

# WATER MONITORING

CONTINUING EDUCATION  
PROFESSIONAL DEVELOPMENT COURSE





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

**Do not solely depend on TLC's Approval list for it may be outdated.**

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***Responsibility***

*This course contains EPA's federal rule requirements. Please be aware that each state implements drinking water/wastewater/safety regulations may be more stringent than EPA's or OSHA's regulations.*

*Check with your state environmental agency for more information. You are solely responsible in ensuring that you abide with your jurisdiction or agency's rules and regulations.*

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# Technical Learning College's Scope and Function

Welcome to the Program,

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

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

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

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

## **Flexible Learning**

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

## **Course Structure**

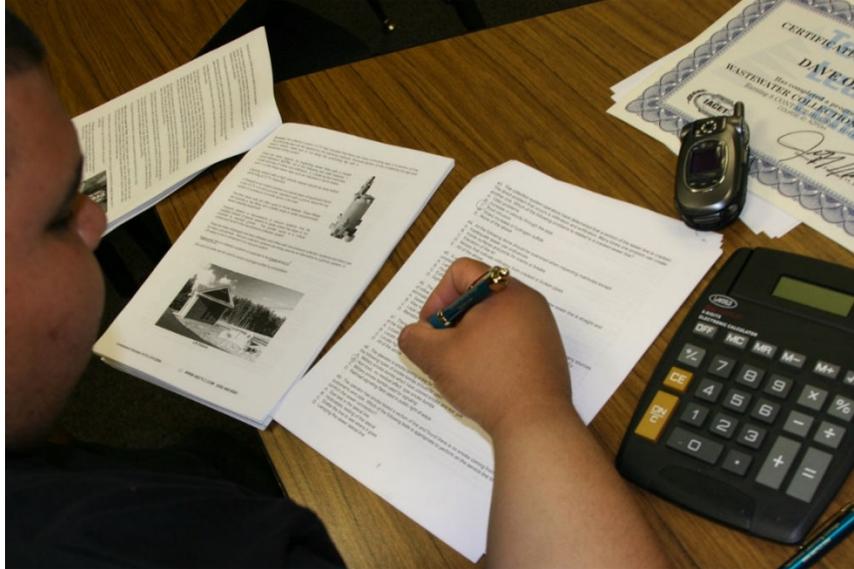
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student-friendly course design allows you the most flexibility in choosing when and where you will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

## **Classroom of One**

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

### **Satisfaction Guaranteed**

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



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

We welcome you to complete the assignment in Word.

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

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## **CEU COURSE DESCRIPTION**

### **WATER MONITORING CEU TRAINING COURSE**

This CEU course is a review of Environmental Protection Agency's Rules and Regulation relating to proper water sampling, water sample preservation, reporting, MCLS and related microbiological concerns. This course will cover the basic requirements of the federal rule concerning water sampling (TCR) 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.

#### **What is the Total Coliform Rule (TCR)?**

The Total Coliform Rule (TCR) requires all public water supplies to monitor for the presence of total coliforms in the distribution system. For drinking water, total coliforms are used to monitor the sanitary quality of the water, adequacy of water treatment, and the integrity of the distribution system. The absence of total coliforms in the distribution system minimizes the likelihood that fecal pathogens are present. Thus, total coliforms are used to determine the vulnerability of a system to fecal contamination.

#### **CEU Training Goals**

1. Define various Water Quality Processes, Terms, and Definitions.
2. Identify and explain Total Coliform Bacteria.
3. Identify and explain Monitoring Requirements.
4. Identify and explain Collecting Samples.
5. Identify and explain Reporting/Collection/Chain-of-Custody form.
6. Interpretation of Results.
7. Identify and explain Repeat Samples / Follow-up to Coliform Positive Samples.
8. Invalidating Sample Results.
9. Identify and explain Laboratory Related Concerns.
10. Identify and explain Compliance, Violations, and Follow-up Actions
11. Identify and explain both Primary Drinking Water Standards and Secondary Drinking Water Standards, including new EPA Rules.
12. Identify various waterborne Pathogens and Protozoan Diseases.
13. Explore Chemical Monitoring Methods.
14. Describe Chlorination Chemistry, Alternate Disinfection, Chlorine Dioxide, Ozone and UV methods.

#### **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 distance 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 a unique number assigned to the student.

### **Instructions for Written Assignments**

The Water Monitoring 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. For security purposes, please fax or e-mail a copy of your driver's license and always call us to confirm we've received your assignment and to confirm your identity. TLC offers students the option of either pass/fail or assignment of a standard letter grade. If a standard letter grade is not requested, a pass/fail notice will be issued.

Final course grades are based on the total number of possible points. The grading scale is administered equally to all students in the course. Do not expect to receive a grade higher than that merited by your total points. No point adjustments will be made for class participation or other subjective factors. If TLC is not notified, you will only receive a pass/fail notice. In order to pass your final assignment, you are required to obtain a minimum score of 70% on your assignment.

### **Required Texts**

The Water Monitoring CEU training course comes complete with a short summary of the EPA's Rules and Regulations (TCR Rule) 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](http://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 States that require your information 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.*

**At the conclusion of this course...**

The student will obtain 8 hours of continuing education after successful completion of the final examination. The student will be able to describe and explain various water sampling procedures, purposes and regulations. The student will be able to describe the TCR rule and various forms of bacteria, e. coli, fecal, and coliform and sampling responsibilities. The student will understand the purposes for proper water sampling procedures, chain of custody, reporting and the violations that occur when the water system is out of compliance.

*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.*



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**Hyperlink to the Glossary and Appendix**

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

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## 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 act or State Regulations, i.e. Compliance, non-compliance, process control related sampling or other drinking water related requirement. This EPA information is to satisfy the regulatory portion of your operator training. Part of O&M or laboratory training requirement for many operators.

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

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

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

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

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

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

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

**TECH - TECHNICAL:** The 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.

**Nephelometric 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 methemoglobinemia, 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-trichloroethane, 1,1-dichloroethylene, and 1,2-dichloroethane.

**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 (SDWA)

- ★ DRAFTED IN 1974.
- ★ AMENDED IN 1986 AND ALSO IN 1996.
- ★ SETS NATIONAL HEALTH-BASED STANDARDS FOR DRINKING WATER TO PROTECT AGAINST BOTH NATURALLY-OCCURRING AND MAN-MADE CONTAMINANTS THAT MAY BE FOUND IN DRINKING WATER.
- ★ THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA) IS RESPONSIBLE FOR REGULATION AND ENFORCEMENT BY SETTING STANDARDS FOR DRINKING WATER BASED ON SOUND SCIENCE TO PROTECT AGAINST HEALTH RISKS, CONSIDERING AVAILABLE TECHNOLOGY AND ASSOCIATED COSTS.
- ★ THE AMENDMENTS REQUIRE MANY ACTIONS TO PROTECT DRINKING WATER AND ITS SOURCES:
  - RIVERS
  - LAKES
  - RESERVOIRS
  - SPRINGS
  - GROUNDWATER WELLS



### SAFE DRINKING WATER ACT FACTS



## 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 CFR 142
- 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.

# 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.

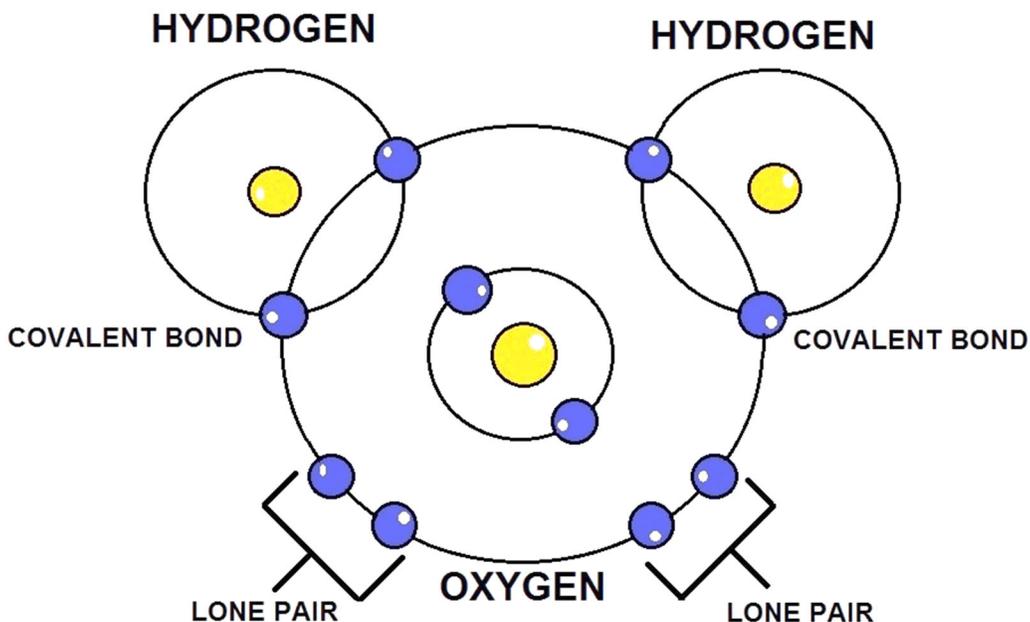
**Radionuclide Rule** Promulgated 2000 Contained 4 contaminants, Targeted: Radionuclides.

**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.

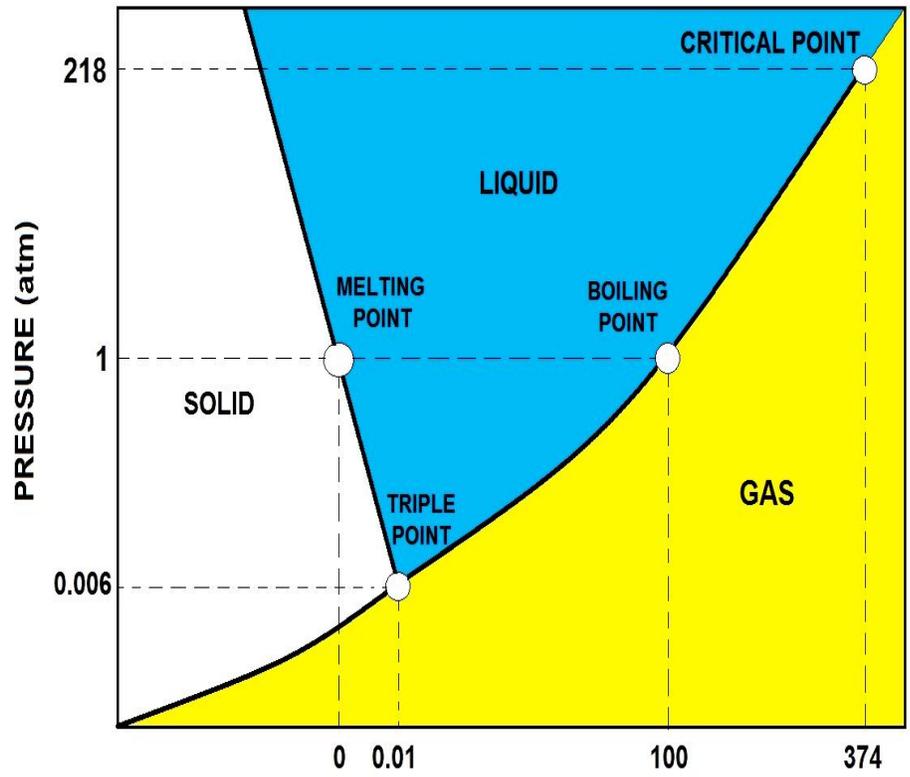


**WATER MOLECULE DIAGRAM**

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.

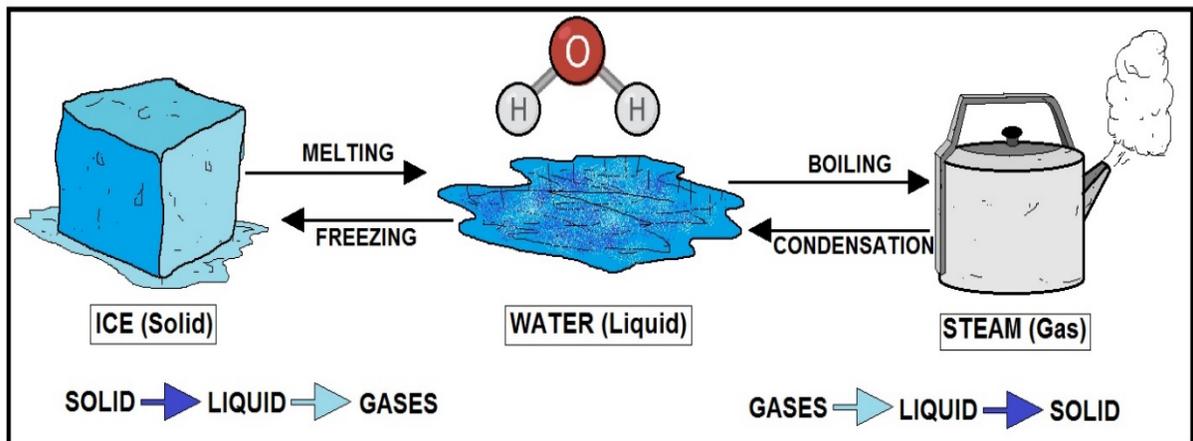
Electrical attraction between water molecules due to this dipole pulls individual molecules closer together, making it more difficult to separate the molecules and therefore raising the boiling point.



**TEMPERATURE (°C) WATER PHASE DIAGRAM**

**Boiling Phase**

Once liquid water is heated to 212°F (100°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**



## Surface (Raw) Water Introduction

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

INTRODUCTION OF RAW WATER	
<b>Raw Water is natural water found in the Environment that has not been treated and does not have any of its Minerals, Ions, Particles, Bacteria, or Parasites removed</b>	 
<b>SOURCES:</b>	 
<ul style="list-style-type: none"><li>• Rain Water</li><li>• Ground Water</li><li>• Water from Infiltration Wells</li><li>• Lakes and River Water</li></ul>	



### 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.

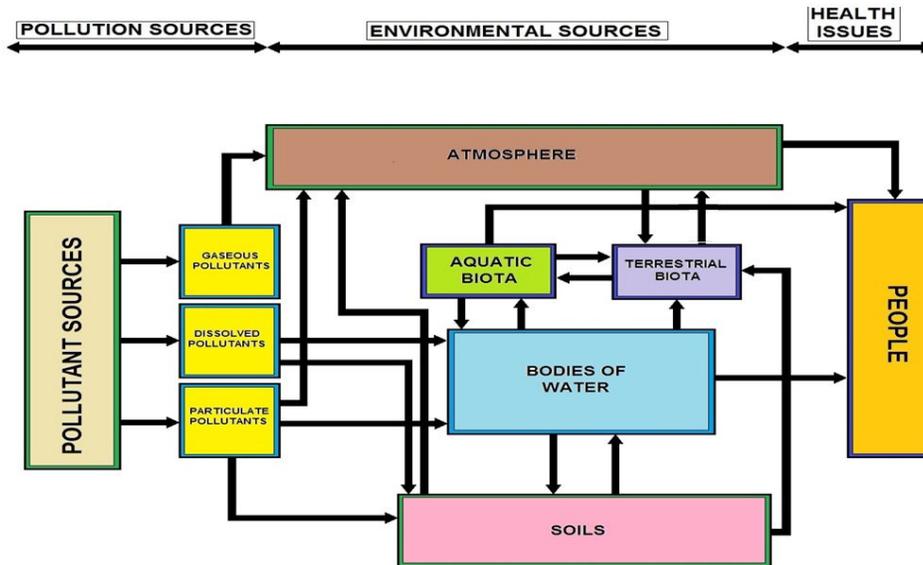
These characteristics have a direct influence on the most effective types of treatment methods and/or chemicals. The improvement of water quality and formation of policy measures (administrative and engineering) revolves around these characteristics.

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.

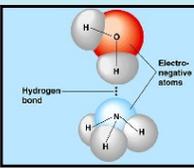
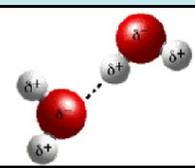
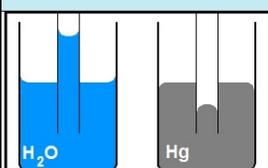
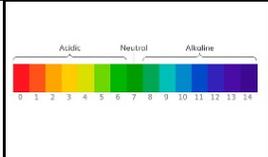
Currently, we also need to deal with contaminants of emerging concern including Pharmaceuticals and Personal Care Products. EPA defines emerging contaminants as: An emerging contaminant (EC) is a chemical or material characterized by a perceived, potential, or real threat to human health or the environment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



## WATER QUALITY INDICATORS

# WATER PROPERTIES

<p style="text-align: center; background-color: #ADD8E6; padding: 2px;"><b>SURFACE TENSION</b></p>  <p style="font-size: small;">WATER PROPERTY OF SURFACE TENSION ALLOWS TO HOLD A CERTAIN WEIGHT ON IT'S SURFACE</p>	<p style="text-align: center; background-color: #ADD8E6; padding: 2px;"><b>ADHESION</b></p>  <p style="font-size: small;">WATER'S ADHESIVE PROPERTY IS WHY WATER STICKS TO OTHER OBJECTS, LIKE A LEAF OR YOUR SKIN WHEN IT GETS WET</p>	<p style="text-align: center; background-color: #ADD8E6; padding: 2px;"><b>COHESION</b></p>  <p style="font-size: small;">WATER'S COHESIVE PROPERTY IS WHY WATER DROPLETS ARE ROUND BEFORE THEY ARE AFFECTED BY ADHESION</p>	<p style="text-align: center; background-color: #ADD8E6; padding: 2px;"><b>CAPILLARY ACTION</b></p>  <p style="font-size: small;">CAPILLARY ACTION IS AN ACTION MADE POSSIBLE BY WATER'S ADHESIVE PROPERTY AND SURFACE TENSION.</p>
<p style="text-align: center; background-color: #ADD8E6; padding: 2px;"><b>NEUTRAL pH</b></p>  <p style="font-size: small;">THE pH SCALE SHOWS HOW ACIDIC - BASIC A SUBSTANCE IS. PURE WATER HAS A NEUTRAL pH OF 7</p>	<p style="text-align: center; background-color: #ADD8E6; padding: 2px;"><b>3 STATES OF MATTER</b></p>  <p style="font-size: small;">WATER, UNLIKE ANY OTHER MATTER, CAN EXIST IN SOLID, LIQUID OR GAS FORMS</p>	<p style="text-align: center; background-color: #ADD8E6; padding: 2px;"><b>HIGH HEAT CAPACITY</b></p>  <p style="font-size: small;">WATER HAS A HIGH SPECIFIC HEAT CAPACITY, MEANING THAT IT TAKES QUITE A LOT OF ENERGY TO MAKE IT WARMER</p>	<p style="text-align: center; background-color: #ADD8E6; padding: 2px;"><b>DENSITY</b></p>  <p style="font-size: small;">WATER'S DENSITY IS SLIGHTLY LESS THAN 1g/cm<sup>3</sup></p>



## PROPERTIES OF WATER

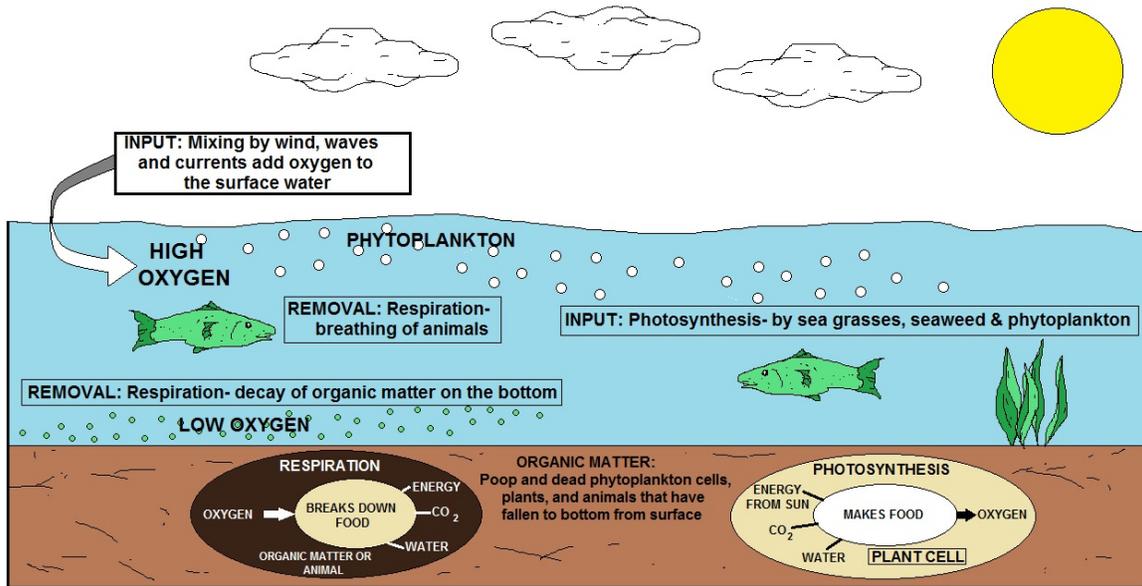
## Surface Water Properties

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.

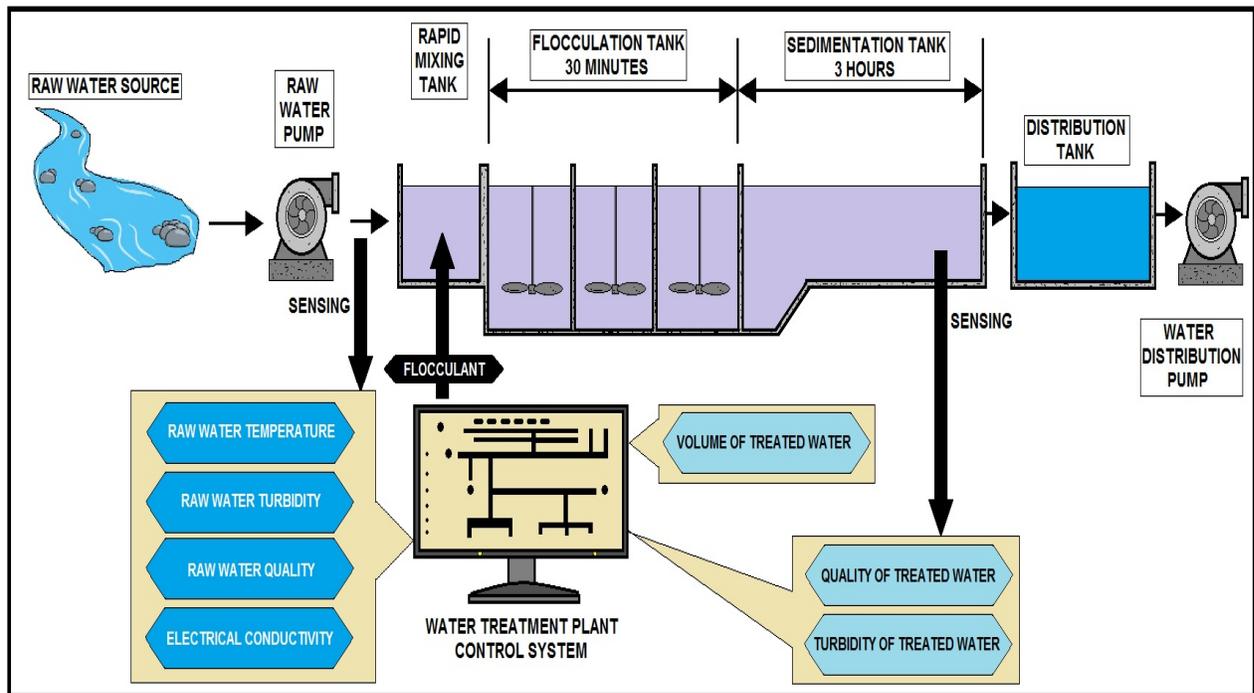
The ecological balance in lakes and reservoirs plays a natural part in purifying and sustaining the life of the lake. For example, algae and rooted aquatic plants are essential in the food chain of fish and birds. Algae growth is the result of photosynthesis. Algae growth is supplied by the energy of 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.

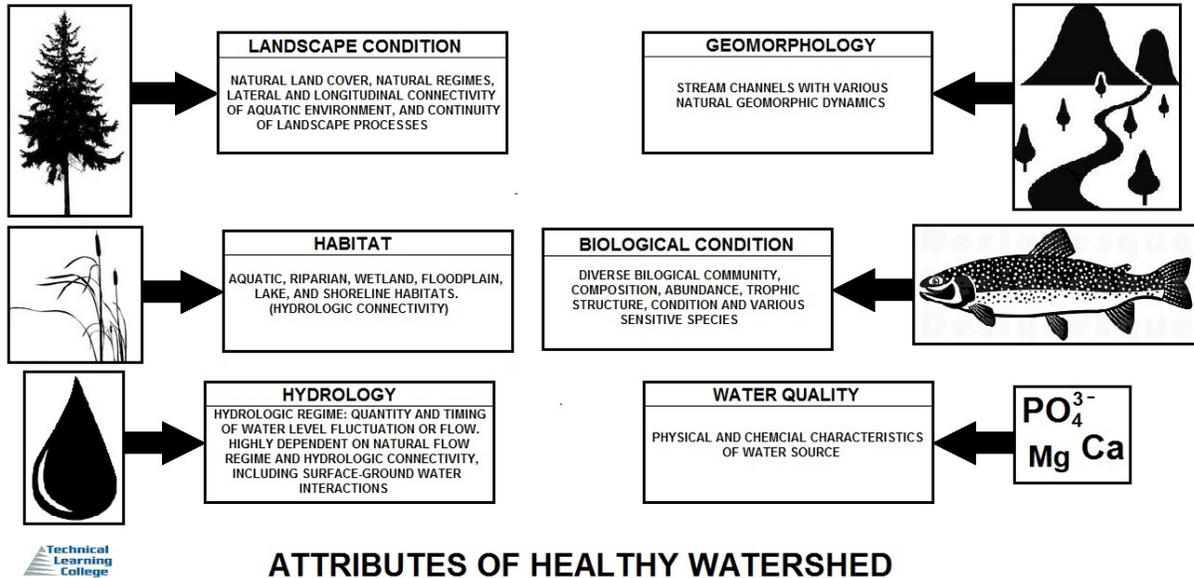


**RAW WATER TURBIDITY MONITORING**



## 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.



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.

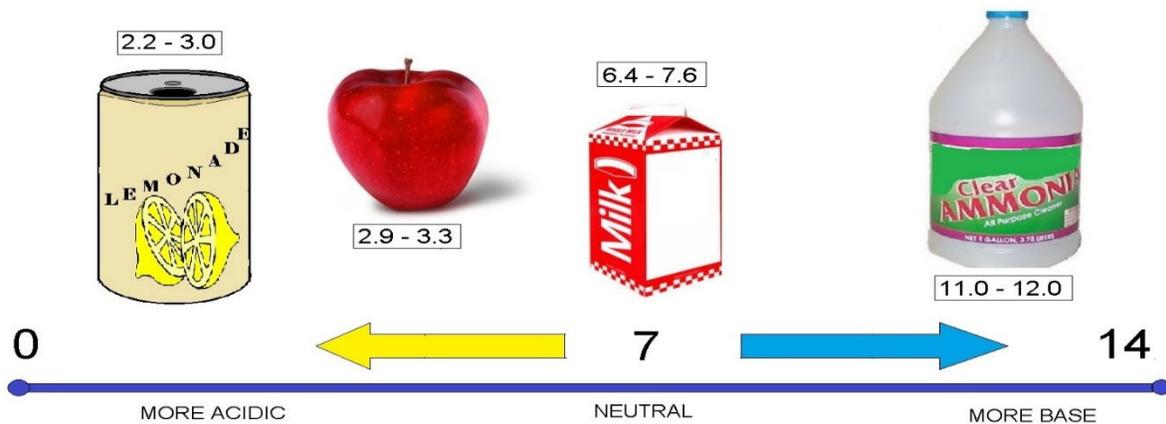
**Salinity** measures water density or conductivity changes caused by dissolved materials.

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**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

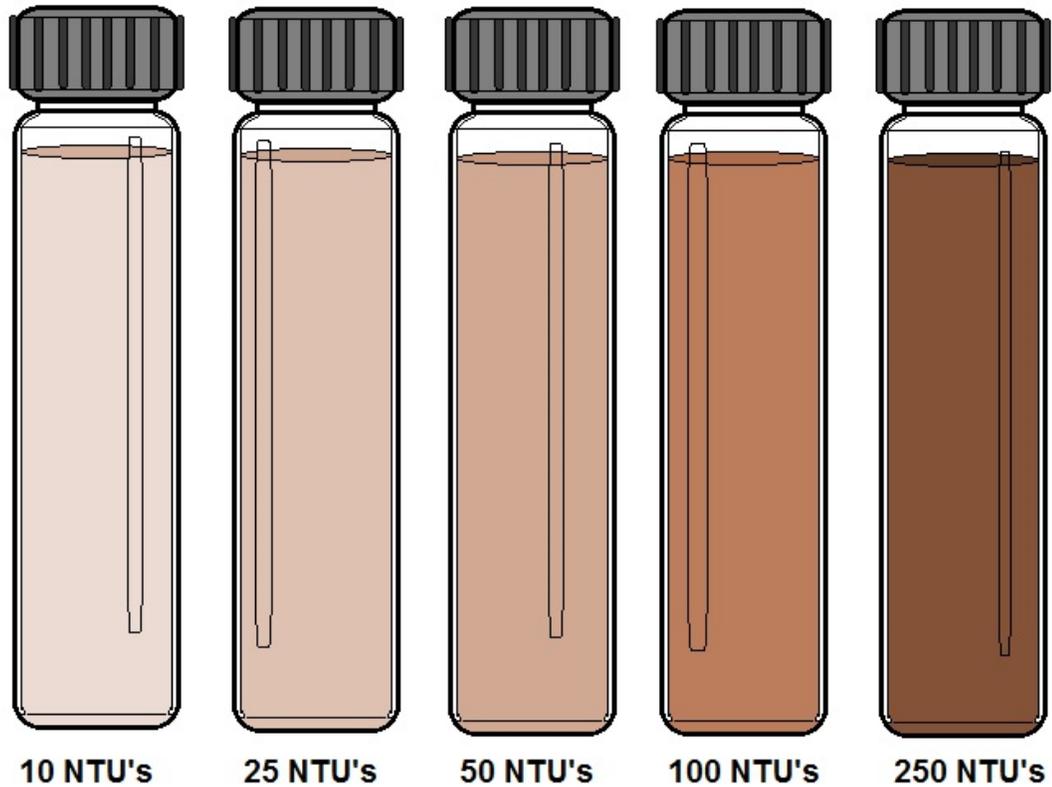
### Alkalinity

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 (Nephelometric 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.

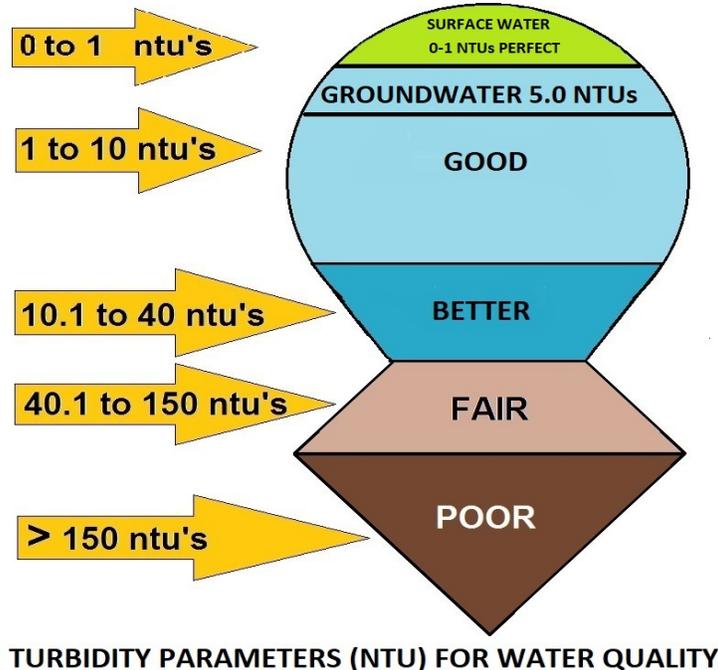
Generally, higher turbidity levels require higher coagulant dosages. However, seldom is the relationship between turbidity level and coagulant dosage linear. Usually, the additional coagulant required is relatively small when turbidities are much higher than normal due to higher collision probabilities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

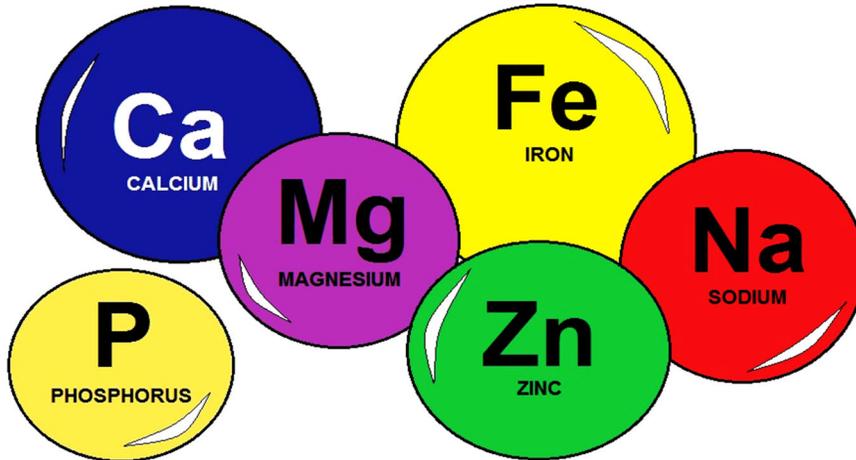


**Surface Water System Compliance Information**  
*(Depends on Systems and Rule)*

- ▶ 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



**EXAMPLES OF TDS**  
(Total Dissolved Solids)  
FOUND IN WATER SOURCES

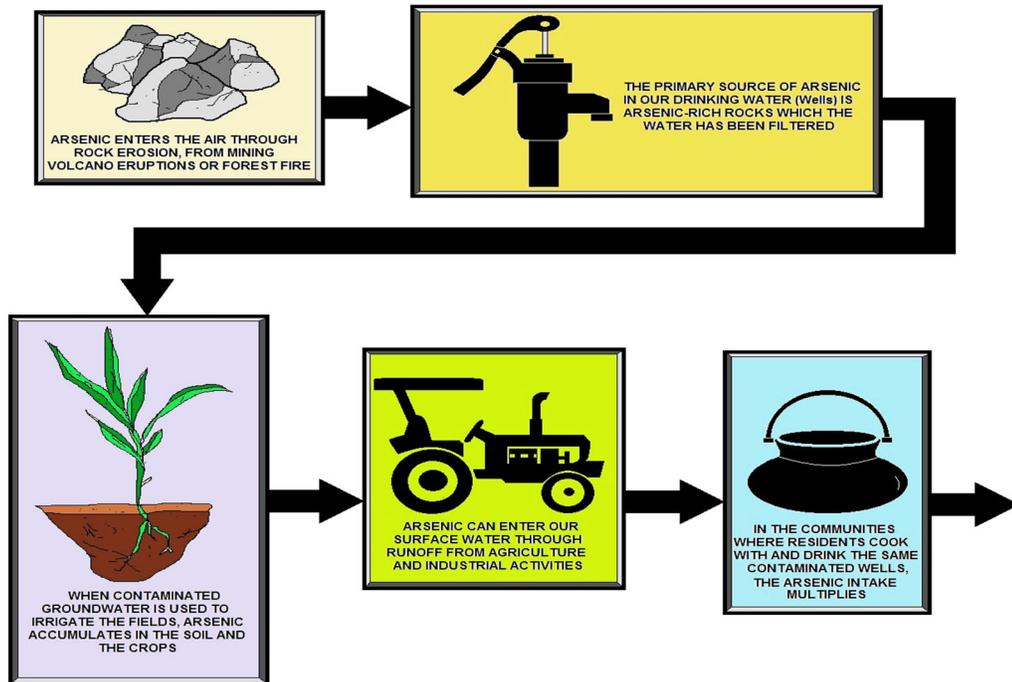
CAN BE FROM AGRICULTURE OR URBAN RUNOFF, WHICH CARRY EXCESS MINERALS INTO THE WATER SOURCE

MINERAL SPRINGS CONTAIN HIGH LEVELS OF TDS BECAUSE THE ROCKS WHICH THE WATER SOURCE FLOWS THROUGH HAVE A HIGH SALT CONTENT

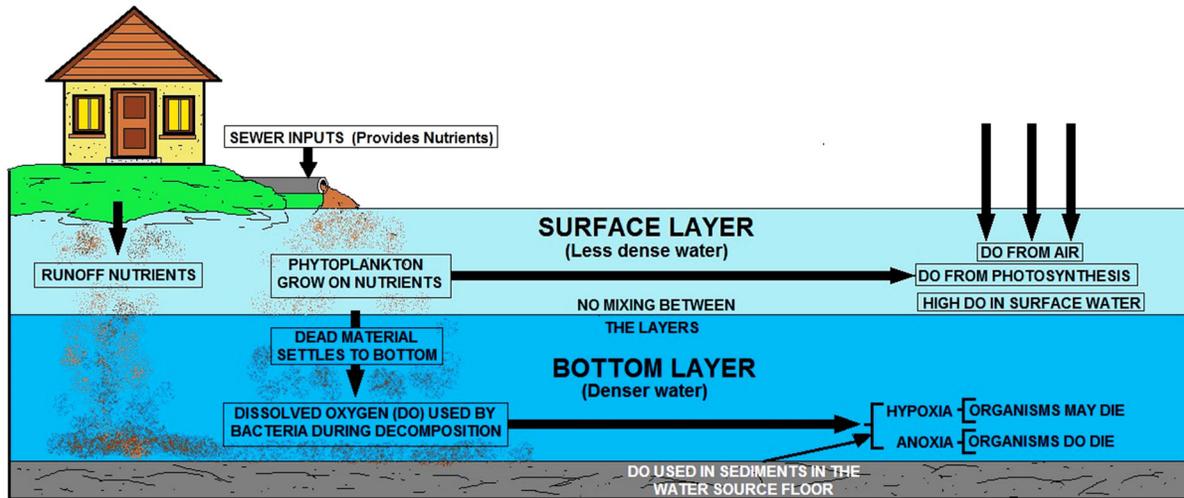


### MINERALS THAT AFFECT THE QUALITY OF WATER SOURCE

**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.



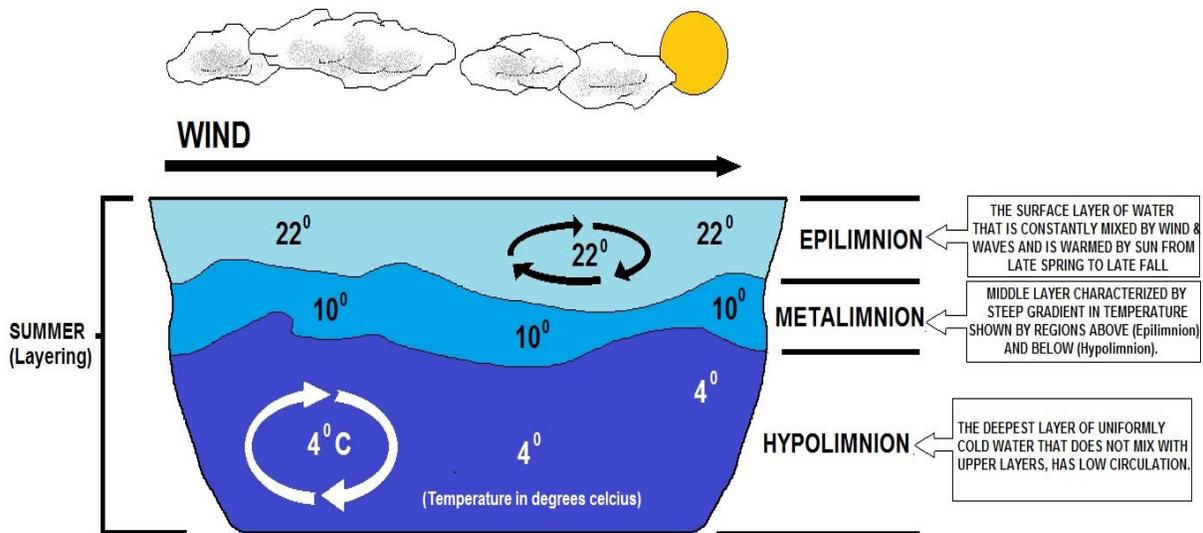
### ARSENIC IN DRINKING WATER



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

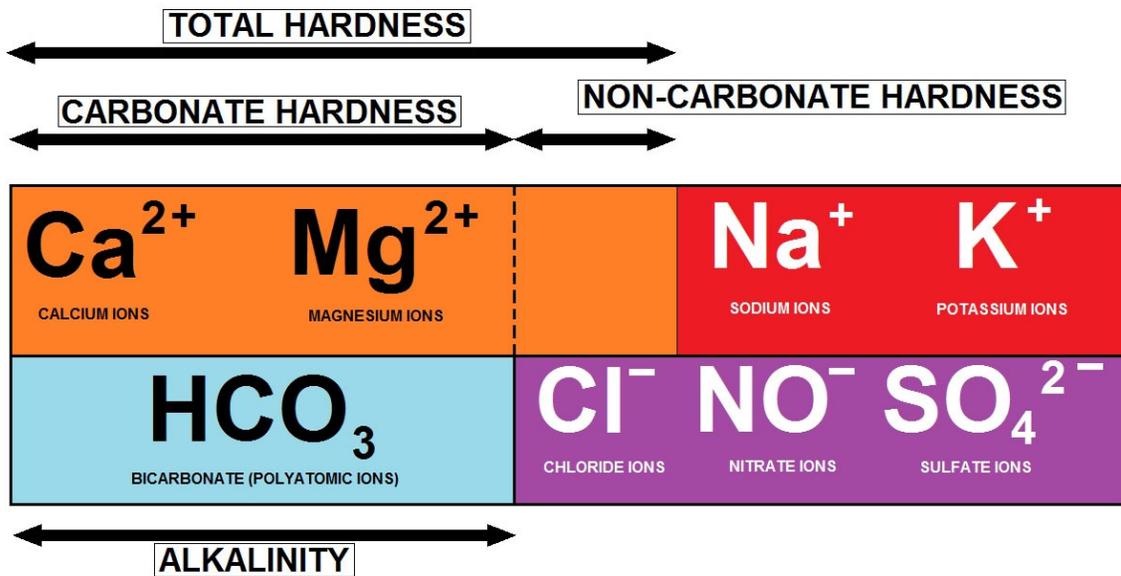
## Temporary and Permanent

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 <sub>3</sub> )	CALCIUM SULPHATE (CaSO <sub>4</sub> )
MAGNESIUM CARBONATE (MgCO <sub>3</sub> )	MAGNESIUM SULPHATE (MgSO <sub>4</sub> )
CALCIUM BICARBONATE (Ca(HCO <sub>3</sub> ) <sub>2</sub> )	CALCIUM CHLORIDE (CaCl <sub>2</sub> )
MAGNESIUM BICARBONATE (Mg(HCO <sub>3</sub> ) <sub>2</sub> )	MAGNESIUM CHLORIDE (MgCl <sub>2</sub> )
CALCIUM HYDROXIDE (Ca(OH) <sub>2</sub> )	
MAGNESIUM HYDROXIDE (Mg(OH) <sub>2</sub> )	



### CAUSES OF HARDNESS THAT AFFECTS WATER QUALITY

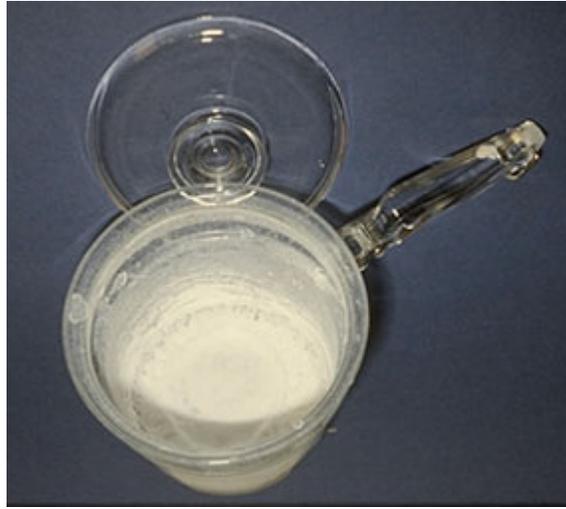


### CARBONATE HARDNESS CHART

## 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  $\text{CaCO}_3$ ), 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)

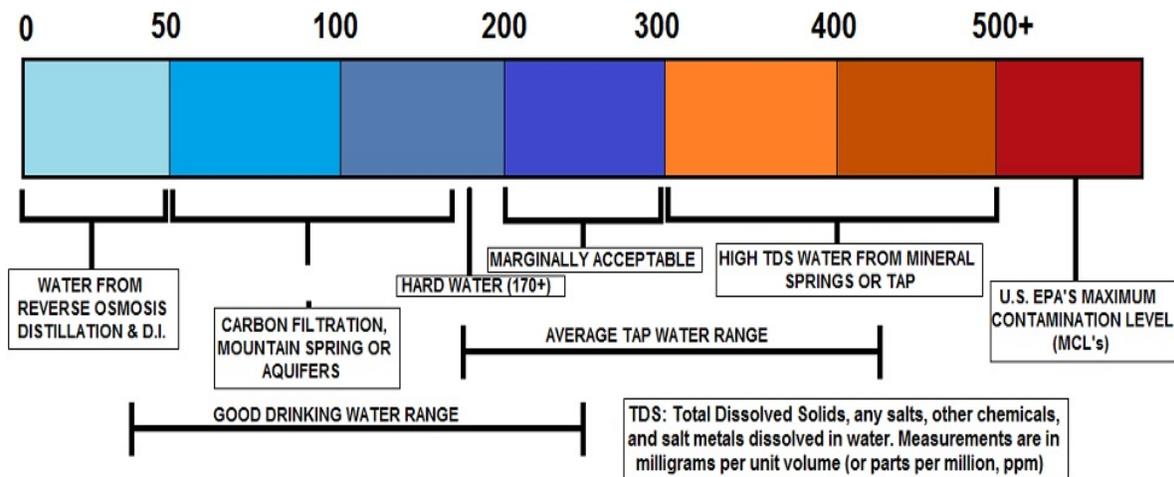
Total dissolved solids (TDS) represents the combined total of all organic and inorganic substances found in drinking water. The total dissolved solids present in water is one of the leading causes of particles and sediments in drinking water, which give water its color, odor, and flavor, and can be a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



## TDS (Total Dissolved Solids) Explained

### 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.

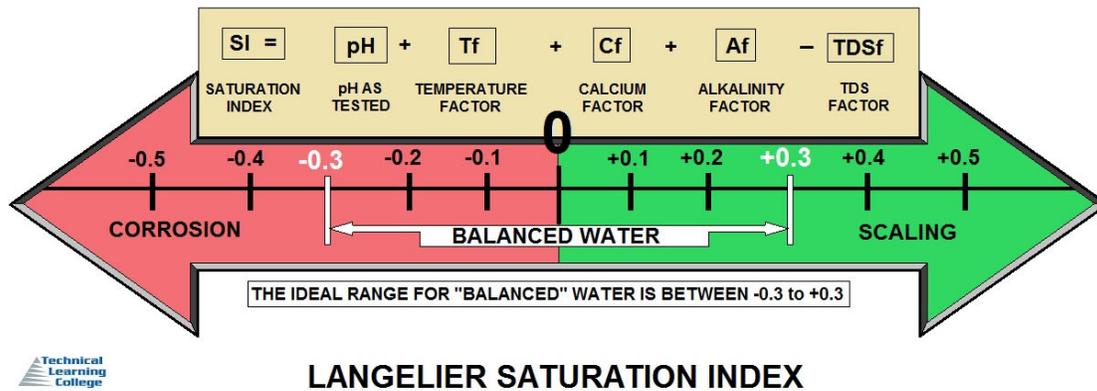
PARAMETERS	CLARITY	TURBIDITY	TOTAL SUSPENDED SOLIDS (TSS)
<b>DEFINITION</b>	HOW FAR LIGHT CAN PASS THROUGH THE WATER COLUMN	MEASURES THE DEGREE TO WHICH WATER LOSES IT'S TRANSPARENCY	PARTICLES THAT ARE LARGER THAN 2 MICRONS FOUND IN THE WATER COLUMN
<b>COMMENTS</b>	TURBIDITY AND CLARITY ARE DIRECTLY 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
<b>WHAT IS MEASURED?</b>	ORGANIC AND INORGANIC SUSPENDED SOLIDS, LIKE CLAY, SILT, SEDIMENT, ALGAE AND BATERIA + DISSOLVED COLORED MATERIALS (Smaller than 2 Microns)		ORGANIC AND INORGANIC SUSPENDED SOLIDS SETTLABLE SOLIDS (Solids that are moved along the bottom of water by strong flow)
<b>HOW IS IT MEASURED?</b>	<u>DIRECT MEASUREMENT:</u> TURBIDIMETER or TURBIDITY SENSOR <u>INDIRECT MEASUREMENT:</u> 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

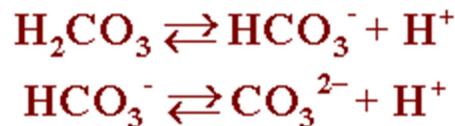


## Langelier Saturation Index

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.



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  $\text{CO}_3^{2-}$  decreases as the pH decreases, according to the equilibria describing the dissociation of carbonic acid:



- If LSI is negative: No potential to scale, the water will dissolve  $\text{CaCO}_3$
- If LSI is positive: Scale can form and  $\text{CaCO}_3$  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  $\text{CaCO}_3$ ), the calcium hardness (mg/l  $\text{Ca}^{2+}$  as  $\text{CaCO}_3$ ), the total dissolved solids (mg/l TDS), the actual pH, and the temperature of the water ( $^{\circ}\text{C}$ ).

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

$$\text{LSI} = \text{pH} - \text{pH}_s$$

Where:

**pH** is the measured water pH

**pH<sub>s</sub>** is the pH at saturation in calcite or calcium carbonate and is defined as:

$$\text{pH}_s = (9.3 + \text{A} + \text{B}) - (\text{C} + \text{D})$$

Where:

$$\text{A} = (\text{Log}_{10} [\text{TDS}] - 1) / 10$$

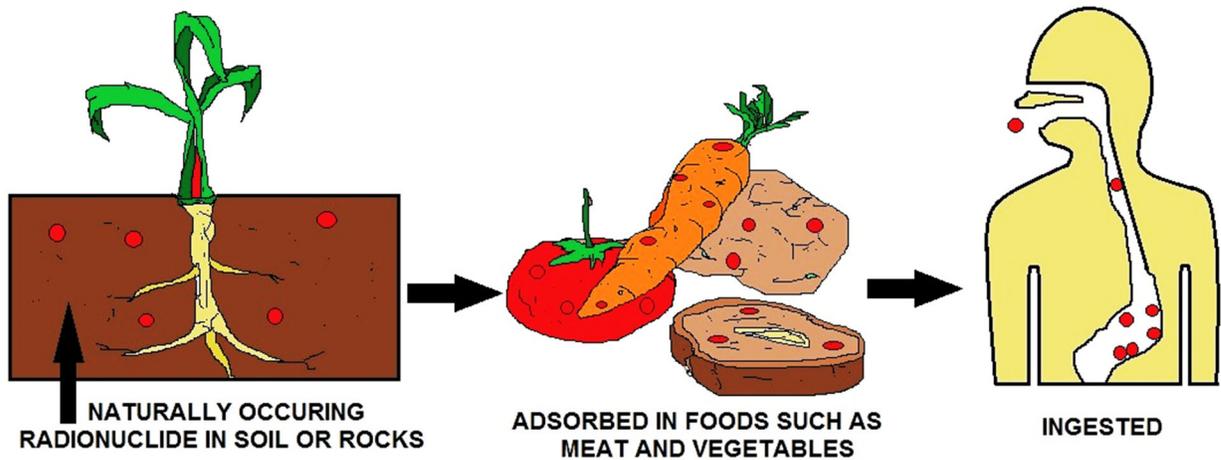
$$\text{B} = -13.12 \times \text{Log}_{10} (^\circ\text{C} + 273) + 34.55$$

$$\text{C} = \text{Log}_{10} [\text{Ca}^{2+} \text{ as CaCO}_3] - 0.4$$

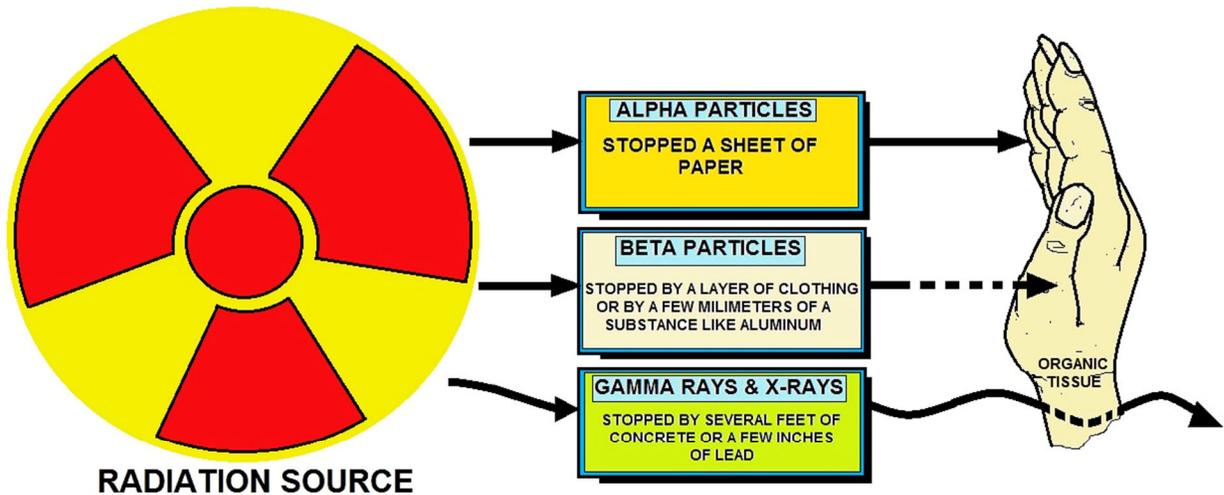
$$\text{D} = \text{Log}_{10} [\text{alkalinity as CaCO}_3]$$

## Radiological Characteristics

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

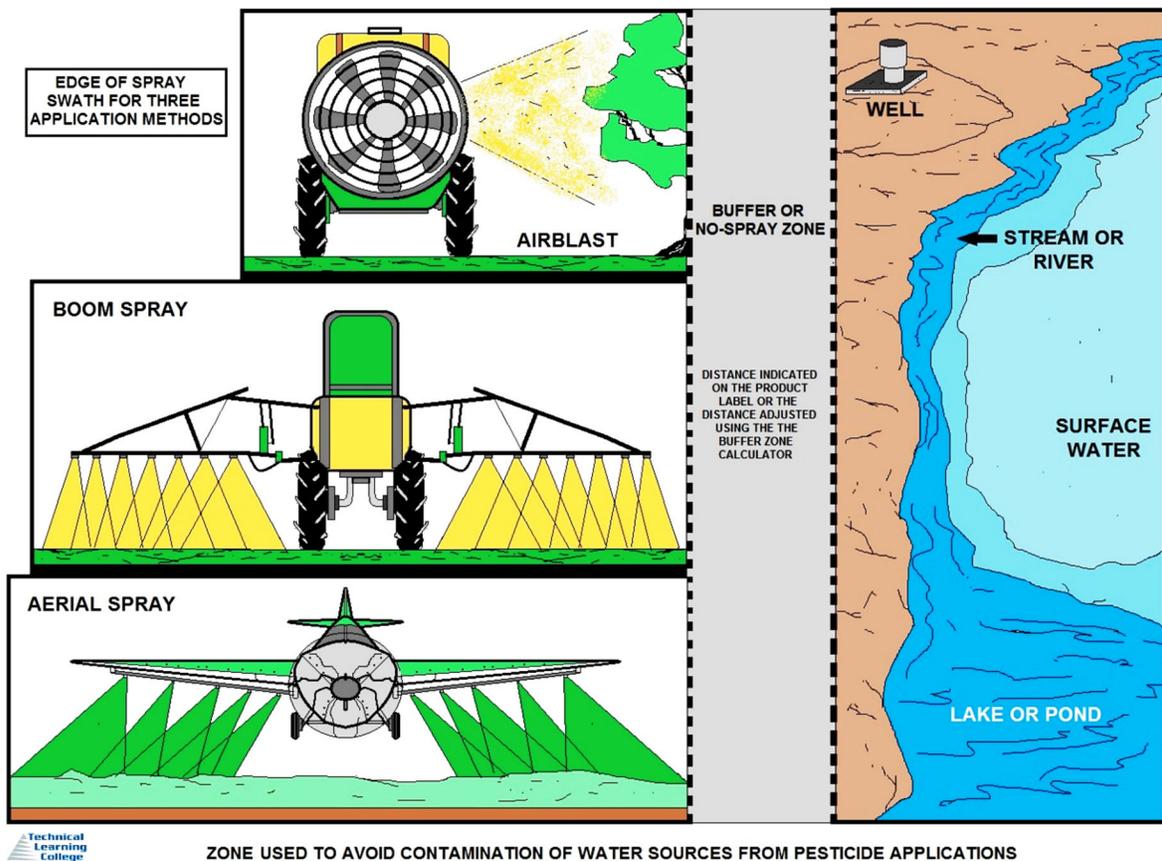


## RADIONUCLIDES



## 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

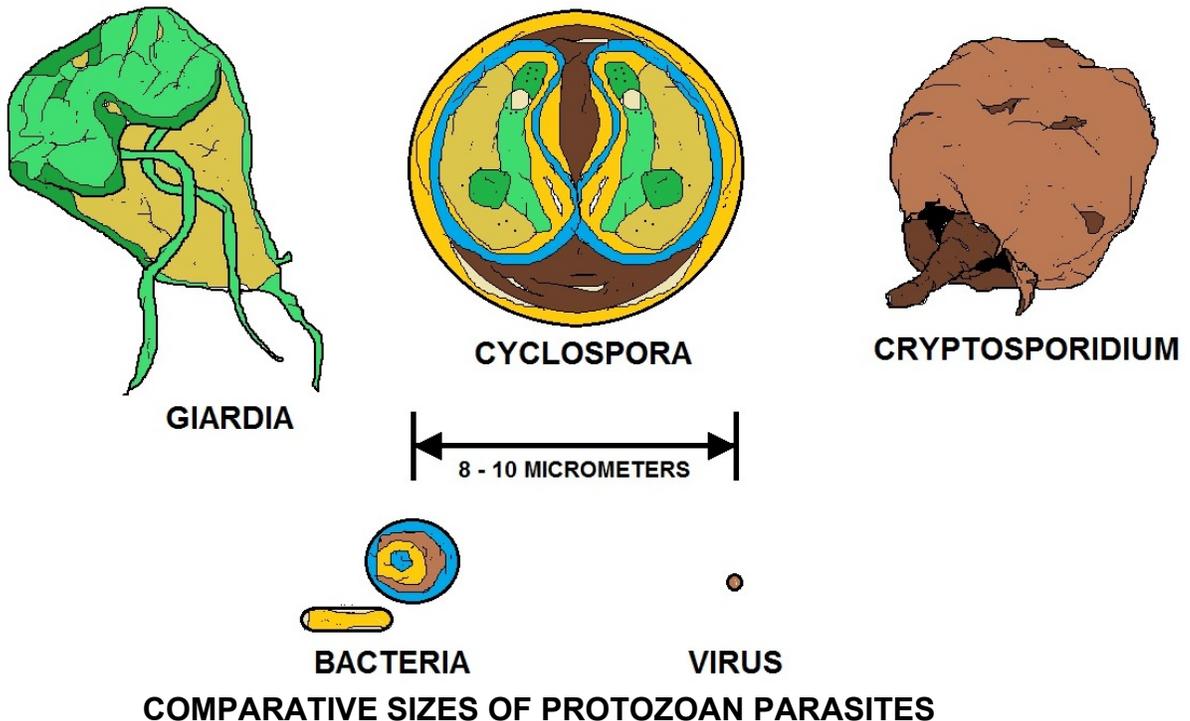
Biological characteristics are the presence of living or dead organisms. Biological characteristics will also interact with the chemical composition of the water. The consumer will become sick or complain about hydrogen sulfide odors, the rotten egg smell. We will cover the Total Coliform Rule in detail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



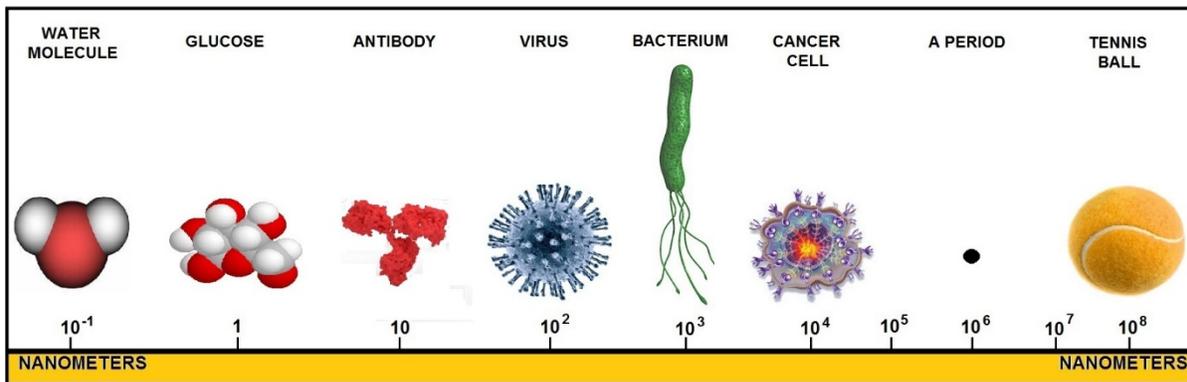
### Bacteriological Aspects of Water Pollution

- 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.



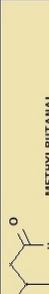
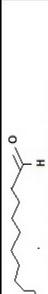
**SIZE COMPARISON**  
HOW SMALL IS SMALL ?

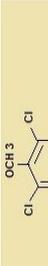
PRESENCE OF PATHOGENS IN WATER	TYPES OF PATHOGENS FOUND IN WATER
THE PRESENCE OF COLIFORM BACTERIA CAN INDICATE THERE MAY BE HARMFUL BACTERIA PATHOGENS IN THE WATER	
THE PRINCIPAL REMOVAL PROCESSES ARE THOSE LIKELY USED TO REMOVE THE MAJORITY OF THE MICROBES IN WATER BEING TREATED	
THE REMOVAL PROCESSES 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.	

**PATHOGENS FOUND IN WATER SUPPLIES**

# 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.

CHEMICAL / HYDROCARBON / MISC.		MEDICINAL / PHENOLIC	FISHY / RANCID	FRAGRANT / FRUITY / FLOWERY		MARSHY / SWAMPY / SEPTIC / SULFUROUS		GRASSY / HAY / STRAW / WOODY						
LICORICE	SWEET SOLVENT	SWEET (TUTTL-FRUITT)	MEDICINAL	RANCID / SWEATY SOCKS	FISHY	SWEET / BUTTERY	CUCUMBER	VIOLET	MARSHY / SWAMPY / GARLICKY	DECAYING VEGETABLES	CANNED CORN	DECAYING CABBAGE	GRASSY	HAY / WOODY
			<b>CHLOROPHENOLS, BROMOPHENOLS</b>						<b>DIMETHYL TRISULFIDE</b>	<b>DIMETHYL SULFIDE (high - conc.)</b>	<b>DIMETHYL SULFIDE (low - conc.)</b>	<b>METHYL MERCAPTAN</b>		

CHLORINOUS / OZONOUS		EARTHY / MUSTY			MOUTHFEEL / NOSEFEEL		BITTER	SALTY	SWEET	SOUR / ACIDIC	
CHLORINOUS	SWIMMING POOL	MUSTY	MOLDY CORK	EARTHY	COOLING	CHALKY	ASTRINGENT	BITTER	SALTY	SWEET	SOUR / ACIDIC
<b>FREE CHLORINE</b>	<b>DICHLORAMINE</b>				<b>MENTHOL</b>	<b>CALCIUM CARBONATE</b>	<b>ALUMINIUM SULFATE</b>	<b>CAFFEINE, QUININE HYDROCHLORIDE</b>	<b>SODIUM CHLORIDE</b>	<b>SUGAR, LEAD SALTS</b>	<b>CITRIC ACID, MAGNESIUM SULFATE</b>



## WATER AND TASTE DECODER

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.

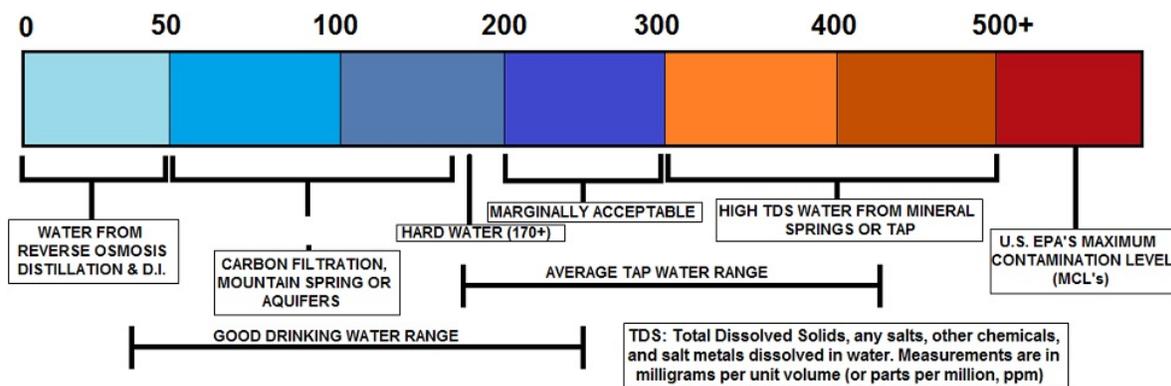
## EPA Guidelines for Nuisance Constituents

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.



## TDS (Total Dissolved Solids) Explained

## 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**

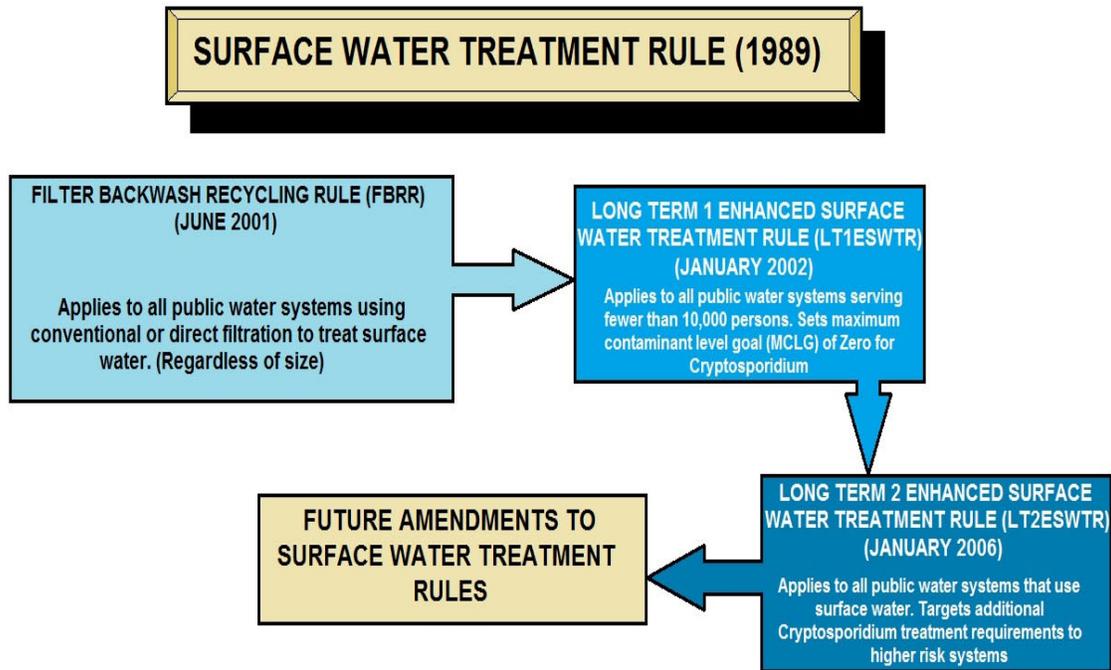
***The following safety procedures shall be maintained:***

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.



## SURFACE WATER TREATMENT RULES

### 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)**

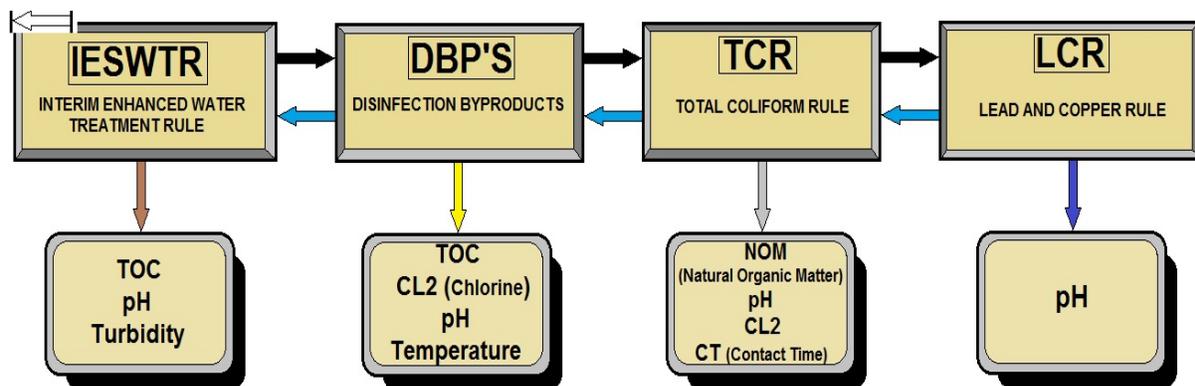
- Provide water to the same population year-round (for example: homes, apartment buildings)
- Approximately 52,000 systems serving the majority of the U.S. population

**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



**PARAMETERS THAT AFFECT SURFACE WATER TREATMENT RULES**



## 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.

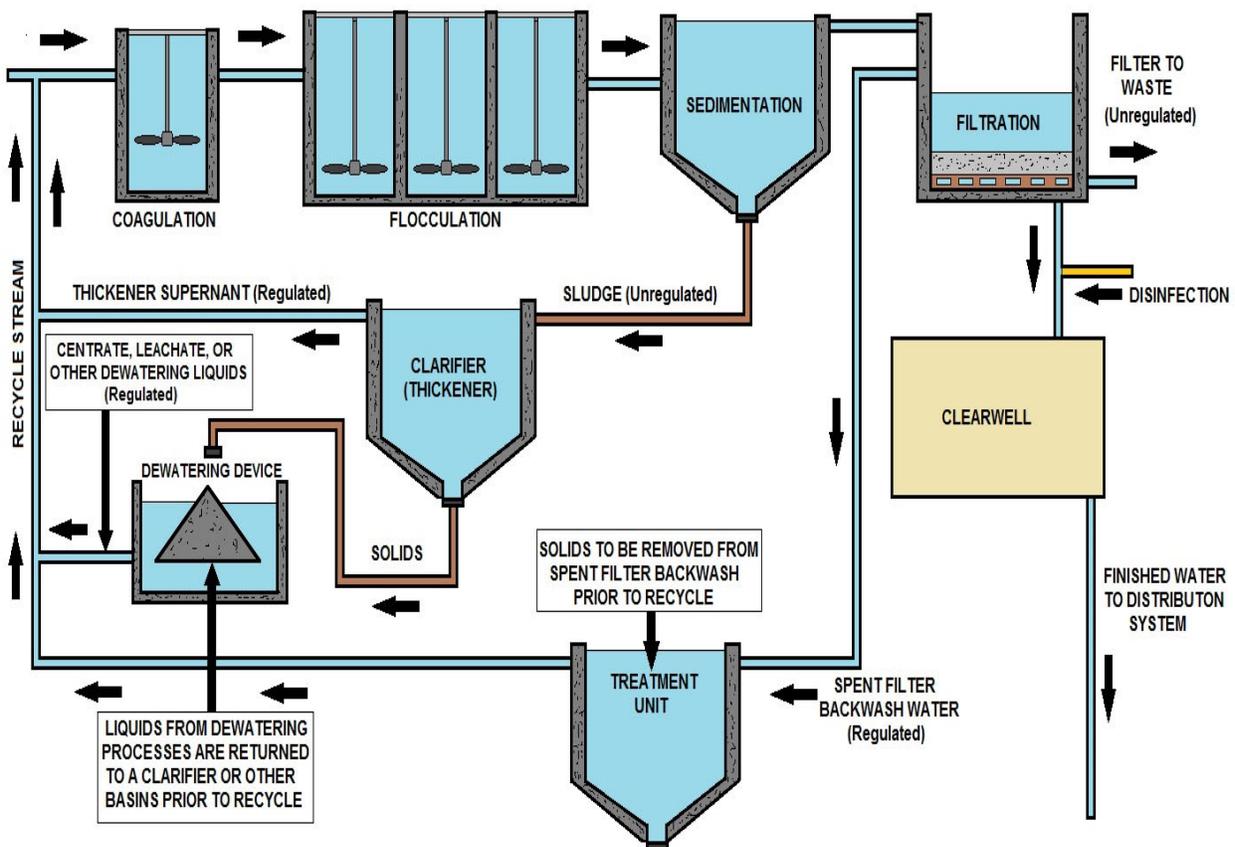
## Synthetic Organic Contaminants, including Pesticides & Herbicides

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

## Other Related EPA Water Treatment Rules



## FILTER BACKWASHED RECYCLING

### 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.

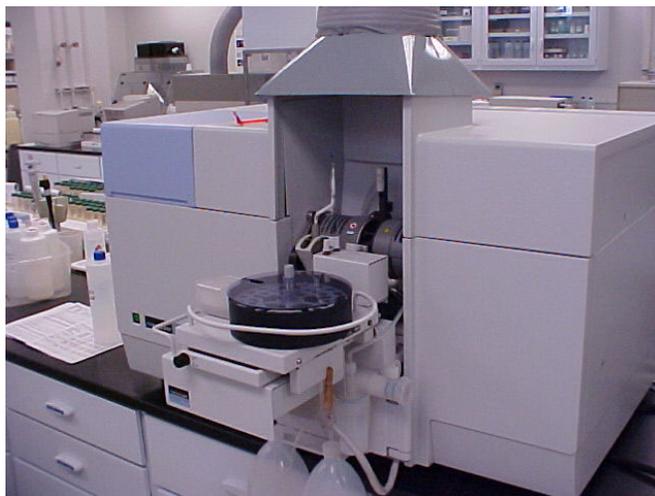
After adopting 10 ppb as the new standard for arsenic in drinking water, the EPA decided to review the decision to ensure that the final standard was based on sound science and accurate estimates of costs and benefits. In October 2001, the EPA decided to move forward with implementing the 10 ppb standard 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](http://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 ( $\text{CaCO}_3$ ). 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 ( $\text{Fe}^{+2}$ ) is in a dissolved state, and water containing ferrous iron is colorless. Ferric iron ( $\text{Fe}^{+3}$ ) 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.

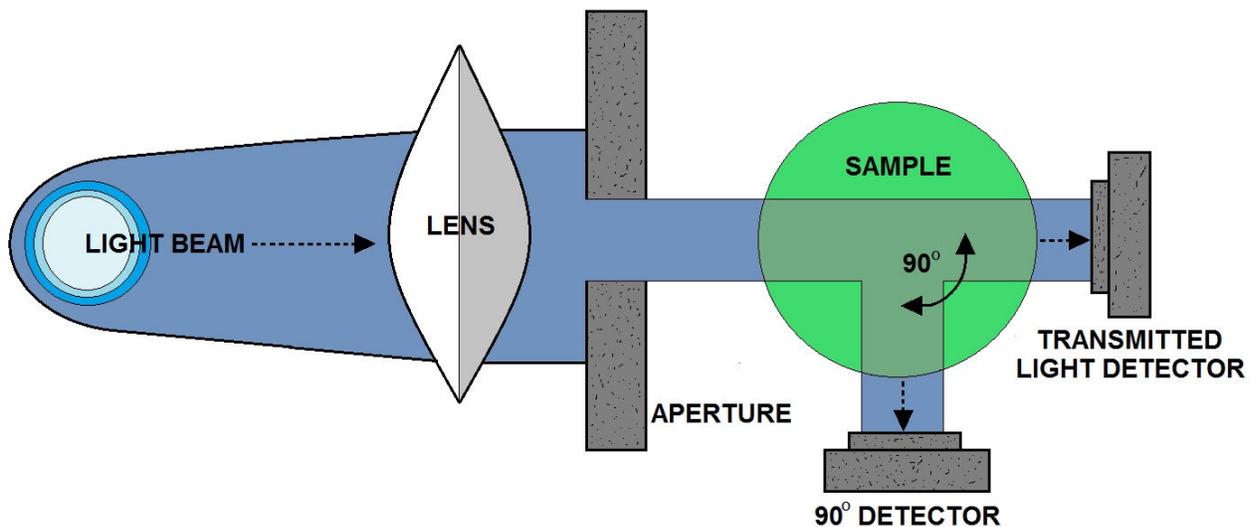
### Manganese

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.

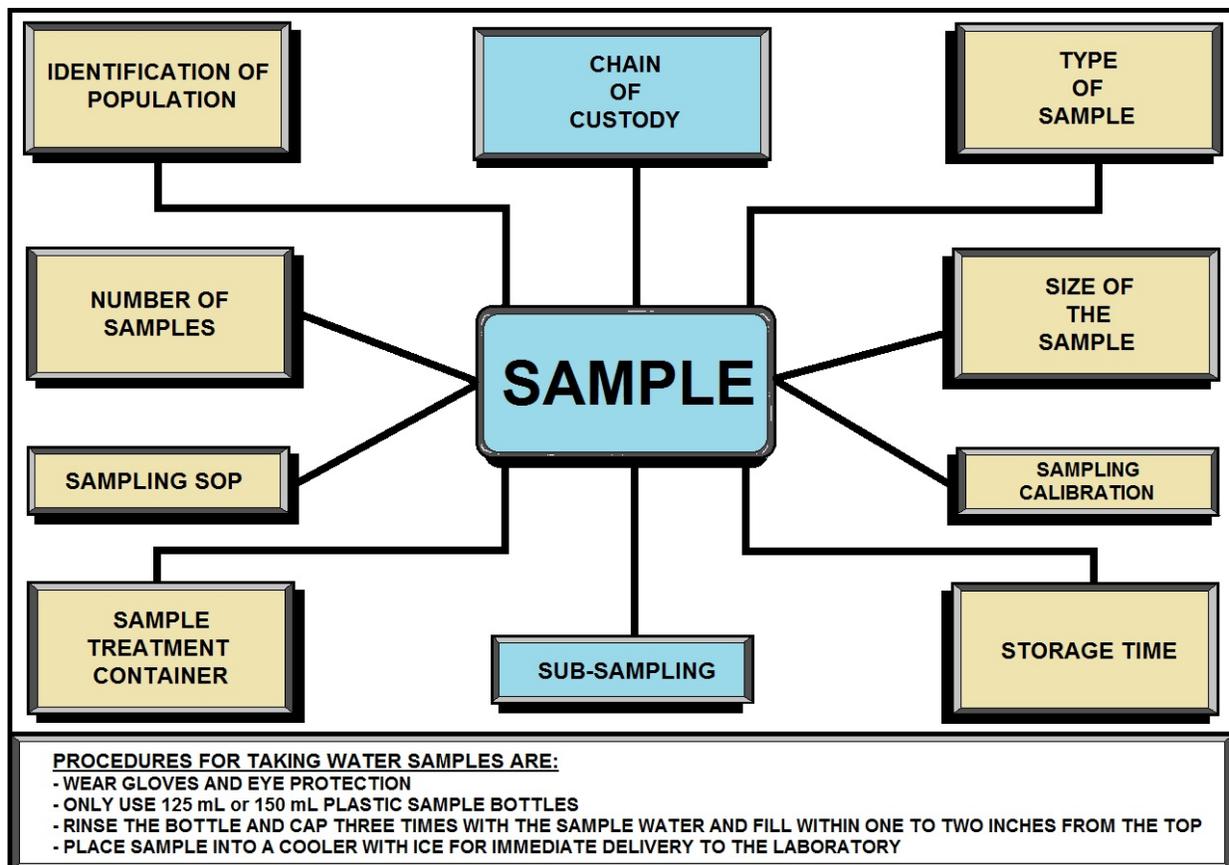


## Sampling Plan Introduction

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
<b>INORGANIC CHEMICALS - Metals</b>			
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
<b>INORGANIC CHEMICALS - Other, and Physical Factors</b>			
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
<b>ORGANIC CHEMICALS - Trihalomethanes:</b>			
T THMS	0.080	0.004	ND

**WATER ANALYSIS REPORT EXAMPLE**

## Older Stage 1 DBPR Information

### Disinfection Byproduct Regulations

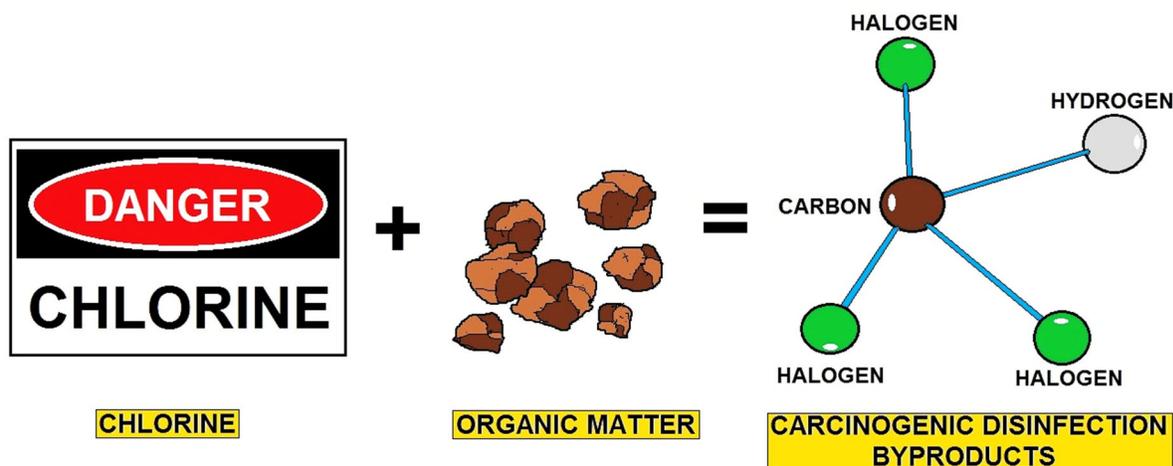
In December 1998, the EPA established the Stage 1 Disinfectants/Disinfection Byproducts Rule that requires public water systems to use treatment measures to reduce the formation of disinfection byproducts and to meet the following specific standards:

**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



### 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](mailto: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:

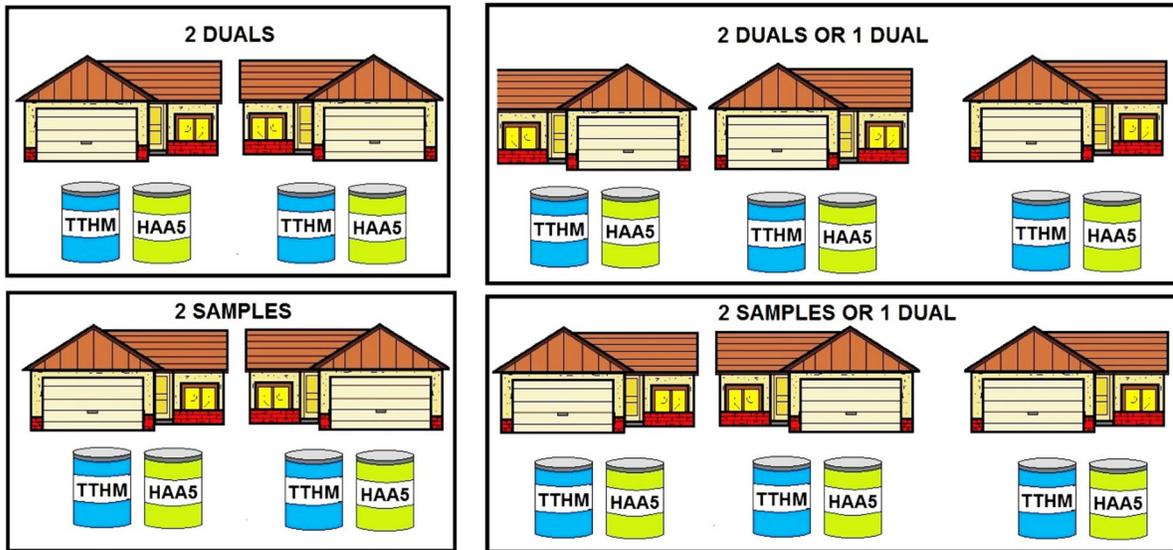
- Subpart H systems that serve fewer than 500 people.
- Subpart H systems that serve 500 to 3,300 people.
- Subpart H systems that serve 3,301 to 9,999 people.
- Ground water systems that serve fewer than 500 people.
- Ground water systems that serve 500 to 9,999 people.

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

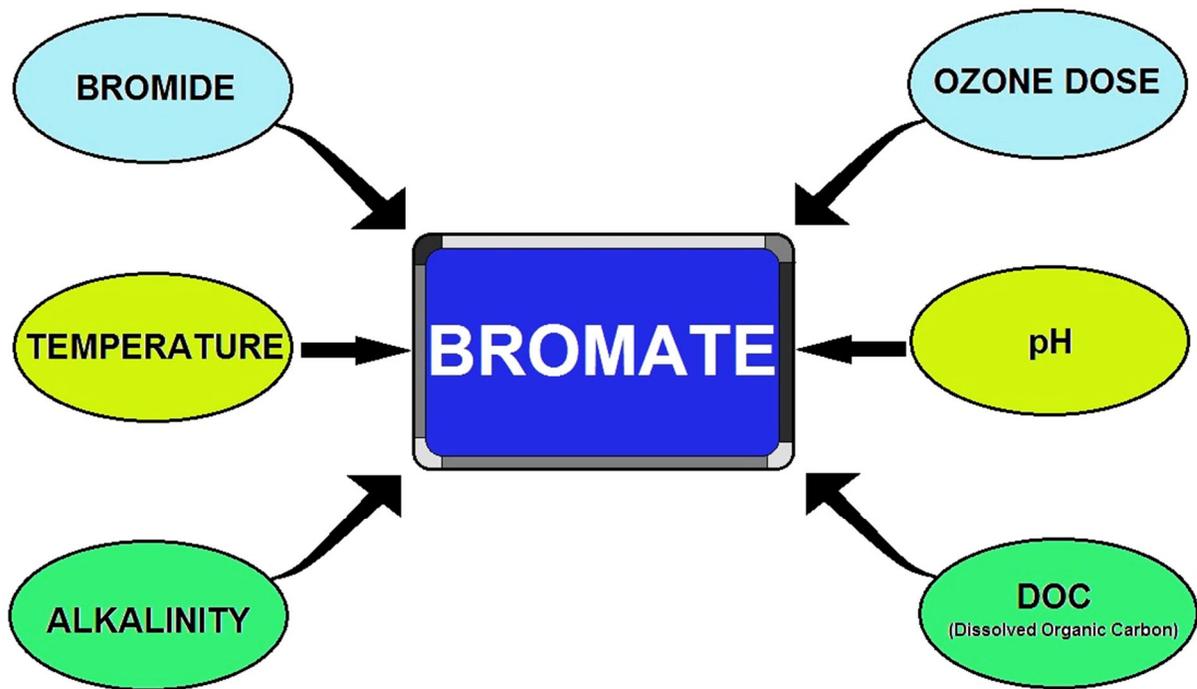
<b>DISINFECTANTS AND DISINFECTION BYPRODUCTS RULE</b>			
<b>DISINFECTION RESIDUAL</b>	<b>MRDLG (mg/L)</b>	<b>MRDL (mg/L)</b>	<b>COMPLIANCE BASED ON:</b>
<b>CHLORINE</b>	<b>4 (as Cl<sub>2</sub>)</b>	<b>4.0 (as Cl<sub>2</sub>)</b>	<b>ANNUAL AVERAGE</b>
<b>CHLORAMINE</b>	<b>4 (as Cl<sub>2</sub>)</b>	<b>4.0 (as Cl<sub>2</sub>)</b>	<b>ANNUAL AVERAGE</b>
<b>CHLORINE DIOXIDE</b>	<b>0.8 (as ClO<sub>2</sub>)</b>	<b>0.8 (as ClO<sub>2</sub>)</b>	<b>ANNUAL AVERAGE</b>
<b>DISINFECTION BYPRODUCTS</b>	<b>MCLG (mg/L)</b>	<b>MCL (mg/L)</b>	<b>COMPLIANCE BASED ON:</b>
<b>TOTAL TRIHALOMETHANES (TTHM)<sup>1</sup></b>	<b>N/A</b>	<b>0.080</b>	<b>ANNUAL AVERAGE</b>
- CHLOROFORM	***		
- BROMODICHLOROMETHANE	0		
- DIBROMOCHLOROMETHANE	0.06		
- BROMOFORM	0		
<b>HALOACETIC ACIDS (five) (HAA5)<sup>2</sup></b>	<b>N/A</b>	<b>0.60</b>	<b>ANNUAL AVERAGE</b>
- DICHLOROACETIC ACID	0		
- TRICHLOROACETIC ACID	0.3		
<b>CHLORITE</b>	<b>0.8</b>	<b>1.0</b>	<b>MONTHLY AVERAGE</b>
<b>BROMATE</b>	<b>0</b>	<b>0.010</b>	<b>ANNUAL AVERAGE</b>

**DISINFECTION BYPRODUCTS RULE PARAMETERS EXAMPLE**





**STAGE 2 DISINFECTION BYPRODUCT RULE  
REPEAT (TRIGGERED) SAMPLING DIAGRAM**



**BROMATE FORMATION FACTORS**

## **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) chlorine 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 (mg/L)	MCL <sup>2</sup> c TT <sup>3</sup> (mg/L)	Potential Health Effects from Ingestion of Water	Sources of Contamination in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood glucose	Discharge from petroleum refineries; fire retardants; ceramic electronics; solder
Arsenic	none <sup>5</sup>	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 <sup>6</sup>	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 <sup>9</sup>	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

**PRIMARY DRINKING WATER REGULATIONS ARE LEGALLY ENFORCEABLE PRIMARY STANDARD AND TREATMENT TECHNIQUES THAT APPLY TO PUBLIC WATER SYSTEMS.**

**PRIMARY STANDARDS AND TREATMENT TECHNIQUES PROTECT PUBLIC HEALTH BY LIMITING THE LEVEL OF CONTAMINANTS IN DRINKING WATER.**

**EXAMPLES OF CONTAMINANTS INCLUDE:**

- Microorganisms
- Disinfectants
- Disinfection Byproducts (DBPs)
- Inorganic Chemicals
- Organic Chemicals
- Radionuclides

The diagram shows a cross-section of a water pipe. Six callout circles point to different contaminants: Radionuclides (top left), Disinfection Byproducts (top middle), Microbes (top right), VOCs (bottom left), Arsenic (bottom middle), and Disinfectants (bottom right, shown as a bottle of chlorine tablets).

## PRIMARY DRINKING WATER REGULATIONS / STANDARDS



Organic Chemicals	MCLG (mg/L)	MCL <sup>2</sup> <sub>c</sub> TT <sup>3</sup> (mg/L)	Potential Health Effect: from Ingestion of Water	Sources of Contaminant Drinking Water
Acrylamide	zero	TT <sup>2</sup>	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	0.005	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	Discharge 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-TCDF)	zero	0.0000001	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 <sup>2</sup>	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
Ethylene 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
Hexachlorocyclopentene	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 <sup>5</sup>	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
<b>Radionuclides</b>	<b>MCLG<sup>2</sup> (mg/L)</b>	<b>MCL<sup>2</sup> c TT<sup>3</sup> (mg/L)</b>	<b>Potential Health Effects from Ingestion of Water</b>	<b>Sources of Contaminant Drinking Water</b>
Beta particles and photon emitters	none <sup>5</sup>	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits
Gross alpha particle activity	none <sup>5</sup>	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits
Radium 226 and Radium 228 (combined)	none <sup>5</sup>	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
<b>Microorganisms</b>	<b>MCLG<sup>2</sup> (mg/L)</b>	<b>MCL<sup>2</sup> c TT<sup>3</sup> (mg/L)</b>	<b>Potential Health Effects from Ingestion of Water</b>	<b>Sources of Contaminant Drinking Water</b>
<i>Giardia lamblia</i>	zero	TT <sup>8</sup>	Giardiasis, a gastroenteric disease	Human and animal fecal waste
Heterotrophic plate count	N/A	TT <sup>8</sup>	HPC has no health effects, but can indicate how effective treatment is at controlling microorganisms.	n/a
<i>Legionella</i>	zero	TT <sup>8</sup>	Legionnaire's Disease, commonly known as pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliforms and <i>E. Coli</i> )	zero	5.0% <sup>9</sup>	Used as an indicator that other potentially harmful bacteria may be present <sup>10</sup>	Human and animal fecal waste
Turbidity	N/A	TT <sup>8</sup>	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 <sup>8</sup>	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

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## Notes

<sup>1</sup> 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 of persons would occur, and which allows for an proper margin of safety. MCLGs are not enforceable public health goals.

<sup>2</sup> 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 do not pose significant risk to public health.

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

<sup>4</sup> Units are in milligrams per Liter (mg/L) unless otherwise noted.

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

<sup>6</sup> 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 mg/L, and for lead is 0.015mg/L.

<sup>7</sup> Each water system must certify, in writing, to the state (using third-party or manufacturer 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 level specified, as follows:

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

<sup>8</sup> 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 nephelometric turbidity units (NTU); systems that filter must ensure that their 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.

<sup>9</sup> 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.

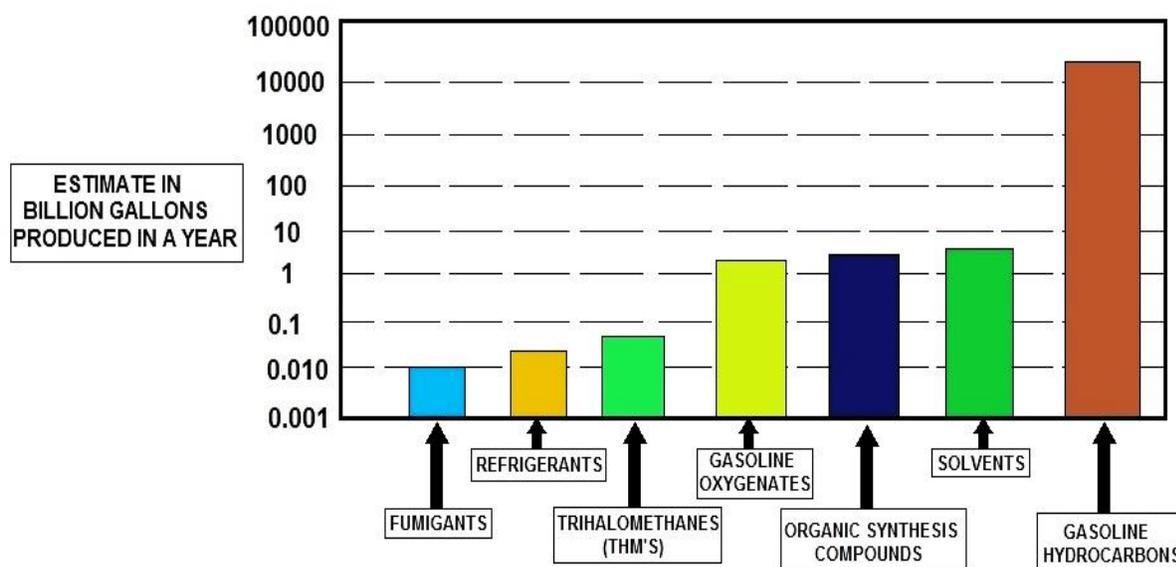
<sup>10</sup> Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms.

## 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 sites*

*(no. of persons served) (standard monitoring) (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**

<i>System size # (no. of persons served)</i>	<i>no. of sites for water quality parameters</i>
<u>&gt;100,000</u>	<u>25</u>
<u>10,001-100,000</u>	<u>10</u>
<u>3,301 to 10,000</u>	<u>3</u>
<u>501 to 3,300</u>	<u>2</u>
<u>101 to 500</u>	<u>1</u>
<u>&lt;100</u>	<u>1</u>

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,  $\text{NH}_4$  and  $\text{NO}_x$  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  $1.5 < \text{pH} < 2$  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.



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

### **WATER QUALITY REPORT INCLUDING UNITS OF MEASUREMENT**

<b>FINISHED WATER REPORTING INFO</b>	<b>UNITS OF MEASUREMENT</b>
FINISHED 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 <sub>3</sub> 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

<u>ANALYSIS</u>	<u>METHOD</u>	<u>HOLDING TIME</u>
<b>Inorganic Compounds (IOC)</b> 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
<b>Primary Pollutants (Short IOC)</b> Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver, Sodium, Thallium, Turbidity, Fluoride, Cyanide, Nitrate, and Nitrite.	(various)	48 hours
<b>Municipal Testing</b>		
<b>Lead and Copper</b>	EPA 200.9 for Pb EPA 200.7 for Cu	14 days
<b>Public or Individual Water Source Testing</b>		
<b>Nitrate</b>	SM-4500 NO3 D	48 hours
<b>Total Coliform &amp; E. Coli</b>	SM-9223 B	30 Hours
<b>Metals Analysis on Drinking Water (per element)</b>		
<b>GFAA</b>  (As, Pb, Sb, Se, Tl)	EPA 200.9	6 months
<b>ICP (Ag, Al, B, Ba, Be, Cd, Cr, Cu, Fe, Mn, Mo, Na, Ni, Zn)</b>	EPA 200.7	6 months
<b>CVAA (Hg)</b>	EPA 245.1	6 months
<b>Primary Pollutant Metals</b>	GFAA/ICP/CVAA	6 months
<b><u>Drinking Water Analysis</u></b>		
<b>PH</b>	EPA 150.1	
<b>Acidity</b>	SM-2310 B (4b)	14 days
<b>Alkalinity (Bicarbonate &amp; Carbonate)</b>	SM-2320 B (4a)	14 days
<b>BOD</b>	SM-5210 B	48 hours
<b>Calcium</b>	EPA 200.7	6 months
<b>Chloride</b>	SM-4500 Cl	8 days
<b>Chlorine, total</b>	SM-4500 Cl	5 hours
<b>Color</b>	SM-2120 B	8 hours
<b>COD</b>	EPA 410.4 (7.3)	28 days
<b>Cyanide</b>	EPA 335.2 (8.7)	28 days
<b>Dissolved Oxygen</b>	SM-4500 O C	8 hours
<b>Fluoride</b>	SM-4500 F C	28 days
<b>Hardness</b>	SM-2340 B	6 months
<b>Magnesium</b>	EPA 200.7	6 months
<b>Nitrogen, ammonia</b>	SM-4500 NH3 E	28 days

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

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

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.*

### Hyperlink to the Glossary and Appendix

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

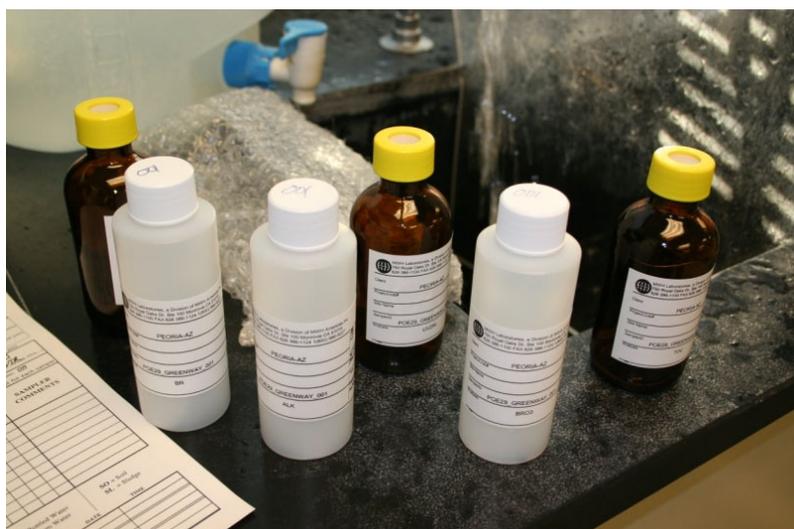
## **SAMPLE CONTAINERS and PRESERVATION**

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.

<b>Parameter</b>	<b>Bottle Type</b>	<b>Minimum Sample Size</b>	<b>Maximum Holding Time</b>	<b>Storage &amp; Preservation</b>
<b>Acidity</b>	P or G <sup>B</sup>	100ml	24 hrs/14 days	refrigerate
<b>Alkalinity</b>	P or G	200ml	24 hrs/14 days	refrigerate
<b>BOD (5 day)</b>	P or G	1L	6 hrs/48 hrs	refrigerate
<b>Boron</b>	P	100ml	28 days/6 month	
<b>Chloride</b>	P or G	250ml	28 days	
<b>Chlorine, residual</b>	P or G	500ml	0.5 hr/stat	analyze on site ASAP
<b>COD</b>	P or G	500ml	28 days/28 day	analyze on site ASAP
<b>Color</b>	P or G	500ml	48 hrs/48 hrs	refrigerate
<b>Coliform, Total</b>	P or G	125ml	30 hrs	refrigerate
<b>Conductivity</b>	P or G	500ml	48 hrs/48 hrs	refrigerate
<b>Cyanide, Total</b>	P or G	500ml	28 days/28 day	add NaOH to pH>12 refrigerate in dark
<b>Fluoride</b>	P	300ml	28days/ 28 day	
<b>Hardness</b>	P or G	100ml	6 months/6 months	add HNO <sub>3</sub> to pH<2
<b>Metals, general</b>	P <sup>A</sup> or G <sup>A</sup>	250ml	6 months/6 months	add HNO <sub>3</sub> to pH<2
<i>Furnace</i>	P <sup>A</sup> or G <sup>A</sup>	250ml	6 months/6 months	
<i>Flame</i>	P <sup>A</sup> or G <sup>A</sup>	250ml	6 months/6 months	
<b>Mercury</b>	P <sup>A</sup> or G <sup>A</sup>	500ml	28 days/28 day	add HNO <sub>3</sub> to pH<2
<b>Nitrogen</b>	P or G	500ml	7 days/ 28 days	ASAP or add H <sub>2</sub> SO <sub>4</sub> to pH<2 & refrigerate
<i>Ammonia</i>				
<i>Nitrate</i>	P or G	100ml	48 hrs/48 hrs	ASAP & refrigerate
<i>Nitrate + Nitrite</i>	P or G	200ml	48 hrs/28 days	ASAP & refrigerate
<i>Nitrite</i>	P or G	100ml	none/48 hrs	ASAP & refrigerate
<i>TKN</i>	P or G	500ml	7 days/28 days	add H <sub>2</sub> SO <sub>4</sub> to pH<2
<b>Oxygen, dissolved</b>	G (BOD)	300ml		
<i>Electrode</i>			0.5 hrs/stat	ASAP on site
<i>Winkler</i>			8hrs/8 hrs	ASAP on site
<b>pH</b>	P or G	50ml	2 hrs/stat	ASAP on site
<b>Phosphate,</b>	G <sup>A</sup>			
<i>Ortho</i>		100ml	48hrs	filter ASAP refrigerate

<i>Total</i>		100ml	28 days/28 day	refrigerate
<b>Solids,</b>	P or G			
<i>Dissolved</i>		250ml	7 days	refrigerate
<i>Settleable</i>		1L	48 hrs	refrigerate
<i>Suspended</i>		250ml	7 days	refrigerate
<i>Total</i>		250ml	7 days	refrigerate
<i>Volatile</i>		250ml	7 days	refrigerate
<b>Silica</b>	P	200ml	28 days/28 day	refrigerate
<b>Sulfate</b>	P or G	100ml	28 days/28 day	refrigerate
<b>Turbidity</b>	P or G	100ml	24 hrs/48 hrs	ASAP/refrigerate, store in dark up to 2 hrs

Refrigerate = storage at 4 degrees C, in the dark. P = plastic (polyethylene or equivalent); G = glass  
 G<sup>A</sup> or P<sup>A</sup> = rinsed with 1:1 HNO<sub>3</sub>; G<sup>B</sup> = glass, borosilicate, G<sup>S</sup> = glass rinsed with organic solvents; N<sup>S</sup>  
 = not stated in cited reference; stat = no storage allowed; analyze immediately.



## Inorganic Compound (IOC) Sub-Section

**Periodic Table of the Elements**

**Element Categories**

- alkali metals
- alkaline metals
- other metals
- transition metals
- lanthanoids
- actinoids
- metalloids
- nonmetals
- halogens
- noble gases
- unknown elements

**Electron Configuration Blocks**

s, d, p, f

**Callout for Iron (Fe):**

- atomic number → 26
- white metal - gas state at 0°C
- chemical symbol → Fe
- chemical name → Iron
- standard atomic weight → 55.85
- (lower upper bounds)
- (closest no stable isotopes)

**Natural Occurrence**

- primordial
- from decay
- synthetic

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La lanthanum 138.9	Ce cerium 140.1	Pr praseodymium 140.9	Nd neodymium 144.2	Pm promethium (145)	Sm samarium 150.4	Eu europium 151.9	Gd gadolinium 157.3	Tb terbium 158.9	Dy dysprosium 162.5	Ho holmium 164.9	Er erbium 167.3	Tm thulium 168.9	Yb ytterbium 173.1	Lu lutetium 174.9
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac actinium (227)	Th thorium 232.0	Pa protactinium 231.0	U uranium 238.0	Np neptunium (237)	Pu plutonium (244)	Am americium (243)	Cm curium (247)	Bk berkelium (247)	Cf californium (251)	Es einsteinium (252)	Fm fermium (257)	Md mendelevium (258)	No nobelium (259)	Lr lawrencium (262)

### 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 obligately 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 <sup>1</sup> (mg/L) <sup>2</sup>	MCL or TT <sup>1</sup> (mg/L) <sup>2</sup>	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
<b>Antimony</b>	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
<b>Arsenic</b>	0 <sup>2</sup>	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
<b>Asbestos (fiber &gt;10 micrometers)</b>	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
<b>Barium</b>	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
<b>Beryllium</b>	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
<b>Cadmium</b>	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
<b>Chromium (total)</b>	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
<b>Copper</b>	1.3	TT <sup>2</sup> ; 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
<b>Cyanide (as free cyanide)</b>	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from

## Inorganic Chemicals

Contaminant	MCLG <sup>1</sup> (mg/L) <sup>2</sup>	MCL or TT <sup>1</sup> (mg/L) <sup>2</sup>	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
				plastic and fertilizer factories
<b>Fluoride</b>	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
<b>Lead</b>	zero	TT <sup>2</sup> ; 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
<b>Mercury (inorganic)</b>	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
<b>Nitrate (measured as Nitrogen)</b>	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
<b>Nitrite (measured as Nitrogen)</b>	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
<b>Selenium</b>	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.

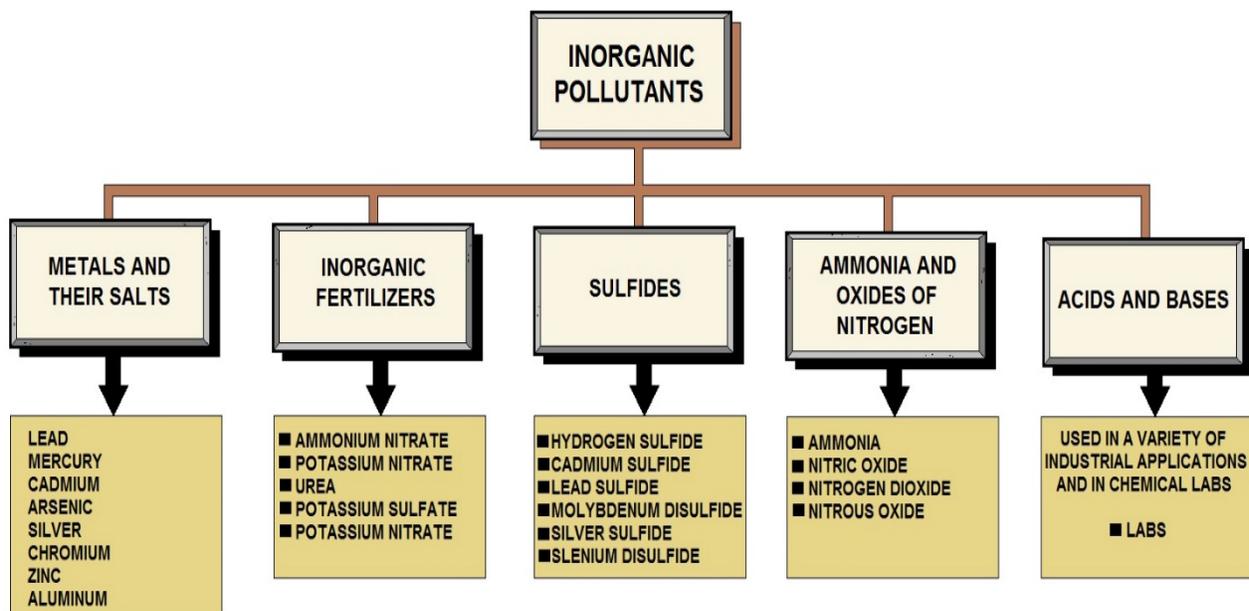
These lists of the organic chemicals—which include pesticides, industrial chemicals, and disinfection by-products—that are tested for in public water systems (those that provide water to the public), along with the maximum standard for the contaminant, and a brief description of the potential health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



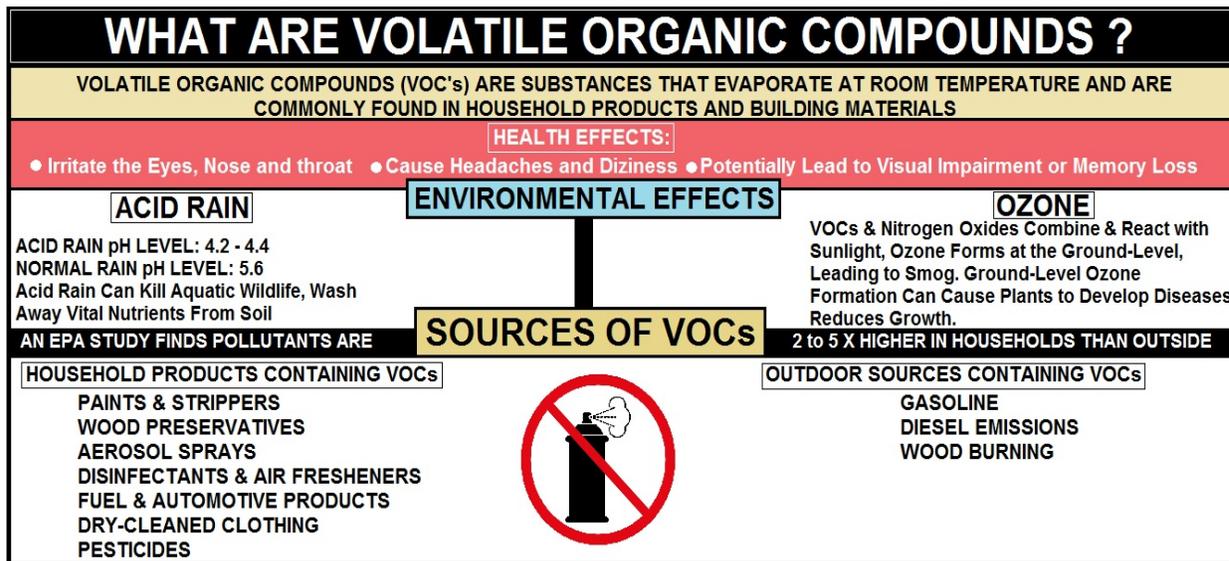
INORGANIC CONTAMINANTS OF WATER EXAMPLES



Synthetic Organic Chemicals	MCL (ppb)	Potential Health Effects
Acrylamide	1	Cancer, nervous system effects
Alachlor		Cancer
Aldicarb		Nervous system effects
Aldicarb sulfoxide		Nervous system effects
Aldicarb sulfone		Nervous system effects
Atrazine		Liver, kidney, lung, cardiovascular effects; possible carcinogen
Benzo(a)pyrene (PAHs)	0	Liver, kidney effects, possible carcinogen
Carbofuran	4	Nervous system, reproductive system effects
Chlordane		Cancer
2,4-D	7	Liver, kidney effects
Di(2-ethylhexyl) adipate	40	Reproductive effects
Di(2-ethylhexyl) phthalate		Cancer
Dibromochloro-propane (DBCP)	0	Cancer
Dinoseb		Thyroid, reproductive effects
Diquat	2	Ocular, liver, kidney effects
Endothall	10	Liver, kidney, gastrointestinal effects
Endrin		Liver, kidney effects
Epichlorohydrin	1	Cancer
Ethylene dibromide (EDB)	0.0	Cancer
Glyphosate	70	Liver, kidney effects
Heptachlor	0	Cancer
Heptachlor epoxide	0	Cancer
Hexachlorobenzene		Cancer
Hexachlorocyclopentadiene (HEX)	5	Kidney, stomach effects

Lindane	0	Liver, kidney, nervous system, immune system, circulatory system effects
Methoxychlor	4	Developmental, liver, kidney, nervous system effects
Oxamyl (Vydate)	20	Kidney effects
Pentachlorophenol		Cancer
Picloram	50	Kidney, liver effects
Polychlorinated biphenyls (PCBs)	0	Cancer
Simazine		Body weight and blood effects, possible carcinogen
2,3,7,8-TCDD (Dioxin)	0.0001	Cancer
Toxaphene		Cancer
2,4,5-TP (Silvex)	1	Liver, kidney effects

## Volatile Organic Compounds (VOCs)



## 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 100°C, 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

## **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 sublime from the liquid or solid form of the compound and enter the surrounding air. An example is formaldehyde, with a boiling point of  $-19\text{ }^{\circ}\text{C}$  ( $-2\text{ }^{\circ}\text{F}$ ), 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 perchloroethylene in the dry cleaning process to reuse it in an effort to save money, they can't recapture it all. To avoid exposure to perchloroethylene, 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 Chemical	MCL (ppb)	Potential Health Effects
Benzene		Cancer
Carbon tetrachloride		Liver effects, cancer
Chlorobenzene	10	Liver, kidney, nervous system effects
o-Dichlorobenzene	60	Liver, kidney, blood cell effects
para-Dichlorobenzene	17	Kidney effects, possible carcinogen
1,2-Dichloroethane		Cancer
1,1-Dichloroethylene		Liver, kidney effects, possible carcinogen
cis-1,2-Dichloroethylene	7	Liver, kidney, nervous system, circulatory system effects
trans-1,2-Dichloroethylene	10	Liver, kidney, nervous system, circulatory system effects
1,2-Dichloropropane		Cancer
Ethylbenzene	70	Liver, kidney, nervous system effects
Methylene chloride		Cancer
Styrene	10	Liver, nervous systems effects, possible carcinogen
Tetrachloroethylene (PCE)		Cancer
Toluene	1,000	Liver, kidney, nervous system, circulatory system effects
Total trihalomethanes		
Chloroform		
Bromoform	10	Cancer
Bromodichloromethane		
Chlorodibromomethane		
1,2,4-Trichlorobenzene	7	Liver, kidney effects
1,1,1-Trichloroethane	20	Liver, nervous system effects
1,1,2-Trichloroethane		Kidney, liver effects, possible carcinogen
Trichloroethylene (TCE)		Cancer
Vinyl chloride		Nervous system, liver effects, cancer
Xylenes (total)	10,000	Liver, kidney, nervous system effects

Disinfection By-products	MCL (ppb)	Potential Health Effects
Bromate	1	Cancer
Chlorate	1,00	Anemia, nervous system effects
Haloacetic Acids (HAA5)*	8	Cancer
Total trihalomethanes (TTHMs)**	8	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/WaterMonitoringAss.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.

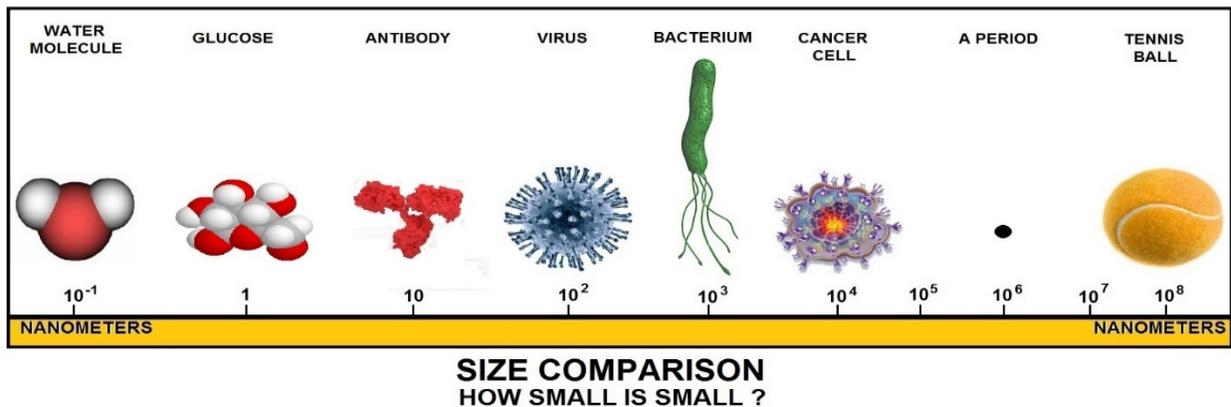
**Scope/Background:** The Environmental Protection Agency (EPA) published the Revised Total Coliform Rule (RTCR) in the Federal Register (FR) on February 13, 2013 (78 FR 10269) and minor corrections on February 26, 2014 (79 FR 10665). The RTCR is the revision to the 1989 Total Coliform Rule (TCR) and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



### 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



**Coccus**



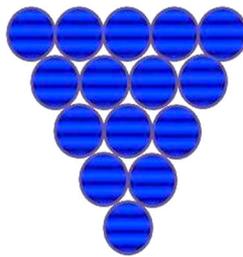
**Bacillus**



**Spirillum**



**Diplo-**



**Staphylo-**



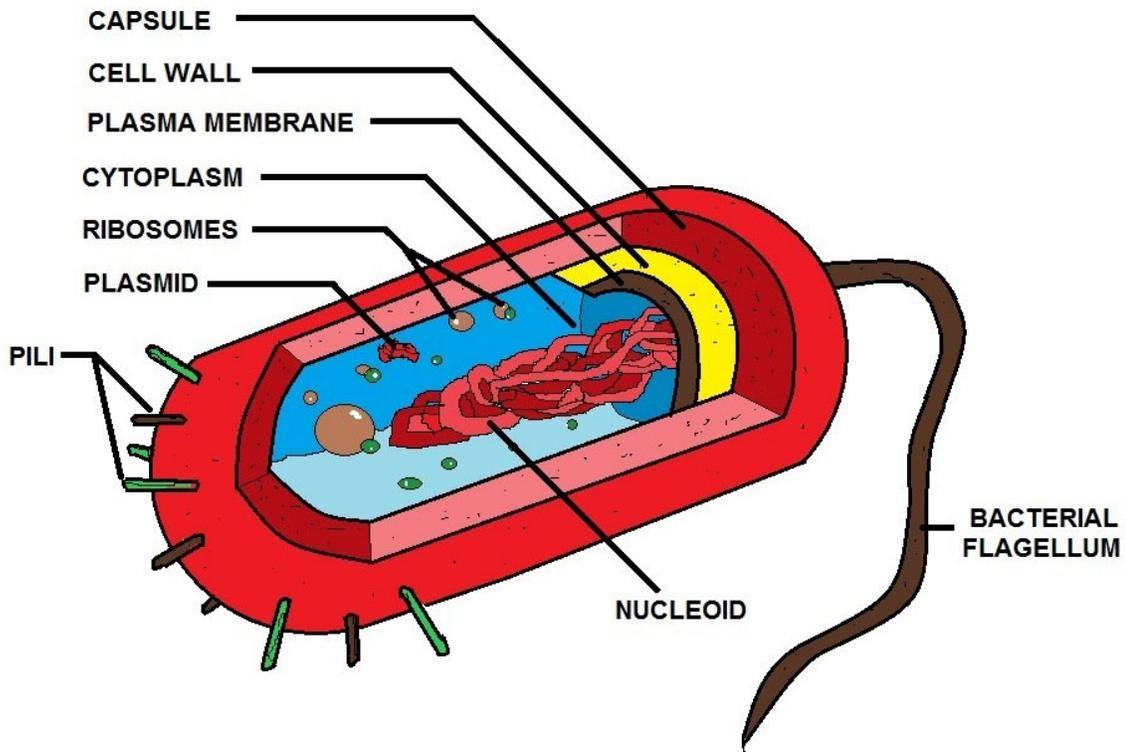
**Strepto-**

### 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



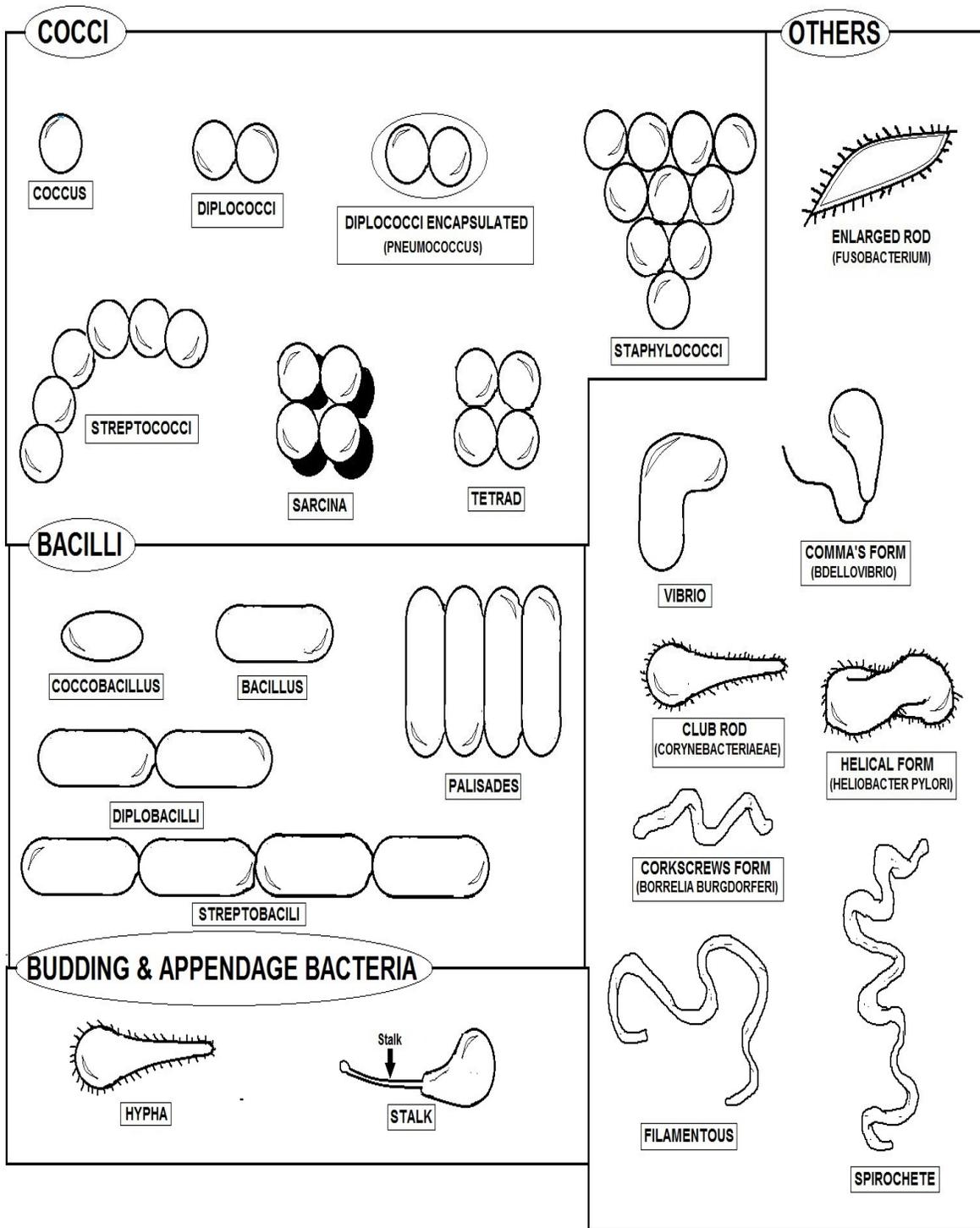
### PROKARYOTIC CELL

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<sub>2</sub>) and water (H<sub>2</sub>O).



## 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:**

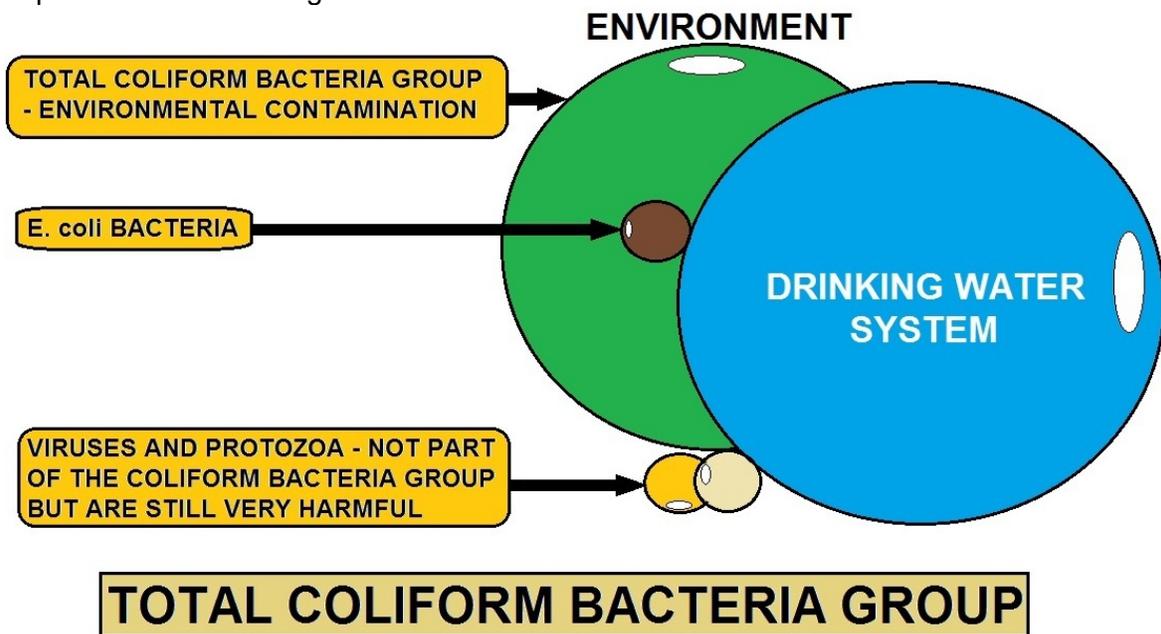
**Microbial contaminants**, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife;

**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 sitting plan subject to state review and revision.

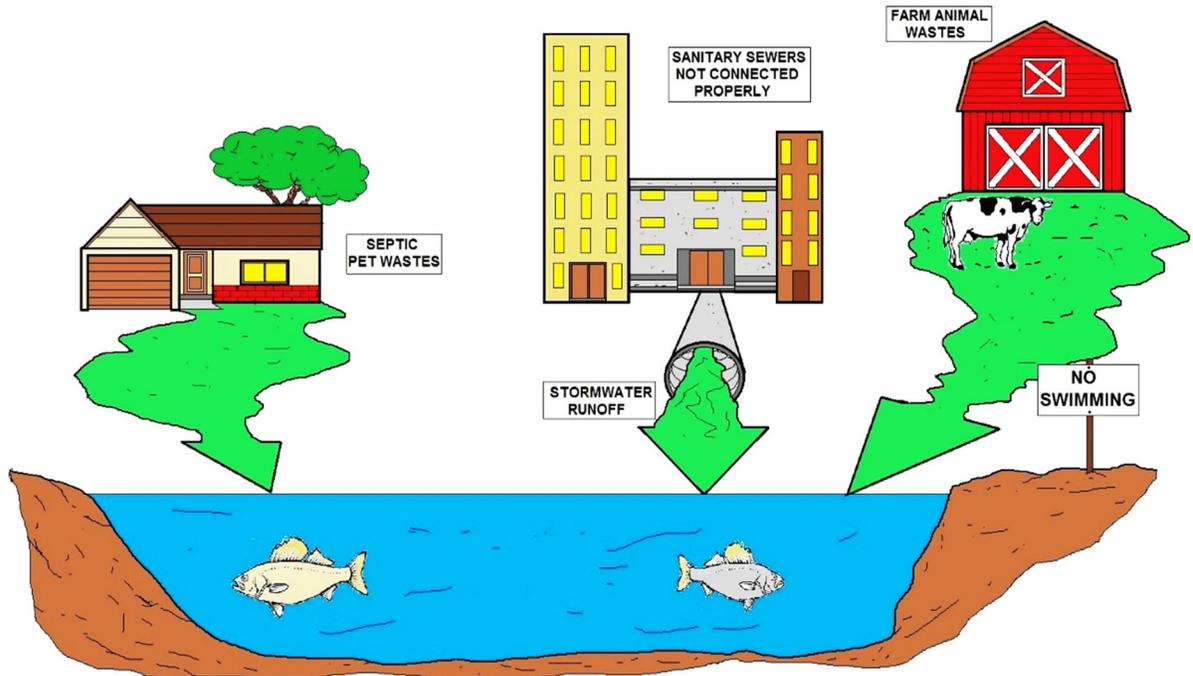
For PWSs collecting more than one sample per month, collect total coliform samples at regular intervals throughout the month, except that ground water systems serving 4,900 or fewer people may collect all required samples on a single day if the samples are taken from different sites.

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.

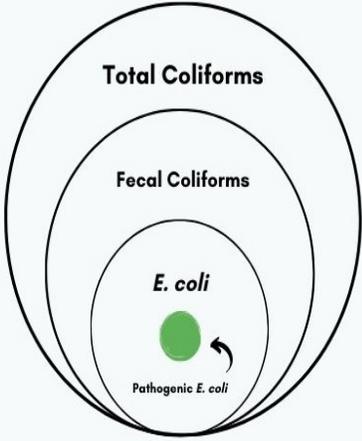
### Key provisions of the RTCR include:

- 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.

<h2 style="text-align: center;">TOTAL COLIFORM RULE (TCR) REVISIONS</h2>	<h2 style="text-align: center;">Coliforms Explained</h2>
<p><b>REVISED TOTAL COLIFORM RULE (RTCR)</b>          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.</p> <p>THE MAXIMUM CONTAMINANT LEVEL (MCL) FOR BACTERIA IN DRINKING WATER IS ZERO TOTAL COLIFORM COLONIES PER 100 MILLILITERS OF WATER.</p> <p>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</p>	



### TOTAL COLIFORM RULE (TCR) REVISIONS

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.

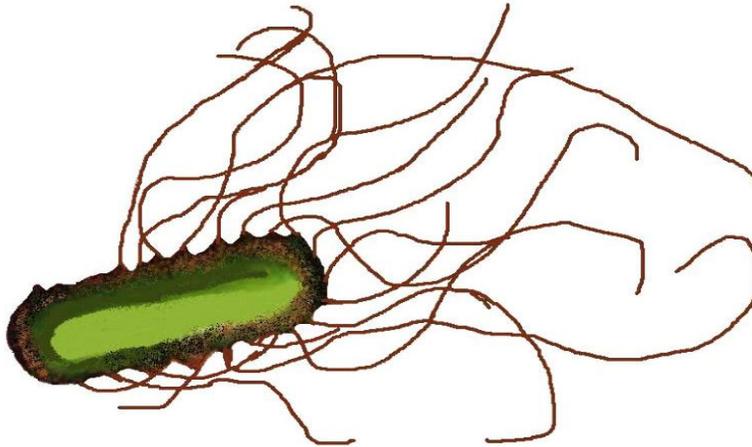
## Dangerous Waterborne Microbes

**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***.

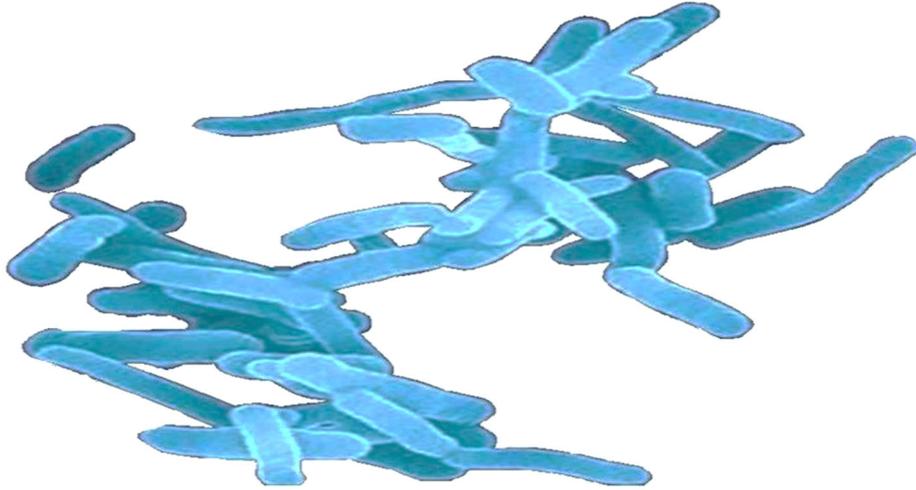
***Giardia lamblia*** is a parasite that enters lakes and rivers through sewage and animal waste. It causes gastrointestinal illness (e.g. diarrhea, vomiting, and cramps).



### PERITRICHOUS SHAPED BACTERIA EXAMPLE

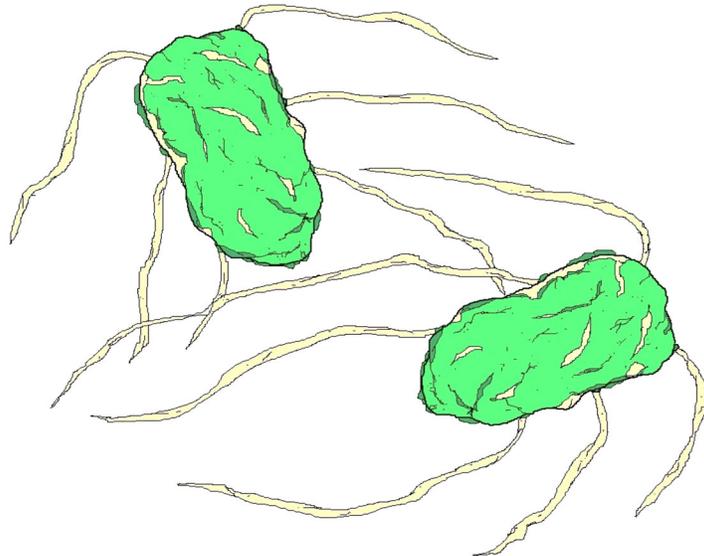
Microbiologists broadly classify bacteria according to their shape: spherical, rod-shaped, and spiral-shaped. Pleomorphic bacteria can assume a variety of shapes. Bacteria may be further classified according to whether they require oxygen (aerobic or anaerobic) and how they react to a test with Gram's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



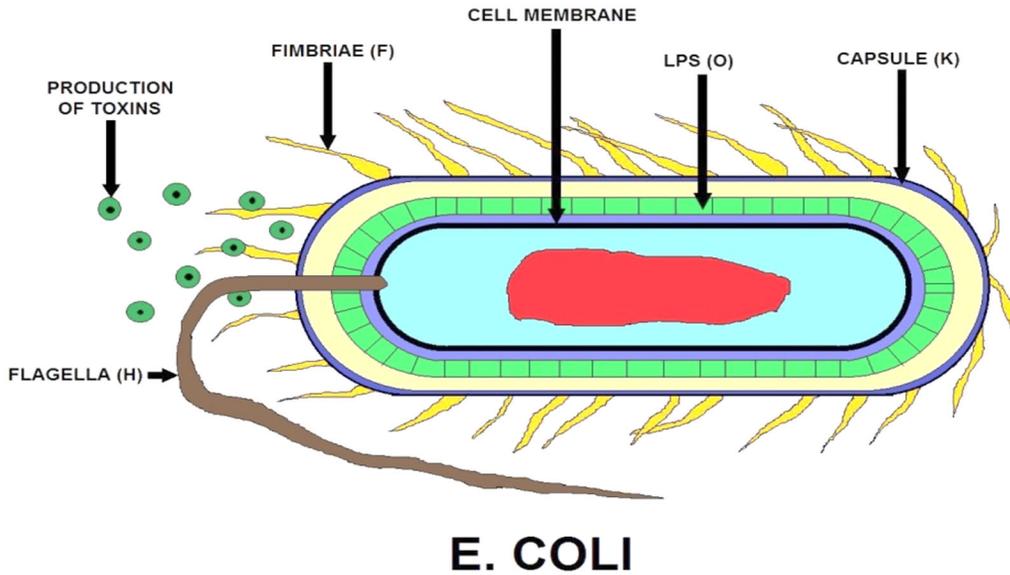
### **SHIGELLA DYSENTERIAE EXAMPLE**

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.



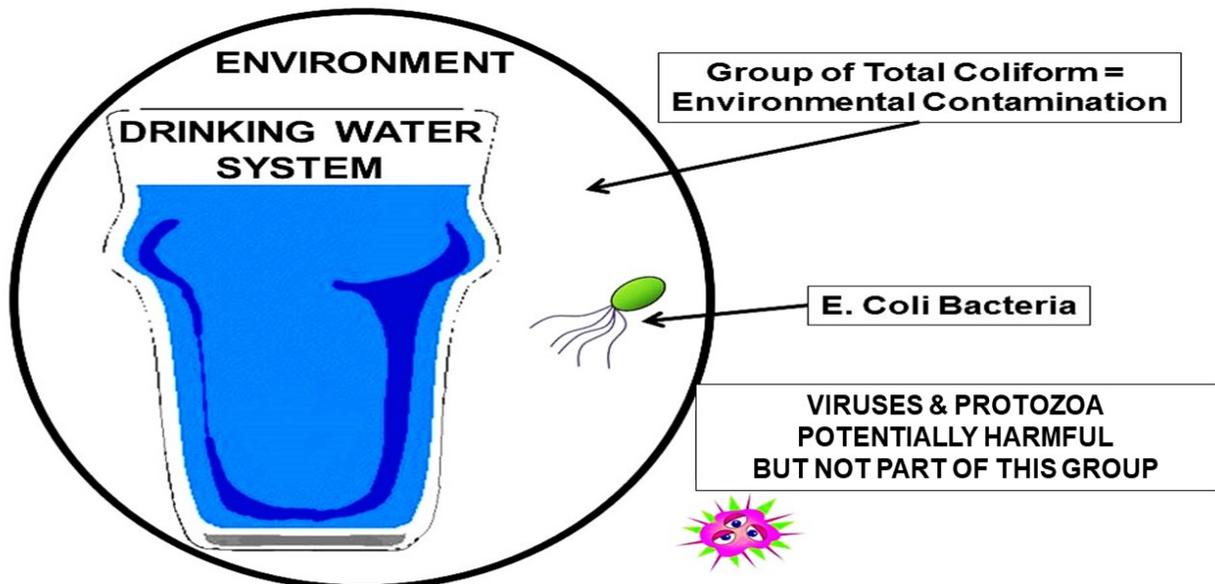
### **SALMONELLA EXAMPLE**

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.

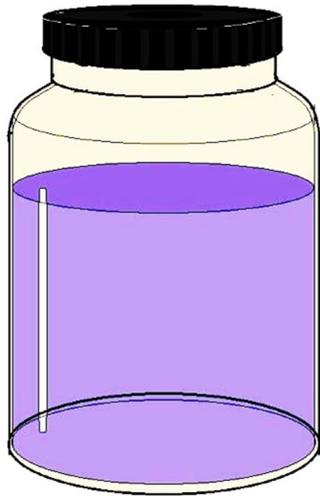


### Fecal Coliform Bacteria

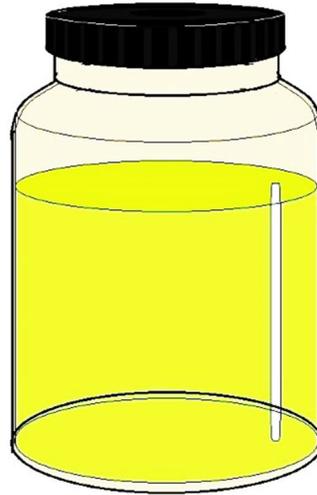
Fecal coliform bacteria are microscopic organisms that live in the intestines of warm-blooded animals. They also live in the waste material, or feces, excreted from the intestinal tract. When fecal coliform bacteria are present in high numbers in a water sample, it means that the water has received fecal matter from one source or another. Although not necessarily agents of disease, fecal coliform bacteria may indicate the presence of disease-carrying organisms, which live in the same environment as the fecal coliform bacteria.



### GROUP OF TOTAL COLIFORM BACTERIA

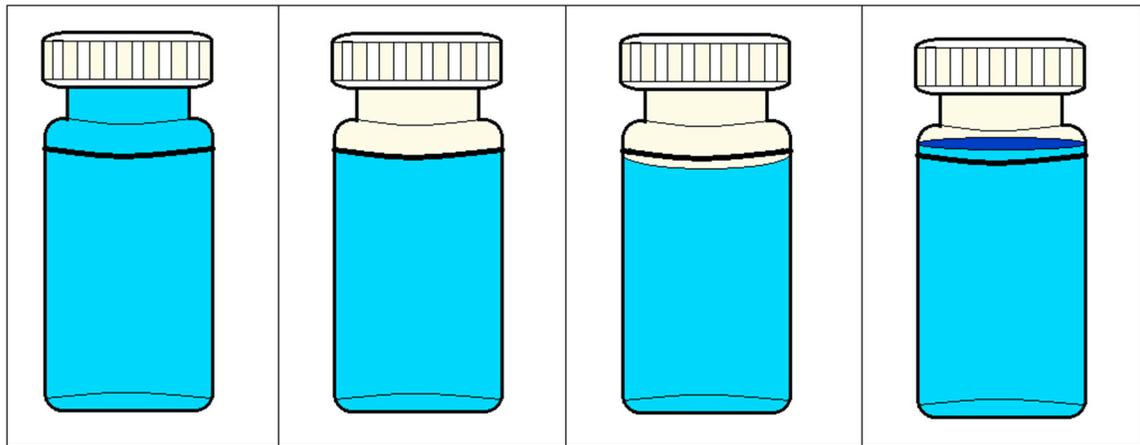


COLIFORM POSITIVE  
SAMPLE



COLIFORM NEGATIVE  
SAMPLE

### COLIFORM BACTERIA PRESENCE TEST EXAMPLE



OVER FILLED

CORRECT (100mL)

INCORRECT (97mL)

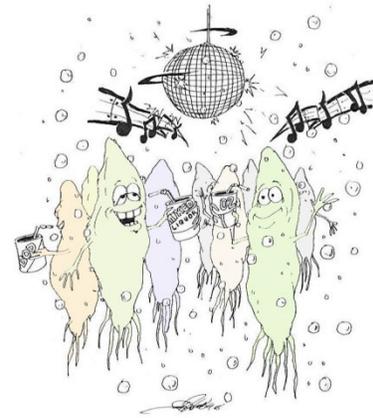
CORRECT  
(Lab will pour off to 100mL)

### 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 bleach 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:

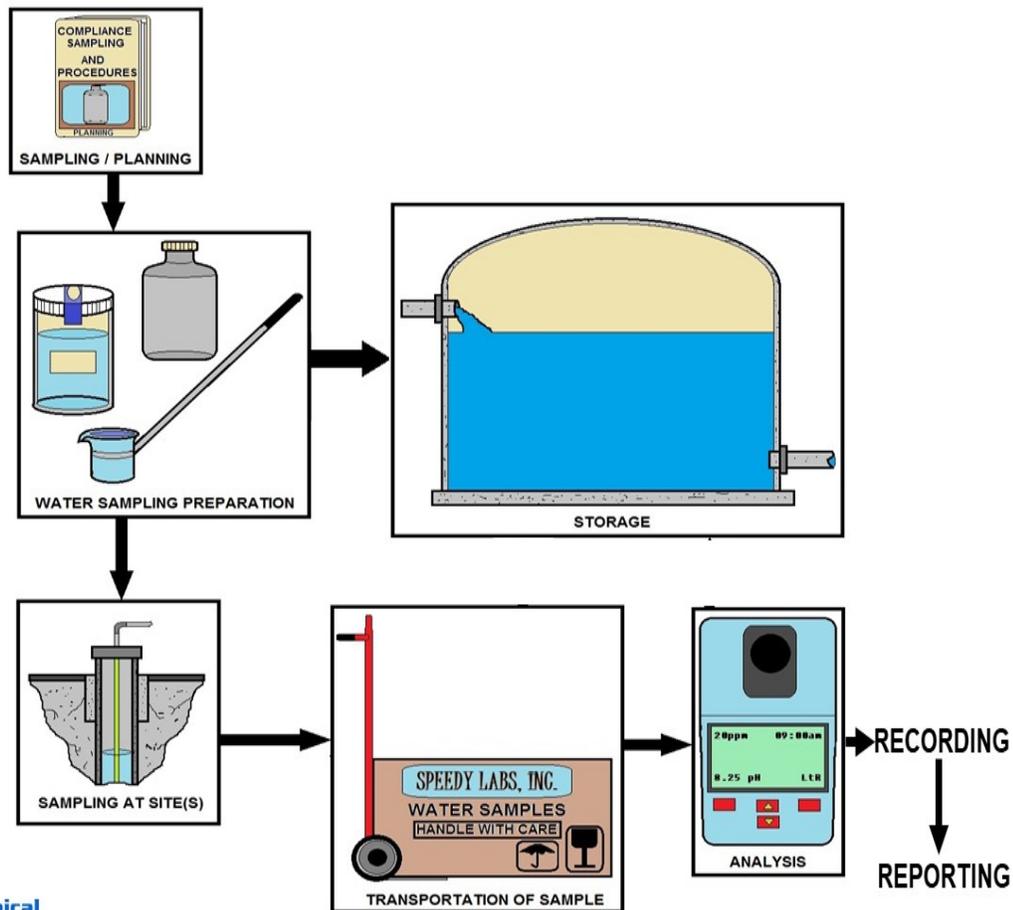
### Methods

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.



## 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

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



### 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 well 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.

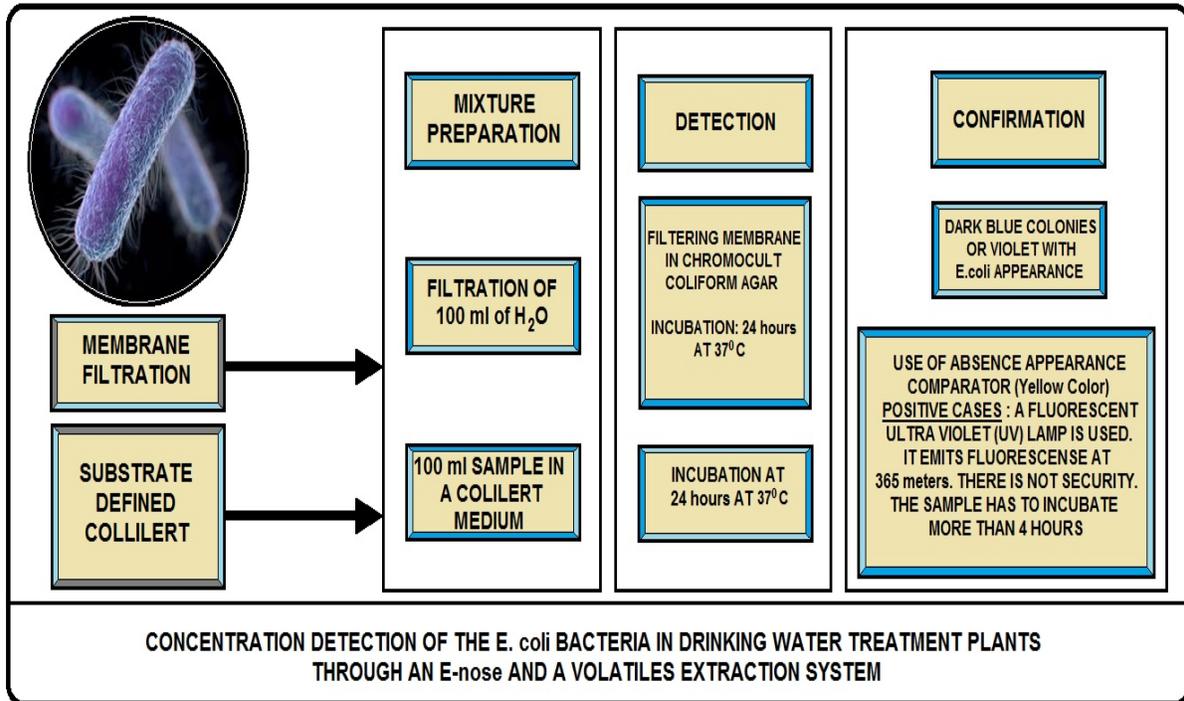
This list provides some basic operation and maintenance procedures that could help eliminate potential bacteriological problems, check with your state drinking water section or health department for further instructions.

## 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.



### CONVENTIONAL BACTERIOLOGICAL MONITORING



BIOLOGICAL PROPERTIES OF WATER					
<p><b>ADHESION:</b> Water tends to stick unlike substances. Example is water sticking to blood vessels</p>	<h4 style="margin: 0;">WATER IS A UNIVERSAL SOLVENT</h4>				
<p><b>COHESION:</b> Which water molecules clings together due to Hydrogen bonding; the surface film (top layer of water) is held by surface tension. Example is spilled water foaming in a puddle</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; padding: 5px;"> <p style="text-align: center; font-size: small;">ADD SUGAR, BECOMES SWEET</p> <div style="text-align: center; margin: 5px 0;"></div> </td> <td style="width: 50%; padding: 5px;"> <p style="text-align: center; font-size: small;">ADD COLOR, BECOMES COLORFUL</p> <div style="text-align: center; margin: 5px 0;"></div> </td> </tr> <tr> <td style="padding: 5px;"> <p style="text-align: center; font-size: small;">ADD NEGATIVE VIBRATION, BECOMES DISCHARGED</p> <div style="text-align: center; margin: 5px 0;"></div> </td> <td style="padding: 5px;"> <p style="text-align: center; font-size: small;">ADD POSITIVE VIBRATION, BECOMES CHARGED</p> <div style="text-align: center; margin: 5px 0;"></div> </td> </tr> </table>	<p style="text-align: center; font-size: small;">ADD SUGAR, BECOMES SWEET</p> <div style="text-align: center; margin: 5px 0;"></div>	<p style="text-align: center; font-size: small;">ADD COLOR, BECOMES COLORFUL</p> <div style="text-align: center; margin: 5px 0;"></div>	<p style="text-align: center; font-size: small;">ADD NEGATIVE VIBRATION, BECOMES DISCHARGED</p> <div style="text-align: center; margin: 5px 0;"></div>	<p style="text-align: center; font-size: small;">ADD POSITIVE VIBRATION, BECOMES CHARGED</p> <div style="text-align: center; margin: 5px 0;"></div>
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<p style="text-align: center; font-size: small;">ADD NEGATIVE VIBRATION, BECOMES DISCHARGED</p> <div style="text-align: center; margin: 5px 0;"></div>	<p style="text-align: center; font-size: small;">ADD POSITIVE VIBRATION, BECOMES CHARGED</p> <div style="text-align: center; margin: 5px 0;"></div>				
<p><b>SOLVENCY:</b> Water is considered a universal solvent for it's ability to dissolve a wide range of substances since it is a polar molecule. Example is salt or sugar dissolving in water</p>					

### BIOLOGICAL PROPERTIES OF WATER EXAMPLE



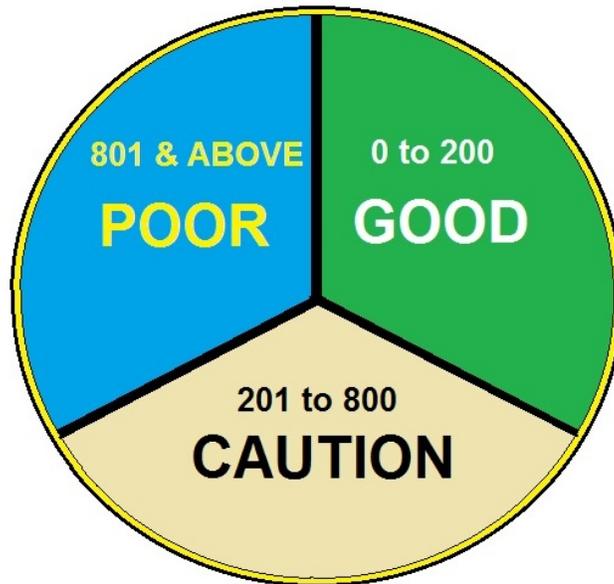
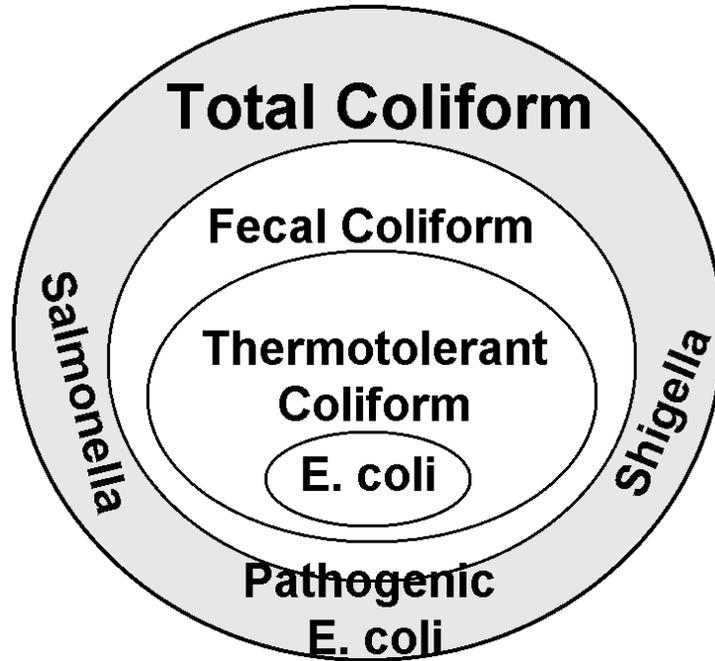


Looking under a black light to identify the presence of E. coli.

Colilert tests simultaneously detect and confirm 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

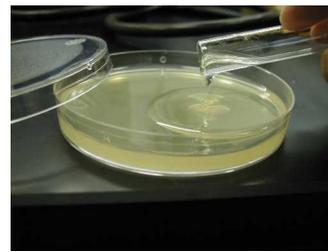
The colonies produced are relatively small and compact, showing less tendency to encroach on each other than those produced by surface growth. On the other hand, submerged colonies often are slower growing and are difficult to transfer.

#### 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:

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

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

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

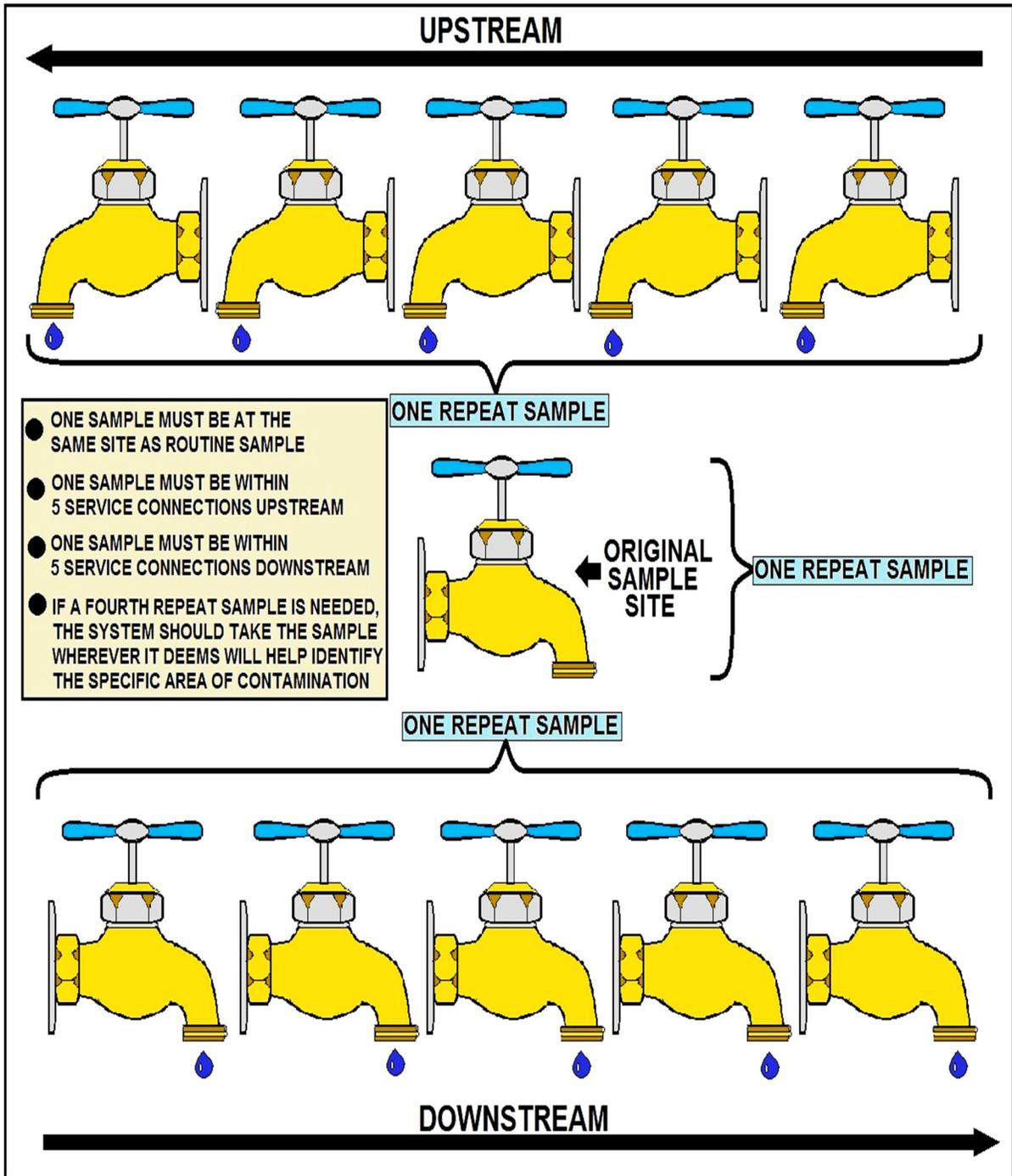
### Assignment

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

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

### Data Table for Samples

Sample ID	Volume of Sample, ml	Colonies Counted per plate



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

## Total Coliforms

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

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

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

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

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

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

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

### Public Notice

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

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

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

### The following are Acute Violations

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

## Sim Plate Method



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

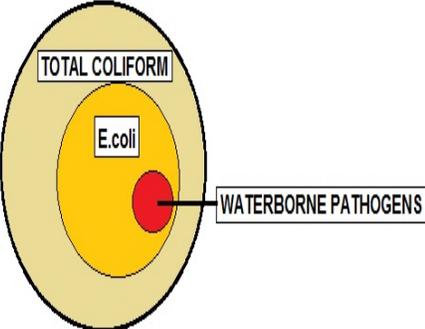
It is based on the Multiple Enzyme Technology which detects viable bacteria in water by testing for the presence of key enzymes known to be present in these little organisms.

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

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

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

## Revised Total Coliform Rule (RTCR) Summary

REVISED RULE OVERVIEW		MAJOR RULE CHANGES	
<b>TITLE:</b>	REVISED TOTAL COLIFORM RULE (RTCR) 78 FR 10269, FEBRUARY 13th, 2013, Vol. 78, No. 30	<b>CURRENT TCR</b> Non-Accute MCL Violation	<b>REVISED TCR</b> Level 1 Assessment Trigger
<b>PURPOSE:</b>	INCREASE PUBLIC HEALTH PROTECTION THROUGH THE REDUCTION OF POTENTIAL PATHWAYS OF ENTRY FOR FECAL CONTAMINATION INTO DISTRIBUTION SYSTEM	FOR A SYSTEM COLLECTING AT LEAST 40 SAMPLES PER MONTH, MORE THAN 5.0% OF SAMPLES COLLECTED ARE TC POSITIVE	FOR A SYSTEM COLLECTING AT LEAST 40 SAMPLES PER MONTH, MORE THAN 5.0% OF SAMPLES COLLECTED ARE TC POSITIVE
<b>GENERAL DESCRIPTION:</b>	THE RTCR ESTABLISHES AN MCL FOR E.coli AND USES E.coli AND TOTAL COLIFORMS TO INITIATE AND "FIND A FIX" APPROACH TO ADDRESS FECAL CONTAMINATION THAT COULD ENTER DISTRIBUTION SYSTEM	FOR A SYSTEM COLLECTING FEWER THAN 40 SAMPLES PER MONTH, MORE THAN 1 SAMPLE TC POSITIVE	FOR A SYSTEM COLLECTING FEWER THAN 40 SAMPLES PER MONTH, MORE THAN 1 SAMPLE TC POSITIVE
<b>UTILITIES COVERED:</b>	THE REVISED TOTAL COLIFORM RULE APPLIES TO <u>ALL</u> PUBLIC WATER SYSTEMS	PUBLIC NOTICE IS REQUIRED	NO PUBLIC NOTICE MUST PERFORM LEVEL 1 ASSESSMENT
<b>PUBLIC HEALTH BENEFITS</b>			
IMPLEMENTATION OF THE REVISED TOTAL COLIFORM RULE <u>WILL</u> RESULT IN:			
<ul style="list-style-type: none"> <li>▶ A DECREASE IN THE PATHWAY BY WHICH FECAL CONTAMINATION CAN ENTER THE DRINKING WATER DISTRIBUTION SYSTEM</li> <li>▶ REDUCTION IN FECAL CONTAMINATION <u>SHOULD</u> REDUCE THE POTENTIAL RISK FROM ALL WATERBORNE PATHOGENS INCLUDING BACTERIA, VIRUSES, PROTOZOA, AND ASSOCIATED ILLNESSES.</li> </ul>			



## REVISED TOTAL COLIFORM RULE (RTCR)

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

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

### Why revise the 1989 TCR?

The 1996 amendments to the Safe Drinking Water Act [Section 1412(b) (9)] require the Administrator to review and revise, as appropriate, each national primary drinking water regulation not less often than 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 (RTCRC)**

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 (RTCRC) – 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 (RTCRC) requirements.

**The RTCRC:**

- 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
<b>Contaminant Level</b>	<p>Addresses the presence of total coliforms and E. coli in drinking water.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>
<b>Monitoring</b>	<p>Develop and follow a sample-siting plan that designates the PWS's collection schedule. This includes location of routine and repeat water samples.</p> <p>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.</p> <p>Analyze all routine or repeat samples that are total coliform positive (TC+) for E. coli.</p> <p>Collect repeat samples (at least 3) for each TC+ positive routine sample.</p> <p>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.</p> <p>Seasonal systems must monitor and certify the completion of a state approved start-up procedures.</p>

<b>RTCR Key Provisions</b> <i>Most of this section comes from the USEPA.</i>	
<b>Level 1 and Level 2 Assessments and Corrective Actions</b>	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.
<b>Reporting and Recordkeeping</b>	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.
<b>Violations, Public Notification (PN) and Consumer Confidence Report (CCR)</b>	<p>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.</p> <p>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.</p> <p>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.</p>

### 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

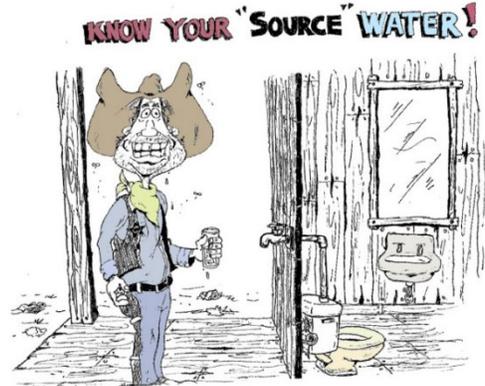
# Troubleshooting Table for Bacteriological Monitoring

## 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.

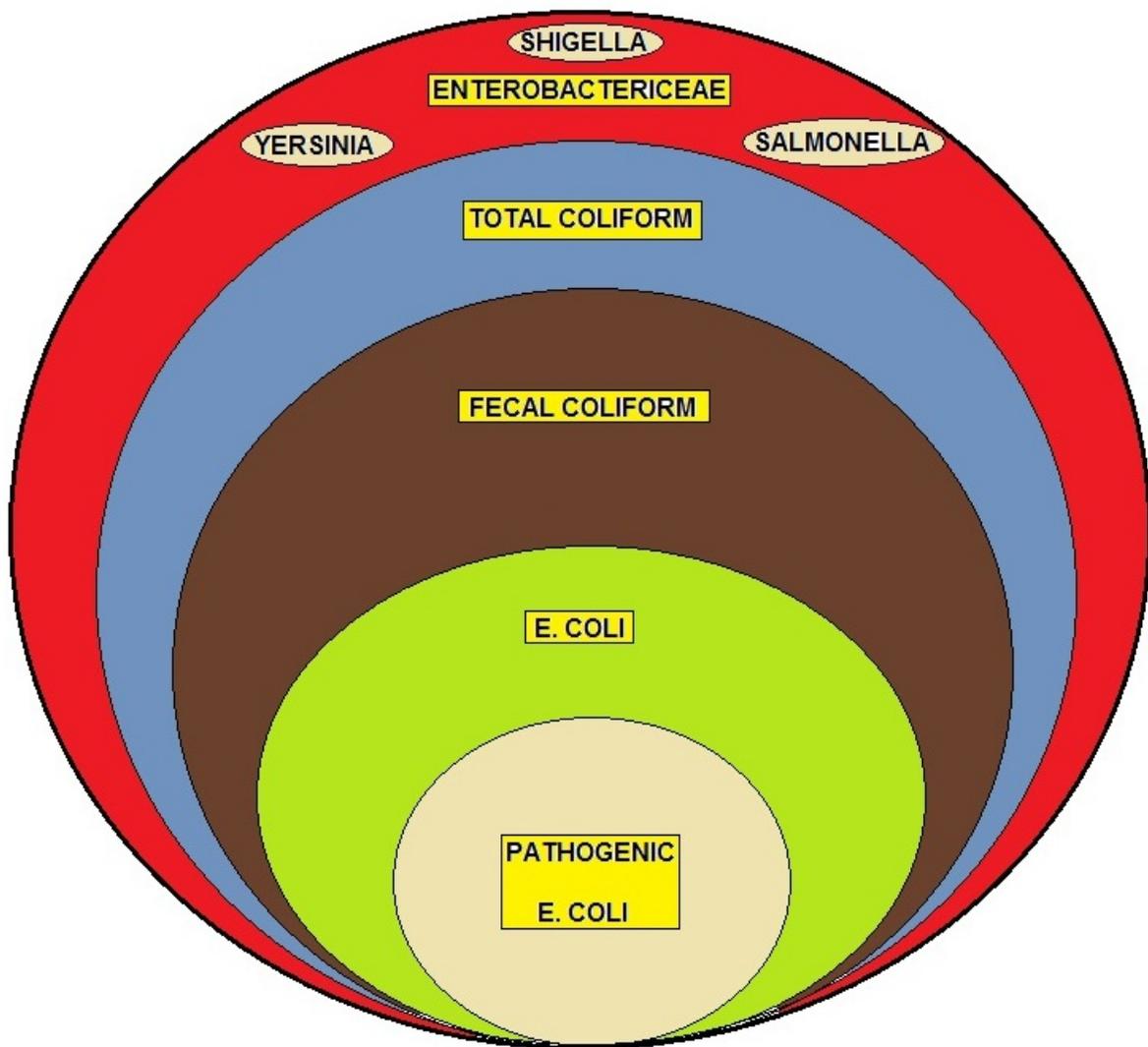
## Possible Causes

- 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.

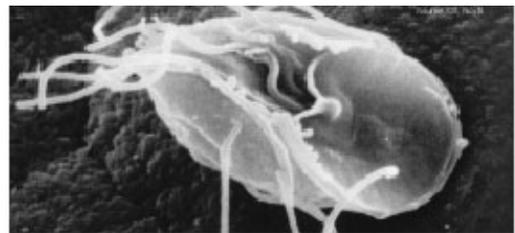
Pathogens that may cause waterborne outbreaks through drinking water have one thing in common: they are spread by the fecal-oral (or feces-to-mouth) route. Pathogens may get into water and spread when infected humans or animals pass the bacteria, viruses, and protozoa in their stool. For another person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

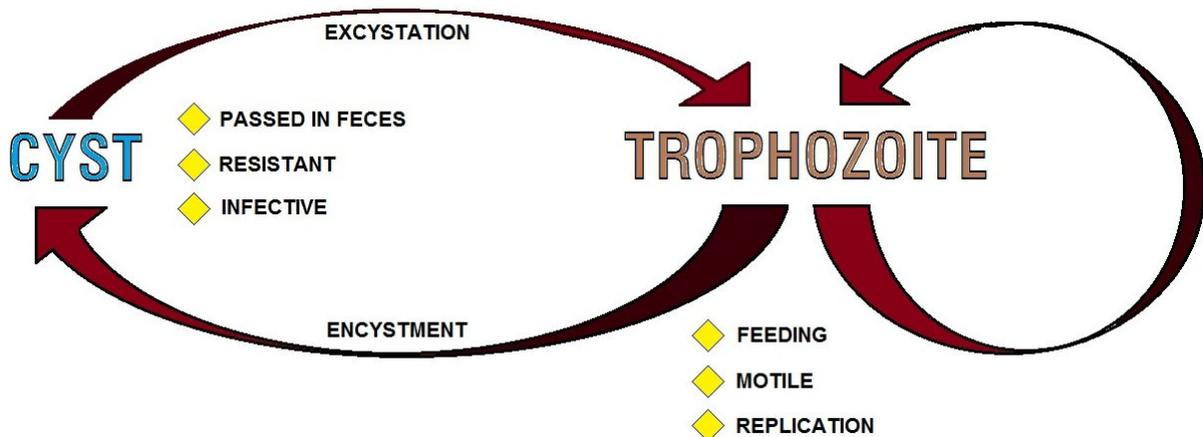
**Campylobacter prevention:** Prevention strategies for this pathogen include source protection, halogenation of water, and boiling water for one minute.

### 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 antihelminthic 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 flexneri. 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.

<b>PRESENCE OF PATHOGENS IN WATER</b>	<b>TYPES OF PATHOGENS FOUND IN WATER</b>
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.	



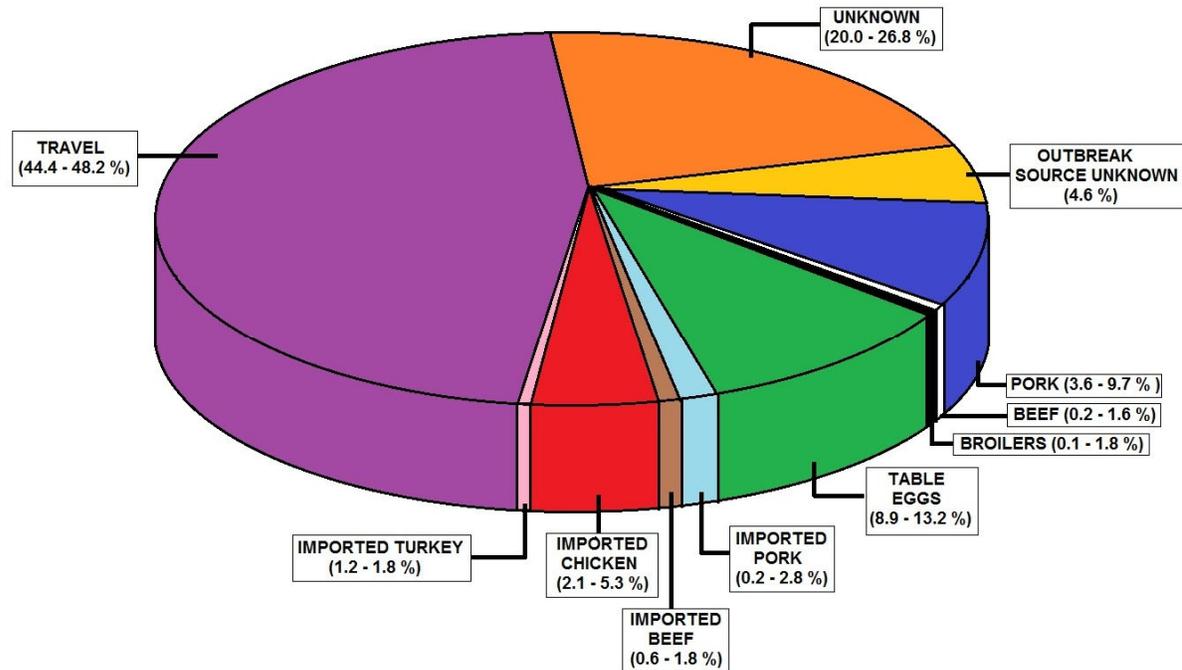
**PATHOGENS FOUND IN WATER SUPPLIES**

<b>MICROBIOLOGICAL CONTAMINANTS FOUND IN WATER</b>	
THESE ARE OFTEN OF FECAL NATURE RELATED TO HUMANS, DOMESTIC ANIMALS OR WILDLIFE	
<p><b><u>CALIVIVIRUS:</u></b></p> <p>SIGNS OF THIS VIRUS INCLUDE SNEEZING, NASAL DISCHARGE, OCULAR DISCHARGE, CONJUNCTIVITIS, ULCERATION OF THE TONGUE, LETHARGY, INAPPETENCE (Lack of Appetite) AND FEVER</p>	
<p><b><u>CAMPYLOBACTER JEJUNI:</u></b></p> <p>THIS IS ONE OF THE MOST COMMON CAUSES OF FOOD POISONING. IT IS CHARACTERIZED BY DIARRHEA, ABDOMINAL PAIN, FEVER, NAUSEA AND SOMETIMES VOMITING</p>	
<p><b><u>ENTEROVIRUS:</u></b></p> <p>SYMPTOMS OF THIS VIRUS INFECTION MAY INCLUDE FEVER, RUNNY NOSE, SNEEZING, COUGH, SKIN RASH, MOUTH BLISTERS, AND BODY AND MUSCLE ACHES</p>	
<p><b><u>ESCHERICHIA COLI:</u></b></p> <p>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</p>	



**MICROBIOLOGICAL CONTAMINANTS**

## Waterborne Bacterial Diseases



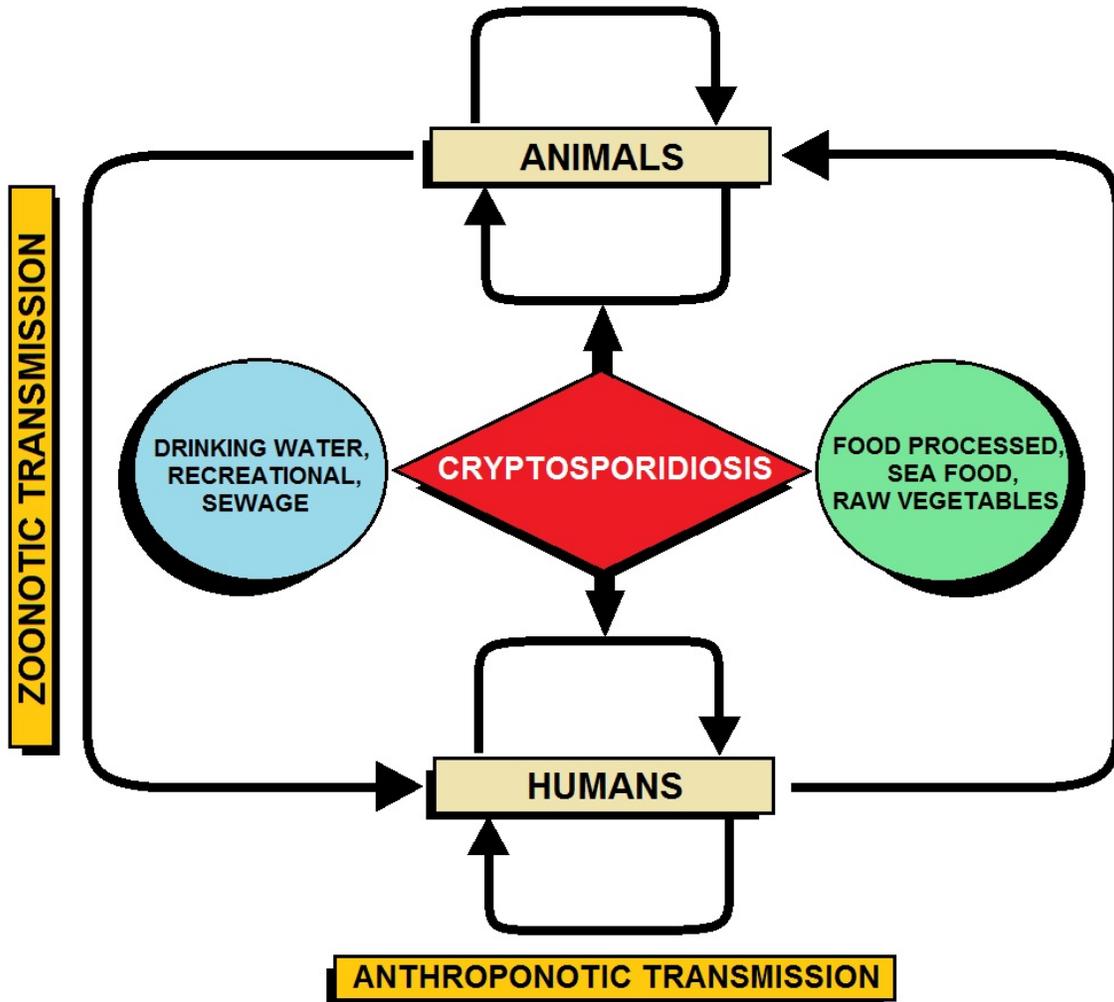
**COURSES OF SAMONELLA PIE CHART**

**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.

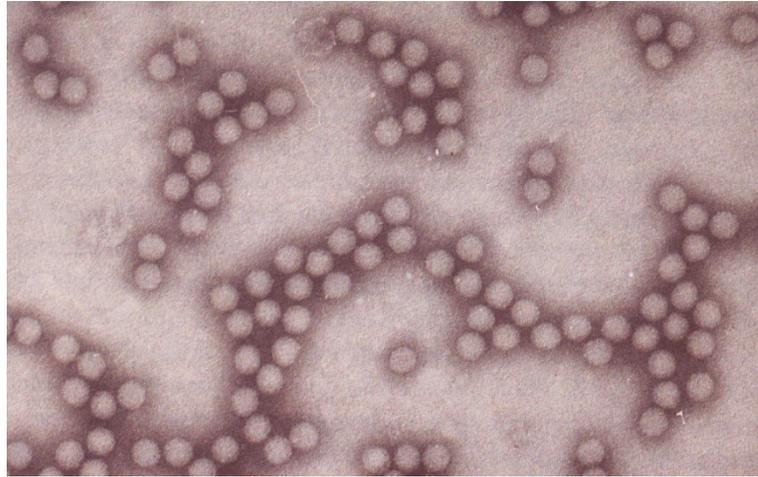


**TRANSMISSION OF CRYPTOSPORIDIOSIS**



## 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.

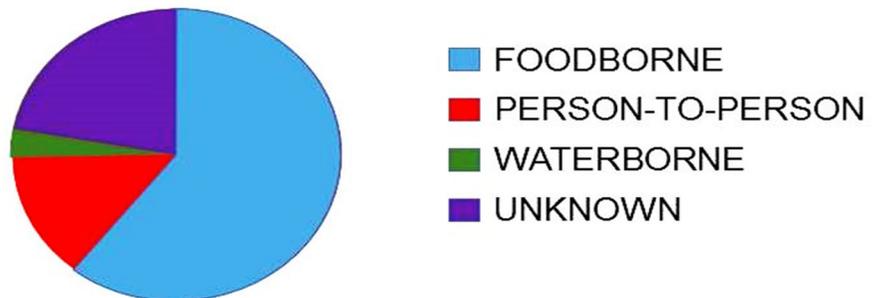
### Coronavirus

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.

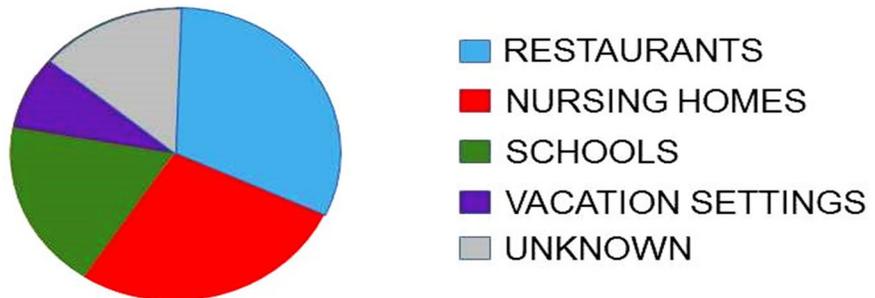
### SARS Virus

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.”

#### A. SOURCE OF NOROVIRUS



#### B. SETTING FOR OUTBREAK



## Waterborne Protozoan Diseases

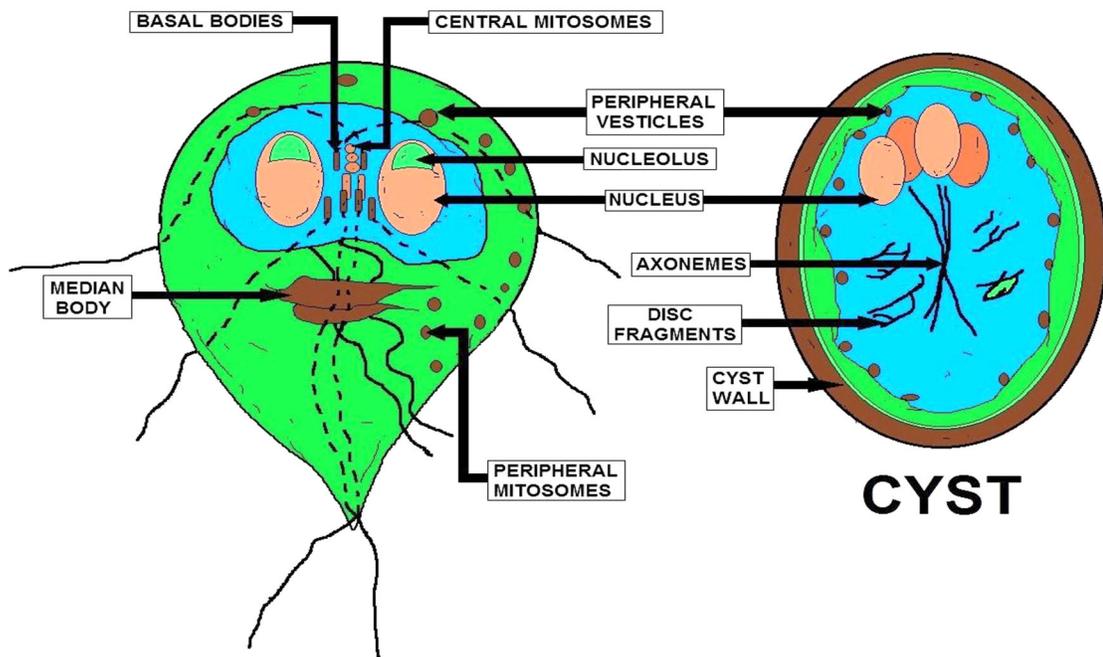
Protozoan pathogens are larger than bacteria and viruses, but still microscopic. They invade and inhabit the gastrointestinal tract. Some parasites enter the environment in a dormant form, with a protective cell wall called a “cyst.” The cyst can survive in the environment for long periods of time and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

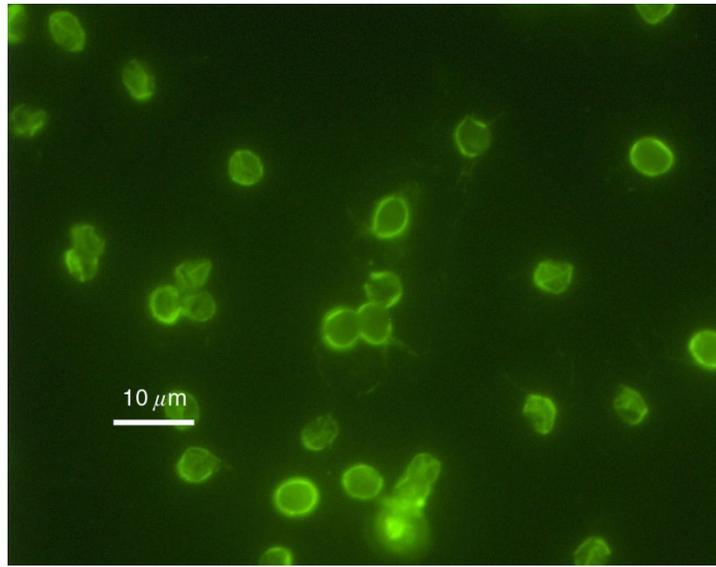
Many infections are asymptomatic (no symptoms). Giardiasis occurs worldwide. Waterborne outbreaks in the United States occur most often in communities receiving their drinking water from streams or rivers without adequate disinfection or a filtration system.

- 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

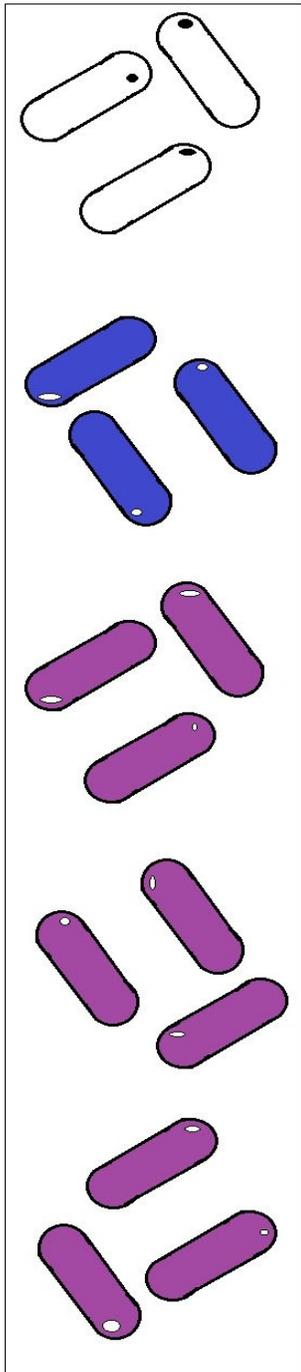
Name	Causative organism	Source of organism	Disease
Viral gastroenteritis	<b>Rotavirus</b> (mostly in young children)	Human feces	Diarrhea or vomiting
Norwalk Agent	<b>Noroviruses</b> (genus <i>Norovirus</i> , family <i>Caliciviridae</i> ) *1	Human feces; also, shellfish; lives in polluted waters	Diarrhea and vomiting
Salmonellosis	<b>Salmonella</b> (bacterium)	Animal or human feces	Diarrhea or vomiting
Gastroenteritis <i>Escherichia coli</i>	-- <b><i>E. coli</i> O157:H7</b> (bacterium): Other <i>E. coli</i> organisms:	Human feces	Symptoms vary with type caused
Typhoid	<b>Salmonella typhi</b> (bacterium)	Human feces, urine	Inflamed intestine, enlarged spleen, high temperature-sometimes fatal
Shigellosis	<b>Shigella</b> (bacterium)	Human feces	Diarrhea
Cholera	<b>Vibrio cholerae</b> (bacterium)	Human feces; also, shellfish; lives in many coastal waters	Vomiting, severe diarrhea, rapid dehydration, mineral loss-high mortality
Hepatitis A	<b>Hepatitis A virus</b>	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	<b>Entamoeba histolytica</b> (protozoan)	Human feces	Mild diarrhea, dysentery, extra intestinal infection
Giardiasis	<b>Giardia lamblia</b> (protozoan)	Animal or human feces	Diarrhea, cramps, nausea, and general weakness — lasts one week to months
Cryptosporidiosis	<b>Cryptosporidium parvum</b>	Animal or human feces	Diarrhea, stomach pain — lasts (protozoan) days to weeks

Notes:

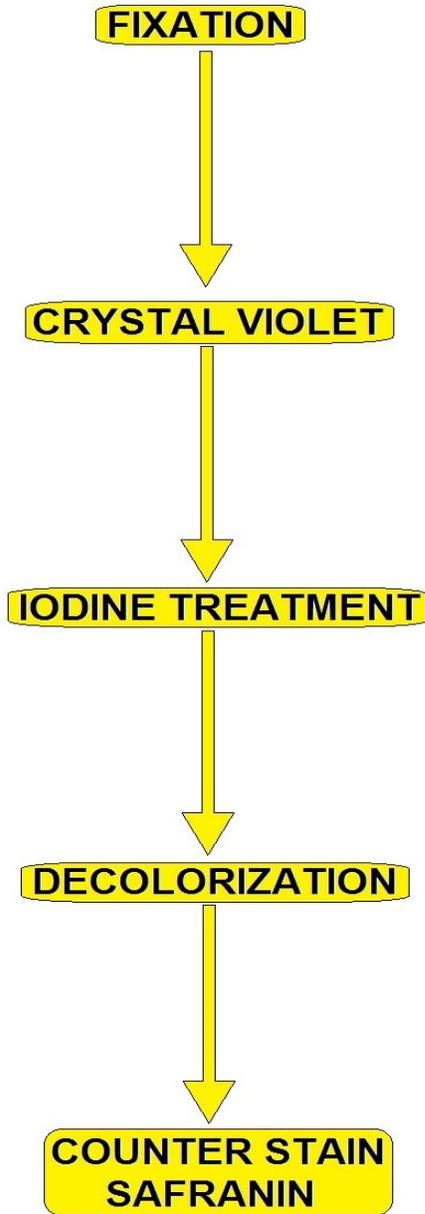
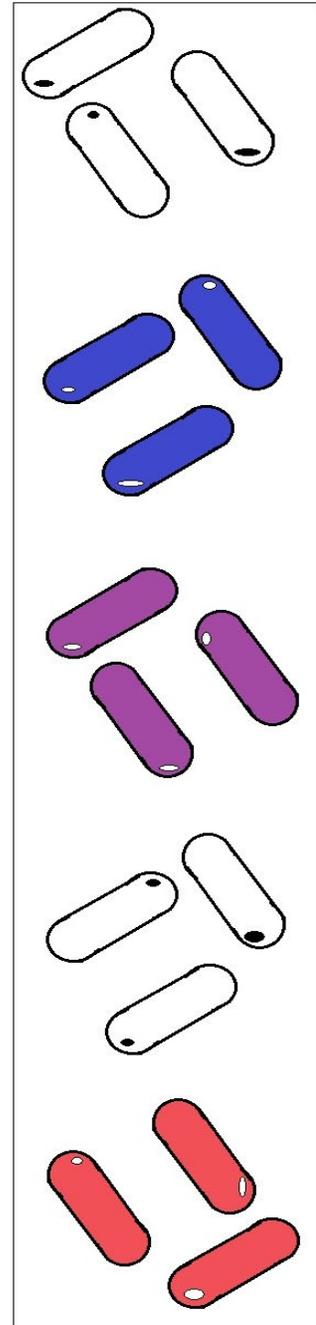
\*1 <http://www.cdc.gov/ncidod/dvrd/revb/gastro/norovirus.htm>

<http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5009a1.htm>

**Gram Positive**



**Gram Negative**



**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.

<b>LAB I.D. NUMBER</b>																							
<b>Laboratory</b> 123 W. Main St Sun City, Arizona 85541																							
DATE: _____ PAGE 1 OF 1																							
Sampler: _____																							
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 Volatil Organics (625)	Chloride	Cyanide	Floride	Surfactants (MBAS)	Tot. Coliform MPN	Fecal Coliform MPN-HPC	Organo-Phosphorus Pest. (8141)	Sulfate	EC Conductivity	Number/Containers
<b>Sample Receipt</b>																							
Project Name					No. Containers: _____ Custody Seals: _____ Received Intact: _____ Received Cold: _____ Temperature: _____ PRIORITY: _____																		
Project Number					Yes No Yes No																		
Field Measurements:					pH: _____ Temp: _____																		
RELINQUISHED BY:					Signature: _____ Time: _____ Printed Name: _____ Date: _____ Company: _____																		
SAMPLED RECEIVED BY:					Signature: _____ Time: _____ Printed Name: _____ Date: _____ Company: _____																		

Chain of Custody Example.



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

## 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.

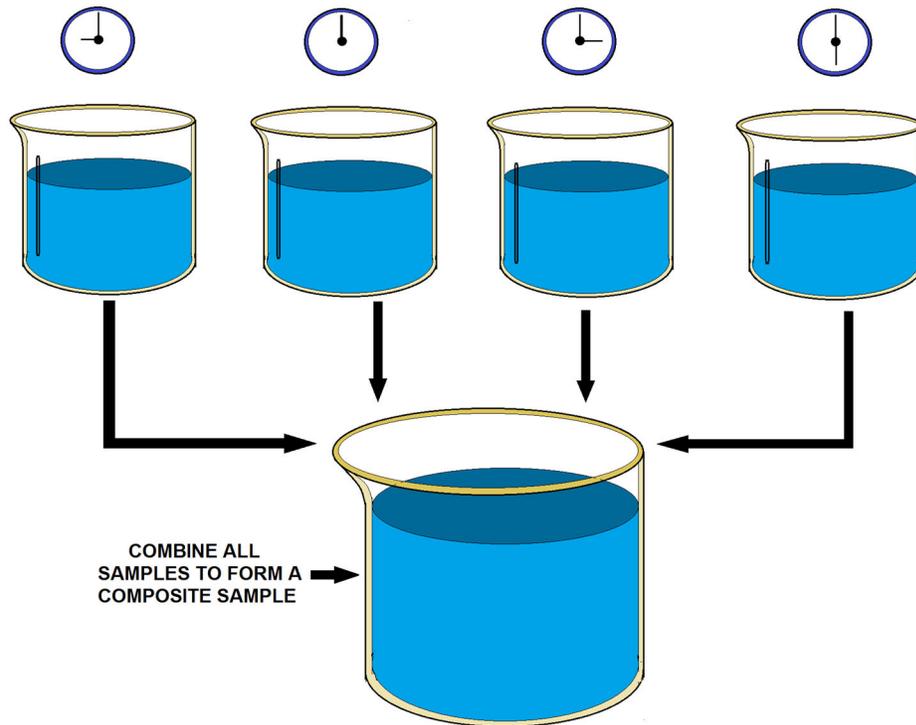
Once the velocity, depth and distance of the cross-section have been determined, the mid-section method can be used for determining the stream's discharge rate. Calculate the discharge in each increment by multiplying the averaged velocity in each increment by the increment width and averaged depth.

(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.

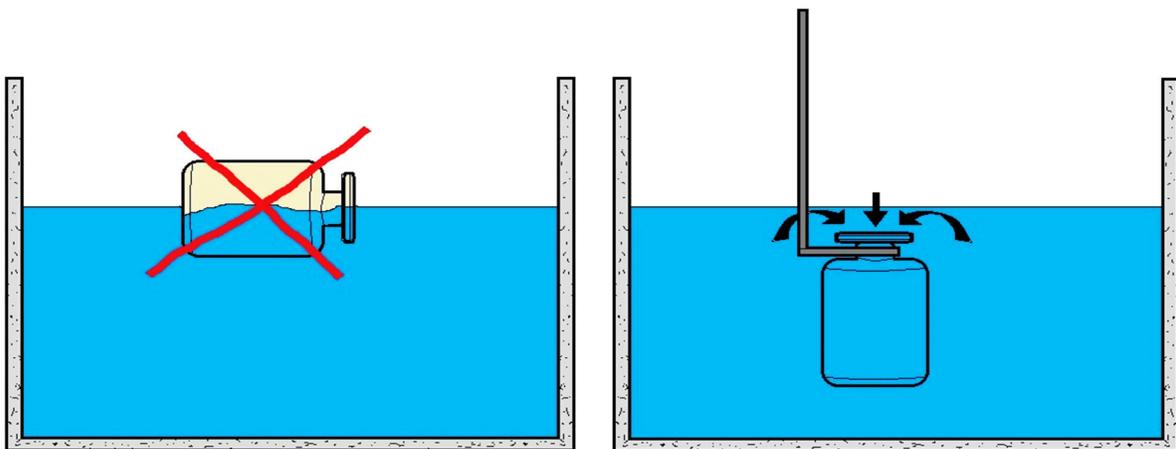
### **Composite Sampling**

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.

SEVERAL GRAB SAMPLES TAKEN AT DIFFERENT TIMES  
FROM THE EXACT SAME LOCATION



### MAKING A COMPOSITE SAMPLE FROM GRAB SAMPLES DIAGRAM



### PROPER METHOD 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.

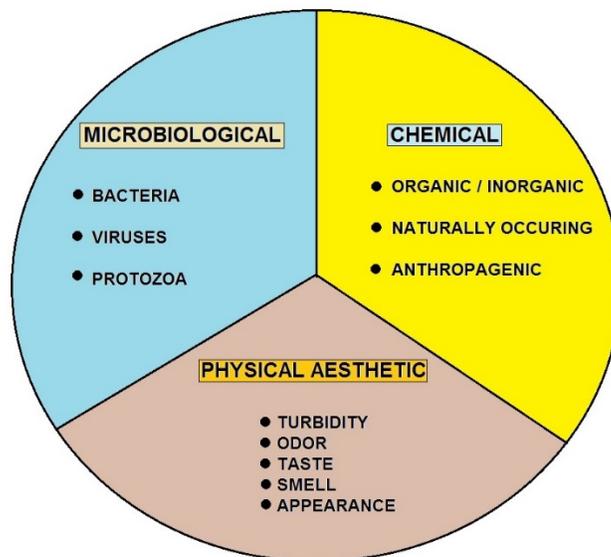
9. A coliform sample site plan is a list of sites by street address, lot number, or other permanent description, that identifies all the approved locations where your routine (monthly) coliform samples may be collected. The list of sites must be plotted on a map of your service area.

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.



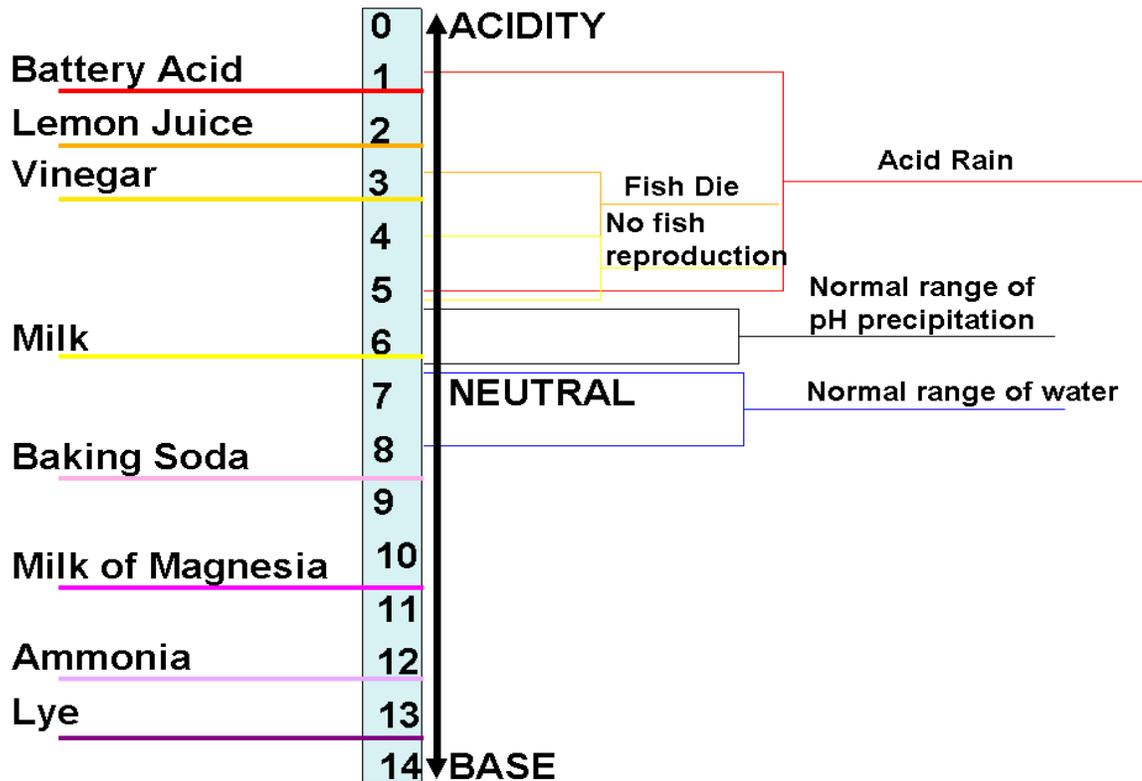
**Biological** characteristics are the presence of living or dead organisms. This will also interact with the chemical composition of the water. The consumer will become sick or complain about hydrogen sulfide odors--the rotten egg smell.

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

<b>FACTOR</b>	<b>TYPE</b>	<b>SOURCE(S)</b>	<b>PROBLEM</b>
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

## 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.

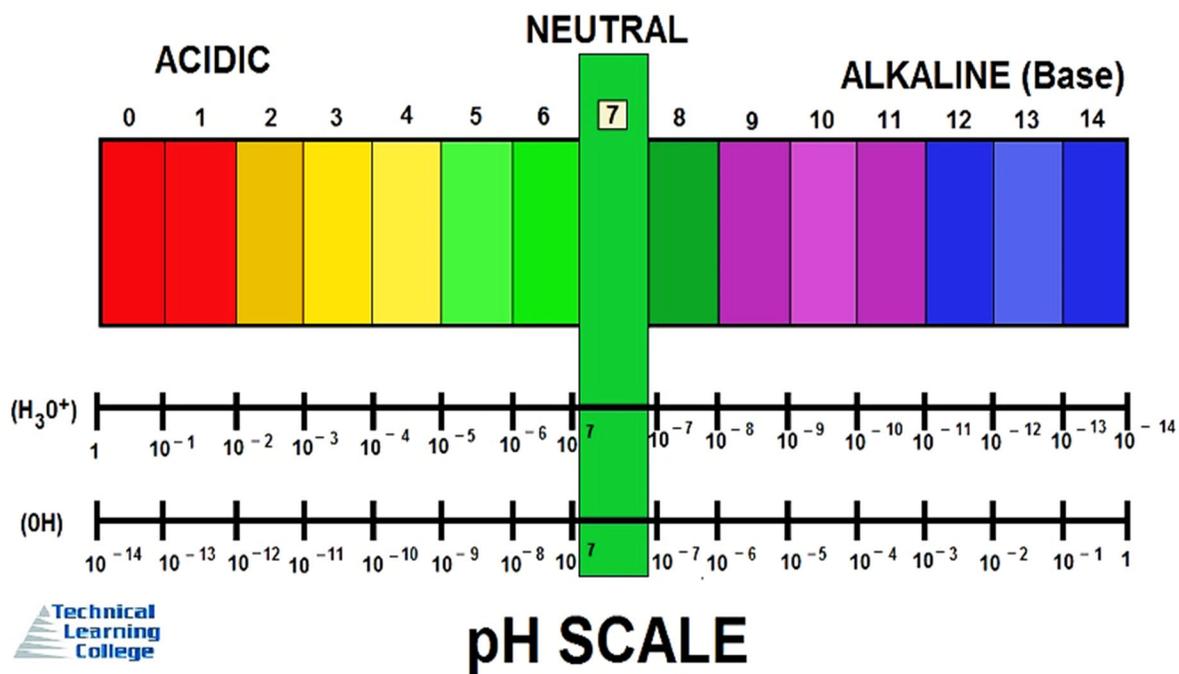
A pH of 7, there are an equal amount or number of hydroxyl (OH-) and Hydrogen (H+) ions in the solution.

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**.

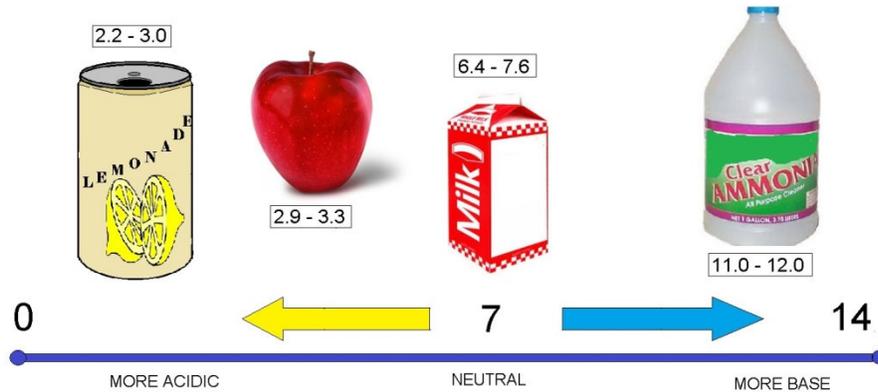
Because the scale is logarithmic, a difference of one pH unit represents a tenfold change. For example, the acidity of a sample with a pH of **5** is ten times greater than that of a sample with a pH of **6**. A difference of 2 units, from **6** to **4**, would mean that the acidity is one hundred times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



**Hydrogen Ion pH Comparison Chart**

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

## pH Testing Section



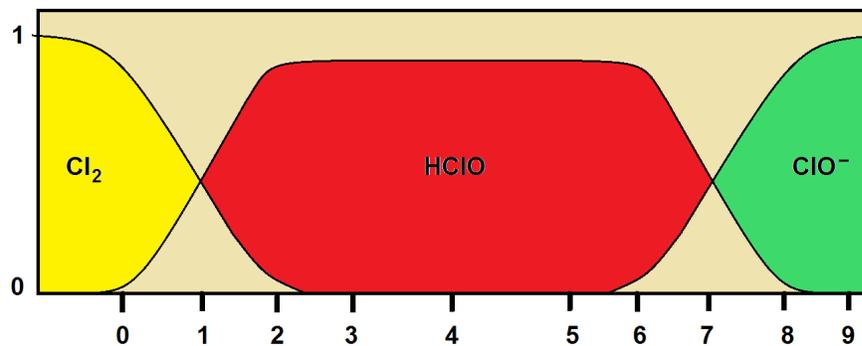
## pH SCALE

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.

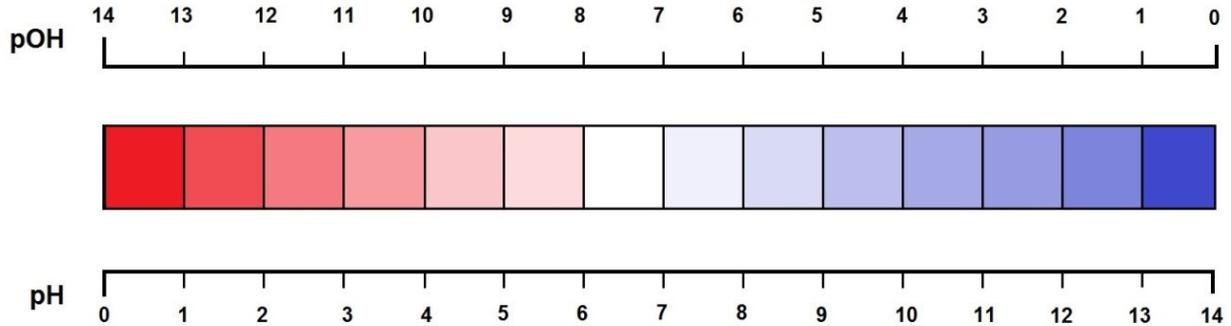
The pH scale is traceable to a set of standard solutions whose pH is established by international agreement.

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 H <sub>2</sub> O	1/10,000,000	14	LIQUID DRAIN CLEANER CAUSTIC SODA	EXAMPLES OF SOLUTIONS AND THEIR RESPECTIVE pH
	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.

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

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

$$E = E^0 + \frac{RT}{F} \ln(a_{H^+}) = E^0 - \frac{2.303RT}{F} pH$$

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<sub>2</sub> | 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<sup>+</sup> 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 or 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,  $\text{OH}^-$ , 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

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]}$$

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

$$\text{pOH} = \text{p}K_w - \text{pH}$$

At room temperature  $\text{pOH} \approx 14 - \text{pH}$ . 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.  $0.003 \text{ mol dm}^{-3}$  acid) and above about 10.5 (ca.  $0.0003 \text{ mol dm}^{-3}$  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  $\text{Na}^+$  and  $\text{K}^+$  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  $\text{p}K_w/2$ , so the pH of pure water is about 7 at  $25^\circ\text{C}$ ; 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  $1 \text{ mol dm}^{-3}$  has a pH of 0. A solution of a strong alkali, such as sodium hydroxide, at concentration  $1 \text{ mol dm}^{-3}$ , 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 **pH<sub>T</sub>**. 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.

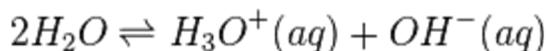
If the pH of a solution contains a weak acid requires the solution of a quadratic equation.

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



with a dissociation constant,  $K_w$  defined as

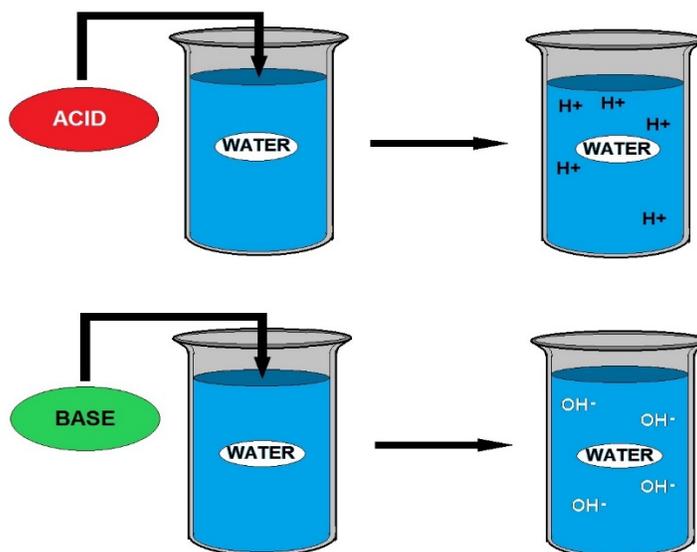
$$K_w = [H^+][OH^-]$$

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.

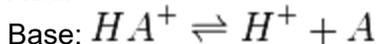
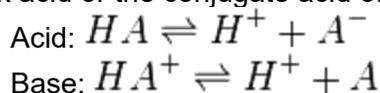
Hydrochloric acid (HCl) is an example of a strong acid. The pH of a 0.01M solution of HCl is equal to  $-\log_{10}(0.01)$ , that is,  $\text{pH} = 2$ .

Sodium hydroxide, NaOH, is an example of a strong base. The  $\text{p}[\text{OH}]$  value of a 0.01M solution of NaOH is equal to  $-\log_{10}(0.01)$ , that is,  $\text{p}[\text{OH}] = 2$ .

From the definition of  $\text{p}[\text{OH}]$  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.



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.

$$\begin{aligned}C_A &= [A] + [HA] \\C_H &= [H] + [HA]\end{aligned}$$

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 ( $\text{CaOH}_2$  or calcium hydroxide), caustic soda ( $\text{NaOH}$  or sodium hydroxide), soda ash ( $\text{Na}_2\text{CO}_3$  or sodium carbonate), and sodium bicarbonate ( $\text{NaHCO}_3$ , 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.

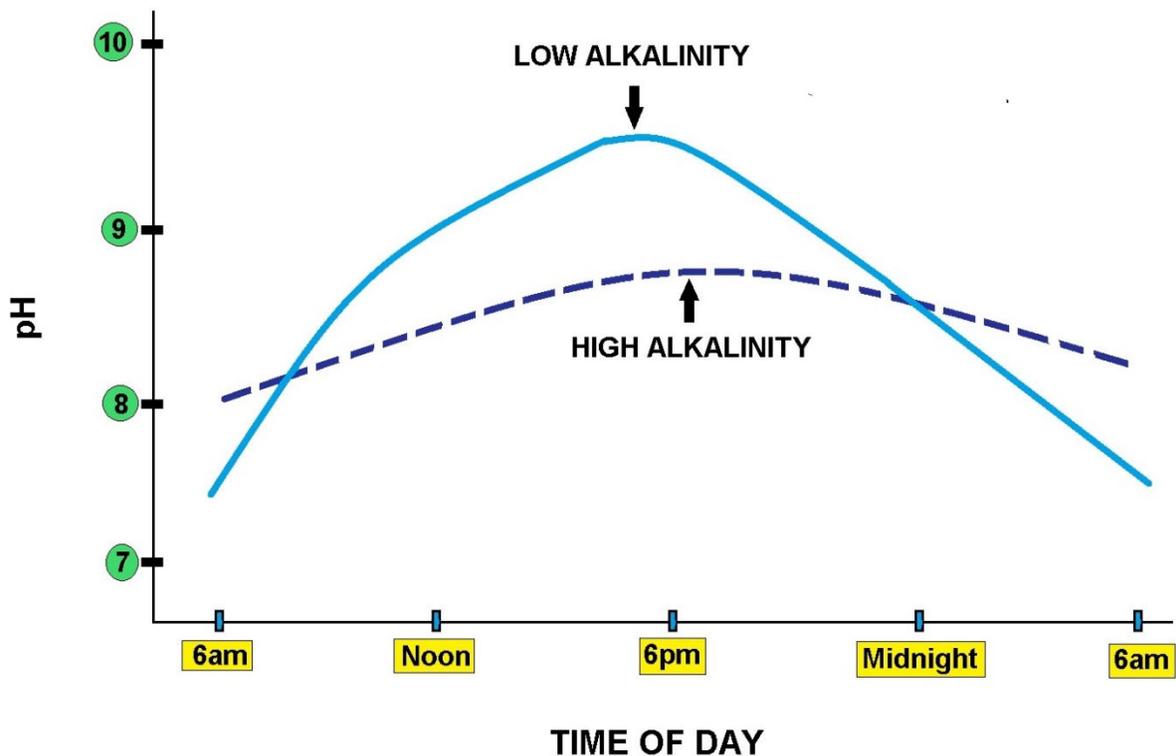
Glassy phosphates, such as sodium hexametaphosphate, effectively reduce iron corrosion at dosages of 20 to 40 mg/l.



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.

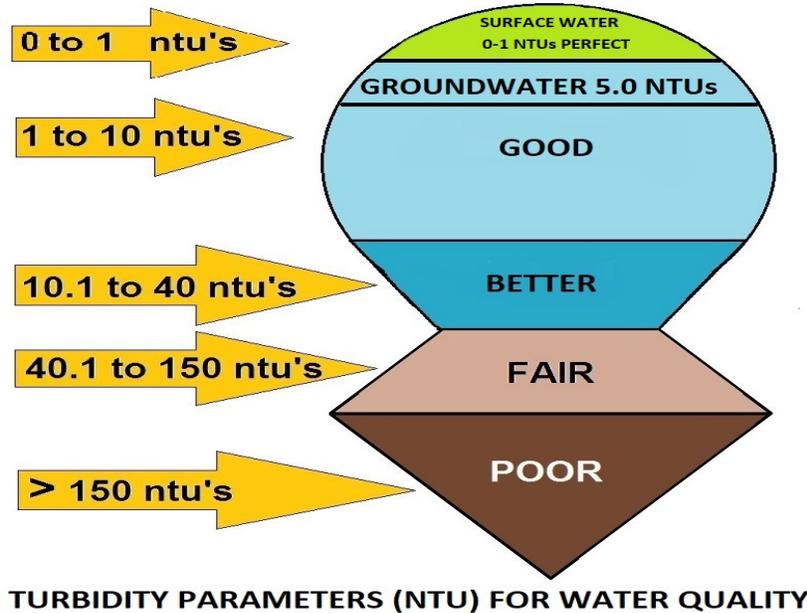
Typical coating maintenance doses range from 2 to 12 mg/l. They offer advantages in hot water systems because of their chemical stability. For this reason, they are often used in the boilers of steam heating systems.



**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.



### 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.

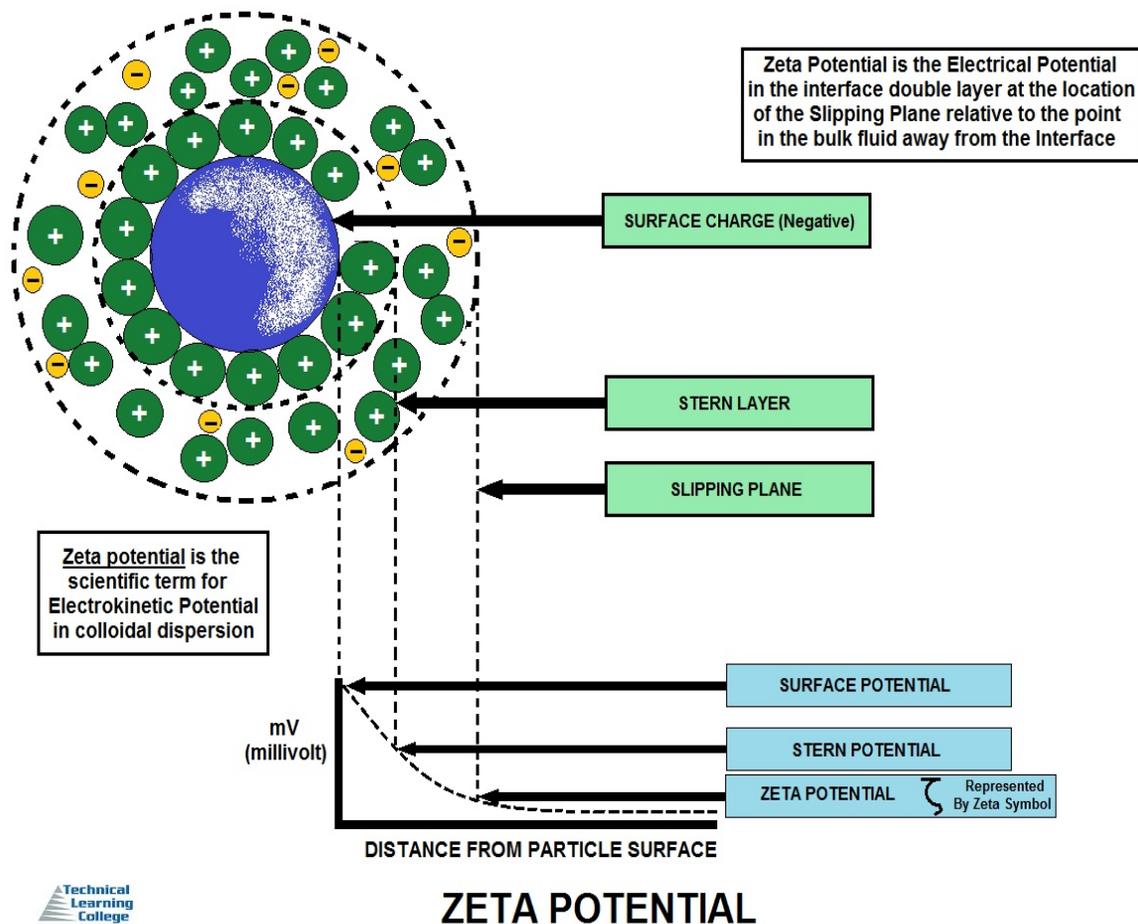
### Turbidity Key

- ▶ 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  $\mu\text{m}$  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**

$$\zeta = \frac{4 \pi q d}{D}$$

An electrostatic force called the “**Zeta Potential**” -

**Where:**

$\zeta$  = 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<sub>2</sub>, 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<sup>6</sup>) 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° 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 ( $\text{Al}_3^+$ ) into the water in the form of Alum ( $\text{Al}_2(\text{SO}_4)_3 \cdot n\text{H}_2\text{O}$ ) 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.  $\text{Al}(\text{OH})_2^+$ ,  $\text{Al}(\text{OH})_2^{1+}$  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.

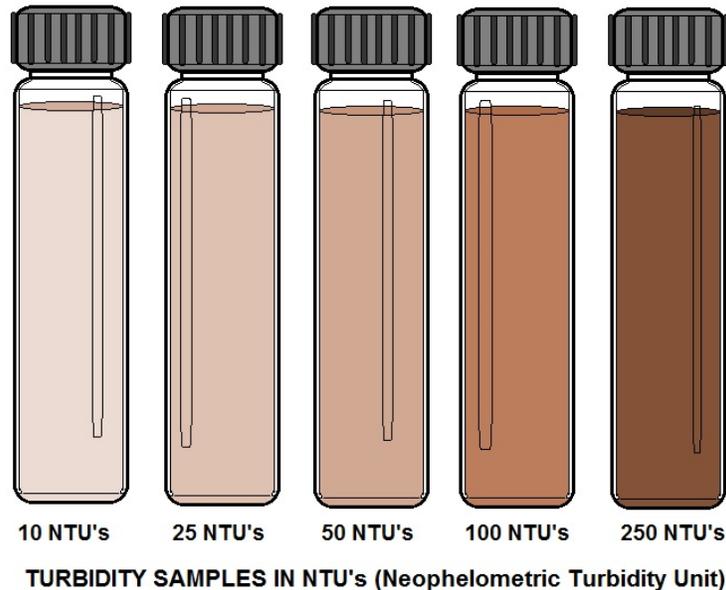
The particles are then able to get close enough together for van der Waals forces to take over and the particles begin to flocculate. The chemical reaction continues until the aluminum ions ( $\text{Al}^{+3}$ ) reach their final form,  $\text{Al}(\text{OH})_3$  (s), and settle out (note – the flocculated particles settle out separately from the precipitated  $\text{Al}(\text{OH})_3$  (s)).

If too much alum is added, then the opposite effect occurs--the particles form sub complexes with the  $\text{Al}^{+3}$  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



### 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

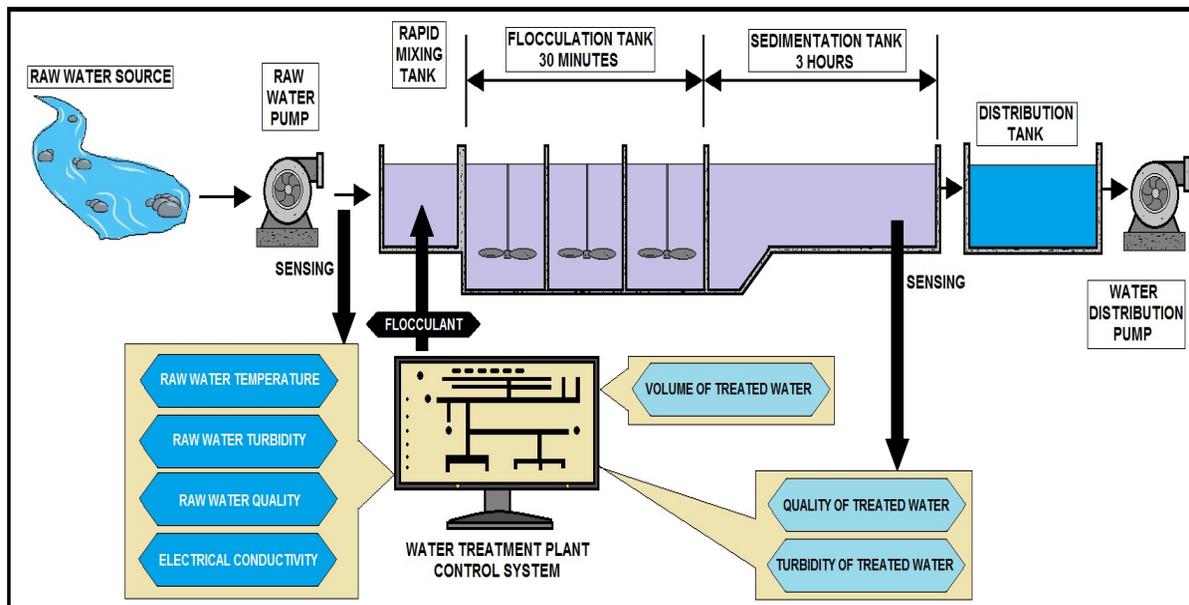
1. Solution I: Dissolve 1.0 gm Hydrazine Sulfate and dilute to 100 mL.
2. Solution II: Dissolve 10.0 gm Hexamethylene tetramine and dilute to 100 mL.
3. Mix 5 mL of I with 5 mL of II. Allow to stand for 24 hrs. at  $25 \pm 3^\circ\text{C}$  and dilute to 100 mL. This solution (III) will have turbidity 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.



This operator is taking a grab sample to measure for turbidity.



### 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.

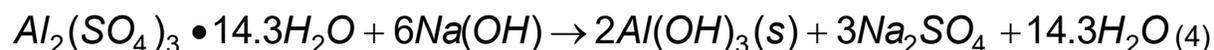
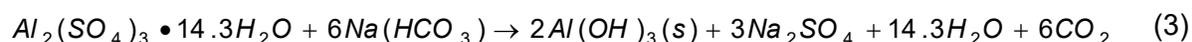
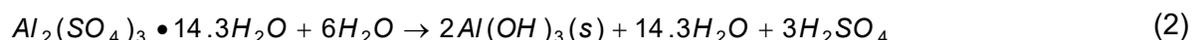
### Scope

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



### 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). ( $\text{Na}^+ = 23 \text{ mg/mmol}$ ,  $\text{O}^{2-} = 16 \text{ mg/mmol}$ ,  $\text{H}^+ = 1 \text{ mg/mmol}$ )
- 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 <sup>a</sup>:

1. Fill the appropriate number of (matched) 1000 mL square transparent jars <sup>b</sup> 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 <sup>a</sup>, 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). <sup>c,d</sup>
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 use 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.



## 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:

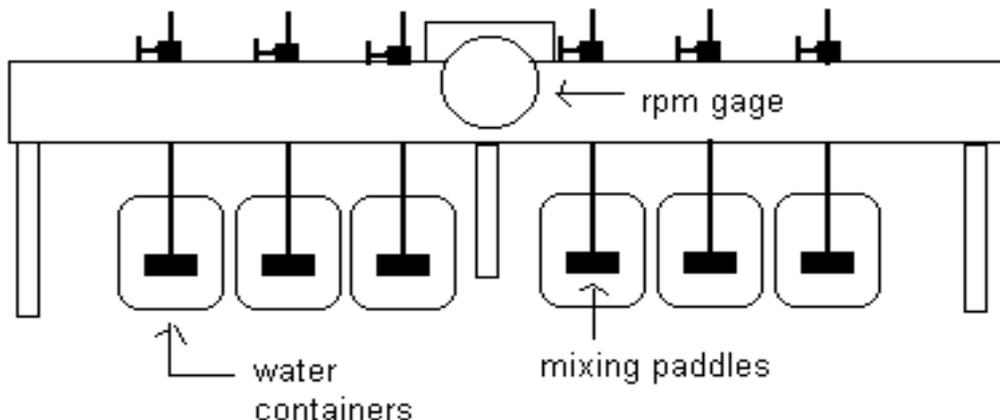
- 250 mL bottles with lids.
- High speed hand mixer (for emulsion polymers).
- Syringes (1cc, 5cc, 10cc).
- 250 and 500 mL beakers.
- Water (it is recommended that the make-down water from the plant be used).
- Graduated cylinder (100 mL).

### Emulsion Polymers (Prepare 1.0% solution.)

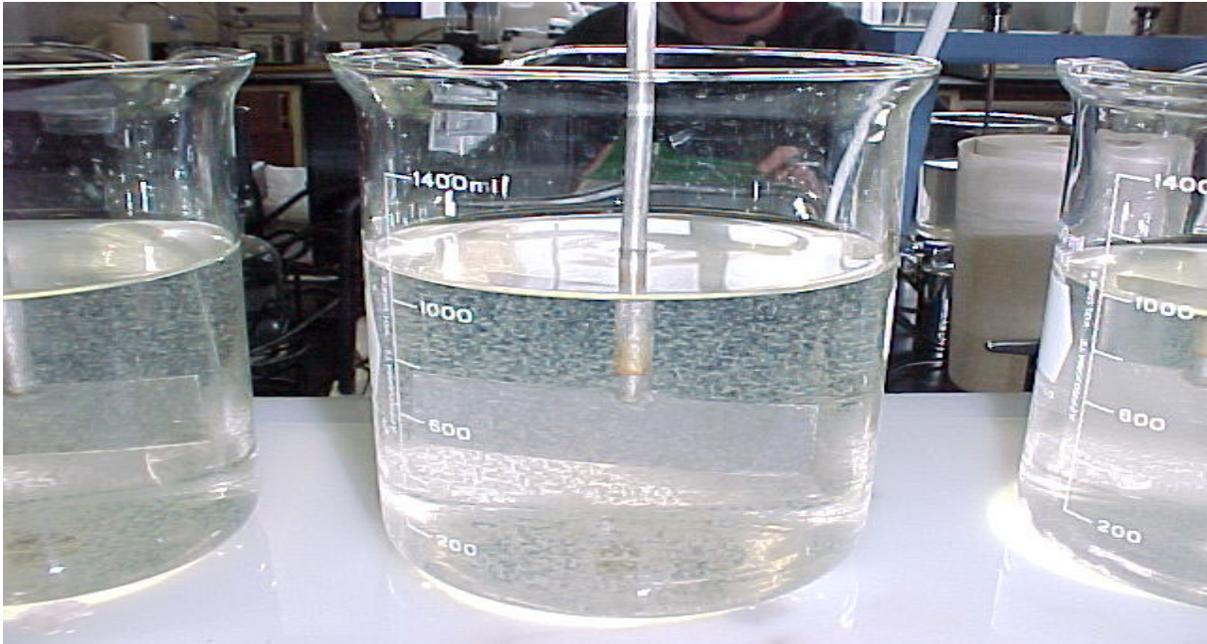
- Add 198 mL of water to a beaker.
- Insert Braun mixer into water and begin mixing.
- Using a syringe, inject 2 mL of neat polymer into vortex.
- Mix for 20 seconds. Do not exceed 20 seconds!
- Allow dilute polymer to age for at least 20 minutes, but preferably overnight. Prepare 0.1% solution.
- Add 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



Jar testing is used to determine what chemical dosage is best.

## Potassium Permanganate Jar Test

Potassium Permanganate has been used for a number of years in both water and wastewater treatment.  $\text{KMnO}_4$  is a strong oxidizer that can be used to destroy many organic compounds of both natural and man-made origin.  $\text{KMnO}_4$  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.

$\text{KMnO}_4$  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 ( $\text{MnO}_2$ ), an insoluble precipitate that can be removed by sedimentation and filtration.

All  $\text{KMnO}_4$  applied must be converted to manganese dioxide ( $\text{MnO}_2$ ) 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 #	$\text{KMnO}_4$ ml	$\text{KMnO}_4$ 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  $\text{KMnO}_4$  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  $\text{KMnO}_4$ .

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  $\text{KMnO}_4$  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,  $\text{KMnO}_4$  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  $\text{KMnO}_4$  for iron and manganese removal, here is the formula to use, based on the amount of iron and manganese in the water:

$$\text{KMnO}_4 \text{ Dose, mg/l} = 0.6(\text{iron, mg/l}) + 2.0(\text{Manganese, mg/l})$$

### Example:

Calculate the  $\text{KMnO}_4$  dose in mg/l for a water with 0.4 of iron. The manganese concentration is 1.2 mg/l.

### Known Unknown

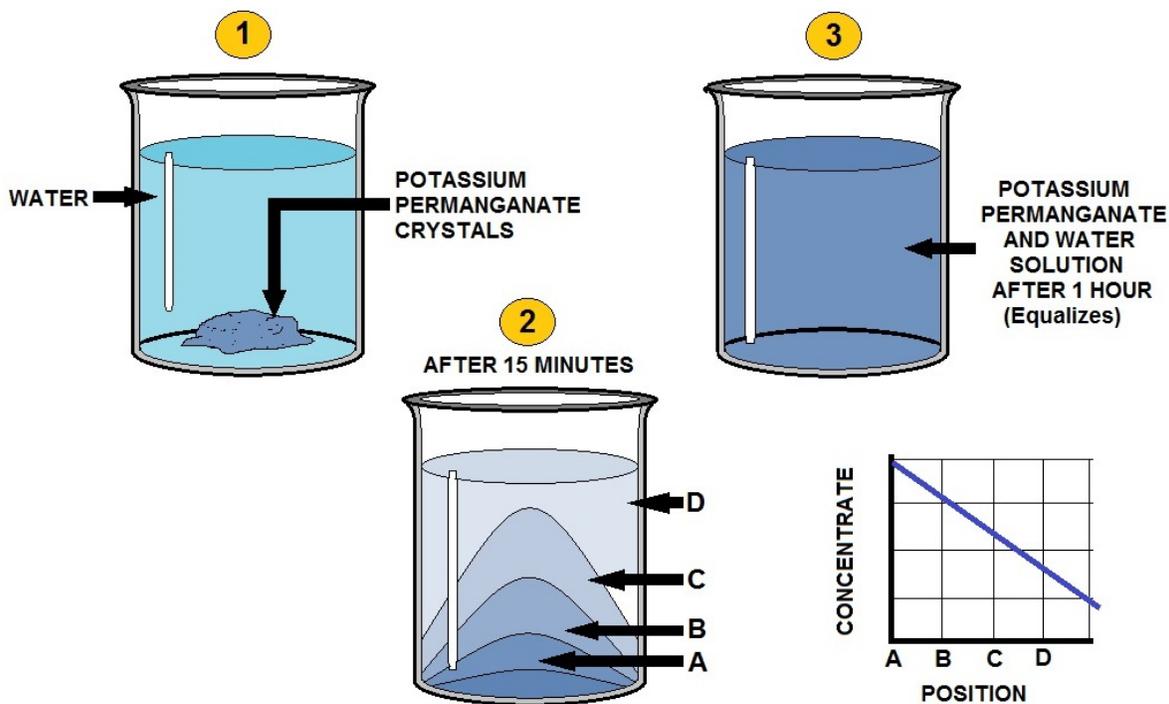
Iron, mg/l = 0.4 mg/l  $\text{KMnO}_4$  Dose, mg/l

Manganese, mg/l = 1.2 mg/l

### Calculate the $\text{KMnO}_4$ dose in mg/l.

$$\begin{aligned} \text{KMnO}_4 \text{ Dose, mg/l} &= 0.6(\text{Iron, mg/l}) + 2.0(\text{Manganese, mg/l}) \\ &= 0.6(0.4 \text{ mg/l}) + 2.0(1.2 \text{ mg/l}) \\ &= 2.64 \text{ mg/l} \end{aligned}$$

**Note:** The calculated 2.64 mg/l  $\text{KMnO}_4$  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.

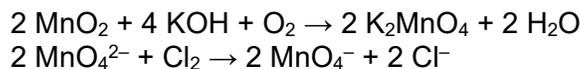


## DIFFUSION OF POTASSIUM PERMANGANATE IN WATER

### Creation of Potassium Permanganate

Potassium permanganate is produced industrially from manganese dioxide ( $\text{MnO}_2$ ), which also occurs as the mineral pyrolusite. The  $\text{MnO}_2$  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.



or:



In which the potassium permanganate is separated by filtering the insoluble manganese dioxide, evaporating the solution to 1/3 and recrystallizing it.



# 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<sub>3</sub>.

## 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<sub>2</sub>CO<sub>3</sub> 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 not 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<sub>3</sub>), mg/l =  $10 V$  or  $N \times V \times 50 \times 1000$

T.A. (as CaCO<sub>3</sub>) =  $\frac{\text{Sample Amount}}{\text{Sample Amount}}$

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 white surface with standard hydrochloric acid.

#### c. Calculation

$$\text{Alkalinity to phenolphthalein (as CaCO}_3\text{), mg/l} = \frac{1000 V_1}{V_2}$$

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>b. Procedure</b> Determine total alkalinity and alkalinity to phenolphthalein and calculate caustic alkalinity as shown in Table below. Result of Titration Caustic Alkalinity as CaCO <sub>3</sub> Hydroxide Alkalinity as CaCO <sub>3</sub> Carbonate Alkalinity as CaCO <sub>3</sub> Bicarbonate Concentration as CaCO <sub>3</sub> <b>Result of Titration</b>	<b>Caustic Alkalinity or Hydroxide Alkalinity as CaCO<sub>3</sub></b>	<b>Carbonate Alkalinity as CaCO<sub>3</sub></b>	<b>Bicarbonate Concentration as CaCO<sub>3</sub></b>
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)  $\text{CaCO}_3$ . 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)**

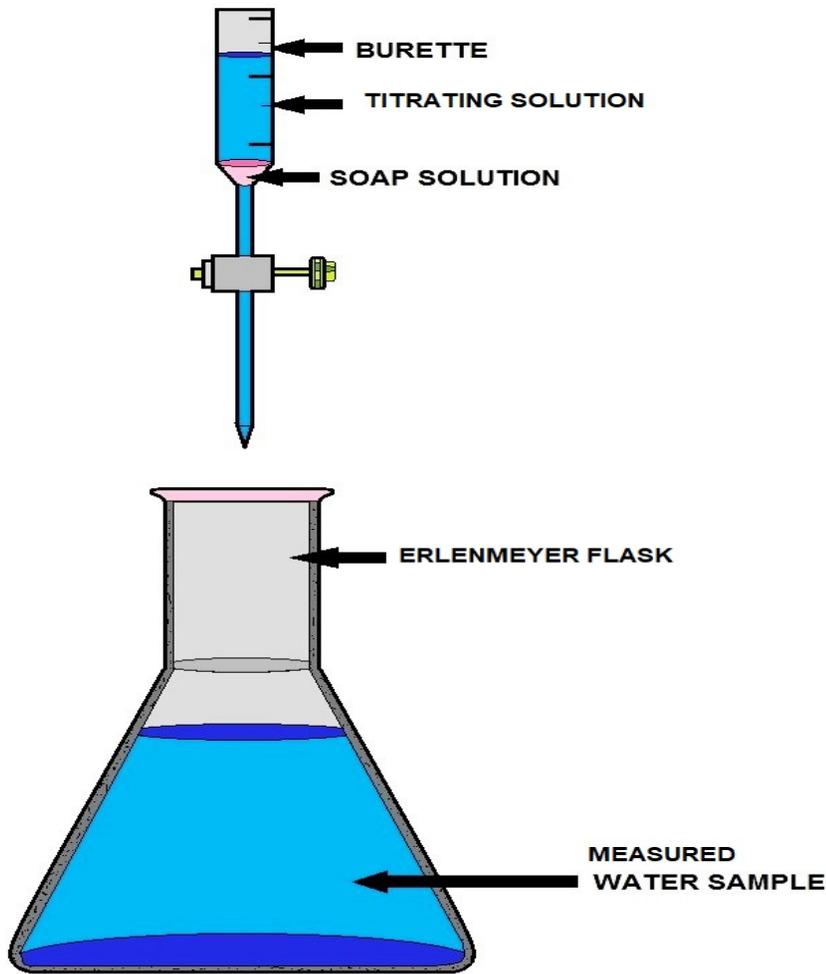
References: Colorimetric-Calcichrome chemistry--Method developed by CHEMetrics, Inc. Titrimetric--APHA Standard Methods, 19th ed., p. 2-36, method 2340 C (1995). EPA Methods for Chemical Analysis of Water and Wastes, method 130.1 (1983).

### **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 ( $\mu\text{g/L}$ )  $\text{CaCO}_3$ . *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)  $\text{CaCO}_3$ .



## TESTING FOR THE HARDNESS OF WATER

WATER HARDNESS (Salt Types)	
CARBONATE HARDNESS COMPOUNDS	NON-CARBONATE HARDNESS COMPOUNDS
CALCIUM CARBONATE ( $\text{CaCO}_3$ )	CALCIUM SULPHATE ( $\text{CaSO}_4$ )
MAGNESIUM CARBONATE ( $\text{MgCO}_3$ )	MAGNESIUM SULPHATE ( $\text{MgSO}_4$ )
CALCIUM BICARBONATE ( $\text{Ca}(\text{HCO}_3)_2$ )	CALCIUM CHLORIDE ( $\text{CaCl}_2$ )
MAGNESIUM BICARBONATE ( $\text{Mg}(\text{HCO}_3)_2$ )	MAGNESIUM CHLORIDE ( $\text{MgCl}_2$ )
CALCIUM HYDROXIDE ( $\text{Ca}(\text{OH})_2$ )	
MAGNESIUM HYDROXIDE ( $\text{Mg}(\text{OH})_2$ )	

**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<sup>-</sup> causes dental fluorosis (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<sup>-</sup> 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 colorimetric 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<sub>4</sub>), 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<sub>6</sub>. Since bleaching is a function of fluoride ions, it is directly proportional to the concentration of F<sup>-</sup>. 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<sub>4</sub> 16 mg/L, SO<sub>4</sub> 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<sub>2</sub>SO<sub>4</sub> concentration.
2. Silver Sulfate Ag<sub>2</sub>SO<sub>4</sub> crystals.
3. SPADNS solution: Dissolve 958 mg SPADNS and dilute to 500 ml.
4. Zirconyl acid reagent: Dissolve 133 mg ZrOCl<sub>2</sub> · 8H<sub>2</sub>O 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<sub>2</sub> and dilute to 1000 ml.
8. **Stock F<sup>-</sup> solution:** Dissolve 221.0 mg anhydrous NaF and dilute to 1000 ml. 1 ml = 100 mg F<sup>-</sup>.
9. **Standard F<sup>-</sup>:** Dilute stock solution 10 times to obtain 1 ml = 10mg F<sup>-</sup>.

### **A. Preliminary Distillation Step**

Place 400 ml distilled water in the distilling flask and carefully add 200 ml conc.  $\text{H}_2\text{SO}_4$ . 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  $180^\circ\text{C}$ . 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  $120^\circ\text{C}$  or below add 300 ml of sample, mix thoroughly, and distill as before until the temperature reaches  $180^\circ\text{C}$ . Do not heat above  $180^\circ\text{C}$  to prevent Sulfate carryover.

Add  $\text{Ag}_2\text{SO}_4$  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)  $\text{NaAsO}_2$  solution 0.1 mg  $\text{Cl}_2$  and mix.  $\text{NaAsO}_2$  conc. should not exceed 1300 mg/L to avoid error due to  $\text{NaAsO}_2$ . 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°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<sup>®</sup> 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<sup>-</sup>.

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.

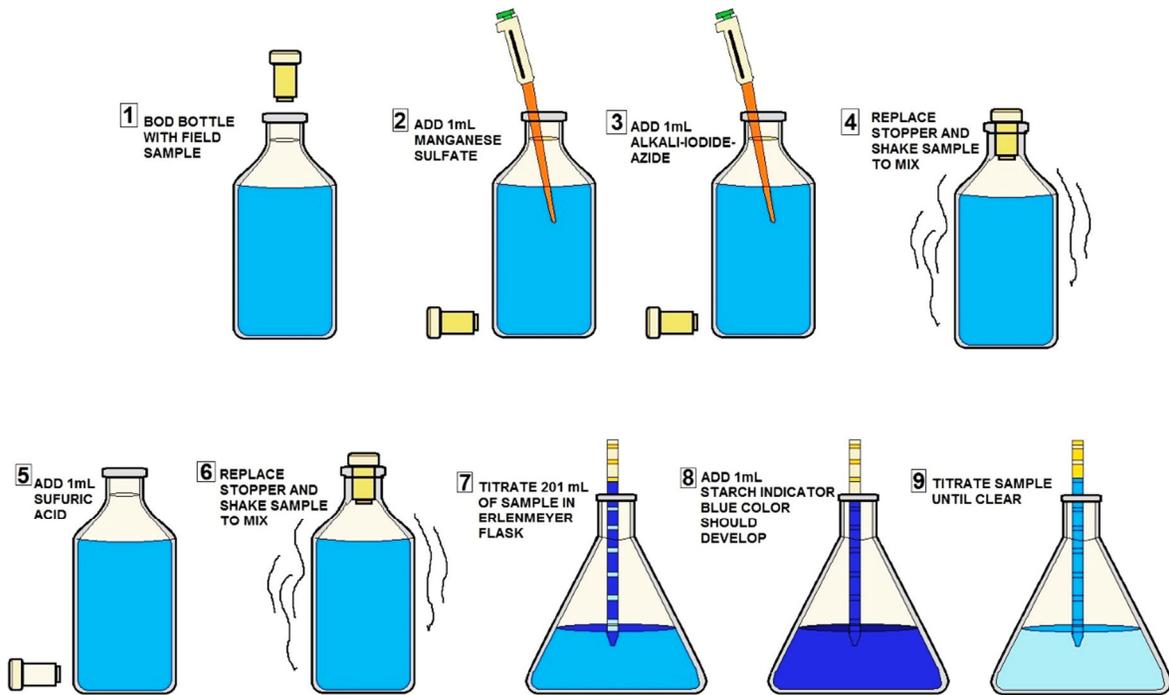
### The Colorimetric Methods

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<sub>2</sub>.

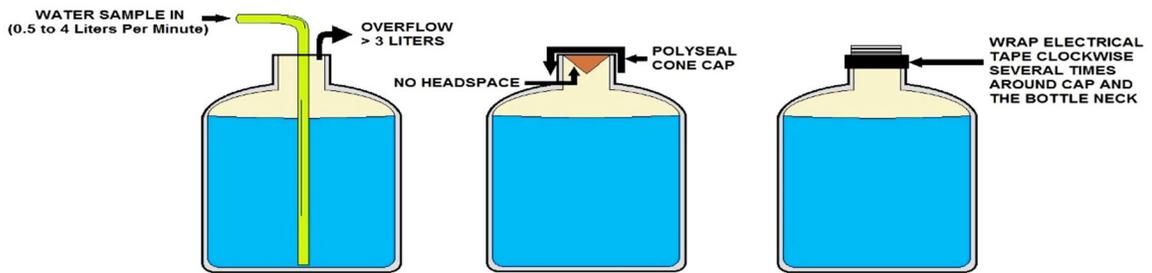
The dissolved oxygen products provide fast, accurate colorimetric oxygen determination. Test kit K-7512 is used to monitor surface waters. ULR CHEMets™ ampoules detect oxygen to 1 ppb. Test kit K-7540 is widely used to monitor boiler feedwater.

### Probe Method

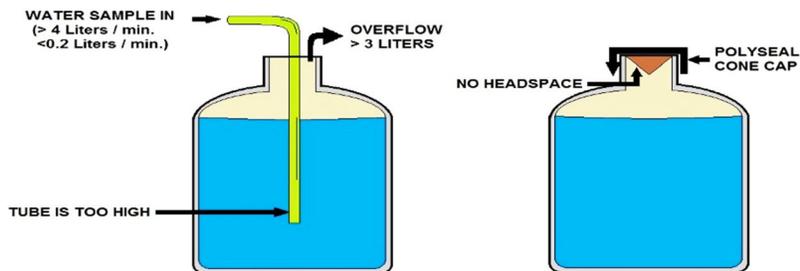
Reliable and accurate D.O. probes are available that can be fitted to 300 ml BOD bottles or other containers for suitable water.



**HOW TO MEASURE DISSOLVED OXYGEN IN A WATER SAMPLE  
DO NOT ALLOW THE PIPETTES 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°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°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<sub>3</sub>. 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<sub>3</sub>.

## Water Quality Summary

A daily chemistry lab sheet will show: Temperature, Turbidity, pH, Alkalinity, Hardness-Calcium and Magnesium, Total Solids, Iron, Fluoride, Free Chlorine, Combined Chlorine, Particle Count, Langelier Index, Log Removal and UV 254.

### Temperature

A measure of the average kinetic energy of the particles in a sample of matter, expressed in terms of units or degrees designated on a standard scale. Depending on how cold or hot the water temperature is, chemical reactions in the process, such as coagulation, will be affected. We are all aware the colder the water, the longer the contact time; consideration must be made when setting the mixing speed due to the viscosity of the water. Disinfection is also influenced by temperature, depending on the amount of demand and contact required. This could increase the formation of THM.

### Turbidity

Particles less than or about 1 to 10  $\mu\text{m}$  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. Lower turbidity improves disinfection and lessens the chance of Viruses and Giardia. 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); or, 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:

$\zeta$  = 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<sub>2</sub>, 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**

- 4.) Jackson Candle Test
- 5.) Secchi Disk - a black and white disk divided like a pie in 4 quadrants about 6" in diameter.
- 6.) Turbidimeter - Light is passed through a sample. A sensitive photomultiplier tube at a 90° 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.
  - a.) *Units* - Nephelometric Turbidity Unit (**NTU**) or Formazin Turbidity Unit (**FTU**).

### **How to Treat Turbidity**

Supercharge the water supply - By supercharging the water supply momentarily with a positive charge, we can upset the charge effect of the particles enough to reduce the Zeta potential (repulsive force) thereby allowing van der Waals forces (attractive forces) to take over.

By introducing aluminum ( $\text{Al}^{3+}$ ) into the water in the form of Alum ( $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ ) 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.  $\text{Al}(\text{OH})_2^+$ ,  $\text{Al}(\text{OH})_2^{1+}$  etc.). These complexes are charged highly positive and therefore upset the stable negative charge of the target particles, thereby displacing the water layer surrounding the charged particle momentarily. 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 ( $\text{Al}^{+3}$ ) reach their final form,  $\text{Al}(\text{OH})_3$  (s), and settle out (note – the flocculated particles settle out separately from the precipitated  $\text{Al}(\text{OH})_3$  (s)).

If too much alum is added then the opposite effect occurs, the particles form sub complexes with the  $\text{Al}^{+3}$  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 would therefore increase the settling time in the clarifier.

## **pH**

The pH of a sample of water is a measure of the concentration of hydrogen ions. The term pH was derived from the manner in which the hydrogen ion concentration is calculated - it is the negative logarithm of the hydrogen ion ( $H^+$ ) concentration. What this means to those of us who are not mathematicians is that at higher pH, there are fewer free hydrogen ions, and that a change of one pH unit reflects a tenfold change in the concentrations of the hydrogen ion. For example, there are 10 times as many hydrogen ions available at a pH of 7 than at a pH of 8. The pH scale ranges from 0 to 14. A pH of 7 is considered to be neutral. Substances with pH of less than 7 are acidic; substances with pH greater than 7 are basic.

The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH may also determine whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.

### **Reasons for Natural Variation**

Photosynthesis uses up dissolved carbon dioxide which acts like carbonic acid ( $H_2CO_3$ ) in water.  $CO_2$  removal, in effect, reduces the acidity of the water and so pH increases. In contrast, respiration of organic matter produces  $CO_2$ , which dissolves in water as carbonic acid, thereby lowering the pH. For this reason, pH may be higher during daylight hours and during the growing season, when photosynthesis is at a maximum. Respiration and decomposition processes lower pH. Like dissolved oxygen concentrations, pH may change with depth in a lake, due again to changes in photosynthesis and other chemical reactions.

There is typically a seasonal decrease in pH in the lower layers of a stratified lake because  $CO_2$  accumulates. There is no light for plants to fix  $CO_2$  and decomposition releases  $CO_2$ . Fortunately, lake water is complex; it is full of chemical "shock absorbers" that prevent major changes in pH. Small or localized changes in pH are quickly modified by various chemical reactions, so little or no change may be measured. This ability to resist change in pH is called buffering capacity. Not only does the buffering capacity control would-be localized changes in pH, but it controls the overall range of pH change under natural conditions. The pH scale may go from 0 to 14, but the pH of natural waters hovers between 6.5 and 8.5.

pH influences how well enhanced coagulation will remove TOC. It also has adverse effects to disinfection and the Distribution system.

### **Alkalinity**

Alkalinity is a total measure of the substances in water that have "acid-neutralizing" ability. Don't confuse alkalinity with pH. pH measures the strength of an acid or base; alkalinity indicates a solution's power to react with acid and "buffer" its pH -- that is, the power to keep its pH from changing.

The main sources of natural alkalinity are rocks, which contain carbonate, bicarbonate, and hydroxide compounds. Borates, silicates, and phosphates may also contribute to alkalinity.

Limestone is rich in carbonates, so waters flowing through limestone regions generally have high alkalinity -- hence it's good buffering capacity. Alkalinity has an impact on enhanced coagulation and SUVA. Without alkalinity corrosion would occur.

### Hardness

Water hardness is a measure of the amount of calcium and magnesium salts in water. Calcium and magnesium enter water mainly through the weathering of rocks. The more calcium and magnesium in water, the harder the water will be.

Water hardness is usually expressed in milligrams per liter (mg/l) of dissolved calcium and magnesium carbonate. The term "hardness" comes from the fact that it is hard to get soapsuds from soap or detergents in hard water. This happens because calcium and magnesium react strongly with negatively-charged chemicals like soap to form insoluble compounds. As a result, hard water can reduce the effectiveness of the cleaning process. This is also known to cause scale formation; it usually correlates with pH increase.

### Total Dissolved Solids

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 give 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. The sources of total dissolved solids can include all of the dissolved cations and anions, but the following table can be used as a generalization of the relationship of TDS to water quality problems.

Cations combined with Carbonates CaCO <sub>3</sub> , MgCO <sub>3</sub> etc.	Associated with hardness, scale formation, bitter taste
Cations combined with Chloride NaCl, KCl	Salty or brackish taste, increase corrosivity

An elevated total dissolved solids (TDS) concentration is not a health hazard. The TDS concentration is a secondary drinking water standard and therefore is regulated because it is more of an aesthetic rather than a health hazard. An elevated TDS indicates the following:

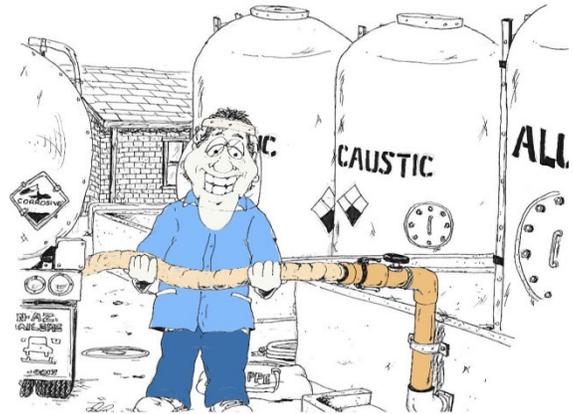
- 1)The concentration of the dissolved ions may cause the water to be corrosive, have a salty or brackish taste, result in scale formation, and interfere and decrease efficiency of hot water heaters; and
- 2)Many contain elevated levels of ions that are above the Primary or Secondary Drinking Water Standards, such as: an elevated level of nitrate, arsenic, aluminum, copper, lead, etc.

### Iron

Iron is part of the Secondary Rules. Iron is one of the most troublesome elements in water supplies. Making up at least 5 percent of the earth's crust, iron is one of the earth's most plentiful resources. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron. It is understandable, therefore, that most groundwater supplies contain some measurable amount of iron. Although present in water, iron is seldom found at concentrations greater than 10 milligrams per liter (mg/l) or 10 parts per million. However, *as little as 0.3 mg/l can cause water to turn a reddish brown color.* Iron stains and contaminates anything it contacts. The resulting stains are usually yellowish-brown to reddish-brown, but may be gray to black in the presence of some organics. *Iron may also cause undesirable odors and tastes in water.*

Iron is mainly present in water in various forms but the two most common forms are either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air or the atmosphere, the water turns cloudy and a reddish brown substance begins to form. This sediment is the oxidized or ferric form of iron that will not dissolve in water.

Manganese is frequently found with and is similar to iron but forms a brownish-black precipitate and stains. Manganese is less commonly found in groundwater than iron, rarely found alone in a water source, and generally found with dissolved iron.



### Fluoride

Fluoride exists naturally in water sources and is derived from fluorine, the thirteenth most common element in the Earth's crust. It is well known that fluoride helps prevent and even reverse the early stages of tooth decay. The primary rule MCL is 4.0 mg/L.

### Free and Combined Residual

When chlorine is added to water, some of the chlorine reacts first with organic materials and metals in the water and is not available for disinfection (this is called the *chlorine demand* of the water). The remaining chlorine concentration after the chlorine demand is accounted for is called *total chlorine*. Total chlorine is further divided into: 1) the amount of chlorine that has reacted with nitrates and is unavailable for disinfection which is called *combined chlorine* and, 2) the *free chlorine*, which is the chlorine available to inactivate disease-causing organisms, and thus a measure to determine the potability of water.

**Particle Count**

Particle counters are instruments currently used in research that have the capacity to count numbers and determine sizes of particles in suspension. Research has shown that reducing the amount of particulate matter in potable water reduces the risk of human pathogens such as *Cryptosporidium parvum* entering drinking water supplies.

Since particle counters have several advantages over turbidity meters, such as a higher sensitivity to changes in water quality at low turbidities (below 0.1 NTU), a higher sensitivity to changes associated with larger particle sizes, and a particle-sizing capability, they may someday replace turbidity meters. However, turbidity meters are the preferred monitoring mechanism for process control of particulate matter in potable water at this time.

**Langelier Index**

The Langelier Saturation Index is a means of evaluating water quality data to determine if the water has a tendency to form a chemical scale. In order to use this index, the following laboratory analysis is needed: pH, conductivity, total dissolved solids, alkalinity, and total hardness. In manipulating the data, the actual pH of the water is compared to the theoretical pH (pHs) based on the chemical analysis.

**The Saturation Index (SI)  $SI = pH - pH_s$** 

The Saturation Index is typically either negative or positive and rarely 0. A Saturation Index of zero indicates that the water is “balanced” and is less likely not to cause scale formation. A negative SI suggests that the water would be undersaturated with respect to carbonate equilibrium and the water may be more likely to have a greater corrosive potential.

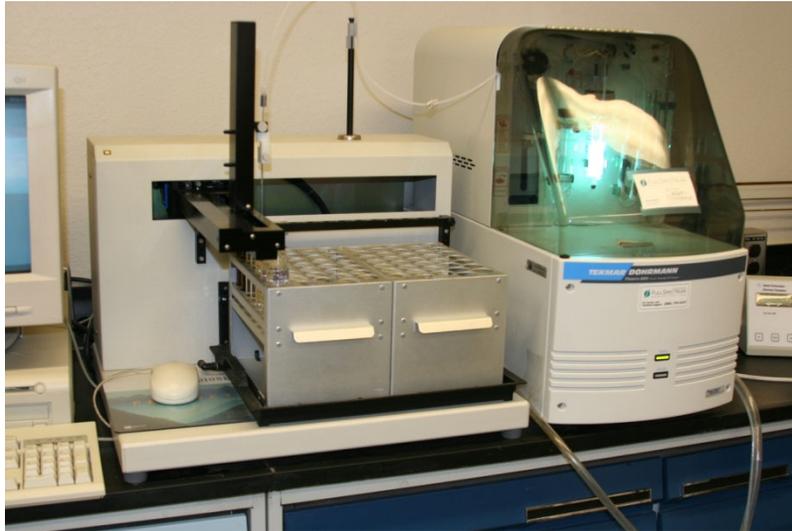
A positive SI suggests that water may be scale forming. The scale, typically a carbonate residue, could clog or reduce the flow in pipes, cause buildup on hot water heaters, impart an alkali taste to the water, reduce the efficiency of the water heaters, and cause other aesthetic problems.

Saturation Index	Description	General Recommendation
- 5	Severe Corrosion	Treatment Recommended
- 4	Severe Corrosion	Treatment Recommended
- 3	Moderate Corrosion	Treatment Recommended
- 2	Moderate Corrosion	Treatment May Be Needed
-1	Mild Corrosion	Treatment May Be Needed
-0.5	None- Mild Corrosion	Probably No Treatment
0	Near Balanced	No Treatment
0.5	Some Faint Coating	Probably No Treatment
1	Mild Scale Coating	Treatment May Be Needed
2	Mild to Moderate Coatings	Treatment May Be Needed
3	Moderate Scale Forming	Treatment Advisable
4	Severe Scale Forming	Treatment Advisable

Please Note- SI Index is not a reliable means of evaluating corrosion potential, but it can be used as a guide.

## UV 254

Total organic carbon (**TOC**) is an important indicator of water quality in drinking water supply systems. Prescribed chlorination rates are often based on TOC levels, and levels of disinfection byproducts (**DBP**) can be subsequently approximated. Unfortunately, TOC is difficult to measure, and some water utilities rely on the more easily measured absorbance of ultraviolet light (specifically at a wavelength of 254 nm, abbreviated UV-254) as a surrogate indicator of organic content. For daily or weekly operating purposes, measurements of UV-254 can provide inexpensive and meaningful prescriptive guidance for disinfection processes.



Water Treatment labs use unit like this to measure total organic carbon (TOC).

## Required EPA Information

- 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.
- EPA must establish a toll-free hot line customers can call to get additional information.
- EPA is required to publish guidelines for states to develop water source assessment programs that delineate protection areas and assess contamination risks.
- EPA is required to identify technologies that are affordable for small systems to comply with drinking water regulations.

### 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.



## Math Formulas and Conversions

$$\text{Acid Feed Rate} = \frac{(\text{Waste Flow}) (\text{Waste Normality})}{\text{Acid Normality}}$$

$$\text{Alkalinity} = \frac{(\text{mL of Titrant}) (\text{Acid Normality}) (50,000)}{\text{mL of Sample}}$$

$$\text{Amperage} = \text{Voltage} \div \text{Ohms}$$

$$\text{Area of Circle} = (0.785)(\text{Diameter}^2) \text{ OR } (\pi)(\text{Radius}^2)$$

$$\text{Area of Rectangle} = (\text{Length})(\text{Width})$$

$$\text{Area of Triangle} = \frac{(\text{Base}) (\text{Height})}{2}$$

$$\text{C Factor Slope} = \text{Energy loss, ft.} \div \text{Distance, ft.}$$

$$\text{C Factor Calculation} = \text{Flow, GPM} \div [193.75 (\text{Diameter, ft.})^{2.63}(\text{Slope})^{0.54}]$$

$$\text{Chemical Feed Pump Setting, \% Stroke} = \frac{(\text{Desired Flow}) (100\%)}{\text{Maximum Flow}}$$

$$\text{Chemical Feed Pump Setting, mL/min} = \frac{(\text{Flow, MGD}) (\text{Dose, mg/L}) (3.785\text{L/gal}) (1,000,000 \text{ gal/MG})}{(\text{Liquid, mg/mL}) (24 \text{ hr. / day}) (60 \text{ min/hr.})}$$

$$\text{Chlorine Demand (mg/L)} = \text{Chlorine dose (mg/L)} - \text{Chlorine residual (mg/L)}$$

$$\text{Circumference of Circle} = (3.141) (\text{Diameter})$$

$$\text{Composite Sample Single Portion} = \frac{(\text{Instantaneous Flow}) (\text{Total Sample Volume})}{(\text{Number of Portions}) (\text{Average Flow})}$$

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Digested Sludge Remaining, \%} = \frac{(\text{Raw Dry Solids}) (\text{Ash Solids}) (100\%)}{(\text{Digested Dry Solids}) (\text{Digested Ash Solids})}$$

$$\text{Discharge} = \frac{\text{Volume}}{\text{Time}}$$

$$\text{Dosage, lbs/day} = (\text{mg/L})(8.34)(\text{MGD})$$

Dry Polymer (lbs.) = (gal. of solution) (8.34 lbs/gal)(% polymer solution)

Efficiency, % =  $\frac{(\text{In} - \text{Out}) (100\%)}{\text{In}}$

Feed rate, lbs/day =  $\frac{(\text{Dosage, mg/L}) (\text{Capacity, MGD}) (8.34 \text{ lbs/gals})}{(\text{Available fluoride ion}) (\text{Purity})}$

Feed rate, gal/min (Saturator) =  $\frac{(\text{Plant capacity, gal/min.}) (\text{Dosage, mg /L})}{18,000 \text{ mg/L}}$

Filter Backwash Rate =  $\frac{\text{Flow}}{\text{Filter Area}}$

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.)

Gallons/Capita/Day =  $\frac{\text{Gallons / day}}{\text{Population}}$

Hardness =  $\frac{(\text{mL of Titrant}) (1,000)}{\text{mL of Sample}}$

Horsepower (brake) =  $\frac{(\text{Flow, gpm}) (\text{Head, ft})}{(3,960) (\text{Efficiency})}$

Horsepower (motor) =  $\frac{(\text{Flow, gpm}) (\text{Head, ft})}{(3960) (\text{Pump, Eff}) (\text{Motor, Eff})}$

Horsepower (water) =  $\frac{(\text{Flow, gpm}) (\text{Head, ft})}{(3960)}$

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

Mean Cell Residence Time (MCRT) =  $\frac{\text{Suspended Solids in Aeration System, lbs}}{\text{SS Wasted, lbs / day} + \text{SS lost, lbs / day}}$

Organic Loading Rate =  $\frac{\text{Organic Load, lbs BOD / day}}{\text{Volume}}$

$$\text{Oxygen Uptake} = \frac{\text{Oxygen Usage}}{\text{Time}}$$

$$\text{Pounds per day} = (\text{Flow, MGD}) (\text{Dose, mg/L}) (8.34)$$

$$\text{Population Equivalent} = \frac{(\text{Flow MGD}) (\text{BOD, mg/L}) (8.34 \text{ lbs / gal})}{\text{Lbs BOD / day / person}}$$

$$\text{RAS Suspended Solids, mg/l} = \frac{1,000,000}{\text{SVI}}$$

$$\text{RAS Flow, MGD} = \frac{(\text{Infl. Flow, MGD}) (\text{MLSS, mg/l})}{\text{RAS Susp. Sol., mg/l} - \text{MLSS, mg/l}}$$

$$\text{RAS Flow \%} = \frac{(\text{RAS Flow, MGD}) (100 \%)}{\text{Infl. Flow, MGD}}$$

$$\text{Reduction in Flow, \%} = \frac{(\text{Original Flow} - \text{Reduced Flow}) (100\%)}{\text{Original Flow}}$$

$$\text{Slope} = \frac{\text{Drop or Rise}}{\text{Run or Distance}}$$

$$\text{Sludge Age} = \frac{\text{Mixed Liquor Solids, lbs}}{\text{Primary Effluent Solids, lbs / day}}$$

$$\text{Sludge Index} = \frac{\% \text{ Settleable Solids}}{\% \text{ Suspended Solids}}$$

$$\text{Sludge Volume Index} = \frac{(\text{Settleable Solids, \%}) (10,000)}{\text{MLSS, mg/L}}$$

$$\text{Solids, mg/L} = \frac{(\text{Dry Solids, grams}) (1,000,000)}{\text{mL of Sample}}$$

$$\text{Solids Applied, lbs/day} = (\text{Flow, MGD})(\text{Concentration, mg/L})(8.34 \text{ lbs/gal})$$

$$\text{Solids Concentration} = \frac{\text{Weight}}{\text{Volume}}$$

$$\text{Solids Loading, lbs/day/sq. ft} = \frac{\text{Solids Applied, lbs / day}}{\text{Surface Area, sq. ft}}$$

$$\text{Surface Loading Rate} = \frac{\text{Flow}}{\text{Rate}}$$

$$\text{Total suspended solids (TSS), mg/L} = \frac{(\text{Dry weight, mg})(1,000 \text{ mL/L})}{(\text{Sample vol., mL})}$$

$$\text{Velocity} = \frac{\text{Flow}}{\text{Area}} \quad \text{O R} \quad \frac{\text{Distance}}{\text{Time}}$$

$$\text{Volatile Solids, \%} = \frac{(\text{Dry Solids} - \text{Ash Solids}) (100\%)}{\text{Dry Solids}}$$

$$\text{Volume of Cone} = (1/3)(0.785)(\text{Diameter}^2)(\text{Height})$$

$$\text{Volume of Cylinder} = (0.785)(\text{Diameter}^2)(\text{Height}) \text{ OR } (\pi)(r^2)(h)$$

$$\text{Volume of Rectangle} = (\text{Length})(\text{Width})(\text{Height})$$

$$\text{Volume of Sphere} = [(\pi)(\text{diameter}^3)] \div 6$$

$$\text{Waste Milliequivalent} = (\text{mL}) (\text{Normality})$$

$$\text{Waste Normality} = \frac{(\text{Titrant Volume}) (\text{Titrant Normality})}{\text{Sample Volume}}$$

$$\text{Weir Overflow Rate} = \frac{\text{Flow}}{\text{Weir Length}}$$

### **Conversion Factors**

1 acre = 43,560 square feet

1 cubic foot = 7.48 gallons

1 foot = 0.305 meters

1 gallon = 3.785 liters

1 gallon = 8.34 pounds

1 grain per gallon = 17.1 mg/L

1 horsepower = 0.746 kilowatts

1 million gallons per day = 694.45 gallons per minute

1 pound = 0.454 kilograms

1 pound per square inch = 2.31 feet of water

1% = 10,000 mg/L

Degrees Celsius = (Degrees Fahrenheit - 32) (5/9)

Degrees Fahrenheit = (Degrees Celsius \* 9/5) + 32

64.7 grains = 1 cubic foot

1,000 meters = 1 kilometer

1,000 grams = 1 kilogram

# 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 Treatment Section Answers

1. pH, 2. Shear pin, 3. Detention Time, 4. NaOH (also called Sodium Hydroxide), 5. Polymer, 6. Coagulation, 7. Stuck together, 8. Coagulant chemicals, 9. False, 10. True, 11. False, 12. True, 13. True, 14. True

## 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



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