygen), and bacteriological analysis. True or False

3. An unweighted composite collects a different sample volume at a constant time interval. True or False

4. A composite sample consists of several grab samples collected from the same spot over a specific period of time and merged into a single sample. True or False

5. A flow meter is connected to the composite sampler and the sampler is programed to draw at different flow intervals. As the flow increases so does the number of samples. True or False

6. A grab sample is more arduous, complicated and usually inconvenient than a simple composite sample. True or False

7. The automatic sampler has the capability to be programmed to draw an unknown volume of sample every few minutes and deposit each sample into one bottles that are preserved or refrigerated. At the end of the sampling period, the operator can retrieve the bottles, bring them back to the lab and create a grab sample. True or False

8. Where applicable, wastewater samples should be collected at the location specified in the NPDES permit (if the source has a permit). True or False

9. In some instances, the sampling location specified in the permit, or the location chosen by the permittee, may be adequate for the collection of a representative wastewater sample. True or False

10. When a conflict exists between the permittee and the regulatory agency regarding the most representative sampling location, both sites should be sampled, and the reason for the conflict should be noted in the field notes and the inspection or study report. True or False

11. Influent wastewaters are preferably sampled at locations of low turbulent flow where the most desirable location is accessible. True or False

12. When possible, influent samples should be collected upstream from sidestream returns. True or False

13. Composite effluent wastewater samples should never be collected from ponds and lagoons. True or False

14. Even if the ponds or lagoons have long retention times, composite sampling is necessary because ponds and lagoons have the tendency to have flow paths that short circuit, which changes the designed detention time. True or False

15. Effluent samples do not be collected at the site specified in the permit, or if no site is specified in the permit, at the most representative site upstream from all entering wastewater streams prior to discharge into the receiving waters.
True or False

Math Formulas and Conversions

$$\text{Acid Feed Rate} = \frac{(\text{Waste Flow})\ (\text{Waste Normality})}{\text{Acid Normality}}$$

$$\text{Alkalinity} = \frac{(\text{mL of Titrant})\ (\text{Acid Normality})\ (50{,}000)}{\text{mL of Sample}}$$

Amperage = Voltage ÷ Ohms

Area of Circle = $(0.785)(\text{Diameter}^2)$ OR $(\pi)(\text{Radius}^2)$

Area of Rectangle = (Length)(Width)

$$\text{Area of Triangle} = \frac{(\text{Base})\ (\text{Height})}{2}$$

C Factor Slope = Energy loss, ft. ÷ Distance, ft.

C Factor Calculation = Flow, GPM ÷ [193.75 (Diameter, ft.)2.63(Slope)0.54]

$$\text{Chemical Feed Pump Setting, \% Stroke} = \frac{(\text{Desired Flow})\ (100\%)}{\text{Maximum Flow}}$$

$$\text{Chemical Feed Pump Setting, mL/min} = \frac{(\text{Flow, MGD})\ \text{Dose, mg/L})\ (3.785\text{L/gal})\ (1{,}000{,}000\ \text{gal/MG})}{(\text{Liquid, mg/mL})\ (24\ \text{hr. / day})\ (60\ \text{min/hr.})}$$

Chlorine Demand (mg/L) = Chlorine dose (mg/L) – Chlorine residual (mg/L)

Circumference of Circle = (3.141) (Diameter)

$$\text{Composite Sample Single Portion} = \frac{(\text{Instantaneous Flow})\ (\text{Total Sample Volume})}{(\text{Number of Portions})\ (\text{Average Flow})}$$

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Digested Sludge Remaining, \%} = \frac{(\text{Raw Dry Solids})\ (\text{Ash Solids})\ (100\%)}{(\text{Digested Dry Solids})\ (\text{Digested Ash Solids})}$$

$$\text{Discharge} = \frac{\text{Volume}}{\text{Time}}$$

Dosage, lbs/day = (mg/L)(8.34)(MGD)

Dry Polymer (lbs.) = (gal. of solution) (8.34 lbs/gal)(% polymer solution)

$$\text{Efficiency, \%} = \frac{(\text{In} - \text{Out})\ (100\%)}{\text{In}}$$

$$\text{Feed rate, lbs/day} = \frac{(\text{Dosage, mg/L})\ (\text{Capacity, MGD})\ (8.34\ \text{lbs/gals})}{(\text{Available fluoride ion})\ (\text{Purity})}$$

$$\text{Feed rate, gal/min (Saturator)} = \frac{(\text{Plant capacity, gal/min.})\ (\text{Dosage, mg /L})}{18{,}000\ \text{mg/L}}$$

$$\text{Filter Backwash Rate} = \frac{\text{Flow}}{\text{Filter Area}}$$

$$\text{Filter Yield, lbs/hr./sq. ft} = \frac{(\text{Solids Loading, lbs/day})\ (\text{Recovery, \% / 100\%})}{(\text{Filter operation, hr./day})\ (\text{Area, ft}^2)}$$

Flow, cu. ft./sec. = (Area, Sq. Ft.)(Velocity, ft./sec.)

$$\text{Gallons/Capita/Day} = \frac{\text{Gallons / day}}{\text{Population}}$$

$$\text{Hardness} = \frac{(\text{mL of Titrant})\ (1{,}000)}{\text{mL of Sample}}$$

$$\text{Horsepower (brake)} = \frac{(\text{Flow, gpm})\ (\text{Head, ft})}{(3{,}960)\ (\text{Efficiency})}$$

$$\text{Horsepower (motor)} = \frac{(\text{Flow, gpm})\ (\text{Head, ft})}{(3960)\ (\text{Pump, Eff})\ (\text{Motor, Eff})}$$

$$\text{Horsepower (water)} = \frac{(\text{Flow, gpm})\ (\text{Head, ft})}{(3960)}$$

$$\text{Hydraulic Loading Rate} = \frac{\text{Flow}}{\text{Area}}$$

Leakage (actual) = Leak rate (GPD) ÷ [Length (mi.) x Diameter (in.)]

Mean = Sum of values ÷ total number of values

$$\text{Mean Cell Residence Time (MCRT)} = \frac{\text{Suspended Solids in Aeration System, lbs}}{\text{SS Wasted, lbs / day + SS lost, lbs / day}}$$

$$\text{Organic Loading Rate} = \frac{\text{Organic Load, lbs BOD / day}}{\text{Volume}}$$

Oxygen Uptake = $\frac{\text{Oxygen Usage}}{\text{Time}}$

Pounds per day = (Flow, MGD) (Dose, mg/L) (8.34)

Population Equivalent = $\frac{\text{(Flow MGD) (BOD, mg/L) (8.34 lbs / gal)}}{\text{Lbs BOD / day / person}}$

RAS Suspended Solids, mg/l = $\frac{1{,}000{,}000}{\text{SVI}}$

RAS Flow, MGD = $\frac{\text{(Infl. Flow, MGD) (MLSS, mg/l)}}{\text{RAS Susp. Sol., mg/l – MLSS, mg/l}}$

RAS Flow % = $\frac{\text{(RAS Flow, MGD) (100 \%)}}{\text{Infl. Flow, MGD}}$

Reduction in Flow, % = $\frac{\text{(Original Flow – Reduced Flow) (100\%)}}{\text{Original Flow}}$

Slope = $\frac{\text{Drop or Rise}}{\text{Run or Distance}}$

Sludge Age = $\frac{\text{Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs / day}}$

Sludge Index = $\frac{\text{\% Settleable Solids}}{\text{\% Suspended Solids}}$

Sludge Volume Index = $\frac{\text{(Settleable Solids, \%) (10,000)}}{\text{MLSS, mg/L}}$

Solids, mg/L = $\frac{\text{(Dry Solids, grams) (1,000,000)}}{\text{mL of Sample}}$

Solids Applied, lbs/day = (Flow, MGD)(Concentration, mg/L)(8.34 lbs/gal)

Solids Concentration = $\frac{\text{Weight}}{\text{Volume}}$

Solids Loading, lbs/day/sq. ft = $\frac{\text{Solids Applied, lbs / day}}{\text{Surface Area, sq. ft}}$

Surface Loading Rate = $\frac{\text{Flow}}{\text{Rate}}$

Total suspended solids (TSS), mg/L =
(Dry weight, mg)(1,000 mL/L) ÷ (Sample vol., mL)

Velocity = $\frac{\text{Flow}}{\text{Area}}$ O R $\frac{\text{Distance}}{\text{Time}}$

Volatile Solids, % = $\frac{\text{(Dry Solids - Ash Solids) (100\%)}}{\text{Dry Solids}}$

Volume of Cone = (1/3)(0.785)(Diameter^2)(Height)

Volume of Cylinder = (0.785)(Diameter^2)(Height) OR (π)(r^2)(h)

Volume of Rectangle = (Length)(Width)(Height)

Volume of Sphere = [(π)(diameter^3)] ÷ 6

Waste Milliequivalent = (mL) (Normality)

Waste Normality = $\frac{\text{(Titrant Volume) (Titrant Normality)}}{\text{Sample Volume}}$

Weir Overflow Rate = $\frac{\text{Flow}}{\text{Weir Length}}$

Conversion Factors

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

Post Quiz Answers

Topic 1- Water Quality Post Quiz Answers
1. Activated alumina, 2. Total Dissolved Solids, 3. Ethylenediaminetetraacetic acid (EDTA), 4. Radon gas, 5. Arsenic, 6. Arsenic,7. True, 8. True, 9. The Stage 2 DBP rule, 10. The Stage 2 DBP rule, 11. Cryptosporidium, 12. The Stage 2 DBPR, 13. The Stage 2 DBPR, 14. Stage 2 DBPR, 15. False, 16. True, 17. True, 18. False.

Topic 2- 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 3 - Water Laboratory Procedures Section Answers
1. Acidity or basicity, 2. True, 3. Strip test paper, 4. False, 5. Alkalinity, 6. 2-10, 7. Compounds, 8. Hydrogen, 9. Carbonate, 10. Scale

Topic 4 - Wastewater Treatment Introduction
1. True, 2. False, 3. True, 4. False, 5. False, 6. True, 7. False, 8. True, 9. False, 10. False, 11. False, 12. True, 13. True, 14. True, 15. False

Topic 5 -Wastewater Sampling Section
1. False, 2. True, 3. False, 4. True, 5. True, 6. False, 7. False, 8. True, 9. False, 10. True, 11. False, 12. True, 13. False, 14. True, 15. False

References

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.

ATS [1987]. Standardization of spirometry -- 1987 update. American Thoracic Society. Am Rev Respir Dis

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. Blti: 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.

Bickford, T.M., Lindsey, B.D., and Beaver, M.R., 1996, Bacteriological quality of ground water used

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.

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

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.

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.

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, 225-237, 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 Association.

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.
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.
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.
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 Report 91- 4073, 33 p.
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.
Flint, K.P., 1987, The long-term survival of Escherichia coli in river water: Journal of Applied Bacteriology, 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. Environmental 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]. Material safety data sheet 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 of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.
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.
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.
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.
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.
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.
Jaffe, Martin and Frank Dinovo. Local Groundwater Protection. American Planning Ass, 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, Ground-water data-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. (1994a). Induced cytolethality and regenerative cell proliferation in the livers and kidneys of male B6C3F1 mice given chloroform by gavage. Fundamentals and Applied Toxicology, 23, 537-543.
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.
Levy, D.A., Bens, M.S., Craun, G.F., Calderon, R.L., and Herwaldt, B.L.,1998, Surveillance for waterborne disease outbreaks—United States, 1995-1996: Morbidity and Mortality Weekly Report—Surveillance Summaries, December 11, 1998, 47(SS-5).
Lewis RJ, ed. [1993]. Lewis condensed chemical dictionary. 12th ed. New York, NY: Van Nostrand Reinhold Company.
Lide DR [1993]. CRC handbook of chemistry and physics. 73rd ed. Boca Raton, FL: CRC Press, Inc.
*Lim, Kieran F. (2006). "Negative pH Does Exist". Journal of Chemical Education. **83** (10): 1465. Bibcode:2006JChEd..83.1465L. doi:10.1021/ed083p1465.*
Lindquist, H.D.A. (1999). Emerging pathogens of concern in drinking water. EPA Publication #EPA 600/R-99/070.
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 Association of Conservation Comm. Ground Water... Maine's Hidden Resource. Hallowell, ME, 1985.
Malard, F., Reygrobellet, J-L., and Soulie, Michel, 1994, Transport and retention of fecal bacteria at sewage polluted fractured rock sites: Journal of Environmental Quality, v. 23, p. 1352-1363.
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.
Mast, A.M., and Turk, J.T., 1999, Environmental Characteristics and Water Quality of Hydrologic Benchmark Network Stations in the Eastern United States, 1963- 95: U.S. Geological Survey Circular 1173-B, 158 p.
McCann, Alyson and Thomas P Husband. "Natural Resources Facts: Household Hazardous Waste." University of Rhode Island, Providence, RI; 1988.
Miller, David W. Groundwater Contamination: 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 Ground Water 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.
Myers, D.N., 1992, Distribution and variability of fecal indicator bacteria in Scioto and Olentangy Rivers in the Columbus, Ohio, area: U.S. Geological Survey Water-Resources Investigations Report 92-4130, 61 p.
Myers, D.N., and Sylvester, M.D., 1997, National field manual for the collection of water-quality data—Biological indicators: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A7, 38 p.
Myers, D.N., Koltun, G.F., and Francy, D.S., 1998, Effects of hydrologic, biological, and environmental processes on sources and concentrations of fecal bacteria in the Cuyahoga River, with implications for management of recreational waters in Summit and Cuyahoga Counties, Ohio: U.S. Geological Survey Water-Resources Investigations Report 98-4089, 38 p.
National Academy of Engineering (2000). Greatest engineering achievements of the 20th century. [On-Line]. Available: (http://www.greatachievements.org/ greatachievements/) (accessed 2-10-03).
National Research Council. Ground Water Quality Protection: State and Local Strategies. National Academy Press, Washington, D.C., 1986.
Natural Resources Defense Council, 1998, Testing the waters—Volume VIII: New York, 145 p. Novotony, V., Sung, Hung-Ming, Bannerman, R., and Baum, K., 1985, Estimating nonpoint pollution from small urban watersheds: Journal of the Water Pollution Control Federation, v. 57, p. 339-348.
New England Interstate Water Pollution Control Commission. "Groundwater: Out of Sight Not Out of Danger." Boston, MA, 1989.
NFPA [1986]. Fire protection guide on hazardous materials. 9th ed. Quincy, MA: National Fire ProAss
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.

NIOSH [1987a]. NIOSH guide to industrial respiratory protection. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-116.
NIOSH [1987b]. NIOSH respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-108.
NIOSH [1992]. Recommendations for occupational safety and health: Compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.
NIOSH [1994]. NIOSH manual of analytical methods. 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.
NIOSH [1995]. Registry of toxic effects of chemical substances: Chlorine. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, Technical Information Branch.
NJDH [1992]. Hazardous substance fact sheet: Chlorine. Trenton, NJ: New Jersey Department of Health.
NLM [1995]. Hazardous substances data bank: Chlorine. Bethesda, MD: National Library of Medicine.
Noake, Kimberly D. Guide to Contamination Sources for Wellhead Protection. Draft. Massachusetts Department of Environmental Quality Engineering, Boston, MA, 1988.
Office of Drinking Water. A Local Planning Process for Groundwater Protection. U.S. EPA, WA, D.C., 1989.
Office of Ground-Water Protection. Guidelines for Delineation of Wellhead Protection Areas. U.S. EPA, Washington, D.C., 1987.
Office of Ground-Water Protection. Survey of State Ground Water Quality Protection Legislation Enacted From 1985 Through 1987. U.S. EPA, Washington, D.C., 1988.
Office of Ground-Water Protection. Wellhead Protection Programs. - Tools for Local Governments. U.S. EPA, Washington, D.C., 1989.
Office of Ground-Water Protection. Wellhead Protection: A Decision-Makers' Guide. U.S. EPA, WA, D.C., 1987
Office of Pesticides and Toxic Substances. Citizen's Guide to Pesticides. U.S. EPA, Washington, 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. Ground Water. Columbus, OH.
Ontario Ministry of the Attorney General, The Honorable Dennis R. O'Connor (2002). Part one: A summary: Report of the Walkerton inquiry: The events of May 2000 and related issues.
Otterstetter, H. and Craun, C. (September, 1997). Disinfection in the Americas: A necessity. Journal of the American Water Works Association, 8-10.
Palmer, M.D., Lock, J.D., and Gowda, T.P.H., 1984, The use of bacteriological indicators for swimming water quality: Water and Pollution Control, v. 122, no. 3, p. 14-15, 17-18, and 74.
Payment, P., and Franco, E., 1993, Clostridium perfringens and somatic coliphages as indicators of the efficiency of drinking water treatment for viruses and protozoan cysts: Applied and Environmental Microbiology, v. 59, no. 8, p. 2418-2424.
Principles and Practices of Water Supply Operations, C.D. Morelli, ed. 1996.
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.
Redlich, Susan. Summary of Municipal Actions for Groundwater Protection in the New England/New York Region. Research, v. 13, p. 33-41.
Robertson, J.B., and Edberg, S.C., 1997, Natural protection of spring and well drinking water against surface microbial contamination. 1. Hydrogeological parameters: Critical Rev in Microbiology, v. 23, no. 2, p. 143-178.
Rose, J.B. (2002). Water quality security. Environmental Science and Technology, 36, 217-256.
Rose, J.B., Atlas, R.M., Gerba, C.P., Gilchrist, M.J.R., Le Chevallier, M.W., Sobsey, M.D., and Yates, M.V., 1999, Microbial pollutants in our Nation's
Rose, J.B., Gerba, C.P., and Jakubowski, W., 1991, Survey of potable water supplies for Cryptosporidium and Giardia: Environmental Science and Technology, v. 25, no. 8, p. 1393-1400.
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.

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 Comm. "On Dangerous Ground: The Problem of Abandoned Wells in Texas." Austin, TX, 1989.
Texas Water Comm. The Underground Subject: An Introduction to Ground Water Issues in TX. Austin, TX, 1989.
U.S. Centers for Disease Control and Prevention (1997). Summary of notifiable diseases. U.S. Centers for Disease Control and Prevention (April 12, 1996). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks, United States, 1993-1994.
U.S. Centers for Disease Control and Prevention (December 11, 1998). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks, United States, 1995-1996.
U.S. Centers for Disease Control and Prevention (May 26, 2000). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks, United States, 1997-1998.
U.S. Centers for Disease Control and Prevention (November 19, 1993). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks-United States, 1991-1992.
U.S. Centers for Disease Control and Prevention, (2002). National Center for Infectious Diseases, Infectious Disease Information, Diseases related to water. [On-Line]. Available: http://www.cdc.gov/ncidod/diseases/water/drinking.htm
U.S. Centers for Disease Control and Prevention, (November 22, 2002). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks, United States, 1999-2000.
U.S. Environmental Protection Agency (1991). Letter from Wilcher, L.S. to Guerra de Macedo, G.
U.S. Environmental Protection Agency (1998a). National Primary Drinking Water Regulations: Disinfectants and Disinfection Byproducts; Final Rule. Federal Register Vol 63, No. 157. Wednesday, Dec.16, 1998.
U.S. Environmental Protection Agency (1998b). Regulatory Impact Analysis of Final Disinfectant/ Disinfection byproducts Regulations. Washington, D.C. EPA Number 815-B-98-002-PB 99-111304
U.S. Environmental Protection Agency (2001a). Toxicological review of chloroform in support of summary information on the Integrated Risk Information System (IRIS). EPA Number 635/R-01/001.
U.S. Environmental Protection Agency (2001b). Controlling Disinfection byproducts and Microbial Contaminants in Drinking Water. EPA Number 600/R-01/110.
U.S. Environmental Protection Agency (2002). Public drinking water systems: Facts and figures. [On-Line]. Available: http://www.epa.gov/safewater/pws/factoids.html (accessed 11-22-02).
U.S. Environmental Protection Agency. Seminar Publication: Protection of Public Water Supplies from Ground-Water Contaminants. Center for Environmental Research Information, Cincinnati, OH, 1985.
U.S. Environmental Protection Agency. Seminar Publication: Protection of Public Water Supplies from Ground-Water Contaminants. Center for Environmental Research Information, Cincinnati, OH, 1985.
Waller, Roger M. Ground Water and the Rural Homeowner. U.S. Geological Survey, Reston, VA, 1988.
Water Treatment, Second Edition
Water, in Groundwater pollution microbiology: New York, John Wiley and Sons, p. 65-88.
water—Environmental and public health issues: Washington, D.C., American Society for Microbiology,
World Health Organization (2002a). Water and Sanitation: Facts and Figures. [On-Line]. Available: http://www.who.int/water_sanitation_health/General/ factsandfigures.htm
World Health Organization (2002b). Water and Sanitation: Guidelines for drinking water quality. [On-Line]. Available: http://www.who.int/ water_sanitation_health/GDWQ/Microbiology/ Microbioladd/microadd5.htm

Glossary References

Benenson, Abram S., editor. 1990. *Control of Communicable Diseases in Man.* 15th ed. Baltimore: Victor Graphics, Inc.
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. Environmental Protection Agency.

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

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

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

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 in order to successfully complete this assignment with a score of 70% or better.

If you need any assistance, please contact TLC's Student Services. Once you are finished, please mail, e-mail or fax your answer sheet along with your registration form.