WATER TREATMENT PRIMER 1

CONTINUING EDUCATION
PROFESSIONAL DEVELOPMENT COURSE

Technical
Learning
College

Printing and Saving Instructions

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

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

You can complete the course by viewing the course on your computer or you can print it out. This course booklet does not have the assignment. Please visit our website and download the assignment (the test).

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

Hyperlink to Assignment…
http://www.abctlc.com/downloads/PDF/WTPrimer1ASS.pdf

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 Do not solely trust our list for it may be outdated.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

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

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

You can obtain a printed version from TLC for an additional $129.95 plus shipping charges.

All downloads are electronically tracked and monitored for security purposes.

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

Do not solely depend on TLC's Approval list for it may be outdated.

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

Responsibility
This course contains EPA's federal rule requirements. Please be aware that each state implements drinking water / 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.

Copyright Notice

1999-2020 Technical Learning College (TLC) No part of this work may be reproduced or distributed in any form or by any means without TLC's prior written approval. Permission has been sought for all images and text where we believe copyright exists and where the copyright holder is traceable and contactable. Other materials including text and artwork are in the public domain or fair use (the state of belonging or being available to the public as a whole, and therefore not subject to copyright.) All material that is not credited or acknowledged or referenced in the rear of this course is the copyright of Technical Learning College. All other unacknowledged references are in TLC's Safety, Pump, Sampling and Chemistry courses in the rear of the manuals. Most unaccredited photographs have been taken by TLC instructors or TLC students. All written, graphic, photographic or other material is provided for educational information only. We will be pleased to hear from any copyright holder and will make good on your work if any unintentional copyright infringements were made as soon as these issues are brought to the editor's attention. This educational training course and assignment is intended for educational purposes only. Every possible effort was made to ensure that all information provided in this course is accurate. Therefore, Technical Learning College accepts no responsibility or liability whatsoever for the application or misuse of any information included herein.

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

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

Contributing Editors

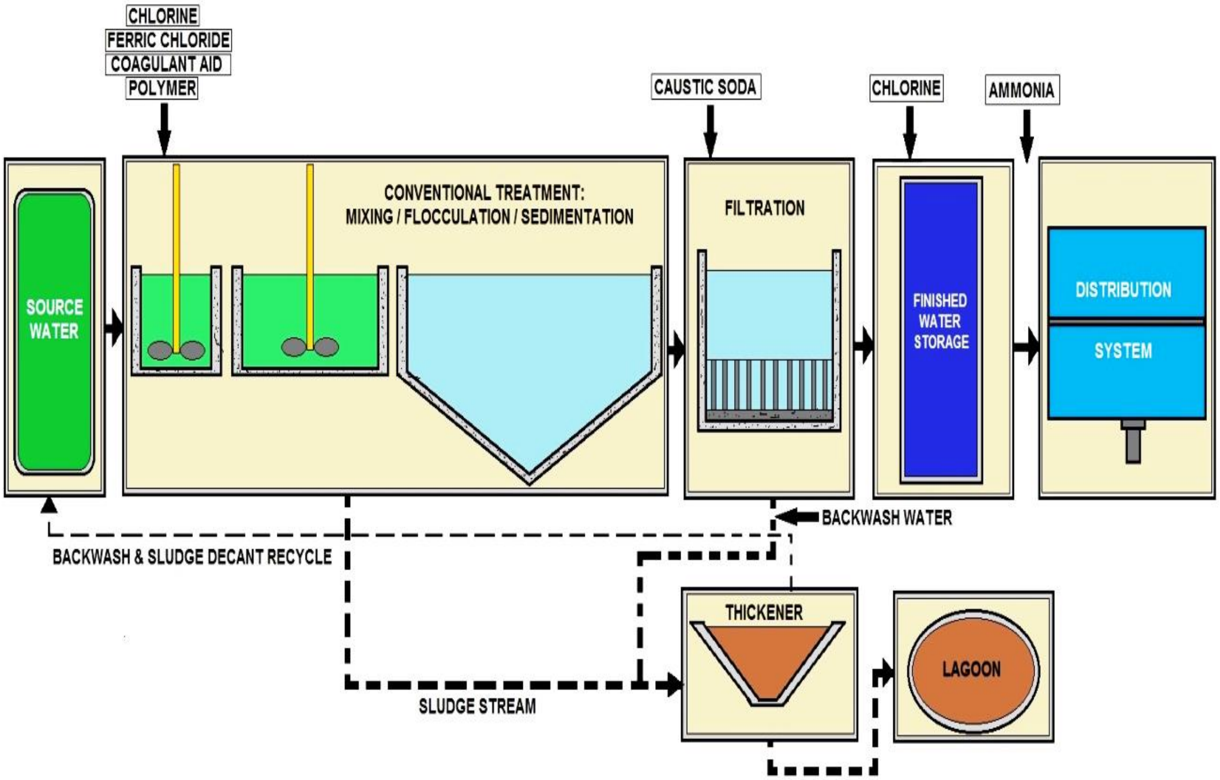
James L. Six Received a Bachelor of Science Degree in Civil Engineering from the University of Akron in June of 1976, Registered Professional Engineer in the State of Ohio, Number 45031 (Retired), Class IV Water Supply Operator issued by Ohio EPA, Number WS4-1012914-08, Class II Wastewater Collection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

Joseph Camerata has a BS in Management with honors (magna cum laude). He retired as a Chemist in 2006 having worked in the field of chemical, environmental, and industrial hygiene sampling and analysis for 40 years.

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

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

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



SURFACE WATER CONVENTIONAL TREATMENT

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. This course is only a guideline and general information for continuing education.

Technical Learning College's Scope and Function

Welcome to the Program,

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

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

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

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

Flexible Learning

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

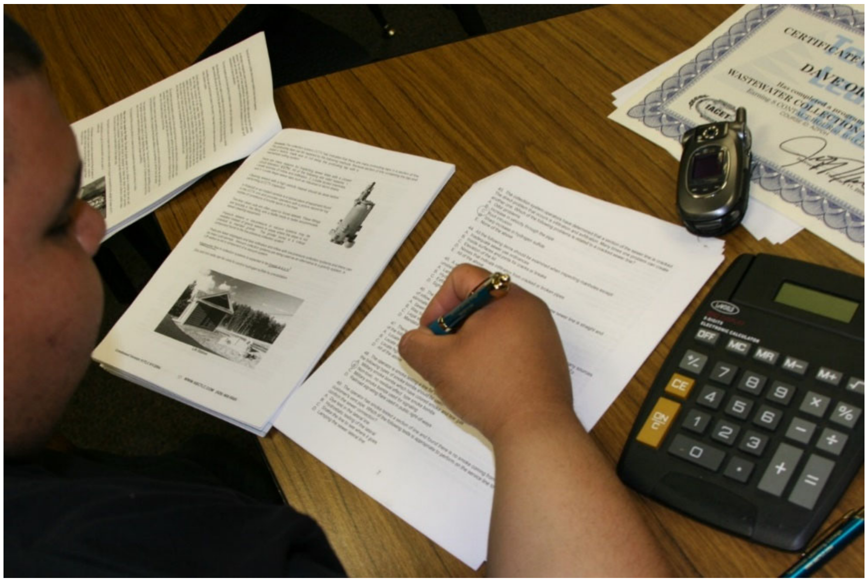
Course Structure

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

Classroom of One

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

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



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

We welcome you to complete the assignment in Word.

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

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

Water Treatment Primer 1 Training Course Description

This is an 8 contact hour training course will cover conventional surface water treatment processes, methods and chemistry fundamentals, starting at the source of water and ending with disinfection to delivery through the distribution system to the customer's tap. As professional Operators, we need to make sure that our finished water meets federal compliance and minimum standards.

Water Distribution, Well Drillers, Pump Installers, Water Treatment Operators, Water Treatment Specialists and Customer Service Personnel are welcomed to take this course. The target audience for this course is the person interested in working in a water treatment or distribution facility and/or wishing to maintain CEUs for a certification license or to learn how to do the job safely and effectively and/or to meet education needs for promotion.

Task Analysis and Training Needs Assessments have been conducted to determine or set Needs-To-Know for this CEU course. The following is a listing of some of those who have conducted extensive valid studies from which TLC has based this program upon: the Environmental Protection Agency (EPA), the Arizona Department of Environmental Quality (ADEQ), the Texas Commission of Environmental Quality (TCEQ) and the American Boards of Certification (ABC).

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 TLC's correspondence courses have complete registration and support service offered. Delivery of service 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 or she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work. If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request. All students will be tracked by a unique assigned number.

Instructions for Written Assignments

The Water Treatment Primer 1 training course uses a multiple-choice and fill-in-the-blank answer key. You can find the Microsoft Word version on the Assignment page. We would prefer the answers are typed and faxed or e-mailed to info@tlch2o.com. If you are unable to do so, please write inside the assignment booklet, make a copy for yourself and mail us the completed manual. Please feel free to call us if you need assistance.

Other Student Information

Feedback Mechanism (Examination procedures)
Each student will receive a feedback form as part of their study packet. You will be able to find this form in the front of the course assignment or lesson. By completing this form, you can help us improve our course and serve your need better in the future.

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 the student forfeiting all fees, and the appropriate agency will be notified.

Grading Criteria

TLC offers the student either pass/fail or a standard letter grading assignment if we are notified by the student. If we are not notified, you will only receive a certificate for passing the test.

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.

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.

Note to Students

Keep a copy of everything that you submit! If your work is lost, you can submit your copy for grading. If you do not receive your certificate of completion or other results within two to three weeks after submitting it, please contact your instructor.

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.

Mission Statement

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

TABLE OF CONTENTS (Learning Objective Legend on Page 13)

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

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

Topic Legend

This CEU course covers several different educational topics/functions/purposes/objectives of conventional water treatment, filtration processes, bacteriological monitoring and regulatory compliance. The topics listed below are to assist in determining which educational objective or goal is covered for a specific topic area:

CRAO - Compliance and Regulatory Affairs: The regulatory and compliance component of your need to know. May be a requirement of the SDWA 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.

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

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

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

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

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

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

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

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

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

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

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

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

Significant Potential Source of Contamination. A facility or activity that stores, uses, or produces chemicals or elements, and that has the potential to release contaminants identified in a state program (contaminants with MCLs plus any others a state considers a health threat) within a source water protection area in an amount which could contribute significantly to the concentration of the contaminants in the source waters of the public water supply.

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

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

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

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

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

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

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

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

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

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

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

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

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

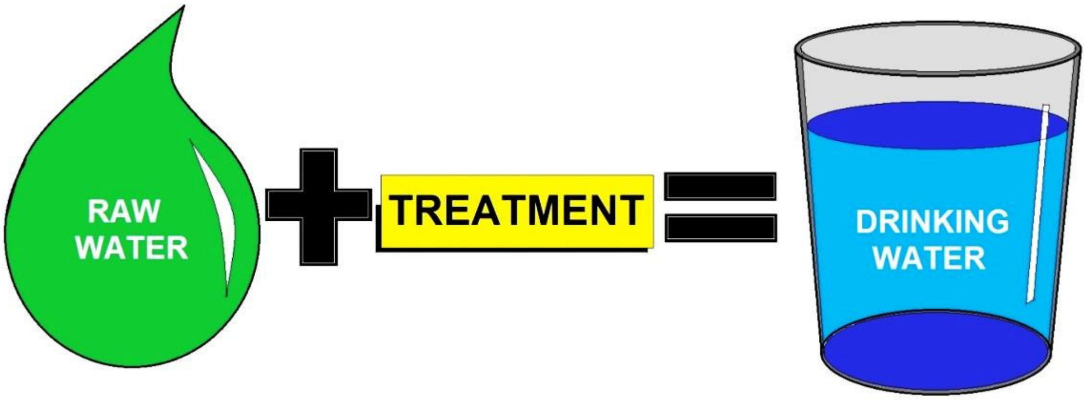
Watershed. A topographic boundary area that is the perimeter of the catchment area of a stream.

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

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

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

Preface



Safe Drinking Water Act of 1974 Introduction

(Public Law 93-523) as amended by:

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

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

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

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

National Drinking Water Regulations

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

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

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

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

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

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

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

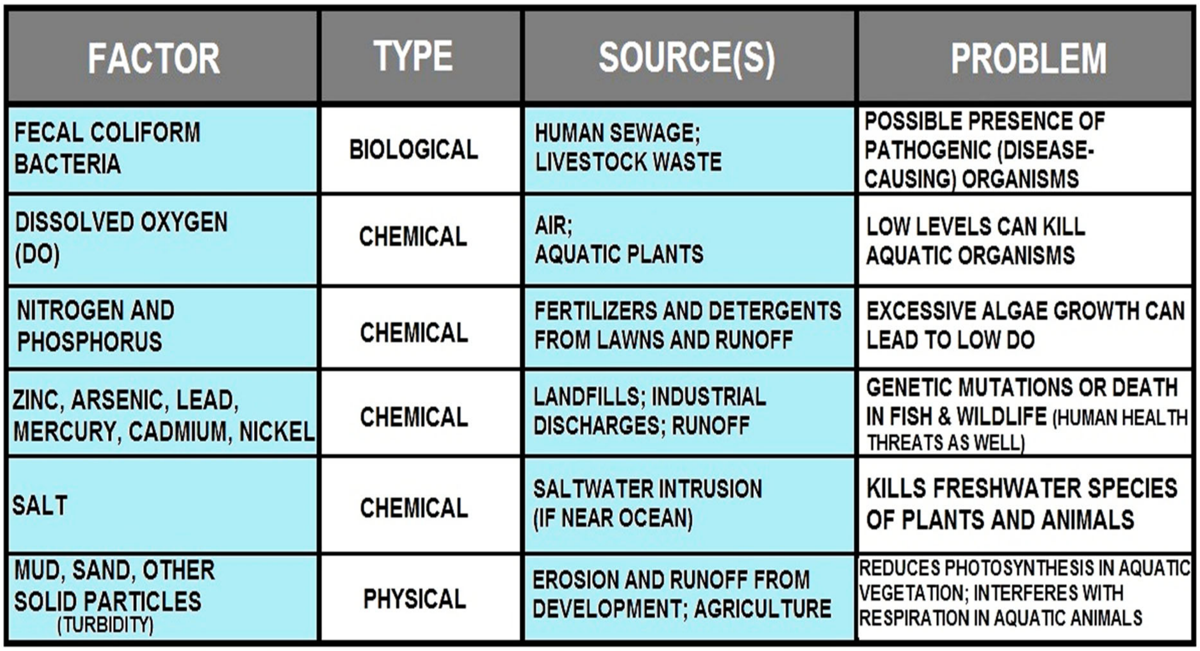
Also, when proposing a regulation, the EPA must now publish a determination as to whether or not the benefits of the standard justify the costs. If the EPA determines that the benefits do not justify the costs, the EPA may, with certain exceptions, promulgate a standard that maximizes health risk reduction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

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

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 the student 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.

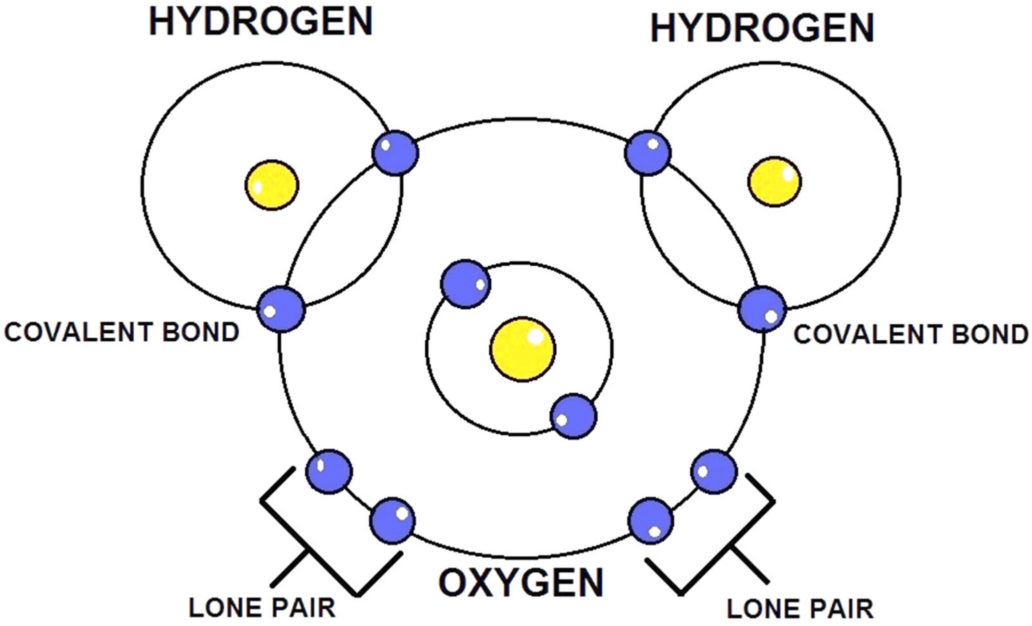
Radionuclide Rule Promulgated 2000 Contained 4 contaminants, Targeted: Radionuclides.

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.

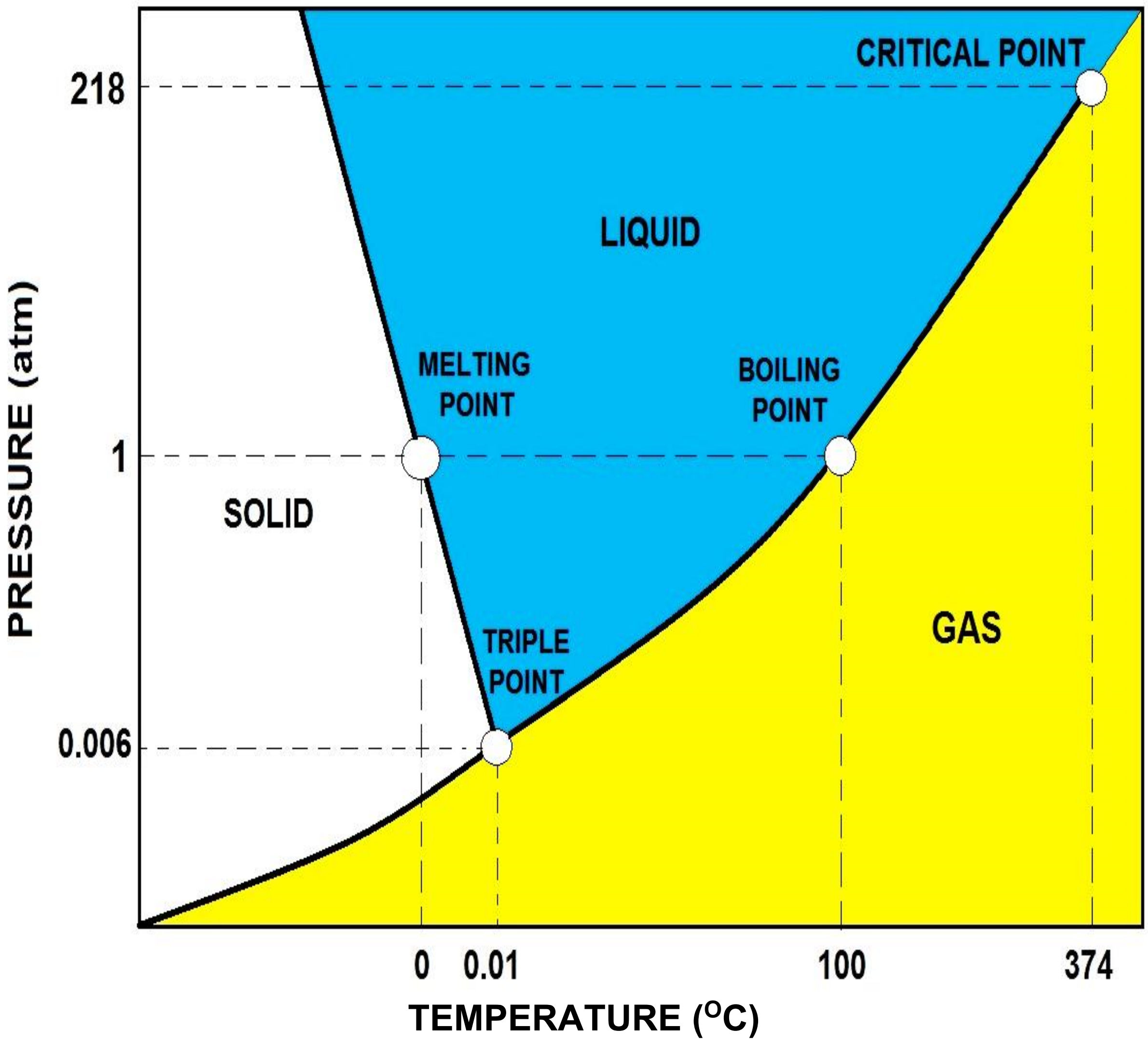


WATER MOLECULE DIAGRAM

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.

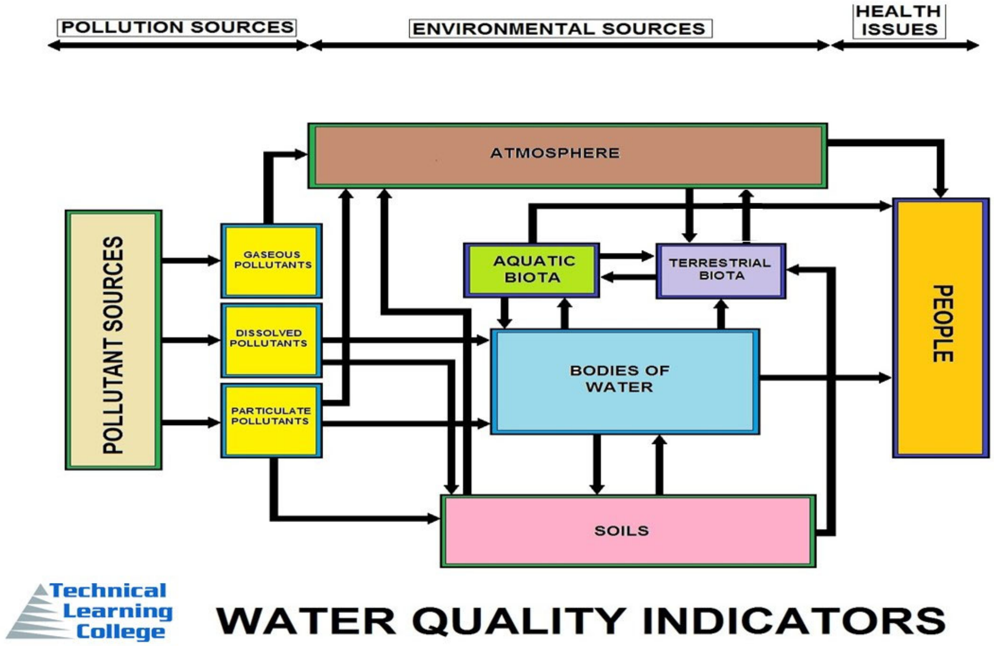


WATER PHASE DIAGRAM

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.

Surface (Raw) Water Introduction

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



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.

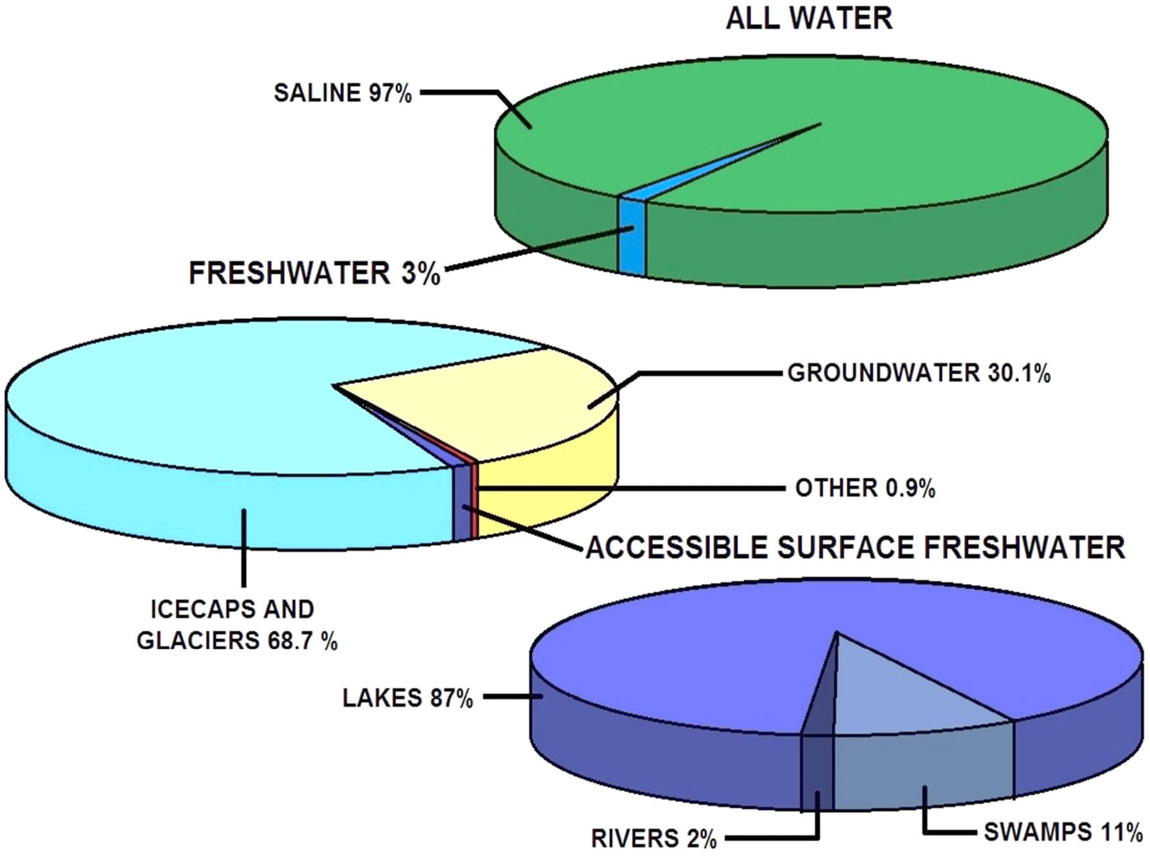
These characteristics have a direct influence on the most effective types of treatment methods and/or chemicals. The improvement of water quality and formation of policy measures (administrative and engineering) revolves around these characteristics.

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.



FRESHWATER DISTRIBUTION BREAKDOWN

Surface water is usually contaminated and unsafe to drink without proper treatment. 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.

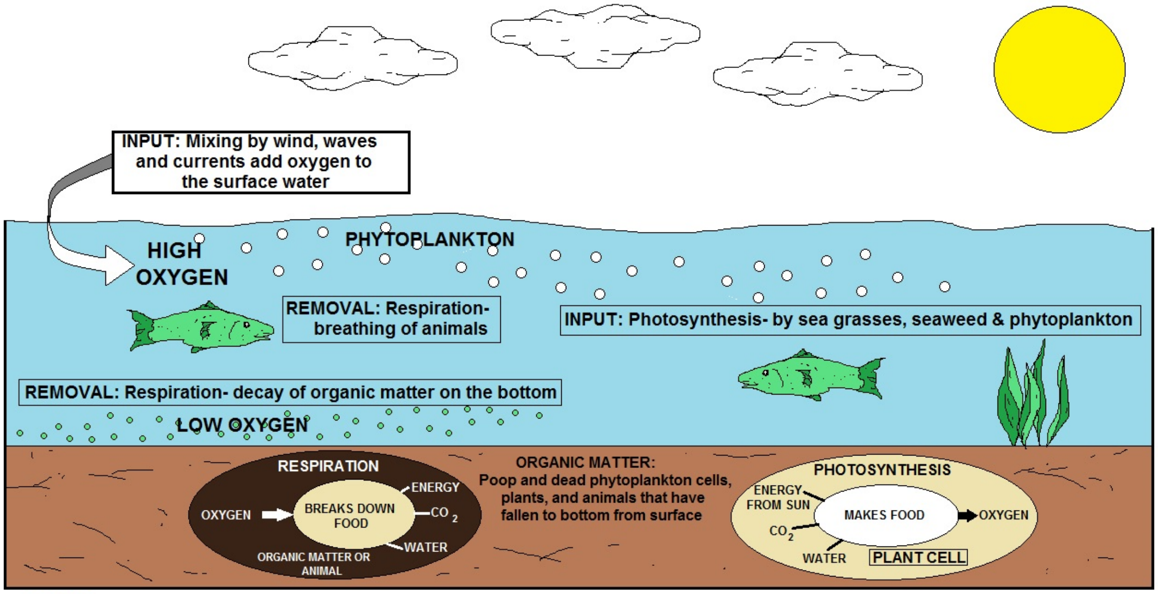
Surface Water Properties

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.

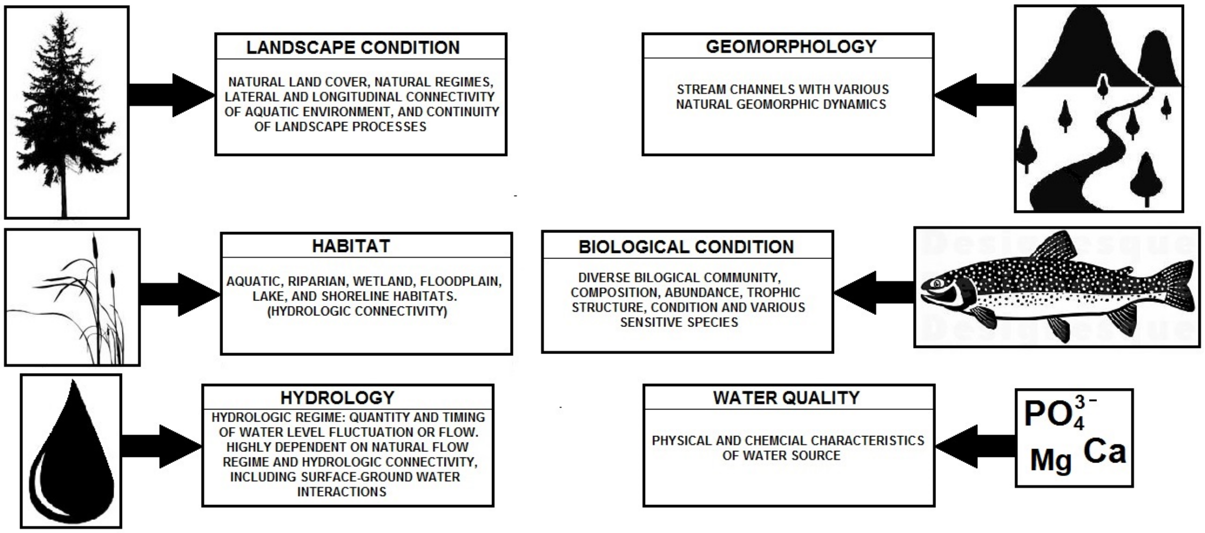
Most treatment plant upsets such as taste and odor, color, and filter clogging is due to algae. The type of algae determines the problem it will cause, for instance slime, corrosion, color, and toxicity. Algae can be controlled in the water supply by using chemicals such as copper sulfate.

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.

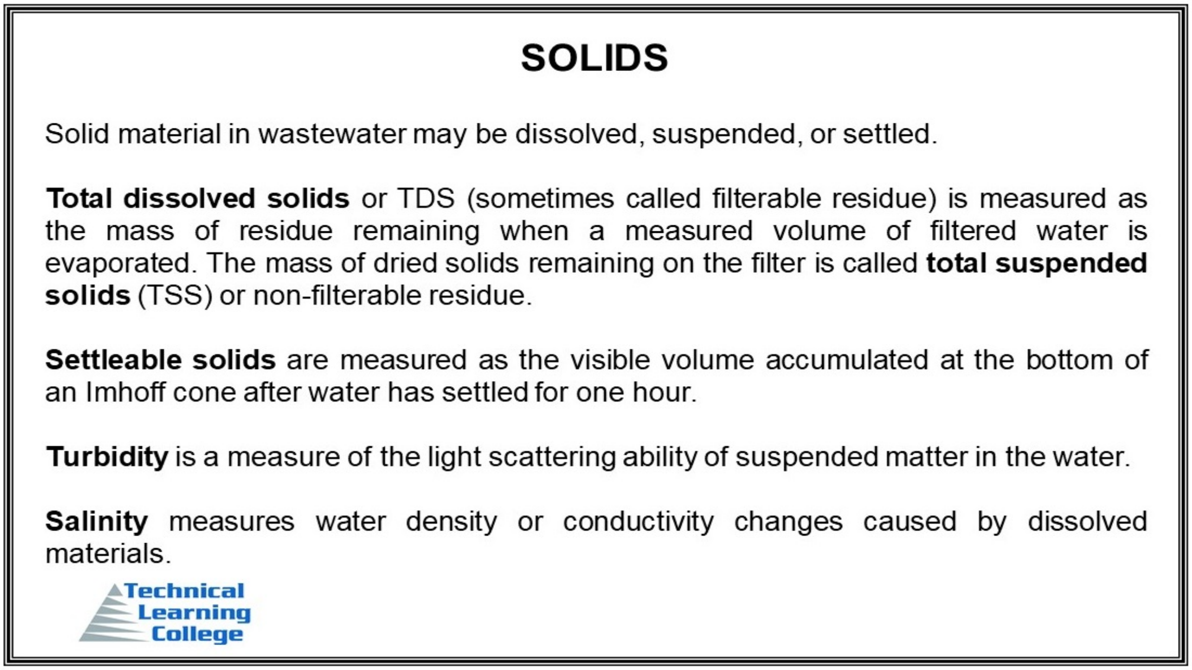
Physical Characteristics of Water

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



ATTRIBUTES OF HEALTHY WATERSHED

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



SOLIDS

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

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

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

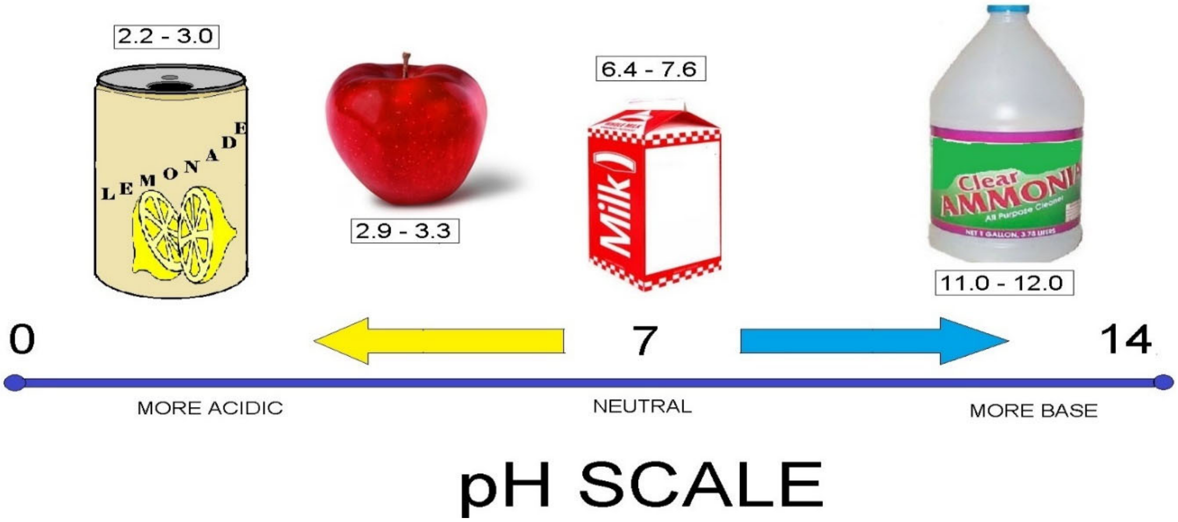
Turbidity is a measure of the light scattering ability of suspended matter in the water.

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

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.



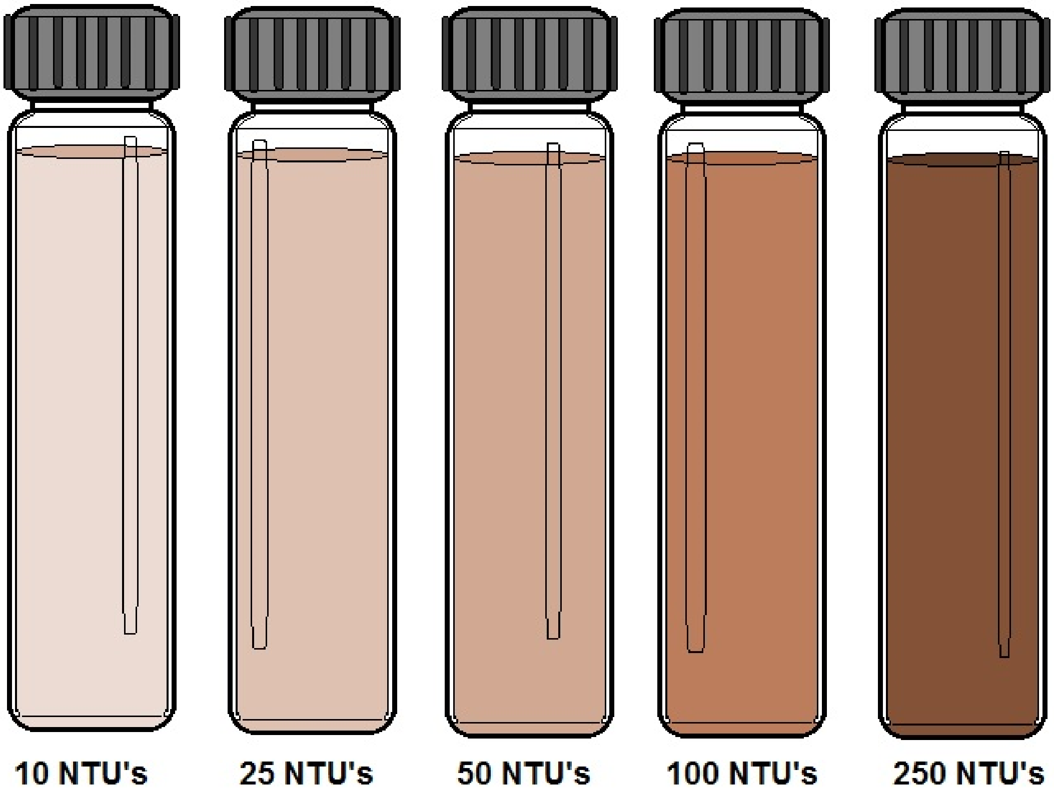
Alkalinity

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

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

Alkalinity Measurements

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



TURBIDITY SAMPLES IN NTU's (Neophelometric Turbidity Unit)

Turbidity Introduction

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

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

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

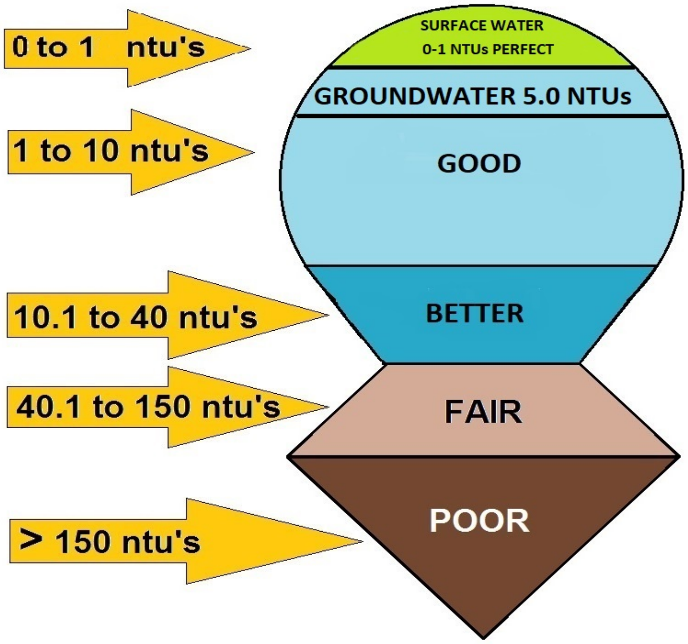
Generally, higher turbidity levels require higher coagulant dosages. However, seldom is the relationship between turbidity level and coagulant dosage linear. Usually, the additional coagulant required is relatively small when turbidities are much higher than normal due to higher collision probabilities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

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

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

Turbidity MCL

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



TURBIDITY PARAMETERS (NTU) FOR WATER QUALITY

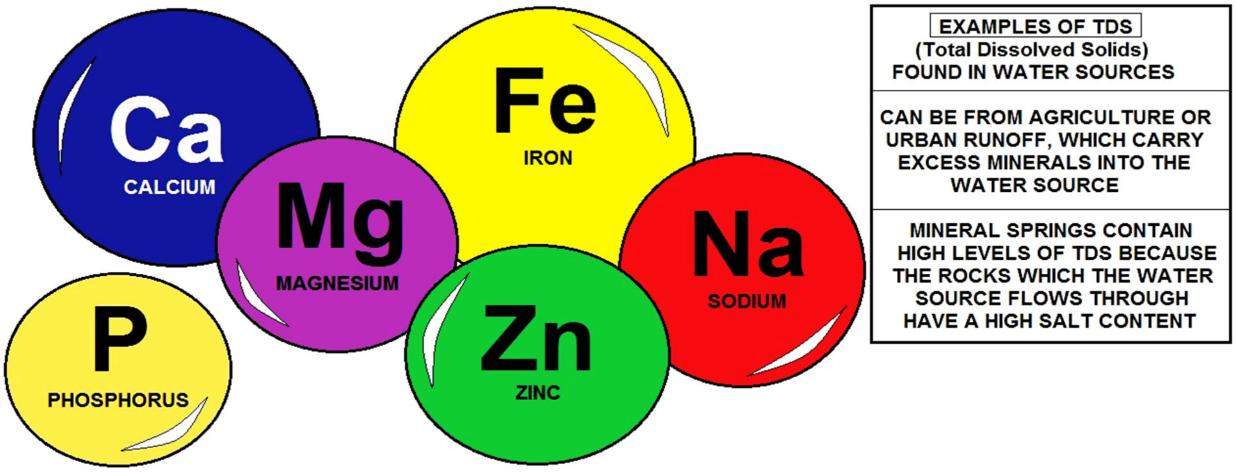
Surface Water System Compliance Information
(Depends on Systems and Rule)

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

Turbidity Key

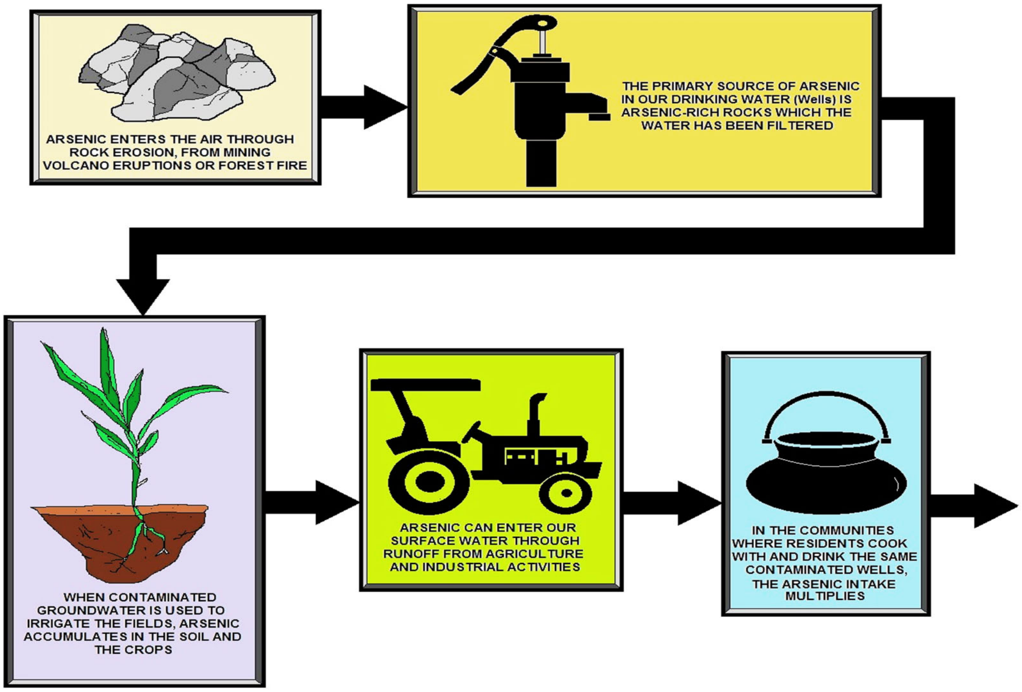
- Turbidity can also be measured in ppm (parts per million) and its size is measured in microns. Turbidity can be particles in the water consisting of finely divided solids, larger than molecules, but not visible by the naked eye; ranging in size from .001 to .150mm (1 to 150 microns).

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

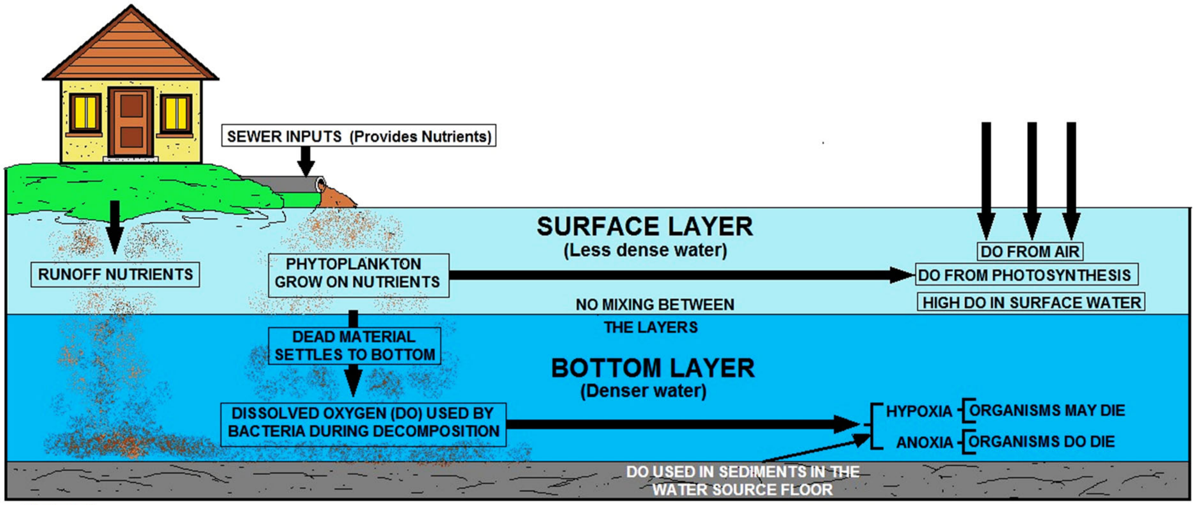


MINERALS THAT AFFECT THE QUALITY OF WATER SOURCE

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



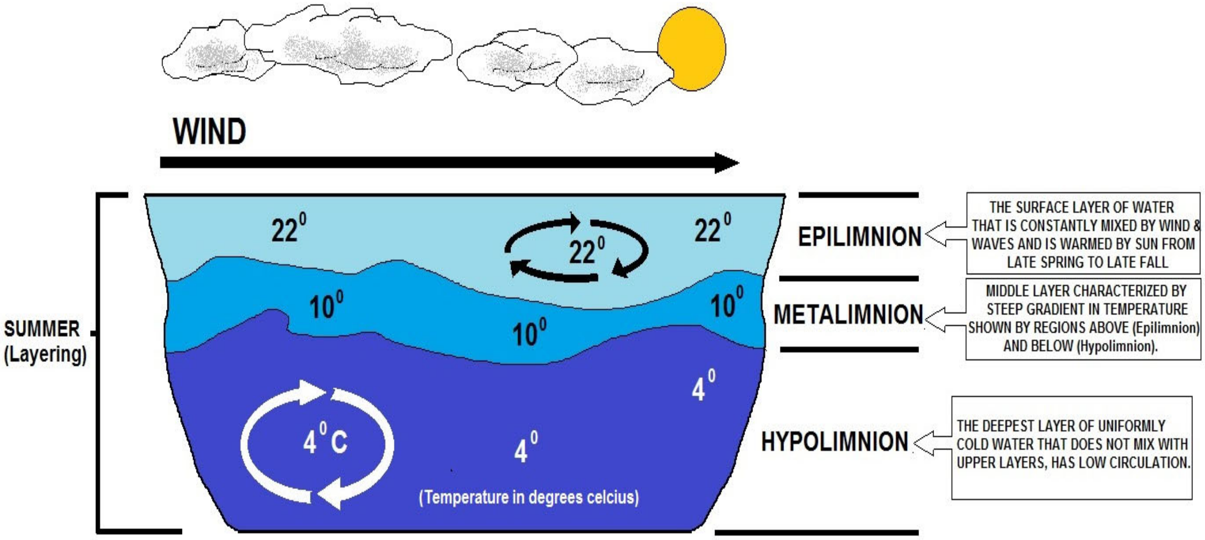
ARSENIC IN DRINKING WATER



DISSOLVED OXYGEN AFFECT IN WATER SOURCES

Dissolved Oxygen

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



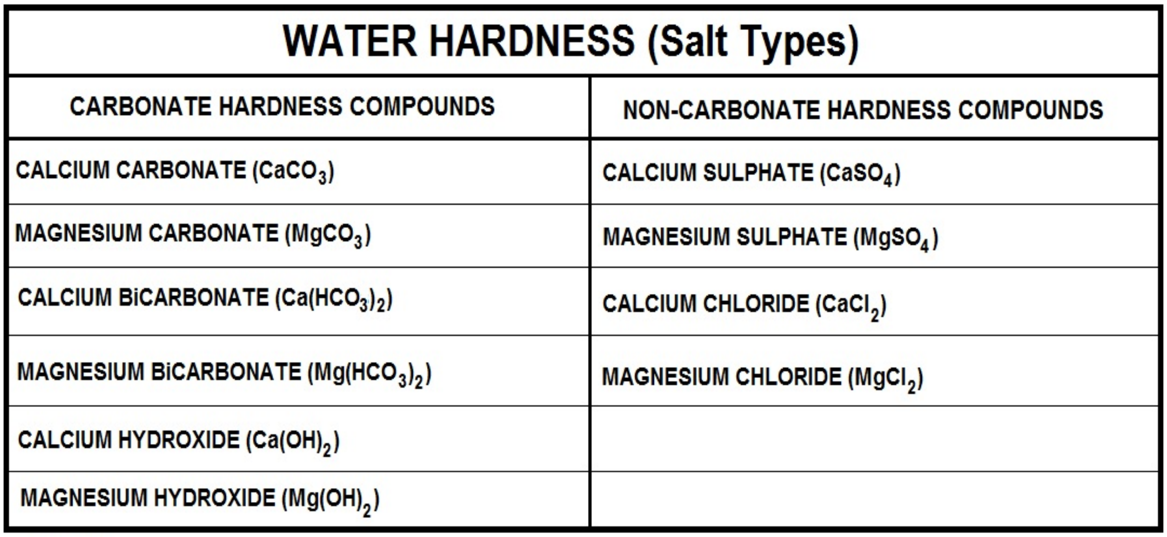
THERMAL STRATIFICATION (Temperature Transition Zones)

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

Hardness Introduction

Temporary and Permanent

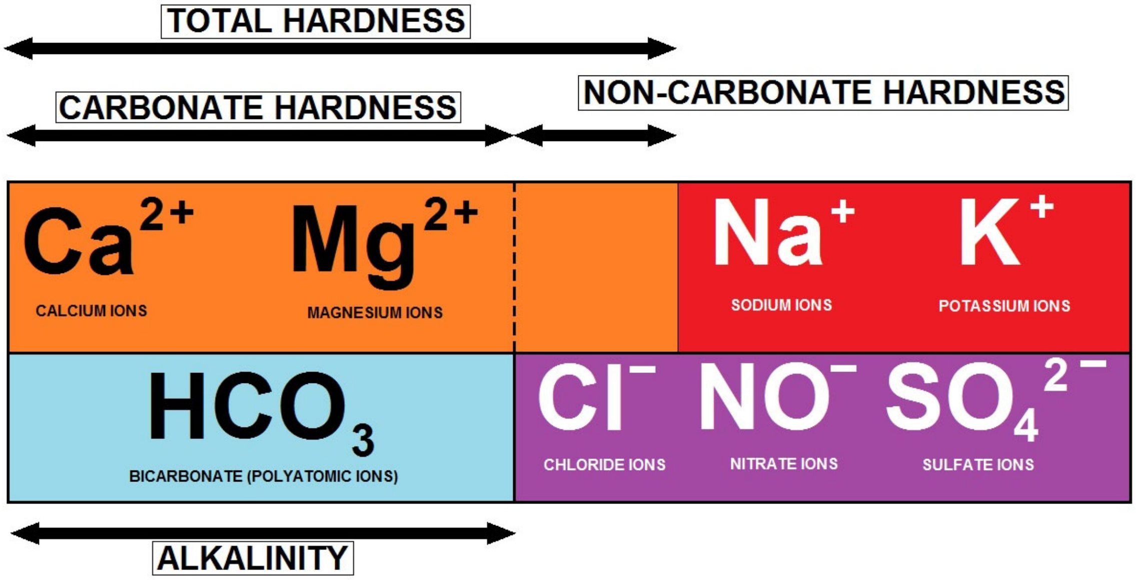
There are two types of hardness: temporary and permanent. Temporary hardness comes out of the water when it is heated and is deposited as scale and “fur” on kettles, coffee makers and taps and appears as a scum or film on tea and coffee. Permanent hardness is unaffected by heating. We will cover this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



WATER HARDNESS (Salt Types)

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

CAUSES OF HARDNESS THAT AFFECTS WATER QUALITY

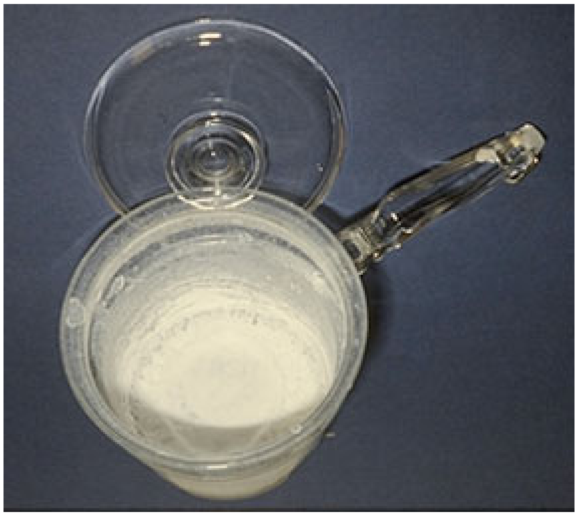


CARBONATE HARDNESS CHART

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 $CaCO_3$), magnesium hydroxide scale will deposit in hot water heaters that are operated at normal temperatures of 140-150^{o}F (60-66^{o}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)

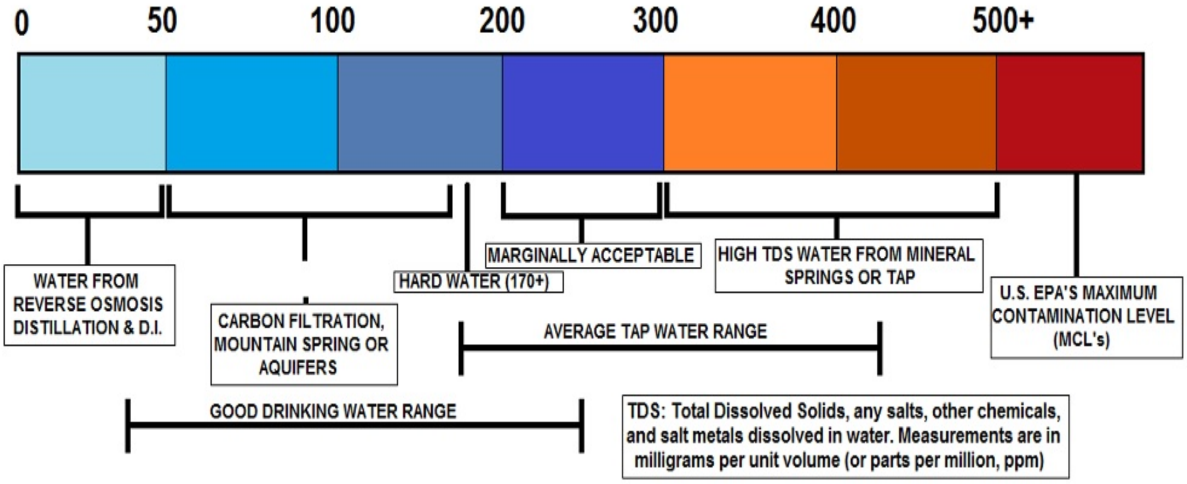
Total dissolved solids (TDS) represents the combined total of all organic and inorganic substances found in drinking water. The total dissolved solids present in water is one of the leading causes of particles and sediments in drinking water, which give water its color, odor, and flavor, and can be a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

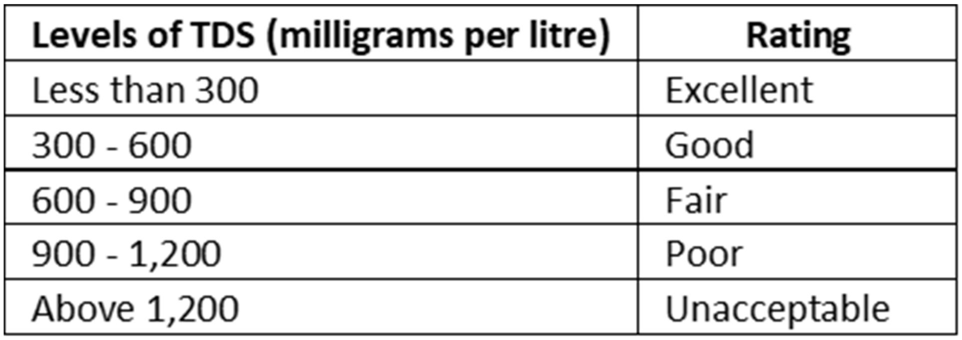


Technical Learning College

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.

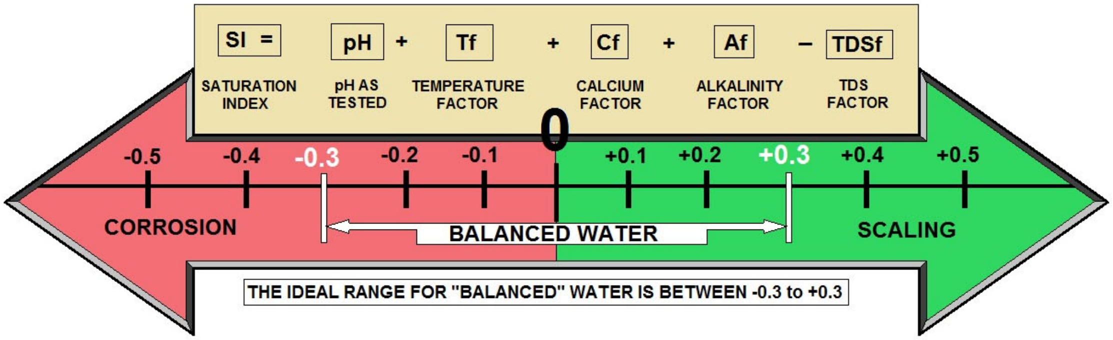


Levels of TDS (milligrams per litre)	Rating
Less than 300	Excellent
300 - 600	Good
600 - 900	Fair
900 - 1,200	Poor
Above 1,200	Unacceptable

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.

Langelier Saturation Index

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



LANGELIER SATURATION INDEX

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

$$H_2CO_3 \rightleftarrows HCO_3^- + H^+$$

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

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

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

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

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

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

Where:

pH is the measured water pH

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

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

Where:

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

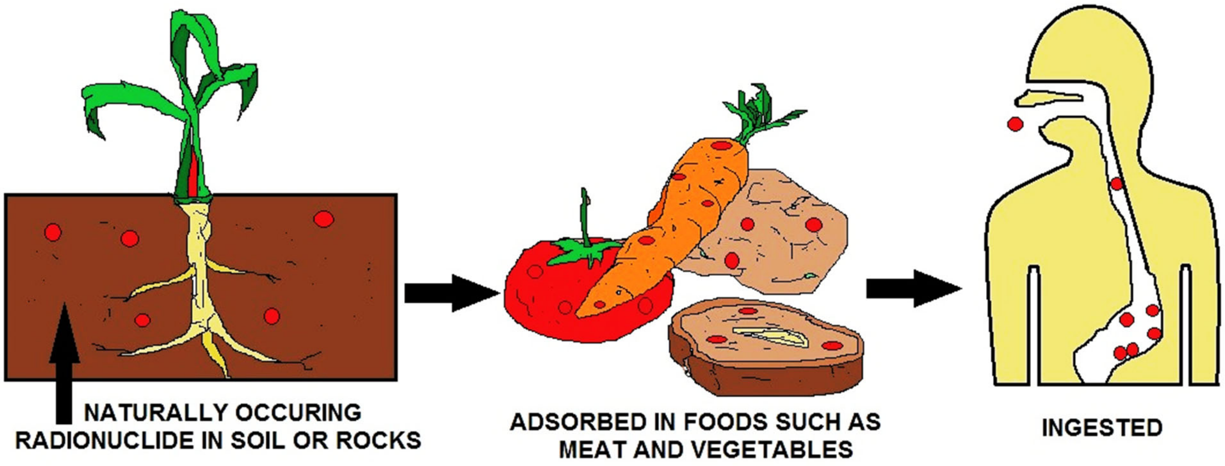
$B = -13.12 \times \text{Log}_{10} ({}^{o}C + 273) + 34.55$

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

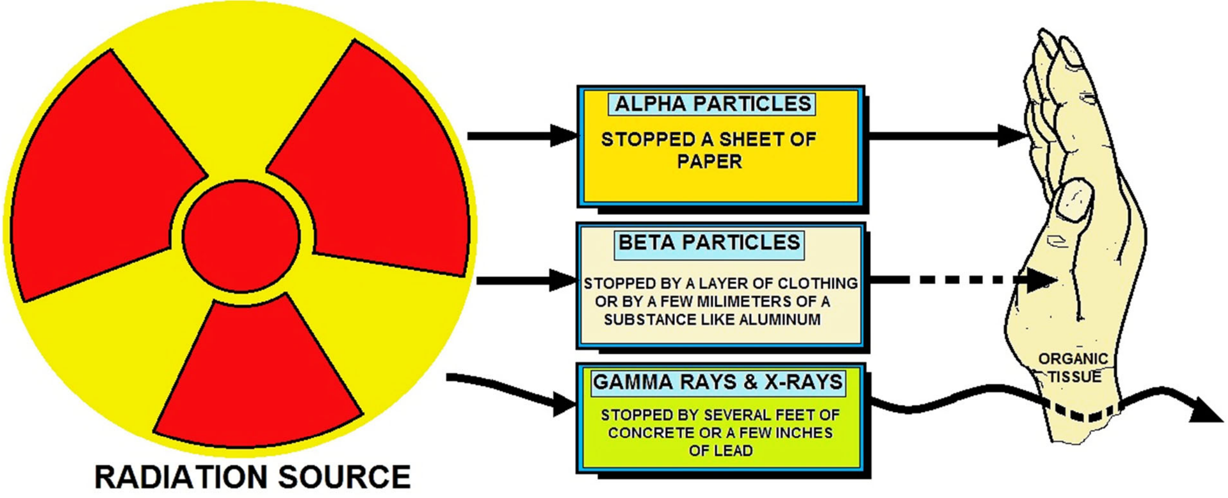
$D = \text{Log}_{10} [\text{alkalinity as } CaCO_3]$

Radiological Characteristics

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

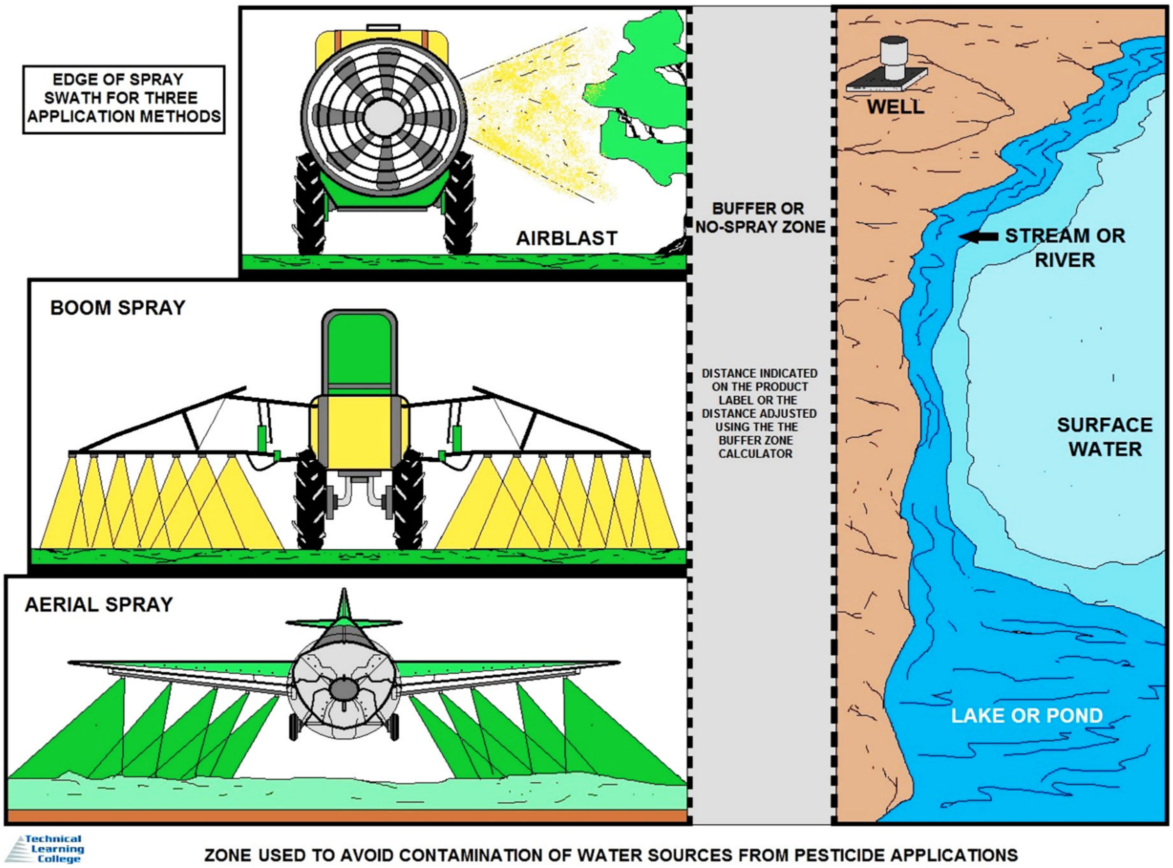


RADIONUCLIDES



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.



ZONE USED TO AVOID CONTAMINATION OF WATER SOURCES FROM PESTICIDE APPLICATIONS

Insecticides and Herbicides

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

Biological Characteristics of Water

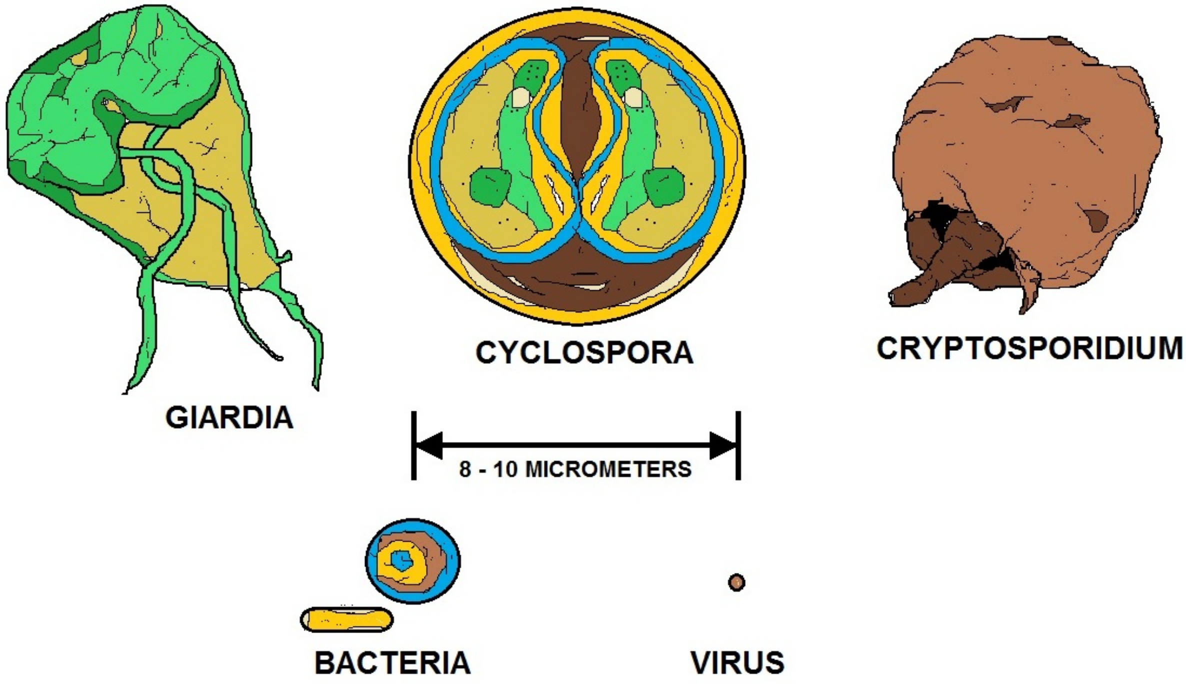
Biological characteristics are the presence of living or dead organisms. Biological characteristics will also interact with the chemical composition of the water. The consumer will become sick or complain about hydrogen sulfide odors, the rotten egg smell. We will cover the Total Coliform Rule in detail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

Pathogen Definition

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

Biological Parameters

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



COMPARATIVE SIZES OF PROTOZOAN PARASITES

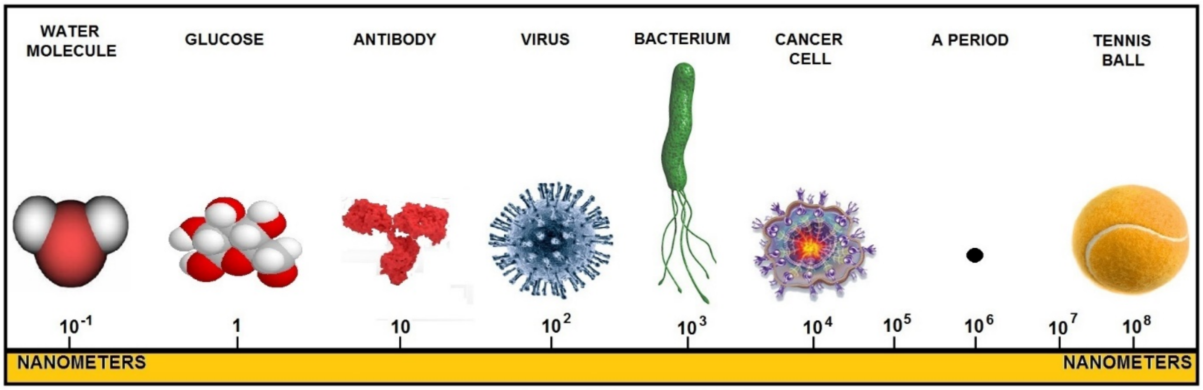
Bacteriological Aspects of Water Pollution

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

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

Cysts

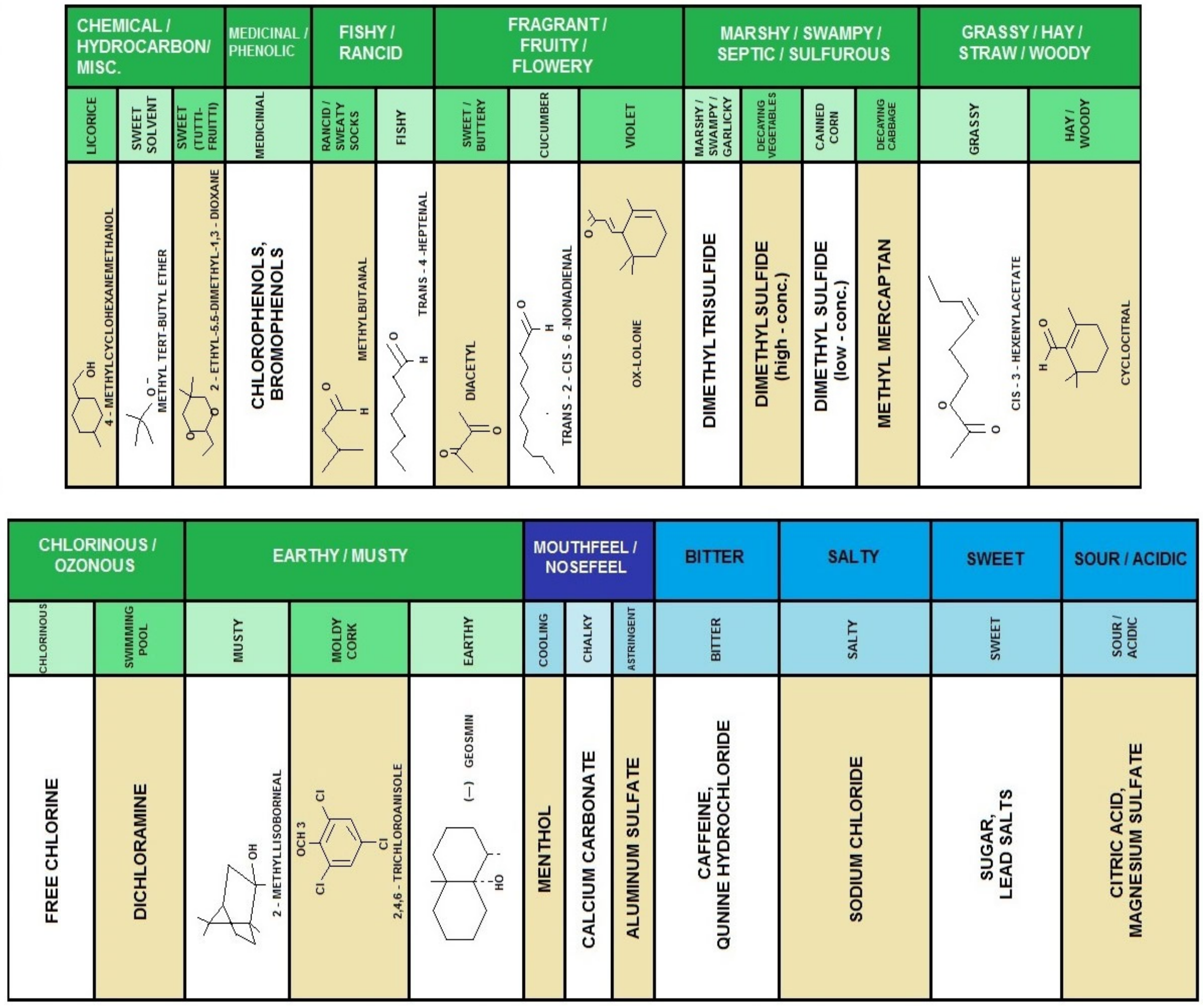
Cysts are associated with the reproductive stages of parasitic microorganisms (protozoans) which can cause acute diarrhea type illnesses; they come from farm animals, wild animals and people. Cysts are very resistant to normal disinfection processes but can be removed by advanced filtration processes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



SIZE COMPARISON
HOW SMALL IS SMALL ?

Drinking Water Tastes and Odors

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



Category	Descriptor	Compound
CHEMICAL / HYDROCARBON/ MISC.	LICORICE	4 - METHYLCYCLOHEXANEMETHANOL
	SWEET SOLVENT	METHYL TERT-BUTYL ETHER
	SWEET (TUTTI-FRUITTI)	2 - ETHYL-5,5-DIMETHYL-1,3 - DIOXANE
MEDICINAL / PHENOLIC	MEDICINAL	CHLOROPHENOLS, BROMOPHENOLS
FISHY / RANCID	RANCID / SWEATY SOCKS	METHYLBUTANAL
	FISHY	TRANS - 4 -HEPTENAL
FRAGRANT / FRUITY / FLOWERY	SWEET / BUTTERY	DIACETYL
	CUCUMBER	TRANS - 2 - CIS - 6 -NONADIENAL
	VIOLET	OX-LOLONE
MARSHY / SWAMPY / SEPTIC / SULFUROUS	MARSHY / SWAMPY / GARLICKY	DIMETHYL TRISULFIDE
	DECAYING VEGETABLES	DIMETHYL SULFIDE (high - conc.)
	CANNED CORN	DIMETHYL SULFIDE (low - conc.)
	DECAYING CABBAGE	METHYL MERCAPTAN
GRASSY / HAY / STRAW / WOODY	GRASSY	CIS - 3 - HEXENYLACETATE
	HAY / WOODY	CYCLOCITRAL
CHLORINOUS / OZONOUS	CHLORINOUS	FREE CHLORINE
	SWIMMING POOL	DICHLORAMINE
EARTHY / MUSTY	MUSTY	2 - METHYLLISOBORNEAL
	MOLDY CORK	2,4,6 - TRICHLOROANISOLE
	EARTHY	(−) GEOSMIN
MOUTHFEEL / NOSEFEEL	COOLING	MENTHOL
	CHALKY	CALCIUM CARBONATE
	ASTRINGENT	ALUMINUM SULFATE
BITTER	BITTER	CAFFEINE, QUNINE HYDROCHLORIDE
SALTY	SALTY	SODIUM CHLORIDE
SWEET	SWEET	SUGAR, LEAD SALTS
SOUR / ACIDIC	SOUR / ACIDIC	CITRIC ACID, MAGNESIUM SULFATE

Technical Learning College

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.

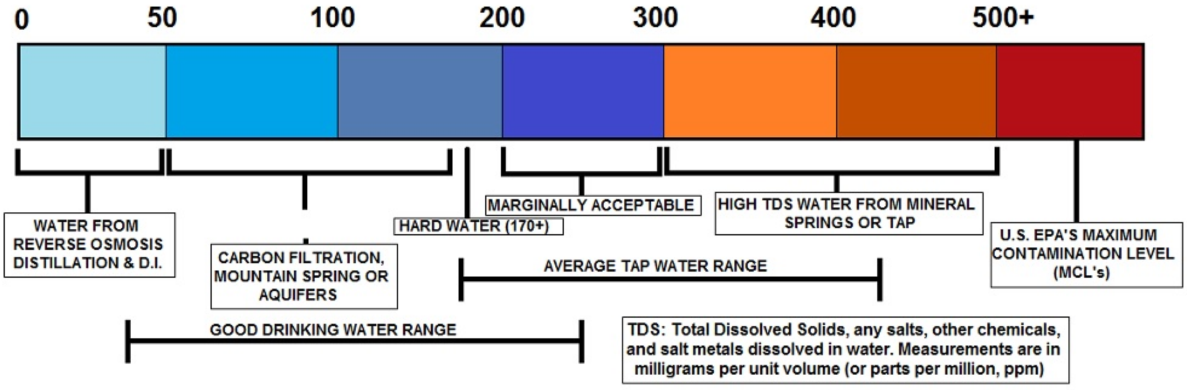
EPA Guidelines for Nuisance Constituents

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, any salts, other chemicals, and salt metals dissolved in water. Measurements are in milligrams per unit volume (or parts per million, ppm)

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

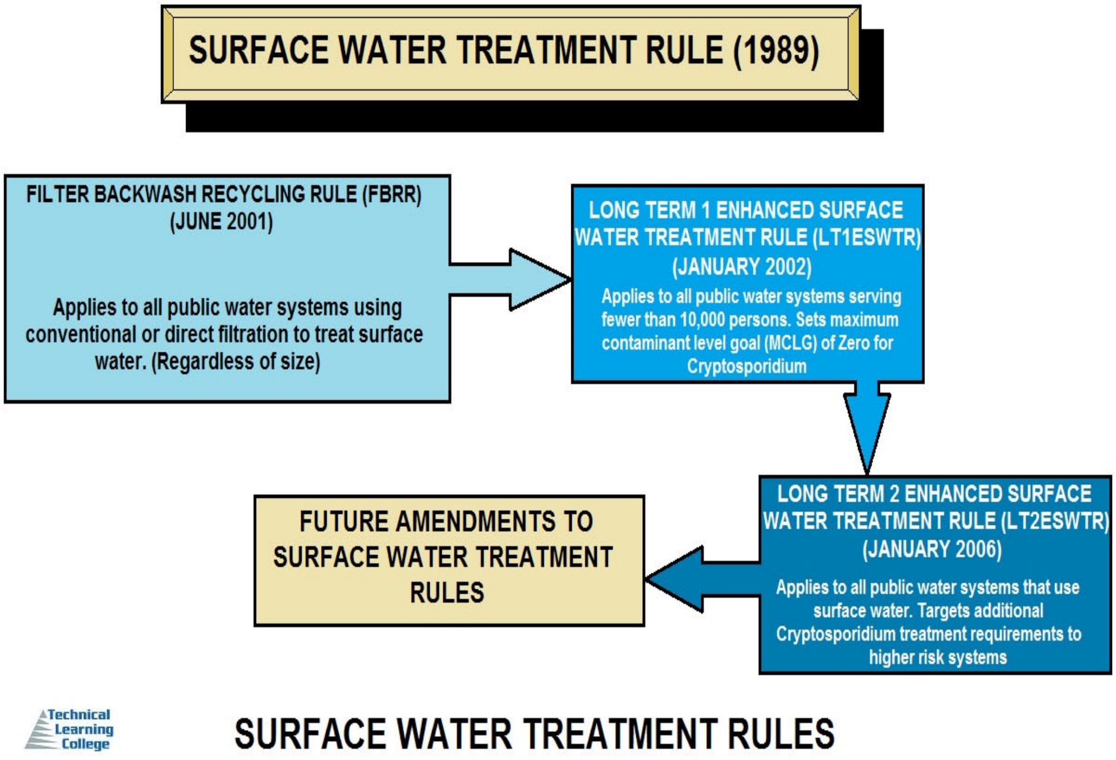
The following safety procedures shall be maintained:

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.



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

Water Quality Key Words

Hyperlink to the Glossary and Appendix

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

Activated alumina: The compound is used as a desiccant (to keep things dry by absorbing water from the air) and as a filter of fluoride, arsenic and selenium in drinking water. It is made of aluminum oxide (alumina; Al_2O_3), the same chemical substance as sapphire and rubies (but without the impurities that give those gems their color). It is manufactured from aluminum hydroxide by dehydroxylating it in a way that produces a highly porous material; this material can have a surface area significantly over 200 square meters/g.

Activated carbon: Also called activated charcoal or activated coal, it is a form of carbon that has been processed to make it extremely porous and thus to have a very large surface area available for adsorption or chemical reactions. The word activated in the name is sometimes substituted by active. Due to its high degree of microporosity, just one gram of activated carbon has a surface area of approximately 500 m^2, as determined typically by nitrogen gas adsorption. Sufficient activation for useful applications may come solely from the high surface area, though further chemical treatment often enhances the adsorbing properties of the material. Activated carbon is usually derived from charcoal.

De-ionized: Water with the ions removed.

Dissolved organic carbon: Dissolved organic carbon (DOC) is a broad classification for organic molecules of varied origin and composition within aquatic systems. The "dissolved" fraction of organic carbon is an operational classification. Many researchers place the dissolved/colloidal cutoff at 0.45 micrometers, but 0.22 micrometers is also typical.

Ethylenediaminetetraacetic acid (EDTA): EDTA is a widely used abbreviation for the chemical compound ethylenediaminetetraacetic acid (and many other names). EDTA refers to the chelating agent with the formula $(HO_2CCH_2)_2NCH_2CH_2N(CH_2CO_2H)_2$. This amino acid is widely used to sequester di- and trivalent metal ions (Ca^{2+} and Mg^{2+} for example). EDTA binds to metals via four carboxylate and two amine groups. EDTA forms especially strong complexes with Mn(II), Cu(II), Fe(III), Pb (II) and Co(III).

High temperature metals recovery: An improved method and apparatus for recovering metal values from Electric Arc Furnace (EAF) dust, particularly zinc and iron values, by mixing EAF dust and carbonaceous fines to form a particulate mixture; heating the mixture at a sufficient temperature and for a sufficient time to reduce and release volatile metals and alkali metals in a flue gas; collecting the released metals, and removing the metal values from the process as product.

Microfiltration: A low pressure membrane filtration process that removes suspended solids and colloids generally larger than 0.1 micron diameter.

Nanofiltration: It is a relatively recent membrane process used most often with low total dissolved solids water such as surface water and fresh groundwater, with the purpose of softening (polyvalent cation removal) and removal of disinfection by-product precursors such as natural organic matter and synthetic organic matter.

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

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.

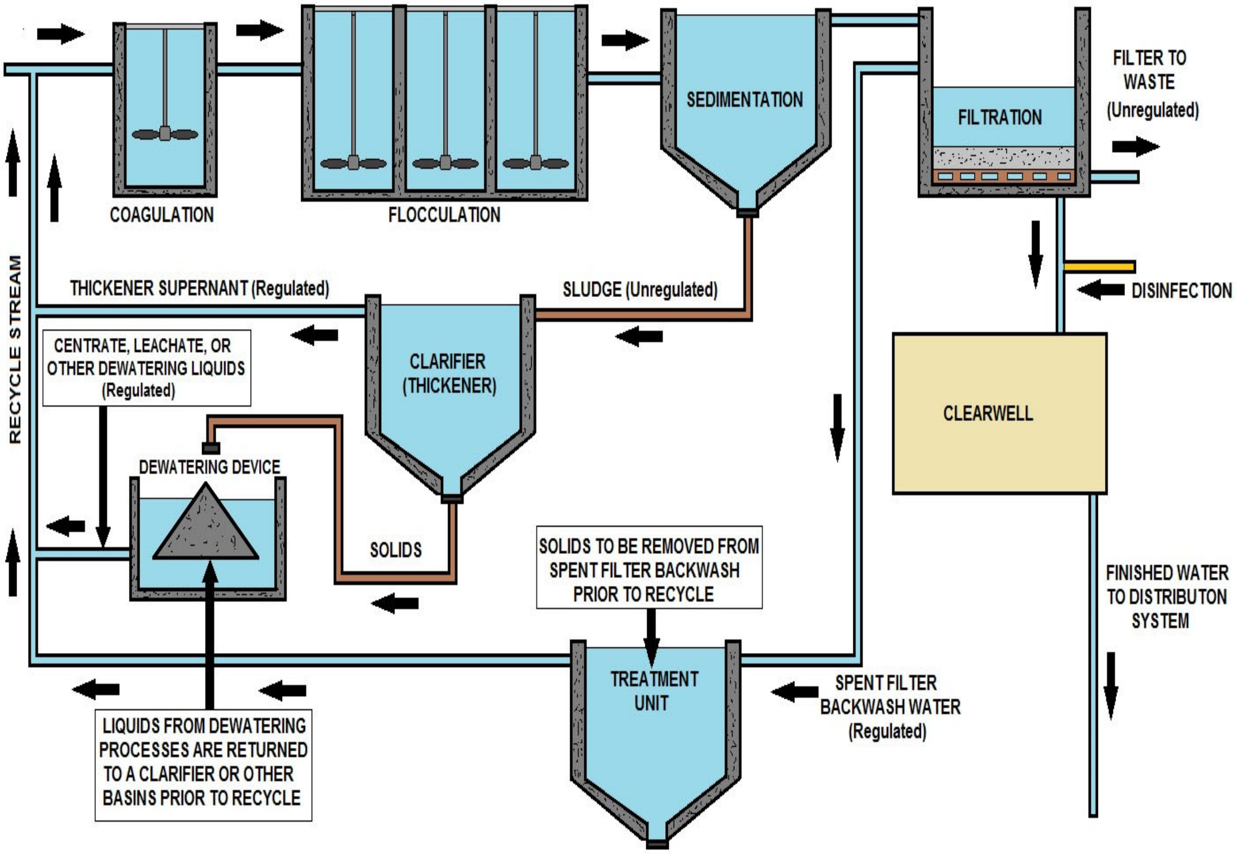
Synthetic Organic Contaminants, including Pesticides & Herbicides

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

Volatile Organic Contaminants

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

Other Related EPA Water Treatment Rules



FILTER BACKWASHED RECYLING

Filter Backwash Recycling Rule (FBRR)

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

IESWTR

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

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

Arsenic

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

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

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

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

ICR Information Collection Rule

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

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

Gas Chromatograph
Used for micro-contaminant water analysis.

Commonly Found Distribution System Water Quality Problems

Turbidity

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

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

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

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

Hardness

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

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

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

Iron

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

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

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

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

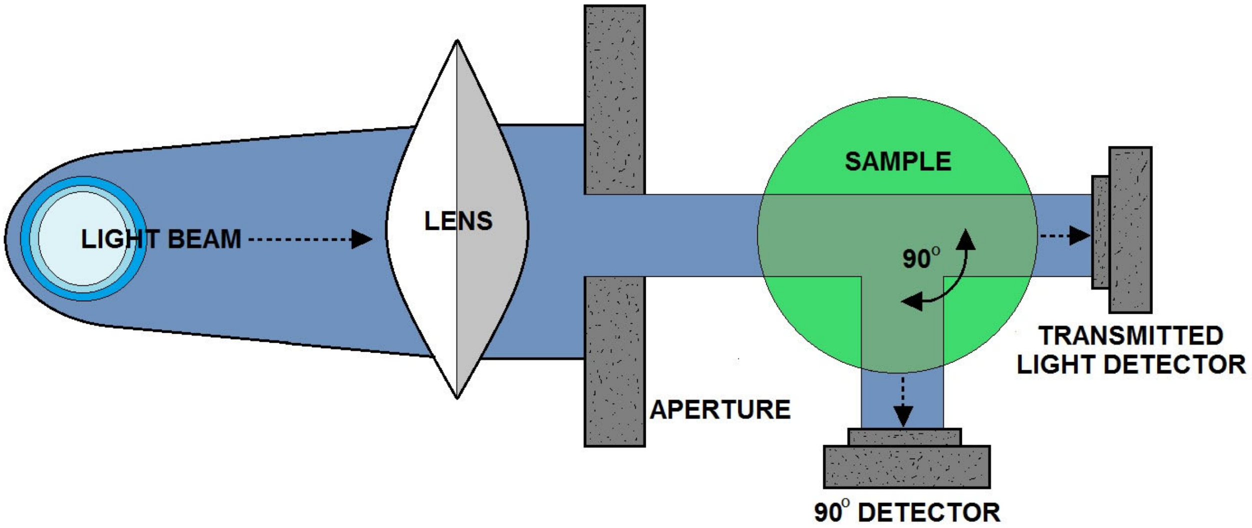
Manganese

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

Water Quality Safeguards

The **critical** safeguard for water distribution system operations are

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



Technical Learning College

BASICS OF A TURBIDIMETER

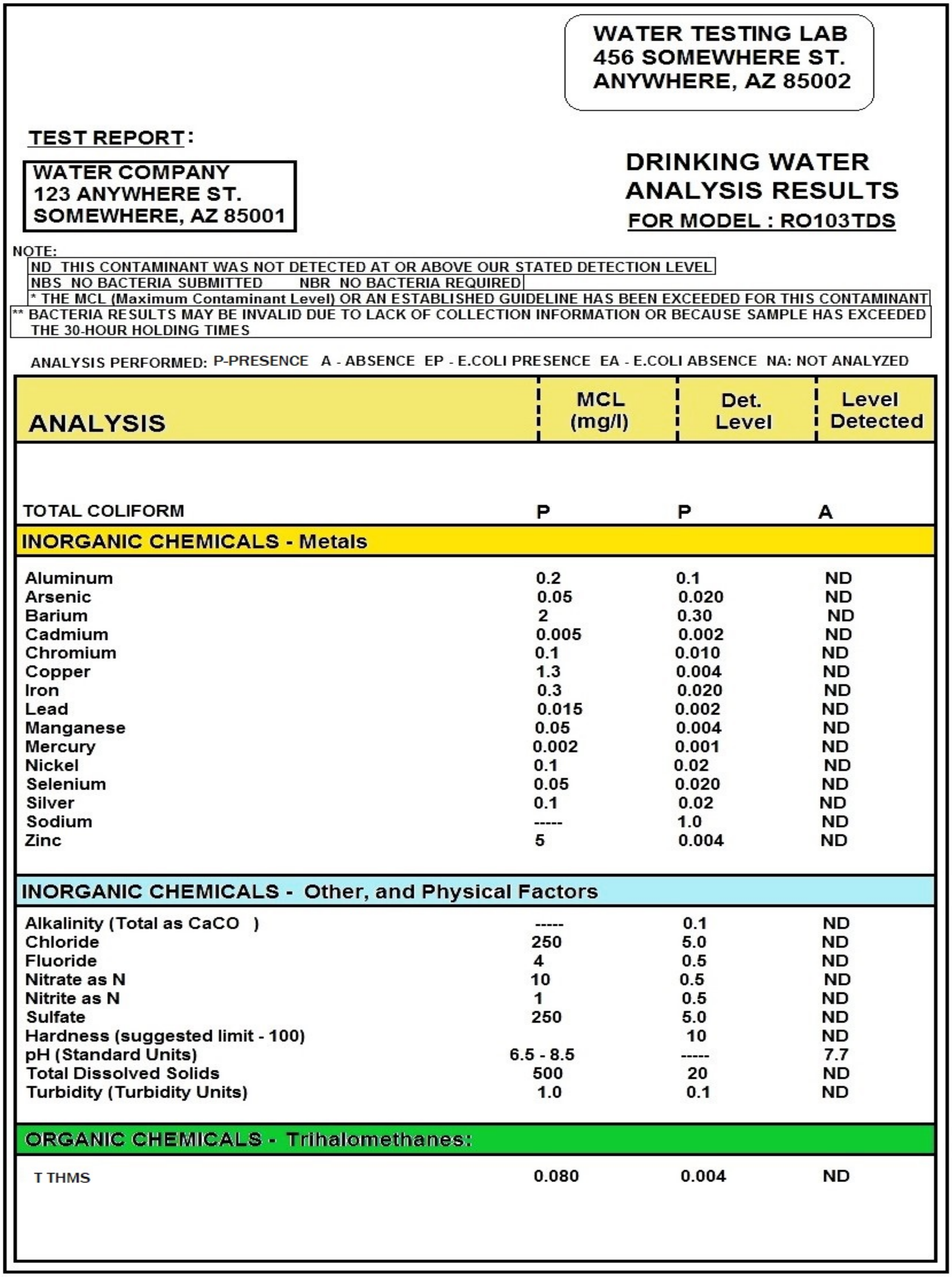
Sampling Plan Introduction

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

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

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

Grabbing a sample from a stream.



WATER TESTING LAB
456 SOMEWHERE ST.
ANYWHERE, AZ 85002

TEST REPORT:

WATER COMPANY
123 ANYWHERE ST.
SOMEWHERE, AZ 85001

DRINKING WATER ANALYSIS RESULTS

FOR MODEL : RO103TDS

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

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

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

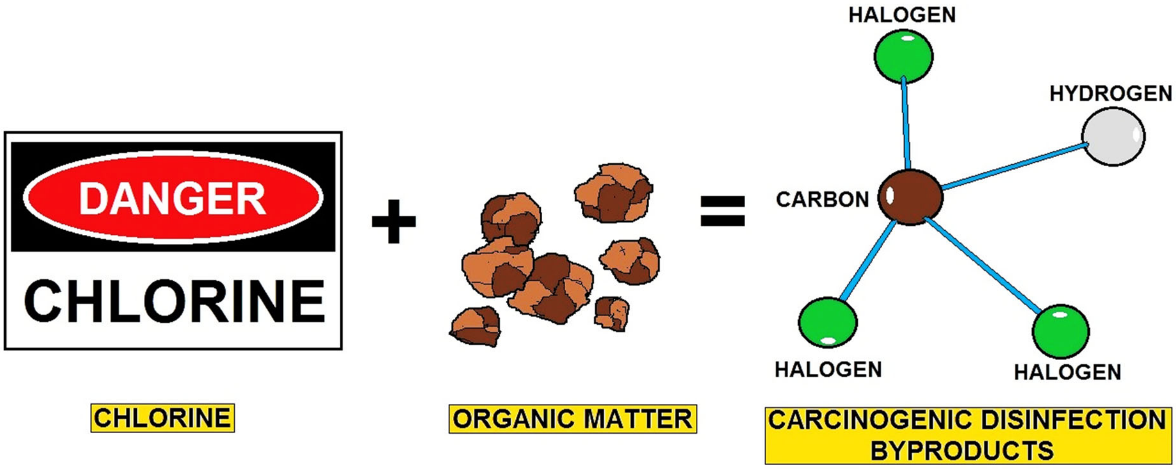
WATER ANALYSIS REPORT EXAMPLE

Older Stage 1 DBPR Information

Disinfection Byproduct Regulations

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

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



DISINFECTION BYPRODUCT PRODUCTION DIAGRAM

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

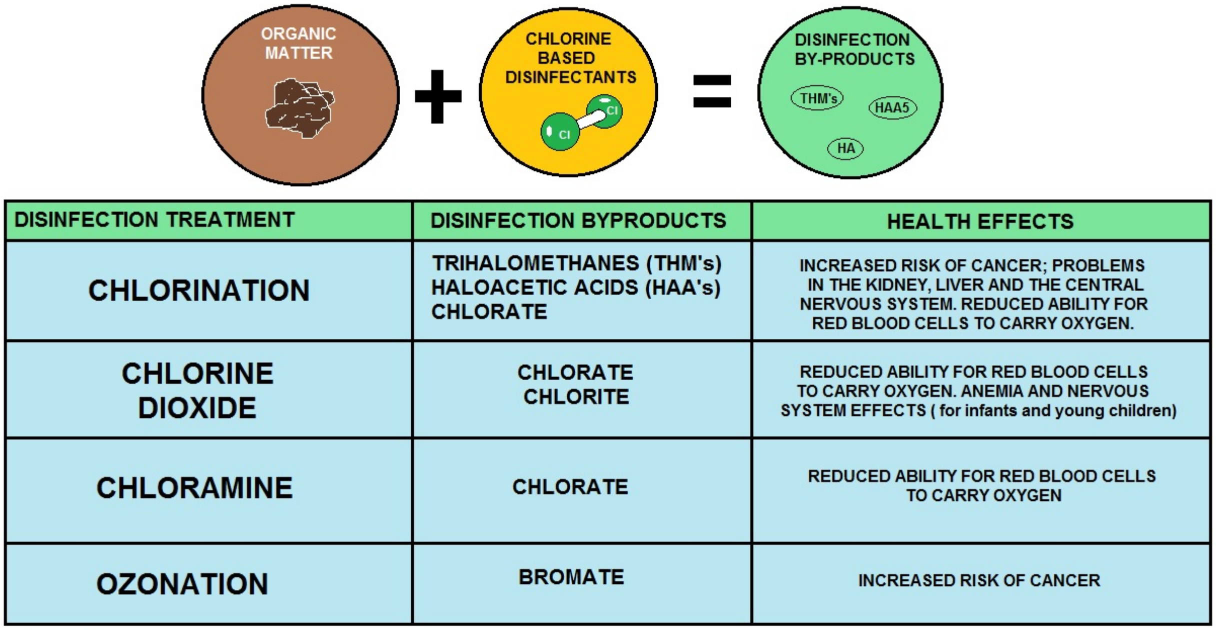
Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.

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

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

Trihalomethanes (**THM**) are a group of four chemicals that are formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The trihalomethanes are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. The EPA has published the Stage 1 Disinfectants/Disinfection Byproducts Rule to regulate total trihalomethanes (TTHM) at a maximum allowable annual average level of 80 parts per billion.

This new standard replaced the old standard of a maximum allowable annual average level of 100 parts per billion back in December 2001 for large surface water public water systems. The standard became effective for the first time back in December 2003 for small surface water and all ground water systems.



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

DISINFECTION BYPRODUCT FORMATION AND EFFECTS

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

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

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

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

Disinfection Rules Stages 1 & 2 DBPR Introduction

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

Stage 2 DBPR

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

General Requirements

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

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

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

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

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

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

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

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

Compliance Timeline

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

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

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

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

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

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

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

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

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

Where do DBPs come from?

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

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

Ensuring Safe Drinking Water

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

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

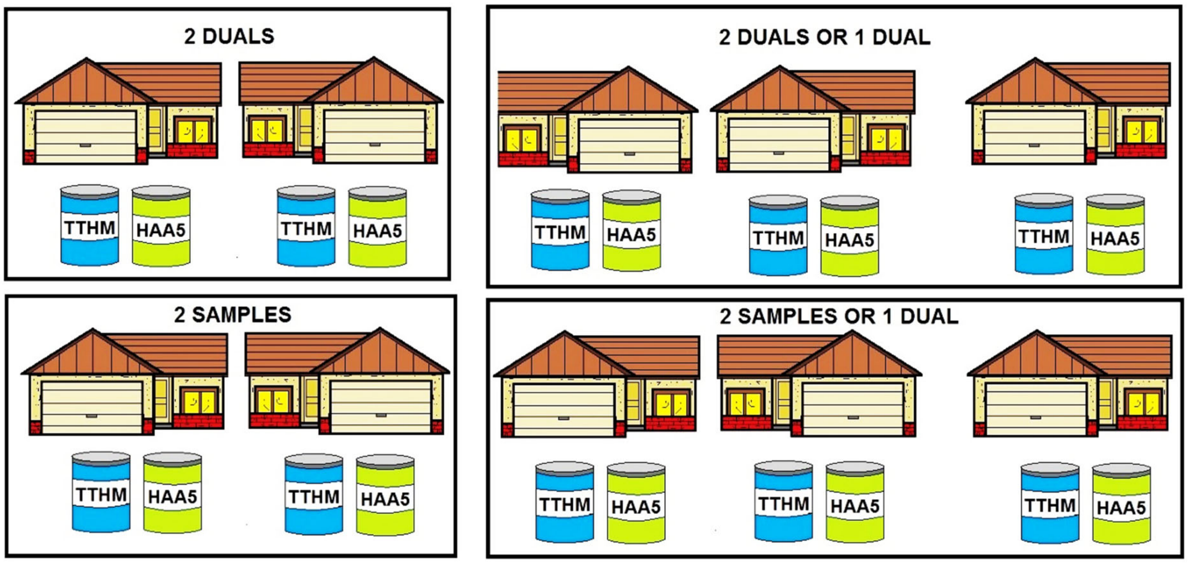
- Making operational improvements at the plant or in the distribution system
- Modifying current treatment operations to remove more DBP precursors or form lower levels of DBPs
- Upgrading or installing a new treatment technology

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

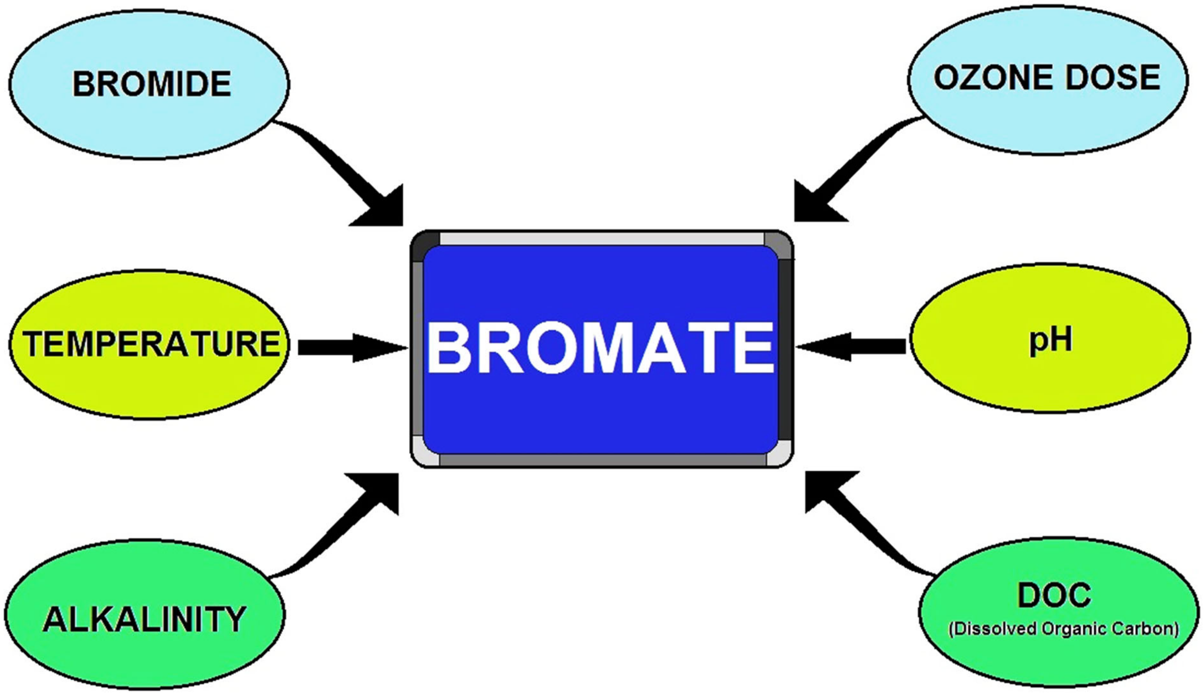
With population-based monitoring, there are five categories of small systems under the Stage 2 DBPR:

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

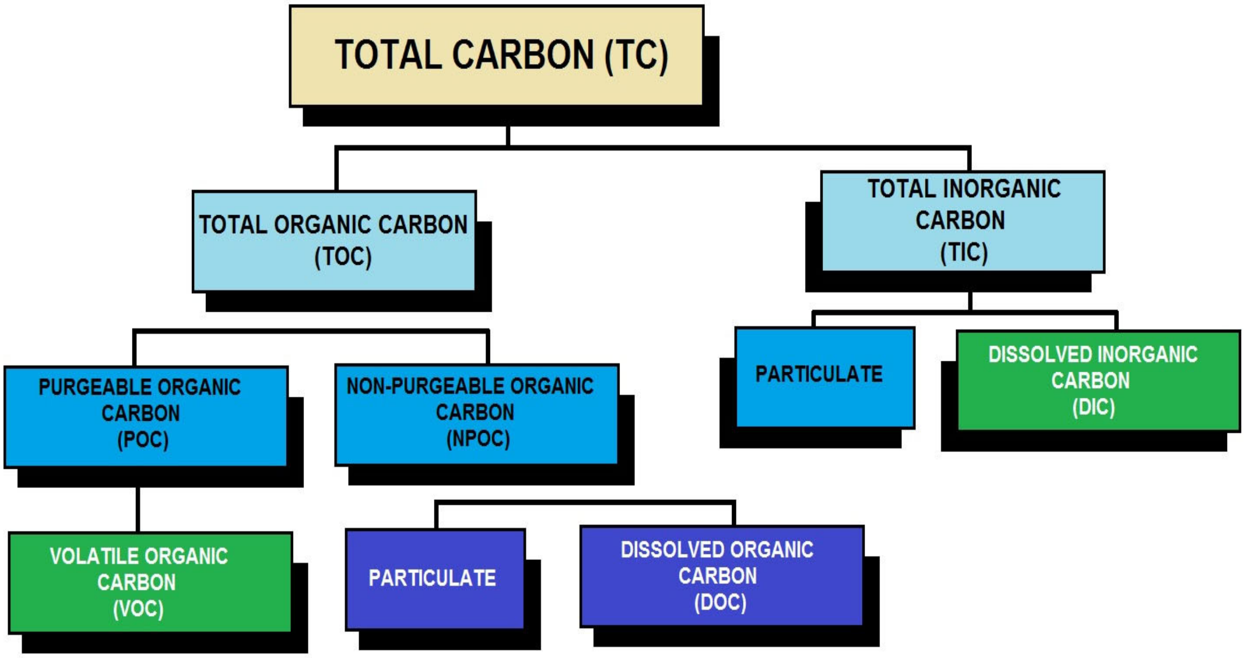
If you do not know what type of system you are, you should contact your State to confirm this information.



STAGE 2 DISINFECTION BYPRODUCT RULE
REPEAT (TRIGGERED) SAMPLING DIAGRAM



BROMATE FORMATION FACTORS



TOTAL CARBON BREAKDOWN

More on the Stage 2 DBP Rule

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

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

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

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

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

What is the Stage 2 DBPR?

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

What does the rule require?

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

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

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

Who must comply with the rule?

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

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

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

What are disinfection byproducts (DBPs)?

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

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

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

More on Evolving Disinfection Rules

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Public Health Concerns

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

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

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

Disinfection Byproduct Research and Regulations Summary

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

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

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

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

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

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

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

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

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

Balancing DBP and Microbial Risks

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

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

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

Controlling Disinfection Byproducts

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

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

1. Coagulation and Clarification

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

2. Absorption

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

3. Membrane Technology

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

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

National Primary Drinking Water Regulations

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

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

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

Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Nervous system effects	Residue of banned insecticide
Epichlorohydrin	zero	TT[7]	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from industrial chemical factories; added to water during treatment process
Ethylbenzene	0.7	0.7	Liver or kidney problems	Discharge from petroleum refineries
Ethelyne dibromide	zero	0.00005	Stomach problems; reproductive difficulties; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased risk of cancer	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, and circulatory problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Total Trihalomethanes (TTHMs)	none[5]	0.10	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories

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

Common water sample bottles for distribution systems.

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

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

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

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

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

National Secondary Drinking Water Regulations

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

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

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

Notes

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

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

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

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

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

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

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

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

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

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

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

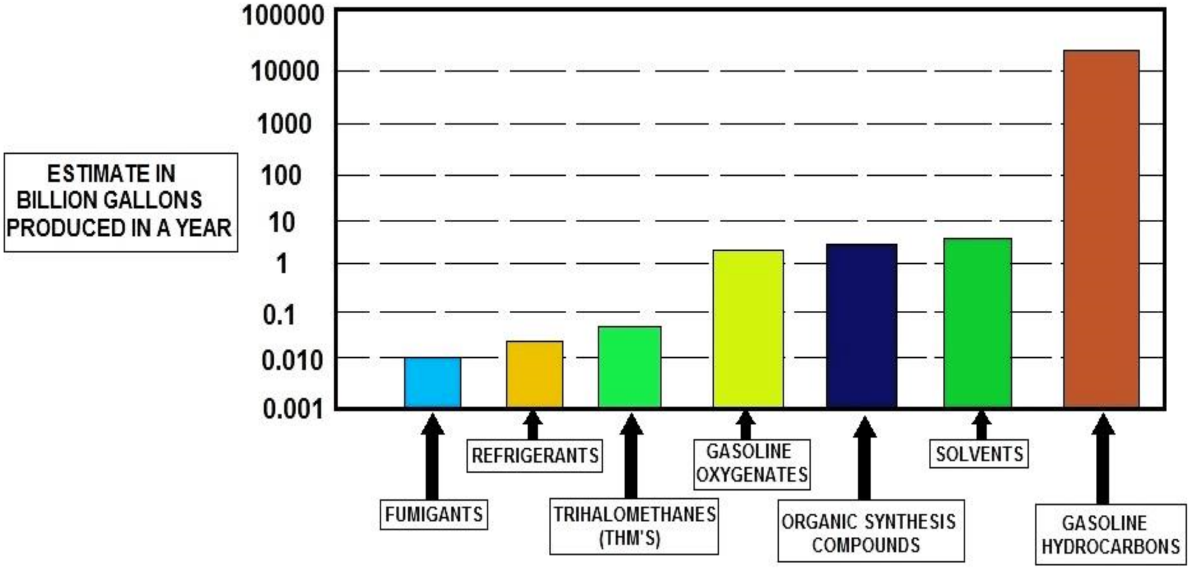
[10] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms.

Chemical Monitoring Sub- Section

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

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

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



VOLATILE ORGANIC COMPOUNDS FOUND IN GROUNDWATER CHART

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

The maximum contaminant level for turbidity for systems that provide filtration treatment:

1. Conventional or direct filtration: less than or equal to 0.5 NTU in at least 95% of the measurements taken each month. Conventional filtration treatment plants should be able to achieve a level of 0.1 NTU with proper chemical addition and operation.
2. Slow sand filtration, cartridge and alternative filtration: less than or equal to 1 NTU in at least 95% of the measurements taken each month. The turbidity levels must not exceed 5 NTU at any turbidity measurements must be performed on representative samples of the filtered water every four (4) hours that the system serves water to the public.

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

Inorganic Chemical Monitoring

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

Nitrates

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

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

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

Radiological Contaminants

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

Total Trihalomethanes (TTHM)

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

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

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

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

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

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

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

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

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

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

Sampling Sites by Population

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

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

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

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

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

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

Number of Water Quality Parameters per Population

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

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

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

Quality Assurance /Quality Control Measures - Introduction

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

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

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

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

Preservation of Samples

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

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

Follow the preservative solution preparation instructions.

Always use strong safety precautions when diluting any acid.

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

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

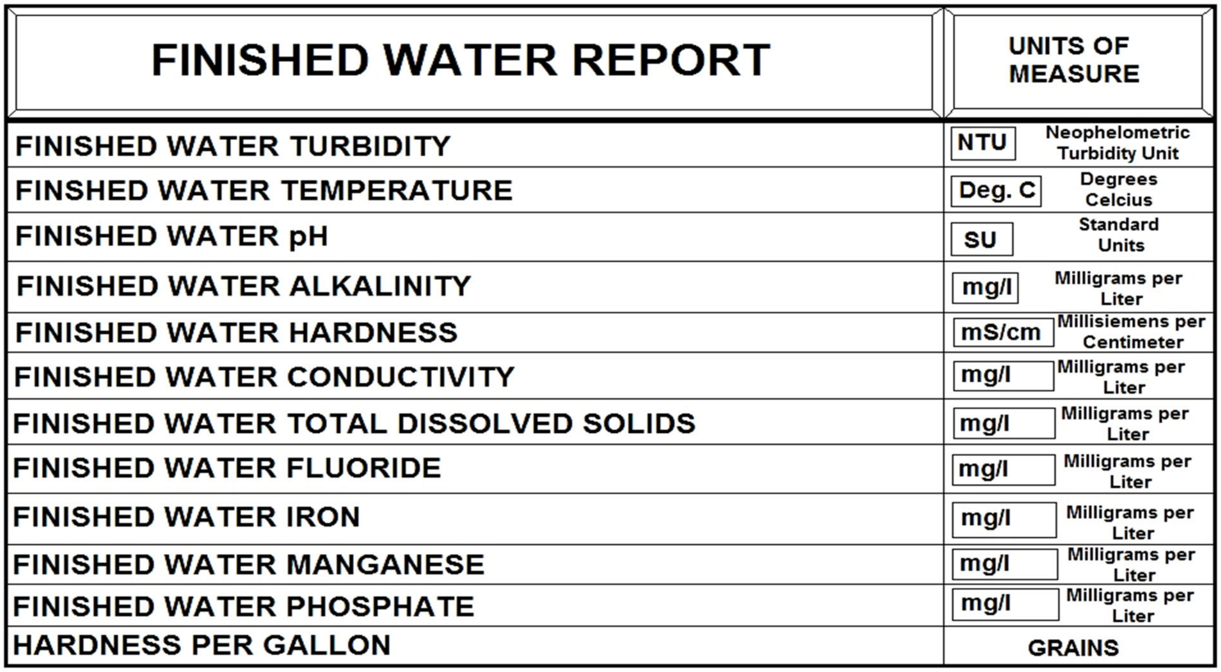
Wait 3-4 hours for the preservative to cool most samples down to 4 degrees Celsius.

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

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

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

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



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

WATER QUALITY REPORT INCLUDING UNITS OF MEASUREMENT

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

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

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

Drinking Water Sampling - Analysis Charts

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

Nitrogen, ammonia	**SM-4500 NH3 E** **SM-4500 NH3 H**	**28 days**
Nitrogen, nitrate	**SM-4500 NO3 D**	**48 hours**
Nitrogen, nitrite	**SM-4500 NO2**	**48 hours**
Nitrate + Nitrite	**SM-4500 NO3 E**	**48 hours**
Nitrogen, TKN	**EPA 351.4**	**28 days**
Odor	**SM-2150**	**6 days**
Phosphorous, ortho	**EPA 200.7**	**48 hours**
Phosphorous, total	**SM-4500 P**	**28 days**
Solids, settle able	**SM-2540**	**7 days**
Solids, suspended	**SM-2540 D**	**7 days**

Drinking Water Analysis

Solids, total dissolved	**SM-2540 B**	**7 days**
Solids, volatile	**SM-2540 E**	**7 days**
Specific Conductance	**SM-2510 B**	**28 days**
Sulfate	**SM-4500 SO-4 E**	**28 days**
Sulfide	**SM-4500 S-2 D**	**28 days**
Sulfite	**EPA 377.1**	**28 days**
Silica	**SM-4500 SI E**	**28 days**
Total Organic Carbon	**EPA 415.1**	**28 days**
Turbidity	**SM- 2130 B**	**48 hours**

ORGANICS		
Semi-volatile Organics in Water (SOC)*	**(various)**	**7 days**
Volatile Organics in Water*	**(various)**	**7 days**
Trihalomethanes*	**EPA 501.1**	**7 days**
Gross Alpha & Bata (Radionuclides)*	**(various)**	**7 days**
BOD	**SM-5210 B**	**48 hours**
COD	**EPA 410.4(7.3)**	**28 days**
Oil and Grease	**EPA 413.1(1.2)**	**28 days**
Hardness W/digestion	**SM-2340 B**	**6 months**
Nitrogen, TKN	**EPA 351.4**	**28 days**
Nitrogen, ammonia	**SM-4500 NH3 F**	**28 days**
Nitrogen, Total Organic	**SM-4500 NorgNH3**	**28 days**
Nitrogen, nitrate	**SM-4500 NO3 D**	**48 hours**
Nitrogen, nitrite	**SM-4500 NO2 B**	**48 hours**
Phosphorous, ortho	**SM-4500 P E**	**48 hours**
Sulfate	**SM-4500 SO4 E**	**28 days**
Solids, dissolved	**SM-2540**	**7 days**
Solids, settle able	**SM-2540 F**	**7 days**
Solids, suspended	**SM-2540 D**	**7 days**
Solids, total	**SM-2540 B**	**7 days**
Solids, volatile	**SM-2540 E**	**7 days**
Total Organic Carbon	**EPA 415.1**	**28 days**
PH	**EPA 150.1**	
Metals (per element)		
ICP (Ag, Al, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Sb, V, Zn)	**EPA 200.7**	**6 months**

GFAA **(As, Pb, Ba, Se, Tl)**	**EPA 200.9**	**6 months**
CVAA (Hg)	**EPA 245.1**	**6 months**

Definitions:

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

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

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

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

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

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

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

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

SAMPLE CONTAINERS and PRESERVATION

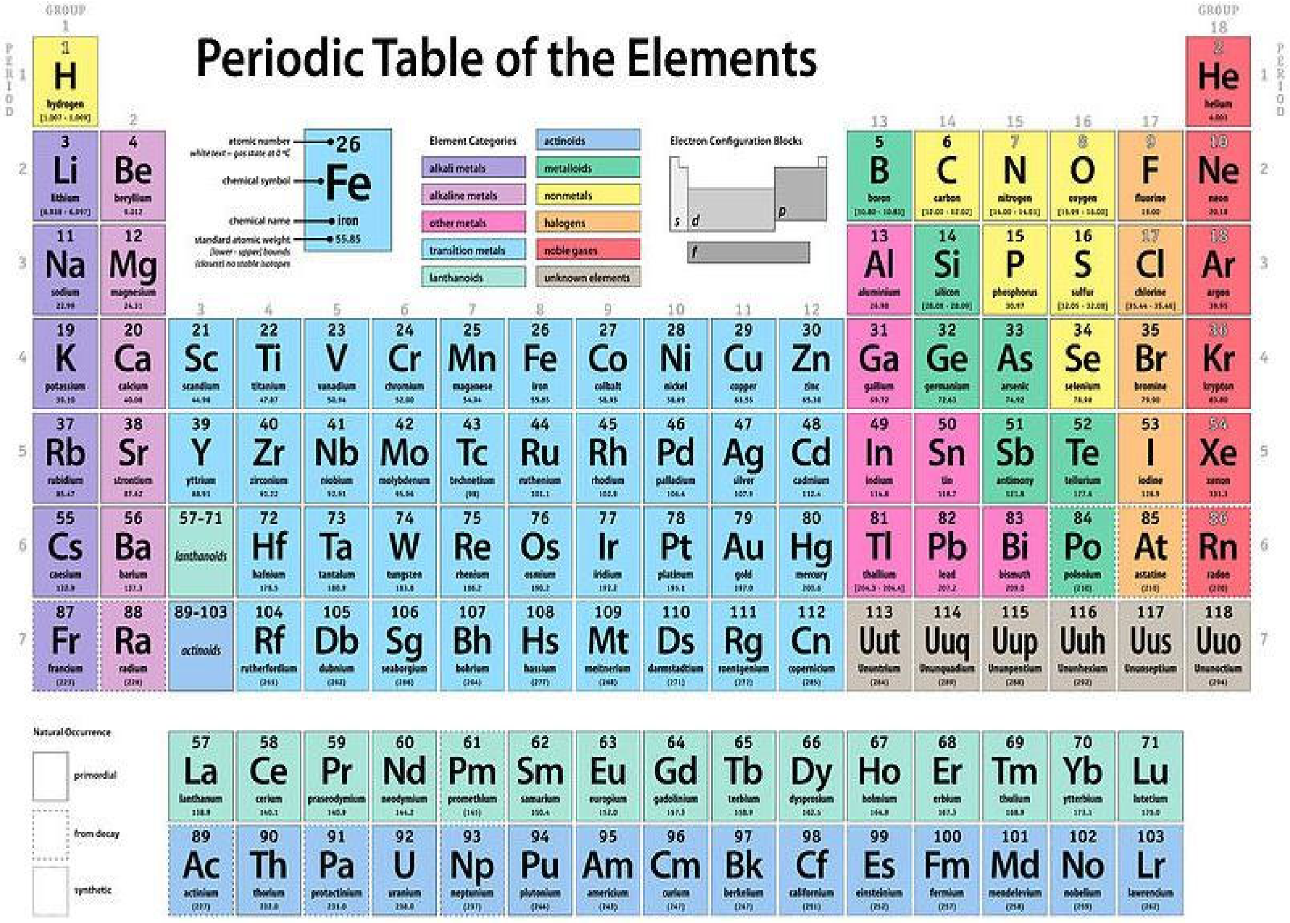
Methods used by the laboratory usually specify what type of container and how much sample is required to run an analysis. The following table provides a summary of the sample handling and preservation requirements for some of the most common tests.

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

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

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

Inorganic Compound (IOC) Section



Inorganic Compound

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

Examples include many toxic or poisonous compounds like:
carbon monoxide, carbon dioxide, carbonates, cyanides, cyanates, carbides, and thiocyanates. Many of these are normal parts of mostly organic systems, including organisms, which means that describing a chemical as inorganic does not 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[1] (mg/L)[2]	MCL or TT[1] (mg/L)[2]	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0[7]	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	TT[7]; Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits

Inorganic Chemicals

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

Synthetic Organic Chemicals (SOCs) Section

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

SOC

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

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

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

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

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

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

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

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

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

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

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

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

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

Unregulated Chemicals

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

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

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

Volatile Organic Compounds (VOCs)

Definitions

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

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

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

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

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

VOCs *Explained*

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

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

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

Specific Components

Paints and Coatings

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

Chlorofluorocarbons and Chlorocarbons

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

Benzene

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

Methylene Chloride

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

Perchloroethylene

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

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

MTBE

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

Formaldehyde

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

Health Risks

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

Health Effects Include:

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

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

Routes of Entry

Eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment are among the immediate symptoms that some people have experienced soon after exposure to some organics. At present, not much is known about what health effects occur from the levels of organics usually found in homes. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans.

Reducing Exposure

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

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

Chemical Fingerprinting

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

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

Vinyl chloride	2	Nervous system, liver effects, cancer
Xylenes (total)	10,000	Liver, kidney, nervous system effects

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

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

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

Safe Drinking Water Act (SDWA) Summary

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

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

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

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

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

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

Assimilable Organic Carbon (AOC)

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

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

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

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

EPANET

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

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

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

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

Topic 1- Water Quality Post Quiz

Internet Link to Assignment…

http://www.abctlc.com/downloads/PDF/WTPrimer1ASS.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

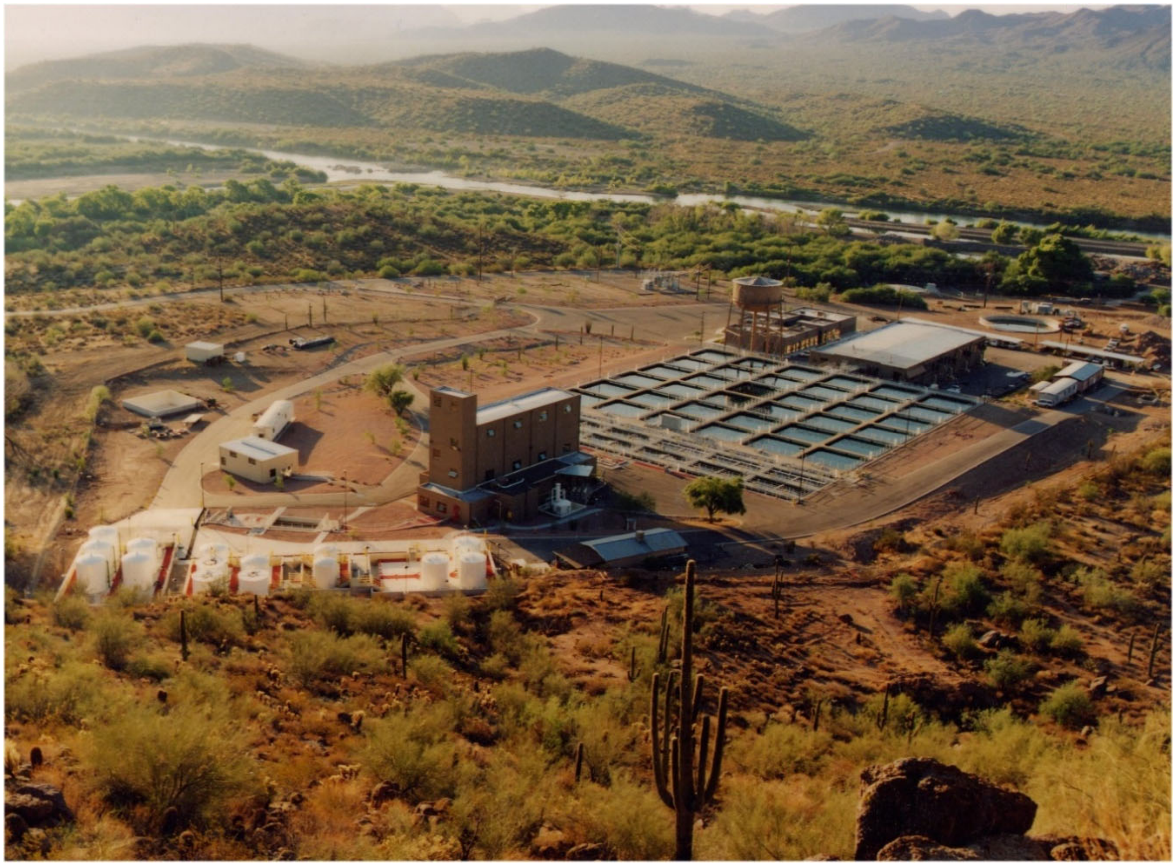
Topic 2- Water Treatment Introduction Section

Section Focus: You will learn the basics of conventional water treatment. At the end of this section, you the student will be able to describe the water treatment process. 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 Safe Drinking Water Act (SDWA) requires the EPA to set enforceable standards to protect public health from contaminants which may occur in drinking water, therefore we need drinking water treatment.

The treatment needs of a water system are likely to differ depending on whether the system uses a groundwater or surface water source. Common surface water contaminants include turbidity, microbiological contaminants *(Giardia*, viruses and bacteria) and low levels of a large number of organic chemicals. Groundwater contaminants include naturally occurring inorganic chemicals (such as arsenic, fluoride, radium, radon and nitrate) and a number of volatile organic chemicals (VOCs) that have recently been detected in localized areas.

When selecting among the different treatment options, the water supplier must consider a number of factors. These include regulatory requirements, characteristics of the raw water, configuration of the existing system, cost, operating requirements and future needs of the service area.



A surface water conventional treatment facility next to a river.

Top Photograph - Final Rectangular Sedimentation Basin Discharge Weirs

Top Photograph –Rectangular Clarifier

Water Treatment Section - Preliminary Treatment Process

Most lakes and reservoirs are not free of logs, tree limbs, sticks, gravel, sand and rocks, weeds, leaves, and trash. If not removed, these will cause problems to the treatment plant's pumps and equipment. The best way to protect the plant is screening.

Bar screens are made of straight steel bars at the intake of the plant. The spacing of the vertical bars will rank the size. Wire mesh screens are woven stainless steel material and the opening of the fabric is narrow. Both of these devices can be made for manual cleaning.

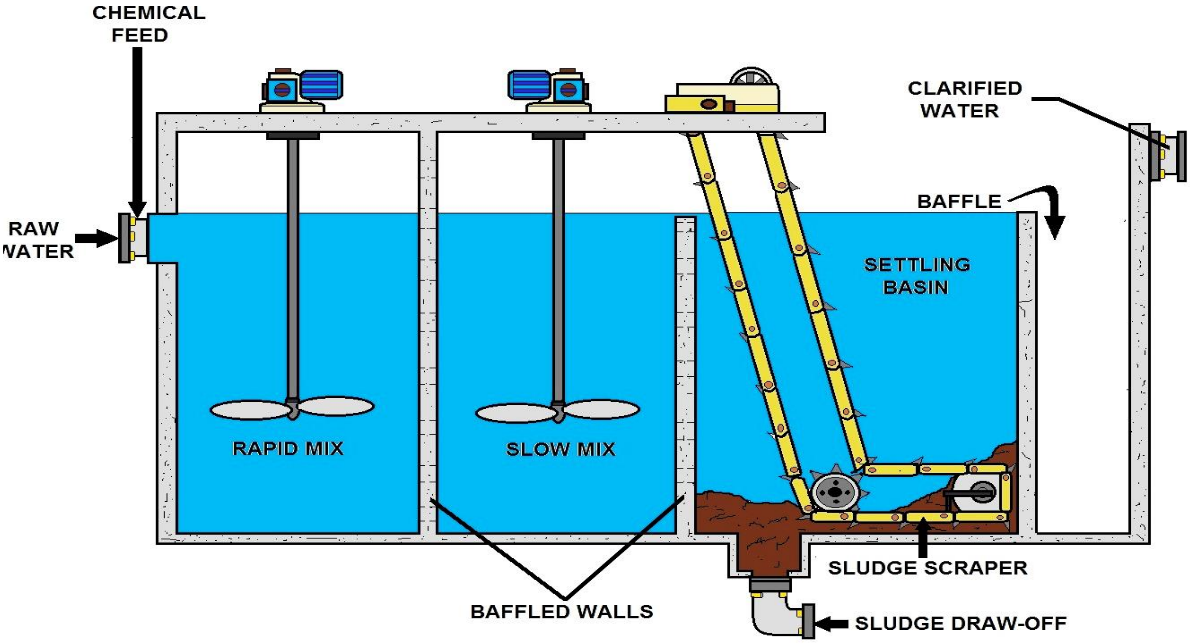
Mechanical bar screens vary in size and use some type of raking mechanism that travels vertically up the bars to scrap the debris off. The type of screening used depends on the material in the raw water and the size of the intake.

Mechanical bar screen, above photograph.
Non-automated bar screen, below.

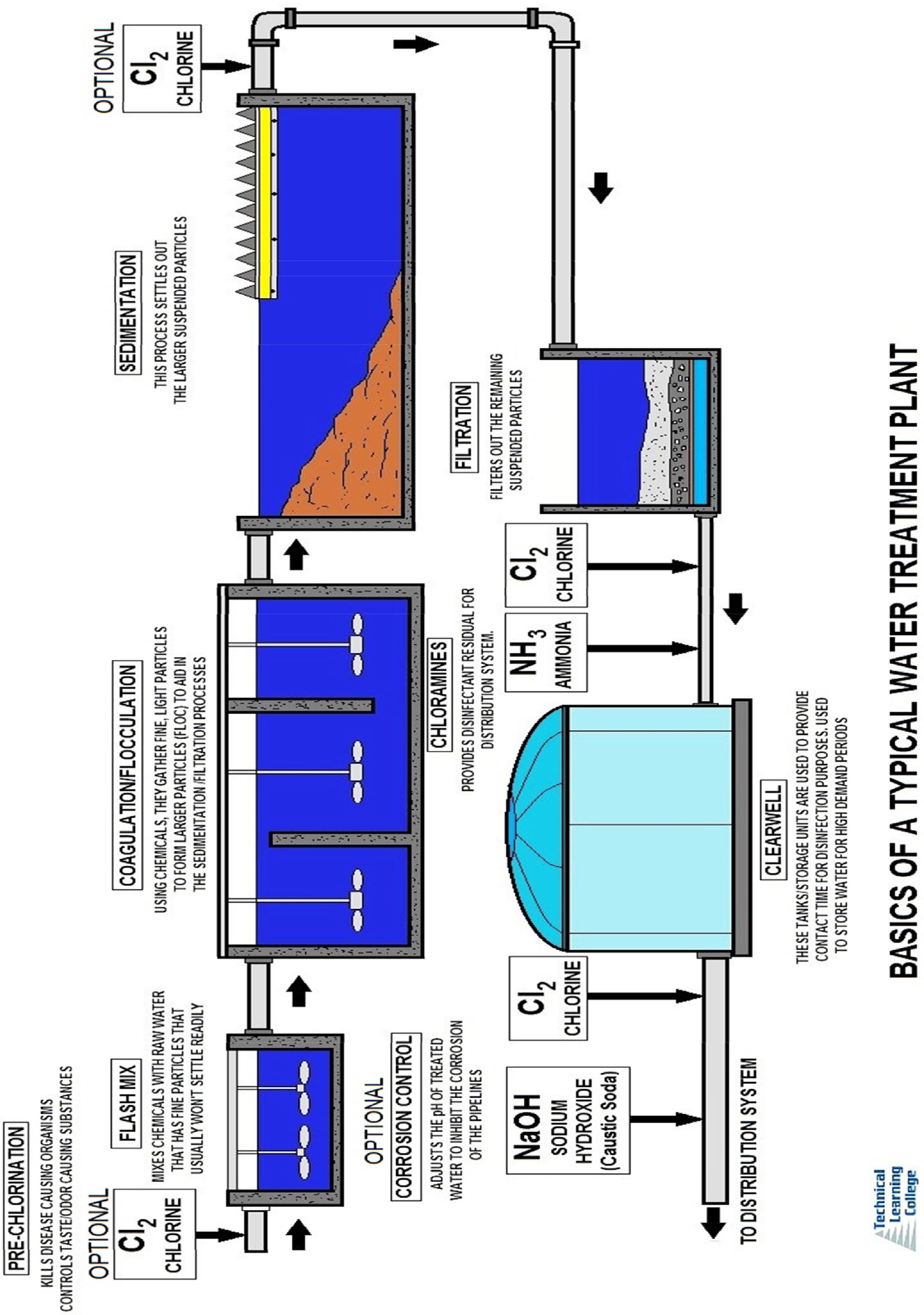
Pre-Sedimentation

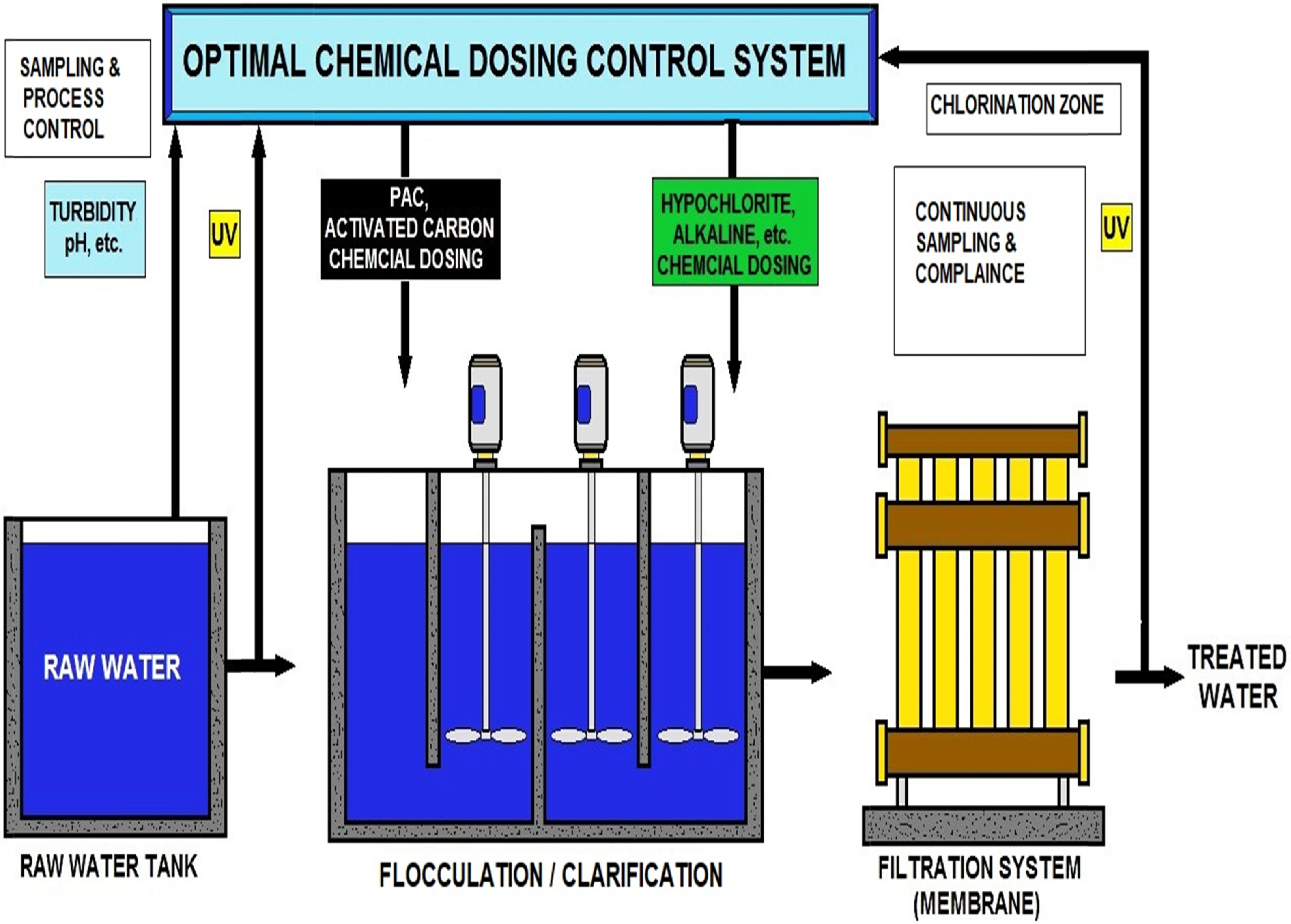
Once the water passes the bar screens, sand and grit are still present. This will damage plant equipment and pipes, so it must be removed. This is generally done with either rectangular- or round-shaped clarifiers. Depending on the raw water quality, initial sedimentation may also be used after the flocculation process.

Let's first look at the components of a rectangular clarifier. Most are designed with scrapers on the bottom to move the settled sludge to one or more hoppers at the end of the tank. It could have a screw conveyor or traveling bridge used to collect the sludge. The most common is a chain and flight collector. Most designs will have baffles to prevent short circuiting and scum from entering the effluent.



RECTANGULAR FLOCCULATION AND CLARIFIER EXAMPLE


BASICS OF A TYPICAL WATER TREATMENT PLANT
PRE-CHLORINATION
KILLS DISEASE CAUSING ORGANISMS
CONTROLS TASTE/ODOR CAUSING SUBSTANCES
OPTIONAL
Cl_2
CHLORINE
FLASH MIX
MIXES CHEMICALS WITH RAW WATER
THAT HAS FINE PARTICLES THAT
USUALLY WON'T SETTLE READILY
COAGULATION/FLOCCULATION
USING CHEMICALS, THEY GATHER FINE, LIGHT PARTICLES
TO FORM LARGER PARTICLES (FLOC) TO AID IN
THE SEDIMENTATION/FILTRATION PROCESSES
SEDIMENTATION
THIS PROCESS SETTLES OUT
THE LARGER SUSPENDED PARTICLES
OPTIONAL
Cl_2
CHLORINE
FILTRATION
FILTERS OUT THE REMAINING
SUSPENDED PARTICLES
Cl_2
CHLORINE
NH_3
AMMONIA
CHLORAMINES
PROVIDES DISINFECTANT RESIDUAL FOR
DISTRIBUTION SYSTEM.
CLEARWELL
THESE TANKS/STORAGE UNITS ARE USED TO PROVIDE
CONTACT TIME FOR DISINFECTION PURPOSES. USED
TO STORE WATER FOR HIGH DEMAND PERIODS
Cl_2
CHLORINE
OPTIONAL
CORROSION CONTROL
ADJUSTS THE pH OF TREATED
WATER TO INHIBIT THE CORROSION
OF THE PIPELINES
NaOH
SODIUM
HYDROXIDE
(Caustic Soda)
TO DISTRIBUTION SYSTEM
Technical
Learning
College



WATER TREATMENT PLANT CHEMICAL DOSING

Flights and Chains

An important thing to understand is the sludge and scum collection mechanism known as the "*flights and chains*". They move the settled sludge to the hopper in the clarifier for removal and they also remove the scum from the surface of the clarifier.

The flights are usually wood or nonmetallic flights mounted on parallel chains.

The motor shaft is connected through a gear reducer to a shaft that turns the drive chain.

The drive chain turns the drive sprockets and the head shafts. The shafts can be located overhead or below.

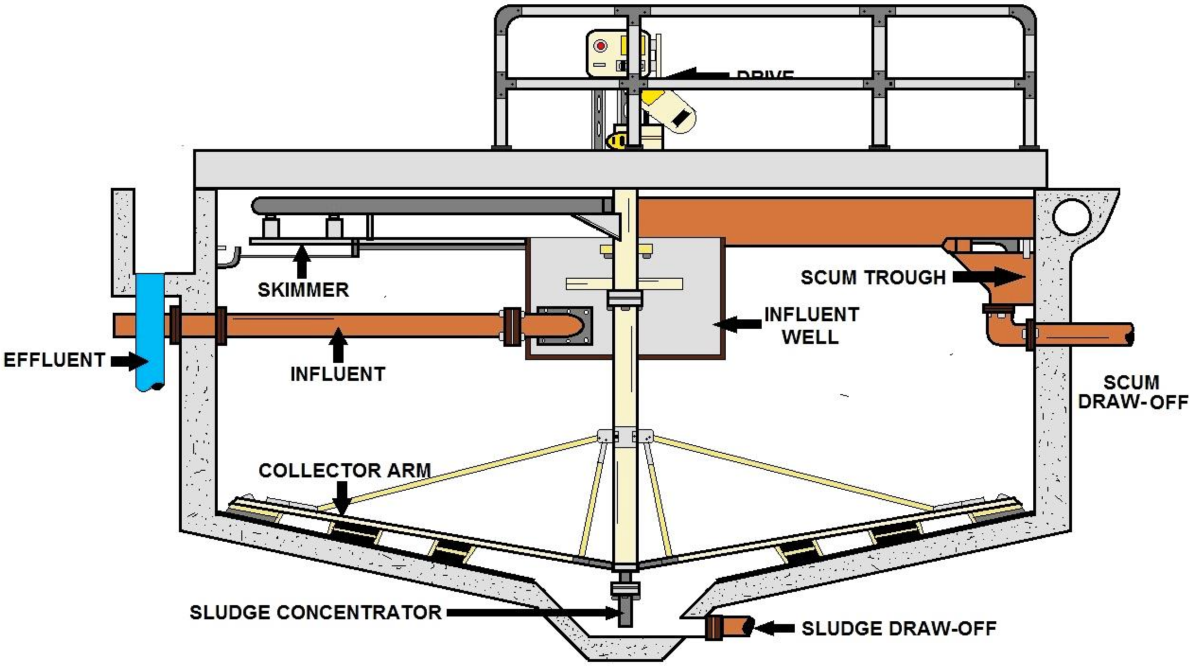
Some clarifiers may not have scum removal equipment, so the configuration of the shaft may vary. As the flights travel across the bottom of the clarifier, wearing shoes are used to protect the flights. The shoes are usually metal or nylon and travel along a metal track.

To prevent damage due to overloads, a shear pin is used. The shear pin holds the gear solidly on the shaft so that no slippage occurs. The gear moves the drive chain. If a heavy load is put on the sludge collector system then the shear pin should break. This means that the gear would simply slide around the shaft and movement of the drive chain would stop.

Rectangular basin flights and chains.

Circular Clarifiers

In some circular or square tanks, rotating scrapers are used. The diagram below shows a typical circular clarifier. The most common type has a center pier or column. The major mechanic parts of the clarifier are the drive unit, the sludge collector mechanism, and the scum removal system**.**



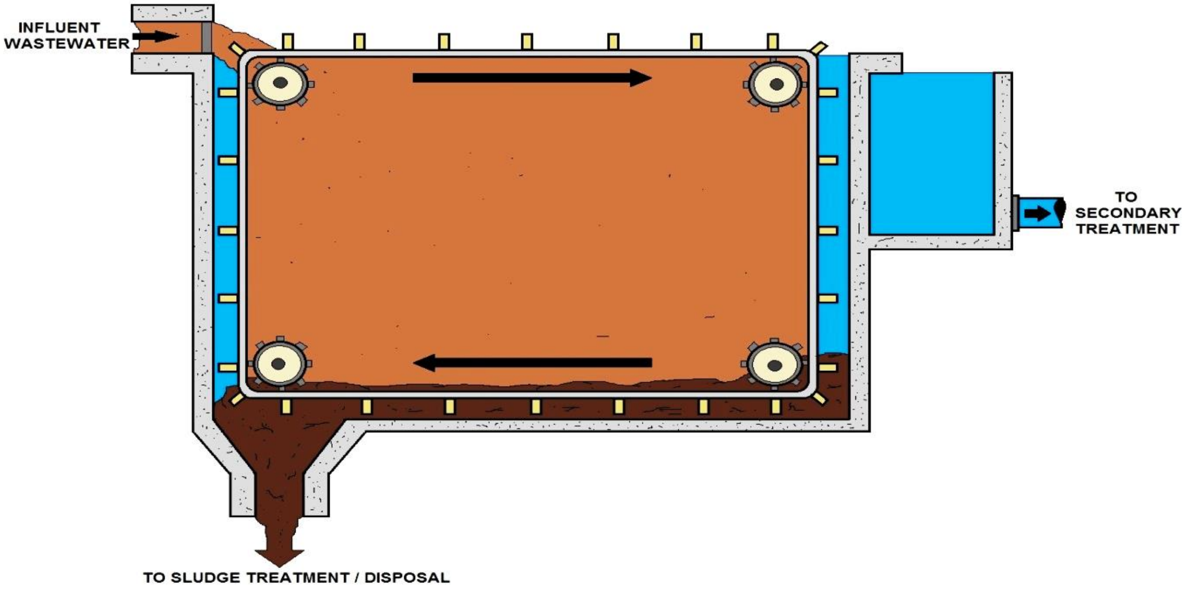
CIRCULAR CLARIFIER AND COLLECTOR MECHANISM

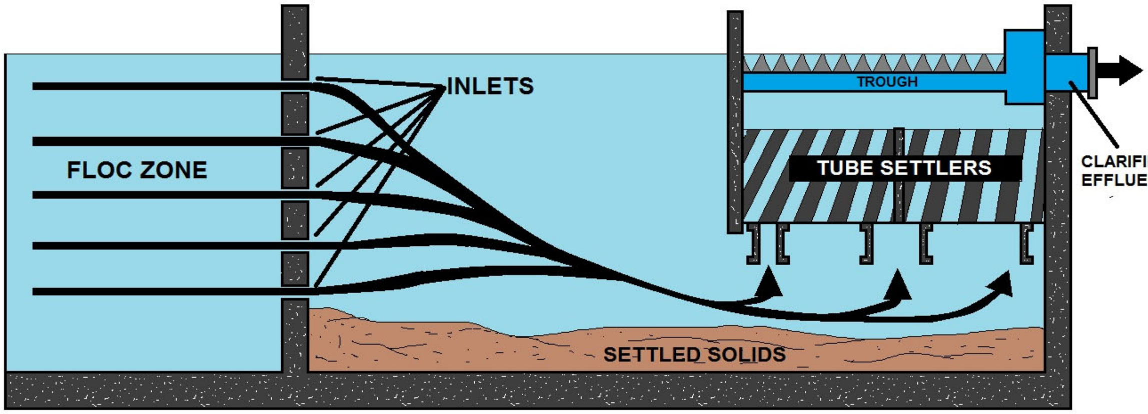
Pre-Treatment

Once the water passes the bar screens, sand and grit are still present. This will damage plant equipment and pipes, so it must be removed. This is generally done with either rectangular or round shaped clarifiers. Sedimentation basins are also used after the flocculation process.

Clarifiers

Let's first look at the components of a rectangular clarifier. Most are designed with scrapers on the bottom to move the settled sludge to one or more hoppers at the influent end of the tank. It could have a screw conveyor or traveling bridge used to collect the sludge. The most common is a chain and flight collector. Most designs will have baffles to prevent short-circuiting and scum from entering the effluent.





TUBE SETTLER (Water Treatment)

Water treatment systems use settling tanks unit to allow for sedimentation and settling. The main aim of tube settlers is to minimize the vertical distance that a small floc particle must settle before agglomerating into larger particles. Water treatment is a major requirement both for raw water for drinking and wastewater management. Both have particles which need to sediment in order to obtain clear water.

Tube settler design involves the use of multiple tubular channels sloping at an angle of 60 degrees and adjacent to each other. This helps in increasing the settling area effectively. Tube settler design reduces the depth significantly compared to the conventional clarifier. This helps in reduction of settling time. Tube settler collects solids into a compact mass and slides it down the tube channel. When using tube settlers water flow is upward through the tubes and the solids slide down against the current using gravity.

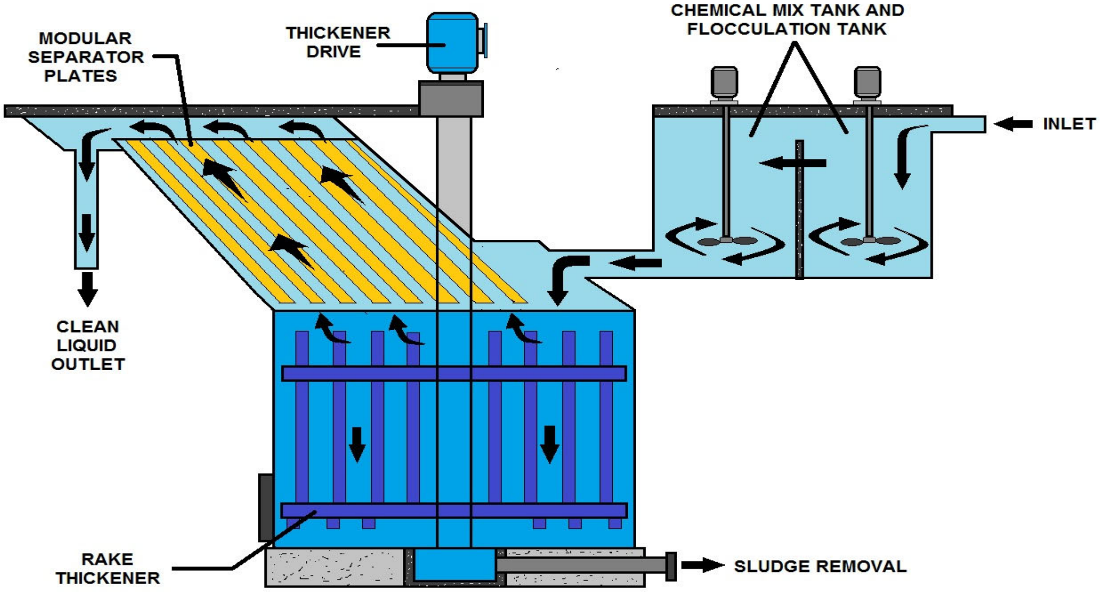
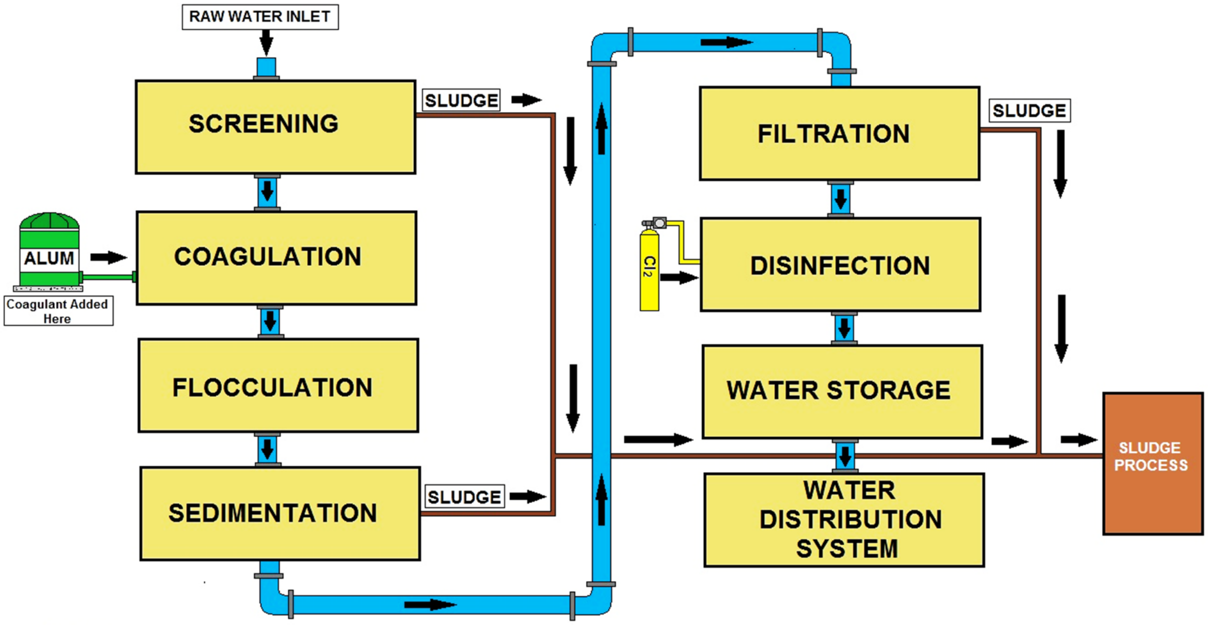


PLATE SETTLER

Review of Conventional Water Treatment Process



Technical Learning College

WATER TREATMENT PLANT LAYOUT

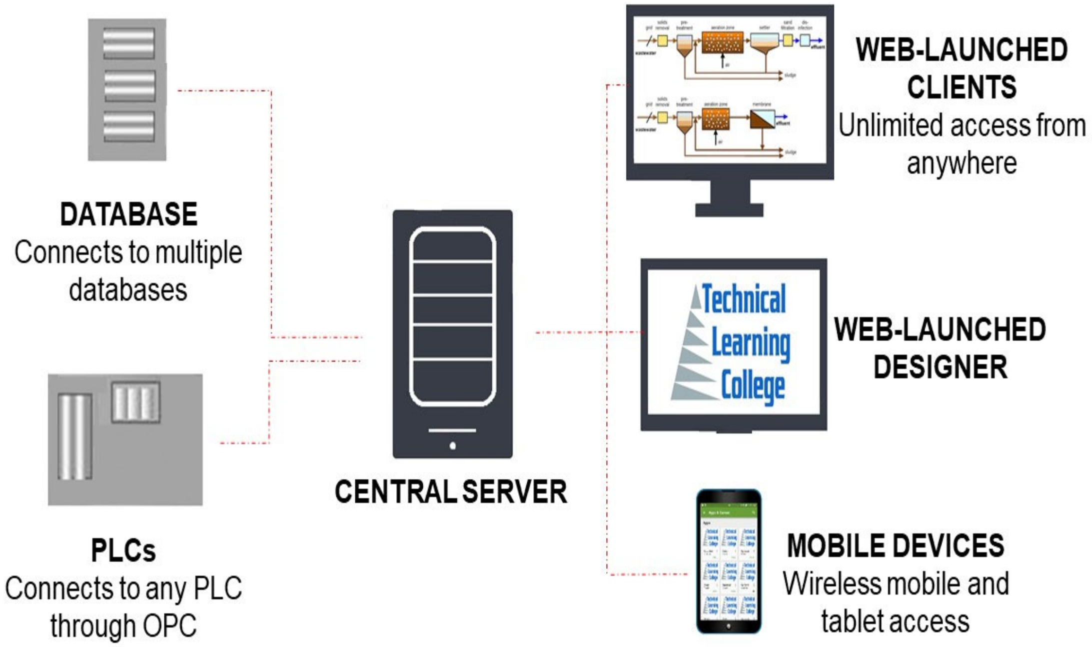
The design of a water treatment plant is determined by the water quality characteristics. Conventional water treatment plants include the steps as shown above if the quality of the source water is variable or poor. Direct filtration plants do not require sedimentation because the water quality characteristics are better.

The following are phases of conventional water treatment processes:

- Pre-treatment for algae control and arresting biological growth
- Aeration along with pre-chlorination for removal of dissolved iron when present with small amounts relative of manganese
- Coagulation or flocculation or slow-sand filtration
- Coagulant aids, also known as polyelectrolytes – to improve coagulation and for more robust floc formation
- Sedimentation for settling and the removal of suspended solids trapped in the floc
- Filtration to remove particles from water either by passage through a sand bed that can be washed and reused or by passage through a purpose- designed filter that is washable.
- Disinfection for killing bacteria viruses and other pathogens.

Constituent	**Unit Processes**
Turbidity and particles	Coagulation/ flocculation, sedimentation, granular filtration
Major dissolved inorganics	Softening, aeration, membranes
Minor dissolved inorganics	Membranes
Pathogens	Sedimentation, filtration, disinfection, membranes
Major dissolved organics	Membranes, adsorption

Treatment Design and Plant Operation
Treatment technologies for potable water and other uses are well developed, and generalized designs are available from which treatment processes can be selected for pilot testing (process control) on the specific source water. In addition, a number of private contractors provide patented technological solutions for the treatment of specific contaminants, e.g. Arsenic.



Technical Learning College

MODERN SCADA DIAGRAM

SCADA (Supervisory Control and Data Acquisition) automation of water treatment is common in the US. Source water quality through the seasons, scale, and environmental impact can dictate capital costs and operating costs. End use of the treated water dictates the necessary quality monitoring technologies.

Flocculation and Coagulation Sub-Section

Coagulation Introduction

Coagulation is a technique that's commonly used in conventional water treatment. It involves applying chemicals called coagulants to wastewater, causing pollutants to stick together so they can be more easily removed. With a sedimentation system, the goal is to get solids to settle to the bottom of the tank for removal.

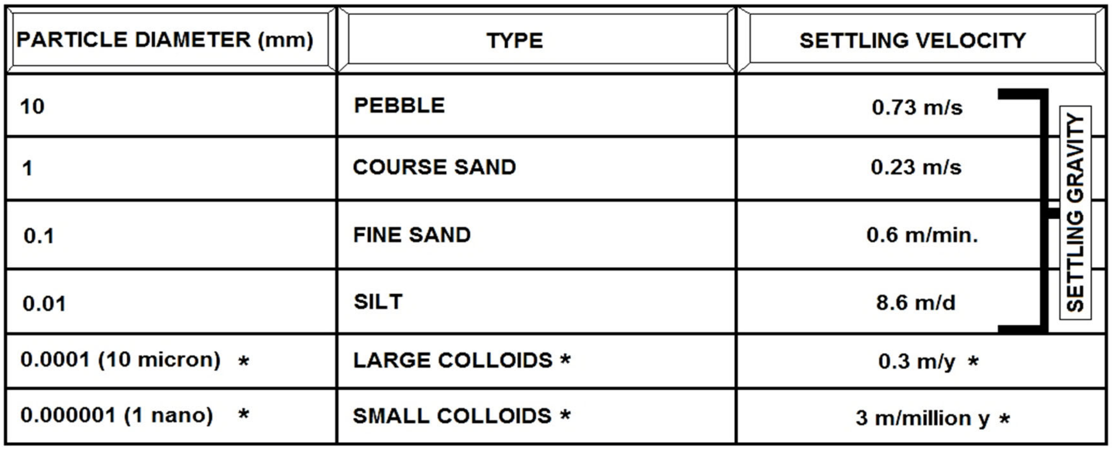
Coagulation and flocculation are important processes in water treatment with coagulation to destabilize particles through chemical reaction between coagulant and colloids, and flocculation to transport the destabilized particles that will cause collisions with floc.

Coagulation and flocculation processes have become more and more popular due to the increasingly stringent filtration requirements for industrial and municipal water treatment and wastewater treatment facilities levied by the U.S. Environmental Protection Agency (EPA.)

SWTR Rule

The U.S. EPA surface water treatment rule requires 99.9 percent (3-log) Giardia removal or inactivation, and at least 99 percent (2-log) removal of Cryptosporidium. The combination of coagulation and flocculation is particularly useful at exceeding these guidelines. Using these two treatment methods with sedimentation and filtration, assigned a 2.5-log removal credit for Giardia, will leave only 0.5-log inactivation. That remaining inactivation is met with disinfection.

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.

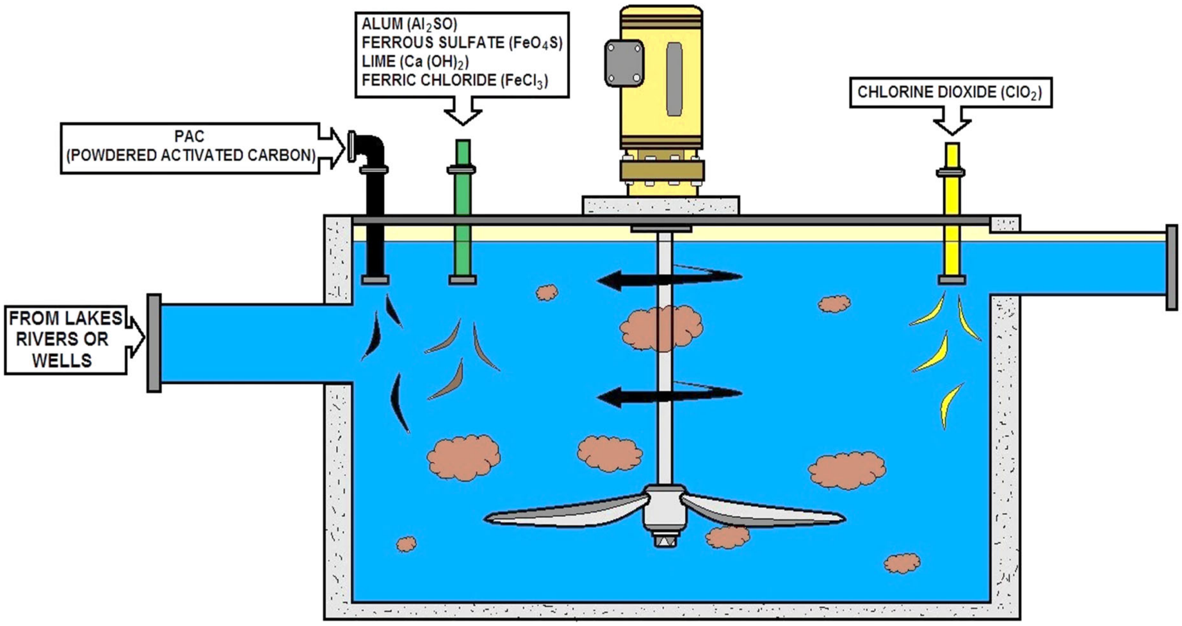


PARTICLE DIAMETER (mm)	TYPE	SETTLING VELOCITY	
10	PEBBLE	0.73 m/s	SETTLING GRAVITY
1	COURSE SAND	0.23 m/s	
0.1	FINE SAND	0.6 m/min.	
0.01	SILT	8.6 m/d	
0.0001 (10 micron) *	LARGE COLLOIDS *	0.3 m/y *	
0.000001 (1 nano) *	SMALL COLLOIDS *	3 m/million y *	

COAGULATION AND FLOCCULATION
(Examples of various sizes of particles in raw water)

* Colloids so small: gravity settling isn't possible

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 also be caused by changes in velocity or inadequate flushing following main replacement.

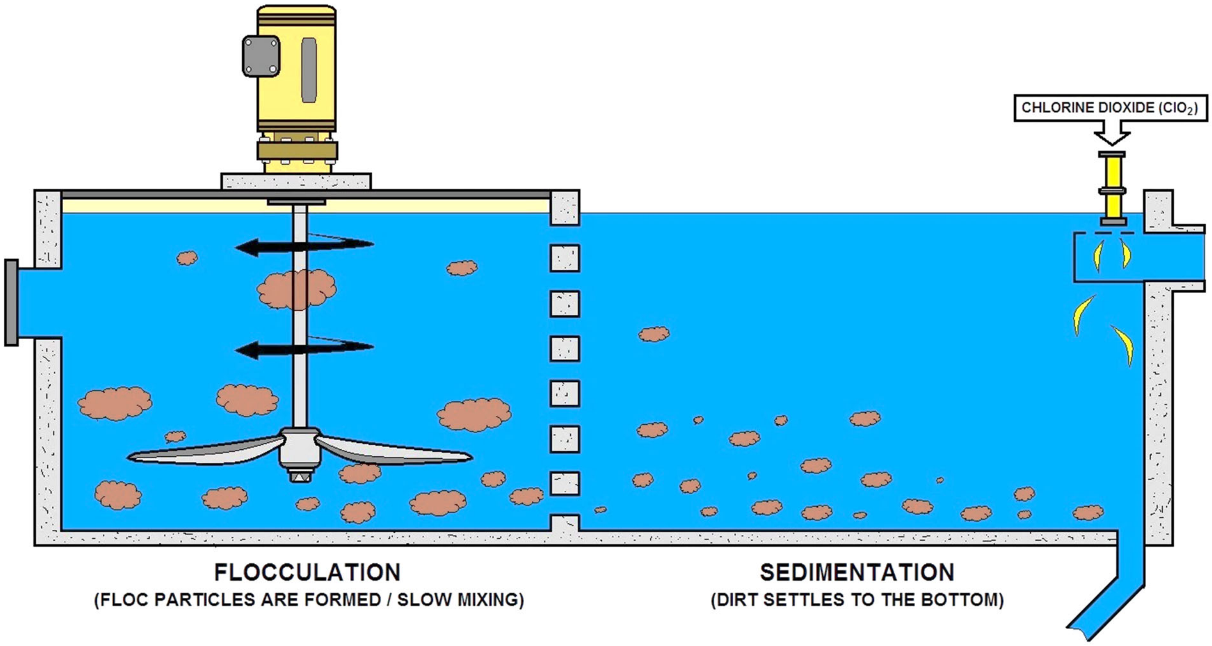


COAGULATION

(FLASH MIXING / WATER IS AGITATED TO EVENLY BLEND COAGULANTS AS FAST AS POSSIBLE)

First Step

The coagulation process in water treatment is often the first step in using chemicals (alum) in to create floc. Instead of passing over particles that would otherwise slip through the filter and fall too slowly to be trapped as sediment, coagulation clumps them together so they are more easily removed by sedimentation or filtration.



FLOCCULATION / SEDIMENTATION

Flocculation

Usually, flocculation follows the coagulation process and helps in getting rid of colloidal particles or flocs through rapid settlement in the solution. In certain cases, flocks also rise to the surface of the treated liquid, which can then be skimmed off or filtered out from the solution through the process of filtration.

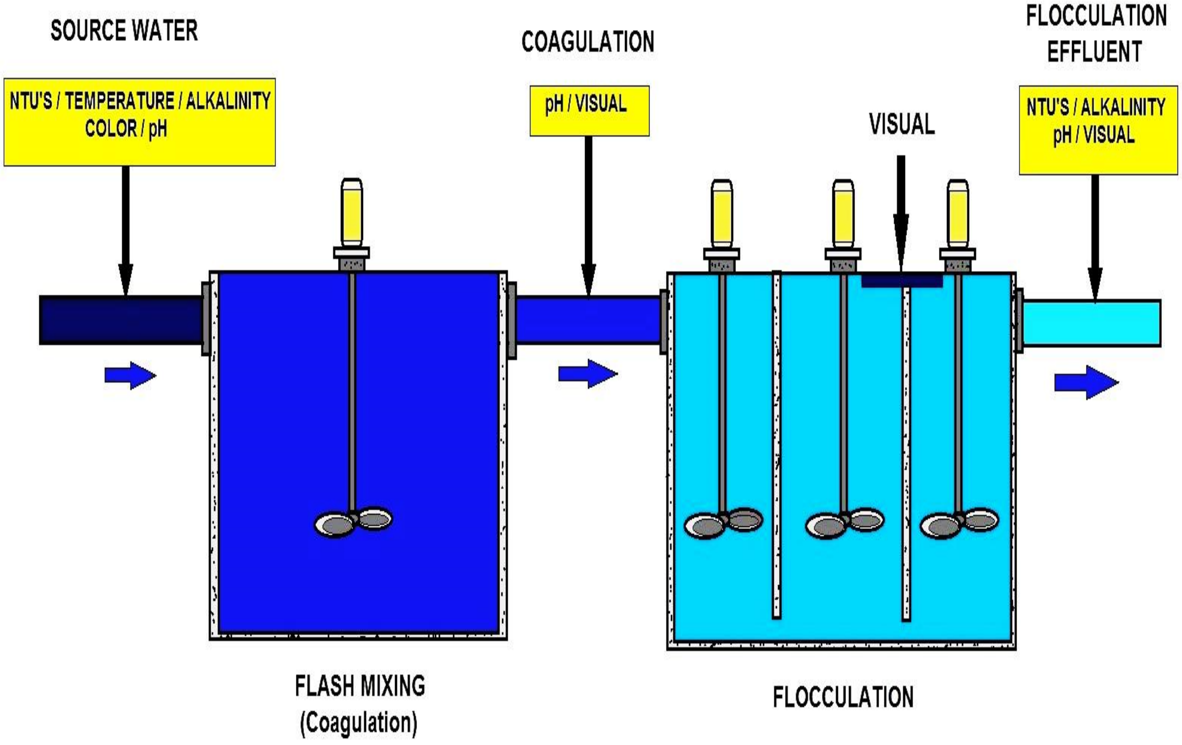
Flocculation and Sedimentation

Flocculation and sedimentation are widely employed in the purification of potable **water** as well as in wastewater treatment. Typical treatment processes consist of grates, coagulation, **flocculation**, sedimentation, granular filtration and disinfection procedures.

Flocculants, or Flocculating Agents

Flocculants, or flocculating agents (also known as flocking agents), are chemicals that promote flocculation by causing colloids and other suspended particles in liquids to aggregate, forming a floc.

Flocculants are used in **water treatment processes to improve the sedimentation or filterability of small particles.**



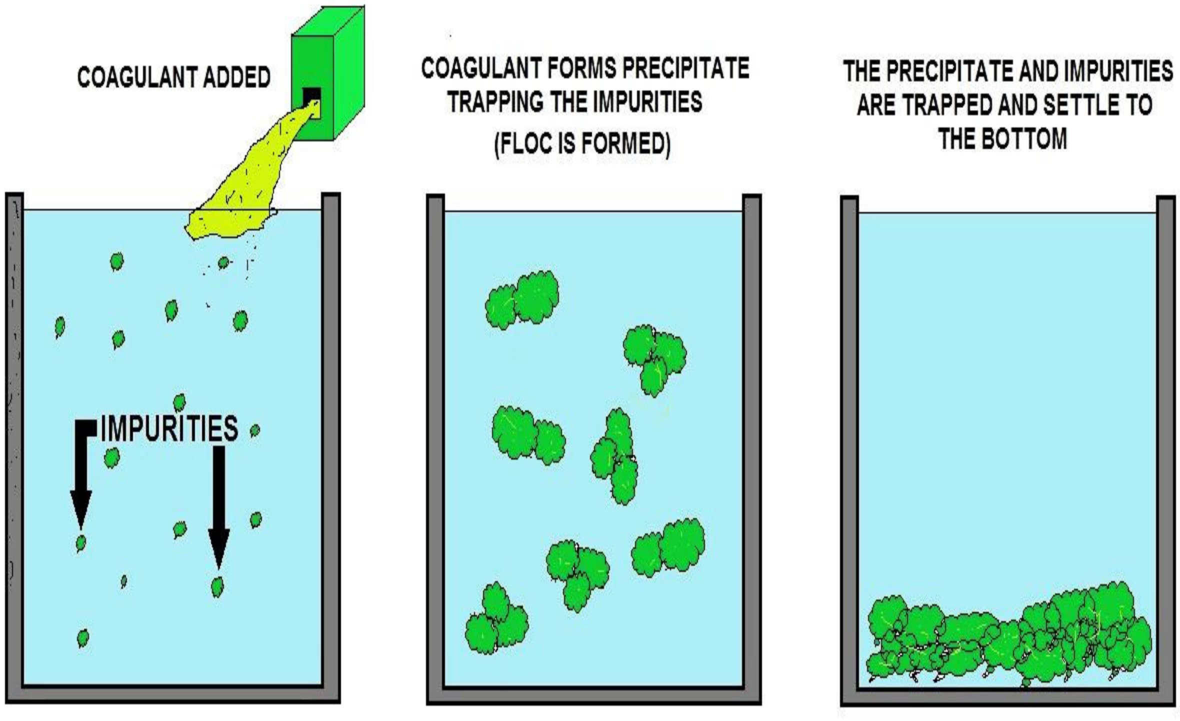
FACTORS THAT AFFECT COAGULATION / FLOCCULATION

Coagulation and Flocculation Processes

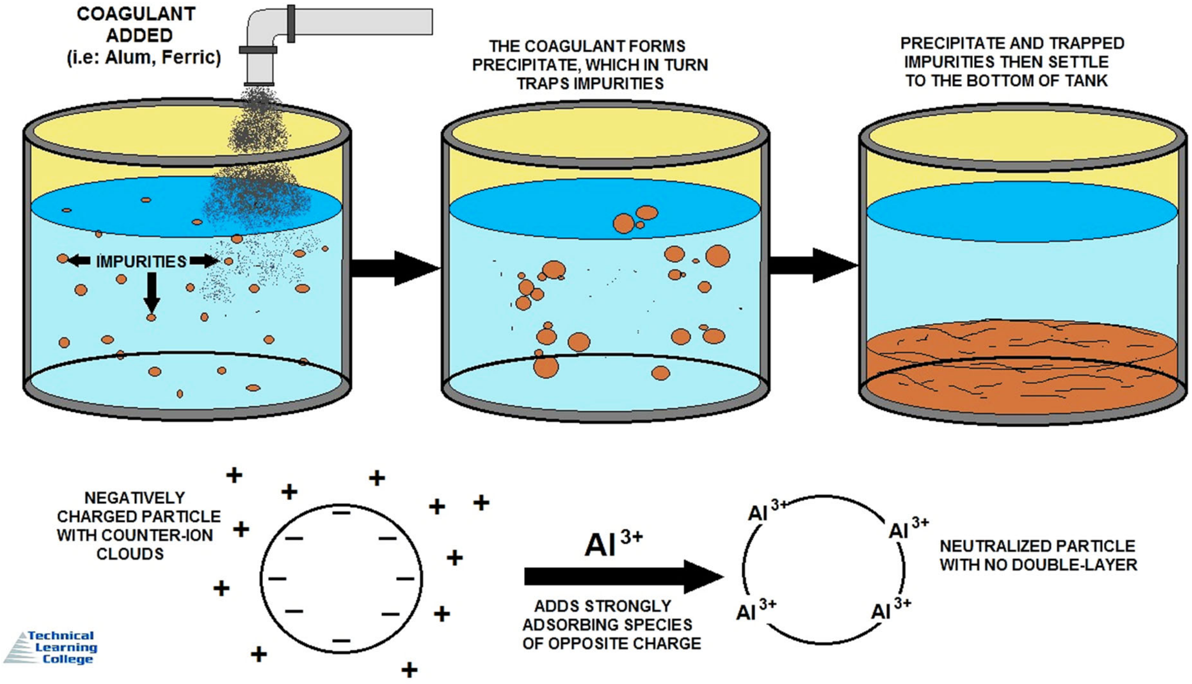
Coagulation and flocculation processes are used to remove iron, suspended solids, organic color, and hardness from influent water. In wastewater treatment these clarification aids help with the removal of other contaminants such as oil, phosphate and heavy metals. The commonly used metal coagulants fall into two general categories: those based on aluminum and those based on iron. The aluminum coagulants include aluminum sulfate, aluminum chloride and sodium aluminate. The iron coagulants include ferric sulfate, ferrous sulfate, ferric chloride and ferric chloride sulfate. Other chemicals used as coagulants include hydrated lime, magnesium carbonate and various polymers.

The effectiveness of aluminum and iron coagulants arises principally from their ability to form multi-charged polynuclear complexes with enhanced adsorption characteristics. The nature of the complexes formed may be controlled by the pH of the system. Polymers are often used to further bind the floc.

There are various chemical and natural substances that are used in removing unwanted particles through flocculation. Flocculants are like a high-tech webs that tie all of the coagulated clumps together.



COAGULATION / FLOCCULATION DIAGRAM #1



THE AIM OF COAGULATION

The raw water source's characteristics and the types of particulates in this raw water determines the best coagulant and flocculant chemical options. Metal salts are effective in removing inorganics while polymers remove numerous contaminants.

Common Chemicals/Flocculants Used for Initiating Flocculation Process are:

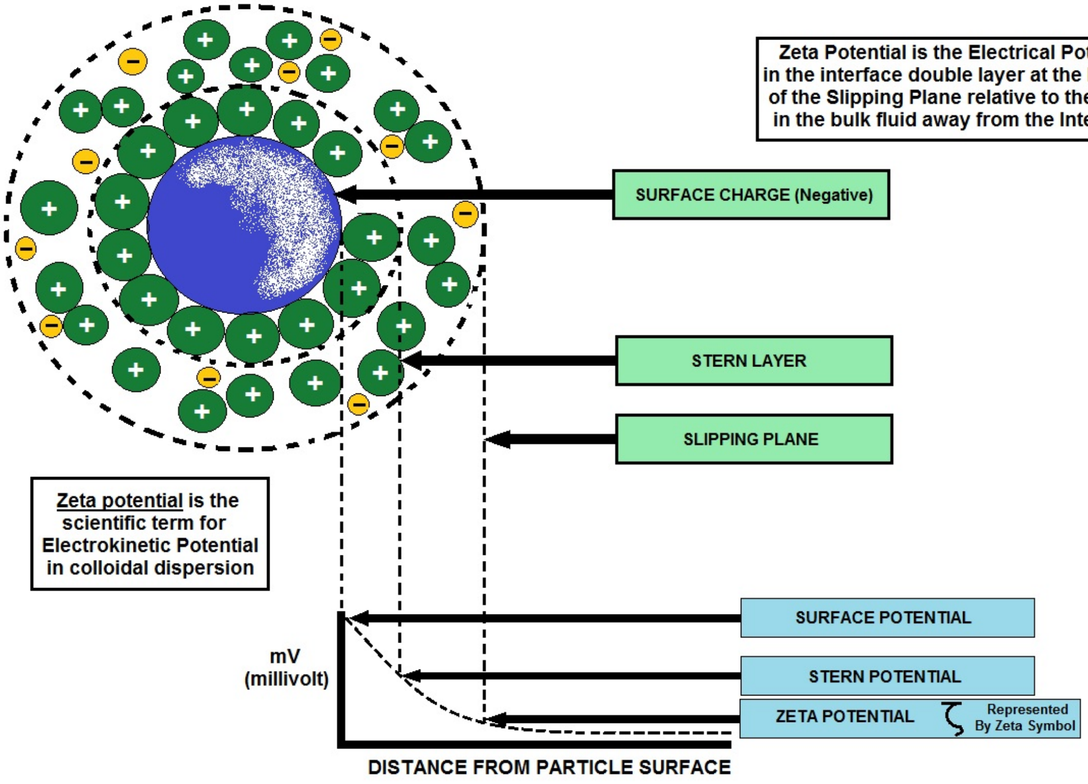
- Alum (Aluminum sulfate)
- Aluminum chlorohydrate
- Calcium oxide
- Calcium hydroxide
- Iron(II) sulfate
- Iron(III) chloride
- Polyacrylamide
- PolyDADMAC
- Sodium aluminate
- Sodium silicate

Factors Affecting Flocculation

Formation of flocs or flakes during flocculation is a complex process that depends on several factors. A few important factors are as follows:

- Physical (e.g., Turbulence)
- Chemical (e.g., Ionic concentration)
- Biological (Bacterial populations and extracellular polymeric material).

Zeta Potential Introduction


Zeta Potential is the Electrical Potential in the interface double layer at the location of the Slipping Plane relative to the point in the bulk fluid away from the Interface

Zeta potential is the scientific term for Electrokinetic Potential in colloidal dispersion

Technical Learning College

ZETA POTENTIAL

Zeta potential is a physical property exhibited by all solid-liquid and liquid-liquid colloidal systems. Surrounding the surface of all dispersed particles is a thin layer of ions that have the opposite charge of the particle's surface called the Stern layer. Further from the surface is an additional layer of more loosely-associated ions of opposite charge to the surface that move with the particle as it travels through a medium due to Brownian motion or sedimentation; this is called the double layer.

The zeta potential is defined as the voltage at the edge of the slipping (shear) plane with respect to the bulk-dispersing medium, where ions, molecules and other agents are no longer associated with a particle's surface. If two adjacent particles have sufficiently high zeta potentials of the same sign, they will not agglomerate due to repulsive electrostatic forces between particles with like charges.

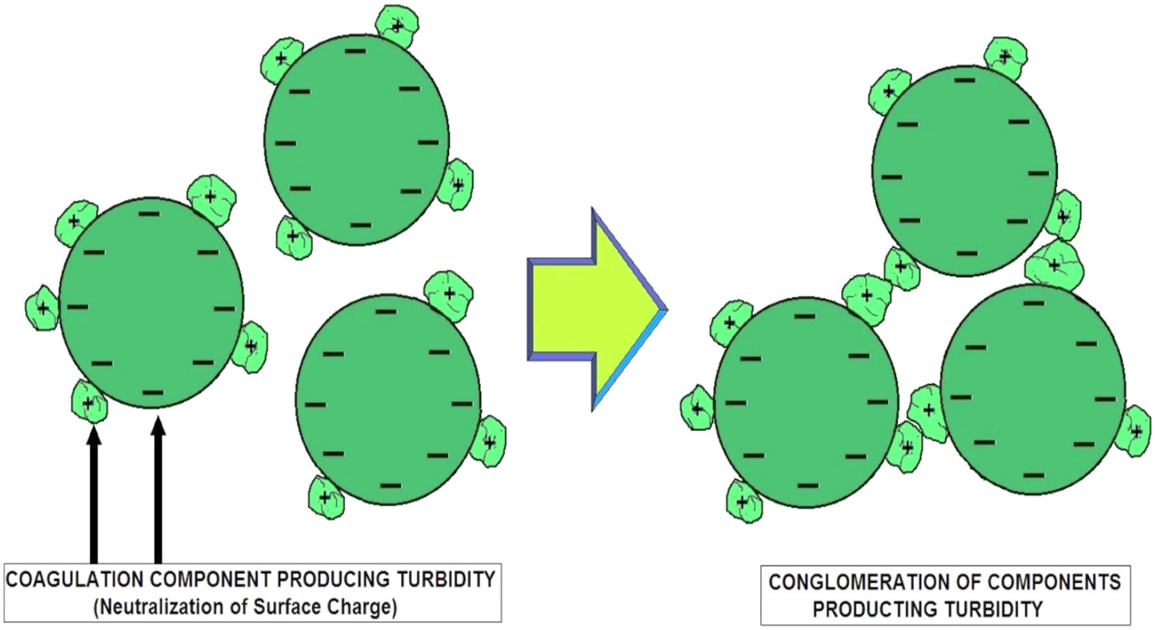
Solubility of Substances in Water

Water is an excellent solvent for many compounds. Some dissolve in it as molecules while others, called electrolytes, dissociate and dissolve not as neutral molecules but as charged species called ions. Compounds which exist as solid ionic crystals dissolve in water as ions, and most of them are highly soluble in water. "Highly soluble" is a somewhat elastic description, but generally means soluble to at least the extent of forming 0.1 to 1.0 molar aqueous solutions. Salts which are less soluble in water than this at room temperature are called slightly soluble salts.

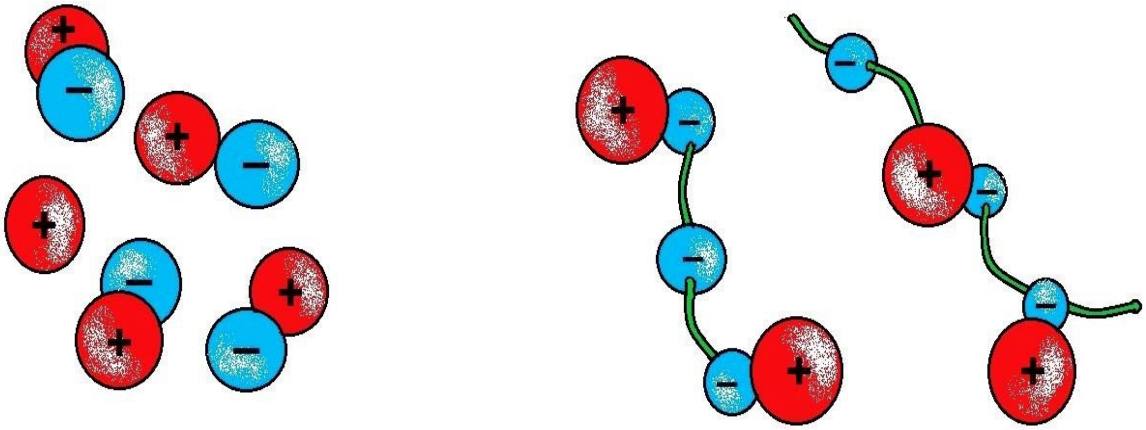
The solubility of an ionic salt depends both upon its cations and its anions, but for simple salts in aqueous solution at room temperature the following general observations are useful. Almost all sodium, potassium, and ammonium salts are highly soluble; the only significant exception is Potassium perchlorate, which is moderately soluble almost without exception. Potassium perchlorate is an inorganic salt with the chemical formula **$KClO_4$**. It is a strong oxidizer with the lowest solubility of the alkali metal perchlorates.

Metal carbonates and phosphates are generally insoluble or slightly soluble, with the exception of those of sodium, potassium, and ammonium which are highly soluble; magnesium ammonium phosphate is used for the precipitation of magnesium ion.

Metal halides are generally highly soluble, with the exception of those of silver, lead, and mercury (I). Lead chloride is slightly soluble while silver and mercury (I) chlorides are much less soluble. Sulfate salts are generally highly soluble as well, with more exceptions; calcium, barium, strontium, lead, and mercury (I) sulfates are almost insoluble while silver sulfate is slightly soluble. Metal sulfides are generally insoluble in water.



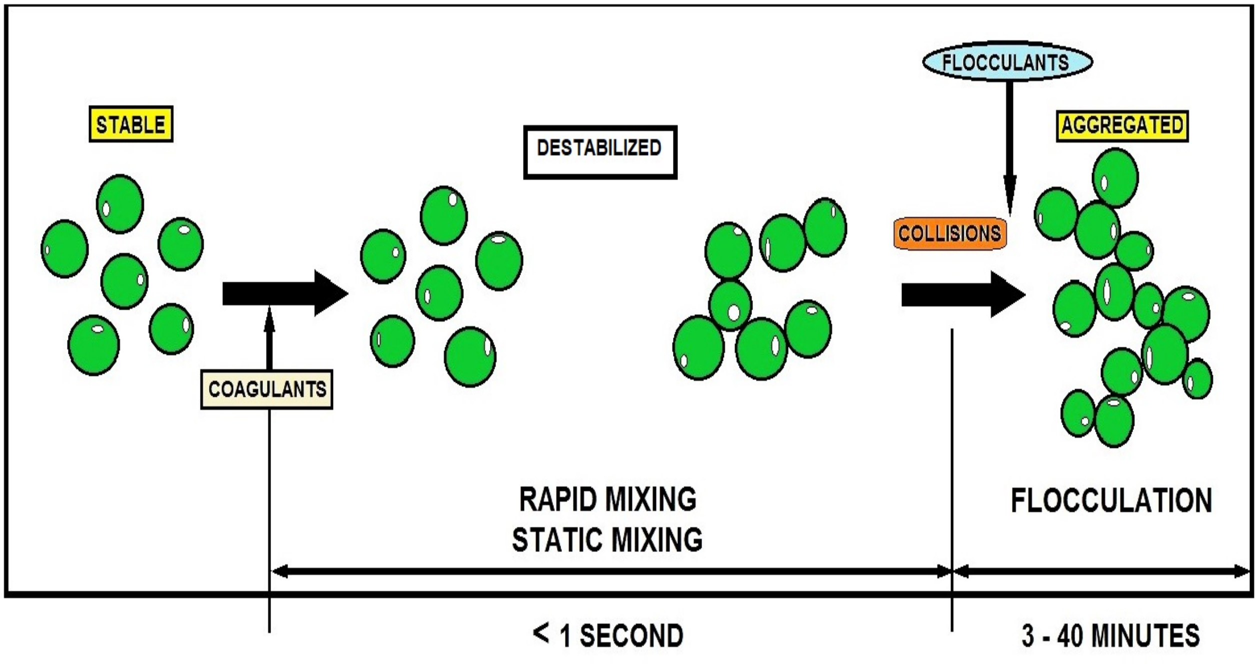
COAGULATION AND FLOCCULATION DIAGRAM #2



COAGULATION VS FLOCCULATION
MOLECULAR LEVEL DIAGRAM

Neutral Charges

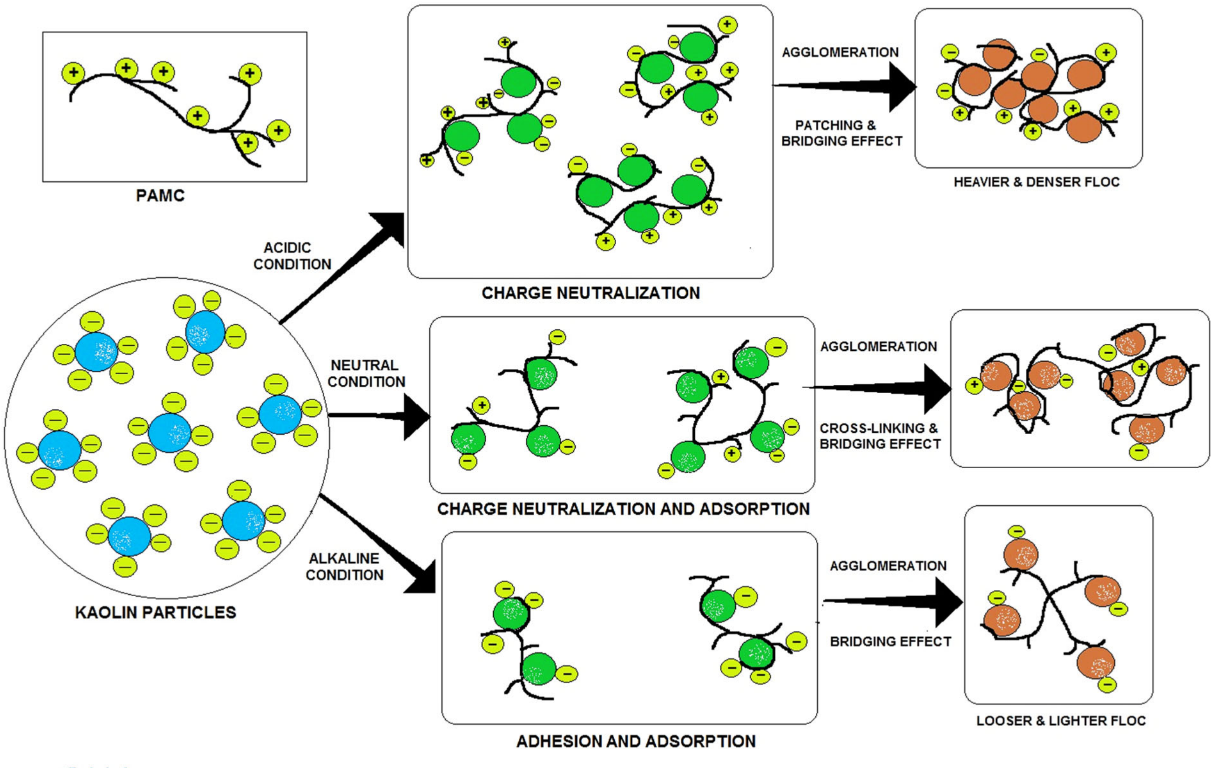
Once particles have a neutral charge, the particles will stick together. The water flows into a tank with paddles that provide slow mixing and bring the small particles together to form larger particles called flocs. Mixing is done quite slowly and gently in the flocculation step. If the mixing is too fast, the flocs will break apart into small particles making them more difficult to remove by sedimentation or filtration.



BASIC COAGULATION AND FLOCCULATION DIAGRAM #2

Purpose of Coagulation

Untreated surface waters often contains clay, minerals, bacteria, inert solids, microbiological organisms, oxidized metals, organic color producing particles, and other suspended materials. Some of the microbiological organisms can include Giardia cysts, pathogenic bacteria, and viruses. Oxidized metals include iron and manganese. All of these materials can inhibit disinfection, cause problems in the distribution system, and leave the water cloudy rather than clear. The purpose of coagulation is to remove these particles.



Technical Learning College

FLOCCULATION PROCESS

Chemical Coagulation in the water/wastewater treatment is the process of bringing suspended matter in untreated water together for the purpose of settling and for the preparation of the water for filtration.

Coagulation in a Conventional Plant involves three specific steps, which are:

- Coagulation
- Flocculation
- Sedimentation

Turbidity Particles

The ability of particles to remain suspended in water is a function of both the particle size and specific gravity. Turbidity particles can range in size from molecular to 50 microns (a tremendous range). Particles that are greater than one micron in diameter are considered silt, and settle out due to their relatively large size and density in a matter of seconds or minutes without the need to coagulate.

Colloidal material ranges in size from 0.001 to one micron in diameter. These materials require days to months for complete settling. Since detention times in the water treatment process are generally less than twelve hours, the rate of settling of these colloidal particles must be increased in the water treatment process. This is accomplished in the coagulation process when tiny particles agglomerate into larger, denser particles which will settle more quickly.

These tiny colloidal particles have a very large surface area to mass ratio, and this factor is important in keeping the particles suspended for long periods of time. In fact, the surface area to mass ratio is so high that electric charges and ionic groups become important in keeping the particles suspended. Two types of colloids exist. These are hydrophobic or water hating colloids, and hydrophilic or water loving colloids.

Hydrophilic Colloids

Hydrophilic colloids form suspensions easily, and can be difficult to remove. These colloids can, however, react chemically with the coagulants commonly added to water under proper conditions. Examples of hydrophilic colloids would be organic color forming compounds. Hydrophobic colloids do not easily form suspensions. The reactions between hydrophobic colloids and the coagulants commonly added to water are largely physical rather than chemical. Examples of hydrophobic colloids would be clays and metal oxides.

The Coagulation Process

Coagulation is accomplished by the addition of ions having the opposite charge to that of the colloidal particles. Since the colloidal particles are almost always negatively charged, the ions which are added are usually cations or positively charged.

The coagulating power of an ion is dependent on its valency or magnitude of charge. A bivalent ion (+2 charge) is 30 to 60 times more effective than a monovalent ion (+l charge). A trivalent ion (+3 charge) is 700 to 1000 times more effective than a monovalent ion.

Typically, two major types of coagulants are added to water. These are aluminum salts and iron salts. The most common aluminum salt is aluminum sulfate, or alum.

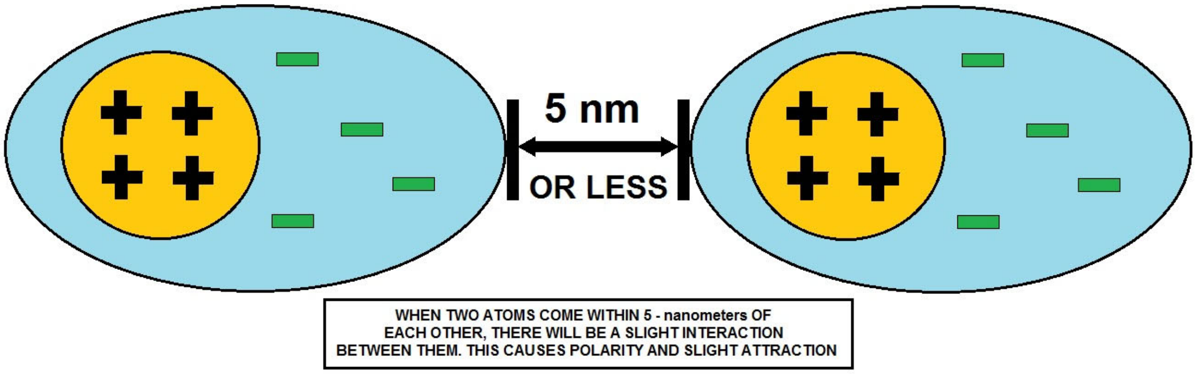
When aluminum sulfate is added to water, the aluminum ions enter into a series of complicated reactions. The aluminum ions become hydrated, meaning that water molecules attach themselves to the aluminum ions. In addition, anions present in the water, such as hydroxide and sulfate ions can attach to the aluminum ions. These reactions result in large, positively charged molecules having aluminum ions at their center. These particles may have charges as high as +4.

Olation

Following these reactions, a second type of reaction occurs, called Olation. This reaction involves the bridging of two or more of these large molecules to form even larger, positively charged ions. A typical molecule can contain eight aluminum ions, twenty hydroxide ions, and will have a +4 charge. Iron salts behave in a similar manner when added to water.

Once these large polymeric aluminum or iron compounds are formed, the magnitude of their high positive charge allows these species to rapidly move toward the colloid, where they are adsorbed onto the negatively charged surface of the turbidity particle. The coagulant compounds can penetrate the bound water layer because of their high positive charge.

This rapid adsorption results in the compression of the electrical double layer, and results in the colloid becoming coated with the coagulant compounds. The net result of this process is that the electrical charges on the particle are reduced. The suspension is now considered to be destabilized, and the particles can be brought together through, among other forces, Brownian Movement, and will be held together by the Van der Waals forces.



VAN DER WAALS FORCES

An additional process occurs which assists this process. As the coagulant continues to undergo the hydrolyzation and olation reactions, progressively larger masses of flocculent material are formed. These compounds can become large enough to settle on their own, and tend to trap turbidity particles as they settle. This is commonly referred to as sweep floc.

Zeta Potential

As the coagulation reactions and destabilization are occurring, the Zeta Potential at the surface of the colloid is also found to be reducing. Typically, the Zeta Potential for a naturally occurring water may be in the range of -10 to -25 millivolts. As the reactions occur, this Zeta Potential will be reduced to approximately -5 millivolts. These figures are only examples of what might be considered typical waters.

Since all waters exhibit a specific set of characteristics, these numbers will vary. It is interesting to note that the Zeta Potential does not have to be reduced to zero in order for coagulation to occur, because the forces of attraction can become predominant before complete destabilization occurs.

Hydrophilic colloids participate in the coagulation process in a slightly different way. These colloids tend to attract water molecules and attach these water molecules to their surfaces. This is also a hydration process, and the water molecules act as a barrier to contact between particles. Also attached to the surfaces are hydroxyl, carboxyl, and phosphate groups, all to which are negatively charged.

Coagulant products react chemically with the negatively charged groups attached to the hydrophilic colloids, forming an insoluble product which is electrically neutral and destabilized.

CHEMICAL NAME	ADVANTAGES	DISADVANTAGES
ALUMINUM SULFATE (Alum) $Al_2(SO_4)_3$ 18 H_2O	EASY TO HANDLE AND APPLY; THE MOST COMMON USED; PRODUCES LESS SLUDGE THAN LIME MOST EFFECTIVE IN THE 6.5 - 7.5 pH RANGE	ADDS DISSOLVED SOLIDS (SALTS) TO THE WATER; EFFECTIVE OVER A LIMITED pH RANGE
SODIUM ALUMINATE $Na_2 AL_2 O_4$	EFFECTIVE IN HARD WATERS; SMALLER DOSES ARE USUALLY NEEDED	OFTEN USED WITH ALUM; HIGH COSTS ASSOCIATED WITH; INEFFECTIVE IN SOFT WATERS
POLYALUMINUM CHLORIDE (PAC) $Al_{13} (OH)_{20} (SO_4)_2 Cl_{15}$	IN SOME APPLICATIONS, FLOC THAT IS FORMED IS MORE DENSE AND FASTER SETTLING THAN ALUM	NOT COMMONLY USED; LITTLE FULL SCALE DATA COMPARED TO OTHER ALUM DERIVATIVES
FERRIC SULFATE $Fe_2 (SO_4)_3$	MOST EFFECTIVE IN THE 4-6 AND 8.8-9.2 pH RANGE	ADDS DISSOLED SOLIDS (SALTS) TO WATER; USUALLY ADDED FOR ALKALINITY
FERRIC CHLORIDE $FeCl_3 6H_2O$	EFFECTIVE BETWEEN THE 4-11 pH RANGE	ADDS DISSOLVED SOLIDS (SALTS) TO WATER; CONSUMES TWICE AS MUCH ALKALINITY AS ALUM
FERROUS SULFATE (COPPERAS) $FeSO_4 7H_2O$	NOT AS pH SENSITIVE AS LIME	ADDS DISSOLVED SOLIDS (SALTS) TO WATER; USUALLY NEEDED TO ADD ALKALINITY
LIME $Ca(OH)_2$	COMMONLY USED; IS VERY EFFECTIVE; IT MAY NOT ADD SALTS TO EFFLUENT	VERY pH DEPENDENT; PRODUCES LARGE QUANTITIES OF SLUDGE; TO MUCH FEED CAN RESULT IN POOR EFFLUENT QUALITY

Technical Learning College

WATER TREATMENT COAGULANTS

Coagulants – Alum and Ferric

Aluminum Sulfate (Alum): Aluminum Sulfate is also known as alum, filter alum, and alumina sulfate. Alum is the most widely used coagulant. Alum is available in dry form as a powder or in lump form. It can also be purchased and fed as a liquid.

Alum has no exact formula due to the varying water molecules of hydration which may be attached to the aluminum sulfate molecule. Once in water, alum can react with hydroxides, carbonates, bicarbonates, and other anions as discussed previously to form large, positively charged molecules. Carbon dioxide and sulfate are generally byproducts of these reactions. During the reactions, alum acts as an acid to reduce the pH and alkalinity of the water supply. It is important that sufficient alkalinity be present in the water supply for the various reactions to occur.

On a theoretical basis, 1.0 mg/l of dry alum will react with:

0.50 mg/l of natural alkalinity as calcium carbonate
0.33 mg/l of 85% quicklime as calcium oxide
0.39 mg/l of 95% hydrated lime as calcium hydroxide
0.54 mg/l of soda ash as sodium carbonate

Alum can be effective in the pH range of 5.5 to 7.8, but seems to work best in most water supplies in a pH range of 6.8 to 7.5. Below a pH range of 5.5, alkalinity in the water supply is generally insufficient. The aluminum ions become soluble rather than insoluble and do not participate in the hydration and olation reactions necessary to make the alum effective as a coagulant. In these instances the plant may experience higher than normal filtered water turbidities, and much of the aluminum will pass through the filters.

When the pH level of the water is above 7.8 after the addition of the alum, the aluminum ions again become soluble, and the efficiency of coagulation is decreased. Under these conditions, aluminum ions again penetrate the filters, and post filtration alum coagulation can occur in the clear well and in the distribution system in some cases.

Ferric Chloride (Ferric): Traditionally, ferric chloride has not been used widely as a coagulant, but this trend is not continuing. Ferric chloride is becoming more extensively used as a coagulant due partially to the fact that the material can be purchased as a liquid.

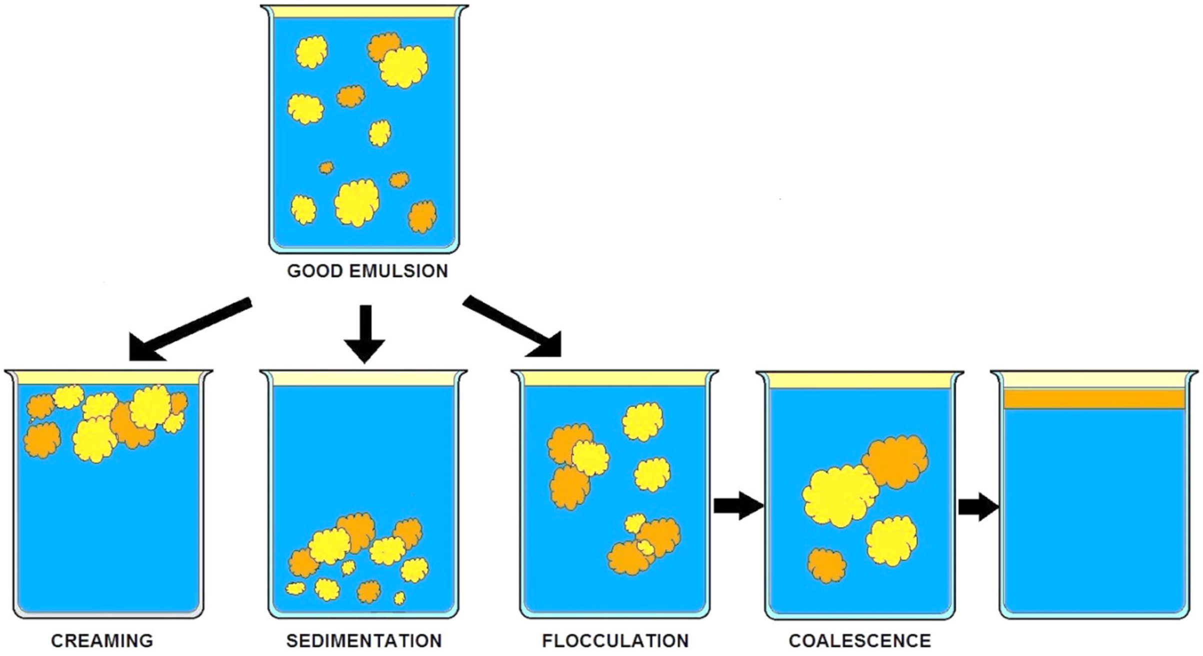
Ferric chloride may also be purchased as an anhydrous solid. Liquid ferric chloride is highly corrosive, and must be isolated from all corrodible metals.

Like ferric sulfate, ferric chloride exhibits a wide pH range for coagulation, and the ferric ion does not easily become soluble. As a result, many plants are replacing alum with ferric chloride to eliminate the penetration of aluminum ions through the plant filters. Ferric chloride also reacts as an acid in water to reduce alkalinity.

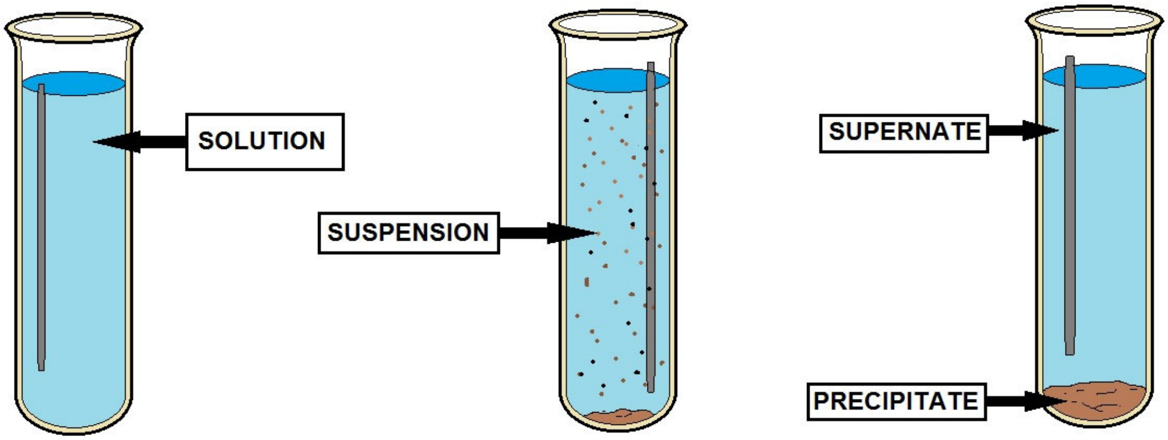
Other inorganic coagulants are available, such as potash alum, ammonia alum, ferrous sulfate (copperas), and chlorinated copperas. None of these materials are widely used. Typical dosages of the inorganic coagulants range from 50 pounds per million gallons of water treated under ideal conditions to as high as 800 to 1000 pounds per million gallons of water treated under worst case conditions.

Destabilizing Particles through Chemical Reaction

Coagulation and flocculation are important processes in water treatment with coagulation to destabilize particles through chemical reaction between coagulant and colloids, and flocculation to transport the destabilized particles that will cause collisions with floc.



EMULSION INSTABILITY MECHANISM DIAGRAM



SUPERNATE / PRECIPITATION / SUSPENSION IN CHEMISTRY

Factors Influencing Coagulation

Effects of pH: The pH range in which a coagulation process occurs may be the single most important factor in proper coagulation. The vast majority of coagulation problems are related to improper pH levels. Whenever possible, coagulation should be conducted in the optimum pH zone. When this is not done, lower coagulation efficiency results, generally resulting in a waste of chemicals and a lowered water quality.

Each of the inorganic salt coagulants has its own characteristic optimum pH range. In many plants, it is necessary to adjust the pH level in the coagulation process. In most cases, this involves the addition of lime, caustic soda, or soda ash to maintain a minimum pH level. In some cases, however, acids may be necessary to raise or lower the pH level to an optimum range. In some water plants, the acidic reactions of the inorganic salts are taken advantage of when the raw water pH levels are higher than desired. In these instances, overfeed of the coagulant is intentionally induced in order for the coagulation process to occur in the optimum range.

Effects of Salts: Since no natural waters are completely pure, each will have various levels of cations and anions such as calcium, sodium, magnesium, iron, manganese, sulfate, chloride, phosphate, and others. Some of these ions may affect the efficiency of the coagulation process. Generally, mono and divalent cations such as sodium, calcium, and magnesium have little or no effect on the coagulation process. Trivalent cations do not have an adverse effect on the process in most instances. In fact, significant concentrations of naturally occurring iron in a water supply has resulted in the ability to feed lower than normal dosages of inorganic salt coagulants.

Some anions can have a more pronounced effect. Generally, monovalent anions such as chloride have little effect on the coagulation process. As the concentration of the divalent anion sulfate in a water supply increases, the optimum pH range of the inorganic salt coagulants tends to broaden, generally toward the lower pH levels. As the concentration of phosphate ions increase, the optimum range of pH tends to shift to lower pH levels, without broadening. These effects could cause a disruption of the coagulation process if abrupt changes in the concentrations of these anions occur in the water supply.

Nature of Turbidity: 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.

Water Temperature: Cold water temperatures can cause two factors which add to the difficulty of the coagulation process. As water temperatures approach freezing, almost all chemical reactions occur more slowly. It can be more difficult therefore to evenly disperse the coagulants into the water. In addition, floc settling characteristics become poor due to the higher density of the water during near freezing temperatures. As a result, the coagulant process becomes less efficient, and higher coagulant dosages are generally used to compensate for these effects.

Mixing Effects: Poor or inadequate mixing results in an uneven dispersion of the coagulant. Unfortunately, many older plants were designed with mixing facilities which generally do not accomplish mixing in the most efficient manner. As a result, it becomes necessary to use higher than necessary dosages of coagulant to achieve an optimum level of efficiency in the process. The effects of low turbidity and cold water temperatures can tend to aggravate the lack of adequate mixing facilities in some plants.

Effect of the Coagulant: The choice of the proper coagulant for the given conditions is of critical importance in maintaining an efficient coagulation scheme under widely varying conditions. The chemicals most commonly used in the coagulation process are Aluminum Sulfate, Ferric Chloride, Ferric Sulfate, and Cationic Polymers.

Jar Testing –Coagulation and Flocculation at different doses and conditions

Jar Testing –Water Chemistry Principles Sub-Section

The jar test is a common laboratory procedure used to determine the optimum operating conditions for water or wastewater treatment. This method allows adjustments in pH, variations in coagulant or polymer dose, alternating mixing speeds, or testing of different coagulant or polymer types, on a small scale in order to predict the functioning of a large scale treatment operation. A jar test simulates the coagulation and flocculation processes that encourage the removal of suspended colloids and organic matter that can lead to turbidity, odor and taste problems.

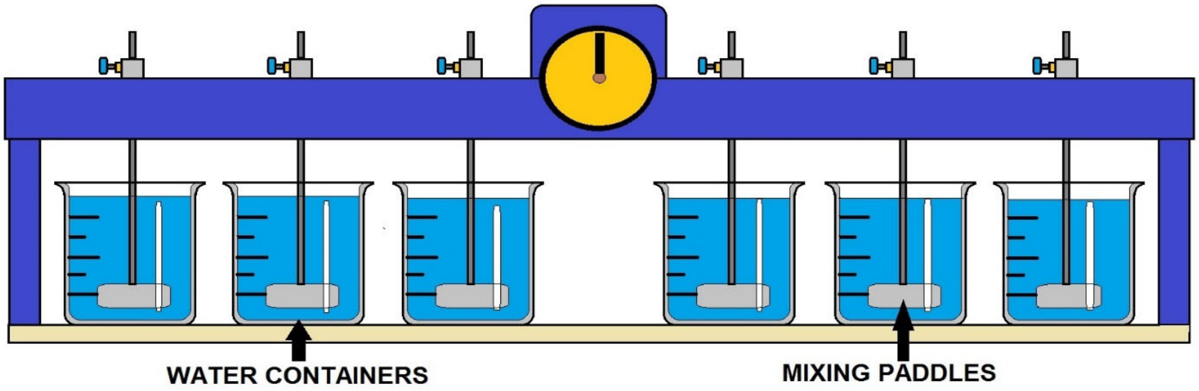
Key Terms

Flocculation - Agglomeration of particles into groups, thereby increasing the effective diameter.

Coagulation - A chemical technique directed toward destabilization of colloidal particles.

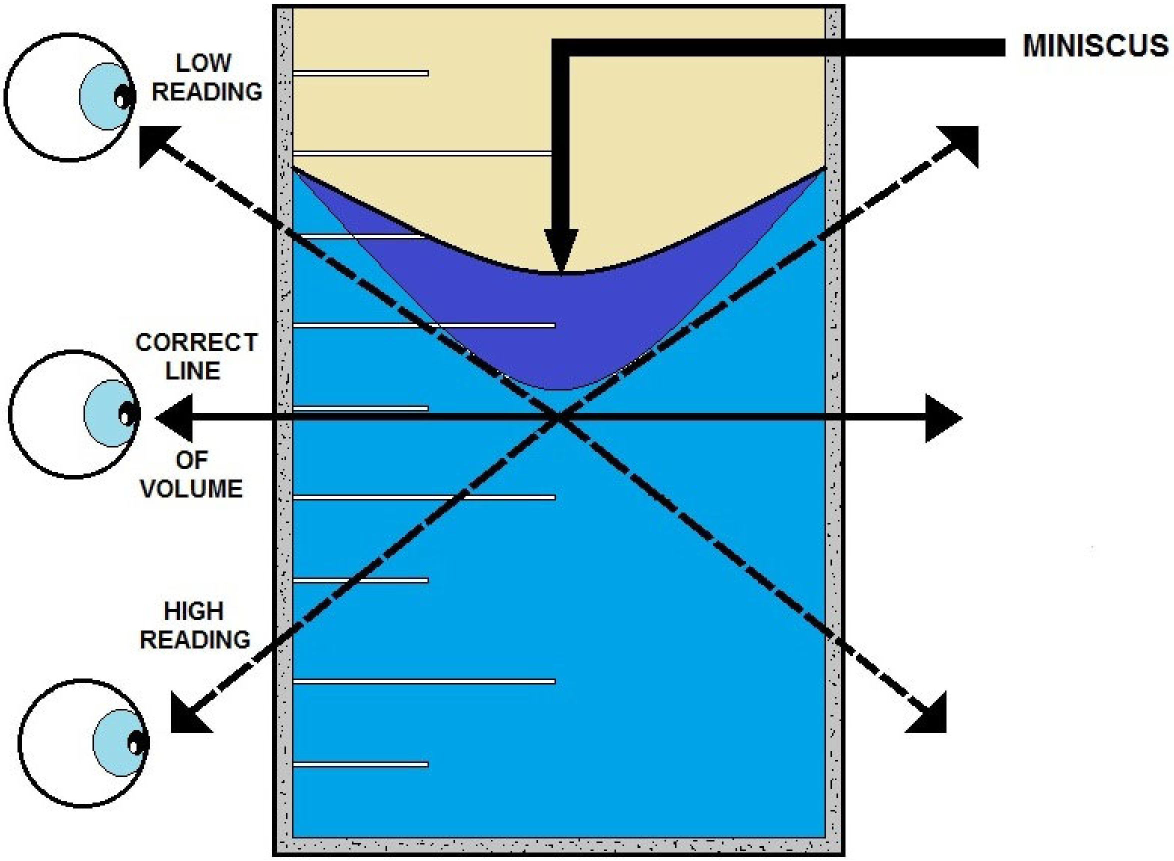
Turbidity - A measure of the presence of suspended solid material.

Colloidal – A suspension of small particles; a suspension of small particles dispersed in another substance.



FLOCCULATION / COAGULATION JAR TEST UNIT

Proper Meniscus Reading Procedure



HOW TO READ A MINISCUS

The **meniscus** (plural: *menisci*, from the Greek for "crescent") is the curve in the upper surface of a liquid close to the surface of the container or another object, caused by surface tension. It can be either convex or concave.

A convex (upwards curving) meniscus occurs when the molecules have a stronger attraction to each other (cohesion) than to the material of the container (adhesion). This may be seen between mercury and glass in barometers and thermometers.

Conversely, a concave (downwards curving) meniscus occurs when the molecules of the liquid attract those of the container's, causing the surface of the liquid to cave downwards. This effect can be easily seen in a glass of water.

Corrosion Control Sub-Section

Introduction

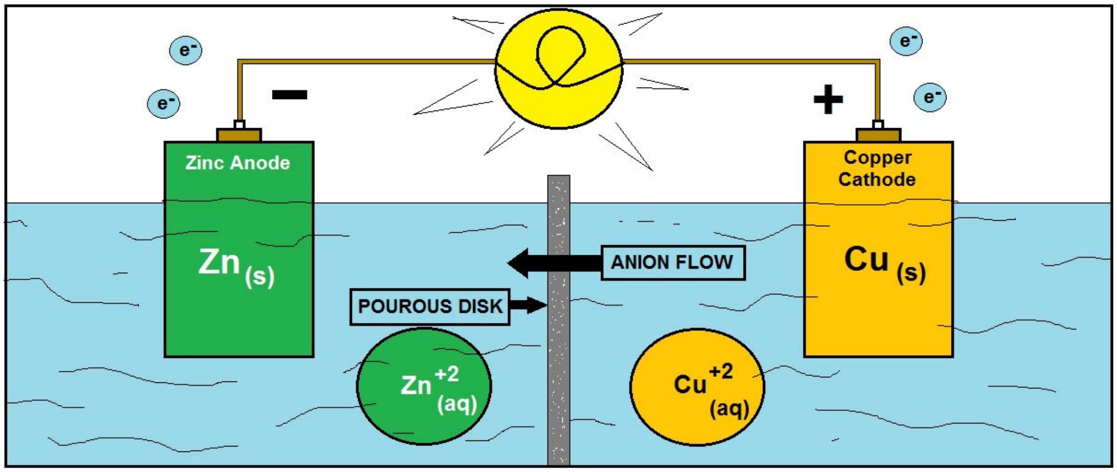
Corrosion is the deterioration of a substance by chemical action. Lead, cadmium, zinc, copper and iron might be found in water when metals in water distribution systems corrode. Drinking water contaminated with certain metals (such as lead and cadmium) can harm human health.

Corrosion also reduces the useful life of water distribution systems and can promote the growth of microorganisms, resulting in disagreeable tastes, odors, slimes and further corrosion. Because it is widespread and highly toxic, lead is the corrosion product of greatest concern.

The EPA has banned the use of lead solders, fluxes and pipes in the installation or repair of any public water system. In the past, solder used in plumbing has been 50% tin and 50% lead. Using lead-free solders, such as silver-tin and antimony-tin is a key factor in lead corrosion control.

The highest level of lead in consumers' tap water will be found in water that has been standing in the pipes after periods of nonuse (overnight or longer). This is because standing water tends to leach lead or copper out of the metals in the distribution system more readily than does moving water. Therefore, the simplest short-term or immediate measure that can be taken to reduce exposure to lead in drinking water is to let the water run for two to three minutes before each use for cooking or drinking. Also, drinking water should not be taken from the hot water tap, as hot water tends to leach lead more readily than cold.

Long-term measures for addressing lead and other corrosion by-products include pH and alkalinity adjustment; corrosion inhibitors; coatings and linings; and cathodic protection, all discussed below.



CATHODE & ANODE IN GALVANIC ELECTROLYSIS CELLS

Cathodic Protection

Cathodic protection protects steel from corrosion that is the natural electrochemical process that results in the deterioration of a material because of its reaction with its environment. Metallic structures, components, and equipment exposed to aqueous environments, soil, or seawater can be subject to corrosive attack and accelerated deterioration.

Therefore, it is often necessary to utilize either impressed current or sacrificial anode cathodic protection (CP) in combination with coatings as a means of suppressing the natural degradation phenomenon to provide a long and useful service life. However, if proper considerations are not given, problems can arise which can produce unexpected, premature failure.

There are two types of Cathodic protection:
Ø Sacrificial Anodes (Galvanic Systems)
Ù Impressed (Induced) Current Systems

Sacrificial Anode Systems
Sacrificial anodes are pieces of metal more electrically active than the steel piping system. Because these anodes are more active, the corrosive current will exit from them rather than the piping system. Thus, the system is protected while the attached anode is "*sacrificed*" or selectively corroded. These anodes are made of materials such as magnesium, aluminum or zinc, which are anodic with respect to the protected structure. The sacrificial anodes are connected directly to the structure.

Sacrificial anodes can be attached to the existing piping system or coated steel for a pre-engineered cathodic protection system. An asphalt coating is not considered a suitable dielectric coating. Depleted anodes must be replaced for continued Cathodic protection of the system.

Advantages
1. Needs no external power source.
2. Does not involve maintenance work
3. If carefully designed, it can render protection for anticipated period.
4. Installation is simple.
5. Does not involve expensive accessories like rectifier unit, etc.
6. Economical for small structures

Disadvantages
1. The driving voltage is small and therefore the anodes have to be fitted close to the structure or on the structure, thereby increasing the weight or load on the structure.
2. The anodes have to be distributed all over the structure (as throwing power is lower) and therefore have design limitations in certain applications.
3. Once designed and installed, protection current cannot be altered or increased as may be needed in case of cathode area extension (unprotected) or foreign structure interference (physical contact).

As a result of the electrochemical properties of the impressed current cathodic protection system, corrosion takes place only at the anodes and not at the piping system. Depleted anodes must be replaced for continued cathodic protection of the piping system.

Impressed Current System
The impressed current anode system, on the other hand, has several advantages over the sacrificial anode systems. In this system the protection current is "*Forced*" through the environment to the structure (cathode) by means of an external D.C. source. Obviously we need some material to function as anodes. It can be high silicon chromium cast iron anodes, graphite anodes, or lead-silver alloy anodes.

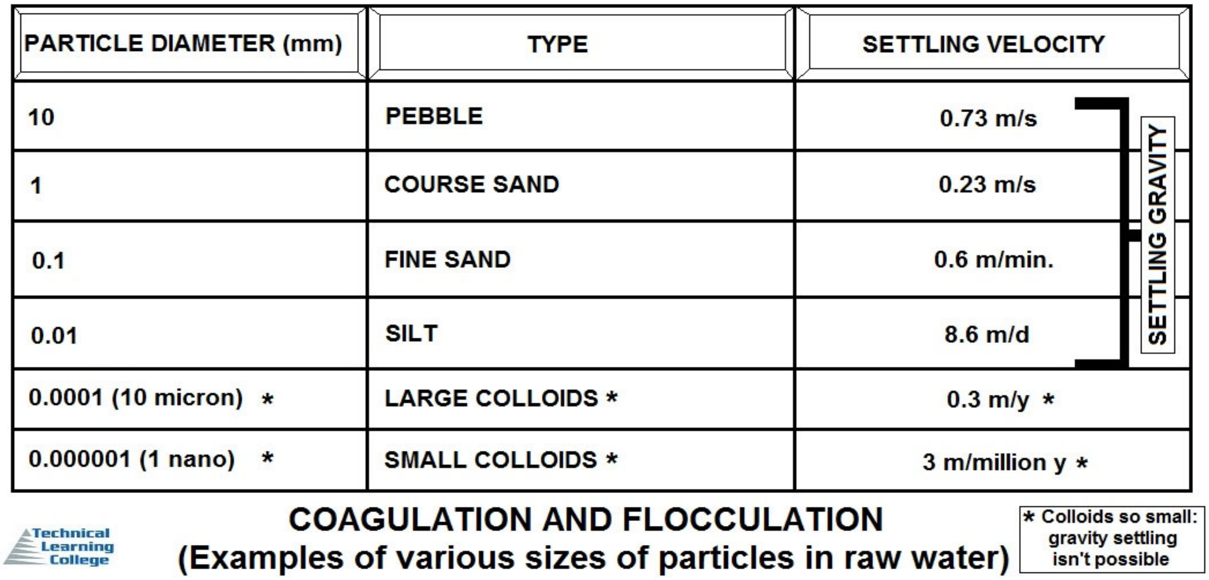
Advantages

1. Since the driving voltage is large, this system offers freedom of installation design and location
2. Fewer anodes can protect a large structure
3. Variations in protection current requirements can be adjusted to some extent (to be incorporated at design stage)

Disadvantages

1. Shut down of D.C. supply for a long time allows structure to corrode again.
2. Reversal of anode - cathode connection at D.C. source will be harmful as structure will dissolve become anodic
3. Needs trained staff for maintenance of units and for monitoring
4. Initial investments are higher and can pay off only in long run and economic only for large structures
5. Power cost must be incorporated in all economic considerations.
6. Possibility of overprotection should be avoided as it will affect the life of the paint.
7. Any foreign structure coming within this field will cause an interference problem.

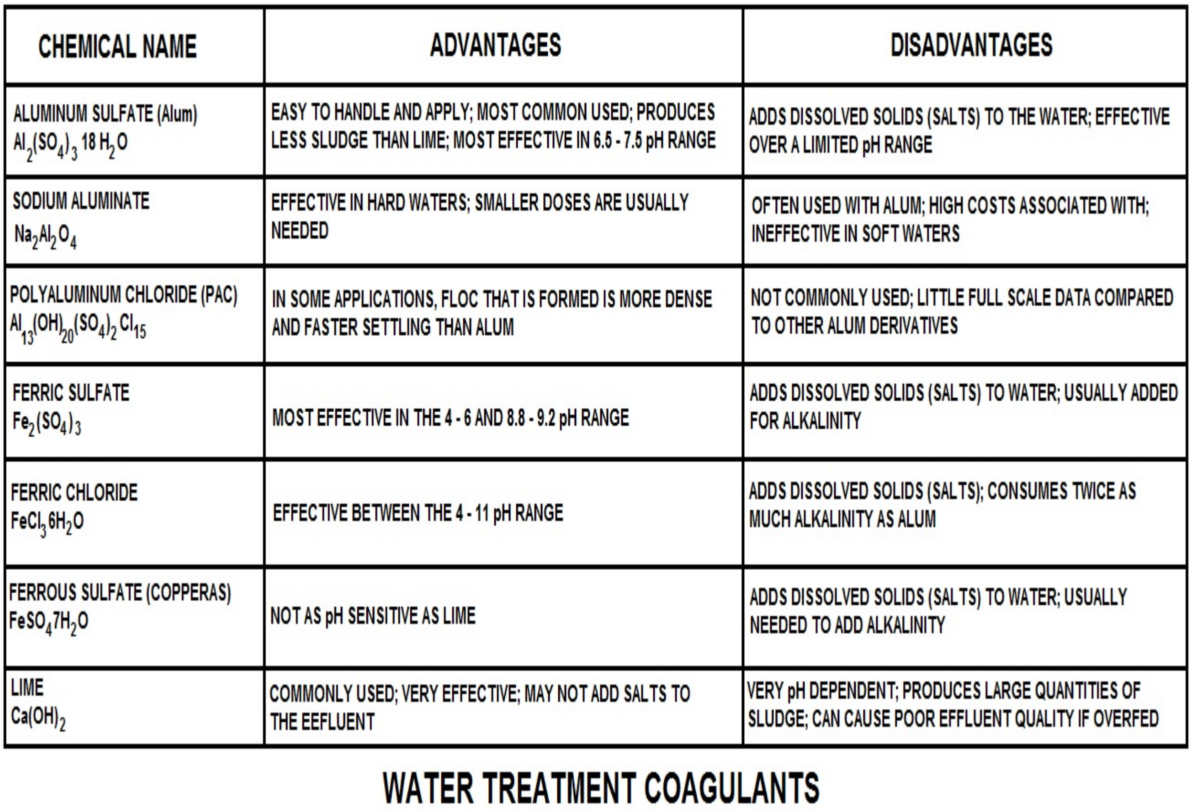
Raw Water Intake
Requires corrosion protection



PARTICLE DIAMETER (mm)	TYPE	SETTLING VELOCITY
10	PEBBLE	0.73 m/s
1	COURSE SAND	0.23 m/s
0.1	FINE SAND	0.6 m/min.
0.01	SILT	8.6 m/d
0.0001 (10 micron) *	LARGE COLLOIDS *	0.3 m/y *
0.000001 (1 nano) *	SMALL COLLOIDS *	3 m/million y *

COAGULATION AND FLOCCULATION
(Examples of various sizes of particles in raw water)

* Colloids so small: gravity settling isn't possible

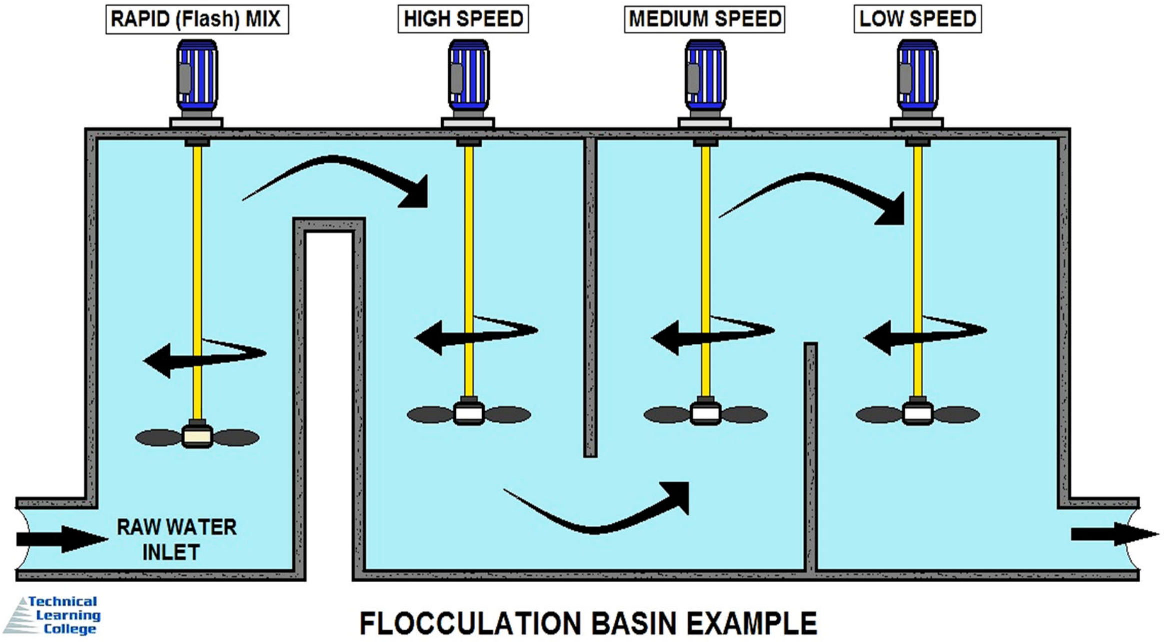


CHEMICAL NAME	ADVANTAGES	DISADVANTAGES
ALUMINUM SULFATE (Alum) $Al_2(SO_4)_3 18 H_2O$	EASY TO HANDLE AND APPLY; MOST COMMON USED; PRODUCES LESS SLUDGE THAN LIME; MOST EFFECTIVE IN 6.5 - 7.5 pH RANGE	ADDS DISSOLVED SOLIDS (SALTS) TO THE WATER; EFFECTIVE OVER A LIMITED pH RANGE
SODIUM ALUMINATE $Na_2Al_2O_4$	EFFECTIVE IN HARD WATERS; SMALLER DOSES ARE USUALLY NEEDED	OFTEN USED WITH ALUM; HIGH COSTS ASSOCIATED WITH; INEFFECTIVE IN SOFT WATERS
POLYALUMINUM CHLORIDE (PAC) $Al_{13}(OH)_{20}(SO_4)_2 Cl_{15}$	IN SOME APPLICATIONS, FLOC THAT IS FORMED IS MORE DENSE AND FASTER SETTLING THAN ALUM	NOT COMMONLY USED; LITTLE FULL SCALE DATA COMPARED TO OTHER ALUM DERIVATIVES
FERRIC SULFATE $Fe_2(SO_4)_3$	MOST EFFECTIVE IN THE 4 - 6 AND 8.8 - 9.2 pH RANGE	ADDS DISSOLVED SOLIDS (SALTS) TO WATER; USUALLY ADDED FOR ALKALINITY
FERRIC CHLORIDE $FeCl_3 6H_2O$	EFFECTIVE BETWEEN THE 4 - 11 pH RANGE	ADDS DISSOLVED SOLIDS (SALTS); CONSUMES TWICE AS MUCH ALKALINITY AS ALUM
FERROUS SULFATE (COPPERAS) $FeSO_4 7H_2O$	NOT AS pH SENSITIVE AS LIME	ADDS DISSOLVED SOLIDS (SALTS) TO WATER; USUALLY NEEDED TO ADD ALKALINITY
LIME $Ca(OH)_2$	COMMONLY USED; VERY EFFECTIVE; MAY NOT ADD SALTS TO THE EEFLUENT	VERY pH DEPENDENT; PRODUCES LARGE QUANTITIES OF SLUDGE; CAN CAUSE POOR EFFLUENT QUALITY IF OVERFED

WATER TREATMENT COAGULANTS

Coagulation and Flocculation Summary

Rapid sand filtration is the most prevalent form of water treatment technology in use today. This filtration process employs a combination of physical and chemical processes in order to achieve maximum effectiveness, as follows:



FLOCCULATION BASIN EXAMPLE

Coagulation Review
At the Water Treatment Plant, aluminum sulfate, commonly called alum, is usually added to the water in the "*flash mix"* to cause microscopic impurities in the water to clump together. The alum and the water are mixed rapidly by the flash mixer. The resulting larger particles will be removed by filtration.

Coagulation is the process of joining together particles in water to help remove organic matter. When solid matter is too small to be removed by a depth filter, the fine particles must be coagulated, or *"stuck together*" to form larger particles which can be filtered. This is achieved through the use of coagulant chemicals such as Alum.

Coagulant chemicals are required since colloidal particles by themselves have the tendency to stay suspended in water and not settle out. This is primarily due to a negative charge on the surface of the particles. All matter has a residual surface charge to a certain degree. But since colloidal particles are so small, their charge per volume is significant. Therefore, the like charges on the particles repel each other, and they stay suspended in water.

Coagulant chemicals such as *alum* (aluminum Sulfate) work by neutralizing the negative charge, which allows the particles to come together. Other coagulants include "cationic polymers", which can be thought of as positively charged strings that attract the particles to them, and in the process, form a larger particle. Also, new chemicals have been developed which combine the properties of alum-type coagulants and cationic polymers. Which chemical is used depends on the application, and will usually be chosen by the engineer designing the water treatment system by jar testing.

Aluminum Sulfate is the most widely used coagulant in water treatment. Coagulation is necessary to meet the current regulations for almost all potable water plants using surface water. Aluminum Sulfate is also excellent for removing nutrients such as phosphorous in wastewater treatment. Liquid Aluminum Sulfate is a 48.86% solution.

Large microorganisms, including algae and amoebic cysts, are readily removed by coagulation and filtration. Bacterial removals of 99% are also achievable. More than 98% of poliovirus type 1 is removed by conventional coagulation and filtration. Several recent studies have shown that bacterial and viral agents are attached to organic and inorganic particulates. Hence, removal of these particulates by conventional coagulation and filtration is a major component of effective treatment for the removal of most pathogens.

Flocculation

The process of bringing together destabilized or coagulated particles to form larger masses which can be settled and/or filtered out of the water being treated. In this process, which follows the rapid mixing, the chemically treated water is sent into a basin where the suspended particles can collide, agglomerate (stick together), and form heavier particles called “floc”. Gentle agitation of the water and appropriate detention times (the length of time water remains in the basin) help facilitate this process.

The water is slowly mixed in contact chambers allowing the coagulated particles, now called "floc," to become larger and stronger. As these floc particles mix in the water, bacteria and other microorganisms are caught in the floc structure.

Pre-Sedimentation

Depending on the quality of the source water, some plants have pre-sedimentation.

A. To allow larger particles time to settle in a reservoir or lake (sand, heavy silt) reducing solid removal loads.

B. Provides an equalization basin which evens out flow fluctuations.

Sedimentation Basin Zones

A. Inlet Zone
B. Settling Zone
C. Sludge Zone
D. Outlet Zone

Shapes for a Sedimentation Basin

A. Rectangular Basins
B. Circular Basins
C. Square Basins
D. Double deck Basins

Sedimentation

The process of suspended solid particles settling out (going to the bottom of the vessel) in water.

Following flocculation, a sedimentation step may be used. During sedimentation, the velocity of the water is decreased so that the suspended material, including flocculated particles, can settle out by gravity. Once settled, the particles combine to form a sludge that is later removed from the bottom of the basin.

Topic 2- Water Treatment Section Post Quiz

1. What measure is an expression of a basic or acid condition of a liquid?

2. To prevent damage due to overloads to flights, ___________is used. This also holds the gear solidly on the shaft so that no slippage occurs during normal operation.

3. What is the term for the time required for a small amount of water to pass through a sedimentation basin at a given rate of flow, or the calculated time required for a small amount of liquid to pass through a tank at a given rate of flow?

4. Name a strong chemical used in the treatment process to neutralize acidity, increase alkalinity, or raise the pH value.

5. What type of chemical, when combined with other types of coagulants, aids in binding small suspended particles to larger particles to help in the settling and filtering processes?

6. Which is the process of joining together particles in water to help remove organic matter?

7. When solid matter is too small to be removed by settling, the fine particles must be coagulated, or "___________________" to form larger particles which can be filtered or settled.

8. ______________________ are the processes required since colloidal particles by themselves have the tendency to stay suspended in water and not settle out.

9. Coagulant chemicals such as *"alum*" (aluminum sulfate) work by neutralizing the particles' positive charge, which allows the particles to come together. True or False

10. Cationic polymers can be thought of as positively charged strings that attract the particles to them, and in the process, form a larger particle. True or False

11. Iron Sulfate is the most widely used coagulant in water treatment. True or False

12. Aluminum Sulfate is excellent for removing nutrients such as phosphorous in treatment. True or False

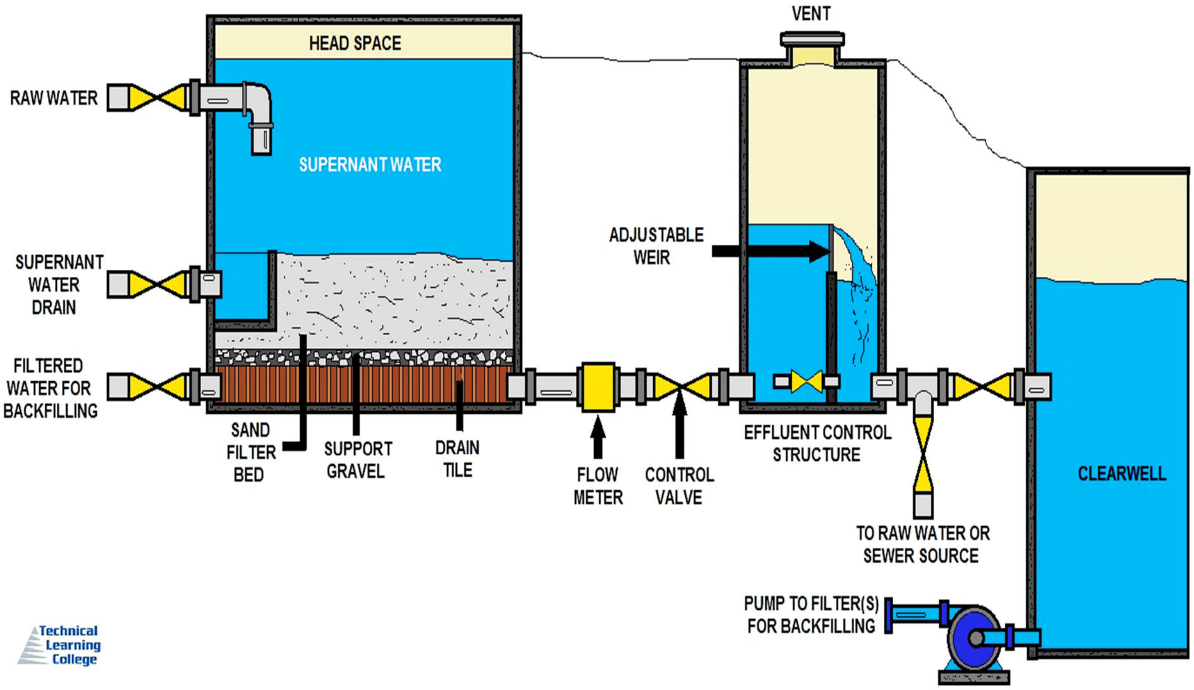
13. In an impressed current cathodic protection system, voltage polarity is important. True or False

14. In a sacrificial anode system, the cathode is the protected equipment. True or False

Topic 3- Water Treatment Filtration Section

Section Focus: You will learn the basics of conventional water treatment filtration. At the end of this section, you will be able to describe the water treatment filtration process. 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 Safe Drinking Water Act (SDWA) requires the EPA to set enforceable standards to protect public health from contaminants which may occur in drinking water, therefore it is necessary to understand proper water filtration.



SLOW SAND FILTER SYSTEM DIAGRAM

Drinking water sources are subject to contamination and require appropriate treatment to remove disease-causing agents. Public drinking water systems use various methods of water treatment to provide safe drinking water for their communities. Today, the most common steps in water treatment used by community water systems (mainly surface water treatment) include:

Slow Sand Filter Description (Primary Water Treatment Filtration Method)
The water filter is a concrete or steel box that contains sand (which does the filtering), gravel (which keeps the sand from getting out) and an underdrain (where the filtered water exits).

After the filter is operated for a while, the sand becomes clogged with particles and must be backwashed. Flow through the filter is reversed and the sand and particles are suspended. The particles are lighter than the sand, so they rise up and are flushed from the system. When backwashing is complete, the sand settles down onto the gravel, flow is reversed, and the treatment process begins again.

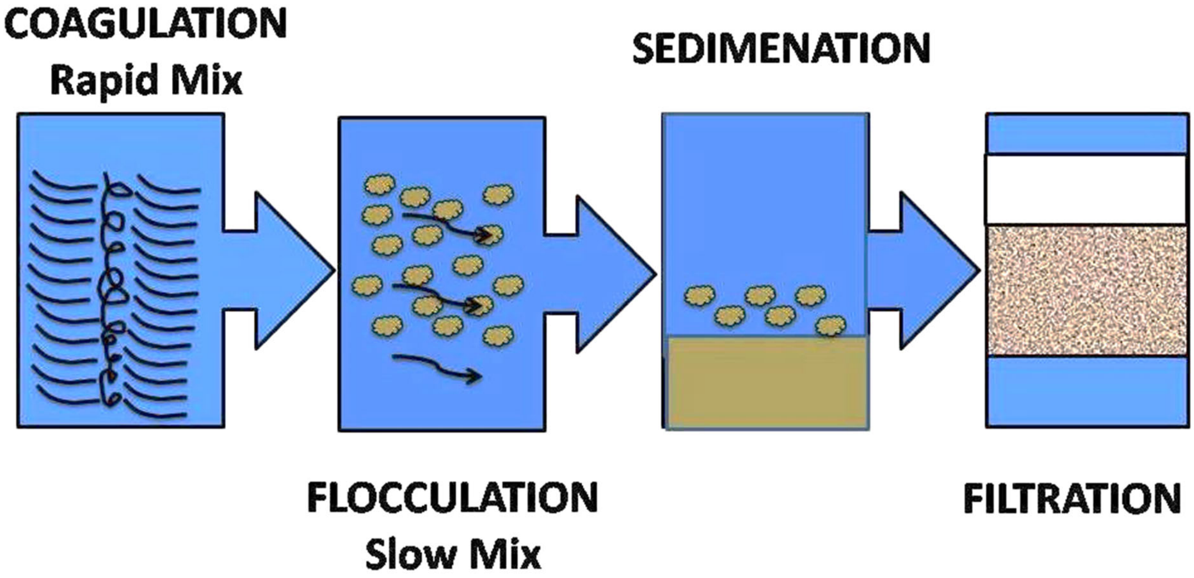
Quick Review of the Water Treatment Process

1. Coagulation and Flocculation
Coagulation and flocculation are often the first steps in water treatment. Chemicals with a positive charge are added to the water. The positive charge of these chemicals neutralizes the negative charge of dirt and other dissolved particles in the water. When this occurs, the particles bind with the chemicals and form larger particles, called floc.

2. Sedimentation
During sedimentation, floc settles to the bottom of the water, due to its weight. This settling process is called sedimentation.

3. Filtration
Once the floc has settled to the bottom of the water, the clear water on top will pass through filters of varying compositions (sand, gravel, and charcoal) and pore sizes, in order to remove dissolved particles, such as dust, parasites, bacteria, viruses, and chemicals.

4. Disinfection
After the water has been filtered, a disinfectant (for example, chlorine, chloramine) may be added in order to kill any remaining parasites, bacteria, and viruses, and to protect the water from germs when it is piped to homes and businesses.



Water Filtration Key Terms

Adsorption Clarifiers
The concept of the adsorption clarifier package plant was developed in the early 1980's. This technology uses an up-flow clarifier with low-density plastic bead media, usually held in place by a screen. This adsorption media is designed to enhance the sedimentation/clarification process by combining flocculation and sedimentation into one step. In this step, turbidity is reduced by adsorption of the coagulated and flocculated solids onto the adsorption media and onto the solids already adsorbed onto the media.

Air scouring cleans adsorption clarifiers followed by water flushing. Cleaning of this type of clarifier is initiated more often than filter backwashing because the clarifier removes more solids. As with the tube-settler type of package plant, the sedimentation/clarification process is followed by mixed-media filtration and disinfection to complete the water treatment.

Caustic
NaOH (also called Sodium Hydroxide) is a strong chemical used in the treatment process to neutralize acidity, increase alkalinity, or raise the pH value.

Chemical Feed and Rapid Mix
Chemicals are added to the water in order to improve the subsequent treatment processes. These may include pH adjusters and coagulants. Coagulants are chemicals, such as alum, that neutralize positive or negative charges on small particles, allowing them to stick together and form larger particles that are more easily removed by sedimentation (settling) or filtration.

A variety of devices, such as baffles, static mixers, impellers, and in-line sprays can be used to mix the water and distribute the chemicals evenly.

Clearwell
The final step in the conventional filtration process, the clearwell provides temporary storage for the treated water. The two main purposes for this storage are to have filtered water available for backwashing the filter, and to provide detention time (or contact time) for the chlorine (or other disinfectant) to kill any microorganisms that may remain in the water.

Corrosion Control
The pH of the water is adjusted with sodium carbonate, commonly called soda ash. Soda ash is fed into the water after filtration to increase pH and reduce the potential for corrosion by the finished water.

Declining Rate Filters
The flow rate will vary with head loss. Each filter operates at the same rate or head, but can have a variable flow rate depending on head loss. This system requires an effluent control structure (weir) to provide adequate media submergence.

Detention Time
The actual time required for a small amount of water to pass through a sedimentation basin at a given rate of flow, or the calculated time required for a small amount of liquid to pass through a tank at a given rate of flow.

Detention Time = (Basin Volume, Gallons) (24 Hours/day)
in hours Flow, Gallons/day

Disinfection (*More information later in manual. See the Disinfection Section*)
Chlorine may be added to the water at the flash mix for pre-disinfection. The chlorine kills or inactivates harmful microorganisms. Chlorine is added again after filtration for post-disinfection.

Hydrofluosilicic Acid
(H_2SiF_6) a clear, fuming, corrosive liquid with a pH ranging from 1 to 1.5. Used in water treatment to fluoridate drinking water.

Jar Testing (*More information later in manual. See the Water Quality Section*)
Jar testing traditionally has been done on a routine basis in most water treatment plants to control the coagulant dose. Much more information, however, can be obtained with only a small modification in the conventional method of jar testing. It is the quickest and most economical way to obtain good reliable data on the many variables which affect the treatment process. These include:

- Determination of most effective coagulant.
- Determination of optimum coagulation pH for the various coagulants.
- Evaluation of the most effective polymers.
- Optimum point of application of polymers in the treatment train.
- Optimum sequence of application of coagulants, polymers, and pH adjustment chemicals.
- Best flocculation time.

pH
Expression of a basic or acid condition of a liquid. The range is from 0-14, zero being the most acid and 14 being the most alkaline. A pH of 7 is considered to be neutral. Most natural water has a pH between 6.0 and 8.5.

Polymer
A type of chemical, when combined with other types of coagulants, which aids in binding small suspended particles to larger particles to help in the settling and filtering processes.

Post-Chlorine
Where the water is chlorinated to make sure it holds a residual in the distribution system.

Pre-Chlorine
Where the raw water is dosed with a larger concentration of chlorine for disinfection.

Pre-Chlorination
The addition of chlorine before the filtration process will help:

- Control algae and slime growth
- Control mud ball formation
- Improve coagulation
- Precipate iron

Raw Turbidity
The turbidity of the water coming to the treatment plant from the raw water source.

Sampling
Collect the water sample at least 6 inches under the surface by plunging the container mouth down into the water and turning the mouth towards the current by dragging the container slowly horizontal. Care should be taken not to disturb the bottom of the water source or along the sides. So as not to stir up any settled solids. This would create erroneous results. There are different techniques for both bacteriological and disinfection byproduct samplings.

Settled Solids
Solids that have been removed from the raw water by the coagulation and settling processes.

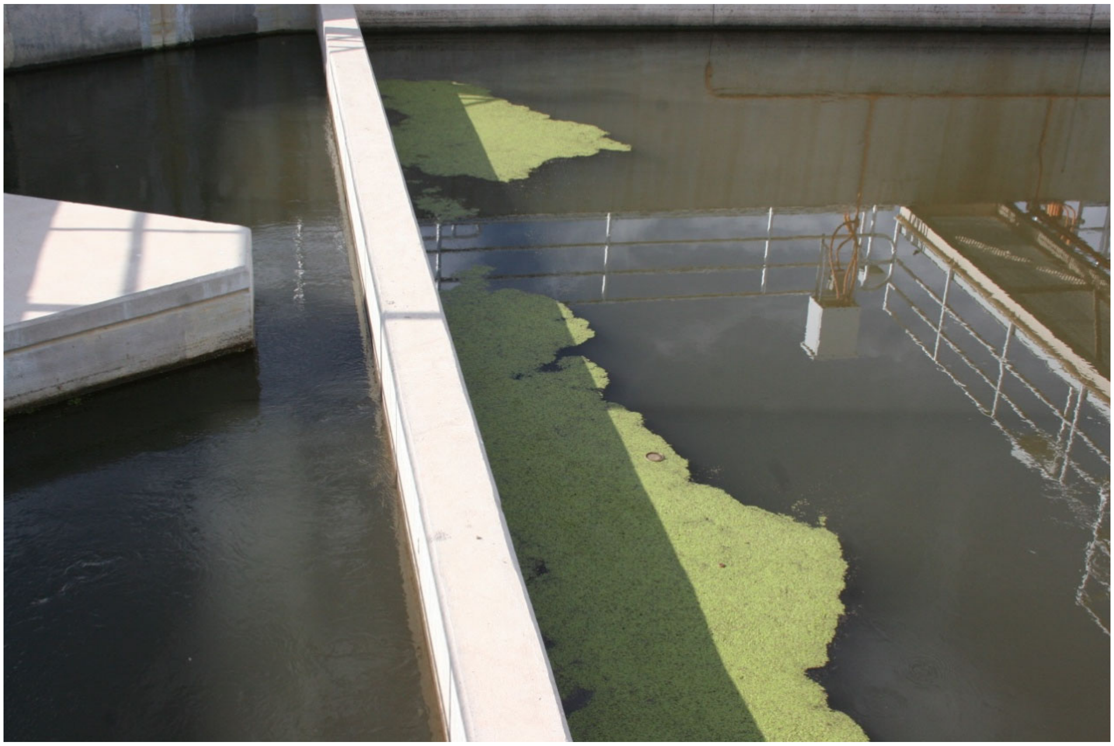
Short-Circuiting
Short-Circuiting is a condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water. This is usually undesirable, since it may result in shorter contact, reaction, or settling times in comparison with the presumed detention times.

Taste and Odor Control
Powdered activated carbon (PAC) is occasionally added for taste and odor control. PAC is added to the flash mix.

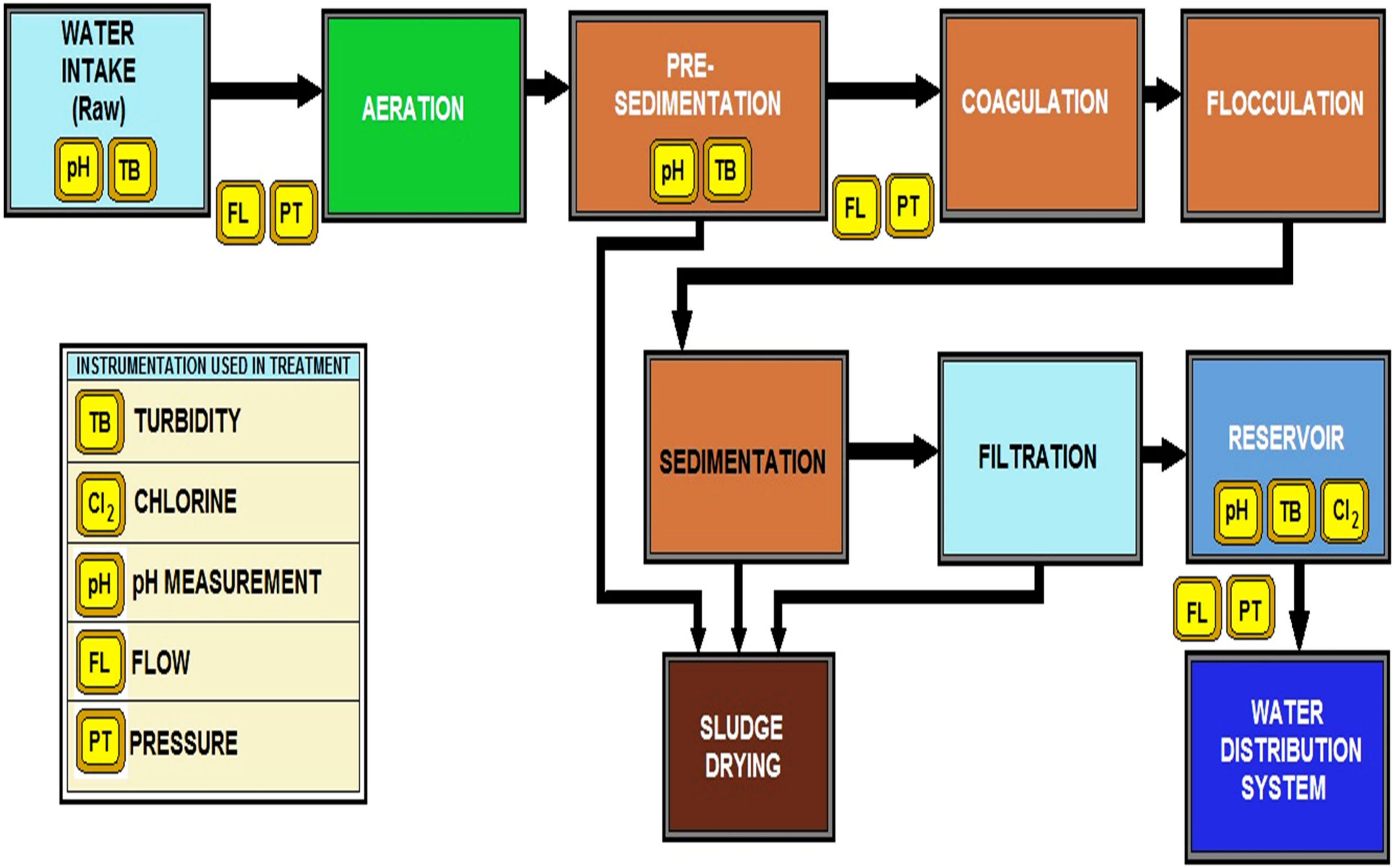
Tube Settlers
This modification of the conventional process contains many metal *"tubes*" that are placed in the sedimentation basin, or clarifier. These tubes are approximately 1-inch in diameter and 36 inches long, split-hexagonal shape, and installed at an angle of 60 degrees or less. These tubes provide for a very large surface area upon which particles may settle as the water flows upwards. The slope of the tubes facilitates gravity settling of the solids to the bottom of the basin, where they can be collected and removed. The large surface settling area also means that adequate clarification can be obtained with detention times of 15 minutes or less. As with conventional treatment, this sedimentation step is followed by filtration through mixed media.

Water Quality
Water testing is conducted throughout the treatment process. Parameters like turbidity, pH, and chlorine residual are monitored and recorded continuously. Some parameters are tested continuously, other several times per day, some once per quarter, and others once per year.

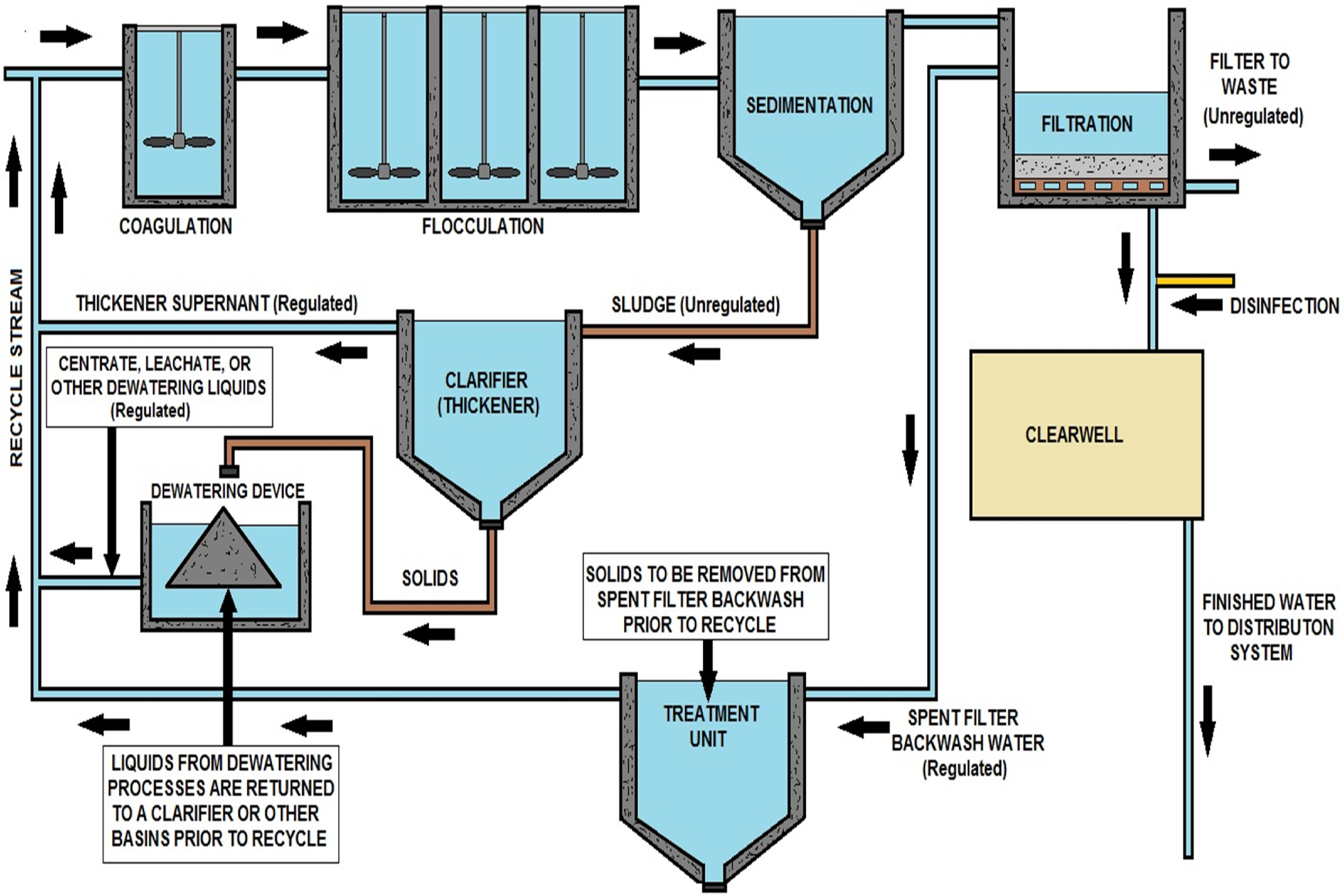
Zinc Orthophosphate
A chemical used to coat the pipes in the distribution system to inhibit corrosion.



Pretreatment sedimentation basin, bottom photograph, sludge drying bed with new grass. Time to remove and dispose of this deep, dried sludge.



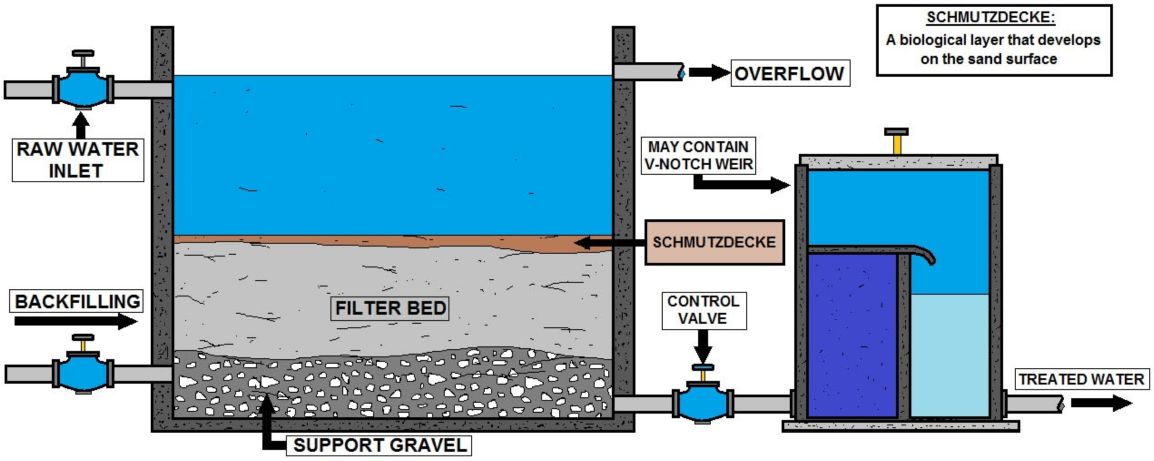
INSTRUMENTATION USED AT WATER TREATMENT PLANTS



FILTER BACKWASHED RECYLING

Types of Water Filters

Several types of filters are used for water treatment. The earliest ones developed were the slow sand filters (biological process). They typically have filter rates of around 0.05 gpm/ft^2 of surface area. This type of filter requires large filter areas. The top several inches of the sand has to be removed regularly, usually by hand due to the mass of growing material ("*schmutzdecke*") that collects in the filter. The sand removed is usually washed and returned to the filter. These filters are still in use in some small plants, especially in the western United States, as well as in many developing countries. They may also be used as a final step in wastewater treatment.



Technical Learning College

SCHMUTZDECKE EXAMPLE

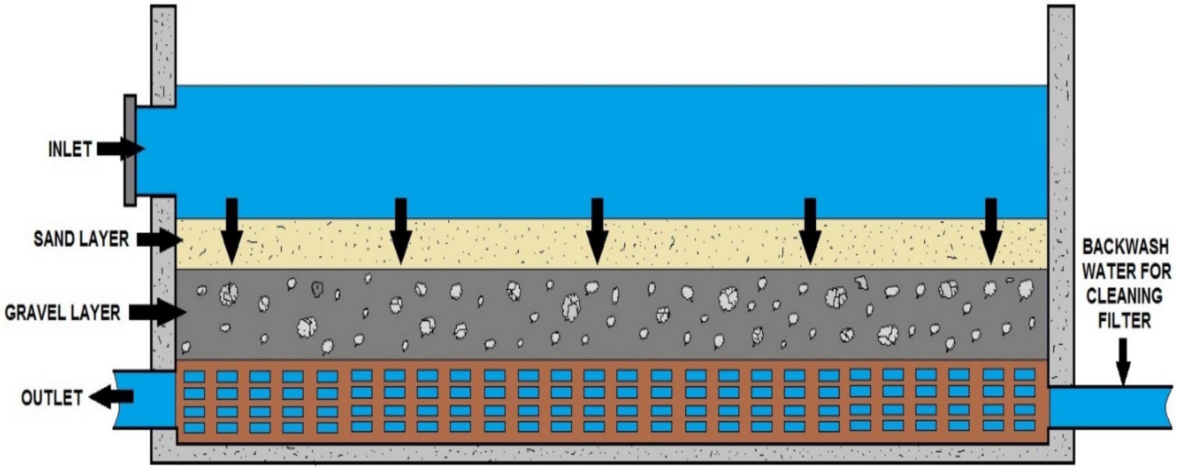
Most filters are classified by filtration rate, type of filter media, or type of operation into the following:

A. Gravity Filters
  1. Rapid Sand Filters
  2. High Rate Filters
    -Dual media
    -Multi-media
B. Pressure Filters
  -Sand or Multi-media

Rapid Sand Filters

Rapid sand filters (physical process) can accommodate filter rates 40 times those of slow sand filters. The major parts of a rapid sand filter are:

- Filter tank or filter box
- Filter sand or mixed-media
- Gravel support bed
- Underdrain system
- Wash water troughs
- Filter bed agitators



FILTRATION
(WATER PASSES THROUGH FILTERS TO PURIFY THE WATER)

The filter tank is generally constructed of concrete and is most often rectangular. Filters in large plants are usually constructed next to each other in a row, allowing the piping from the sedimentation basins to feed the filters from a central pipe gallery. Some smaller plants are designed with the filters forming a square of four filters with a central pipe gallery feeding the filters from a center well.

Filter Sand

The filter sand used in rapid sand filters is manufactured specifically for the purpose of water filtration. Most rapid sand filters contain 24-30 inches of sand, but some newer filters are deeper. The sand used is generally 0.4 to 0.6 mm in diameter. This is larger than the sand used in slow rate filtration. The coarser sand in the rapid filters has larger voids that do not fill as easily. In many newer filtration systems, other media is used in addition or instead of sand.

The gravel installed under the sand layer(s) in the filter prevents the filter sand from being lost during the operation. The under-gravel also distributes the backwash water evenly across the total filter. This under-gravel supports the filter sand and is usually graded in three to five layers, each generally 6-18 inches in thickness, depending on the type of underdrain used.

Underdrain

The filter underdrain can be one of many types, such as:

- Pipe laterals
- False floor
- Leopold system
- Porous plates or strainer nozzles
- Pipe laterals

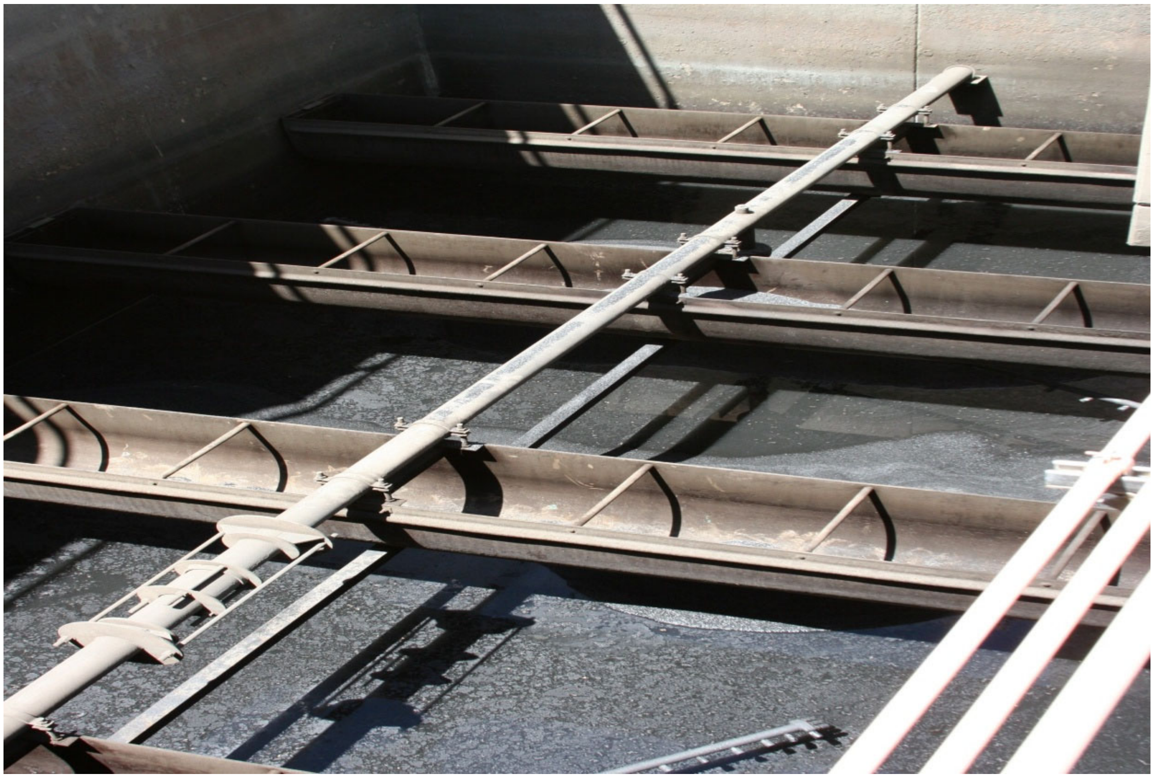
A pipe lateral system uses a control manifold with several perforated laterals on each side. Piping materials include cast iron, asbestos cement, and PVC. The perforations are usually placed on the underside of the laterals to prevent them from plugging with sand. This also allows the backwash to be directed against the floor, which helps keep the gravel and sand beds from being directly disturbed by the high velocity water jets.

False Floor
The false floor design of a filter underdrain is used together with a porous plate design or with screens that retain the sand when there is no undergravel layer. This type of underdrain allows the plenum or open space under the floor to act as the collection area for the filtered water and for the distribution of the filter backwash water.

Leopold System
The Leopold system consists of a series of clay or plastic blocks that form the channels to remove the filtered water from the filter and distribute the backwash water. This type of underdrain is generally used with an undergravel layer, although some new designs allow for sand retention without gravel.

Wash Troughs
Washwater troughs placed above the filter media collect the backwash water and carry it to the drain system. These are used for the water supply during filtration. Proper placement of these troughs at the same elevation is very important to ensure that the filter media is not carried into the troughs during the backwash and removed from the filter.

The wash troughs must supply an even head across the entire filter. These backwash troughs are constructed from concrete, plastic, fiberglass, or other corrosion-resistant materials.



The photograph above shows exposed filter wash troughs.

Filtration Overview

A water treatment step used to remove turbidity, dissolved organics, odor, taste and color. The water flows by gravity through large filters that may be composed of anthracite coal, silica sand, garnet and gravel. The floc particles are removed in these filters. The rate of filtration can be adjusted to meet water consumption needs. Filters for suspended particle removal can also be made of graded sand, granular synthetic material, screens of various materials, and fabrics.

The most widely used are rapid-sand filters in tanks. In these units, gravity holds the material in place and the flow is downward. The filter is periodically cleaned by a reversal of flow and the discharge of back-flushed water into a drain.

Cartridge Filters

In very small plants, cartridge filters made of fabric, paper, or plastic material are also common and are often much smaller and cheaper, as well as disposable. Filters are available in several ratings, depending on the size of particles to be removed. Activated carbon filters, described earlier, will also remove turbidity, but would not be recommended for that purpose only.

With most of the larger particles settled out, the water now goes to the filtration process. At a rate of between 2 and 10 gpm per square foot, the water is filtered through an approximate 36" depth of graded sand. Anthracite coal or activated carbon may also be included in the sand to improve the filtration process, especially for the removal of organic contaminants and taste and odor problems.

The filtration process removes the following types of particles:

- Silts and clay
- Colloids
- Biological material
- Floc

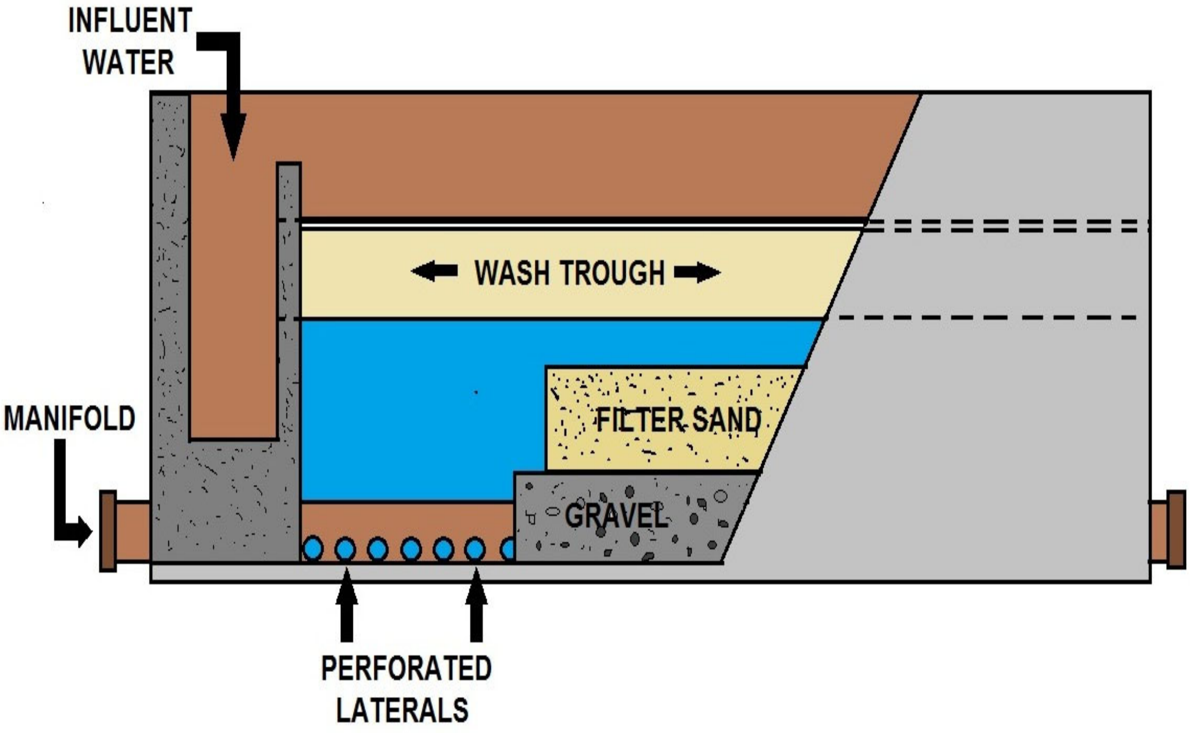
Four Desirable Characteristics of Filter Media

- Good hydraulic characteristics (permeable)
- Does not react with substances in the water (inert and easy to clean)
- Hard and durable
- Free of impurities and insoluble in water

Evaluation of overall filtration process performance should be conducted on a routine basis, at least once per day.

Poor chemical treatment can often result in either early turbidity breakthrough or rapid head loss buildup. The more uniform the media, the slower head loss buildup.

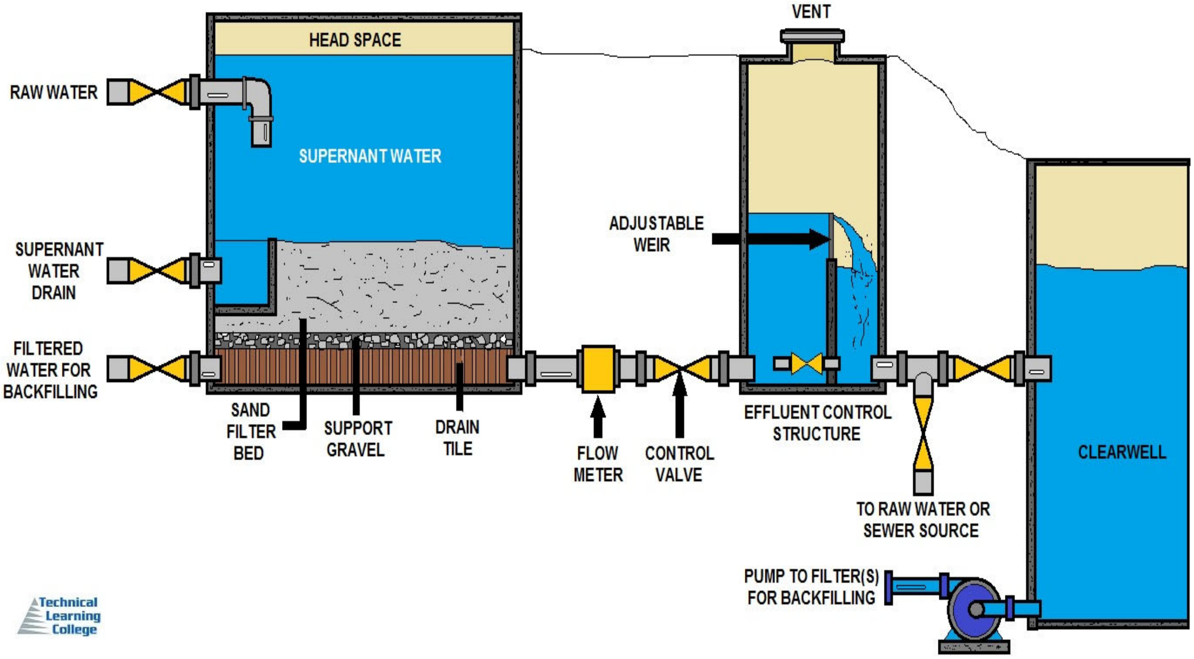
All water treatment plants that use surface water are governed by the U.S. EPA’s Surface Water Treatment Rules or SWTR.



RAPID SAND FILTER DIAGRAM

The rapid sand filter or rapid gravity filter is a type of filter used in water purification and is commonly used in municipal drinking water facilities as part of a multiple-stage treatment system. Rapid sand filters were first developed in the 1890s, and improved designs were developed by the 1920s. The first modern rapid sand filtration plant was designed and built by George W. Fuller in Little Falls, New Jersey. Rapid sand filters were widely used in large municipal water systems by the 1920s, because they required smaller land areas compared to slow sand filters.

Dried backwash channels on the top of a cleaned filter bed.



SLOW SAND FILTER

SLOW SAND FILTER

These have become obsolete

EPA Filter Backwash Rule- Introduction

The U.S. Environmental Protection Agency (EPA) has finalized the Long Term 1 Enhanced Surface Water Treatment Rule and Filter Backwash Rule (LT1FBR) to increase protection of finished drinking water supplies from contamination by *Cryptosporidium* and other microbial pathogens.

This rule will apply to public water systems using surface water or ground water under the direct influence of surface water. This rule will extend protections against *Cryptosporidium* and other disease-causing microbes to the 11,500 small water systems which serve fewer than 10,000 people annually.

This rule also establishes filter backwash requirements for certain public water systems of all sizes. The filter backwash requirements will reduce the potential risks associated with recycling contaminants removed during the filtration process.

Background

The Safe Drinking Water Act (SDWA) requires the EPA to set enforceable standards to protect public health from contaminants that may occur in drinking water. The EPA has determined that the presence of microbiological contaminants is a health concern. If finished water supplies contain microbiological contaminants, disease outbreaks may result. Disease symptoms may include diarrhea, cramps, nausea, possibly jaundice, headaches and fatigue. The EPA has set enforceable drinking water treatment requirements to reduce the risk of waterborne disease outbreaks. Treatment technologies such as filtration and disinfection remove or inactivate microbiological contaminants.

Physical removal is critical to the control of *Cryptosporidium* because it is highly resistant to standard disinfection practice. Cryptosporidiosis may manifest itself as a severe infection that can last several weeks and may cause the death of individuals with compromised immune systems. In 1993, *Cryptosporidium* caused over 400,000 people in Milwaukee to experience intestinal illness. More than 4,000 were hospitalized, and at least 50 deaths were attributed to the cryptosporidiosis outbreak.

The 1996 Amendments to SDWA require the EPA to promulgate an Interim Enhanced Surface Water Treatment Rule (IESWTR) and a Stage 1 Disinfection Byproducts Rule (announced in December 1998). The IESWTR set the first drinking water standards to control *Cryptosporidium* in large water systems, by establishing filtration and monitoring requirements for systems serving more than 10,000 people each. The LT1FBR proposal builds on those standards by extending the requirements to small systems.

The 1996 Amendments also required the EPA to promulgate a Long Term 1 Enhanced Surface Water Treatment Rule (for systems serving less than 10,000 people) back in November, 2000 ((1412(b)(2)(C)) and also require the EPA to "*promulgate a regulation to govern the recycling of filter backwash water within the treatment process of a public water system*" back in August, 2000 ((1412(b)(14)). The current rule includes provisions addressing both of these requirements.

LT1FBR Required

The LT1FBR provisions will apply to public water systems using surface water or ground water under the direct influence of surface water systems.

LT1 Provisions - Applied to systems serving fewer than 10,000 people, and fall into the three following categories:

Turbidity

- Conventional and direct filtration systems must comply with specific combined filter effluent turbidity requirements;
- Conventional and direct filtration systems must comply with individual filter turbidity requirements;

Disinfection Benchmarking

- Public water systems will be required to develop a disinfection profile unless they perform applicability monitoring which demonstrates their disinfection byproduct levels are less than 80% of the maximum contaminant levels;
- If a system considers making a significant change to their disinfection practice they must develop a disinfection benchmark and receive State approval for implementing the change.

Other Requirements

- Finished water reservoirs for which construction begins after the effective date of the rule must be covered; and
- Unfiltered systems must comply with updated watershed control requirements that add Cryptosporidium as a pathogen of concern.

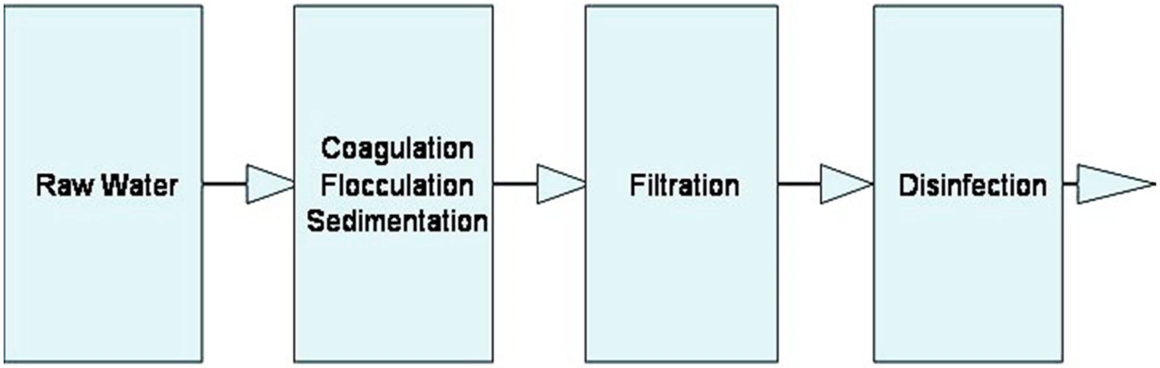
FBR Provisions - Apply to all systems which recycle regardless of population served:

- Recycle systems will be required to return spent filter backwash water, thickener supernatant, and liquids from the dewatering process prior to the point of primary coagulant addition unless the State specifies an alternative location;
- Direct filtration systems recycling to the treatment process must provide detailed recycle treatment information to the State, which may require that modifications to the recycle practice be made, and;
- Conventional systems that practice direct recycle, employ 20 or fewer filters to meet production requirements during a selected month, and recycle spent filter backwash water, thickener supernatant, and/or liquids from the dewatering process within the treatment process must perform a one month, one-time recycle self-assessment. The self-assessment requires hydraulic flow monitoring and that certain data be reported to the State, which may require that modifications to the recycle practice be made to protect public health.

Often under the filtration basins are work tunnels, complex machinery, gauges and huge water pumps.

Conventional Treatment Overview

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



Suspended particles carry an electrical charge which causes them to repel one another. The conventional process uses alum (aluminum sulfate or ferric chloride) and cationic polymer to neutralize the charge. That allows suspended particles to clump together to form more easily filtered particles.

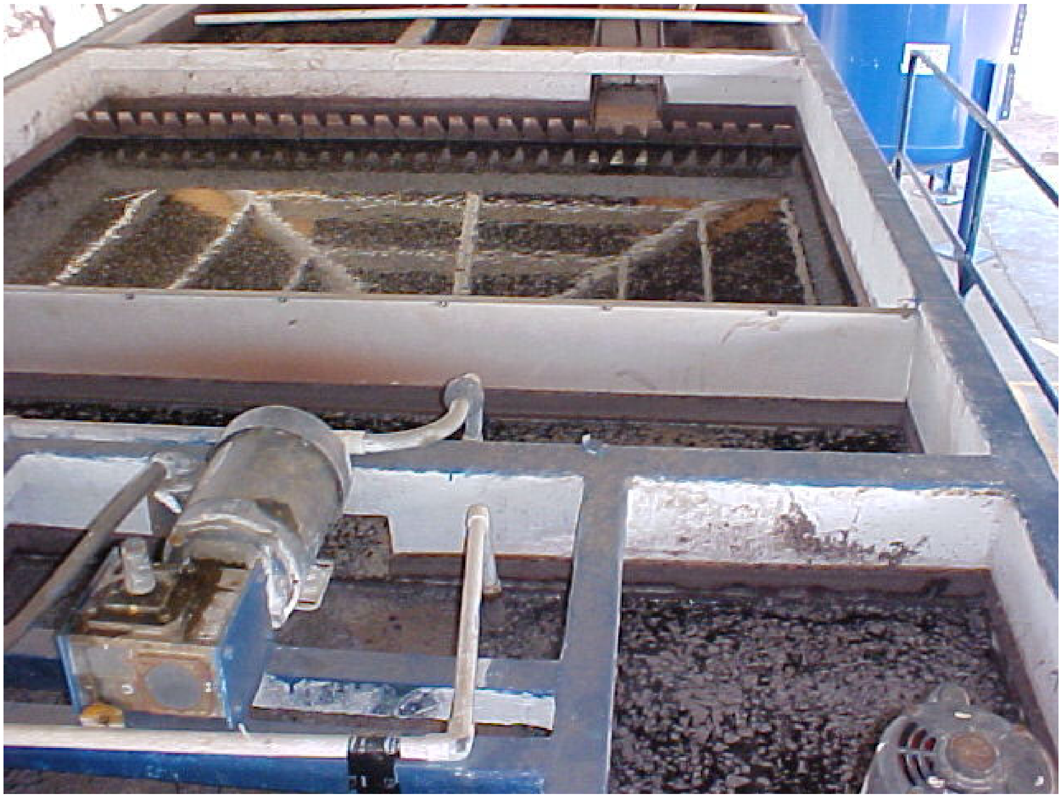
Chemical Pretreatment
Chemical pretreatment may increase filtered water clarity, measured in NTU, by 90% compared with filtration alone. If an operator is present to make adjustments for variations in the raw water, filtered water clarity improvements in the range of 93 to 95% are achievable.

Conventional Technology
Alum combines with alkalinity in the raw water to form a white precipitate that neutralizes suspended particles' electrical charge and forms a base for coagulating those particles. Conventional technology uses a 30 to 50 mg/L alum dosage to form a large floc that requires extensive retention time to permit settling. Traditional filter systems use graded silica sand filter media. Since the sand grains all have about the same density, larger grains lay toward the bottom of the filter bed and finer grains lay at the top of the filter bed. As a result, most filtration occurs only within the first few inches of the finer grains at the top of the bed.

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

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

The reconditioning cycle consists of an up-flow backwash followed by a down-flow rinse. Backwash is an up-flow operation, at about 14 gpm per square foot (34m/hr) of filter bed area that lasts about 10 minutes. Turbidity washes out of the filter bed as the filter media particles scour one another. The down-flow rinse settles the bed before the filter returns to service. This fast rinse lasts about 5 to 10 minutes. Often this process is called “filter-to-waste” cycle.



Example of a small water treatment package plant with coagulation, flocculation and filtration all within a 20-foot area.

Package Plants

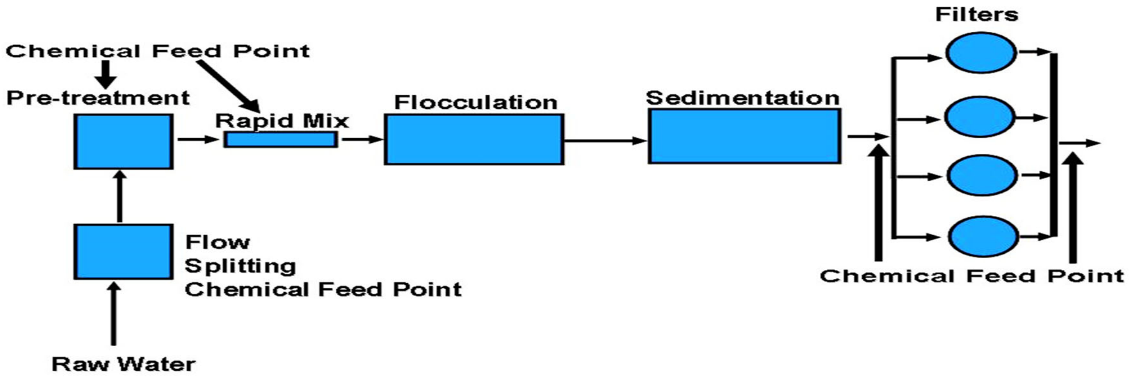
Representing a slight modification of conventional filtration technology, package plants are usually built in a factory, mounted on skids, and transported virtually assembled to the operation site.

These are appropriate for small community systems where full water treatment is desired, but without the construction costs and space requirements associated with separately constructed sedimentation basins, filter beds, clear wells, etc.

In addition to the conventional filtration processes, package plants include as two other types: tube-type clarifiers and adsorption clarifiers.

Filtration Process- Detailed

Removal of suspended solids by filtration plays an important role in the natural treatment of groundwater as it percolates through the soil. It is also a major part of most water treatment. Groundwater that has been softened or treated through iron and manganese removal will require filtration to remove floc created by coagulation or oxidation processes. Since surface water sources are subject to run-off and do not undergo natural filtration, it must be filtered to remove particles and impurities.



The filter used in the filtration process can be compared to a sieve or microstrainer that traps suspended material between the grains of filter media. However, since most suspended particles can easily pass through the spaces between the grains of the filter media, straining is the least important process in filtration.

The photograph on the right illustrates debris removed during the backwash process. The particles were trapped on top of the filter and trapped within the filter media.

Filtration primarily depends on a combination of complex physical and chemical mechanisms, the most important being adsorption.

Adsorption
Adsorption is the process of particles sticking onto the surface of the individual filter grains or onto the previously deposited materials. The forces that attract and hold the particles to the grains are the same as those that work in coagulation and flocculation.

In fact, some coagulation and flocculation may occur in the filter bed, especially if coagulation and flocculation of the water before filtration was not properly controlled. Incomplete coagulation can cause serious problems in filter operation.

Conventional and Alternative Filtration Methods

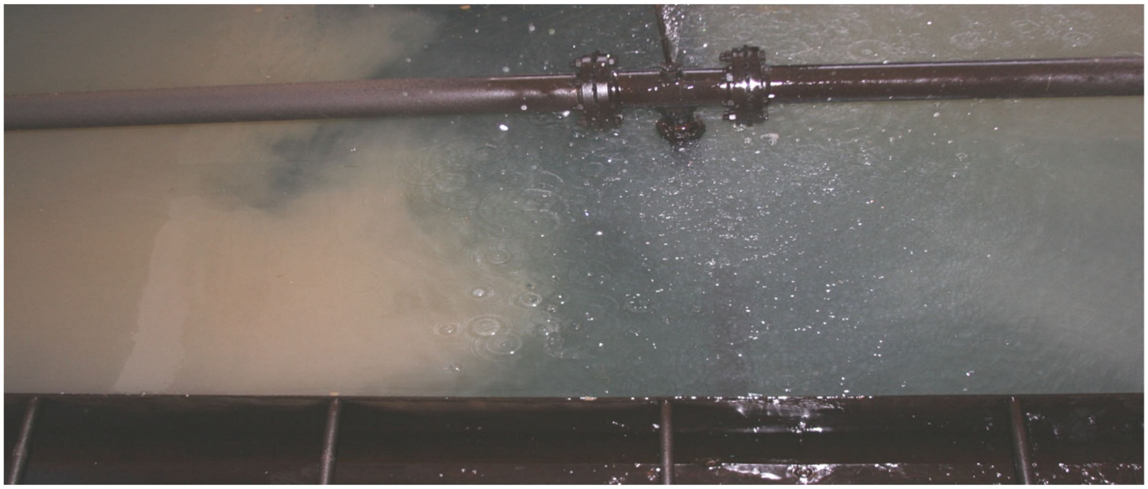
The conventional type of water treatment filtration method includes coagulation, flocculation, sedimentation, and filtration. **Direct filtration method** is similar to conventional except that the sedimentation step is omitted. **Slow sand filtration process** does not require pretreatment, has a flow of 0.1 gallons per minute per square foot of filter surface area, and is simple to operate and maintain.

Diatomaceous earth method uses a thin layer of fine siliceous material on a porous plate. This type of filtration medium is only used for water with low turbidity. Sedimentation, adsorption, and **biological action treatment methods** are a filtration process that involves a number of interrelated removal mechanisms. **Demineralization** is primarily used to remove total dissolved solids from industrial wastewater, municipal water, and seawater.

Surface Wash Sub-Section

The photograph above shows a drained filter with the surface wash agitator and nozzles exposed. During operation these will spin, spraying water during the water backwash.

During the operation of a filter, the upper six-to-ten inches of the filter media remove most of the suspended material from the water. It is important that this layer be thoroughly cleaned during the backwash cycle. Normal backwashing does not, in most cases, clean this layer completely; therefore, some method of agitation is needed to break up the top layers of the filter and to help the backwash water remove any material caught there.

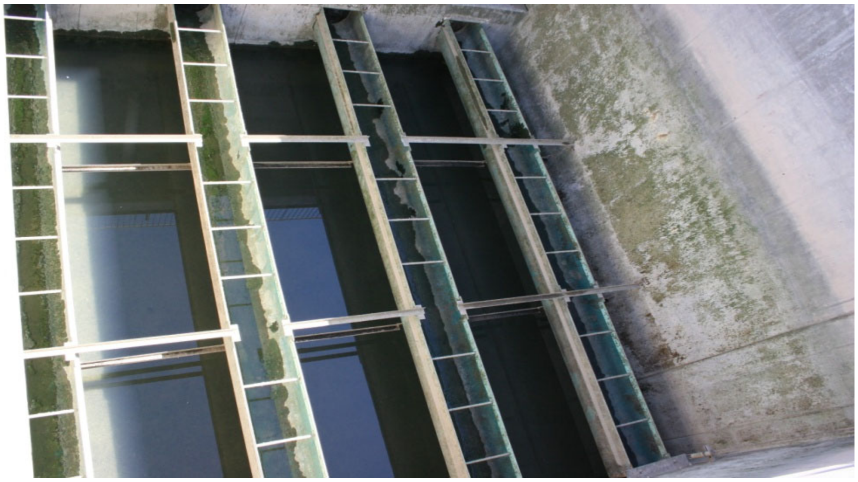


The surface wash system consists of a series of pipes installed in the filter that introduce high velocity water or air jet action into the upper layer of the filter. This jet action will generally be supplied by rotating arms that are activated during the backwashing of the filter.

A newer design of surface wash uses compressed air to mix the upper layer and loosen the particles from the sand so that the backwash water can remove the particles more easily. This air wash generally is turned on before the backwash cycle. If both are used at the same time, some sand may be washed away. The compressed air rate can be two-to-five cubic feet per minute per square foot (cfm/ft^2) of filter surface, depending on the design of the filter.

High Rate Filters

High rate filters, which operate at a rate three-to-four times that of rapid sand filters, use a combination of different filter media, not just sand. The combinations vary with the application, but generally they are sand and anthracite coal. Multi-media or mixed-media filters use three or four different materials, generally sand, anthracite coal, and garnet.

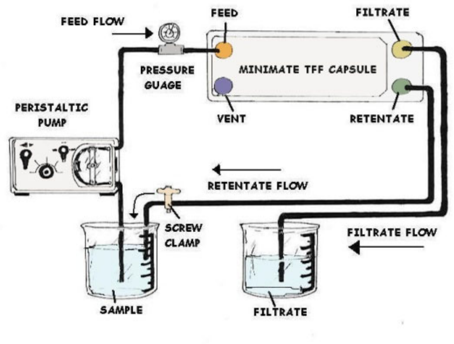


In this photograph, you can see the water lines on the wall of the filter. The deeper the water the more head pressure exerted on the filter media.

In rapid sand filters, finer sand grains are at the top of the sand layer with larger grains farther down into the filter. As a result, the filter removes more suspended material in the first few inches of the filter. In the high rate filter, the media size decreases. The top layers consist of a coarse material with the finer material farther down, allowing the suspended material to penetrate deeper into the filter.

The material in a filter bed forms layers in the filter, depending on their weight and specific gravities. In the coarse layer at the top, the larger suspended particles are removed first, followed by the finer materials. This allows for longer filter runs at higher rates than is possible with rapid sand filters.

The type of filter media used in a high rate filter depends on many factors, including the raw-water quality, raw-water variations, and the chemical treatment used. Pilot studies help the operator and the design engineer evaluate which material, or combination of materials, will give the best result.



LABORATORY FILTRATION SYSTEM

Pressure Filters

Pressure filters fall into two categories: pressure sand and diatomite filters.

Pressure Sand Filters
This type of filter is used extensively in iron and manganese removal plants.

A pressure sand filter is contained under pressure in a steel tank, which may be vertical or horizontal, depending on the space available. As with gravity filters, the media is usually sand or a combination of media. Filtration rates are similar to gravity filters.

These filters are commonly used for iron and manganese removal from groundwater, which is first aerated to oxidize the iron or manganese present, then pumped through the filter to remove the suspended material.

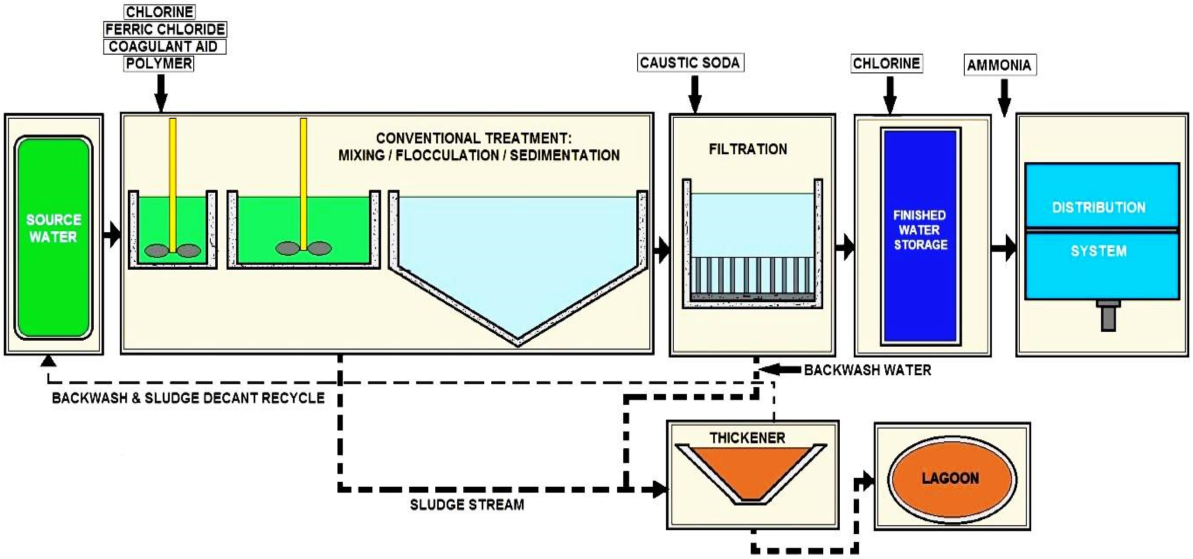
Filter Media

Because the water is under pressure, air binding will not occur in the filter. However, pressure filters have a major disadvantage in that the backwash cannot be observed; in addition, cracking of the filter bed can occur quite easily, allowing the iron and manganese particles to go straight through the filter. When using pressure filters for iron and manganese removal, the operator must regularly measure the iron and manganese concentration of the filter effluent and backwash the filter before breakthrough occurs. Because of these limitations, pressure filters must not be used to treat surface water.

Diatomaceous Earth Filter
This type of filter is commonly used for the treatment of swimming pools. The process was developed by the military during World War II to remove microorganisms that cause amoebic dysentery from water used in the field.

More About Water Filtration Processes

Two basic types of filtration processes are currently used in the United States. Conventional filtration, the traditional design for many years, provides effective treatment for just about any range of raw-water turbidity. Its success is due partially to the sedimentation that precedes filtration and follows the coagulation and flocculation steps. Sedimentation, if operated properly, should remove most of the suspended material.



SURFACE WATER CONVENTIONAL TREATMENT

After sedimentation, the water passing through to the filters should not have turbidity higher than 10-to-15 NTU. Rapid sand filters were once used in the conventional process, but many have been converted to multi-media filters in an attempt to increase plant capacity.

In the other type of filtration process--direct filtration--no sedimentation follows the coagulation phase. Direct filtration is designed to filter water with an average turbidity of less than 25 NTU.

Dual and multi-media filters are used with direct filtration. They are able to remove more suspended material per cubic foot of filter media than sand filters.

Direct filtration plants have a lower capital cost. However, the process cannot handle large variations in raw water turbidity.

Filtration Operation

Filtration operation is divided into three steps: filtering, backwashing, and filtering to waste.

Filter Control of the filter operation requires the following equipment:
- Rate of flow controller
- Loss of head indicator
- On-line turbidimeter

Rate of Flow Controllers
Flow rates through filters are controlled by one of two different methods:

Declining Rate
This method of control is used where the head loss through the plant is quite large. It allows the filter head to increase until the filter becomes plugged with particles and the head loss is too great to continue operation of the filter. The rate through the filter is much greater in the beginning of a filter run than at the end when the filter is dirty. This method tends to be the most commonly installed in new filter plants.

The photograph on right shows operators walking through the filter gallery of a plant that uses declining rate filters. This is also showing pipelines to and from the filter boxes.

Constant Rate
This type of control monitors the level of water on the top of the filter and attempts to control this level from the start of the operation to the end. This is accomplished by the controller operating a valve on the effluent of the filter. The valve will be nearly closed at the start of the filter run and fully open at the end. This design is used when the head or pressure on the filter is limited.

The photograph above shows the overflow wall opening in case the filter level gets too high.

Both controllers consist of a venturi tube or some other type of metering device, as well as a valve to control the flow from the filter. In most cases, the valve is controlled by an automatic control device, often an air-actuated type valve that is controlled by the flow tube controller.

Loss of Head Indicator

As filtration proceeds, an increasing amount of pressure, called head loss across the filter, is required to force the water through the filter. The head loss should be continuously measured to help determine when the filter should be backwashed.

Usually the difference in the head is measured by a piezometer connected to the filter above the media and the effluent line.

In-line Turbidimeter

Turbidity in water is caused by small suspended particles that scatter or reflect light so that the water appears to be cloudy.

Turbidity of the filtered water may shelter bacteria, preventing chlorine from reaching it during the final disinfection process. The turbidity of the filtered water is one of the factors that determine the length of a filter run. At some point, the suspended material will start to break through the filter media and increase the turbidity of the filter effluent. At this time, the filter should be backwashed.

Continuous turbidity monitors provide information about when the filter is approaching this point so that the operators can start the backwash before the turbidity is too great. Turbidity measurements will also indicate whether the coagulation and other treatment processes are operating properly.

Turbidity Meter Digital Reading

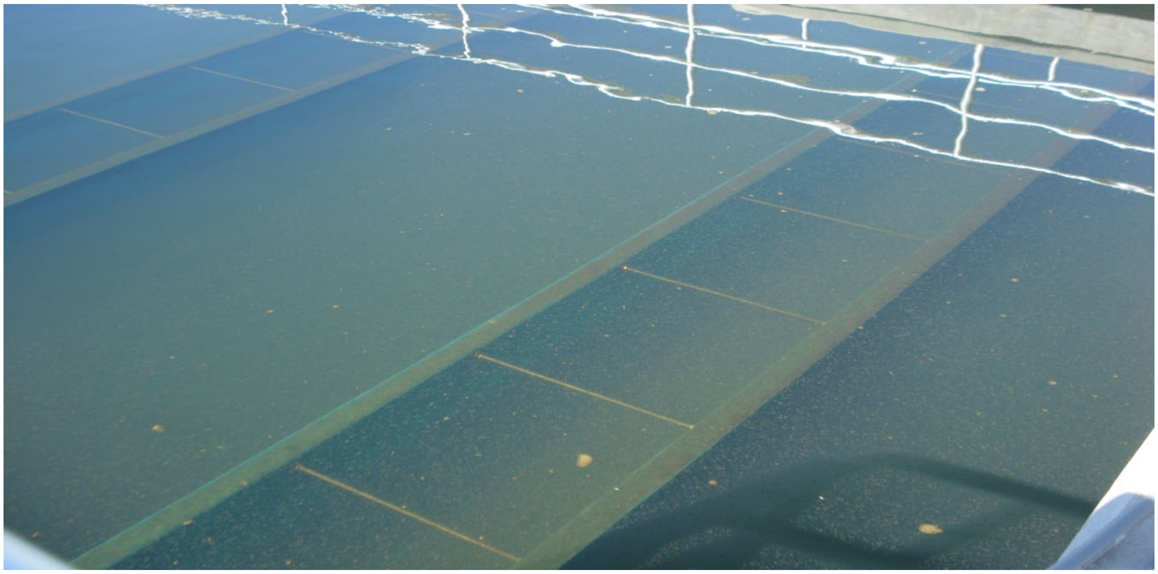
Filtration Process - Rate of Flow

Water from the source or, more commonly, from pre-treatment processes, is applied to the top of the filter; it then flows downward. The water level above the filter bed is usually kept at two-to-six feet.

When the filtration is started after being backwashed, there will be little head loss. In filters with a control valve installed on the filter effluent pipe, the filter flow is restricted during this time. The control valve also has the important function of preventing filter surges, which could disturb the media and force floc through the filter.

The rate of flow on a filter depends on the type of filter. A rapid sand filter will have a flow of two-to-three gpm/square foot of filter area. The high rate filter may have four-to-six gpm/square foot applied to the surface.

A constant rate flow valve is almost fully closed when a filter is clean so that the desired water level on top of the filter is maintained. As the filter becomes dirty with suspended material, the valve opens gradually until the increase in the water level above the filter indicates that the filter needs backwashing.



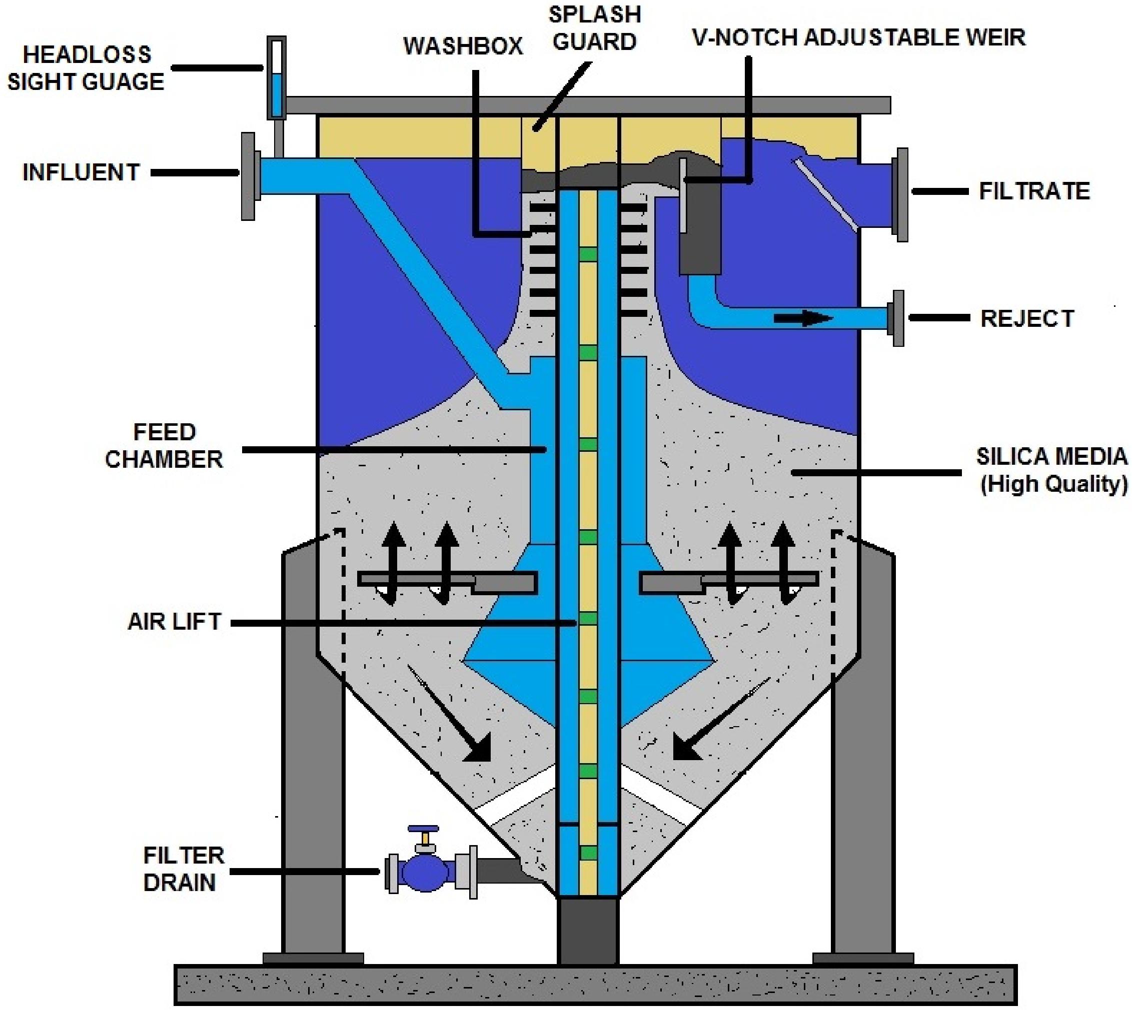
The above photograph is a filter from a direct filtration plant; notice the size of the floc – a good size for filtration.

In filters with variable declining rate flow control, the filters are allowed to take on as much water as they can handle. As the filters become dirty, both the headloss and the depth of the water on the surface increase until the filters need backwashing. This method is generally preferred because it requires less operator attention.

With this method, a filter accepts as much flow as it can handle. As the filter becomes dirty, the flow through the filter becomes less and, if the plant has more than one filter, additional flow redistributes across the other filters.

A flow restrictor or actuated valve is placed in the filter effluent pipe to prevent a filter flow rate that is too great for the filter.

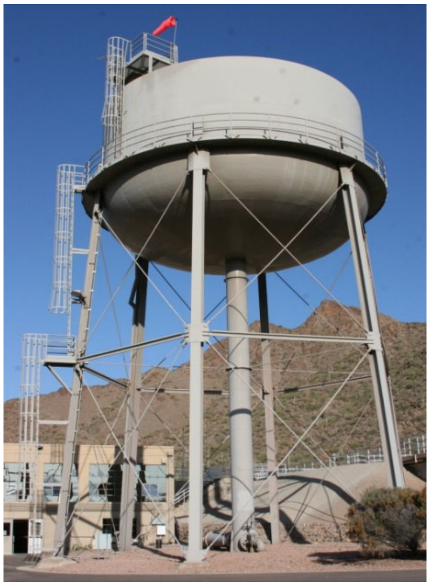
Regardless of the method of control, the filter eventually fills with suspended material. At some time, usually after 15 to 30 hours, it will need to be backwashed to clean the media.



Technical Learning College "UPFLOW" GRAVITY SAND FILTER

The “Upflow” gravity sand filter, also known for continuous backwashing of the media, is used for many applications such as water treatment and tertiary treatment. This process aids in the removal of inorganic and organic contaminants.

Filter Backwashing



Proper backwashing is a very important step in the operation of a filter. If the filter is not backwashed completely, it will eventually develop additional operational problems. If a filter is to operate efficiently, it must be cleaned before the next filter run. Treated water from storage is used for the backwash cycle. This treated water is generally taken from elevated storage tanks or pumped in from the clear well.

During filtration, the filter media becomes coated with the floc, which plugs the voids between the filter grains, making the filter difficult to clean. The media must be expanded to clean the filter during the backwash. This expansion causes the filter grains to violently rub against each other, dislodging the floc from the media.

The filter backwash rate has to be great enough to expand and agitate the filter media and suspend the flocs in the water for removal. However, if the filter backwash rate is too high, media will be washed from the filter into the troughs and out of the filter. A normal backwash rate is between 12 to 15 gpm per square foot of filter surface area.

In most cases, the filter backwash rate will not break up the mass on the top of the filter. The design engineer will recommend the installation of a surface wash of some type, the most common being a set of rotary arms that are suspended above the media during filtration. During filter backwash, the media expands upwards and around the washing arms.

A newer method of surface wash involves using air scour before the water wash. This is a very efficient method, but requires the installation of a large air blower to produce the air. The normal design for the air wash will be two-to-five cubic feet of air per square foot of filter area.

Both photos are of essential components of the backwash equipment for the water plant: an elevated storage tank and/or backwash pumps.

The filter should be backwashed when the following conditions have been met:

- The head loss is so high that the filter no longer produces water at the desired rate; and/or
- Floc starts to break through the filter and the turbidity in the filter effluent increases; and/or
- A filter run reaches a given number of hours of operation.
- If a filter is taken out of service for some reason, it must always be backwashed before being taken out of service and prior to going back on line.

The decision to backwash the filter can be based on any one of the above conditions.

If a filter is not backwashed until the headloss exceeds a certain number of feet, the turbidity may break through and cause the filter to exceed the standard of 0.5 NTU of turbidity.

Similarly, depending on filter effluent- turbidity alone can cause high head loss and decreased filter flow rate, which can cause the pressure in the filter to drop below atmospheric pressure and cause the filter to air bind and stop filtering.

If the water applied to a filter is very good quality, the filter runs can be very long.

Some filters can operate longer than one week before needing to be backwashed. However, this is not recommended as long filter runs can cause the filter media to pack down so that it is difficult to expand the bed during the backwash.

Backwashing Process

The normal method for backwashing a filter involves draining the water level above the filter to a point six inches above the filter media. The surface wash is then turned on and allowed to operate for several minutes to break up the crust on the filter.

After that, the backwash valve is opened, allowing backwash water to start flowing into the filter and start carrying suspended material away from the filter. For a filter with usually an air wash instead of a water-surface wash, the filter backwash water and the air wash should not be used together. This would be possible only if some means of controlling the media carryover is installed.

A filter control panel.

The time elapsed from when the filter wash is started until full flow is applied to the filter should be greater than one minute. After a few minutes, the filter backwash valve should be fully opened to allow full expansion of the filter media.

Generally, this expansion will be from 20 to 40 percent over the normal filter bed volume. The expansion needed will depend on how much agitation is needed to suspend the filter media to remove to suspended material trapped in the filter. With a multi-media filter, the rate must be high enough to scrub the interface between the coal and the sand, where the highest amount of suspended solids will be removed from the media.

The filter will be washed for 10 to 15 minutes, depending on the amount of solids that must be removed. The best way to determine how long the filter should be washed is to measure the turbidity of the backwash water leaving the filter. In most cases, a filter is washed too long. This could be costly. Too much backwash water is used, and it must be treated after use. Backwash valves must be opened slowly. Opening the valves too rapidly can cause serious damage to the filter underdrain, filter gravel, and filter media.

Disposal of Filter Backwash Water
Water from the filter backwash cannot be returned directly to the environment. Normally the water is discharged into a backwash tank and allowed to settle. The supernatant, or cleared liquid, is then pumped back to the head of the treatment plant at a rate not exceeding ten percent of the raw water flow entering the plant.

Settled Material
The settled material is pumped to a sewer or is treated in the solids-handling process of the plant. This conserves most of the backwash water and eliminates the need to obtain a pollution discharge permit for the disposal of the filter backwash water.

Since backwash is a very high flow operation, the surges that are created from the backwash coming from the filter must not be allowed to enter the head of the plant. Therefore, the spent backwash water must be stored in storage tanks and returned slowly to the treatment process.

Filter to Waste

When filtration is started after backwash, filtered water should be wasted until the turbidity in the effluent meets standards. Depending on the type of filter, this may last from two to 20 minutes. This wasting is needed also some suspended material remains with floc the filter media following the backwash. The media needs to become somewhat sticky again to start to capture the suspended material.

Also, the filtration rate is higher in a clean filter, causing more material to be swept from the filter during the start-up. Filtration should always be started slowly after a backwash to prevent breakthrough of suspended material.

Filter Aids

Sometimes, when water passes through a filter, the floc is torn apart into smaller particles that will penetrate deeply into the filter media, causing premature turbidity breakthrough.

This will require more frequent filter backwashing of the filter and use of large volumes of backwash water to be able to remove the floc that has penetrated deeply into the filter bed.

A filter aid is a material that adds strength to the floc and prevents its breakup. Generally, a polymer is used as a filter aid because it creates strong bonds with the floc. Polymers are water-soluble, organic compounds that can be purchased in either wet or dry form.

The photo on the left is showing dry Polymer and on the right is the liquid.

Polymers have very high molecular weight and cause the floc to coagulate and flocculate quickly. Polymers can have positive or negative charges, depending on the type needed to cause attraction to the specific floc filtered.

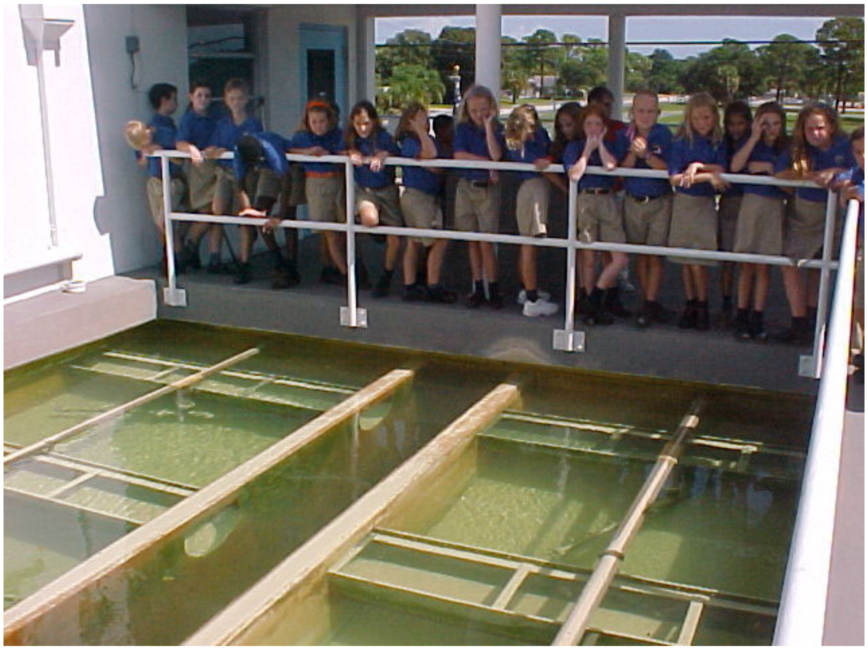
When used as a filter aid, the polymer strengthens the bonds and prevents the shearing forces in the filter from breaking the floc apart. For best results, the polymer should be added just ahead of the filter. A normal dose of polymer for filter aiding will be less than 0.1 ppm, but the exact dose will be decided by the result of a jar test and by experimentation in the treatment plant. Too much polymer will cause the bonds to become too strong, which may then cause the filter to plug, especially the top few inches of the filter media.

Filter Operating Problems
There are three major types of filter problems. They can be caused by chemical treatment before the filter, control of filter flow rate, and backwashing of filters.

The above photo shows clumps formed by Powder Activated Carbon.

Direct Filtration Plant vs. Conventional Plant

The only difference is that the sedimentation process or step is omitted from the Direct Filtration plant.



Tours of your facility are a wonderful public image tool. Many facilities are worried about their public image and what could possibly negatively happen, but if you can think positive, you may find more support and funding for your future projects.

Chemical Treatment before the Filter

The coagulation and flocculation stages of the water treatment must be monitored continuously. Adjustments in the amount of coagulant added must be made frequently to prevent the filter from becoming overloaded with suspended material. This overload may cause the filter to prematurely reach its maximum headloss.

If there is early turbidity breakthrough in the filter effluent, more coagulant may have to be added to the coagulation process. There may be a need for better mixing during the coagulation or the addition of more filter aid.

If there is a rapid increase in filter head loss, too much coagulant may be clogging the filter. Less coagulant or less filter aid should be used. The operator needs to learn to recognize these problems and choose the proper corrections.

Filter aid being fed at the weirs of sedimentation.

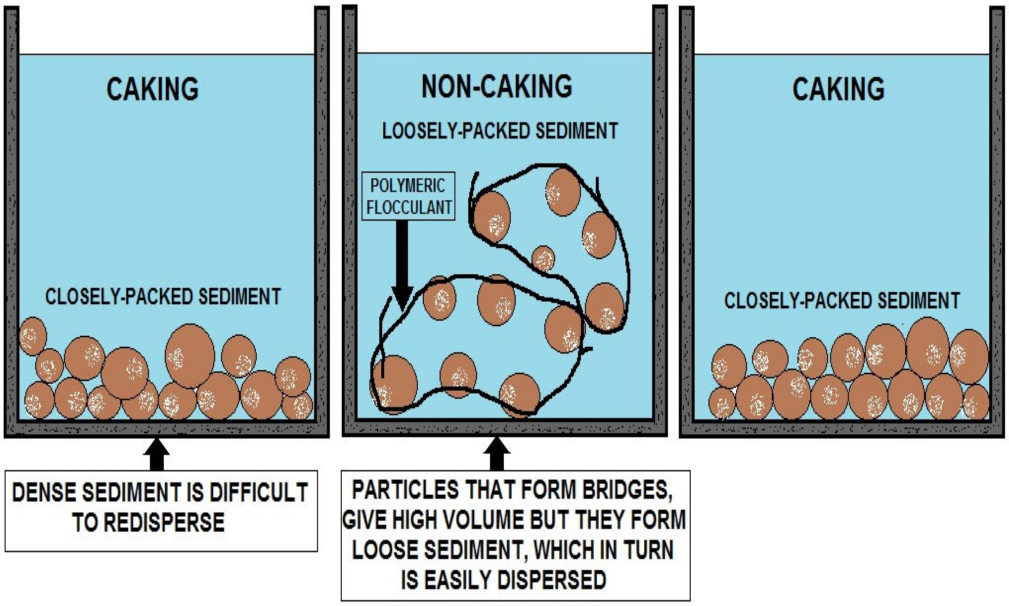
In the photograph above, overfeeding flocculants to meet federal regulations caused Iron to precipitate on the filter walls, resulting in this dark stain.

Control of Filter Flow Rate

When a filter is subjected to rapid changes in flow rate, the turbidity of the effluent may be affected; the dirtier the filter media, the greater the effect.

When a plant flow changes, the filter flow also has to change to produce the water needed. If an increase is necessary, the flow should, if possible, be increased gradually over a ten-minute period to reduce the impact on the filter. Addition of filter aids may also reduce the impact on the filter effluent.

When backwashing a filter and therefore temporarily taking it out of service, the remaining filter(s) must pick up the additional flow. This can cause an abrupt change in flow that will cause turbidity breakthrough. This problem can be avoided by keeping one filter in reserve to accept this additional flow. If the plant has a backwash storage basin, this will also prevent surges to the filters.



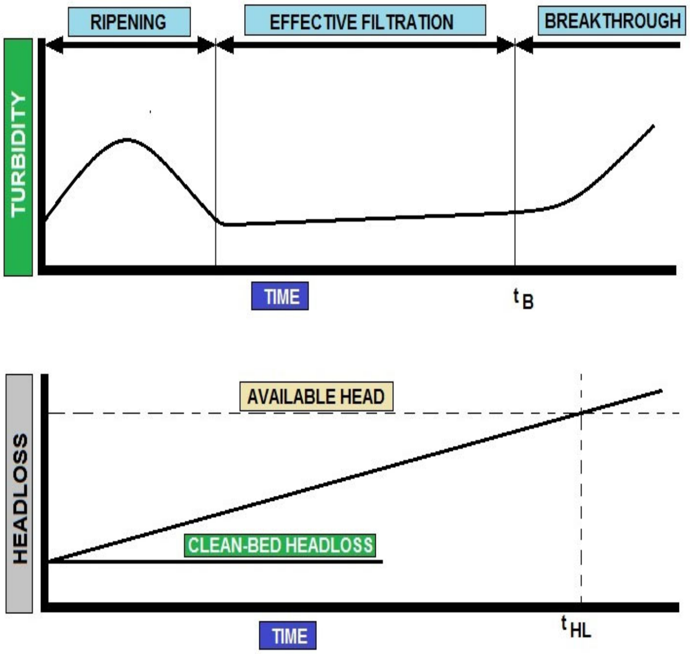
Technical Learning College

TYPE AND VOLUME OF SEDIMENT

Many plants are not operated continuously, and the start-up at the beginning of the day will cause a surge to the filter(s). The filters should be backwashed before putting them back into operation or operated to waste until the effluent meets the standards.

Backwashing of Filters

Backwashing of the filters is the single most important operation in the maintenance of the filters. If the filter is not backwashed effectively, problems may occur that may be impossible to correct without totally replacing the filter media. These problems could be caused by improper backwashing procedures:



TURBIDITY EFFLUENT IS CHARACTERIZED BY THREE SEGMENTS:

- **RIPENING**
  - Size and duration can be reduced by specific backwashing procedure
  - Media conditioning (15 min.- 2 hrs.)
- **EFFECTIVE FILTRATION**
  - Steady state turbidity <0.1 NTU
  - Gradual increasing in head loss
- **BREAKTHROUGH**
  - Filter cannot hold any more particles
  - The effluent turbidity increases
  - Increase in headloss

FLOC BREAKTHROUGH CHART

- Mud balls are formed by the filter media cementing together with the floc that the filter is supposed to remove. If the filter is backwashed effectively, the mud balls are broken apart and removed. As the balls gain weight, they will settle to the bottom of the filter and occupy valuable filter volume. This will cause the flow to increase in the areas of the filter that have not been plugged. Additional problems, such as filter cracking and separation of the media from the filter walls may also be the result of mud-ball formation.

- Filter bed shrinkage or compaction can result from ineffective backwashing. Media grains in a clean filter should rest directly against each other with very little compaction.

- Filter media in a dirty filter are surrounded by a soft layer that causes it to compact. This causes filter bed cracking and separation of the filter media from the walls of the filter. When the filter is cracked, it is obvious that the filter will short circuit. The flow will seek the crack and go straight through, resulting in excessive turbidity in the effluent.

A backwash basin that has wasted or lost media caked on the bottom.

- Separation of the gravel is caused by the backwash valve opening too quickly; as a result, the supporting gravel is forced to the top of the filter. This could also be caused by the filter underdrain being plugged or damaged, causing uneven distribution of the backwash water. When this happens, a boil occurs from the increased velocity in the filter. The filter media will start washing into the filter underdrain system and be removed from the filter. If displacement has occurred, the filter media must be removed from the filter and the filter rebuilt by the placement of each grade of media in its proper place.

- Air binding of the filter is not common as long as the filter is washed regularly. Air binding is the result of pressure in the filter becoming negative during operation. This causes the air dissolved in the water to come out of the solution and become trapped in the filter, resulting in resistance and short filter runs. This negative head generally occurs in a filter that has less than five feet of head above the unexpanded filter bed. If a filter head of five feet is not possible, filter backwash should be started at a lower head loss than normal.

The photograph above shows a filter support bed under construction.

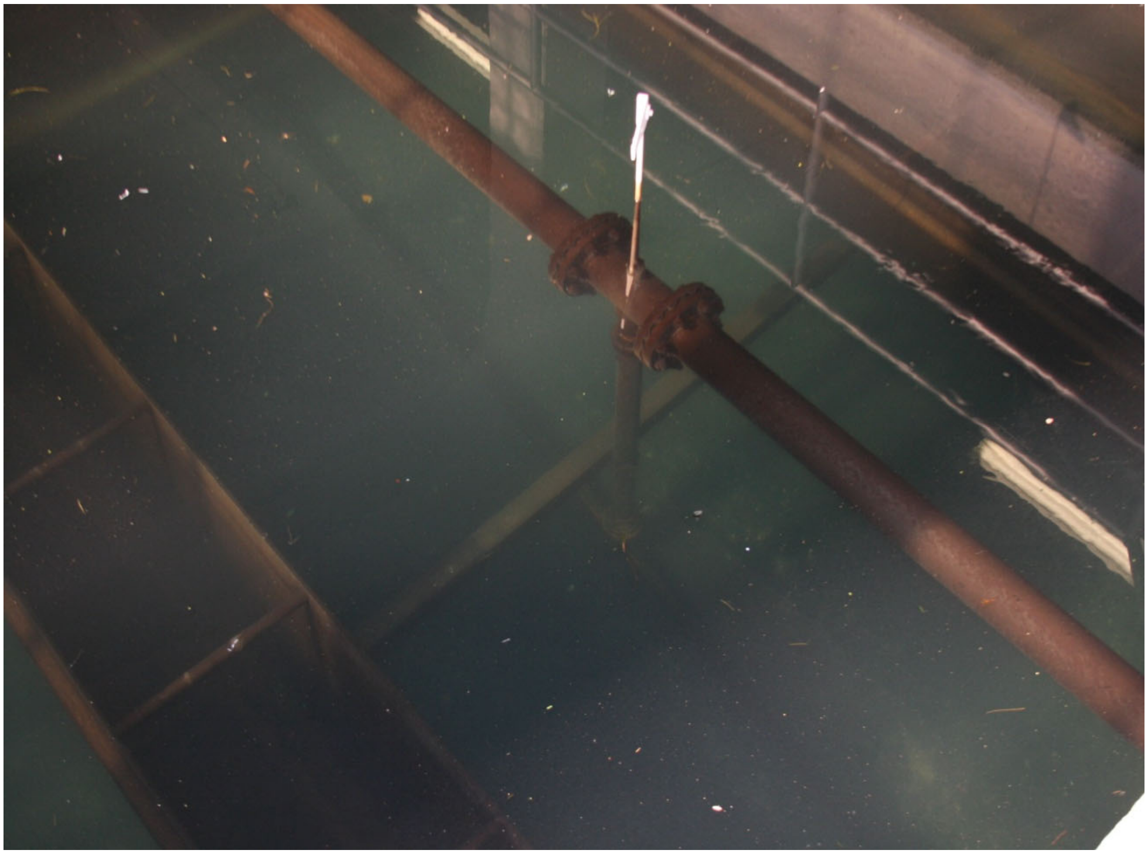
Air Binding

Air binding can also be caused by the water being cold and super-saturated with air. This air bubbles out as the water warms up. It is not possible for the operator to control this situation. If it happens, the filter must be backwashed more frequently to correct the filter air binding.

- Media loss is normal in any filter. Some are lost each time the filter is backwashed, especially if the filter surface wash is used. If a large amount of media is being lost, the method of washing should be inspected and corrected. The bed should not have to be expanded more than 20 percent during the backwash cycle. It may help to turn off the surface wash approximately two minutes before the end of the backwash. If this does not correct the problem, the filter troughs may have to be raised to prevent the excessive media loss.

Filter On-Line

After a well-operated filter backwash, the filter should be level and smooth with no cracks or mud balls at the surface. A good bed will appear to move laterally during the backwash and there will be no boils at the surface. The filter should clear up evenly during cleaning. If some areas are not clean, there could be an under-drain problem.



Mudballs can be seen on the top layer of the media bed or during the backwash water cycle. Typically, these will not flow over into the filter troughs. Mudballs must be removed manually, generally requiring extensive filter media reworking.

Granular Activated Carbon / Powdered Activated Carbon

Along with aeration, granular activated carbon (GAC) and powdered activated carbon (PAC) are suitable treatments for removal of organic contaminants such as VOCs, solvents, PCBs, herbicides and pesticides. Activated carbon is carbon that has been exposed to a very high temperature, creating a vast network of pores with a very large internal surface area; one gram of activated carbon has a surface area equivalent to that of a football field. It removes contaminants through adsorption, a process in which dissolved contaminants adhere to the surface of the carbon particles.

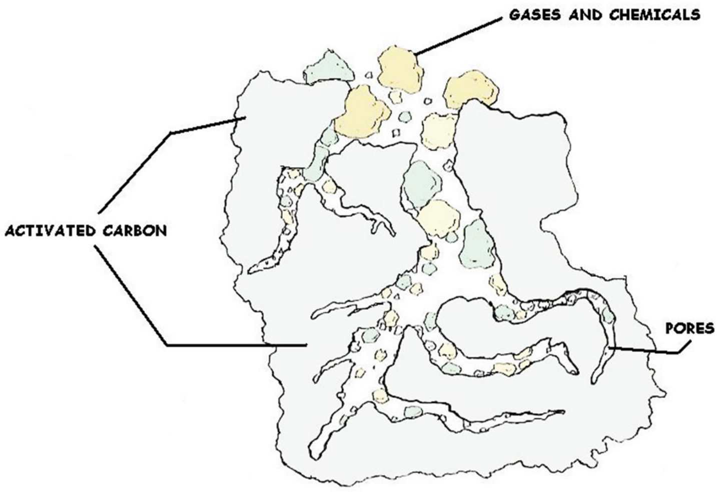
GAC can be used as a replacement for existing media (such as sand) in a conventional filter or it can be used in a separate contactor such as a vertical steel pressure vessel used to hold the activated carbon bed. After a period of a few months or years, depending on the concentration of the contaminants, the surface of the pores in the GAC can no longer adsorb contaminants and the carbon must be replaced. Several operational and maintenance factors affect the performance of granular activated carbon. Contaminants in the water can occupy adsorption sites, whether or not they are targeted for removal. Also, adsorbed contaminants can be replaced by other contaminants with which GAC has a greater affinity, so their presence might interfere with removal of contaminants of concern.

A significant drop in the contaminant level in influent water can cause a GAC filter to desorb, or slough off adsorbed contaminants, because GAC is essentially an equilibrium process. As a result, raw water with frequently changing contaminant levels can result in treated water of unpredictable quality. Bacterial growth on the carbon is another potential problem. Excessive bacterial growth may cause clogging and higher bacterial counts in the treated water. The disinfection process must be carefully monitored in order to avoid this problem.

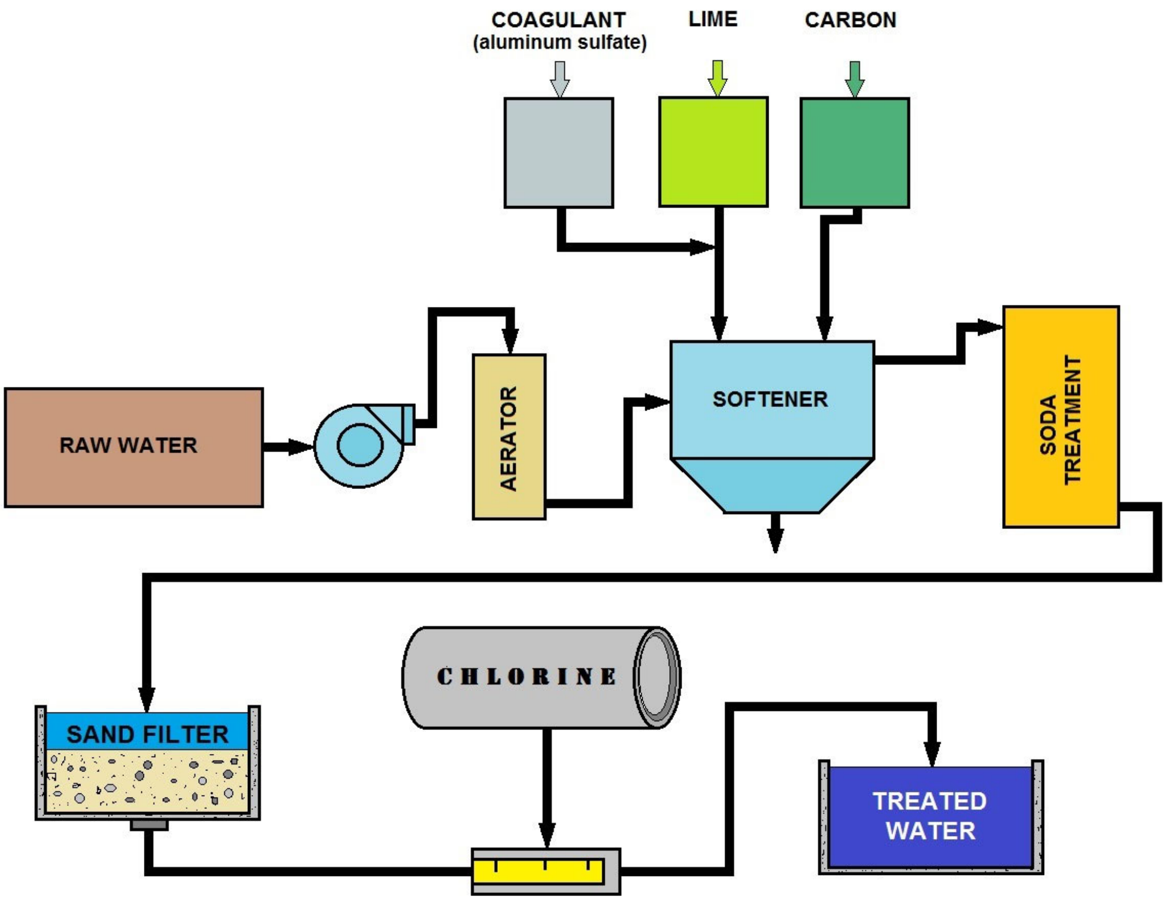
Powdered activated carbon consists of finely ground particles and exhibits the same adsorptive properties as the granular form. PAC is normally applied to the water in a slurry and then filtered out. The addition of PAC can improve the organic removal effectiveness of conventional treatment processes and also remove tastes and odors.

The advantages of PAC are that it can be used on a short-term or emergency basis with conventional treatment, it creates no headloss, it does not encourage microbial growth, and it has relatively small capital costs.

The main disadvantage is that some contaminants require large doses of PAC for removal. It is also somewhat ineffective in removing natural organic matter due to the competition from other contaminants for surface adsorption and the limited contact time between the water and the carbon.



ACTIVATED CARBON ABSORBS GASES AND CHEMICALS



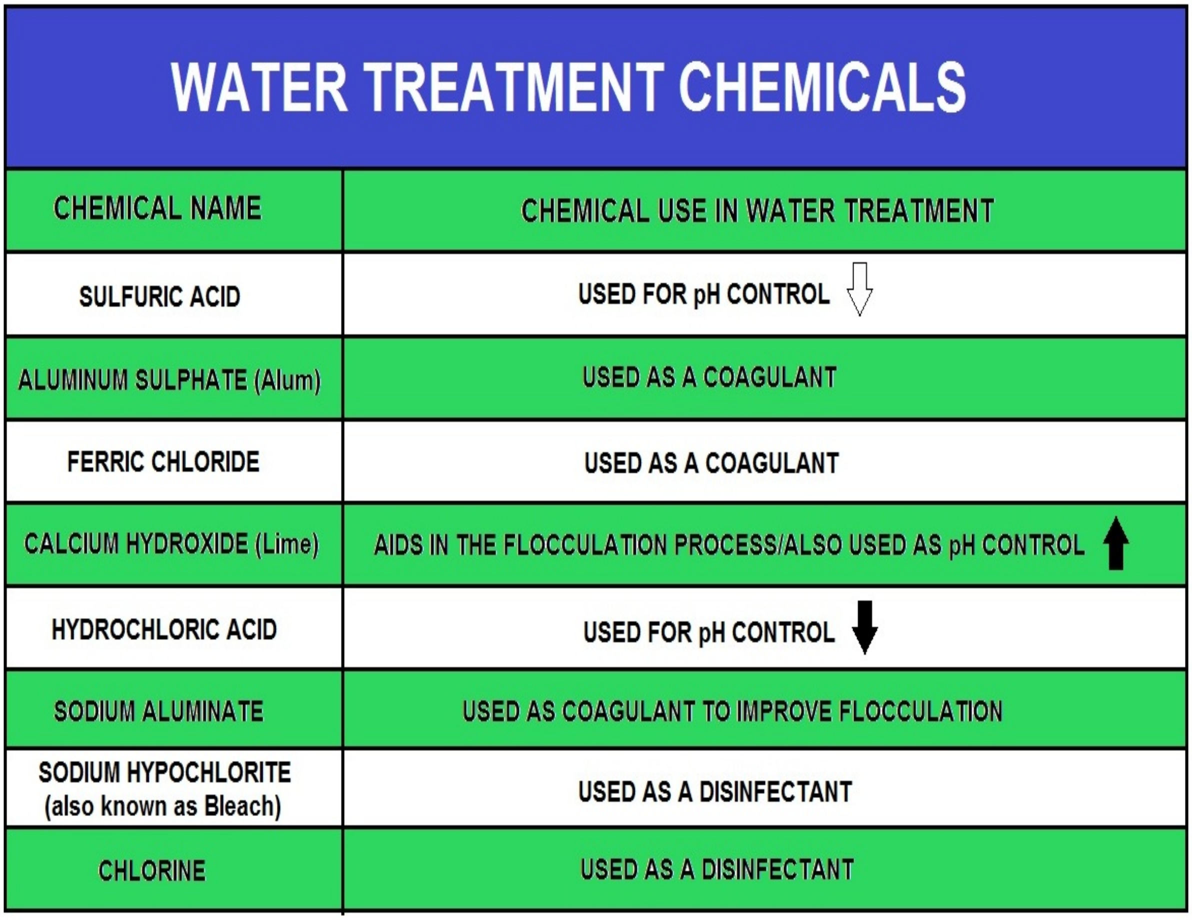
Summary of Conventional Water Treatment Processes

A combination selected from the following processes is used for municipal drinking water treatment worldwide:

- Pre-chlorination - for algae control and arresting any biological growth
- Aeration - along with pre-chlorination for removal of dissolved iron and manganese
- Coagulation - for flocculation
- Coagulant aids, also known as polyelectrolytes - to improve coagulation and for thicker floc formation
- Sedimentation - for solids separation, that is, removal of suspended solids trapped in the floc
- Filtration - removing particles from water
- Desalination - Process of removing salt from the water
- Disinfection - for killing bacteria.

There is no unique solution (selection of processes) for any type of water. Also, it is difficult to standardize the solution in the form of processes for water from different sources.

Treatability studies for each source of water in different seasons need to be carried out to arrive at most appropriate processes.



WATER TREATMENT CHEMICALS

CHEMICAL NAME	CHEMICAL USE IN WATER TREATMENT
SULFURIC ACID	USED FOR pH CONTROL ⇩
ALUMINUM SULPHATE (Alum)	USED AS A COAGULANT
FERRIC CHLORIDE	USED AS A COAGULANT
CALCIUM HYDROXIDE (Lime)	AIDS IN THE FLOCCULATION PROCESS/ALSO USED AS pH CONTROL ⬆
HYDROCHLORIC ACID	USED FOR pH CONTROL ⬇
SODIUM ALUMINATE	USED AS COAGULANT TO IMPROVE FLOCCULATION
SODIUM HYPOCHLORITE (also known as Bleach)	USED AS A DISINFECTANT
CHLORINE	USED AS A DISINFECTANT

Specific Water Treatment Chemicals

Similar chemicals are used for process control, odor control and sludge conditioning in Water and Wastewater Treatment. Students will learn about the types of chemicals used and how they react in the process. Students will also learn about chemical safety and how to perform on-site equipment assessment.

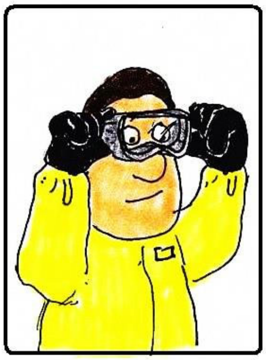
The table below is a list of general chemicals used in Water and Wastewater. They may vary by the manufacture; a perfect example would be Thioguard®, which is Magnesium Hydroxide. In this class we will discuss the chemical name and compound and leave out manufacture trade names.

Common Water/Wastewater Treatment Chemicals

Chemical Name	Common Name	Chemical Formula
Aluminum hydroxide		$Al(OH)_3$
Aluminum sulfate	Alum, liquid	$AL_2(SO_4)3 . 14(H_2O)$
Ammonia		NH_3
Ammonium		NH_4
Bentonitic clay	Bentonite	
Calcium bicarbonate		$Ca(HCO_3)2$
Calcium carbonate	Limestone	$CaCO_3$
Calcium chloride		$CaCl2$
Calcium Hypochlorite	HTH	$Ca(OCl)_2 . 4H_2O$
Calcium hydroxide	Slaked Lime	$Ca(OH)_2$
Calcium oxide	Unslaked (Quicklime)	CaO
Calcium sulfate	Gypsum	$CaSO_4$
Carbon	Activated Carbon	C
Carbon dioxide		CO_2
Carbonic acid		$H2CO_3$
Chlorine gas		$Cl2$
Chlorine Dioxide		ClO_2
Copper sulfate	Blue vitriol	$CuSO_4 . 5H_2O$
Dichloramine		$NHCl2$
Ferric chloride	Iron chloride	$FeCl_3$
Ferric hydroxide		$Fe(OH)_3$
Ferric sulfate	Iron sulfate	$Fe_2(SO_4)_3$
Ferrous bicarbonate		$Fe(HCO_3)_2$
Ferrous hydroxide		$Fe(OH)_3$
Ferrous sulfate	Copperas	$FeSO_4.7H_20$
Hydrofluorsilicic acid		H_2SiF_6
Hydrochloric acid	Muriatic acid	HCl
Hydrogen sulfide		H_2S

Chemical Name	Common Name	Chemical Formula
Hypochlorous acid		HOCL
Magnesium bicarbonate		$Mg(HCO_3)2$
Magnesium carbonate		$MgCO_3$
Magnesium chloride		$MgCl2$
Magnesium hydroxide		$Mg(OH)_2$
Magnesium dioxide		MgO_2
Manganous bicarbonate		$Mn(HCO_3)2$
Manganous sulfate		$MnSO_4$
Monochloramine		NH_2Cl
Potassium bicarbonate		$KHCO_3$
Potassium permanganate		$KMnO_4$
Sodium carbonate	Soda ash	Na_2CO_3
Sodium chloride	Salt	NaCl
Sodium chlorite		$NaClO_2$
Sodium fluoride		NaF
Sodium fluorosilicate		Na_2SiF_6
Sodium hydroxide	Lye	NaOH
Sodium hypochlorite		NaOCl
Sodium Metaphosphate	Hexametaphosphate	$NaPO_3$
Sodium phosphate	Disodium phosphate	Na_3PO_4
Sodium sulfate		Na_2SO_4
Sulfuric acid		H_2SO_4

READ THE SAFETY DATA SHEET



WEAR PROPER PPE

HANDLING CHEMICALS

Topic 3- Water Treatment Filtration Section Post Quiz

1. What is a typical range for the turbidity of the water coming to the treatment plant from the raw water source?

2. What chemical is often used to coat the pipes in the distribution system to inhibit corrosion?

3. The mass of growing material that collects in the filter is called?

4. Solids that have been removed from the raw water by the coagulation, flocculation and settling processes are referred to as?

5. What chemical is a clear, fuming, corrosive liquid with a pH ranging from 1 to 1.5. Used in water treatment to fluoridate drinking water?

6. Powdered activated carbon (PAC) is occasionally added for taste and odor control. PAC is added to the________________________.

7. What is a condition that occurs in tanks or basins when some of the water travels faster than the rest of the flowing water?

8. Water testing is conducted throughout the treatment process. Items like _______________are monitored and recorded continuously. Some items are tested several times per day, some once per quarter and others once per year.

9. What type of chemical, when combined with other types of coagulants, aids in binding small suspended particles to larger particles to help in the settling and filtering processes.

10. What is a strong chemical used in the treatment process to neutralize acidity, increase alkalinity, or raise the pH value?

11. Coagulants are chemicals, such as alum, that neutralize ____________charges on small particles, allowing them to stick together and form larger particles that are more easily removed by sedimentation (settling) or filtration.

12. Chemicals are added to the water in order to improve the subsequent treatment processes. These may include pH adjusters and coagulants.
True or False

13. A variety of devices, such as baffles, static mixers, impellers, and in-line sprays can be used to mix the water and distribute the chemicals evenly.
True or False

14. The final step in the conventional filtration process, the clarifier provides temporary storage for the treated water.

15. Water scouring cleans adsorption clarifiers followed by chemical flushing.

Math Formulas and Conversions

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

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

Amperage = Voltage ÷ Ohms

Area of Circle = (0.785)(Diameter^2) OR (π)(Radius^2)

Area of Rectangle = (Length)(Width)

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

C Factor Slope = Energy loss, ft. ÷ Distance, ft.

C Factor Calculation = Flow, GPM ÷ [193.75 (Diameter, ft.)2.63(Slope)0.54]

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

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

Chlorine Demand (mg/L) = Chlorine dose (mg/L) – Chlorine residual (mg/L)

Circumference of Circle = (3.141) (Diameter)

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

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

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

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

Dosage, lbs/day = (mg/L)(8.34)(MGD)

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

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

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

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

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

$$\text{Filter Yield, lbs/hr./sq. ft} = \frac{(\text{Solids Loading, lbs/day})\ (\text{Recovery, \% / 100\%})}{(\text{Filter operation, hr./day})\ (\text{Area, ft}^2)}$$

Flow, cu. ft./sec. = (Area, Sq. Ft.)(Velocity, ft./sec.)

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

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

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

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

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

$$\text{Hydraulic Loading Rate} = \frac{\text{Flow}}{\text{Area}}$$

Leakage (actual) = Leak rate (GPD) ÷ [Length (mi.) x Diameter (in.)]

Mean = Sum of values ÷ total number of values

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

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

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

Pounds per day = (Flow, MGD) (Dose, mg/L) (8.34)

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

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

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

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

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

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

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

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

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

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

Solids Applied, lbs/day = (Flow, MGD)(Concentration, mg/L)(8.34 lbs/gal)

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

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

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

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

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

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

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

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

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

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

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

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

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

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- 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 Treatment Filtration Section Post Quiz Answers
1. Raw Turbidity, 2. Zinc Orthophosphate, 3. Schmutzdecke, 4. Settled Solids, 5. Hydrofluosilicic Acid, 6. Flash mix, 7. Short-Circuiting, 8. Turbidity, pH, and chlorine residual, 9. Polymer, 10. NaOH (also called Sodium Hydroxide), 11. Positive or negative, 12. True, 13. True, 14. False, 15. False

References

ACGIH [1991]. Documentation of the threshold limit values and biological exposure indices. 6th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [1994]. 1994-1995 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ATS [1987]. Standardization of spirometry -- 1987 update. American Thoracic Society. Am Rev Respir Dis

Basic Principles of Water Treatment, Littleton, Colorado. Tall Oaks Publishing Inc.

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

Benenson, Abram S., editor. 1990. Control of Communicable Diseases in Man. 15th ed. Blti: Victor Graphics, Inc.

Bick, H. 1972. Ciliated protozoa. An illustrated guide to the species used as biological indicators in freshwater biology. World Health Organization, Geneva. 198 pp.

Bickford, T.M., Lindsey, B.D., and Beaver, M.R., 1996, Bacteriological quality of ground water used

Bisson, J.W. and Cabelli, V.J., 1980, Clostridium perfringens as a water pollution indicator: Journal of the Water Pollution Control Federation, v. 52, no. 2, p. 241-248.

Born, Stephen M., Douglas A. Yanggen, and Alexander Zaporozec. A Guide to Groundwater Quality Planning and Management for Local Governments. Wisconsin Geological and Natural History Survey, Madison, WI, 1987.

Brenner, K.P., Rankin, C.C., Roybal, Y.R., Stelma, G.R., Scarpino, P.V., and Dufour, A.P., 1993, New medium for simultaneous detection of total coliforms and Escherichia coli in water: Applied and Environmental Microbiology, v. 59, no. 11, p. 3534-3544.

Britton, L.J., and Greeson, P.E., ed., 1989, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A4, 363 p.

Brooks, D., and Cech, I., 1979, Nitrates and bacterial distribution in rural domestic water supplies: Water

Butterworth, B.E., Kedderis, G.L., and Conolly, R.B. (1998) The chloroform risk assessment: A mirror of scientific understanding. CIIT Activities,18 no.4.

Cabelli, V.J., 1981, Health effects criteria for marine recreational waters: Cincinnati, Ohio, U.S. Environmental Protection Agency, EPA-600/1-80-031.

Cairns, J., and J.A. Ruthven. 1972. A test of the cosmopolitan distribution of fresh-water protozoans. Hydrobiologia 39:405-427.

Cairns, J., and W.H. Yongue. 1977. Factors affecting the number of species of freshwater protozoan communities. Pages 257-303 in J. Cairns, ed. Aquatic microbial communities. Garland, New York.

Cairns, J., G.R. Lanza, and B.C. Parker. 1972. Pollution related structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa. Proceedings of the National Academy of Sciences 124:79-127.

Cairns, J., G.R. Lanza, and B.C. Parker. 1972. Pollution related structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa. Proceedings of the National Academy of Sciences 124:79-127.

CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Christian, M.S., York, R.G., Hoberman, A.M., Diener, R.M., Fisher, L.C., and Gates, G.A. (2001a). Biodisposition of dibromoacetic acid (DBA) and bromodichloromethane (BDCM) administered to rats and rabbits in drinking water during range-finding reproduction and developmental toxicity studies. International Journal of Toxicology, 20, 225-237,   239-253.

Christian, M.S., York, R.G., Hoberman, A.M., Fisher, L.C., and Brown, W.R. (2002a). Oral (drinking water) two-generation reproductive toxicity study of bromodichloromethane (BDCM) in rats. International Journal of Toxicology, 21, 115-146.

Christian, M.S., York, R.G., Hoberman, A.M., Frazee, J., Fisher, L.C., Brown, W.R., and Creasy, D.M. (2002b). Oral (drinking water) two-generation reproductive toxicity study of dibromoacetic acid (DBA) in rats. International Journal of Toxicology, 21, 1-40.

Clayton G, Clayton F [1981-1982]. Patty's industrial hygiene and toxicology. 3rd rev. ed. New York, NY: John Wiley & Sons.

Concern, Inc. Groundwater: A Community Action Guide. Washington, D.C., 1989.

Connell, G.F. (1996). The chlorination/chloramination handbook. Denver: American Water Works Association.

Coulston, F., and Kolbye, A. (Eds.) (1994). Regulatory Toxicology and Pharmacology, vol. 20, no. 1, pt 2.

Covington, A. K.; Bates, R. G.; Durst, R. A. (1985). "Definitions of pH scales, standard reference values, measurement of pH, and related terminology" (PDF). Pure Appl. Chem. ***57*** *(3): 531–542. doi:10.1351/pac198557030531.*

Craun, G.F., 1992, Waterborne disease outbreaks in the United States of America—Causes and prevention: World Health Statistician Quarterly, v. 45.

Craun, G.F., and Calderon, R., 1996, Microbial risks in groundwater systems–Epidemiology of waterborne outbreaks, in Under the microscope–Examining microbes in groundwater, Proceedings of the Groundwater Foundation's 12th Annual Fall Symposium, Sept. 5-6, 1996, Boston, Mass.: Research Foundation of the American Water Works Association.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Genium [1992]. Material safety data sheet No. 53. Schenectady, NY: Genium Publishing Corporation.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Larson, J.L., Wolf, D.C., and Butterworth, B.E. (1994a). Induced cytolethality and regenerative cell proliferation in the livers and kidneys of male B6C3F1 mice given chloroform by gavage. Fundamentals and Applied Toxicology, 23, 537-543.

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

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

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

Lee, C.C., and T. Fenchel. 1972. Studies on ciliates associated with sea ice from Antarctica. II. Temperature responses and tolerances in ciliates from Antarctica, temperate and tropical habitats. Archive für Protistenkunde 114:237-244.
Levy, D.A., Bens, M.S., Craun, G.F., Calderon, R.L., and Herwaldt, B.L.,1998, Surveillance for waterborne disease outbreaks—United States, 1995-1996: Morbidity and Mortality Weekly Report—Surveillance Summaries, December 11, 1998, 47(SS-5).
Lewis RJ, ed. [1993]. Lewis condensed chemical dictionary. 12th ed. New York, NY: Van Nostrand Reinhold Company.
Lide DR [1993]. CRC handbook of chemistry and physics. 73rd ed. Boca Raton, FL: CRC Press, Inc.
Lim, Kieran F. (2006). "Negative pH Does Exist". Journal of Chemical Education. ***83*** *(10): 1465. Bibcode:2006JChEd..83.1465L. doi:10.1021/ed083p1465.*
Lindquist, H.D.A. (1999). Emerging pathogens of concern in drinking water. EPA Publication #EPA 600/R-99/070.
Loomis, George and Yael Calhoon. "Natural Resource Facts: Maintaining Your Septic System." University of Rhode Island, Providence, RI, 1988.
Macozzi, Maureen. Groundwater- Protecting Wisconsin's Buried Treasure. Wisconsin Department of Natural Resources, Madison, WI, 1989.
Maine Association of Conservation Comm. Ground Water... Maine's Hidden Resource. Hallowell, ME, 1985.
Malard, F., Reygrobellet, J-L., and Soulie, Michel, 1994, Transport and retention of fecal bacteria at sewage polluted fractured rock sites: Journal of Environmental Quality, v. 23, p. 1352-1363.
Massachusetts Audubon Society "Local Authority for Groundwater Protection." Groundwater Information Flyer #4. Lincoln, MA, 1984.
Massachusetts Audubon Society. "Groundwater and Contamination: From the Watershed into the Well." Groundwater Information Flyer # 2. Lincoln, MA, 1984.
Massachusetts Audubon Society. "Mapping Aquifers and Recharge Areas." Groundwater Information Flyer # 3. Lincoln, MA, 1984.
Massachusetts Audubon Society. "Road Salt and Groundwater Protection." Groundwater Information Flyer # 9. Lincoln, MA, 1987.
Mast, A.M., and Turk, J.T., 1999, Environmental Characteristics and Water Quality of Hydrologic Benchmark Network Stations in the Eastern United States, 1963- 95: U.S. Geological Survey Circular 1173-B, 158 p.
McCann, Alyson and Thomas P Husband. "Natural Resources Facts: Household Hazardous Waste." University of Rhode Island, Providence, RI; 1988.
Miller, David W. Groundwater Contamination: A Special Report. Geraghty & Miller, Inc., Syosset, NY 1982.
Montagnes, D.J.S., D.H. Lynn, J.C. Roff, and W.D. Taylor. 1988. The annual cycle of heterotrophic planktonic ciliates in the waters surrounding the Isles of Shoals, Gulf of Maine: an assessment of their trophic role. Marine Biology 99:21-30.
Mullikin, Elizabeth B. An Ounce of Prevention: A Ground Water Protection Handbook for Local Officials. Vermont Departments of Water Resources and Environmental Engineering, Health, and Agriculture, Montpelier, VT, 1984.
Murphy, Jim. "Groundwater and Your Town: What Your Town Can Do Right Now." Connecticut Department of Environmental Protection, Hartford, CT.
Myers, D.N., 1992, Distribution and variability of fecal indicator bacteria in Scioto and Olentangy Rivers in the Columbus, Ohio, area: U.S. Geological Survey Water-Resources Investigations Report 92-4130, 61 p.
Myers, D.N., and Sylvester, M.D., 1997, National field manual for the collection of water-quality data—Biological indicators: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A7, 38 p.
Myers, D.N., Koltun, G.F., and Francy, D.S., 1998, Effects of hydrologic, biological, and environmental processes on sources and concentrations of fecal bacteria in the Cuyahoga River, with implications for management of recreational waters in Summit and Cuyahoga Counties, Ohio: U.S. Geological Survey Water-Resources Investigations Report 98-4089, 38 p.
National Academy of Engineering (2000). Greatest engineering achievements of the 20th century. [On-Line]. Available: (http://www.greatachievements.org/ greatachievements/) (accessed 2-10-03).
National Research Council. Ground Water Quality Protection: State and Local Strategies. National Academy Press, Washington, D.C., 1986.
Natural Resources Defense Council, 1998, Testing the waters—Volume VIII: New York, 145 p. Novotony, V., Sung, Hung-Ming, Bannerman, R., and Baum, K., 1985, Estimating nonpoint pollution from small urban watersheds: Journal of the Water Pollution Control Federation, v. 57, p. 339-348.
New England Interstate Water Pollution Control Commission. "Groundwater: Out of Sight Not Out of Danger." Boston, MA, 1989.
NFPA [1986]. Fire protection guide on hazardous materials. 9th ed. Quincy, MA: National Fire ProAss
Niederlehner, B.R., K.W. Pontasch, J.R. Pratt, and J. Cairns. 1990. Field evaluation of predictions of environmental effects from multispecies microcosm toxicity test. Archives of Environmental Contamination and Toxicology 19:62-71.

NIOSH [1987a]. NIOSH guide to industrial respiratory protection. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-116.
NIOSH [1987b]. NIOSH respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-108.
NIOSH [1992]. Recommendations for occupational safety and health: Compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.
NIOSH [1994]. NIOSH manual of analytical methods. 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.
NIOSH [1995]. Registry of toxic effects of chemical substances: Chlorine. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, Technical Information Branch.
NJDH [1992]. Hazardous substance fact sheet: Chlorine. Trenton, NJ: New Jersey Department of Health.
NLM [1995]. Hazardous substances data bank: Chlorine. Bethesda, MD: National Library of Medicine.
Noake, Kimberly D. Guide to Contamination Sources for Wellhead Protection. Draft. Massachusetts Department of Environmental Quality Engineering, Boston, MA, 1988.
Office of Drinking Water. A Local Planning Process for Groundwater Protection. U.S. EPA, WA, D.C., 1989.
Office of Ground-Water Protection. Guidelines for Delineation of Wellhead Protection Areas. U.S. EPA, Washington, D.C., 1987.
Office of Ground-Water Protection. Survey of State Ground Water Quality Protection Legislation Enacted From 1985 Through 1987. U.S. EPA, Washington, D.C., 1988.
Office of Ground-Water Protection. Wellhead Protection Programs. - Tools for Local Governments. U.S. EPA, Washington, D.C., 1989.
Office of Ground-Water Protection. Wellhead Protection: A Decision-Makers' Guide. U.S. EPA, WA, D.C., 1987
Office of Pesticides and Toxic Substances. Citizen's Guide to Pesticides. U.S. EPA, Washington, D.C., 1989.
Office of Underground Storage Tanks. Musts for USGS. - A Summary of the New Regulations for Underground Storage Tank Systems. U.S. EPA, Washington, D.C., 1988.
Ohio Environmental Protection Agency. Ground Water. Columbus, OH.
Ontario Ministry of the Attorney General, The Honorable Dennis R. O'Connor (2002). Part one: A summary: Report of the Walkerton inquiry: The events of May 2000 and related issues.
Otterstetter, H. and Craun, C. (September, 1997). Disinfection in the Americas: A necessity. Journal of the American Water Works Association, 8-10.
Palmer, M.D., Lock, J.D., and Gowda, T.P.H., 1984, The use of bacteriological indicators for swimming water quality: Water and Pollution Control, v. 122, no. 3, p. 14-15, 17-18, and 74.
Payment, P., and Franco, E., 1993, Clostridium perfringens and somatic coliphages as indicators of the efficiency of drinking water treatment for viruses and protozoan cysts: Applied and Environmental Microbiology, v. 59, no. 8, p. 2418-2424.
Principles and Practices of Water Supply Operations, C.D. Morelli, ed. 1996.
Redlich, Susan. Summary of Municipal Actions for Groundwater Protection in the New England/New York Region. New England Interstate Water Pollution Control Commission, Boston, MA, 1988.
Redlich, Susan. Summary of Municipal Actions for Groundwater Protection in the New England/New York Region. Research, v. 13, p. 33-41.
Robertson, J.B., and Edberg, S.C., 1997, Natural protection of spring and well drinking water against surface microbial contamination. 1. Hydrogeological parameters: Critical Rev in Microbiology, v. 23, no. 2, p. 143-178.
Rose, J.B. (2002). Water quality security. Environmental Science and Technology, 36, 217-256.
Rose, J.B., Atlas, R.M., Gerba, C.P., Gilchrist, M.J.R., Le Chevallier, M.W., Sobsey, M.D., and Yates, M.V., 1999, Microbial pollutants in our Nation's
Rose, J.B., Gerba, C.P., and Jakubowski, W., 1991, Survey of potable water supplies for Cryptosporidium and Giardia: Environmental Science and Technology, v. 25, no. 8, p. 1393-1400.
Southern Arizona Water Resources Association. "Water Warnings: Our Drinking Water.... It Takes Everyone to Keep It Clean." Tucson, AZ.
Sponenberg, Torsten D. and Jacob H. Kahn. A Groundwater Primer for Virginians. Virginia Polytechnic Institute and State University, Blacksburg, VA, 1984.
Taylor, W., and R. Sanders. 1991. Protozoa. Pages 37-93 in J.H. Thorp and A.P. Covich, eds. Ecology and classification of North American freshwater invertebrates. Academic Press, New York.
Texas Water Commission. "On Dangerous Ground: The Problem of Abandoned Wells in Texas." Austin, TX, 1989.

Taylor, W., and R. Sanders. 1991. Protozoa. Pages 37-93 in J.H. Thorp and A.P. Covich, eds. Ecology and classification of North American freshwater invertebrates. Academic Press, New York.
Texas Water Comm. "On Dangerous Ground: The Problem of Abandoned Wells in Texas." Austin, TX, 1989.
Texas Water Comm. The Underground Subject: An Introduction to Ground Water Issues in TX. Austin, TX, 1989.
U.S. Centers for Disease Control and Prevention (1997). Summary of notifiable diseases. U.S. Centers for Disease Control and Prevention (April 12, 1996). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks, United States, 1993-1994.
U.S. Centers for Disease Control and Prevention (December 11, 1998). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks, United States, 1995-1996.
U.S. Centers for Disease Control and Prevention (May 26, 2000). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks, United States, 1997-1998.
U.S. Centers for Disease Control and Prevention (November 19, 1993). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks-United States, 1991-1992.
U.S. Centers for Disease Control and Prevention, (2002). National Center for Infectious Diseases, Infectious Disease Information, Diseases related to water. [On-Line]. Available: http://www.cdc.gov/ncidod/diseases/water/drinking.htm
U.S. Centers for Disease Control and Prevention, (November 22, 2002). Morbidity and Mortality Weekly Report, CDC Surveillance summaries: Surveillance for waterborne disease outbreaks, United States, 1999-2000.
U.S. Environmental Protection Agency (1991). Letter from Wilcher, L.S. to Guerra de Macedo, G.
U.S. Environmental Protection Agency (1998a). National Primary Drinking Water Regulations: Disinfectants and Disinfection Byproducts; Final Rule. Federal Register Vol 63, No. 157. Wednesday, Dec.16, 1998.
U.S. Environmental Protection Agency (1998b). Regulatory Impact Analysis of Final Disinfectant/ Disinfection byproducts Regulations. Washington, D.C. EPA Number 815-B-98-002-PB 99-111304
U.S. Environmental Protection Agency (2001a). Toxicological review of chloroform in support of summary information on the Integrated Risk Information System (IRIS). EPA Number 635/R-01/001.
U.S. Environmental Protection Agency (2001b). Controlling Disinfection byproducts and Microbial Contaminants in Drinking Water. EPA Number 600/R-01/110.
U.S. Environmental Protection Agency (2002). Public drinking water systems: Facts and figures. [On-Line]. Available: http://www.epa.gov/safewater/pws/factoids.html (accessed 11-22-02).
U.S. Environmental Protection Agency. Seminar Publication: Protection of Public Water Supplies from Ground-Water Contaminants. Center for Environmental Research Information, Cincinnati, OH, 1985.
U.S. Environmental Protection Agency. Seminar Publication: Protection of Public Water Supplies from Ground-Water Contaminants. Center for Environmental Research Information, Cincinnati, OH, 1985.
Waller, Roger M. Ground Water and the Rural Homeowner. U.S. Geological Survey, Reston, VA, 1988.
Water Treatment, Second Edition
Water, in Groundwater pollution microbiology: New York, John Wiley and Sons, p. 65-88.
water—Environmental and public health issues: Washington, D.C., American Society for Microbiology,
World Health Organization (2002a). Water and Sanitation: Facts and Figures. [On-Line]. Available: http://www.who.int/water_sanitation_health/General/ factsandfigures.htm
World Health Organization (2002b). Water and Sanitation: Guidelines for drinking water quality. [On-Line]. Available: http://www.who.int/ water_sanitation_health/GDWQ/Microbiology/ Microbioladd/microadd5.htm

Glossary References

Benenson, Abram S., editor. 1990. *Control of Communicable Diseases in Man.* 15th ed. Baltimore: Victor Graphics, Inc.
Foster, Laurence, M.D. 1985. “Waterborne Disease - It’s Our Job to Prevent It”. PIPELINE newsletter, Oregon Health Division, Drinking Water Program, Portland, Oregon 1(4): 1-3.
Foster, Laurence, M.D. 1990. “Waterborne *Disease,” Methods for the Investigation and Prevention of Waterborne Disease Outbreaks.* Ed. Gunther F. Craun. Cincinnati: U.S. Environmental Protection Agency.

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

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

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

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

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

You will have 90 days in order to successfully complete this assignment with a score of 70% or better.

If you need any assistance, please contact TLC's Student Services. Once you are finished, please mail, e-mail or fax your answer sheet along with your registration form.