WATER TREATMENT FUNDAMENTALS

CONTINUING EDUCATION
PROFESSIONAL DEVELOPMENT COURSE

1st Edition

Technical
Learning
College

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Important Information about this Manual

This manual has been prepared to educate operators in the general education of valves, valve system design, valve operation, and hydraulic principles including basic mechanical training and different valve related applications. For most students, the study of valving and hydraulics is quite large, requiring a major effort to bring it under control.

This manual should not be used as a guidance document for employees who are involved with cross-connection control. It is not designed to meet the requirements of the United States Environmental Protection Agency (EPA) or the Department of Labor-Occupational Safety and Health Administration (OSHA) or your state environmental or health agency. Technical Learning College or Technical Learning Consultants, Inc. make no warranty, guarantee or representation as to the absolute correctness or appropriateness of the information in this manual and assumes no responsibility in connection with the implementation of this information.

It cannot be assumed that this manual contains all measures and concepts required for specific conditions or circumstances. This document should be used for educational purposes and is not considered a legal document. Individuals who are responsible for hydraulic equipment, cross-connection control, backflow prevention or water distribution should obtain and comply with the most recent federal, state, and local regulations relevant to these sites and are urged to consult with OSHA, the EPA and other appropriate federal, state and local agencies.

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TLC
PO Box 3060
Chino Valley, AZ 86323

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

Do not solely depend on TLC's Approval list for it may be outdated.

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

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

Responsibility

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

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 format and you are welcome to examine this material on your computer with no obligation. 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 do finish the material on your leisure. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and 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.)

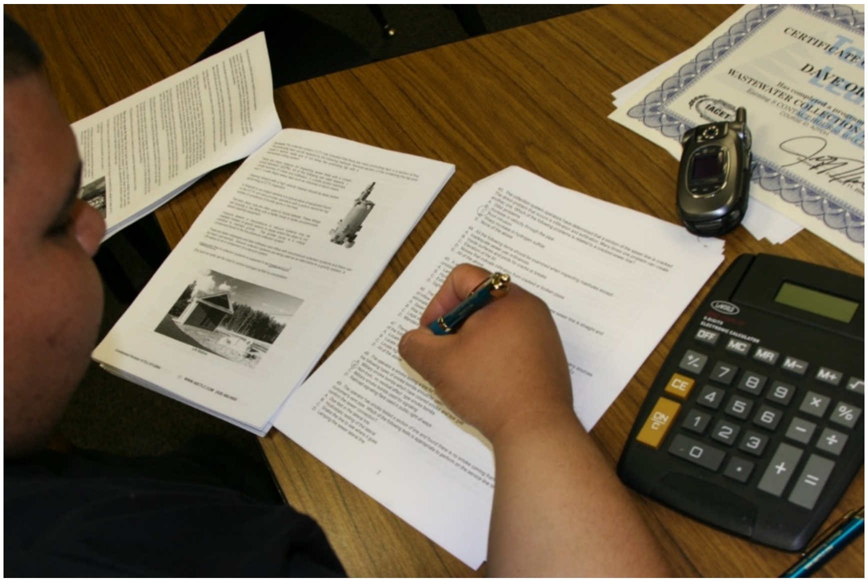
Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling, i.e.,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

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



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail.

If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of $50.

Contact Numbers

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

Water Treatment Fundamentals CEU Training Course Description

This CEU training course will cover various and commonly found water treatment processes, methods and fundamentals starting at the source of water and ending with disinfection to delivery and distribution. Making sure that our 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).

CEU Course Learning Objectives and Timed Outcomes
Knowledge obtained by this CEU Course and the average times the student will approximately spend on each subject. This includes assignment reading, glossary review, pre-test, math exercise and post-exam.

Prerequisites: None

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

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

When a student registers for a distance or correspondence course, he/she is assigned a start date and an end date. It is the student's responsibility to note dates for assignments and keep up with the course work. If a student falls behind, he/she must contact TLC and request an end date extension in order to complete the course. It is the prerogative of TLC to decide whether to grant the request.

Instructions for Written Assignments
The Water Treatment Fundamentals CEU training course uses a multiple-choice and fill-in-the-blank answer key. You can find the Word version on the Assignment page. We would prefer that the answers are typed and faxed or e-mailed to, info@tlch2o.com. If you are unable to do so, please write inside the booklet and make a copy for yourself and mail me

the completed manual. You can find course assistance on the website under the Assignment Page. 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 rear of the course or lesson.

Security and Integrity
All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage sharing of answers. Any fraud or deceit and the student will forfeit all fees and the appropriate agency will be notified.

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

Recordkeeping and Reporting Practices
TLC will keep all student records for a minimum of seven years. It is 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.

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

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

Checking the fittings on a 1 ton chlorine container. The top valve is for the gas and the bottom valve is for extracting chlorine liquid.

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.

Bac-T sample bottle and notice the Quanti-trays in background. The yellow color indicates that the water sample is positive for coliform bacteria. If the sample fluoresces under a black light, this will indicate that the sample is positive for fecal or E. Coli bacteria. Check out the water monitoring section for more information on bacteria and different water sampling information.

Water Filter galleries

Large flat panel televisions are frequently used to monitor the water treatment process. Below, water treatment plants are now using public information displays to inform the customer about water quality and water conservation. If you can notice the narrow widows allow the customer to peer into the SCADA system.

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Inside an Ozone generator.

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, H3AsO3
As(V) Pentavalent arsenic, common inorganic form in water is arsenate, H2AsO4
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
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
GJO DOE's Grand Junction Office
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
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

Here is an inspector using a pH meter to check a grab sample in the field.

Homeland Security Presidential Directive Chapter 1

Purpose
The Nation requires a Homeland Security Advisory System to provide a comprehensive and effective means to disseminate information regarding the risk of terrorist acts to Federal, State, and local authorities and to the American people.

Such a system would provide warnings in the form of a set of graduated "**Threat Conditions**" that would increase as the risk of the threat increases. At each Threat Condition, Federal departments and agencies would implement a corresponding set of "**Protective Measures**" to further reduce vulnerability or increase response capability during a period of heightened alert.

This system is intended to create a common vocabulary, context, and structure for an ongoing national discussion about the nature of the threats that confront the homeland and the appropriate measures that should be taken in response. It seeks to inform and facilitate decisions appropriate to different levels of government and to private citizens at home and at work.

Homeland Security Advisory System
The Homeland Security Advisory System shall be binding on the executive branch and suggested, although voluntary, to other levels of government and the private sector. There are five Threat Conditions, each identified by a description and corresponding color. ***From lowest to highest, the levels and colors are***:
Low = Green;
Guarded = Blue;
Elevated = Yellow;
High = Orange;
Severe = Red.

The higher the Threat Condition, the greater the risk of a terrorist attack. Risk includes both the probability of an attack occurring and its potential gravity. Threat Conditions shall be assigned by the Attorney General in consultation with the Assistant to the President for Homeland Security.

Except in exigent circumstances, the Attorney General shall seek the views of the appropriate Homeland Security Principals or their subordinates, and other parties as appropriate, on the Threat Condition to be assigned.

Threat Conditions may be assigned for the entire Nation, or they may be set for a particular geographic area or industrial sector. Assigned Threat Conditions shall be reviewed at regular intervals to determine whether adjustments are warranted.

For facilities, personnel, and operations inside the territorial United States, all Federal departments, agencies, and offices other than military facilities shall conform their existing threat advisory systems to this system and henceforth administer their systems consistent with the determination of the Attorney General with regard to the Threat Condition in effect.

Every utility should have a security system in place, even a wastewater treatment plant.
Two security "Keys" are *hardening* and *surveillance* of your facility.
Video and sound surveillance is only as good as your equipment and the operator.

If you use Video, use a digital format which leaves a "watermark" to insure authentication.

Digital cameras can see 50 miles and record only when there is "activity". This recording can be placed on a DVD.

There are now infrared cameras for areas with no – or low lighting.

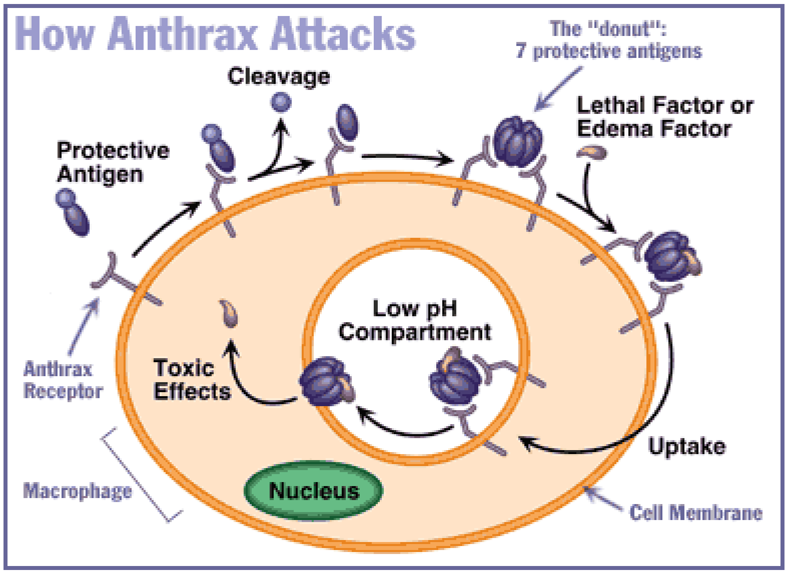
Bio-Chemical Terror

The threat of bio-chemical terror has initiated a revolution in security thinking.

Until new portable sensor technology is available, security forces and water treatment plants have very little control - beyond intelligence sources - of the transfer of lethal materials. Only small quantities are required for great effect. These can be contained in plastic or glass and thus pass freely through metal -detectors or x-ray devices. Their proximity in appearance to pharmaceuticals, perfumeries, cosmetics is such that a primitive labeling would not give unbraided security personnel cause for suspicion. Many of these agents can be designed in aerosol form and can be silently distributed through unguarded air-condition systems.

Anthrax and Biological Agents

In its crude form anthrax can be manufactured in-house using widely-available biological skills and materials. An extremely infectious disease found in livestock, inhalation causes flu-like symptoms followed for a number of days followed by a brief respite while the disease lies dormant, then the onset of respiratory failure, shock and death. Vaccinations are presently being upgraded in the US to include the full range of anthrax types. American special units and general emergency personnel are to receive vaccinations in addition to soldiers.



Certain antibiotics together with antidote are to some degree effective in treating although how far is still highly uncertain (tests for strains have been done only on animals). Effectively for the very old and very young (the vulnerable heart of the civilian frontier) is extremely doubtful. Moreover, treatment should begin immediately- creating problems in the event of an undeclared attack (90 percent fatality).Like many other biological killers anthrax spores can be contained in plastic aerosol form.

Most of America's enemies have anthrax stockpiles. Terrorist groups in the Middle East and their supporters have shown a keen interest in the virus that has claimed the spotlight of the American media. Other Biological agents cultivated for terrorist use include: Botulism, plague, Ricin and Aflatoxin. Where Americans have reason to fear a large scale (mass casualty) attack - a single crop sprayer over a major city could kill 3 million. Biological weapons can be used in many different ways in a variety of scenarios: for example, Ricin is a deadly toxin that could be used for assassinations; insects could be used to spread deadly diseases; food or water supplies could be contaminated.

Biological Agents
Undoubtedly, however, rapid, large-scale anti- personnel use of biological agents requires their dissemination through the air and inhalation into the lungs. When used effectively in this way biological weapons have an area coverage which makes them equivalent to nuclear weapons as weapons of mass destruction. There are many estimates in the open literature that confirm this conclusion.

For example, the Office of Technology Assessment of the United States Congress has calculated that a mere 100 kg of anthrax spores, spread as a line source and allowed to drift on the wind on a clear, calm night over Washington DC, could kill between 1 and 3 million people. The difference between nuclear and biological weapons of mass destruction, as the Iraqi example clearly demonstrates, is that it is much easier and cheaper to produce a biological weapons arsenal.

The ease with which such agents can be produced means that they could also be available to rogue states or even sub-state terrorist groups. It is known that the Japanese sect which used Sarin nerve gas against commuters on the Tokyo underground were also interested in the use of anthrax.

Anthrax

Anthrax is one of a group of so-called '***classical***' biological warfare agents. It was weaponized in the US offensive biological weapons program which ran from 1942 to 1969. Anthrax is an obvious agent of choice because it forms a spore which is resistant to environmental damage. Also, as the Joint CB Technical Data Source Book pointed out (6): "...***The mortality rate for respiratory anthrax is essentially 100 per cent. Since early diagnosis of inhalation anthrax is unlikely, treatment with antibiotics is ineffective***..."

Nevertheless, there was doubt about the utility of biological weapons during the Cold War period when biological weapons were often seen as unpredictable and uncontrollable. Yet a senior UK official specifically rejected this view in an article in the Journal of the Royal United Services Institute in 1992. He argued that by 1969 (7): "...***The utility of BW had been demonstrated by all means, short of use in war, and the established feasibility could clearly not become disestablished with time***..."

Moreover, the threat from biological weapons has continued to develop since 1969. Infectious diseases caused by microbial agents - bubonic plague, cholera, influenza, leprosy, measles, smallpox, tuberculosis, typhoid fever, typhus, yellow fever etc. - have long created misery for human populations in both peace and war. And sporadic attempts have been made in the past to deliberately use disease as a weapon of war: the British, for example, gave Native American Indians blankets contaminated with smallpox. Yet, it was only towards the end of the last century that scientific understanding of these diseases and their agents began to develop. Inevitably, perhaps, this precise new knowledge was applied in warfare, an example being the attempts by both sides in the First World War to infect vital stocks of horses with the disease glanders.

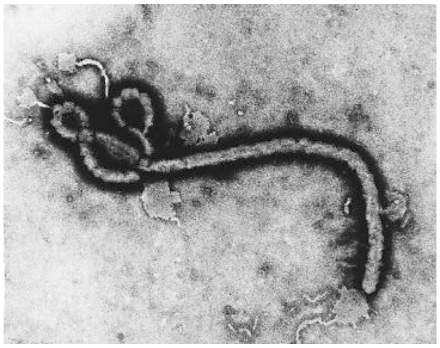
The large-scale Japanese, British, and American offensive biological weapons programs then followed in the 1930s, '40s, '50s, and '60s. Knowledge of bacteria developed faster than that of viruses and it seems probable that the Soviet/Russian program, which was only officially terminated in the 1990s, would have benefited from the growing knowledge of viral agents and diseases. Only in the early 1970s did genetic engineering - the effective transfer of functional genes across species - become possible and the growth of modern biotechnology began.

Genetic engineering, as is well recognized, allows the easier production of militarily significant quantities of toxins. Essentially, it has become possible to produce strategic weapons, using very limited physical and financial resources, with a relatively small number of trained personnel. It also allows the possibility of enhancing the characteristics of biological warfare agents in order to improve their environmental stability, their infectivity and their resistance to antibiotics. Humans have long been involved in modifying others species by deliberate, selective breeding, for example to produce the vast range of modern dog varieties.

But the difference between this traditional activity and modern capabilities, like making a human gene function in a bacterium, can hardly be overstated. These dangers are clearly set out in the background scientific papers produced for the Fourth Review Conference of the Biological Weapons Convention in 1996. It was also recognized at the Review Conference that the Human Genome Project, which will deliver a complete account of the structure of our genetic material by the early years of the next century, could pose new dangers. A number of analysts have argued that knowledge of the human genome at this level, combined with the obvious diversity of human groups, and the current advances in gene therapy, could perhaps allow the development of '***ethnic***' biological weapons targeted at specific groups.

There is, additionally, an obvious danger that our growing knowledge of bioregulatory peptides will allow the development of a new range of anti-personnel agents. Such misuse of biological knowledge could happen if the international community is unable to enforce the disarmament norm embodied in the Biological Weapons Convention. Also, our over-confidence (as a species) that we have beaten microbial pathogens has been severely dented. The phenomenon of drug-resistant tuberculosis has epitomized the threat that could affect any of us even in the developed world. Microbial pathogens can evolve very quickly to evade the defenses we erect. Alongside this renewed threat from '***old***' diseases, there are new threats from diseases with frightening characteristics, such as Ebola, as the human population expands and moves in large numbers into different ecosystems.

The analysis of the threats we face today is much more complex than a decade ago, and potential errors that could lead to worst-case analyses abound, but as two naval analysts recently pointed out: "***Functional distortion in intelligence analysis amounts to de- emphasis of security threats that may be acknowledged and real, but which existing forces can do little about, or that cannot be countered without significant investment in capabilities that differ from those in hand***..."



Ebola→

Ignoring the very real dangers in the evolving threat from biological agents would appear to fit into this precise category of distortion, and the consequences of that mistake could be extremely dangerous. Yet, if the problem is recognized and properly prioritized, a great deal can be done to reinforce the norm of international behavior embodied in the Biological and Toxin Weapons Convention.

At a scientific level, for example, our ability to detect and identify agents and toxins has increased considerably in recent years. Alongside rapid increases in specific knowledge about individual disease agents, broader generalizations about the mechanisms of pathogenicity are becoming possible. This should increasingly allow a more generic approach to be taken in dealing with emerging threats.

An interesting example of what might become possible is the Unconventional Pathogen Countermeasures Program in the Defense Sciences Office of the US Defense Advanced Research Projects Agency (**DARPA**). This program is seeking novel and unconventional methods of providing protection against pathogens used adversarially.

Table 1. Critical Biological Agent Categories for Public Health Preparedness

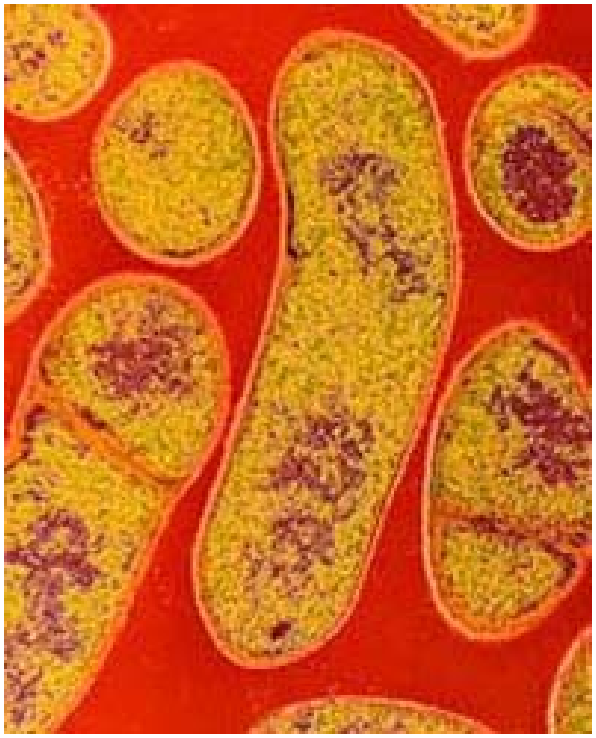
Biological agent(s)	Disease
Category A	
Variola major	Smallpox
Bacillus anthracis	Anthrax
Yersinia pestis	Plague
Clostridium botulinum (botulinum toxins)	Botulism
Francisella tularensis	Tularemia
Filoviruses and Arenaviruses (e.g*., Ebola virus, Lassa virus*)	Viral hemorrhagic fevers
Category B	
Coxiella burnetii	Q fever
Brucella spp.	Brucellosis
Burkholderia mallei	Glanders
Burkholderia pseudomallei	Melioidosis
Alphaviruses (VEE, EEE, WEE[a])	Encephalitis
Rickettsia prowazekii	Typhus fever
Toxins (e.g., Ricin, Staphylococcal enterotoxin B)	Toxic syndromes
Chlamydia psittaci	Psittacosis
Food safety threats (e.g., *Salmonella spp*., *Escherichia coli* O157:H7)	
Water safety threats (e.g., *Vibrio cholerae*, Cryptosporidium parvum)	
Category C	
Emerging threat agents (e.g., *Nipah virus*, hantavirus)	

[a] Venezuelan equine (VEE), eastern equine (EEE), and western equine encephalomyelitis (WEE) viruses

Table 2. Criteria and weighting[a] used to evaluate potential biological threat agents

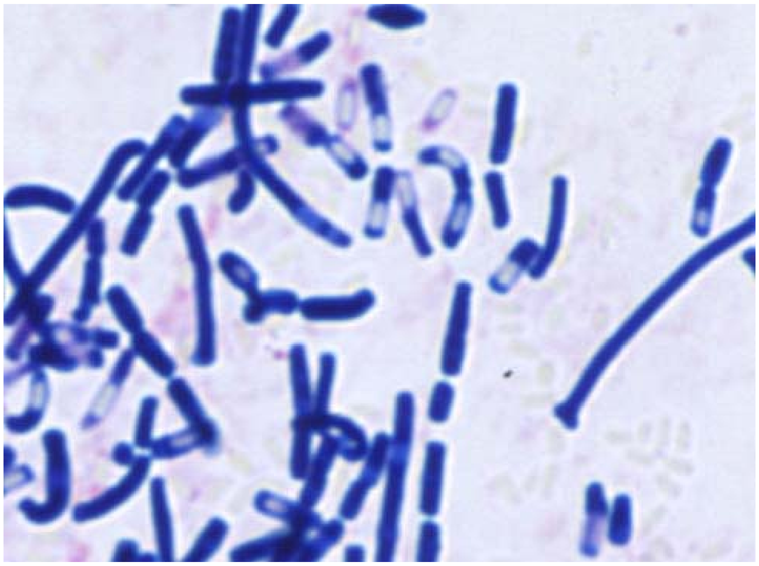
	Public health impact		Dissemination potential				
Disease	Disease	Death	P-D[b]	P - P[c]	Public perception	Special preparation	Category
Smallpox	+	++	+	+++	+++	+++	A
Anthrax	++	+++	+++	0	+++	+++	A
Plague[d]	++	+++	++	++	++	+++	A
Botulism	++	+++	++	0	++	+++	A
Tularemia	++	++	++	0	+	+++	A
VHF[e]	++	+++	+	+	+++	++	A
VE[f]	++	+	+	0	++	++	B
Q Fever	+	+	++	0	+	++	B
Brucellosis	+	+	++	0	+	++	B
Glanders	++	+++	++	0	0	++	B
Melioidosis	+	+	++	0	0	++	B
Psittacosis	+	+	++	0	0	+	B
Ricin toxin	++	++	++	0	0	++	B
Typhus	+	+	++	0	0	+	B
Cholera[g]	+	+	++	+/-	+++	+	B
Shigellosis[g]	+	+	++	+	+	+	B

[a] Agents were ranked from highest threat (+++) to lowest (0).
[b] Potential for production and dissemination in quantities that would affect a large population, based on availability, BSL requirements, most effective route of infection, and environmental stability.
[c] Person-to-person transmissibility.
[d] Pneumonic plague.
[e] Viral hemorrhagic fevers due to Filoviruses (*Ebola, Marburg*) or Arenaviruses (e.g., *Lassa, Machupo*).
[f] Viral encephalitis.
[g] Examples of food- and waterborne diseases.



Botulism

Plague



Anthrax Spores

Hemorrhagic Fever

Safe Drinking Water Act (SDWA) Chapter 2

On August 6, 1996, President Clinton signed the Reauthorization of the Safe Drinking Water Act, bringing to 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 new 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 the new 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.

Safe Drinking Water Act of 1974

(PL 93-523) as amended by:

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

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

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

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

National Drinking Water Regulations

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

Contaminant Selection

P.L. 104-182 establishes a new process for the EPA to select contaminants for regulatory consideration based on occurrence, health effects, and meaningful opportunity for health risk reduction. By February 1998 and every 5 years thereafter, the EPA must publish a list of contaminants that may warrant regulation. Starting in 2001, and 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 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.

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 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. By August 1998, 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 nonprimacy 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 FY2001, 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. The District of Columbia will receive 1% of funds as well. A state may transfer up to 33% of the grant to the Clean Water Act (**CWA**) SRF, or an equivalent amount from the CWA SRF to the SDWA SRF.

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).

Safe Drinking Water Act 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 that 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 State that has the responsibility for ensuring a law is implemented, and has the authority to enforce the law and related regulations. 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 (e.g. 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.

More SDWA Information

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). Citizen suits may be brought against any person or agency allegedly in violation of provisions of the Act, or against the Administrator for alleged failure to perform any action or duty which is not discretionary.

EPA may use the new estrogenic substances screening program created in the Food Quality Protection Act of 1996 (P .L. 104-170) to provide for testing of substances that may be found in drinking water if the Administrator determines that a substantial population may be exposed to such substances (Section 1457).

EPA is directed to conduct drinking water studies involving subpopulations at greater risk and biological mechanisms, and studies to support several rules including those addressing D/DBPs and ***Cryptasporidium***. The Centers for Disease Control and Prevention and EPA must conduct pilot waterborne disease occurrence studies by August 1998. (Section 1458).

The Act includes a provision amending the Federal Food, Drug, and Cosmetic Act, generally requiring the Secretary of Health and Human Services to issue bottled drinking water standards for contaminants regulated under the Safe Drinking Water Act.

Other provisions of P.L. 104-182 authorize water and wastewater grants for *colonias* and Alaska rural and native villages, and authorize the transfer of the Washington (D.C.) Aqueduct to a regional authority.

The 1996 Amendments also authorize a $50 million per year grant program for additional infrastructure and watershed protection projects; the conference report lists, and directs EPA to give priority consideration to, 24 such projects.

IDEXX's SimPlate for HPC method is used for the quantification of heterotrophic plate count (HPC) in water. It is based on the Multiple Enzyme Technology which detects viable bacteria in water by testing for the presence of key enzymes known to be present in these little organisms. This technique uses enzyme substrates that produce a blue fluorescence when metabolized by waterborne bacteria. The sample and media are added to a SimPlate Plate, incubated and then examined for fluorescing wells. The number of wells corresponds to a Most Probable Number (MPN) of total bacteria in the original sample. The MPN values generated by the SimPlate for HPC method correlate with the Pour Plate method using the Total Plate Count Agar incubated at 35ºC for 48 hours as described in *Standard Methods for the Examination of Water and Wastewater, 19th Edition.*

We will go more into detail in the Water Monitoring Section.

42 USC Part A – SDWA Rule Definitions

TITLE 42 - THE PUBLIC HEALTH AND WELFARE
CHAPTER 6A - PUBLIC HEALTH SERVICE
SUBCHAPTER XII - SAFETY OF PUBLIC WATER SYSTEMS
Part A - Definitions

Part A - Definitions

42 USC Sec. 300f 01/05/99

TITLE 42 - THE PUBLIC HEALTH AND WELFARE
CHAPTER 6A - PUBLIC HEALTH SERVICE
SUBCHAPTER XII - SAFETY OF PUBLIC WATER SYSTEMS
Part A - Definitions

Sec. 300f. Definitions

For purposes of this subchapter:

(1) The term ''primary drinking water regulation'' means a regulation which -

(A) applies to public water systems;

(B) specifies contaminants which, in the judgment of the Administrator, may have any adverse effect on the health of persons;

(C) specifies for each such contaminant either -

(i) a maximum contaminant level, if, in the judgment of the Administrator, it is economically and technologically feasible to ascertain the level of such contaminant in water in public water systems, or

(ii) if, in the judgment of the Administrator, it is not economically or technologically feasible to so ascertain the level of such contaminant, each treatment technique known to the Administrator which leads to a reduction in the level of such contaminant sufficient to satisfy the requirements of section 300g-1 of this title; and

(D) contains criteria and procedures to assure a supply of drinking water which dependably complies with such maximum contaminant levels; including accepted methods for quality control and testing procedures to insure compliance with such levels and to insure proper operation and maintenance of the system, and requirements as to (i) the minimum quality of water which may be taken into the system and (ii) sitting for new facilities for public water systems.

At any time after promulgation of a regulation referred to in this paragraph, the Administrator may add equally effective quality control and testing procedures by guidance published in the Federal Register. Such procedures shall be treated as an alternative for public water systems to the quality control and testing procedures listed in the regulation.

(2) The term ''secondary drinking water regulation'' which

applies to public water systems and which specifies the maximum contaminant levels which, in the judgment of the Administrator, are requisite to protect the public welfare. Such regulations may apply to any contaminant in drinking water (A) which may adversely affect the odor or appearance of such water and consequently may cause a substantial number of the persons served by the public water system providing such water to discontinue its use, or (B) which may otherwise adversely affect the public welfare. Such regulations may vary accordingly to geographic and other circumstances.

(3) The term ''maximum contaminant level'' means the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

(4) Public water system. -

(A) In general. - The term ''public water system'' means a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. Such term includes (i) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (ii) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system.

(B) Connections. -

(i) In general. - For purposes of subparagraph (A), a connection to a system that delivers water by a constructed conveyance other than a pipe shall not be considered a connection, if -

(I) the water is used exclusively for purposes other than residential uses (consisting of drinking, bathing, and cooking, or other similar uses);

(II) the Administrator or the State (in the case of a State exercising primary enforcement responsibility for public water systems) determines that alternative water to achieve the equivalent level of public health protection provided by the applicable national primary drinking water regulation is provided for residential or similar uses for drinking and cooking; or

(III) the Administrator or the State (in the case of a State exercising primary enforcement responsibility for public water systems) determines that the water provided for residential or similar uses for drinking, cooking, and bathing is centrally treated or treated at the point of entry by the provider, a pass-through entity, or the user to achieve the equivalent level of protection provided by the applicable national primary drinking water regulations.

(ii) Irrigation districts. - An irrigation district in existence prior to May 18, 1994, that provides primarily agricultural service through a piped water system with only incidental residential or similar use shall not be considered to be a public water system if the system or the residential or similar users of the system comply with subclause (II) or (III) of clause (i).

(C) Transition period. - A water supplier that would be a public water system only as a result of modifications made to this paragraph by the Safe Drinking Water Act Amendments of 1996 shall not be considered a public water system for purposes of the Act until the date that is two years after August 6, 1996. If a water supplier does not serve 15 service connections (as defined in subparagraphs (A) and (B)) or 25 people at any time after the conclusion of the 2-year period, the water supplier shall not be considered a public water system.

(5) The term ''supplier of water'' means any person who owns or operates a public water system.

(6) The term ''contaminant'' means any physical, chemical, biological, or radiological substance or matter in water.

(7) The term ''Administrator'' means the Administrator of the Environmental Protection Agency.

(8) The term ''Agency'' means the Environmental Protection Agency.

(9) The term ''Council'' means the National Drinking Water Advisory Council established under section 300j-5 of this title.

(10) The term ''municipality'' means a city, town, or other public body created by or pursuant to State law, or an Indian Tribe.

(11) The term ''Federal agency'' means any department, agency, or instrumentality of the United States.

(12) The term ''person'' means an individual, corporation, company, association, partnership, State, municipality, or Federal agency (and includes officers, employees, and agents of any corporation, company, association, State, municipality, or Federal agency).

(13)(A) Except as provided in subparagraph (B), the term ''State'' includes, in addition to the several States, only the District of Columbia, Guam, the Commonwealth of Puerto Rico, the Northern Mariana Islands, the Virgin Islands, American Samoa, and the Trust Territory of the Pacific Islands.

(B) For purposes of section 300j-12 of this title, the term ''State'' means each of the 50 States, the District of Columbia, and the Commonwealth of Puerto Rico.

(14) The term ''Indian Tribe'' means any Indian tribe having a Federally recognized governing body carrying out substantial governmental duties and powers over any area. For purposes of section 300j-12 of this title, the term includes any Native village (as defined in section 1602(c) of title 43).

(15) Community water system. - The term ''community water system'' means a public water system that -

(A) serves at least 15 service connections used by year-round residents of the area served by the system; or

(B) regularly serves at least 25 year-round residents.

(16) Noncommunity water system. - The term ''noncommunity water system'' means a public water system that is not a community water system.

The Safe Drinking Water Act Amendments of 1996, referred to in par. (4)(C), is Pub. L. 104-182, Aug. 6, 1996, 110 Stat. 1613. For complete classification of this Act to the Code, see Short Title of 1996 Amendment note set out under section 201 of this title and Tables.

SDWA Water Quality Information and MCLs

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 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.

Common water sampling bottles, VOC and THM bottles are in the front.

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 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

New EPA Water Rules

Arsenic

Arsenic is a chemical that occurs naturally in the earth's crust. When 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. In January 2001, the EPA revised the standard from 50 parts per billion (**ppb**), ordering that it fall to 10 ppb by 2006. After adopting 10ppb 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 10ppb 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 10ppb can be found at www.epa.gov/safewater/arsenic.html or in the Water Quality Chapter in the Arsenic information section.

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

Disinfection Byproduct Regulations

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

Total trihalomethanes (TTHM)	80 parts per billion (ppb)
Haloacetic acids (HAA5)	60 ppb
Bromate	10 ppb
Chlorite	1.0 parts per million (ppm)

Currently trihalomethanes are regulated at a maximum allowable annual average level of 100 parts per billion for water systems serving over 10,000 people under the Total Trihalomethane Rule finalized by the EPA in 1979. The Stage 1 Disinfectant/Disinfection Byproduct Rule standards became effective for trihalomethanes and other disinfection byproducts listed above in December 2001 for large surface water public water systems. Those standards became effective in December 2003 for small surface water and all ground water public water systems.

Disinfection byproducts are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (i.e., decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts for which regulations have been established have been identified in drinking water, including trihalomethanes, haloacetic acids, bromate, and chlorite.

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

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. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate HAA5 at **60 parts per billion** annual average.

Bromate is a chemical that is formed when ozone used to disinfect drinking water reacts with naturally occurring bromide found in source water. The EPA has established the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate bromate at annual average of **10 parts per billion** in drinking water.

Chlorite is a byproduct formed when chlorine dioxide is used to disinfect water. The EPA has published the **Stage 1 Disinfectants/Disinfection Byproducts Rule** to regulate chlorite at a monthly average level of **1 part per million** in drinking water.

Microbial Regulations

One of the key regulations developed and implemented by the United States Environmental Protection Agency (**USEPA**) to counter pathogens in drinking water is the **Surface Water Treatment Rule**. Among its provisions, the rule requires that a public water system, using surface water (or ground water under the direct influence of surface water) as its source, have sufficient treatment to reduce the source water concentration of ***Giardia*** and viruses by at least 99.9% and 99.99%, respectively.

The Surface Water Treatment Rule specifies treatment criteria to assure that these performance requirements are met; they include turbidity limits, disinfectant residual, and disinfectant contact time conditions.

The **Interim Enhanced Surface Water Treatment Rule** was established in December 1998 to control ***Cryptosporidium***, and to maintain control of pathogens while systems lower disinfection byproduct levels to comply with the **Stage 1 Disinfectants/Disinfection Byproducts Rule**. The EPA established a Maximum Contaminant Level Goal (**MCLG**) of zero for all public water systems and a 99% removal requirement for Cryptosporidium in filtered public water systems that serve at least 10,000 people.

The new rule tightened turbidity standards in December 2001. Turbidity is an indicator of the physical removal of particulates, including pathogens.

The EPA is also planning to develop other rules to further control pathogens. The EPA will be promulgating a Long Term 1 Enhanced Surface Water Treatment Rule, for systems serving fewer than 10,000 people, in November 2000 to improve physical removal of *Cryptosporidium*, and to maintain control of pathogens while systems comply with **Stage 1 Disinfectants/Disinfection Byproducts Rule**.

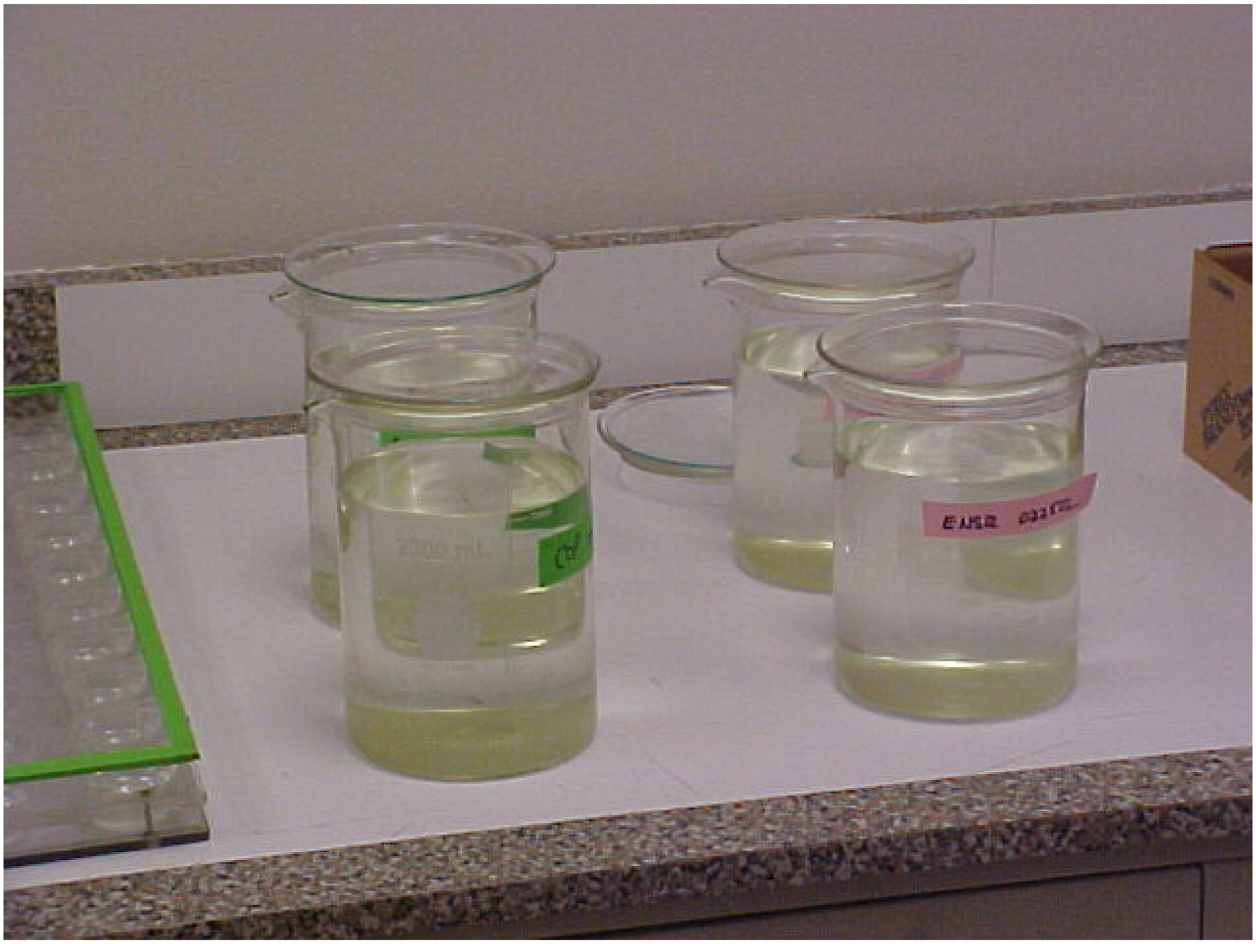
Microbes

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

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

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

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



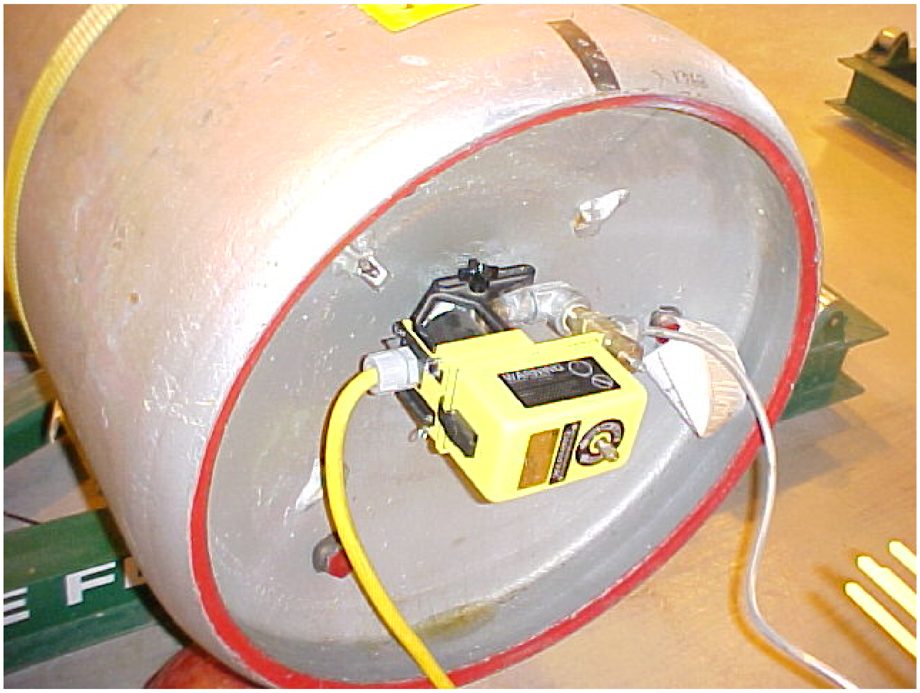
Counting Water Fleas is just one daily task for many water treatment operators. Water Fleas or Daphnia are small crustaceans are great bio-indicators. Changes in heart rate might suggest a chemical compound has a physiological effect and more importantly- *Daphnia Magna* is used to measure the toxicity of a chemical compound in water (LD50 measurements).

Various pictures of Arsenic and it’s effect on humans

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



1 Ton Chlorine container with an automatic leak detection and shut-off device

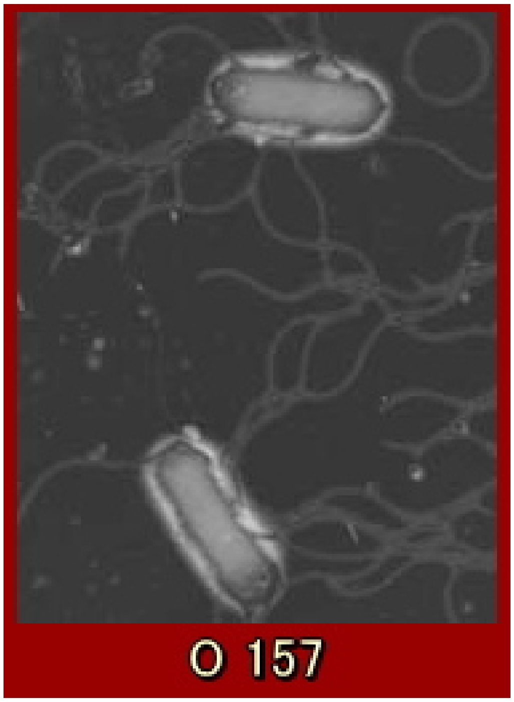
Organic Chemicals	MCLG [1] (mg/L) [4]	MCL[2] or TT[3] (mg/L) [4]	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Acrylamide	zero	TT[7]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	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 hepatachlor
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



E. Coli HO-157

Legionella

Cryptosporidium

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.

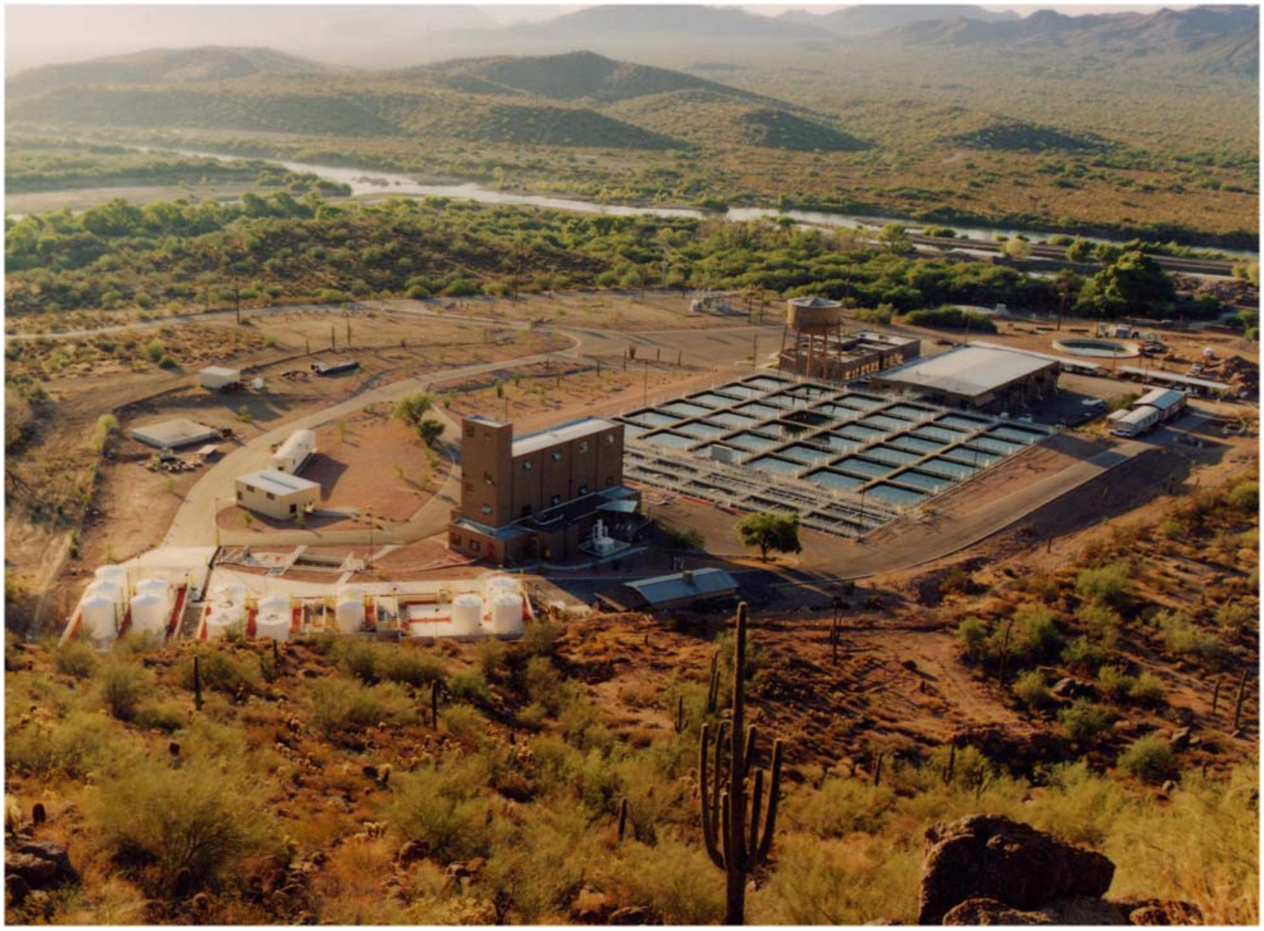
[10] Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human animal wastes. Microbes in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms.

Water Treatment Section Chapter 3

For thousands of years, people have treated water intended for drinking to remove particles of solid matter, reduce health risks, and improve aesthetic qualities such as appearance, odor, color, and taste. As early as 2000 B.C., medical lore of India advised, "***Impure water should be purified by being boiled over a fire, or being heated in the sun or by dipping a heated iron into it, or it may be purified by filtration through sand and coarse gravel and then allowed to cool***."

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 large conventional surface water treatment facility

Top Picture - Final Rectangle Sedimentation Basin
Bottom - Clarifier

Preliminary Treatment

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 horizontal bars will rank the size. Wire mesh screens are woven stainless steel material and the opening of the fabric is narrow. Both require manual cleaning.

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

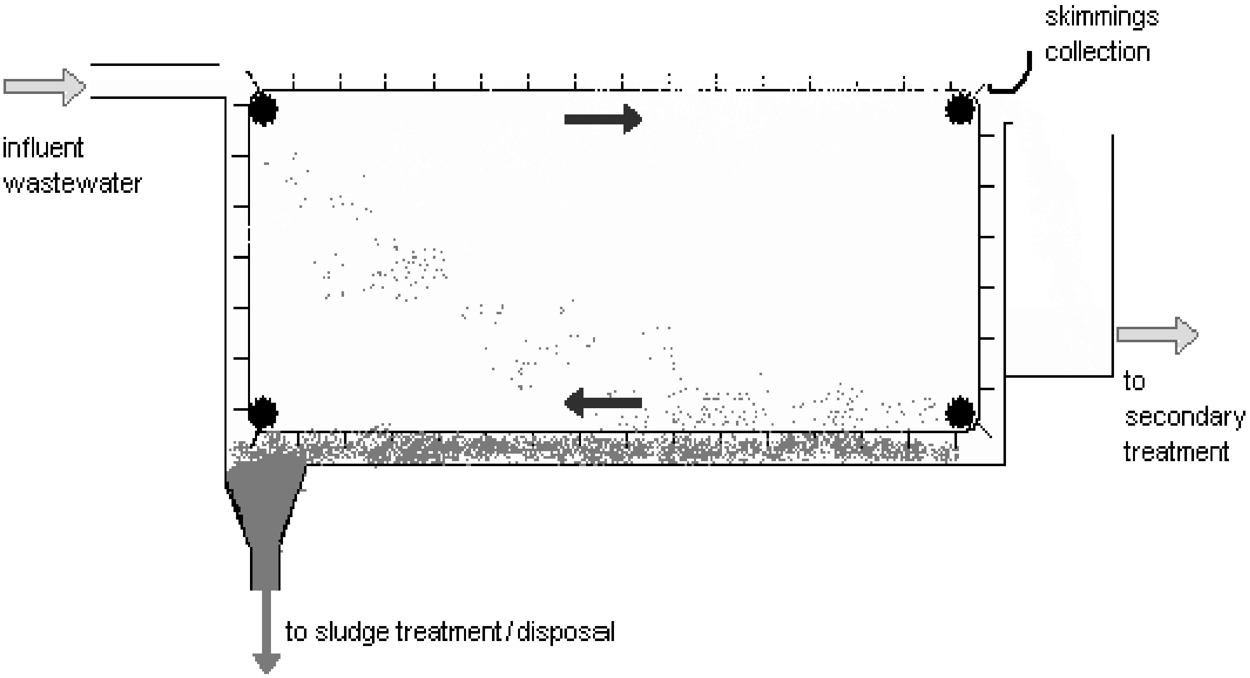
Mechanical bar screen

Non-automated bar screen

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 clarifers. Sedimentation basins are also 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 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.

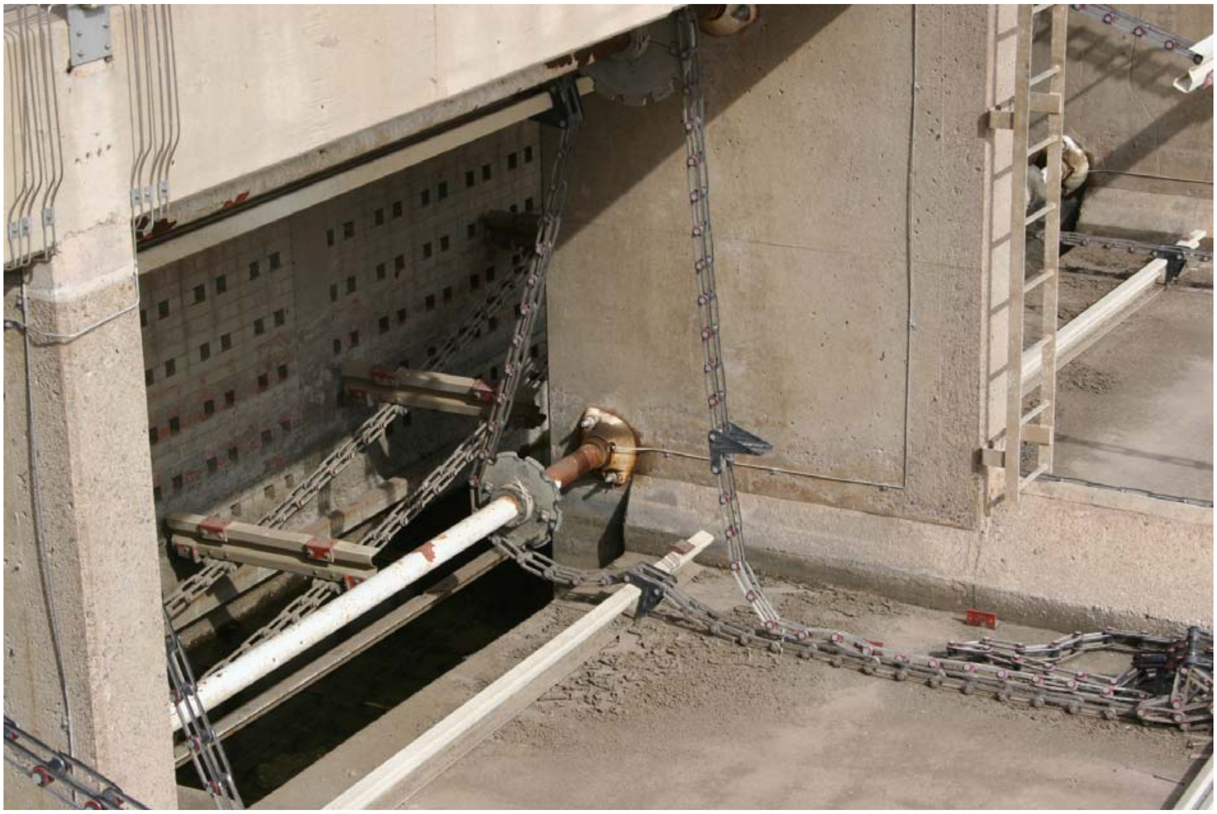


Flights and Chains

The most important thing to consider 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 return 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 which turns the drive chain. The drive chain turns the drive sprockets and the head shafts. The shafts can be located overhead or below.

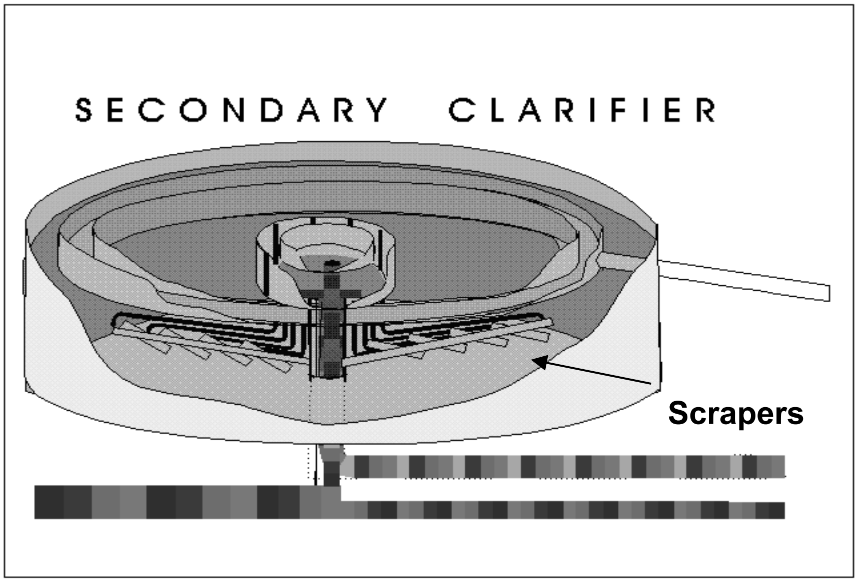
Some clarifiers may not have scum removal equipment, so the configuration of the shaft may vary. As the flights travel across the bottom of the clarifier, wearing shoes are used to protect the flights. The shoes are usually metal and travel across a metal track.

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. Remember, 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

In some circular or square tanks, rotating scrapers are used. The diagram below shows a typical circular clarifier.

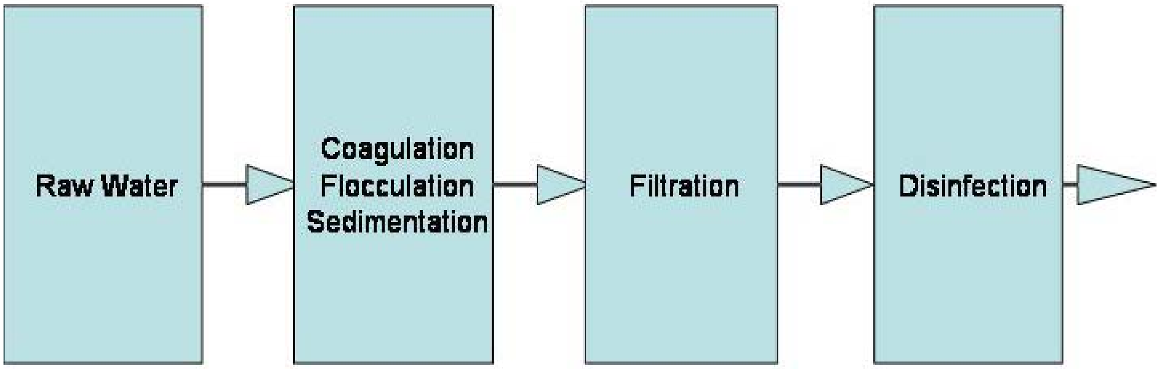


The most common type has a center pier or column. The major mechanic parts of the clarifier are the drive unit; the sludge collector mechanism; and the scum removal system**.**

Circular clarifier and collector mechanism

Conventional Treatment

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.



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

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, filtration occurs only within the first few inches of the finer grains at the top of the bed.

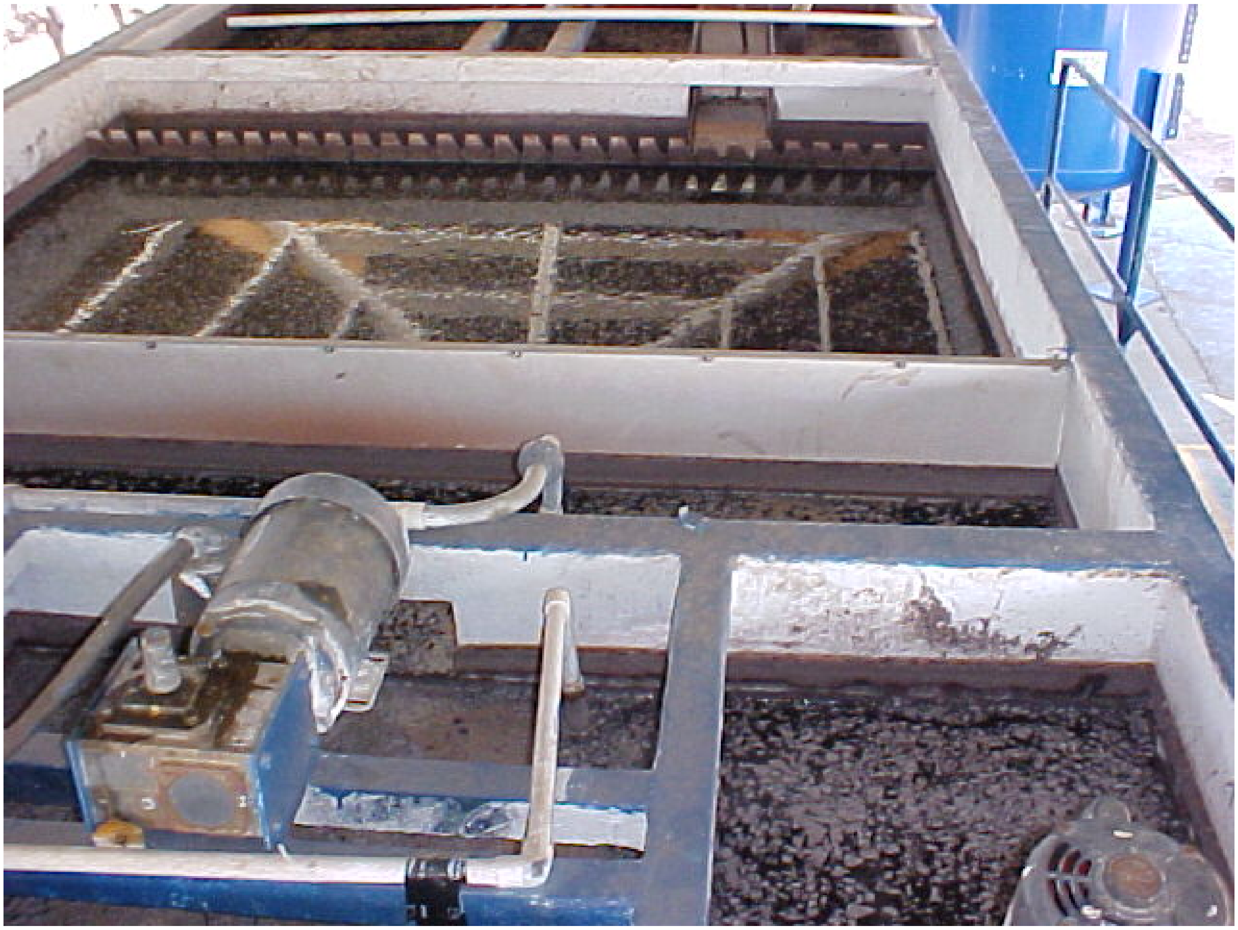
A depth filter has four layers of filtration media, each of different size and density. Light, coarse material lies at the top of the filter bed. The media become progressively finer and denser in the lower layers. Larger suspended particles are removed by the upper layers while smaller particles are 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. Fast rinse lasts about 5 to 10 minutes.

Chemical pretreatment is often used to enhance filter performance, particularly when turbidity includes fine colloidal particles. Suspended particles are usually electrically charged. Feeding chemicals such as alum (aluminum sulfate), ferric chloride, or a cationic polymer neutralizes the charge, allowing the particles to cling to one another and to the filter media.

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.



Small water treatment package plant 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 are found as two types: tube-type clarifiers and adsorption clarifiers.

Rapid Sand Filtration **Highlight this section for your Assignment.**

Also known as rapid-sand filtration, this 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:

Coagulation

At the Water Treatment Plant, aluminum sulfate, commonly called alum, is 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 used of coagulant chemicals.

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 are called "**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. As well, 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.

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 was removed by conventional coagulation and filtration. Several recent studies have shown that bacteria 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 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 fluctuations in concentrations of suspended

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.

Filtration
A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.

The water flows by gravity through large filters 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 downwards. The filter is periodically cleaned by a reversal of flow and the discharge of back flushed water into a drain.

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 forms
- Floc

Four Desirable Characteristics of Filter Media

A. Good hydraulic characteristics (permeable)
B. Does not react with substances in the water (inert and easy to clean)
C. Hard and durable
D. 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**.

Direct Filtration Plant vs. Conventional Plant

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

Declining Rate Filters

The flow rate will vary with head loss. Each filter operates at the same rate, but can have a variable water level. 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.

$$\text{Detention Time} = \frac{(\text{Basin Volume, Gallons})\ (24\ \text{Hours/day})}{\text{Flow, Gallons/day}}$$

Disinfection

Chlorine is 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.

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:

1. Determination of most effective coagulant.
2. Determination of optimum coagulation pH for the various coagulants.
3. Evaluation of most effective polymers.
4. Optimum point of application of polymers in the treatment train.
5. Optimum sequence of application of coagulants, polymers and pH adjustment chemicals.
6. 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.

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.

Polymer

A 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.

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

Pre-Chlorine
Where the raw water is dosed with a large concentration of chlorine.

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

A. Control algae and slime growth
B. Control mud ball formation
C. Improve coagulation
D. Precipitate iron

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

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

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.

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.

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

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

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

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 errors.

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.

Short Circuiting ***On your assignment***
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.

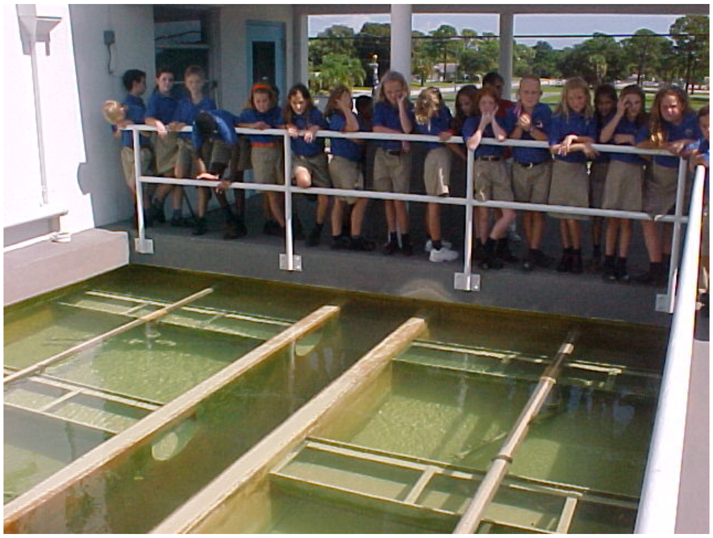
Tube Settlers
This modification of the conventional process contains many metal ***"tubes***" that are placed in the sedimentation basin, or clarifier. These tubes are approximately 1 inch deep and 36 inches long, split-hexagonal shape, and installed at an angle of 60 degrees or less.

These tubes provide for a very large surface area upon which particles may settle as the water flows 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.

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.

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.



Tours of your facility are a wonderful public image tool.

Backwash Channels

EPA Filter Backwash Rule

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 proposes to 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 which 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, and 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 can 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 require the EPA to promulgate a Long Term 1 Enhanced Surface Water Treatment Rule (for systems serving less than 10,000 people) by 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***" by August, 2000 ((1412(b)(14)). The current rule includes provisions addressing both of these requirements.

What will the LT1FBR require?

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 - Apply 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.

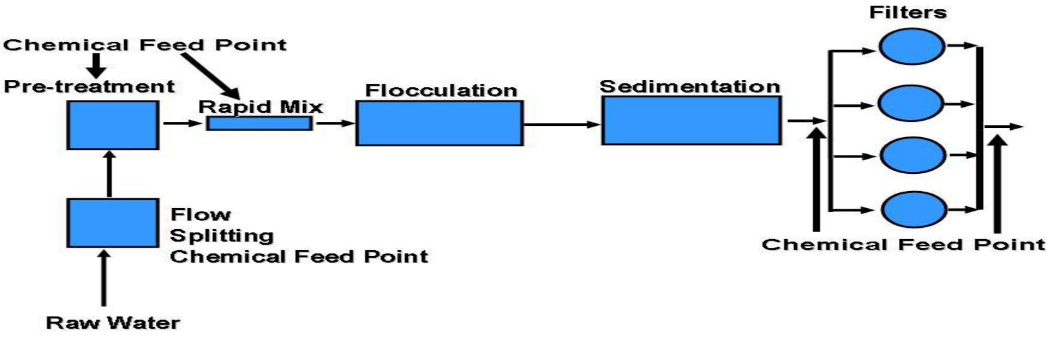
FBR Provisions - Apply to all systems which recycle regardless of population served:

- 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.

Under the filtration basins are tunnels and complex machinery, gauges and pumps.

The Filtration Process

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.

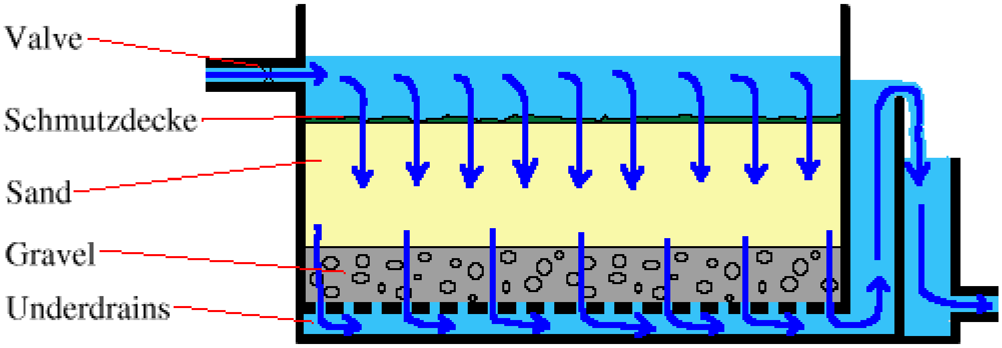
The picture on the right illustrates debris removed during the backwash process. The particles are trapped on top of the filter media and trapped within the media.

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

The photo on the right shows small class beads laid on top of a sieve.

Types of Filters

Several types of filters are used for water treatment. The earliest ones developed were the slow sand filters. They typically have filter rates of around 0.05 gpm/ft2 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.



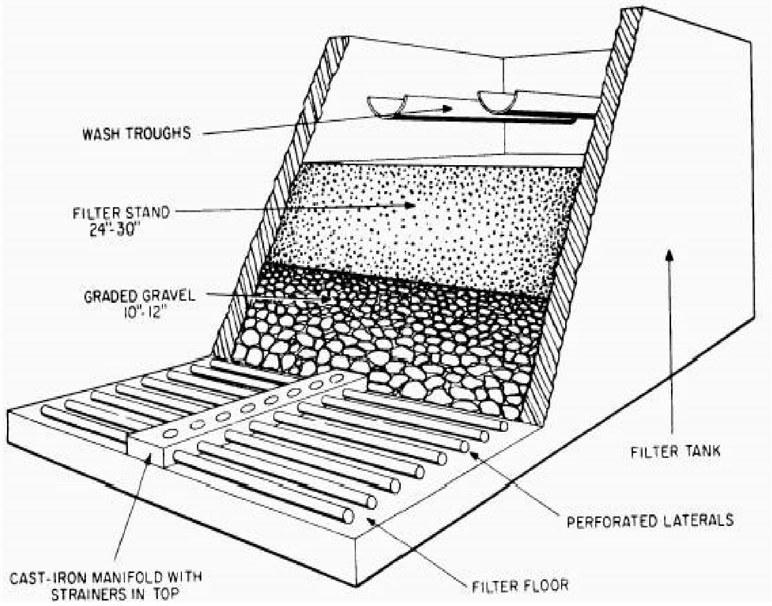
Most filters are classified by filtration rate, type of filter media, or type of operation into:

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 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



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.

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.

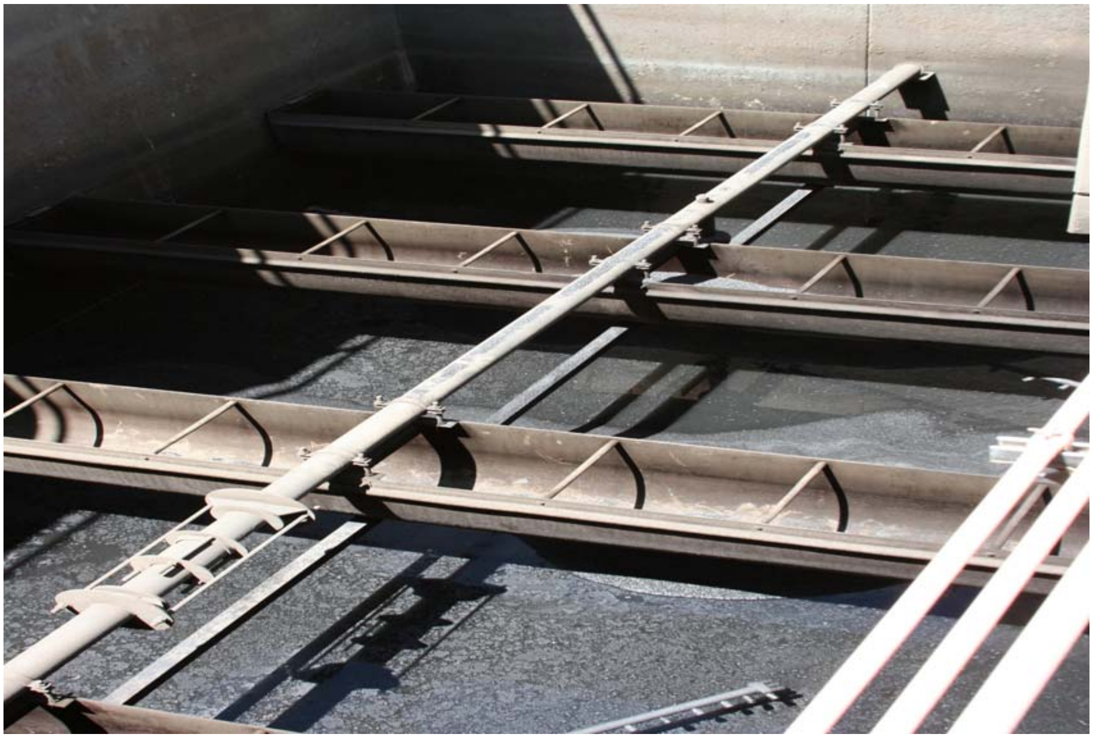
Leopold system

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.

Washwater Troughs

Washwater troughs placed above the filter media collect the backwash water and carry it to the drain system. Proper placement of these troughs 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 be installed at the same elevation so that they remove the backwash evenly from the filter and so that an even head is maintained across the entire filter. These backwash troughs are constructed from concrete, plastic, fiberglass, or other corrosion-resistant materials.

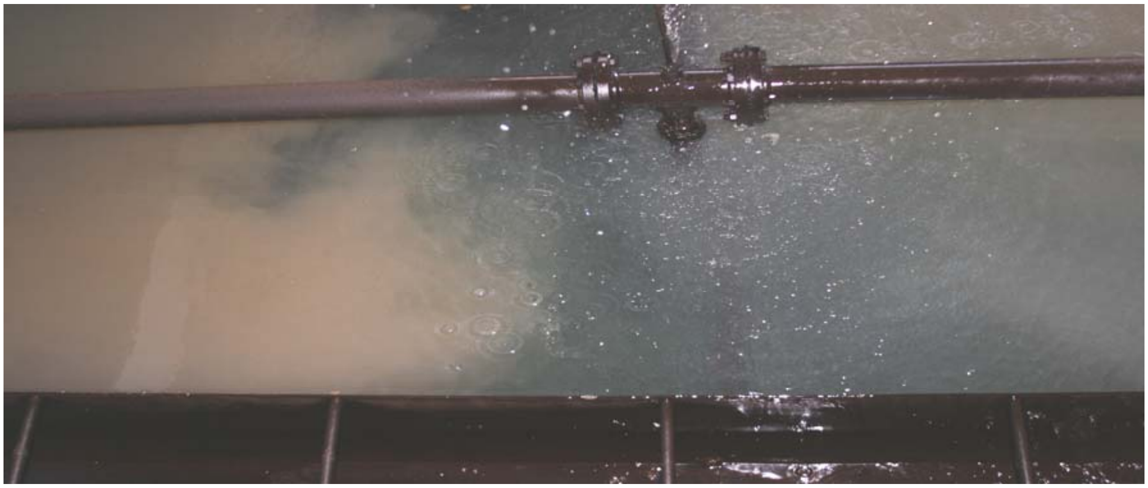
The photograph below shows exposed filter troughs.



Surface Wash

The photograph above shows a drained filter with the agitator and nozzles exposed. During operation the 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/ft2) 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 picture 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 evaluate which material, or combination of materials, will give the best result.

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

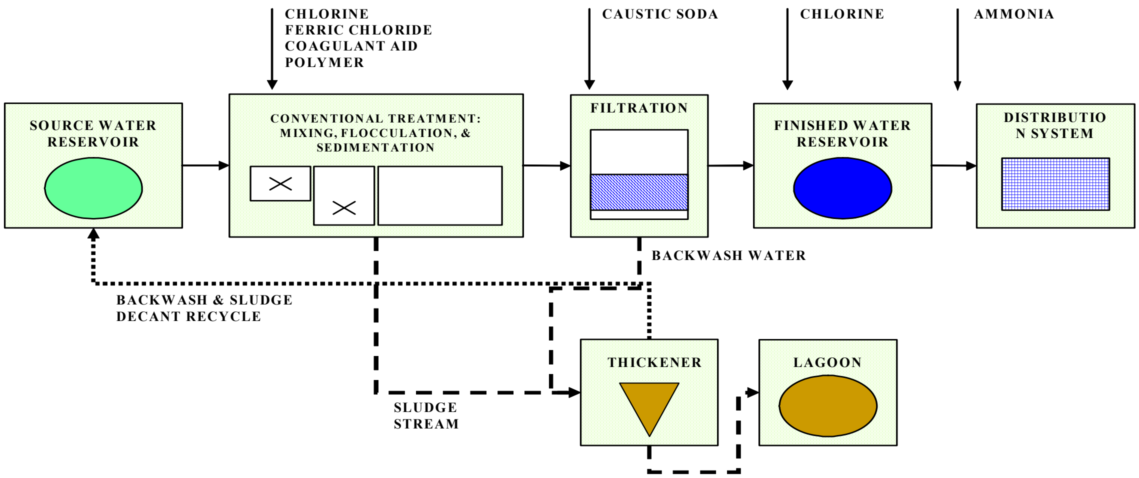
Because the water is under pressure, air binding will not occur in the filter. However, pressure filters have a major disadvantage in that the backwash cannot be observed; in addition, cracking of the filter bed can occur quite easily, allowing the iron and manganese particles to go straight through 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.

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: 50 MGD

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 capitol 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:

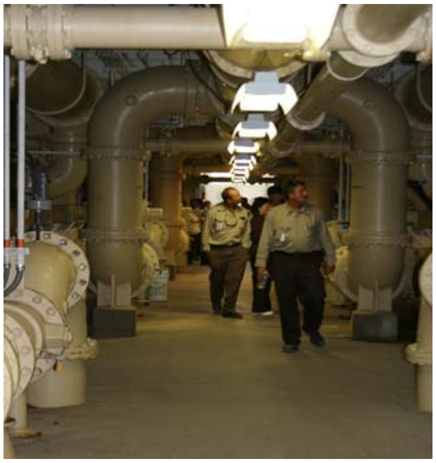
- Rate of flow controller
- Loss of head indicator
- On-line turbidimeter

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 picture above 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 picture below shows the overflow incase the filter level gets to 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.

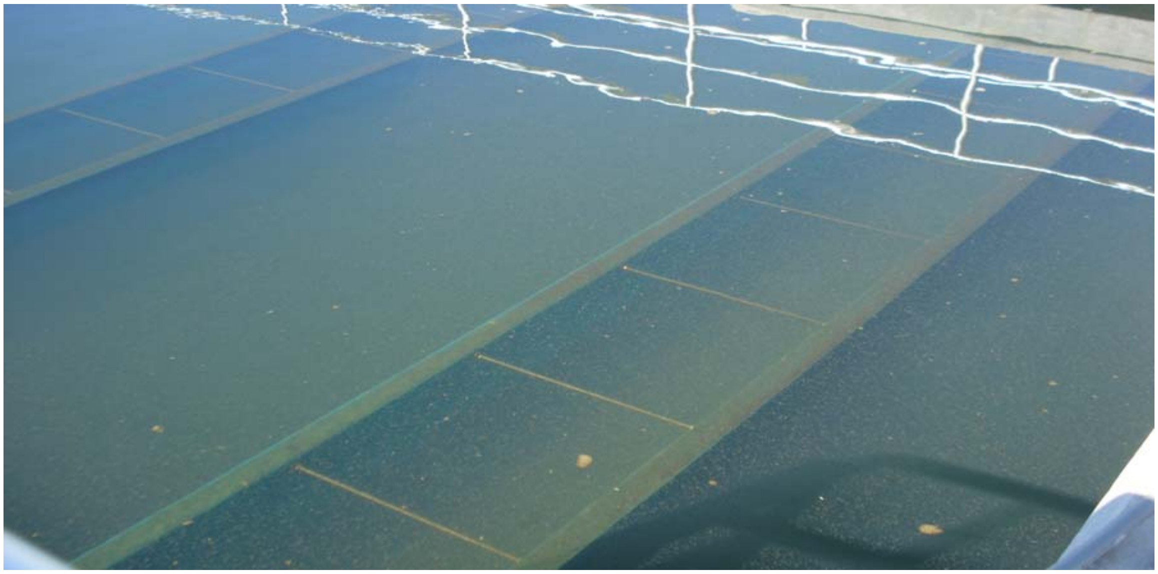
In-line turbidimeter

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.

Filtration Process

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 picture is a filter from a direct filtration plant; notice the size of the floc?

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 is placed in the filter effluent pipe to prevent a filter inflow 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.

Back Washing

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.

The photograph above and below both are part of the backwash equipment for the water plant.

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 hour of operation.
- If a filter is taken out of service for some reason, it must always be backwashed prior to be putting on line.

The decision to backwash the filter should not be based on only 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 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.

This is 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. 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 as some suspended material remains in 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 photograph on the right is dry Polymer and on the left is 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 photograph shows clumps formed by Powder Activated Carbon.

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.

Filter aid being fed at the weirs of sedimentation.

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.

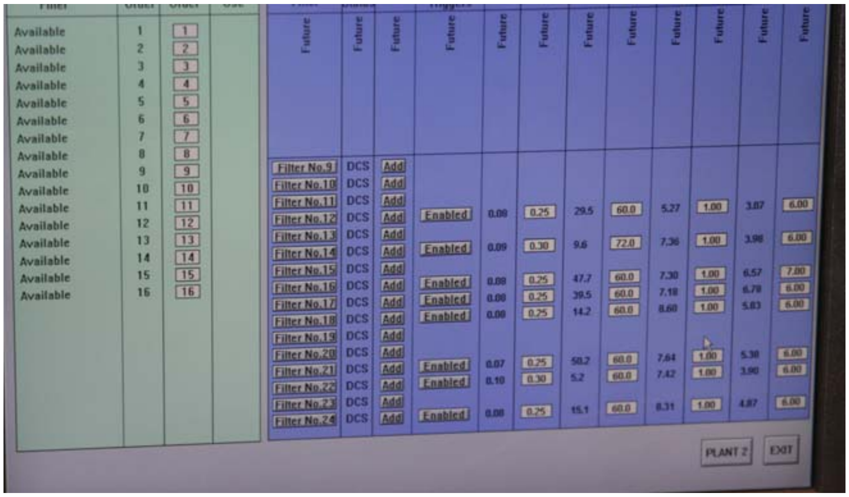
In the picture above, overfeeding flocculants to meet federal regulations caused Iron to precipitates on the filter walls.

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.



Available	1	1	
Available	2	2	
Available	3	3	
Available	4	4	
Available	5	5	
Available	6	6	
Available	7	7	
Available	8	8	
Available	9	9	
Available	10	10	
Available	11	11	
Available	12	12	
Available	13	13	
Available	14	14	
Available	15	15	
Available	16	16	

Future	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future	Future
Filter No.9	DCS	Add									
Filter No.10	DCS	Add									
Filter No.11	DCS	Add									
Filter No.12	DCS	Add	Enabled	0.08	0.25	29.5	60.0	5.27	1.00	3.87	6.00
Filter No.13	DCS	Add									
Filter No.14	DCS	Add	Enabled	0.09	0.30	9.6	72.0	7.36	1.00	3.98	6.00
Filter No.15	DCS	Add									
Filter No.16	DCS	Add	Enabled	0.08	0.25	47.7	60.0	7.30	1.00	6.57	7.00
Filter No.17	DCS	Add	Enabled	0.08	0.25	39.5	60.0	7.18	1.00	6.78	6.00
Filter No.18	DCS	Add	Enabled	0.08	0.25	14.2	60.0	8.60	1.00	5.83	6.00
Filter No.19	DCS	Add									
Filter No.20	DCS	Add									
Filter No.21	DCS	Add	Enabled	0.07	0.25	50.2	60.0	7.64	1.00	5.38	6.00
Filter No.22	DCS	Add	Enabled	0.10	0.30	5.2	60.0	7.42	1.00	3.90	6.00
Filter No.23	DCS	Add									
Filter No.24	DCS	Add	Enabled	0.08	0.25	15.1	60.0	8.31	1.00	4.87	6.00

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:

- 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 rest directly against each other with very little compaction. Filter media in a dirty filter are surrounded by a soft layer which 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 picture of a backwash basin that has 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, 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.

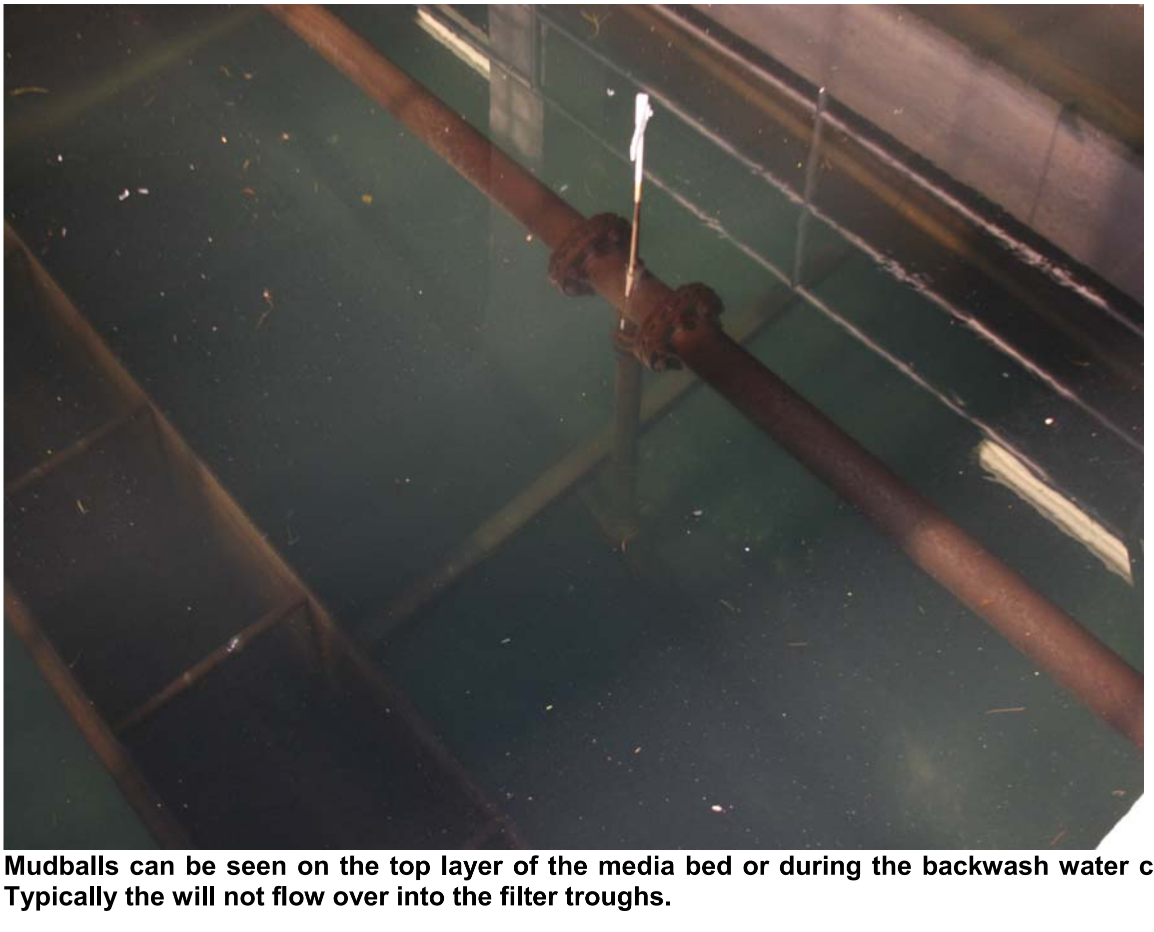
The photograph on the right shows a filter support bed under construction.

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 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 the will not flow over into the filter troughs.

Hard Water Section

Water contains various amounts of dissolved minerals, some of which impart a quality known as hardness. Consumers frequently complain about problems attributes to hard water, such as the formation of scale on cooking utensils and hot water heaters. In this document we will discusses the occurrence, and effects, of hard water and the hard water treatment or softening process that removes the hardness-causing minerals. The precipitation process most frequently used is generally known as the lime process or lime soda process. Because of the special facilities required and the complexity of the process, it is generally applicable only to medium- or large-size water systems where all treatment can be accomplished at a central location. This process will provide softened water at the lowest cost. Lime softening can be used for treatment of either groundwater or surface water sources.

The other commonly used method of softening involves the ion exchange process. This process has the advantages of a considerably lower initial cost and ease of use by small systems or by large systems at multiple locations. The principal disadvantage is that operating costs are considerably higher. Ion exchange processes can typically be used for direct treatment of groundwater, so long as turbidity and iron levels are not excessive. For treatment of surface water, the process normally must be preceded by conventional treatment. Softening can also be accomplished using membrane technology, electrodialysis, distillation, and freezing. Of these, membrane methods seem to have the greatest potential.

Distillers

Various sizes of distillers are available for home use. They all work on the principle of vaporizing water and then condensing the vapor. In the process, dissolved solids such as salt, metals, minerals, asbestos fibers, and other particles are removed. Some organic chemicals are also removed, but those that are more volatile are often vaporized and condensed with the product water. Distillers are effective in killing all microorganisms.

The principal problem with a distiller is that a small unit can produce only 2-3 gal (7.5 -11 Lt) a day, and that the power cost for operation will be substantially higher than the operating cost of other types of treatment devices.

Water Distillers have a high energy cost (approximately 20-30 cents per gallon). They must be carbon filtered before and/or after to remove volatile chemicals. It is considered "***dead***" water because the process removes all extra oxygen and energy. It has no taste. It is still second only to reverse osmosis water for health. Diet should be rich in electrolytes, as the aggressive nature of distilled water can "**leech**" electrolytes from the body.

Occurrence of Hard Water

Hard water is caused by soluble, divalent, metallic cations, (positive ions having valence of 2). The principal chemicals that cause water hardness are calcium (**Ca**) and magnesium (**Mg**). Strontium, aluminum, barium, and iron are usually present in large enough concentrations to contribute significantly to the total hardness.

Water hardness varies considerably in different geographic areas of the contiguous 48 states. This is due to different geologic formations, and is also a function of the contact time between water and limestone deposits. Magnesium is dissolved as water passes over and through dolomite and other magnesium-bearing minerals. Because groundwater is in contact with these formations for a longer period of time than surface water, groundwater is normally harder than surface water.

Expressing Water Hardness Concentration

Water hardness is generally expressed as a concentration of calcium carbonate, in terms of milligrams per liter as $CaCO_3$. The degree of hardness that consumers consider objectionable will vary, depending on other qualities of the water and on the hardness to which they have become accustomed. We will show two different classifications of the relative hardness of water:

Comparative classifications of water for softness and hardness

Classification	mg/L as $CaCO_3$ *	mg/L as $CaCO_3$ +
Soft	0 – 75	0 – 60
Moderately hard	75 – 150	61 – 120
Hard	150 – 300	121 – 180
Very hard	Over 300	Over 180

Source: Adapted from sawyer 1960 and Briggs and Ficke 1977.

* Per Sawyer (1960)
+ Per Briggs and Ficke (1977)

Types of Water Hardness

Hardness can be categorized by either of two methods: calcium versus magnesium hardness and carbonate versus non-carbonate hardness. The calcium-magnesium distinction is based on the minerals involved. Hardness caused by calcium is called calcium hardness, regardless of the salts associated with it, which include calcium sulfate (**$CaSO_4$**), calcium chloride (**$CaCl_2$**), and others. Likewise, hardness caused by magnesium is called magnesium hardness. Calcium and magnesium are normally the only significant minerals that cause harness, so it is generally assumed that

Total harness = calcium hardness + magnesium hardness

The carbonate-noncarbonate distinction, however, is based on hardness from either the bicarbonate salts of calcium or the normal salts of calcium and magnesium involved in causing water hardness. Carbonate hardness is caused primarily by the bicarbonate salts of calcium and magnesium, which are calcium bicarbonate, $Ca(HCO_3)_2$, and magnesium bicarbonate $Mg(HCO_3)_2$. Calcium and magnesium combined with carbonate (CO_3) also contribute to carbonate hardness. Noncarbonate hardness is a measure of calcium and magnesium salts other than carbonate and bicarbonate salts. These salts are calcium sulfate, calcium chloride, magnesium sulfate ($MgSO_4$), and magnesium chloride ($MgCl_2$). Calcium and magnesium combined with nitrate may also contribute to noncarbonate hardness, although it is a very rare condition. For carbonate and noncarbonate hardness,

Total hardness = carbonate hardness + noncarbonate hardness

When hard water is boiled, carbon dioxide (CO_2) is driven off, and Bicarbonate salts of calcium and magnesium then settle out of the water to form calcium and magnesium carbonate precipitates. These precipitates form the familiar chalky deposits on teapots. Because it can be removed by heating, carbonate hardness is sometimes called ***"Temporary hardness."*** Because noncarbonated hardness cannot be removed or precipitated by prolonged boiling, it is sometimes called ***"permanent hardness."***

Objections to Hard Water

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

When hard water is heated, scale forms much faster. In particular, when the magnesium hardness is more than about 40 mg/l (**as $CaCO_3$**), magnesium hydroxide scale will deposit in hot water heaters that are operated at normal temperatures of 140-150°F (60-66°C). A coating of only 0.04 in. (1 mm) of scale on the heating surfaces of a hot water heater creates an insulation effect that will increase heating costs by about 10 percent.

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

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

Water Softening

Water softening is a method of removing from water the minerals that make it hard. Hard water does not dissolve soap readily. It forms scale in pipes, boilers, and other equipment in which it is used. The principal methods of softening water are the lime soda process and the ion exchange process.

In the ***lime soda process,*** soda ash and lime are added to the water in amounts determined by chemical tests. These chemicals combine with the calcium and magnesium in the water to make insoluble compounds that settle to the bottom of the water tank.

In the ***ion exchange process,*** the water filters through minerals called ***zeolites.*** As the water passes through the filter, the sodium ions in the zeolite are exchanged for the calcium and magnesium ions in the water, and the water is softened. After household softeners become exhausted, a strong solution of ***sodium chloride*** (salt) is passed through the filter to replace the sodium that has been lost. The use of two exchange materials makes it possible to remove both metal and acid ions from water. Some cities and towns, however, prohibit or restrict the use of ion exchange equipment on drinking water, pending the results of studies on how people are affected by the consumption of the added sodium in softened water. The containers hold the resin for the deionization. Calcium and magnesium in water create hard water, and high levels can clog pipes. The best way to soften water is to use a water softener unit connected into the water supply line. You may want to consider installing a separate faucet for unsoftened water for drinking and cooking. Water softening units also remove iron.

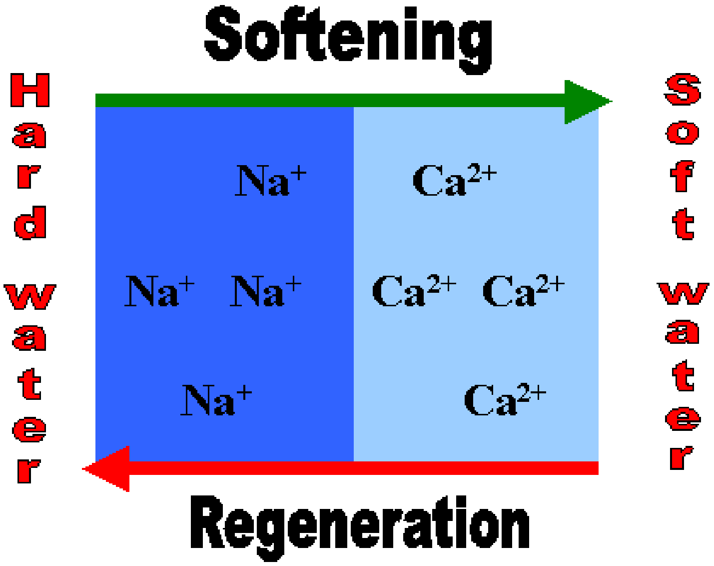
The most common way to soften household water is to use a water softener. Softeners may also be safely used to remove up to about 5 milligrams per liter of dissolved iron if the water softener is rated for that amount of iron removal. Softeners are automatic, semi-automatic, or manual. Each type is available in several sizes and is rated on the amount of hardness it can remove before regeneration is necessary. Using a softener to remove iron in naturally soft water is not advised; a green-sand filter is a better method. When the resin is filled to capacity, it must be recharged. Fully automatic softeners regenerate on a preset schedule and return to service automatically. Regeneration is usually started by a preset time clock; some units are started by water use meters or hardness detectors.

Semi automatic softeners have automatic controls for everything except for the start of regeneration. Manual units require manual operation of one or more valves to control back washing, brining and rinsing. In many areas, there are companies that provide a water softening service. For a monthly fee the company installs a softener unit and replaces it periodically with a freshly charged unit.

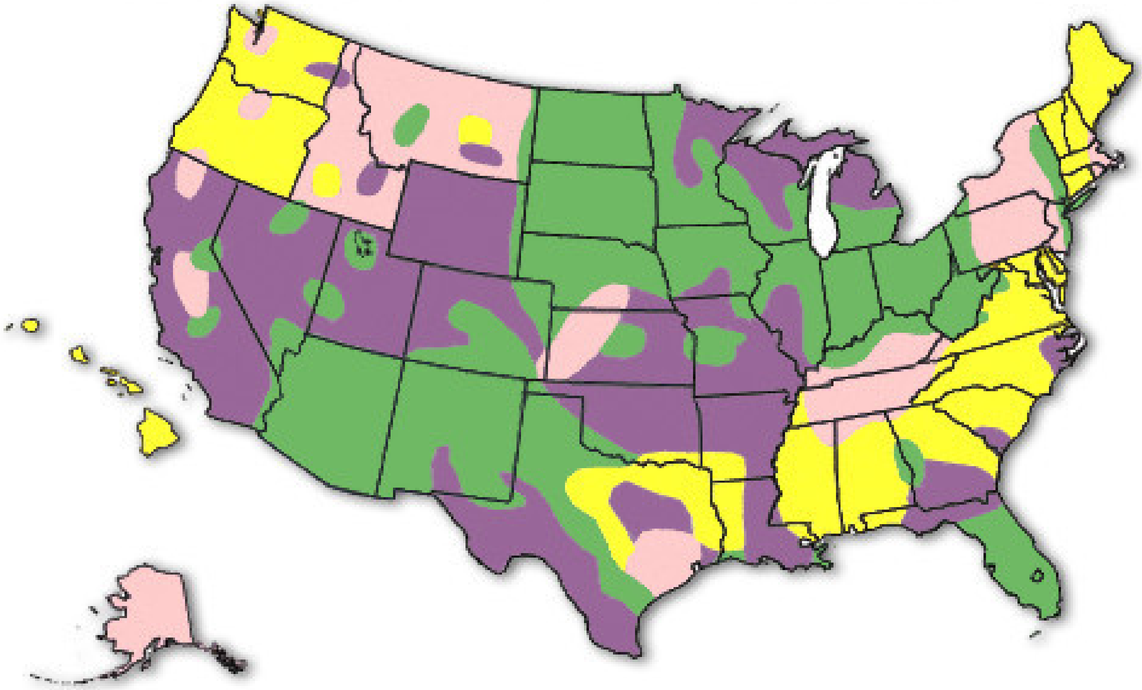
The principle behind water softening is really just simple chemistry. A water softener contains resin beads which hold electrically charged ions. When hard water passes through the softener, calcium and magnesium ions are attracted to the charged resin beads. It's the resulting removal of calcium and magnesium ions that produces "***soft water***." The diagram shows the exchange that takes place during the water softening process. When the resin beads in your softener become saturated with calcium and magnesium ions, they need to be recharged. Sodium ions from the water softening salt reactivate the resin beads so they can continue to do their job. Without sufficient softening salt, your water softener is less efficient. As a rule, you should check your water softener once a week to be sure the salt level is always at least one quarter full.

Resin beads with small stones from a nearby water well

Conventional Household Water Softener



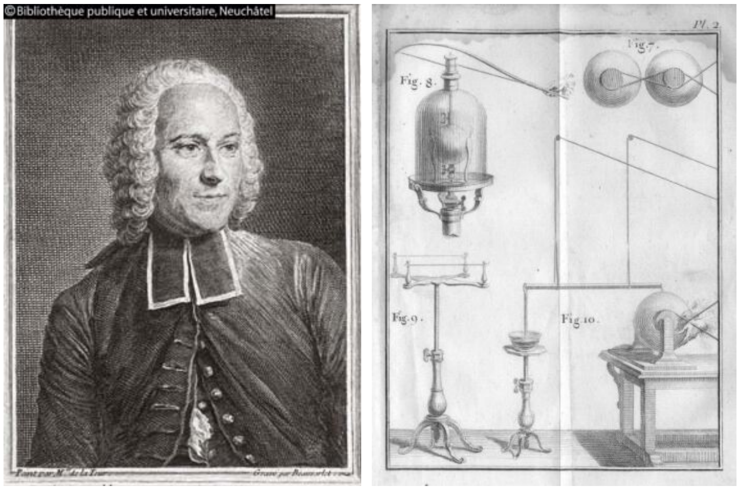
HARD WATER LEVELS THROUGHOUT THE U.S.



LEGEND

🟨 0 - 3.5 grains per gallon – Soft
🟥 3.5 - 7.0 grains per gallon – Moderately Hard
🟪 7.0 - 10.5 grains per gallon – Hard
🟩 over 10.5 grains per gallon – Very Hard

Due to the nature of the water bed sub-soil structure, water hardness may vary from one source to another within a general area.



French physicist Nollet and his first RO unit

Membrane Filtration Processes

In 1748, the French physicist Nollet first noted that water would diffuse through a pig bladder membrane into alcohol. This was the discovery of osmosis, a process in which water from a dilute solution will naturally pass through a porous membrane into a concentrate solution. Over the years, scientists have attempted to develop a membrane that would be useful in industrial processes, but it wasn't until the late 1950s that membranes were produced that could be used for what is known as reverse osmosis. In reverse osmosis, water is forced to move through a membrane from a concentrate solution to a dilute solution.

Since that time, continual improvements and new developments have been made in membrane technology, resulting in ever-increasing uses in many industries. In potable water treatment, membranes have been used for desalinization, removal of dissolved inorganic and organic chemicals, water softening, and removal of the fine solids.

In particular, membrane technology enables some water systems having contaminated water sources to meet new, more stringent regulations. In some cases, it can also allow secondary sources, such as brackish groundwater, to be used. There is great potential for the continuing wide use of membrane filtration processes in potable water treatment, especially as technology is improved and cost are reduced.

Description of Membrane Filtration Processes

In the simplest membrane processes, water is forced through a porous membrane under pressure while suspended solids, large molecules or ions are held back or rejected.

Types of Membrane Filtration Processes

The two general classes of membrane processes, based on the driving force used to make the process work, are:

- Pressure-driven processes
- Electric-driven processes

Pressure-Driven Processes

The four general membrane processes that operate by applying pressure to the raw water are:

- Microfiltration
- Ultrafiltration
- Nanofiltration
- Reverse Osmosis

Microfiltration

Microfiltration (**MF**) is a process in which water is forced under pressure through a porous membrane. Membranes with a pore size of 0.45 μm are normally used; this size is relatively large compared with the other membrane filtration processes. This process has not been generally applicable to drinking water treatment because it either does not remove substances that require removal from potable water, or the problem substances can be removed more economically using other processes.

The current primary use of MF is by industries to remove very fine particles from process water, such as in electronic manufacturing. In addition, the process has also been used as a pretreatment for other membrane processes. In particular, RO membranes are susceptible to clogging or binding unless the water being processed is already quite clean.

However, in recent years, microfiltration has been proposed as a filtering method for particles resulting from the direct filtration process. Traditionally, this direct filtration process has used the injection of coagulants such as alum or polymers into the raw water stream to remove turbidity such as clay or silts. The formed particles were then removed by rapid sand filters. Their suggested use is to improve filtering efficiency, especially for small particles that could contain bacterial and protozoan life.

Ultrafiltration

Ultrafiltration (**UF**) is a process that uses a membrane with a pore size generally below 0.1 μm. The smaller pore size is designed to remove colloids and substances that have larger molecules, which are called high-molecular-weight materials. UF membranes can be designed to pass material that weigh less than or equal to a certain molecular weight. This weight is called the molecular weight cutoff (**MWC**) of the membrane. Although UF does not generally work well for removal of salt or dissolved solids, it can be used effectively for removal or most organic chemicals.

Nanofiltration

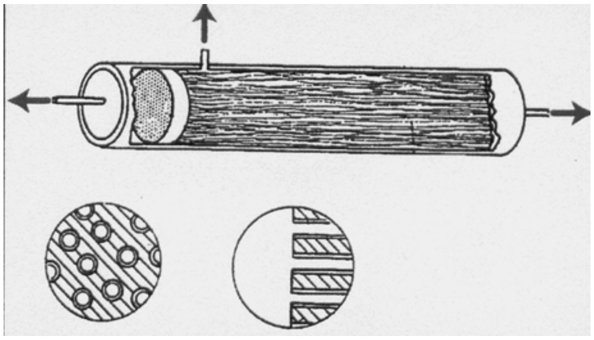
Nanofiltration (**NF**) is a process using membrane that will reject even smaller molecules than UF. The process has been used primarily for water softening and reduction of total dissolved solids (**TDS**). NF operates with less pressure than reverse osmosis and is still able to remove a significant proportion of inorganic and organic molecules. This capability will undoubtedly increase the use of NF for potable water treatment.

Reverse Osmosis

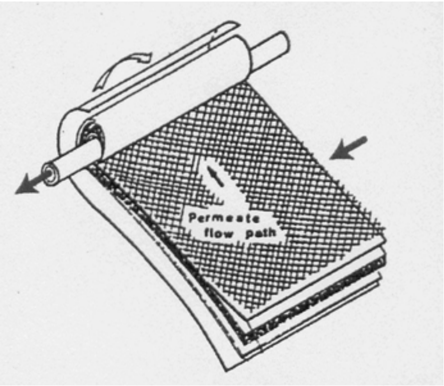
Reverse Osmosis (**RO**) is a membrane process that has the highest rejection capability of all the membrane processes. These RO membranes have very low pore size that can reject ions at very high rates, including chloride and sodium. Water from this process is very pure due to the high reject rates. The process has been used primarily in the water industry for desalinization of seawater because the capital and operating costs are competitive with other processes for this service.

The RO also works for most organic chemicals, radionuclides and microorganisms. For industrial water uses such as semiconductor manufacturing, is also an important RO process. RO is discussed in more detail later.

Membrane Configurations



Hollow Fiber



Spiral Wound

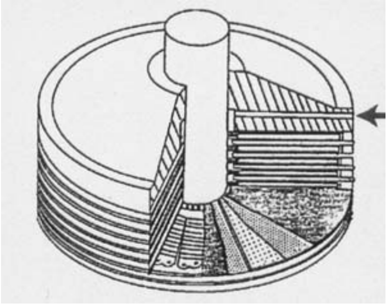
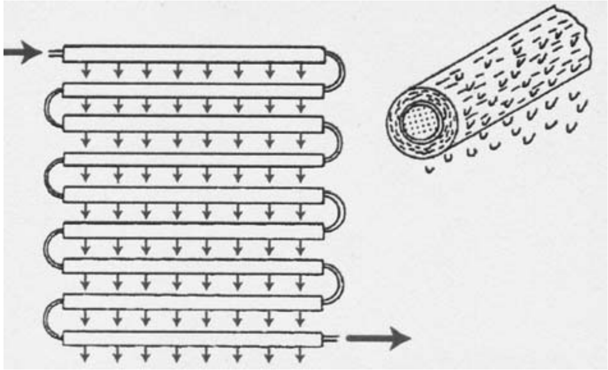


Plate and Frame



Tubular

Electric-Driven Processes

There are two membrane processes that purify a water stream by using an electric current to move ions across a membrane.

These processes are
- **Electrodialysis**
- **Electrodialysis Reversal**

Electrodialysis

Electrodialysis (**ED**) is a process in which ions are transferred through a membrane as a result of direct electric current applied to the solution. The current carries the ions through a membrane from the less concentrated solution to the more concentrated one.

Electrodialysis Reversal

Electrodialysis Reversal (**EDR**) is a process similar to ED, except that the polarity of the direct current is periodically reversed. The reversal in polarity reverses the flow of ions between demineralizing compartments, which provides automatic flushing of scale-forming materials from the membrane surface.

As a result, EDR can often be used with little or no pretreatment of feedwater to prevent fouling. So far, ED and EDR have been used at only a few locations for drinking water treatment.

Carbon vessels used for taste and odor control

Reverse Osmosis

Osmosis is a natural phenomenon in which a liquid - water, in this case - passes through a semi-permeable membrane from a relatively dilute solution toward a more concentrated solution. This flow produces a measurable pressure, called osmotic pressure.

If pressure is applied to the more concentrated solution, and if that pressure exceeds the osmotic pressure, water flows through the membrane from the more concentrated solution toward the dilute solution. This process, called reverse osmosis, or RO, removes up to 98% of dissolved minerals, and virtually 100% of colloidal and suspended matter. RO produces high quality water at low cost compared to other purification processes.

The membrane must be physically strong to stand up to high osmotic pressure - in the case of sea water, 2500 kg/m. Most membranes are made of cellulose acetate or polyamide composites cast into a thin film, either as a sheet or fine hollow fibers.

The membrane is constructed into a cartridge called a reverse osmosis module.

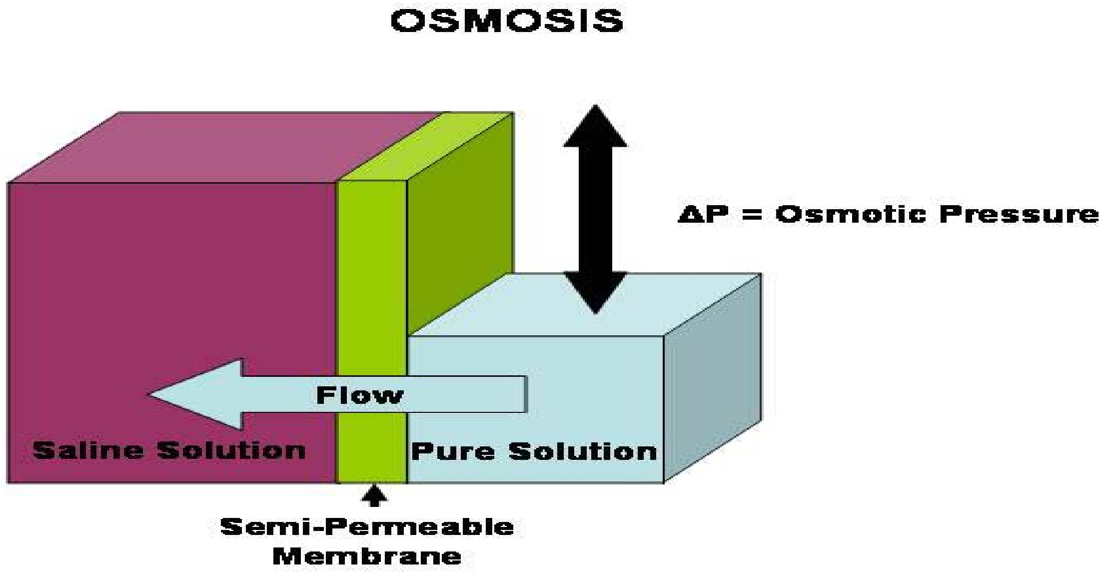
RO Skid

After filtration to remove suspended particles, incoming water is pressurized with a pump to 200 - 400 psi (1380 - 2760 kPa) depending on the RO system model.

This exceeds the water's osmotic pressure. A portion of the water (**permeate**) diffuses through the membrane, leaving dissolved salts and other contaminants behind with the remaining water where they are sent to drain as waste (**concentrate**).

RO

Pretreatment is important because it influences permeate quality and quantity. It also affects the module's life because many water-borne contaminants can deposit on the membrane and foul it. Generally, the need for pretreatment increases as systems become larger and operate at higher pressures, and as permeate quality requirements become more demanding. Because reverse osmosis is the principal membrane filtration process used in water treatment, it is described here in greater detail. To understand Reverse Osmosis, one must begin by understanding the process of osmosis, which occurs in nature. In living things, osmosis is frequently seen. The component parts include a pure or relatively pure water solution and a saline or contaminated water solution, separated by a semi-permeable membrane, and a container or transport mechanism of some type.



The semi-permeable membrane is so designated because it permits certain elements to pass through, while blocking others. The elements that pass through include water, usually smaller molecules of dissolved solids, and most gases. The dissolved solids are usually further restricted based on their respective electrical charge. In osmosis, naturally occurring in living things, the pure solution passes through the membrane until the osmotic pressure becomes equalized, at which point osmosis ceases. The osmotic pressure is defined as the pressure differential required to stop osmosis from occurring. This pressure differential is determined by the total dissolved solids content of the saline solution or contaminated solution on one side of the membrane. The higher the content of dissolved solids, the higher the osmotic pressure. Each element that may be dissolved in the solution contributes to the osmotic pressure, in that the molecular weight of the element affects the osmotic pressure.

Generally, higher molecular weights result in higher osmotic pressures. Hence, the formula for calculating osmotic pressure is very complex. However, approximate osmotic pressures are usually sufficient to design a system. Common tap water as found in most areas may have an osmotic pressure of about 10 PSI (Pounds per Square Inch), or about 1.68 Bar. Seawater at 36,000 PPM typically has an osmotic pressure of about 376 PSI (26.75 Bar). Thus, to reach the point at which osmosis stops for tap water, a pressure of 10 PSI would have to be applied to the saline solution, and to stop osmosis in seawater, a pressure of 376 PSI would have to be applied to the seawater side of the membrane.

Several decades ago, U.S. Government scientists had the idea that the principles of osmosis could be harnessed to purify water from various sources, including brackish water and seawater. In order to transform this process into one that purifies water, osmosis would have to be reversed, and suitable synthetic membrane materials would have to be developed. Additionally, ways of configuring the membranes would have to be engineered to handle a continuous flow of raw and processed water without clogging or scaling the membrane material. These ideas were crystallized, and, fueled by U.S. Government funding, usable membrane materials and designs resulted. One of the membrane designs was the spiral wound membrane element. This design enabled the engineers to construct a membrane element that could contain a generous amount of membrane area in a small package, and to permit the flow of raw water to pass along the length of the membrane.

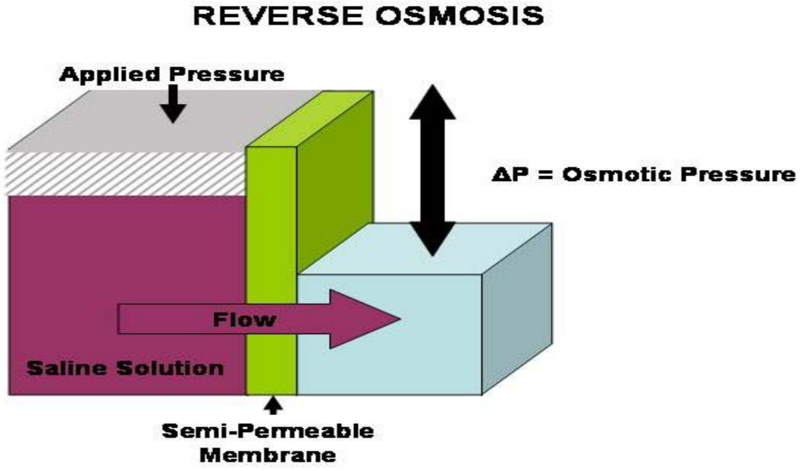
This permits flows and pressures to be developed to the point that ample processed or purified water is produced, while keeping the membrane surface relatively free from particulate, colloidal, bacteriological or mineralogical fouling.

The design features a perforated tube in the center of the element, called the product or permeate tube, and wound around this tube are one or more "***envelopes***" of membrane material, opening at the permeate tube. Each envelope is sealed at the incoming and exiting edge. Thus when water penetrates or permeates though the membrane, it travels, aided by a fine mesh called the permeate channel, around the spiral and collects in the permeate tube. The permeate or product water is collected from the end of each membrane element, and becomes the product or result of the purification process.

Meanwhile, as the raw water flows along the "***brine channel***" or coarse medium provided to facilitate good flow characteristics, it gets more and more concentrated. This concentrated raw water is called the reject stream or concentrate stream. It may also be called brine if it is coming from a salt water source. The concentrate, when sufficient flows are maintained, serves to carry away the impurities removed by the membrane, thus keeping the membrane surface clean and functional. This is important, as buildup on the membrane surface, called fouling, impedes or even prevents the purification process.

The membrane material itself is a special thin film composite (**TFC**) polyamide material, cast in a microscopically thin layer on another, thicker cast layer of Polysulfone, called the microporous support layer. The microporous support layer is cast on sheets of paper-like material that are made from synthetic fibers such as polyester, and manufactured to the required tolerances.

Each sheet of membrane material is inspected at special light tables to ensure the quality of the membrane coating, before being assembled into the spiral wound element design. To achieve Reverse Osmosis, the osmotic pressure must be exceeded, and to produce a reasonable amount of purified water, the osmotic pressure is generally doubled. Thus with seawater osmotic pressure of 376 PSI, a typical system operating pressure is about 800 PSI. Factors that affect the pressure required include raw water temperature, raw water TDS (**Total Dissolved Solids**), membrane age, and membrane fouling.



The effect of temperature is that with higher temperatures, the salt passage increases, flux (permeate flow) increases, and operating pressure required is lower. With lower temperatures, the inverse occurs, in that salt passage decreases (reducing the TDS in the permeate or product water), while operating pressures increase. Or if operating pressures do not increase, then the amount of permeate or product water is reduced. In general, Reverse Osmosis (**R/O**) systems are designed for raw water temperatures of 25° C (77° F). Higher temperatures or lower temperatures can be accommodated with appropriate adjustments in the system design.

Membranes are available in "**standard rejection**" or "**high rejection**" models for seawater and brackish water. The rejection rate is the percentage of dissolved solids rejected, or prevented from passing through the membrane. For example, a membrane with a rejection rate of 99% (usually based on Na (**Sodium**)) will allow only 1% of the concentration of dissolved solids to pass through into the permeate. Hence product water from a source containing 10,000 PPM would have 100 PPM remaining. Of course, as the raw water is processed, the concentrations of TDS increase as it passes along the membrane's length, and usually multiple membranes are employed, with each membrane in the series seeing progressively higher dissolved solids levels.

Typically, starting with seawater of 36,000 PPM, standard rejection membranes produce permeate below 500 PPM, while high rejection membranes under the same conditions produce drinking water TDS of below 300 PPM. There are many considerations when designing R/O systems that competent engineers are aware of. These include optimum flows and pressures, optimum recovery rates (the percentage of permeate from a given stream of raw water), prefiltration and other pretreatment considerations, and so forth. Membrane systems in general cannot handle the typical load of particulate contaminants without prefiltration. Often, well designed systems employ multiple stages of prefiltration, tailored to the application, including multi-media filtration and one or more stages of cartridge filtration. Usually the last stage would be 5m or smaller, to provide sufficient protection for the membranes.

R/O systems typically have the following components:
A supply pump or pressurized raw water supply; prefiltration in one or more stages; chemical injection of one or more pretreatment agents may be added; a pressure pump suited to the application, sized and driven appropriately for the flow and pressure required; a membrane array including one or more membranes installed in one or more pressure tubes (also called pressure vessels, R/O pressure vessels, or similar); various gauges and flow meters; a pressure regulating valve, relief valve(s) and/or safety pressure switches; and possibly some form of post treatment. Post treatment should usually include a form of sterilization such as Chlorine, Bromine, Ultra-Violet (**U-V**), or Ozone. Other types of post treatment may include carbon filters, pH adjustment, or mineral injection for some applications.

Packaged skid with instrumentation, UV, and softening.

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.

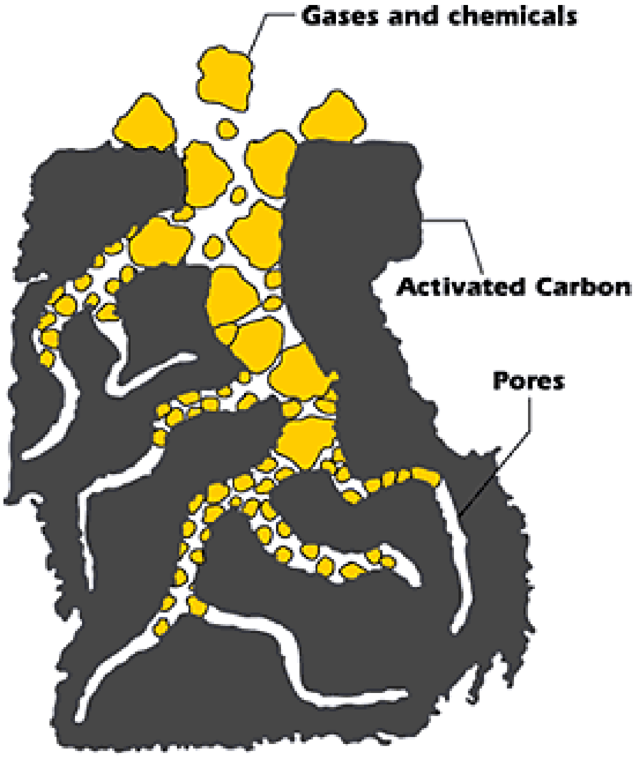
GAC can be used as a replacement for existing media (such as sand) in a conventional filter or it can be used in a separate contactor such as a vertical steel pressure vessel used to hold the activated carbon bed. After a period of a few months or years, depending on the concentration of the contaminants, 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 adsorbs gases and chemicals

Clean-In-Place

Some very low cost R/O systems may dispense with most of the controls and instruments. However, systems installed in critical applications should be equipped with a permeate or product flow meter, a reject, concentrate or brine flow meter; multiple pressure gauges to indicate the pressure before and after each filtration device and the system operation pressure in the membrane loop; preferably both before and after the membrane array. Another feature found in better systems is a provision to clean the membranes in place, commonly known as a "**Clean In Place**" (**CIP**) system. Such a system may be built right into the R/O system or may be provided as an attachment for use as required.

Reverse Osmosis has proven to be the most reliable and cost effective method of desalinating water, and hence its use has become more and more widespread. Energy consumption is usually some 70% less than for comparable evaporation technologies. Advancements have been made in membrane technology, resulting in stable, long-lived membrane elements. Component parts have been improved as well, reducing maintenance and down time. Additional advancements in pretreatment have been made in recent years, further extending membrane life and improving performance.

Reverse Osmosis delivers product water or permeate having essentially the same temperature as the raw water source (an increase of 1° C or 1.8° F may occur due to pumping and friction in the piping). This is more desirable than the hot water produced by evaporation technologies. R/O Systems can be designed to deliver virtually any required product water quality. For these and other reasons, R/O is usually the preferred method of desalination today.

Reverse osmosis, also known as hyperfiltration, is the finest filtration known. This process will allow the removal of particles as small as ions from a solution. Reverse osmosis is used to purify water and remove salts and other impurities in order to improve the color, taste or properties of the fluid. It can be used to purify fluids such as ethanol and glycol, which will pass through the reverse osmosis membrane, while rejecting other ions and contaminants from passing. The most common use for reverse osmosis is in purifying water. It is used to produce water that meets the most demanding specifications that are currently in place.

Reverse osmosis uses a membrane that is semi-permeable, allowing the fluid that is being purified to pass through it, while rejecting the contaminants that remain. Most reverse osmosis technology uses a process known as cross-flow to allow the membrane to continually clean itself. As some of the fluid passes through the membrane the rest continues downstream, sweeping the rejected species away from the membrane. The process of reverse osmosis requires a driving force to push the fluid through the membrane, and the most common force is pressure from a pump. The higher the pressure, the larger the driving force. As the concentration of the fluid being rejected increases, the driving force required to continue concentrating the fluid increases.

Reverse osmosis is capable of rejecting bacteria, salts, sugars, proteins, particles, dyes, and other constituents that have a molecular weight of greater than 150-250 Daltons. The separation of ions with reverse osmosis is aided by charged particles. This means that dissolved ions that carry a charge, such as salts, are more likely to be rejected by the membrane than those that are not charged, such as organics. The larger the charge and the larger the particle, the more likely it will be rejected.

Reverse Osmosis, when properly configured with sediment, carbon and/or carbon block technology, produces pure water that is clearly the body's choice for optimal health. It is the best tasting because it is oxygen-rich.

A Reverse Osmosis System removes virtually all of the following: bad taste, odor, turbidity, organic compounds, herbicides, insecticides, pesticides, chlorine and THM's, bacteria, virus, cysts, parasites, arsenic, heavy metals, lead, cadmium, aluminum, dissolved solids, sodium, calcium, magnesium, inorganic dead dirt minerals, fluoride, sulfates, nitrates, phosphates, detergents, radioactivity and asbestos.

Ozone

Ozone (**O_3**) is probably the strongest oxidizing agent available for water treatment. Although it is widely used throughout the world, is has not found much application in the United States. Ozone is obtained by passing a flow of air or oxygen between two electrodes that are subjected to an alternating current in the order of 10,000 to 20,000 volts.

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

Liquid ozone is very unstable and can readily explode. As a result, it is not shipped and must be manufactured on-site. Ozone is a light blue gas at room temperature. It has a self-policing pungent odor similar to that sometimes noticed during and after heavy electrical storms. In use, ozone breaks down into oxygen and nascent oxygen.

$$O_3 = O_2 + O$$

It is the nascent oxygen that produces the high oxidation and disinfections, and even sterilization. Each water has its own ozone demand, in the order of 0.5 ppm to 5.0 ppm. Contact time, temperature, and pH of the water are factors in determining Ozone demand. Ozone acts as a complete disinfectant. It is an excellent aid to the flocculation and coagulation process, and will remove practically all color, taste, odor, iron, and manganese. It does not form chloramines or THMs, and while it may destroy some THMs, it may produce other byproducts when followed by chlorination. Ozone is not practical for complete removal of chlorine or chloramines, or of THM and other inorganics. Further, because of the possibility of formation of other carcinogens (such as aldehydes or phthalates) it falls into the same category as other disinfectants in that it can produce DBPs.

Ozone Generator

Ultraviolet Radiation

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

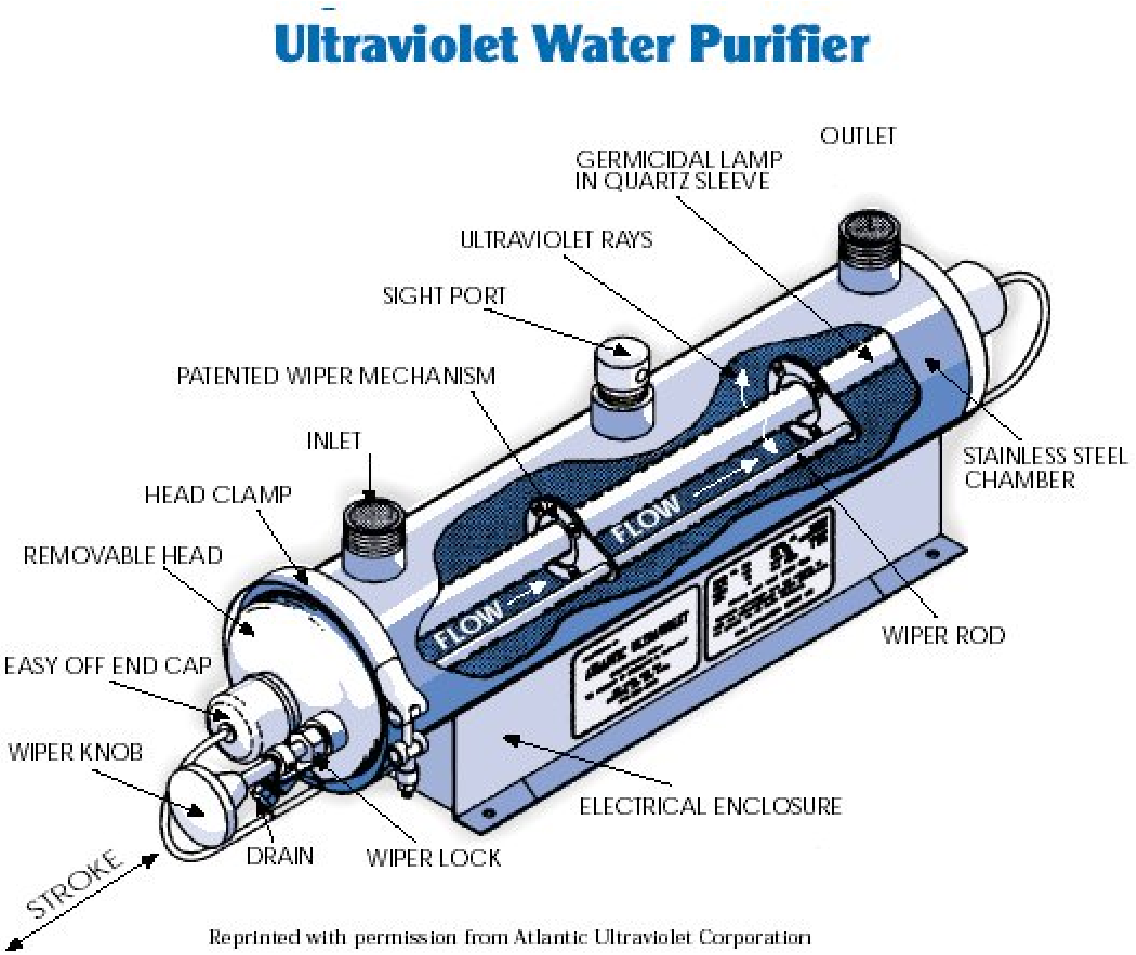
This radiation can be artificially produced by sending strong electric currents thorough various substances. A sun lamp, for example, sends out UV rays that, when properly controlled, result in a suntan. Of course, too much will cause sunburn.

The UV lamp that can be used for the disinfection of water depends upon the low-pressure mercury vapor lamp to produce the ultraviolet energy. A mercury vapor lamp is one in which an electric arc is passed through an inert gas. This, in turn, will vaporize the mercury contained in the lamp; it is a result of this vaporization that UV rays are produced.

The lamp itself does not come in direct contact with the water, The lamp is placed inside a quartz tube, and the water is in contact with the outside of the quartz tube. Quartz is used in this case since practically none of the UV rays are absorbed by the quartz, allowing all of the rays to reach the water. Ordinary glass cannot be used since it will absorb the UV rays, leaving little for disinfection. The water flows around the quartz tube. The UV sterilizer will consist of a various number of lamps and tubes, depending upon the quantity of water to be treated. As water enters the sterilizer, it is given a tangential flow pattern so that the water spins over and around the quartz sleeves. In this way, the microorganisms spend maximum time in contact with the outside of the quartz tube and the source of the UV rays. The basic design flow of water of certain UV units is in the order of 2.0 gpm for each inch of the lamp.

Further, the units are designed so that the contact or retention time of the water in the unit is not less than 15 seconds.
Most manufacturers claim that the UV lamps have a life of about 7,500 hours, which is about 1 year's time. The lamp must be replaced when it loses about 40% to 50% of its UV output; in any installation this is determined by means of a photoelectric cell and a meter that shows the output of the lamp. Each lamp is outfitted with its own photoelectric cell, and with an alarm that will be activated when the penetration drops to a preset level.

Ultraviolet radiation is an excellent disinfectant that is highly effective against viruses, molds, and yeasts; and it is safe to use. It adds no chemicals to the water, it leaves no residual, and it does not form THMs. It is used to remove traces of ozone and chloramines from the finished water. Alone, UV radiation will not remove precursors, but in combination with ozone, it is said to be effective in the removal of THM precursors and THMs.



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The germicidal effect of UV is thought to be associated with its absorption by various organic components essential to the cell's function. For effective use of ultraviolet, the water to be disinfected must be clean and free of any suspended solids. The water must also be colorless and must be free of any colloids, iron, manganese, taste, and odor. These are conditions that must be met. Also, although water may appear to be clear, such substances as excesses of chlorides, bicarbonates, and sulfates affect absorption of the ultraviolet rays. These parameters will probably require at least filtration of one type or another. The UV manufacturer will, of course, stipulate which pretreatment may be necessary.

Removal of Disinfection By-Products

Disinfectant	***Disinfectant By-product***	***Disinfectant By-product Removal***
Chlorine (HOCl)	Trialomethane (THM)	Granular Activated Carbon (**GAC**), resins, controlled coagulation, aeration.
	Chloramine	GAC-UV
	Chlorophenol	GAC
Chloramine (NH_xCl_y)	Probably no THM	GAC
	Others?	UV?
Chlorine dioxide (ClO_2)	Chlorites Chlorates	Use of Fe2+ in coagulation, RO, ion-exchange
Permanganate ($KMnO_4$)	No THMs	
Ozone (O_3)	Aldehydes, Carboxylics, Phthalates	GAC
Ultraviolet (UV)	None known	GAC

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

If it is decided that removal of precursors is needed, research to date indicates that this removal can be attained through the application of controlled chlorination plus coagulation and filtration, aeration, reverse osmosis, nanofiltration, GAC or combinations of other processes.

Modern Water Treatment Disinfectants

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

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

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

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

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

Disinfection Byproducts (DBPS)

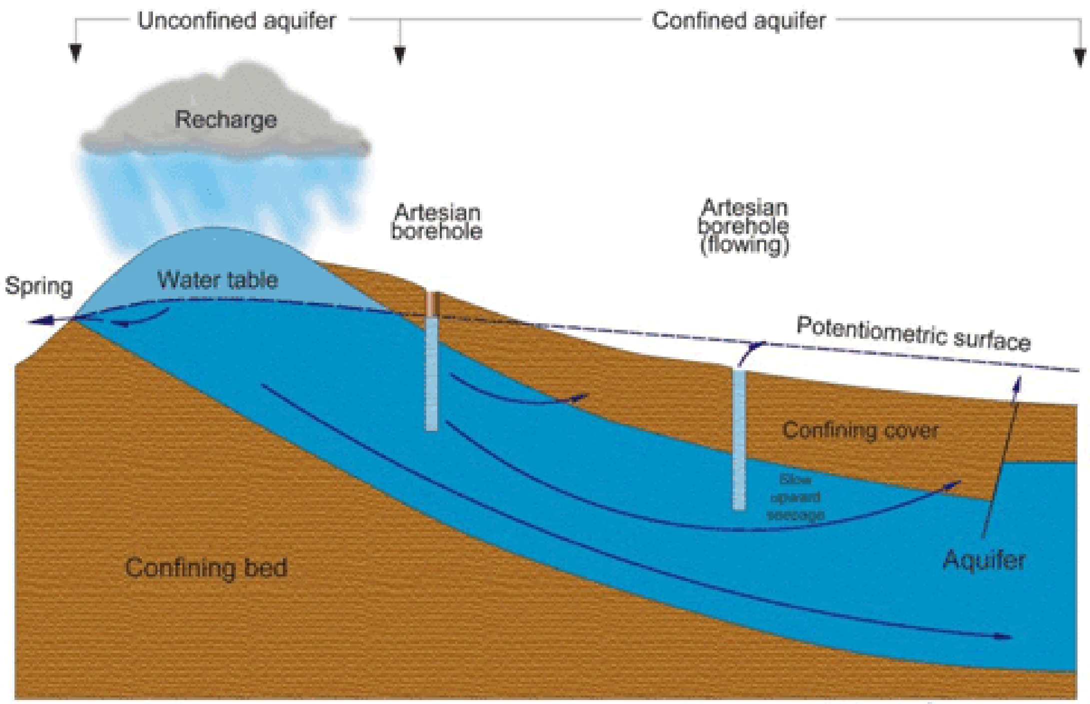
Disinfection byproducts form when disinfectants added to drinking water to kill germs react with naturally-occurring organic matter in water.

Total Trihalomethanes. Some people who drink water containing trihalomethanes in excess of EPA standards over many years may experience problems with their liver, kidneys, or central nervous systems, and may have an increased risk of getting cancer.

Haloacetic Acids. Some people who drink water containing haloacetic acids in excess of EPA standards over many years may have an increased risk of getting cancer.

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

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



UK Groundwater Forum

Different types of Aquifers

Water Production Section Chapter 4

Groundwater and Wells

A well can be easily contaminated if it is not properly constructed or if toxic materials are released into the well. Toxic material spilled or dumped near a well can leach into the aquifer and contaminate the groundwater drawn from that well. Contaminated wells used for drinking water are especially dangerous. Wells can be tested to see what chemicals may be in the well and if they are present in dangerous quantities.

Groundwater is withdrawn from wells to provide water for everything from drinking water for the home and business to water for irrigation to industrial processing water. When water is pumped from the ground, the dynamics of groundwater flow change in response to this withdrawal. Groundwater flows slowly through water-bearing formations (aquifers) at different rates. In some places, where groundwater has dissolved limestone to form caverns and large openings, its rate of flow can be relatively fast, but this is exceptional.

Well with a mineral oil sealed vertical turbine pump

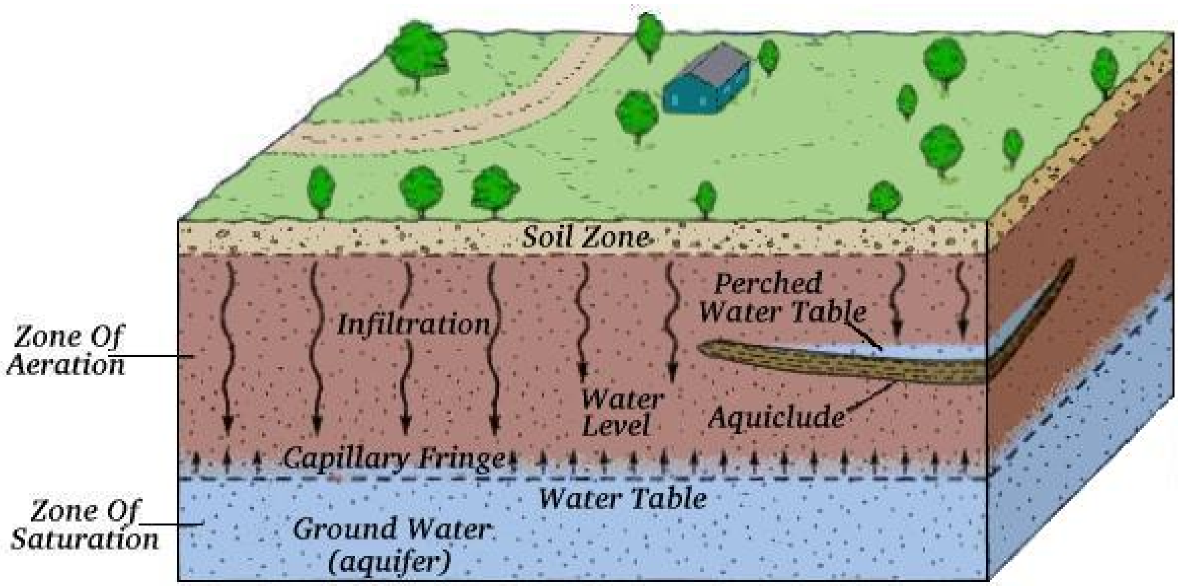
Groundwater Resource

Many terms are used to describe the nature and extent of the groundwater resource. The level below which all the spaces are filled with water is called the ***water table***. Above the water table lies the ***unsaturated zone*.** Here the spaces in the rock and soil contain both air and water. Water in this zone is called ***soil moisture*.** The entire region below the water table is called the ***saturated zone*** and water in this saturated zone is called ***groundwater.***

Fractured aquifers are rocks in which the groundwater moves through cracks, joints or fractures in otherwise solid rock. Examples of fractured aquifers include granite and basalt. Limestones are often fractured aquifers, but here the cracks and fractures may be enlarged by solution, forming large channels or even caverns.

Limestone terrain where solution has been very active is termed ***karst***. Porous media such as sandstone may become so highly cemented or recrystalized that all of the original space is filled. In this case, the rock is no longer a porous medium. However, if it contains cracks it can still act as a fractured aquifer.

Most of the aquifers of importance to us are unconsolidated porous media such as sand and gravel. Some very porous materials are not permeable. Clay, for instance, has many spaces between its grains, but the spaces are not large enough to permit free movement of water.



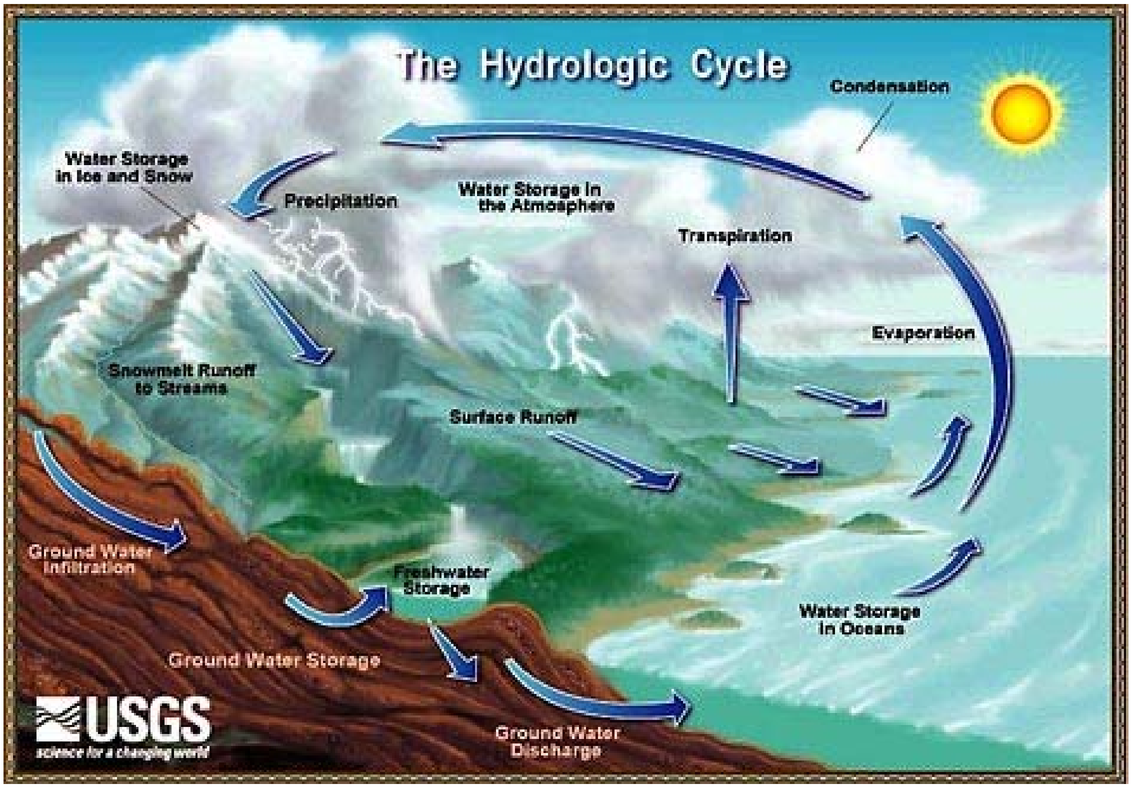
Groundwater usually flows downhill with the slope of the water table. Like surface water, groundwater flows toward, and eventually drains into, streams, rivers, lakes and the oceans. Groundwater flow in the aquifers underlying surface drainage basins, however, does not always mirror the flow of water on the surface. Therefore, groundwater may move in different directions below the ground than the water flowing on the surface.

Unconfined aquifers are those that are bounded by the water table. Some aquifers, however, lie beneath layers of impermeable materials. These are called ***confined aquifers*,** or sometimes ***artesian aquifers***.

A well in such an aquifer is called an *artesian well*. The water in these wells rises higher than the top of the aquifer because of confining pressure. If the water level rises above the ground surface, a ***flowing artesian well*** occurs. The ***piezometric surface*** is the level to which the water in an artesian aquifer will rise.

Water Sources

Before we discuss the types of treatment it is easier to first understand how the source of water arrives.



Water Cycle Terms- Good information for your Assignment

1. **Precipitation:** The process by which atmospheric moisture falls onto the land or water surface as rain, snow, hail or other forms of moisture.
2. **Infiltration:** The gradual flow or movement of water into and through the pores of the soil.
3. **Evaporation:** The process by which the water or other liquids become a gas.
4. **Condensation:** The collection of the evaporated water in the atmosphere.
5. **Runoff:** Water that drains from a saturated or impermeable surface into stream channels or other surface water areas. Most lakes and rivers are formed this way.
6. **Transpiration**: Moisture that will come from plants as a byproduct of photosynthesis.

Once the precipitation begins, water is no longer in its purest form. Water will be collected as surface supplies or circulate to form in the ground. As it becomes rain or snow it may be polluted with organisms, organic compounds, and inorganic compounds. Because of this, we must treat the water for human consumption.

Source Water Quality

Groundwater

Groundwater contributes most of all of the water that is derived from wells or springs. It occurs in the natural open spaces (e.g., fractures or pore spaces between grains) in sediments and rocks below the surface. Groundwater is distributed fairly evenly throughout the crust of the earth, but it is not readily accessible or extractable everywhere. More than 90 percent of the world's total supply of drinkable water is groundwater.

Groundwater originates as precipitation that sinks into the ground. Some of this water percolates down to the water table (shallowest surface of the groundwater) and recharges the aquifer. For shallow wells (for example less than 50-75 feet) the recharge area is often the immediate vicinity around the well or ***"wellhead."*** Some wells are recharged in areas that may be a great distance from the well itself.

If the downward percolating precipitation encounters any source of contamination, at the surface or below it, the water may dissolve some of that contaminant and carry it to the aquifer. Groundwater moves from areas where the water table is high to where the water table is low. Consequently, a contaminant may enter the aquifer some distance upgradient from you and still move towards your well. When a well is pumping, it lowers the water table in the immediate vicinity of the well, increasing the tendency for water to move towards the well.

Contaminants can be conveniently lumped into three categories: microorganisms (bacteria, viruses, Giardia, etc.), inorganic chemicals (nitrate, arsenic, metals, etc.) and organic chemicals (solvents, fuels, pesticides, etc.).

Although it is common practice to associate contamination with highly visible features such as landfills, gas stations, industry or agriculture, potential contaminants are widespread and often come from common everyday activities as well, such as septic systems, lawn and garden chemicals, pesticides applied to highway right-of-ways, stormwater runoff, auto repair shops, beauty shops, dry cleaners, medical institutions, photo processing labs, etc. Importantly, it takes only a very small amount of some chemicals in drinking water to raise health concerns. For example, one gallon of pure trichloroethylene, a common solvent, will contaminate approximately 292 million gallons of water.

Wellhead Protection

Wellhead protection refers to programs designed to maintain the quality of groundwater used as public drinking water sources, by managing the land uses around the wellfield. The theory is that management of land use around the well, and over water moving (underground) toward the well, will help to minimize damage to subsurface water supplies by spills or improper use of chemicals. The concept usually includes several stages.

Wellhead Protection Sequence

A) Build a community-wide planning team.
B) Delineate geologically the protection zone.
C) Perform a contaminant use inventory.
D) Create a management plan for the protection zone.
E) Plan for the future.

Water Rights, Remember this section for your Assignment.

Appropriative: Acquired water rights for exclusive use.
Prescriptive: Rights based upon legal prescription or long use or custom.
Riparian: Water rights because property is adjacent to a river or surface water.

Surface Water

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.

Quality of Water

If you classified the way water characteristic change as it passes on the surface and below the ground it would be in four categories:

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

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

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

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

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 the purification 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 absorb 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 this will result in fish kill.

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 have been controlled 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. The pH and alkalinity of the water will determine how these chemicals will react. Most systems no longer use Chlorine because it reacts with the organics in the water to form Trihalomethanes.

Different types of chemical storage tanks found in water treatment facilities

Corrosion Control

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. 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.

Cathodic Protection

Cathodic protection protects steel from corrosion which 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

How Does Cathodic Protection Work ?

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***."

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.

Impressed or Induced Current Systems

An impressed current Cathodic protection system consists of anodes, cathodes, a rectifier and the soil. The rectifier converts the alternating current to direct current. The direct current is then sent through an insulated copper wire to anodes that are buried in the soil near the piping system. Typical anode materials are ceramic, high silicon cast iron, or graphite.

Ceramic anodes are not consumed, where as high silicon cast iron and graphite anodes partially dissolve each year and must be replaced over time. The direct current then flows from the anode through the soil to the piping system, which acts as the cathode, and back to the rectifier through another insulated copper wire.

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.

Sacrificial Anode System
In this system, a metal or alloy reacting more vigorously than the corroding specimen acts as an anode and the corroding structure as a whole is rendered Cathodic. 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.

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).

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 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 consideration.
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.

Alkalinity and pH Adjustment

Adjusting pH and alkalinity is the most common corrosion control method because it is simple and inexpensive. pH is a measure of the concentration of hydrogen ions present in water; alkalinity is a measure of water's ability to neutralize acids.

Generally, water pH less than 6.5 is associated with uniform corrosion, while pH between 6.5 and 8.0 can be associated with pitting corrosion. Some studies have suggested that systems using only pH to control corrosion should maintain a pH of at least 9.0 to reduce the availability of hydrogen ions as electron receptors. However, pH is not the only factor in the corrosion equation; carbonate and alkalinity levels affect corrosion as well.

Generally, an increase in pH and alkalinity can decrease corrosion rates and help form a protective layer of scale on corrodible pipe material. Chemicals commonly used for pH and alkalinity adjustment are hydrated lime (CaOH2 or calcium hydroxide), caustic soda (NaOH or sodium hydroxide), soda ash (Na2CO3 or sodium carbonate), and sodium bicarbonate (NaHCO3, essentially baking soda).

Care must be taken, however, to maintain pH at a level that will control corrosion but not conflict with optimum pH levels for disinfection and control of disinfection by-products.

Corrosion Inhibitors
Inhibitors reduce corrosion by forming protective coatings on pipes. The most common corrosion inhibitors are inorganic phosphates, sodium silicates and mixtures of phosphates and silicates. These chemicals have proven successful in reducing corrosion in many water systems.

The phosphates used as corrosion inhibitors include polyphosphates, orthophosphates, glassy phosphates and bimetallic phosphates. In some cases, zinc is added in conjunction with orthophosphates or polyphosphates.

Glassy phosphates, such as sodium hexametaphosphate, effectively reduce iron corrosion at dosages of 20 to 40 mg/l. Glassy phosphate has an appearance of broken glass and can cut the operator. Sodium silicates have been used for over 50 years to inhibit corrosion. The effectiveness depends on the water pH and carbonate concentration.

Sodium silicates are particularly effective for systems with high water velocities, low hardness, low alkalinity and a pH of less than 8.4. Typical coating maintenance doses range from 2 to 12 mg/1. They offer advantages in hot water systems because of their chemical stability. For this reason, they are often used in the boilers of steam heating systems.

Water Storage Section

Water storage facilities and tanks vary in size, shape, and application. There are different types that are used in the water distribution systems, such as standpipes, elevated tanks and reservoirs, hydropneumatic tanks and surge tanks.

These tanks serve multiple purposes in the distribution system. Just the name alone can give you an idea of its purpose.

- **SURGE tanks**
- **RESERVOIRS**
- **ELEVATED tanks** *Water towers and Standpipes*

Surge Tanks

What really causes water main breaks - **ENERGY** - when released in a confined space, such as a water distribution system. Shock waves are created when hydrants, valves, or pumps are opened and closed quickly, trapping the kinetic energy of moving water within the confined space of a piping system.

These shock waves can create a turbulence that travels at the speed of sound, seeking a point of release. The release the surge usually finds is an elevated tank, but the surge doesn't always find this release quickly enough. Something has to give, often times, it's your pipe fittings.

Distribution operators are aware of this phenomenon! It's called **WATER HAMMER**.

This banging can be heard as water hammer. Try it at home - turn on your tap, then turn it off very quickly. You should hear a bang, and maybe even several. If you turn the tap off more slowly, it should stay quiet, as the liquid in the pipes slows down more gradually.

A Surge tank should not be used for water storage.

The goal of the water tower or standpipe is to store water high in the air, where it has lots of gravitational potential energy. This stored energy can be converted to pressure potential energy or kinetic energy for delivery to homes. Since height is everything, building a cylindrical water tower is inefficient. Most of the water is then near the ground. By making the tower wider near the top, it puts most of its water high up.

Water Quality Section   Chapter 5

What's that Stuff in the Tap Water?

by Jameel Rahman and Gary A. Burlingame

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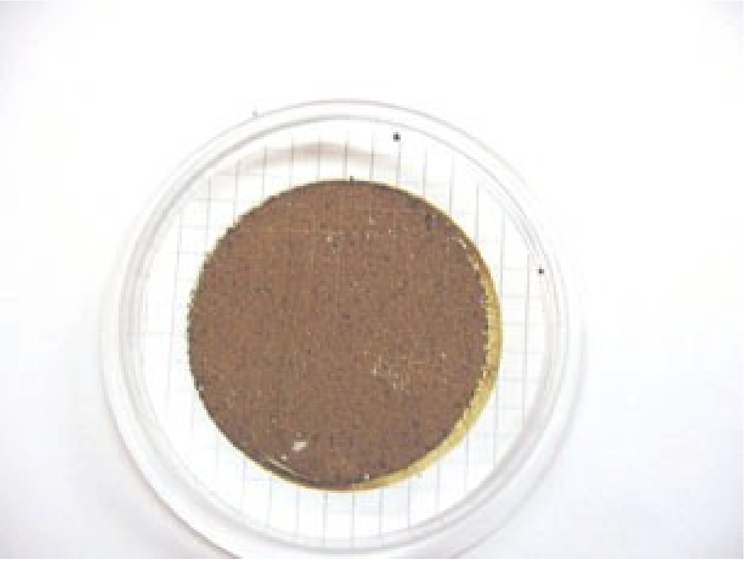
Almost every water utility employee responsible for solving customer problems has fielded a complaint about particles in a bathtub or faucet aerator. Although particles can come from cold or hot water systems, household plumbing, water distribution systems, and water treatment, the water supplier—at least in customers' eyes—is usually "*guilty until proven innocent*."

The Philadelphia Water Department has standardized procedures in place that can identify offending materials and help pinpoint their source.

Collecting and Identifying Particulates

Typically, the suspended matter customers complain about is particulate in form. The most important step in solving a particulate complaint is to collect as much suspect material as possible, making sure it represents the customer's actual concern. Sometimes enough material for analysis can be collected from faucet aerators. A container may be left with the customer for sample collection during normal tap use. Particulates can also accumulate in the toilet tank.



Particulate matter can be extracted from water samples by using nitrocellulose membrane filters. A 0.45 µm filter can be used if the water's colloidal matter doesn't clog the filter before enough particulate material is collected for analysis. Enough particulate matter can usually be captured with a water sample of approximately 250 mL. When samples have low turbidity, larger volumes will need to be filtered.

←Granular Rust

Under a microscope, examine the particulate matter captured on a filter. Use a zoom microscope with at least 40×, preferably 75×, magnification to identify matter on the membrane filter disk, which can be stored in a Plexiglas Petri dish. For optimum observation, illuminate the particulates from above with a fiber-optic light.

Some particulates can be identified by their appearance and, sometimes, by touching them with a sharp needle and observing their physical properties, such as softness, stickiness, or solubility in a solvent. Particulates can be quantified as few, several, or numerous. If particulates cannot be identified by their appearance, perform simple chemical tests on the filter.

A characteristic evolution of a gas, such as carbon dioxide from scale particulates or marble, can be observed under the microscope. Color formed by chemical reactions can be seen by the unaided eye. If these tests still fail to identify the debris, or further delineation is required, use infrared spectroscopy (**IR**).

Visual Identification

Sand particulates have a characteristic vitreous appearance and irregular shape with smooth facets. They can be colorful but usually appear translucent to whitish.

Mica particulates have a characteristic platelet shape and shine under reflected light. You will need to understand the common soil minerals in your area to identify them.

Man-made fibers, found in all colors and with a characteristic wrinkled strip shape, are present in single strands, have significant length, and often are visible to the unaided eye. Usually, fibers are not present in large numbers — at most, 10 per filter. Fibers used in apparel are round, but fibers found in water typically have a strip shape, indicating a common source, such as pump packing.

Glass chips are transparent, may have smooth facets with sharp edges, and may be colorful. Relatively large amounts of similar particulates often indicate a problem within a plumbing system. Usually the source of such particulates is disintegrating plastic, a rubber gasket, or a corroding component of the plumbing system.

Heat Identification

Activated carbon particulates are black and usually coated with debris. They can show porosity but appear dull compared to anthracite particulates, which display a shiny luster under reflected light. Pick up a few particulates on the tip of a wetted platinum wire and burn them in the blue part of a Bunsen burner flame. AC particulates will burn instantaneously with a glitter and no visible smoke or residue.

Disintegrated plastic particulates are usually white, large, and may be present in large numbers. Pick up a few particulates and burn them in a Bunsen burner flame. Plastic burns with a smoke. With fine-tipped tweezers, remove sufficient particulates from the disk and further identify them by IR. Most often they are polypropylene plastic. Disintegrated rubber gasket particulates are usually black, relatively large, and do not smear the filter disk with black when a drop of toluene is applied. If pressed with a needle, they flex. Remove a few particulates and burn them; rubber burns with a black smoke. Identify them further by IR. Often these particulates are ethylene-propylene-diene monomer, used in gaskets.

Acid Identification

Rust particulates are usually abundant and are easy to identify with their typically brown and rough irregular shapes. Large particulates may have yellow and black streaks or inclusions, while fine rust particulates form a uniform brown film on the filter disk. To confirm rust, add a drop of (1+1) hydrochloric acid (500 mL of 11.5N hydrochloric acid [**HC**l] solution plus 500 mL of distilled water) to the filter. Yellow staining indicates the presence of ferric chloride. Add a drop of 2 percent solution of potassium thiocyanate on the yellow area where HCl was added. Brick-red staining confirms the presence of potassium ferrithiocyanate.

Large Rust Particles

Lead solder particulates are gray and may have a whitish coating, are usually brittle, and can be easily pulverized. Often, they are relatively large in size compared to most other particulates on the filter disk. If lead particulates are suspected, add a drop of pH 2.8 tartrate-buffer solution followed by a drop of 0.2 percent solution of freshly prepared sodium rhodizonate. If the particulates turn scarlet red, lead solder is present.

Prepare a pH 2.8 buffer solution by dissolving 1.9 g of sodium bitartrate and 1.5 g of tartaric acid in 100 mL of distilled water. To prepare the sodium rhodizonate reagent, dissolve 0.2 g of rhodizonic acid disodium salt in 100 mL of distilled water.

Patina is hydrated basic copper carbonate and has a greenish color. These irregularly shaped particulates result from corrosion of copper and copper alloys. To confirm their presence, add a drop of (1+1) HCl from a Pasture pipette. If tiny bubbles of carbon dioxide form under the microscope, the presence of patina is indicated. Remove a few particulates and place them in the cavity of a spot- test plate. Add a drop of (1+1) HCl followed by a drop of ammonia. Appearance of a blue precipitate or blue color confirms the presence of patina particulates. Rust particulates will interfere with this test if it is performed on the rust-coated filter. Calcium carbonate can develop as a white scale through evaporation of hard water or can occur as a particulate of limestone or calcite. Scales can form in water heaters.

Limestone can come from water treatment processes. Add a drop of HCl (1+1) on the particulates and observe the evolution of carbon dioxide under the microscope. The brisk evolution of gas confirms the presence of carbonates.

Solvent Identification

Asphalt pipe-coating compounds are black. To differentiate between various black particulates, add a drop of toluene or chloroform to the filter disk under the microscope. If the disk becomes smeared with black around the particulates, the particulates are classified as pipe-coating of an asphaltic nature. Anthracite, activated carbon, and rubber particulates are insoluble in the solvents used.

Anthracite particulates appear shiny compared with other black particulates and do not smear the filter disk if a drop of toluene is applied. These particulates can be removed from the filter disk and burned in a crucible; they will leave a solid residue.

Grease particulates are black and may be shiny. They are usually present as tiny heaps on the filter disk because of their softness and hydrophobic nature. They are soft and sticky when touched with a needle and can be smeared easily on the disk. Add a drop of toluene; grease will dissolve and a black color will spread around the particulates.

Let the toluene evaporate or use an oven to expedite drying. Touch the particulates with a needle in the area where toluene was added; they should no longer be sticky and may behave like a black powder. All greases may not behave this way, but their stickiness and extreme softness differentiates them from other black particulates.

Infrared Spectroscopy

When particulates cannot be completely identified by the above means, use IR to identify organic and inorganic materials. Inorganic compounds include calcium carbonate, calcium sulfate, barium sulfate, lead carbonate, metal oxides, silicates, or phosphates. Visually, and with the aid of heat, you might suspect a particulate is plastic in nature, but various types of plastics can occur in water systems, including polypropylene, polyvinyl chloride, and polyethylene. IR can differentiate between plastic materials.

Atoms in a molecule are in constant motion, changing bond angles by bending and bond lengths by stretching. Among these motions only certain vibrations absorb infrared radiation of specific energy. When portions of electromagnetic radiation are absorbed by such vibrations, an IR absorption band spectrum appears, which an infrared spectrometer records.

Each compound has a unique infrared absorption spectrum, and various compounds can be identified by comparing absorption band positions in the IR spectrum of an unknown compound to band positions of known compounds.

Particulates are removed with fine-tipped tweezers one by one from the filter disk and transferred to a small vial for dissolving in a solvent or to a small agate mortar for grinding and mixing with KBr for making a potassium bromide (KBr) pellet. The usually brittle plastic fragments can be powdered easily, and 10 mg of sample is all that is commonly needed to produce a good infrared absorption spectrum. Inorganic materials are identified by IR scanning of the KBr pellet of the sample alone; organic materials are identified by scanning a pellet or a film of the sample cast on a KBr plate.

Zeolite Particles from a Water Softener

Most plastics are readily soluble in hot o-dichlorobenzene; try dissolving the sample in this solvent first. If soluble, cast a film of the sample on a KBr plate and scan it. If the sample is insoluble, evaporate the solvent completely and transfer the particulates to an agate mortar, make a KBr pellet, and scan the pellet. After obtaining a reasonably strong infrared spectrogram, the sample is identified by manual means or a computer search of a commercially available online IR library.

Standard Chemical Analyses

Chemical analyses available in most full-service water testing laboratories can be used to identify particulates when sufficient material is available. For example, hydrated aluminum oxide can occur as white slurry and be analyzed by inductively coupled plasma emission spectrometry after dissolving in mineral acids.

Similarly, granules of lead solder can also be analyzed by wet chemical or instrumental methods. After a sample is dissolved in a mineral acid, it can be analyzed for various elements by atomic absorption spectrophotometry. A variety of materials, including iron oxides, manganese dioxides, aluminum oxides, calcium carbonates, and copper and silicate particulates, can be identified by common chemical analyses.

During the late 1990s, customers in Philadelphia and across the country complained about white particulates clogging faucet aerators. Infrared spectroscopy revealed the particulates to be polypropylene, a plastic not used in the distribution system. The only common source for this plastic was found to be the dip tubes in residential gas hot-water heaters (see Opflow, December 1998).

Eventually, the dip-tube manufacturer admitted to changing materials to a less-durable plastic, prompting water heater manufacturers to give rebates to customers for dip-tube replacements. When this issue made the TV news, Philadelphia was in a good position to explain the situation to customers because our procedure was already in place for testing and characterizing particulates.

Dip Tube Particles

Table 1. Potential sources for particulate matter found in tap water

Particulate	From Customer Plumbing	From Water Supplier Piping
Activated carbon fines		X
Asphaltic lining fragments		X
Backfill sand		X
Calcium carbonate scale	X	X
Cast iron rust		X
Cement lining fragments		X
Copper fragments	X	
Glass chips		X
Greases and lubricants	X	X
Lead fragments	X	
Manganese dioxide deposits		X
Man-made fibers		X
On-site treatment device media		X
Plastic fragments	X	
Rubber gasket fragments	X	X
Soil minerals, mica		X

Table 2. Suspended matter classified by size

Soluble	< 0.45 μm
Colloidal	< 1.0 μm but > 0.45 μm
Particulate	> 1.0 μm

End of Article *by Jameel Rahman and Gary A. Burlingame*

Types of Algae

The simplest algae are single cells (e.g., the **diatoms**); the more complex forms consist of many cells grouped in a spherical colony (e.g., *Volvox*), in a ribbon like filament (e.g., *Spirogyra*), or in a branching thallus form (e.g., *Fucus*).

The cells of the colonies are generally similar, but some are differentiated for reproduction and for other functions.

Kelps, the largest algae, may attain a length of more than 200 ft (61 m). *Euglena* and similar genera are free-swimming one-celled forms that contain chlorophyll but that are also able, under certain conditions, to ingest food in an animal like manner.

The green algae include most of the freshwater forms. The **pond scum**, a green slime found in stagnant water, is a green alga, as is the green film found on the bark of trees. The more complex brown algae and red algae are chiefly saltwater forms; the green color of the chlorophyll is masked by the presence of other pigments. Blue-green algae have been grouped with other prokaryotes in the kingdom **Monera** and renamed **cyanobacteria**.

Pond scum, is an accumulation of floating green **algae** on the surface of stagnant or slowly moving waters, such as ponds and reservoirs. One of the most common forms is *Spirogyra.*

With the exception of the larger Algae -- seaweeds and kelp -- Protoctista are pretty much all microscopic organisms.

- **Green Algae (*Gamophyta* & *Chlorophyta*)**
  - **7000 species**
- **Red Algae (*Rhodophyta*)**
  - **4000 species such as this Coralline Alga (*Calliarthron tuberculosum*)**

Other species include Diatoms (*Bacillariophyta*, 10,000 species) and various Plankton

Major Algae Groups

Blue-green algae are the slimy stuff. Its cells lack nuclei and its pigment is scattered. Blue-green algae are not actually algae, they are bacteria.

Green algae cells have nuclei and the pigment is distinct. Green algae are the most common algae in ponds and can be multicellular.

Euglenoids are green or brown and swim with their flagellum, too. They are easy to spot because of their red eye. Euglenoids are microscopic and single celled.

Dinoflagellates have a flagella and can swim in open waters. They are microscopic and single celled.

Diatoms look like two shells that fit together. They are microscopic and single celled

Common Water Treatment and Distribution Chemicals

Chemical Name	Common Name	Chemical Formula
Aluminum hydroxide		Al(OH)3
Aluminum sulfate	Alum, liquid	AL2(SO4)3 . 14(H2O)
Ammonia		NH3
Ammonium		NH4
Bentonitic clay	Bentonite	
Calcium bicarbonate		Ca(HCO3)2
Calcium carbonate	Limestone	CaCO3
Calcium chloride		CaCl2
Calcium Hypochlorite	HTH	Ca(OCl)2 . 4H2O
Calcium hydroxide	Slaked Lime	Ca(OH)2
Calcium oxide	Unslaked (Quicklime)	CaO
Calcium sulfate	Gypsum	CaSO4
Carbon	Activated Carbon	C
Carbon dioxide		CO2
Carbonic acid		H2CO3
Chlorine gas		Cl2
Chlorine Dioxide		ClO2
Copper sulfate	Blue vitriol	CuSO4 . 5H2O
Dichloramine		NHCl2
Ferric chloride	Iron chloride	FeCl3
Ferric hydroxide		Fe(OH)3
Ferric sulfate	Iron sulfate	Fe2(SO4)3
Ferrous bicarbonate		Fe(HCO3)2
Ferrous hydroxide		Fe(OH)3
Ferrous sulfate	Copperas	FeSO4.7H20
Hydrofluorsilicic acid		H2SiF6
Hydrochloric acid	Muriatic acid	HCl
Hydrogen sulfide		H2S
Hypochlorous acid		HOCL
Magnesium bicarbonate		Mg(HCO3)2
Magnesium carbonate		MgCO3
Magnesium chloride		MgCl2
Magnesium hydroxide		Mg(OH)2
Magnesium dioxide		MgO2
Manganous bicarbonate		Mn(HCO3)2
Manganous sulfate		MnSO4
Monochloramine		NH2Cl
Potassium bicarbonate		KHCO3
Potassium permanganate		KMnO3

Chemical Name	Common Name	Chemical Formula
Sodium carbonate	Soda ash	Na_2CO_3
Sodium chloride	Salt	$NaCl$
Sodium chlorite		$NaClO_2$
Sodium fluoride		NaF
Sodium fluorsilicate		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

Elemental Information

Number	Element	Valence
1	Hydrogen	(-1), +1
2	Helium	0
3	Lithium	+1
4	Beryllium	+2
5	Boron	-3, +3
6	Carbon	(+2), +4
7	Nitrogen	-3, -2, -1, (+1), +2, +3, +4, +5
8	Oxygen	-2
9	Fluorine	-1, (+1)
10	Neon	0
11	Sodium	+1
12	Magnesium	+2
13	Aluminum	+3
14	Silicon	-4, (+2), +4
15	Phosphorus	-3, +1, +3, +5
16	Sulfur	-2, +2, +4, +6
17	Chlorine	-1, +1, (+2), +3, (+4), +5, +7
18	Argon	0
19	Potassium	+1
20	Calcium	+2
21	Scandium	+3
22	Titanium	+2, +3, +4
23	Vanadium	+2, +3, +4, +5
24	Chromium	+2, +3, +6
25	Manganese	+2, (+3), +4, (+6), +7
26	Iron	+2, +3, (+4), (+6)
27	Cobalt	+2, +3, (+4)
28	Nickel	(+1), +2, (+3), (+4)
29	Copper	+1, +2, (+3)
30	Zinc	+2
31	Gallium	(+2). +3
32	Germanium	-4, +2, +4
33	Arsenic	-3, (+2), +3, +5
34	Selenium	-2, (+2), +4, +6
35	Bromine	-1, +1, (+3), (+4), +5
36	Krypton	0
37	Rubidium	+1
38	Strontium	+2
39	Yttrium	+3
40	Zirconium	(+2), (+3), +4
41	Niobium	(+2), +3, (+4), +5
42	Molybdenum	(+2), +3, (+4), (+5), +6
43	Technetium	+6
44	Rubidium	(+2), +3, +4, (+6), (+7), +8
45	Rhodium	(+2), (+3), +4, (+6)
46	Palladium	+2, +4, (+6)
47	Silver	+1, (+2), (+3)
48	Cadmium	(+1), +2
49	Indium	(+1), (+2), +3
50	Tin	+2, +4
51	Antimony	-3, +3, (+4), +5
52	Tellurium	-2, (+2), +4, +6
53	Iodine	-1, +1, (+3), (+4), +5, +7

54	Xenon	0
55	Cesium	+1
56	Barium	+2
57	Lanthanum	+3
58	Cerium	+3, +4
59	Praseodymium	+3
60	Neodymium	+3, +4
61	Promethium	+3
62	Samarium	(+2), +3
63	Europium	(+2), +3
64	Gadolinium	+3
65	Terbium	+3, +4
66	Dysprosium	+3
67	Holmium	+3
68	Erbium	+3
69	Thulium	(+2), +3
70	Ytterbium	(+2), +3
71	Lutetium	+3
72	Hafnium	+4
73	Tantalum	(+3), (+4), +5
74	Tungsten	(+2), (+3), (+4), (+5), +6
75	Rhenium	(-1), (+1), +2, (+3), +4, (+5), +6, +7
76	Osmium	(+2), +3, +4, +6, +8
77	Iridium	(+1), (+2), +3, +4, +6
78	Platinum	(+1), +2, (+3), +4, +6
79	Gold	+1, (+2), +3
80	Mercury	+1, +2
81	Thallium	+1, (+2), +3
82	Lead	+2, +4
83	Bismuth	(-3), (+2), +3, (+4), (+5)
84	Polonium	(-2), +2, +4, (+6)
85	Astatine	?
86	Radon	0
87	Francium	?
88	Radium	+2
89	Actinium	+3
90	Thorium	+4
91	Protactinium	+5
92	Uranium	(+2), +3, +4, (+5), +6

Reference: *Lange's Handbook of Chemistry, 8th Ed.*, Norbert A. Lange (Ed.), Handbook Publishers, Inc. 1952.

Common Used Products	Chemical Name
acetone	dimethyl ketone
acid of sugar	oxalic acid
alcohol, grain	ethyl alcohol
alcohol, wood	methyl alcohol
alum	aluminum potassium sulfate
alumina	aluminum oxide
antichlor	sodium thiosulfate
aqua ammonia	aqueous solution of ammonium hydroxide
aqua regia	nitrohydrochloric acid
aqua fortis	nitric acid
aromatic spirit of ammonia	ammonia in alcohol
asbestos	magnesium silicate
aspirin	acetylsalicylic acid
baking soda	sodium bicarbonate
banana oil (artificial)	isoamyl acetate
benzol	benzene
bichloride of mercury	mercuric chloride
black copper oxide	cupric oxide
black lead	graphite (carbon)
bleaching powder	chlorinated lime
blue vitriol	copper sulfate
bluestone	copper sulfate
borax	sodium borate
brimstone	sulfur
brine	aqueous sodium chloride solution
butter of antimony	antimony trichloride
butter of tin	anhydrous stannic chloride
calomel	mercury chloride
carbolic acid	phenol
carbonic acid gas	carbon dioxide
caustic potash	potassium hydroxide
caustic soda	sodium hydroxide
chalk	calcium carbonate
Chile saltpeter	sodium nitrate
chrome, alum	chromic potassium sulfate
chrome, yellow	lead (VI) chromate
copperas	ferrous sulfate
cream of tartar	potassium bitartrate
crocus powder	ferric oxide
emery powder	impure aluminum oxide
Epsom salts	magnesium sulfate
ethanol	ethyl alcohol
fluorspar	natural calcium fluoride
formalin	aqueous formaldehyde solution
French chalk	natural magnesium silicate
galena	natural lead sulfide
Glauber's salt	sodium sulfate
gypsum	natural calcium sulfate
hydrocyanic acid	hydrogen cynanide
hypo (photography)	sodium thiosulfate solution
lime	calcium oxide

Common Used Products	Chemical Name
limewater	aqueous solution of calcium hydroxide
lunar caustic	silver nitrate
magnesia	magnesium oxide
mercury oxide, black	mercurous oxide
methanol	methyl alcohol
methylated spirits	methyl alcohol
muriatic acid	hydrochloric acid
oil of vitriol	sulfuric acid
oil of wintergreen (artificial)	methyl salicylate
Paris green	copper acetoarsenite
Paris white	powdered calcium carbonate
pear oil (artificial)	isoamyl acetate
pearl ash	potassium carbonate
plaster of Paris	calcium sulfate
plumbago	graphite
potash	potassium carbonate
potassa	potassium hydroxide
Prussic acid	hydrogen cyanide
pyro	tetrasodium pyrophosphate
quicklime	calcium oxide
quicksilver	mercury
red lead	lead tetraoxide
Rochelle salt	potassium sodium tartrate
rouge, jeweler's	ferric oxide
rubbing alcohol	isopropyl alcohol
sal ammoniac	ammonium chloride
sal soda	sodium carbonate
salt, table	sodium chloride
salt of lemon	potassium binoxalate
salt of tartar	potassium carbonate
saltpeter	potassium nitrate
silica	silicon dioxide
soda ash	sodium carbonate
soda lye	sodium hydroxide
soluble glass	sodium silicate
spirit of hartshorn	ammonium hydroxide solution
sugar, table	sucrose
talc or talcum	magnesium silicate
vinegar	impure dilute acetic acid
vitamin C	ascorbic acid
washing soda	sodium carbonate
water glass	sodium silicate

Jar Test Section

Jar testing, to determine the proper coagulant dosage, continues to be one of the most effective tools available to surface water plant operators. Finished water quality, cost of production, length of filter runs and overall filter life all depend on the proper application of chemicals to the raw water entering the treatment plant.

Before You Start

The jar test, as with any coagulant test, will only provide accurate results when properly performed. Because the jar test is intended to simulate conditions in your plant, developing the proper procedure is very important. Take time to observe what happens to the raw water in your plant after the chemicals have been added, then simulate this during the jar test. **THE RPM OF THE STIRRER AND THE MINUTES TO COMPLETE THE TEST DEPEND ON CONDITIONS IN YOUR PLANT.** If, for instance, your plant does not have a static or flash mixer, starting the test at high rpm would provide misleading results. This rule applies to flocculator speed, length of settling time and floc development. Again, operate the jar test to simulate conditions in **YOUR** plant.

1. Scope

1.1 This practice covers a general procedure for the evaluation of a treatment to reduce dissolved, suspended, colloidal, and nonsettleable matter from water by chemical coagulation-flocculation, followed by gravity settling. The procedure may be used to evaluate color, turbidity, and hardness reduction.

1.2 The practice provides a systematic evaluation of the variables normally encountered in the coagulation-flocculation process.

1.3 This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Terms **Great information for your assignment**

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.

Turbidity

Particles less about 1 to 10 μm in diameter (primarily colloidal particles) will not settle out by gravitational forces, therefore making them very difficult to remove. These particles are the primary contributors to the turbidity of the raw water causing it to be ***"cloudy".*** The most important factor(s) contributing to the stability of colloidal particles is not their mass, but their surface properties.

This idea can be better understood by relating the colloidal particles' large surface area to their small volume (**S/V**) ratio resulting from their very small size. In order to remove these small particles we must either filter the water or somehow incorporate gravitational forces such that these particles will *settle* out. In order to have gravity affect these particles, we must somehow make them larger, somehow have them come together (agglomerate); in other words, somehow make them ***"stick"*** together, thereby increasing their size and mass.

The two primary forces that control whether or not colloidal particles will agglomerate are:

Repulsive force

An electrostatic force called the **"Zeta Potential"** -

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

Where:

ζ = Zeta Potential
q = charge per unit area of the particle
d = thickness of the layer surrounding the shear surface through which the charge is effective
D = dielectric constant of the liquid

Attractive force

Force due to van der Waals forces

van der Waals forces are weak forces based on a polar characteristic induced by neighboring molecules.

When two or more nonpolar molecules, such as He, Ar, H_2, are in close proximity, the nucleus of each atom will weakly attract electrons in the counter atom resulting, at least momentarily, in an asymmetrical arrangement of the nucleus.

This force, van der Waals force, is inversely proportional to the sixth power of the distance ($1/d^6$) between the particles.

As can clearly be seen from this relationship, decay of this force occurs exponentially with distance.

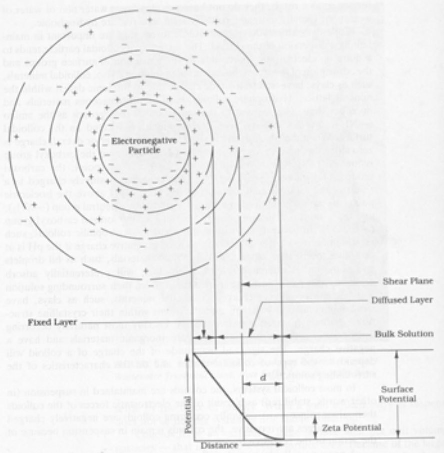


FIGURE 8.3 *A Negative Colloidal Particle with Its Electrostatic Field*

Adapted with permission from "A Theory of Coagulation Useful for Design" by C. P. Priesing. In *Industrial and Engineering Chemistry* 54, no. 8 (August 1962): 38. Copyright 1962, American Chemical Society.

Ways to Measure Turbidity

1.) Jackson Candle Test
2.) Secchi Disk - a black and white disk divided like a pie in 4 quadrants about 6" in diameter.
3.) Turbidimeter - Light is passed through a sample. A sensitive photomultiplier tube at a 90° angle from the incident light beam detects the light scattered by the particles in the sample. The photomultiplier tube converts the light energy into an electrical signal, which is amplified and displayed on the instrument.
    a.) *Units* - Nephelometric Turbidity Unit (**NTU**) or Formazin Turbidity Unit (**FTU**).

How to Treat Turbidity

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

By introducing aluminum (Al^{3+}) into the water in the form of Alum ($Al_2(SO_4)_3 \bullet nH_20$) we can accomplish the supercharging of the water. This is the *coagulation* part of the coagulation/flocculation process; flocculation follows coagulation. During the *flocculation* process the particles join together to form flocs; the larger the flocs, the faster they will settle within a clarifier.

Other chemical coagulants used are Ferric Chloride and Ferrous Sulfate. Alum works best in the pH range of natural waters, 5.0 - 7.5. Ferric Chloride works best at lower pH values, down to pH 4.5. Ferrous Sulfate works well in through a range of pH values, 4.5 to 9.5.

During the coagulation process charged hydroxy-metallic complexes are formed momentarily (i.e. $Al(OH)^{2+}$, $Al(OH)_2^{1+}$ etc). Theses complexes are charged highly positive and therefore upset the stable negative charge of the target particles, thereby momentarily displacing the water layer surrounding the charged particle. This upset decreases the distance “d,” in turn decreasing the Zeta potential.

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

If too much alum is added, then the opposite effect occurs--the particles form sub complexes with the Al^{+3} and gain a positive charge about them, and the particles re-stabilize.

The final key to obtaining good flocs is the added energy put into the system by way of rotating paddles in the flocculator tanks. By ***“pushing”*** (adding energy) the particles together we can aid in the flocculation process, forming larger flocs.

It important to understand that too much energy, i.e. rotating the paddles too fast, would cause the particles to shear (breakup), thereby reducing the size of the particles and increasing the settling time in the clarifier.

Key Equations

$$Al_2(SO_4)_3 \bullet 14.3H_2O + 6H_2O \rightarrow 2Al(OH)_3(s) + 14.3H_2O + 3H_2SO_4 \qquad (2)$$

$$Al_2(SO_4)_3 \bullet 14.3H_2O + 6Na(HCO_3) \rightarrow 2Al(OH)_3(s) + 3Na_2SO_4 + 14.3H_2O + 6CO_2 \qquad (3)$$

$$Al_2(SO_4)_3 \bullet 14.3H_2O + 6Na(OH) \rightarrow 2Al(OH)_3(s) + 3Na_2SO_4 + 14.3H_2O \qquad (4)$$

Apparatus

1) Jar Test Apparatus
2) 6 1500 mL Beakers
3) pH meter
4) Pipettes
5) Conductivity Meter
6) Turbidimeter

Procedure

1) Make up a 10-g/L solution of alum.
2) Make up a 0.1 N solution of NaOH (buffer). (Na^{+1} = 23 mg/mmol, O^{-2} = 16 mg/mmol, H^{+} = 1 mg/mmol)
3) Fill each of the six 1500 mL beakers with one-liter of river water.
4) Measure the temperature and conductivity.
5) Measure the initial pH
6) Add alum and NaOH solutions in equal portions as specified by instructor.
7) Mixing protocol:
    a. rapid mix - 1 minute (100 rpm)
    b. slow mix - 15 minutes (20 rpm)
    c. off, settling - 30 minutes
8) Measure final turbidity. Take the sample from the center, about 2" down for each one liter sample. Be careful not to disturb the flocs that have settled.
9) Measure final pH

Information to be Recorded

Initial Turbidity = ? NTU Alum - g/L Buffer - 0.1 N

Beaker	Alum (ml)	Buffer (ml)	Turbidity (NTU)	pH-Before	pH-After	Temp. °C

Preparing Polymers for the Jar Test

A successful Jar Test is very reliant upon the proper preparation of the polymers being tested. Dilution technique ***("make down")*** is especially critical, since it involves compactly coiled large molecules in emulsions, prior to activation. The polymer must be uncoiled to provide maximum contact with the colloidal particles to be flocculated. If the following procedures are not followed, the Jar Test results will be very unreliable.

Required Equipment:

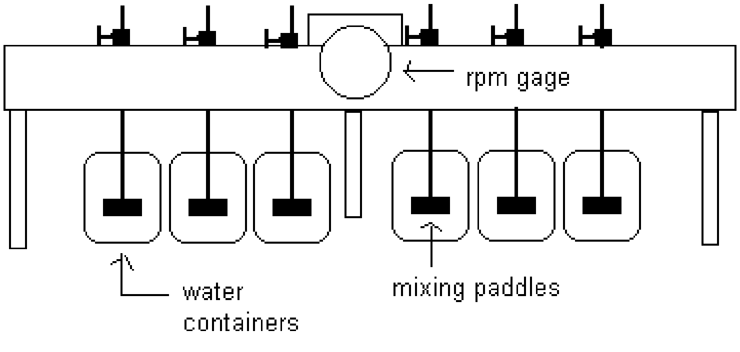
1. 250 mL bottles with lids.
2. High speed hand mixer (for emulsion polymers).
3. Syringes (1cc, 5cc, 10cc).
4. 250 and 500 mL beakers.
5. Water (it is recommended that the makedown water from the plant be used).
6. Graduated cylinder (100 mL).

Emulsion Polymers (Prepare 1.0% solution.)

1. Add 198 mL of water to a beaker.
2. Insert Braun mixer into water and begin mixing.
3. Using a syringe, inject 2 mL of neat polymer into vortex.
4. Mix for 20 seconds. Do not exceed 20 seconds!
5. Allow dilute polymer to age for at least 20 minutes, but preferably overnight. Prepare 0.1% solution.
6. Add 180 mL of water to 250 mL bottle.
7. Add 20 mL of 1.0% polymer solution.
8. Shake vigorously for at least one minute.

Solution Polymers and Inorganics (Prepare a 1.0% solution.)

1. Add 198 mL of water to 250 mL bottle.
2. Using a syringe, add 2 mL of neat product to bottle.
3. Shake vigorously for at least 1 minute.
4. Prepare 0.1% solution.
5. Add 180 mL to 250 mL bottle.
6. Add 20 mL of 1 % solution.
7. Shake vigorously for at least one minute.



Potassium Permanganate Jar Test

Potassium Permanganate has been used for a number of years in both water & wastewater treatment. KMn04 is a strong oxidizer which can be used to destroy many organic compounds of both the natural and man made origin. KMn04 is also used to oxidize iron, manganese and sulfide compounds and other taste and odor producing substances usually due to the presence of very small quantities of secretions given off by microscopic algae, which develop on the surface waters and on beds of lakes and rivers under certain conditions of temperature and chemical composition.

KMn04 must be used with caution, as this material produces an intense purple color when mixed with water. As the permanganate ion is reduced during its reaction with compounds that it oxidizes, it changes color from purple to yellow or brown. The final product formed is manganese dioxide (**Mn02**), an insoluble precipitate that can be removed by sedimentation and filtration.

I must caution you that all KMn04 applied must be converted to manganese dioxide (Mn02) prior to filtration. If it is not all converted and is still purple or pink it will pass through the filter into the clearwell or distribution system. This may cause the customer to find pink tap water, or the reaction may continue in the system and the same conditions as exist with naturally occurring manganese may cause staining of the plumbing fixtures.

Stock Solutions
(Strong Stock Solution)
5 grams potassium permanganate dissolved in 500 ml distilled water.
(Test Stock Solution)
4 ml strong stock solution thoroughly mixed in 100 ml distilled water.
Each 5 ml of the test stock solution added to a 2000 ml sample equals 1 mg/l.

Jar Testing Example
If you have a six position stirrer:
Using a graduated cylinder, measure 2000 ml of the sample to be tested into each of the six beakers. Dose each beaker to simulate plant practices in pre-treatment, pH adjustment, coagulant,- etc. Do not add carbon or chlorine. Using a graduated pipette, dose each beaker with the test stock solution in the following manner.

Jar #	KMn04 ml	KMn04 mg/l	Color
1	0.50	0.10	no pink
2	0.75	0.15	no pink
3	1.00	0.20	no pink
4	1.25	0.25	no pink
5	1.50	0.30	pink
6	1.75	0.35	pink

Stir the beakers to simulate the turbulence where the KMn04 is to be added and observe the color change.

As the iron and manganese begin to oxidize, the sample will turn varying shades of brown, indicating the presence of oxidized iron and or manganese. Samples which retain a brown or yellow color indicate that the oxidation process is incomplete and will require a higher dosage of KMn04.

The end point has been reached when a pink color is observed and remains for at least 10 minutes. In the preceding table a pink color first developed in beaker #5 which had been dosed with 1.5 ml/ 0.3 mg/l. If the first jar test does not produce the correct color change, continue with increased dosages.

When applying potassium permanganate to raw water, care must be taken not to bring pink water to the filter unless you have "***greensand***". Also, permanganate generally reacts more quickly at pH levels above 7.0.

Quick Test
A quick way to check the success of a KMn04 application is by adding 1.25 ml of the test stock solution to 1000 ml finished water. If the sample turns brown there is iron or manganese remaining in the finished water. If the sample remains pink, oxidation is complete.

With proper application, potassium permanganate is an extremely useful chemical treatment.

As well as being a strong oxidizer for iron and manganese, KMn04 used as a disinfectant in pre-treatment could help control the formation of trihalomethanes by allowing chlorine to be added later in the treatment process or after filtration. Its usefulness also extends to algae control as well as many taste odor problems.

To calculate the dosage of KMn04 for iron and manganese removal here is the formula to use.

KMn04 Dose, mg/l = 0.6(iron, mg/l) + 2.0(Manganese, mg/l)

Example:
Calculate the KMn04 dose in mg/l for a water with 0.4 of iron. The manganese concentration is 1.2 mg/l.

Known Unknown
Iron, mg/l = 0.4 mg/l Kmn04 Dose, mg/l
Manganese, mg/l = 1.2 mg/l

Calculate the KMn04 dose in mg/l.

KMn04 Dose, mg/l = 0.6(Iron, mg/l) + 2.0(Manganese, mg/l)
= 0.6(0.4 mg/l) + 2.0(1.2 mg/l)
= 2.64 mg/l

Note: The calculated 2.64 mg/l KMn04 dose is the minimum dose. This dose assumes there are no oxidizable compounds in the raw water. Therefore, the actual dose may be higher. Jar testing should be done to determine the required dose.

Alkalinity

Introduction

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

Alkalinity 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 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.

Titration Method

a. Principle

Hydroxyl ions present in a sample as a result of dissociation or hydrolysis of solutes react with additions of standard acid. Alkalinity thus depends on the end-point pH used.

b. Reagents

i) Standard Hydrochloric Acid – 0.02 N.
ii) Methyl Orange Indicator – Dissolve 0.1 g of methyl orange in distilled water and dilute to 1 liter.
iii) Sodium carbonate solution, 0.02 N : Dry 3 to 5 g primary standard Na_2CO_3 at 250°C for 4 h and cool in a desiccator. Weigh 1.03 gm.
(to the nearest mg), transfer to a 1-L volumetric flask, fill flask to the mark with distilled water, and dissolve and mix reagent. Do no keep longer than 1 week.

c. Procedure

Titrate over a white surface 100 ml of the sample contained in a 250-ml conical flask with standard hydrochloric acid using two or three drops of methyl orange Indicator.
(**NOTE** – If more than 30 ml of acid is required for the titration, a smaller suitable aliquot of the sample shall be taken.)

d. Calculation

Total alkalinity (as $CaCO_3$), mg/l = 10 V or

$$\text{T.A. (as } CaCO_3) = \frac{N x V x 50 x 1000}{\text{Sample Amount}}$$

Where N = Normality of HCl used
V = volume in ml of standard hydrochloric acid used in the titration.

Alkalinity to Phenolphthalein

The sample is titrated against standard acid using phenolphthalein indicator.

a. Reagents

i) Phenolphthalein Indicator Solution :
Dissolve 0.1 g of phenolphthalein in 60 ml of ETHANOL and dilute with Distilled water to 100 ml.
ii) Standard hydrochloric Acid – 0.02 N.

b. Procedure

Add 2 drops of phenolphthalein indicator solution to a sample of suitable size, 50 or 100 ml, in a conical flask and titrate over a while surface with standard hydrochloric acid.

c. Calculation

Alkalinity to phenolphthalein (as $CaCO_3$), mg/l $= \dfrac{1000\ V_1}{V_2}$

Where
V_1 = volume in ml of standard hydrochloric acid used in the titration , and
V_2 = Volume in ml of the sample taken for the test.

Caustic Alkalinity
a. General
Caustic alkalinity is the alkalinity corresponding to the hydroxides present in water and is calculated from total alkalinity (T) and alkalinity to phenolphthalein (P).

b. Procedure Determine total alkalinity and alkalinity to phenolphthalein and calculate caustic alkalinity as shown in Table below. Result of Titration Caustic Alkalinity or Hydroxide Alkalinity as $CaCO_3$ Carbonate Alkalinity as $CaCO_3$ Bicarbonate Concentration as $CaCO_3$ **Result of Titration**	**Caustic Alkalinity or Hydroxide Alkalinity as $CaCO_3$**	**Carbonate Alkalinity as $CaCO_3$**	**Bicarbonate Concentration as $CaCO_3$**
P=0	0	0	0
P<1/2T	0	2P	T-2P
P=1/2T	0	2P	0
P>1/2T	2P-T	2(T-P)	0
P=T	T	0	0

The alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity of natural water is due to the salts of carbonate, bicarbonate, borates, silicates and phosphates along with the hydroxyl ions in free state. However the major portion of the alkalinity in natural waters is caused by hydroxide, carbonate and bicarbonates which may be ranked in order of their association with high pH values. Alkalinity values provide guidance in applying proper doses of chemicals in water and waste water treatment processes, particularly in coagulation and softening.

Alkalinity (total)

References: ASTM D 1067-92, Acidity or Alkalinity of Water.
APHA Standard Methods, 19th ed., p. 2-26, method 2320B (1995).
EPA Methods for Chemical Analysis of Water and Wastes, method 310.1 (1983).

The alkalinity of water is a measurement of its buffering capacity or ability to react with strong acids to a designated pH. Alkalinity of natural waters is typically a combination of bicarbonate, carbonate and hydroxide ions. Sewage and wastewaters usually exhibit higher alkalinities either due to the presence of silicates and phosphates or to a concentration of the ions from natural waters.

Alkalinity inhibits corrosion in boiler and cooling waters and is therefore a desired quality which must be maintained. It is also measured as a means of controlling water and wastewater treatment processes or the quality of various process waters. In natural waters, excessive alkalinity can render water unsuitable for irrigation purposes and may indicate the presence of industrial effluents. The Titrimetric Method. CHEMetrics' tests determine total or "M" alkalinity using an acid titrant and a pH indicator. The end point of the titration occurs at pH 4.5. Results are expressed as ppm (mg/L) CaCO3.

Hardness (calcium)

Reference: West, T. S., DSC, Ph.D., Complexometry with EDTA and Related Reagents, 3rd ed., p. 46, 164 (1969).

Originally described as water's capacity to precipitate soap, hardness is one of the most frequently determined qualities of water. It is a composite of the calcium, magnesium, strontium and barium concentrations in a sample. The current practice is to assume total hardness refers to the calcium and magnesium concentrations only.

Completely dehardened water, resulting from sodium zeolite or other suitable ion exchange treatment, is required for various processes-including power generation, printing and photo finishing, pulp and paper manufacturing, and food and beverage processing. Hard water can cause scale formation on heat exchange surfaces, resulting in decreased heat transfer and equipment damage.

The Titrimetric Method. This method is specific for calcium hardness. The EGTA titrant in alkaline solution is employed with zincon indicator. Results are expressed as ppm (mg/L) CaCO3.

Shelf-life. 8 months. Although the reagent itself is stable, the end point indicator has a limited shelf-life. We recommend stocking quantities that will be used within 7 months.

Hardness (total)

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

For a discussion of hardness, see Hardness (calcium).
The colorimetric method is applicable to monitoring boiler feedwater and other industrial waters. The titrimetric method is applicable to drinking, surface, and brine waters. The Colorimetric Method. CHEMetrics developed the sensitive Calcichrome reagent, which is a dark purple color. It reacts to form a light purple color at the lower end of the range, and forms a light blue color at the end of the range. Results are expressed as ppm (mg/L) or ppb (µg/L) CaCO3.

The Titrimetric Method. The EDTA titrant is employed in alkaline solution with a calmagite indicator. This method determines the combined calcium and magnesium concentration of a sample. If no magnesium is present, the end point of the titration normally appears sluggish. However, the reagent has been specially formulated to ensure a sharp end point regardless of the presence of magnesium. Results are expressed as ppm (mg/L) CaCO3.

Iron (total)

Reference: J. A. Tetlow and A. L. Wilson, "Determination of Iron in Boiler Feedwater", Analyst, 1958. See discussion under Iron (total & soluble). CHEMetrics' colorimetric method for determining total iron uses thioglycolic acid to dissolve particulate iron and to reduce any iron from the ferric to the ferrous state. Ferrous iron then reacts with PDTS in acid solution to form a purple-colored chelate. Results are expressed as ppm (mg/L) Fe.

Manganese

Reference: APHA Standard Methods, 14th ed., p. 227, method 314C (1975).
Surface and ground waters rarely contain more than 1 mg/L of soluble or suspended manganese. Manganese can act as an oxidizing or reducing agent depending on its valence state. In various forms, it is used as a pigment or a bleaching agent. Manganese concentrations in potable water should not exceed 0.05 mg/L. Concentrations greater than 0.1 mg/L will impart a foul taste to water and discolor laundry and porcelain surfaces. Levels higher than 1 mg/l in surface waters can result from mining operations or excessive discharging from domestic waste treatment facilities or industrial plants.

The Colorimetric Method.
CHEMetrics' tests measure soluble manganese compounds but do not differentiate the various valence states. Manganese is oxidized in the presence of periodate to form a deep-red reaction product. Reducing agents will interfere. Results are expressed as ppm (mg/L) Mn.

Fluorides

Fluoride ions have dual significance in water supplies. High concentration of F- causes dental fluorisis (disfigurement of the teeth). At the same time, a concentration less than 0.8 mg/l results in `dental caries'. Hence it is essential to maintain the F- conc. between 0.8 to 1.0 mg/L in drinking water. Among the many methods suggested for the determination of fluoride ion in water, the colormetric method (SPADNS) & the ion selective electrode method are the most satisfactory and applicable to variety of samples. Because all of the colorimetric methods are subject to errors due to the presence of interfering ions, it may be necessary to distill the sample before making the fluoride estimation while addition of the prescribed buffer frees the electrode method from the interference caused by such relatively common ions as aluminum hexametaphosphate and orthophosphate which adversely affect the colorimetric methods. However, samples containing fluoroborate ion (BF_4) must be subject to a preliminary distillation step in either of the methods. Both the methods and the preliminary distillation step are discussed below.

1. SPADNS METHOD

Principle:
Under acid condition fluorides (**HF**) react with zirconium SPADNS solution and the `Lake' (color of SPADNS reagent) gets bleached due to formation of ZrF_6. Since bleaching is a function of fluoride ions, it is directly proportional to the concentration of F. It obeys Beer's law in a reverse manner.

Interference
Alkalinity 5000 mg/L, aluminum 0.1 mg/L, chlorides 7000 mg/L, Fe 10 mg/L, PO_4 16 mg/L, SO_4 200 mg/L, and hexametaphosphate 1.0 mg/L interfere in the bleaching action. In presence of interfering radicals distillation of sample is recommended.

Apparatus
1. Distillation apparatus (as shown in the Fig. 3)
2. Colorimeter for use at 570 nm.
3. Nessler's tubes cap. 100 ml.

Reagents
1. Sulphuric acid H_2SO_4 concentration.
2. Silver Sulfate Ag_2SO_4 crystals.
3. SPADNS solution : Dissolve 958 mg SPADNS and dilute to 500 ml.
4. Ziroconyl acid reagent : Dissolve 133 mg $ZrOCl_2$ $8H_2O$ in 25 ml water. Add 350 ml. conc. HCl and dilute to 500 ml.
5. Mix equal volume of 3 and 4 to produce a single reagent. Protect from direct light.
6. **Reference solution:** Add 10 ml SPADNS solution to 100 ml distilled water. Dilute 7 ml concentration HCl to 10 ml and add to diluted SPADNS solution.
7. **Sodium arsenite solution:** Dissolve 5.0 g $NaAsO_2$ and dilute to 1000 ml.
8. **Stock F- solution:** Dissolve 221.0 mg anhydrous NaF and dilute to 1000 ml. 1 ml = 100 mg F-.
9. **Standard F :** Dilute stock solution 10 times to obtain 1 ml = 10mg F.

A. Preliminary Distillation Step
Place 400 ml distilled water in the distilling flask and carefully add 200 ml conc. H_2SO_4. Swirl until the flask contents are homogenous, add 25 to 30 glass beads and connect the apparatus as shown in Fig 1. Begin heating slowly at first and then rapidly until the temperature of the flask reaches exactly 180°C. Discard the distillate. This process removes fluoride contamination and adjusts the acid-water ratio for subsequent distillations.
After cooling, the acid mixture remaining after above step or previous distillation to 120°C or below add 300 ml of sample, mix thoroughly, and distill as before until the temperature reaches 180°C. Do not

heat above 180°C to prevent Sulfate carryover.
Add Ag_2SO_4 to distilling flask at the rate of 5 mg/mg Cl when high chloride samples are distilled. Use the sulphuric acid solution in the flask repeatedly until the contaminants from the samples accumulate to such an extent that recovery is affected or interferences appear in the distillate. After the distillation of high fluoride samples, flush the still with 300 ml. distilled water and combine the two fluoride distillates. After periods of inactivity, similarly flush the still, discard the distillate.

B. Procedure
1. Prepare standard curve in the range 0.0 to 1.40 mg/L by diluting appropriate volume of standard F solution to 50 ml in Nessler's tubes.
2. Add 10.0 mL mixed reagent prepared as in 5 above to all the samples, mix well and read optical density of bleached colour at 570 nm using reference solution for setting zero absorbance.
3. Plot conc. Vs % transmission or absorbance.
4. If sample contains residual chlorine remove it by adding 1 drop (0.05ml) NaAsO2 solution 0.1 mg Cl_2 and mix. $NaAsO_2$ conc. should not exceed 1300 mg/L to avoid error due to $NaAsO_2$. Take suitable aliquot & dilute it to 50 mL.
5. Add acid Zirconyl - SPADNS reagent 10 ml; Mix well and read % transmission or absorbance.
6. Take suitable aliquots of sample either direct or after distillation in Nessler's tubes Follow the step 5.
7. Calculate the mg F present in the sample using standard curve.

2. Ion Selective Electrode Method
Principle
The fluoride sensitive electrode is of the solid state type, consisting of a lanthanum fluoride crystal; in use it forms a cell in combination with a reference electrode, normally the calomel electrode. The crystal contacts the sample solution at one face and an internal reference solution at the other. A potential is established by the presence of fluoride ions across the crystal which is measured by a device called ion meter or by an moder pH meter having an expanded millivolt scale.

The fluoride ion selective electrode can be used to measure the activity or concentration of fluoride in an aqueous sample by use of an appropriate calibration curve. However, fluoride activity depends on the total ionic strength of the sample. The electrode does not respond to bound or complex fluoride. Addition of a buffer solution of high total ionic strength containing a chelate to complex aluminum preferentially overcomes these difficulties.

Interference
Polyvalent cations such as Al (III), Fe (III) and Si (IV) will complex fluoride ions. However the addition of CDTA (Cyclohexylene diamine tetra acetic acid) preferentially will complex concentrations of aluminum up to 5 mg/L. Hydrogen ion forms complex with fluoride while hydroxide ion interferes with electrode response. By adjusting the pH between 5 to 8 no interference occurs.

Apparatus
1. Ion meter (field / laboratory model) or pH/mV meter for precision laboratory measurements.
2. Reference electrode (calomel electrode)
3. Fluoride sensitive electrode.
4. Magnetic stirrer.
5. Plastic labware (Samples and standards always be stored in plastic containers as fluoride reacts with glass).

Reagents
1. Standard fluoride solution prepared as directed in SPADNS method.
2. Total Ionic strength adjustment buffer (TISAB).

Place approximately 500 ml distilled water in a 1 - L beaker add 57 mL glacial acetic acid, 58 gm NaCl and 4.0 gm 1, 2 cyclohexylene diamine tetraacetic acid. Stir to dissolve. Place beaker in a cool water bath and add slowly 6 N NaOH (About 125 ml) with stirring, until pH is between 5 and 5.5. Transfer to a 1 - L volumetric flask and make up the volume to the mark.

Procedure

1. For connecting the electrodes to meter, and for further operation of the instrument, follow the instruction manual supplied by the manufacturer.
2. Check the electrode slope with the ion meter (59.16 mV for monovalent ions and 29.58 mV for diavalent ions at 25°C)
3. Take 50 ml of each 1 ppm and 10 ppm fluoride standard. Add 50 ml TISAB (or 5 ml if conc. TISAB is used) and calibrate the instrument.
4. Transfer 50 to 100 ml of sample to a 150 ml plastic beaker. Add TISAB as mentioned in (3).
5. Rinse electrode, blot dry and place in the sample. Stir thoroughly and note down the steady reading on the meter.
6. Recalibrate every 1 or 2 hours.
7. Direct measurement is a simple procedure for measuring a large number of samples. The temperature of samples and standard should be the same and the ionic strength of standard and samples should be made the same by addition of TISAB to all solutions.
8. Direct measurement results can be verified by a known addition procedure. The known addition procedure involves adding a standard of known concentration to a sample solution. From the change in electrode potential before and after addition, the original sample concentration is determined.

Fluoride SPADNS Method

References:
APHA Standard Methods, 20th ed., p. 4-82, method 1500 F-(1998).
EPA Methods for Chemical Analysis of Water and Wastes, method 340.1 (1974,1978).
Thomas and Chamberlain, 1974, Colorimetric Analytical Methods, pp 186-193.

The Fluoride Vacu-vials® test method is based on the reaction between fluoride and a red zirconium-dye lake that has been formed with SPADNS. The loss of color resulting from the reaction of the fluoride with the dye lake is a function of the fluoride concentration. Results are expressed in ppm (mg/Liter) F-.

This method is approved by the EPA for NPDES and NPDWR reporting purposes when the samples have been distilled from an acid solution. Seawater and wastewater samples must be pre-distilled. Distillation removes most contaminating interferences except chlorine. Sodium Arsenite has been added to remove up to 5 mg/L chlorine.

Hydrofluorsilicic Acid Tanks

Oxygen (dissolved)

References: Indigo Carmine--ASTM D 888-87, Colorimetric Indigo Carmine, Test Method A.

Gilbert, T.W., Behymer, T.D., Castaneda, H.B., "Determination of Dissolved Oxygen in Natural and Wastewaters," *American Laboratory*, March 1982, pp. 119-134.
Rhodazine D method--(Method developed by CHEMetrics, Inc.) Power Plant Manual, First ed., p. 169 (1984).

ASTM D 5543-94, Standard Test Methods for Low Level Dissolved Oxygen in Water.
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. Waste treatment plants which employ aerobic digestion must maintain a level of at least 2 ppm dissolved oxygen. This is usually accomplished by mechanical aeration.

At elevated temperatures, oxygen is highly corrosive to metals, causing ***"pitting"*** in ferrous systems such as high-pressure boilers and deep well oil recovery equipment. To prevent costly corrosion damage, the liquids in contact with the metal surfaces must be treated, usually by a combination of physical and chemical means. De-aeration can reduce the dissolved oxygen concentration of boiler feedwater from several ppm to a few ppb. Chemical reducing agents such as hydrazine or sodium sulfite are sometimes used instead of de-aeration, but more often are used to react with residual oxygen which remains after the de-aeration process.

The Colorimetric Methods. Test kits for environmental and drinking water applications (ppm range) employ the indigo carmine method. The reduced form of indigo carmine reacts with D.O. to form a blue product. The indigo carmine methodology is not subject to interferences from temperature, salinity or dissolved gases such as sulfide, which plague users of D.O. meters. Results are expressed as ppm (mg/L) O2.

Test kits for boiler waters and applications requiring trace levels of D.O. (ppb range) employ the Rhodazine D methodology. Developed by CHEMetrics, Inc., the Rhodazine D compound in reduced form reacts with dissolved oxygen to form a bright pink reaction product. This method is not subject to the temperature, salinity, or dissolved gas interferences which plague dissolved oxygen meters. Oxidizing agents, including benzoquinone, can cause high results. Reducing agents such as hydrazine and sulfite do not interfere. Results are expressed as ppm (mg/L) or ppb (µg/L) O2.

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

Boiler feedwater testing: Low range dissolved oxygen test kits include a special "***sampling tube***" (see diagram) for use with boiler feedwater. This device allows the user to break the tip of the ampoule in a flowing sample stream in order to preclude error from contamination by atmospheric oxygen.

Total Dissolved Solids (Filterable)

The dissolved (Filterable) solids can be determined from the difference between the residue on evaporation and total suspended solids, but if the dissolved solids content is low and the suspended solids high, a direct determination is better. It is preferable to adopt the centrifugal method of separating suspended matter in order that a sufficiently large volume of separated liquid is available for the determination.

Principle

A known volume of filtered sample is evaporated and dried in a weighed dish at 105ºC to constant weight; the increase in weight over the empty dish represents the dissolved solids.

Apparatus

1. Evaporating dishes, 50, 100 mL capacity (Preferably porcelain or silica).
2. Pipettes 25, 50 ml capacity
3. Water bath & Oven
4. Balance to weigh up to 4th decimal.

Procedure

The known volume (V) of filtered sample in a previously ignited and weighed basin (W_1). Evaporate to dryness on a steam bath and further dry at 105ºC for one or two hours in an oven. Cool in dessicator and weight (W_2). Repeat by further heating for 15 minutes and cooling until successive results do not differ by more than about 0.4 mg.

Calculation

$$\text{Dissolved solids mg/L} = \frac{(W_2 - W_1) \times 1000}{V}$$

Where
W_2 = Weight of residue and dish
W_1 = Weight of empty and dry dish
V = Weight of sample

Ozone

Reference:
DDPD method: Developed by CHEMetrics, Inc.
Indigo method: Bader, H. and Hoigne, J., "Determination of Ozone in Water by the Indigo Method," Water Research, Vol. 15, 449-456, 1981. APHA Standard Methods, 20th ed., p. 4-137, Method 4500-03 B (1998).

Ozone is a strong oxidizing agent. Ozonation is used as an alternative biocide and disinfectant to chlorination of drinking water. Ozone is used to remove odor, decolorize, and to control algae and other aquatic growths. Because ozone is unstable in water, monitoring ozone residuals is important to ensure that proper treatment levels are maintained.

The Colorimetric Methods

The DDPD chemistry employs a methyl substituted form of the DPD reagent. The A-7400 activator solution (potassium iodide) is added to the sample before analysis. Ozone reacts with the iodide to liberate iodine. The iodine then reacts with the reagent to give a blue-violet color. Various free halogens and halogenating agents produce color with the reagent. Chromate in test samples below 25 ppm will not interfere with results. Results are expressed as ppm (mg/L) O_3..The **new** ozone method employs the indigo trisulfonate reagent, which reacts instantly and quantitatively with ozone, bleaching the blue color in direct proportion to the amount of ozone present. Malonic acid is included in the formulation to prevent interference from chlorine. Results are expressed as ppm (mg/L) O_3.

Turbidity

Suspension of particles in water interfering with passage of light is called turbidity. Turbidity is caused by wide variety of suspended matter which range in size from colloidal to coarse dispersions depending upon the degree of turbulence and also ranges from pure inorganic substances to those that are highly organic in nature. Turbid waters are undesirable from an aesthetic point of view in drinking water supplies and may also affect products in industries. Turbidity is measured to evaluate the performance of water treatment plants.

Principle

Turbidity can be measured either by its effect on the transmission of light which is termed as Turbidimetry, or by its effect on the scattering of light which is termed as Nephelometry. A Turbidimeter can be used for samples with moderate turbidity and a Nephelometer for samples with low turbidity. The higher the intensity of scattered light, the higher the turbidity.

Interference

Color is the main source of interference in the measurement of turbidity.

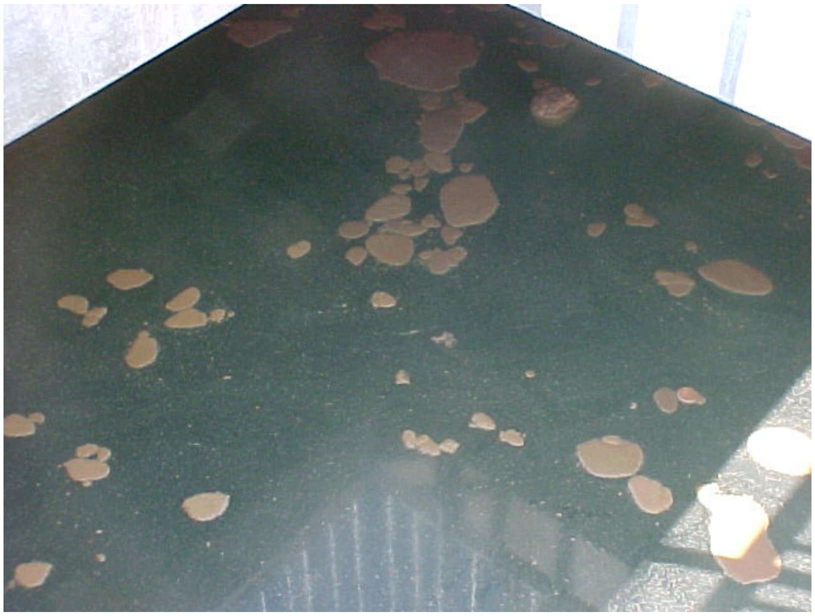
Apparatus : Turbidimeter or Nephelometer.

Reagents

1. Solution I : Dissolve 1.0 gm Hydrazine Sulfate and dilute to 100 mL.
2. Solution II : Dissolve 10.0 gm Hexamethylene tetramine and dilute to 100 mL.
3. Mix 5 mL of I with 5 mL of II. Allow to stand for 24 hrs. at 25 ± 3°C and dilute to 100 mL. This solution (III) will have turbidity of 400 units (N.T.U.)
4. Standard turbidity suspension : Dilute 10 mL of solution III as prepared above to 100 mL to have solution of the turbidity of 40 units. (N.T.U.)

Procedure

1. Prepare calibration curve in the range of 0-400 units by carrying out appropriate dilutions of solutions III and IV above taking readings on turbidimeter.
2. Take sample or a suitably diluted aliquot and determine its turbidity either by visual comparison with the diluted standards or by reading on turbidimeter.
3. Read turbidity from the standard curves and apply correction due to dilution, if necessary.
4. Report the readings in turbidity units.



Standard Operating Procedure for the Determination of Total Organic Carbon in Water

1.0 Scope and Application

This method is used to determine total organic carbon (**TOC**) in water. A concentration of 0.01 mg/L can be measured by some instruments if scrupulous attention is given to minimizing sample contamination and method background.

2.0 Summary of Method

There are two different ways to determine total organic carbon (TOC). The first way is by the TOC mode. The inorganic carbon (IC) is first removed from the sample by acidification and sparging and then the organic carbon (OC) is oxidized to carbon dioxide (CO^2) by sodium persulfate in the presence of ultraviolet light. The CO^2 produced is purged from the sample, dried, and transferred with a carrier gas to a non-dispersive infrared (NDIR) analyzer that is specifically tuned to the absorptive wavelength of CO2. The instrument's microprocessor converts the detector signal to organic carbon concentrations in mg/L based on stored calibration data. The second way is TOC by difference. This is just total carbon (TC) minus inorganic carbon. The TC is all the carbon in the sample, both IC and OC. The IC is determined in the same manner as in the TOC mode.

3.0 Definitions

3.1 The definitions and purposes below are specific to this method, but have been conformed to common usage as much as possible.

3.2 Liter: L
Milliliter: mL
Grams: g
Total Organic Carbon: TOC
Total Carbon: TC
Inorganic Carbon: IC
Organic Carbon: OC
Carbon Dioxide: CO^2
Non dispersive infrared: NDIR
Dissolved organic carbon: DOC

3.3 May: This action, activity, or procedural step is neither required nor prohibited. **May not**: This action, activity, or procedural step is prohibited. **Must**: This action, activity, or procedural step is required. **Shall**: This action, activity, or procedural step is required. **Should**: This action, activity, or procedural step is suggested, but not required

4.0 Interferences

4.1 Removal of carbonate and bicarbonate by acidification and purging with purified gas results in the loss of volatile organic substances. The volatiles also can be lost during sample blending, particularly if the temperature is allowed to rise. Another important loss can occur if large carbon-containing particles fail to enter the needle used for injection.

Filtration, although necessary to eliminate particulate organic matter when only dissolved organic carbon (DOC) is to be determined, can result in loss or gain of DOC, depending on the physical properties of the carbon-containing compounds and adsorption and desorption of the carbon matter on the filter. Avoid contaminated glassware, plastic containers, and rubber tubing. Insufficient acidification will result in incomplete release of CO^2.

4.2 The intensity of the ultraviolet light reaching the sample matrix may be reduced by highly turbid samples or with aging of the ultraviolet source, resulting in sluggish or incomplete oxidation. Large organic particles or very large or complex organic molecules such as tannins, lignins, and humic acid may be oxidized slowly because persulfate oxidation is rate-limited. However, oxidation of many large biological molecules such as proteins and monoclonal antibodies proceeds rapidly.

4.3 Persulfate oxidation of organic molecules is slowed in samples containing sufficient concentrations of chloride by the preferential oxidation of chloride; at concentrations above 0.05% chloride, oxidation of organic matter may be inhibited. To remove this interference add mercuric nitrate to the persulfate solution in UV-persulfate instruments, or extend reaction time and/or increase amount of persulfate solution in heated persulfate instruments.

4.4 With any organic carbon measurement, contamination during sample handling and treatment is a likely source of interference. This is especially true of trace analysis. Take extreme care in sampling, handling and analysis of samples below 1 mg/L TOC.

5.0 Safety

5.1 This method does not address all safety issues associated with its use. The laboratory is responsible for maintaining a safe work environment and a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material safety data sheets for each chemical used in this method should be available to all personnel involved in these analyses.

5.2 Each chemical should be treated as a potential health hazard. Exposure to these chemicals should be reduced to the lowest possible level. It is suggested that the laboratory perform personal hygiene monitoring of each analyst using this method and that the results of this monitoring be made available to the analyst.

5.3 Unknown samples may contain high concentrations of volatile compounds. Sample containers should be opened in a hood and handled with gloves to prevent exposure.

6.0 Equipment and Supplies

Note: Brand names, suppliers, and part numbers are cited for illustrative purposes only. No endorsement is implied. Equivalent performance may be achieved using equipment and materials other than those specified here, but demonstration of equivalent performance that meets the requirements of this method is the responsibility of the laboratory.

6.1 Tekmar-Dohrman Phoenix 8000 TOC uv-persulfate analyzer or other comparable brand with autosampler.

6.2 0-14 pH paper.

6.3 10 ml syringe.

6.4 0.45 micron glass fiber filters.

6.5 125 ml sample bottles:

6.6 Autosampler vials: 40 mL amber glass vials with Teflon-faced septa. These vials should be washed with laboratory detergent and thoroughly rinsed with tap water followed by reverse osmosis water and allowed to dry. The vials should then be rinsed with acetone followed by hexane and allowed to dry. Finally, the vials should be dried in the drying oven used for drying vials used for the analysis of volatile organic compounds.

7.0 Reagents and Standards

7.1 Reagent water: ultrapure from the spectroscopy lab.

7.2 21% phosphoric acid: add 37 ml of 85% phosphoric acid to 188 ml of reagent water. Always add acid to water.

7.3 LabChem Inc. Catalog number LC12910-1 Organic carbon stock solution. 1000 parts per million. Primary standard grade. 1mL=1mg. If it is prepared in the laboratory, it should be preserved by adding phosphoric acid until the pH is <2.
This stock standard solution is used with drinking water samples.
7.4 Inorganic carbon stock solution: Dissolve 4.4122 g anhydrous sodium carbonate, in reagent water, add 3.4970 g anhydrous sodium bicarbonate and dilute to 1000 mL; 1mL=1mg carbon. Keep tightly stoppered. Do not acidify. Used for analysis of surface waters in determining TOC by difference. To make the standards use 4 mL to make 20 ppm, 20 mL for 100 ppm, and 40 mL for 200 ppm. There are different methods in the Phoenix 8000 that can be used. Choose the one that best suits the samples involved.
7.5 Carrier gas. This lab uses nitrogen, CO2-free and containing less than 1 ppm hydrocarbon.
7.6 Purging gas. Any gas free of CO2 and hydrocarbons. This lab uses nitrogen.
7.7 Persulfate solution. Acros. 98+ %. Add 25 g of sodium persulfate to 213 mL of reagent water and add 9 mL of phosphoric acid.

8.0 Sample Collection, Preservation, and Storage

8.1 If possible, rinse bottles with sample before filling.
8.2 Collect and store samples in glass bottles protected from sunlight and seal with TFE-backed septa. Preferably use thick silicone rubber-backed TFE septa with open ring caps to produce a positive seal. Before use, wash bottles with laboratory detergent, rinse thoroughly with tap and reverse osmosis water and allow to dry. Then rinse with acetone and hexane and dry in the oven used for drying vials used for analysis of volatile organic carbon compounds. Analyze a bottle blank with each set of sample bottles to determine effectiveness or necessity of cleaning. This can be done by filling a sample bottle (bottle blank) with reagent water in the laboratory when the sample containers are shipped out and holding the sample bottle at 0-4 degrees C until the associated samples are analyzed.
8.3 Drinking water-related samples must either be analyzed or must be acidified to achieve pH <2.0 by addition of minimal phosphoric or sulfuric acid as soon as practical after sampling, not to exceed 24 hours. Check pH before analysis by using a stirring rod to dip in the container and then touch it to the pH paper. If the sample is a groundwater sample, it should not be acidified because there would be a loss of inorganic carbon from the sample in the form of CO2. Regardless of what is being analyzed, all samples must be stored at 0 - 4 degrees C from the time of collection until analysis.
8.4 All samples must be analyzed within 28 days of the date and time collected.

9.0 Quality Control

9.1 For every set of ten samples, analyze a reagent blank, a known-value check sample, and a duplicate. Analysis of blanks is to show freedom from contamination.
9.2 Analyze a sample bottle blank with each set of samples. See section 8.2 for details.

10.0 Calibration and Standardization

10.1 Use the standard described in section 7.4 for finding TC. If only TOC is to be found, there is a stock solution of organic carbon. The same concentrations can be made up for the organic carbon.
10.2 Depending on whether TC-IC is to be found or TOC is to be found, will determine what curve or curves need to be set active. If just TOC is to be found, then choose SETUP, CALIBRATION, SET ACTIVE, then choose TOC. It will then give ranges of different values.

The choice that has been used is 20ppm-200ppm for most samples. If TOC is found by way of TC-IC, both curves for TC and IC must be set active. They also must have the same range of calibration. The TOC range should not be set active.

10.3 Once the calibration curve is formed, stop the run and go to the calibration results. Choose the standards that have just been run and click on the RECALC button. If you want to keep the curve click on OK and then start the run again. The curve is supposed to be linear, so the closer to 1.0000 the better the curve.

11.0 Procedure

11.1 Filtration of drinking water-related samples prior to TOC analysis is not permitted as this could result in removal of organic carbon. Where turbidity interferes with TOC analysis, samples should be homogenized and, if necessary, diluted with organic-free reagent water.

11.2 Bring the analytical batch of samples to room temperature. Make sure the samples are homogenized and pour into labeled amber 40 mL vials. Put on a new septa and place on the rack.

11.3 Check the carbonate and bicarbonate levels of the samples to be analyzed. If they are over 800 mg/L then dilute.

11.4 Make up the reagents weekly. Make up new standards when quality control checks start to fail.

11.5 Warm up the instrument at least one-half hour before use. This means just switch from standby to run, and make sure that the gas flow is 200 cc/min. Make sure the baseline has stabilized.

11.6 Create a file and label it according to the current date. An easy way to do this is to load an old file from the setup menu and change the samples that are in it to go along with the new run. Go to the file and use the "save as" and then type in the day of the run. Put the year first then the month and then day. Example: for the date of January 21st, 2002 should be read as 020121.

11.7 Set the curve for the desired analysis. The TOC curve should be set for analyzing drinking water-related samples. The TC and IC curve needs to be set active for analysis of TOC by difference. Make sure that all other curves that are not used are not active.

11.8 Put the samples on and select run.

11.9 The calibration curve should be checked after the first standard is run. This will be sure that the correct calibration is made. The analyst can choose the points on the calibration menu. The more linear the line the better, so if the r-squared number is close to one, and the check sample is in the tolerance limits, let the rest of the samples run.

11.10 Only TOC results will be displayed for the drinking water-related samples; whereas, the TOC by difference will be shown as TC, IC, and TOC on the results portion of the screen.

12.0 Data Analysis, Calculations, and Reporting Results

12.1 Calculations

If the instrument does not already do this, calculate corrected instrument response of standards and samples by subtracting the reagent-water blank instrument response vs. TOC concentration. Subtract procedural blank from each sample instrument response and compare to standard curve to determine carbon content. Apply appropriate dilution factor when necessary. Subtract inorganic carbon form total carbon when TOC is determined by difference.

12.2 Reporting Results

The results can be hand entered or electronically transferred to the Laboratory Information Management System (LIMS). The units should be mg/L.

13.0 Method Performance

Interlaboratory studies of persulfate and/or UV with NDIR detection methods have been conducted in the range of 0.1 mg/L to 4,000 mg/L of carbon. The resulting equation for organic carbon single-operator precision is :

$S_o = 0.04x + 0.1$

Overall precision is expressed as: $S_t = 0.08x + 0.1$

where:

S_o = single-operator precision
S_t = overall precision, and
x = TOC concentration, mg/L

14.0 Pollution Prevention

If mercuric nitrate is used to complex the chloride, use an appropriate disposal method for the treated waste to prevent mercury contamination.

15.0 Waste Management

15.1 Disposal of any hazardous waste from this method must be done in accordance with appropriate regulations.

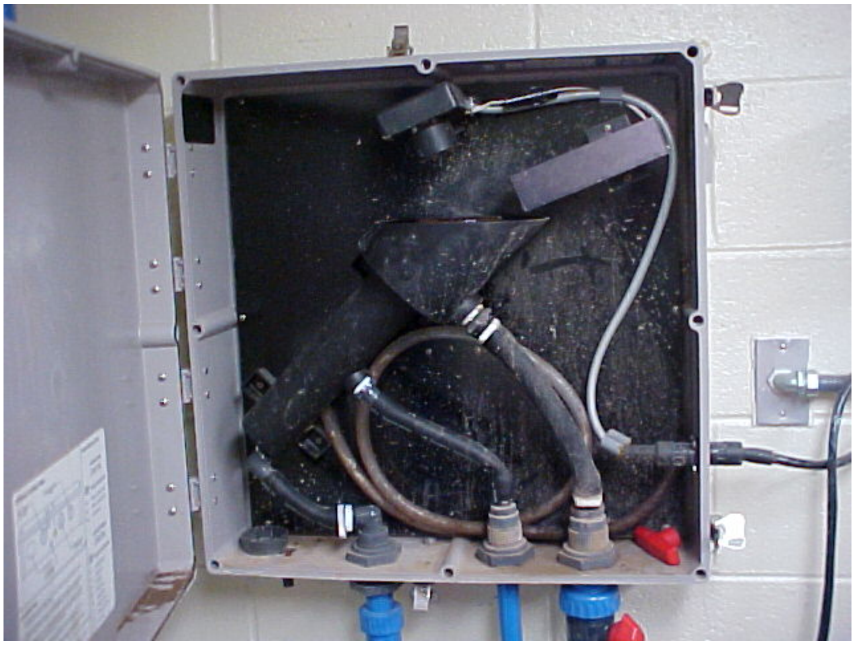
15.2 For further information on waste management consult The Waste Management Manual for Laboratory Personnel and Less is Better: Laboratory Chemical Management for Waste Reduction, both available from the American Chemical society's Department of Government Relations and Science Policy, 1155 16th Street N.W., Washington D.C. 20036

16.0 References

16.1 Method 5310 C: Total Organic Carbon(TOC), Persulfate-Ultraviolet or Heated-Persulfate Oxidation Method, *Standard Methods for the Examination of Water and Wastewater,* 19th edition supplement, 1996, pp.9-14.

16.2 "Dohrman Phoenix 8000 User Manual", 7413 East Kemper Road, Cincinnati, Ohio 45242-9576.

16.3 *Federal Register*, Wednesday, December 16, 1998, p 69417.



Inside a Turbimeter

New EPA Arsenic Rule

EPA 815-F-00-016

1. What are we announcing?

Today's final rule revises the current Maximum Contaminant Level **(MCL**) from 50 µg/L to 10 µg/L and sets a Maximum Contaminant Level Goal (**MCLG**) of zero for arsenic in drinking water. In addition, this final rule also clarifies how compliance is demonstrated for many inorganic and organic contaminants in drinking water.

2. What are the requirements of this final rule?

Both community water systems (**CWSs**) and non-transient, non-community water systems (**NTNCWSs**) will be required to reduce the arsenic concentration in their drinking water systems to 10 g/L.

A CWS is a public water system that serves at least 15 locations or 25 residents regularly year round (e.g., most cities and towns, apartments, and mobile home parks with their own water supplies). An NTNCWS is a public water system that is not a CWS and serves at least 25 of the same people more than 6 months of the year (e.g., schools, churches, nursing homes, and factories).

This final rule is also a vehicle for clarifying two compliance requirements for inorganic contaminants (**IOCs**), volatile organic contaminants (**VOCs**), and synthetic organic contaminants(**SOCs**). When a system fails to collect the required number of samples, compliance averages will be based on the actual number of samples collected. Also, new public water systems and systems using new sources of water must demonstrate compliance within State-specified time and sampling frequencies.

3. How soon after publishing the final rule will the changes take effect?

All CWSs and all NTNCWSs that exceed the MCL of 10 µg/L will be required to come into compliance 5 years after the promulgation of the final rule. Beginning with reports that are due by July 1, 2002, all CWSs will begin providing health information and arsenic concentrations in their annual consumer confidence report (**CCR**) for water that exceeds ½ the revised MCL.

4. Why is this rule significant?

In the 1996 amendments to the Safe Drinking Water Act (**SDWA**), Congress directed the EPA to propose a new arsenic regulation by January 1, 2000 and to issue the final rule by January 1, 2001 (Congress subsequently extended the final rule date to June 22, 2001). The EPA published the proposed rule for arsenic on June 22, 2000. The rule proposed an MCL of 5 µg/L for arsenic and the EPA took comment on regulatory options of 3 µg/L (the feasible level), 10 µg/L and 20 µg/L.

The 1996 amendments to SDWA added discretionary authority for the EPA Administrator to adjust the maximum contaminant level (**MCL**) if the benefits would not justify the costs (1412(b)(6)). Today's rule is important because it is the second drinking water regulation in which the EPA will use the discretionary authority under SDWA Section 1412(b)(6). After careful consideration of the benefits and the costs, the EPA has decided to set the drinking water standard for arsenic higher than the technically feasible level of 3 µg/L because the EPA believes that the costs would not justify the benefits at this level. The EPA believes that the final MCL of 10 µg/L maximizes health risk reduction at a cost justified by the benefits.

5. What health effects are associated with exposure to arsenic from drinking water?

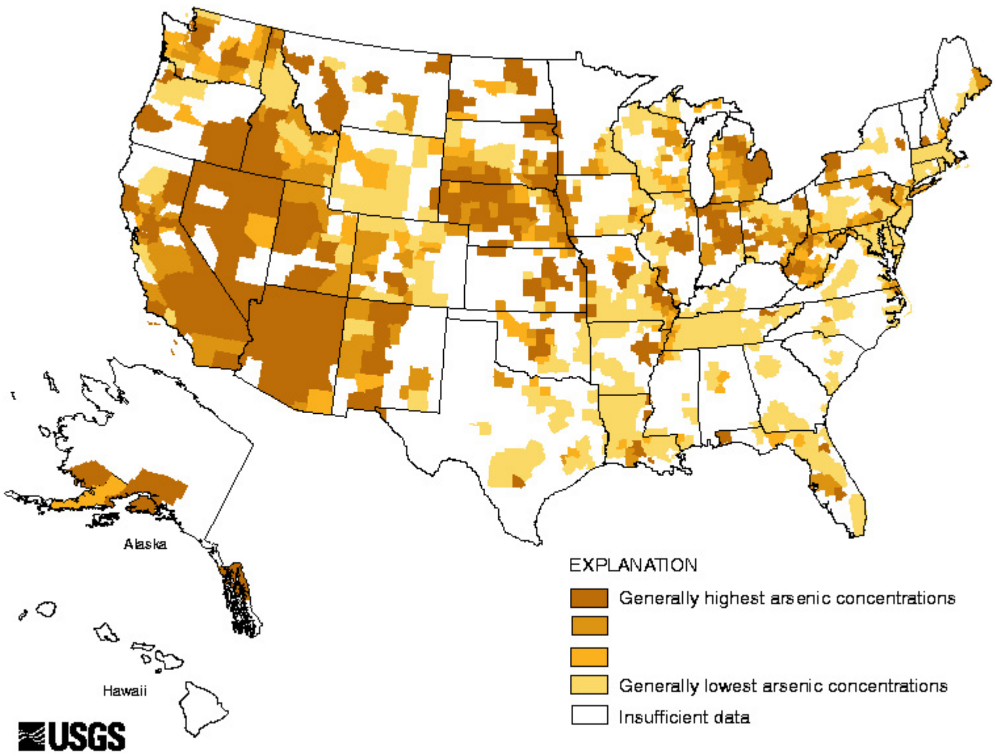
In most drinking water sources, the inorganic form of arsenic tends to be more predominant than organic forms. Inorganic arsenic in drinking water can exert toxic effects after acute (short-term) or chronic (long-term) exposure. Although acute exposures to high doses of inorganic arsenic can cause adverse effects, such exposures do not occur from public water systems in the U.S. that are in compliance with the existing MCL of 50 µg/L.

Today's final rule addresses the long-term, chronic effects of exposure to low concentrations of inorganic arsenic in drinking water. Studies link inorganic arsenic ingestion to a number of health effects.

These health effects include:
• **Cancerous Effects:** skin, bladder, lung, kidney, nasal passages, liver and prostate cancer; and
• **Non-cancerous effects**: cardiovascular, pulmonary, immunological, neurological and endocrine (e.g., diabetes) effects.

6. What are the sources of arsenic contamination in water?
The contamination of a drinking water source by arsenic can result from either natural or human activities. Arsenic is an element that occurs naturally in rocks and soil, water, air, plants, and animals.

Volcanic activity, the erosion of rocks and minerals, and forest fires are natural sources that can release arsenic into the environment. Although about 90 percent of the arsenic used by industry in the United States is currently used for wood preservative purposes, arsenic is also used in paints, drugs, dyes, soaps, metals and semi-conductors.



Agricultural applications, mining, and smelting also contribute to arsenic releases.

7. How many people and how many systems will be affected by this rule?
Higher levels of arsenic tend to be found more in ground water sources than in surface water sources (i.e., lakes and rivers) of drinking water. Compared to the rest of the United States, the Western states have more systems with arsenic levels greater than 10 µg/L.

Parts of the Midwest and New England have some systems whose current arsenic levels are greater than 10 µg/L, but more systems with arsenic levels that range from 2-10 µg/L of arsenic.

While many systems may not have detected arsenic in their drinking water above 10 µg/L, there may be geographic "***hot spots***" with systems that may have higher levels of arsenic than the predicted occurrence for that area.

About 3,000 (or 5.5 percent) of the nation's 54,000 CWSs and 1,100 (or 5.5 percent) of the 20,000 NTNCWSs will need to take measures to lower arsenic in their drinking water. Of the affected systems, 97 percent serve less than 10,000 people.

Table 1 below shows the estimated number of CWSs and NTNCWSs that would be affected by this rule and the estimated population served by these public water systems.

Table 1. Estimates of the Number of CWSs and NTNCWSs That Would Need to Treat and the Population Served by These Systems

Regulatory Action	**Type of System and Total Number**	**Number Systems Affected**	**Total Population Served by the Affected System**	
10 µg/L	CWSs	(54,000)	~ 3,000	~ 11 million
10 µg/L	NTNCWSs	(20,000)	~ 1,100	~ 1.7 million

8. How much will this rule cost?
The EPA estimates the total national annualized costs of treatment, monitoring, reporting, recordkeeping, and administration for this rule to be approximately $181 million (using 1999dollars at a three percent discount rate - Table 2). Most of the cost is due to the cost of installing and operating the treatment technologies needed to reduce arsenic in public water systems (both CWSs and NTNCWS). The EPA estimates the total treatment cost to be approximately $177 million per year. Annual monitoring and administrative costs will be about $2.7 million and States' costs will be approximately $1 million.

Table 2. Annual National System and State Compliance Costs (3% Discount Rate, $millions)

	CWS	**NTNCWS**	**Total**
System Costs			
Treatment	$170	$7.0	$177
Monitoring/Administrative	$1.8	$0.9	$2.7
State Costs	$0.9	$0.1	$1.0
Total Cost	$173	$8.0	$181

The average annual household costs for the homes served by the approximately 2,387 CWSs that require treatment are expected to be approximately $32 per year. The average annual household costs are shown categorized by system size in Table 3. The disparity in household costs between system size is due to economies of scale. Larger systems are able to spread the costs they incur over a larger customer base.

Table 3. Total Annual Costs (Dollars) per Household for CWSs

System Size	**25-500**	**501-3,300**	**3.3K-10K**	**10K-and above**
Annual	$ 327-$162	$ 71-$58	$ 38	$32-$0.86

Household Costs
The estimated average annual costs for CWSs, which exceed the final MCL of 10 µg/L and are required to treat, are shown in Table 4 categorized by system size.

Table 4: Average Annual Costs per CWS (Dollars)

CWS System Size	Costs ($)
25-500	$6,494-$12,358
501-3,300	$22,100-$53,086
3,300-10,000	$111,646
10,000 and above	$531,584-$1,340,716

What are the benefits of this rule?

The rule will protect approximately 13 million Americans served by CWSs and NTNCWSs (this number is based on reducing arsenic from 50 to 10 µg/L). Reducing arsenic from 50 to 10 µg/L will prevent ~ 19-31 cases of bladder cancer and ~ 5-8 deaths due to bladder cancer per year.

The EPA estimates that reducing arsenic from 50 to 10 µg/L will prevent ~ 19-25 cases of lung cancer and ~ 16-22 deaths due to lung cancer per year. In addition to these quantified benefits, there are substantial non-quantified benefits of this rule, including reducing the incidences of non-cancerous effects summarized above.

The quantified annual benefits for the today's rule range from $140 to $198 million. The benefit range consists of both lower and upper bound estimates. These estimates reflect the upper and lower bound of the risk range addressed by this rule as well as different drinking water consumption distributions that were used in our analysis.

Is there funding associated with this rule?

Since 1996, the DWSRF has made over $3.2 billion available for loans to help water systems improve their infrastructure. The EPA also provides funding to States that have primary enforcement responsibility for their drinking water programs through the Public Water Systems Supervision (**PWSS**) grants program. Other federal funds are available through Housing and Urban Development's Community Development Block Grant Program, and the Rural Utilities Service of the U.S. Department of Agriculture. In the most recent year, 2000, the DWSRF and Rural Utilities Service combined made $1.7 billion available to States and public water systems for capital improvements and infrastructure needs.

How did EPA consult with stakeholders?

From 1997-1999, the EPA conducted a number of Agency workgroup meetings on arsenic as well as five stakeholder meetings across the country. Representatives of eight federal agencies, 19 State offices, 16 associations, 13 corporations, 14 consulting engineering companies, two environmental organizations, three members of the press, 37 public utilities and cities, four universities, and one Indian tribe attended the stakeholder meetings on arsenic.

Five States also provided written comments on implementation issues during the rule development process. The Office of Water staff presented an overview of the arsenic rulemaking to over 900 Tribal attendees in 1998 and provided more detailed information in 1999 to 25 Tribal council members and water utility operators from 12 Indian tribes. As part of the Small Business Regulatory and Enforcement Flexibility Act (**SBREFA**) consultation process, the EPA also received substantial input from discussions with small entity representatives. The National Drinking Water Advisory Council (**NDWAC**) provided useful input, particularly on the benefits analysis and small systems affordability.

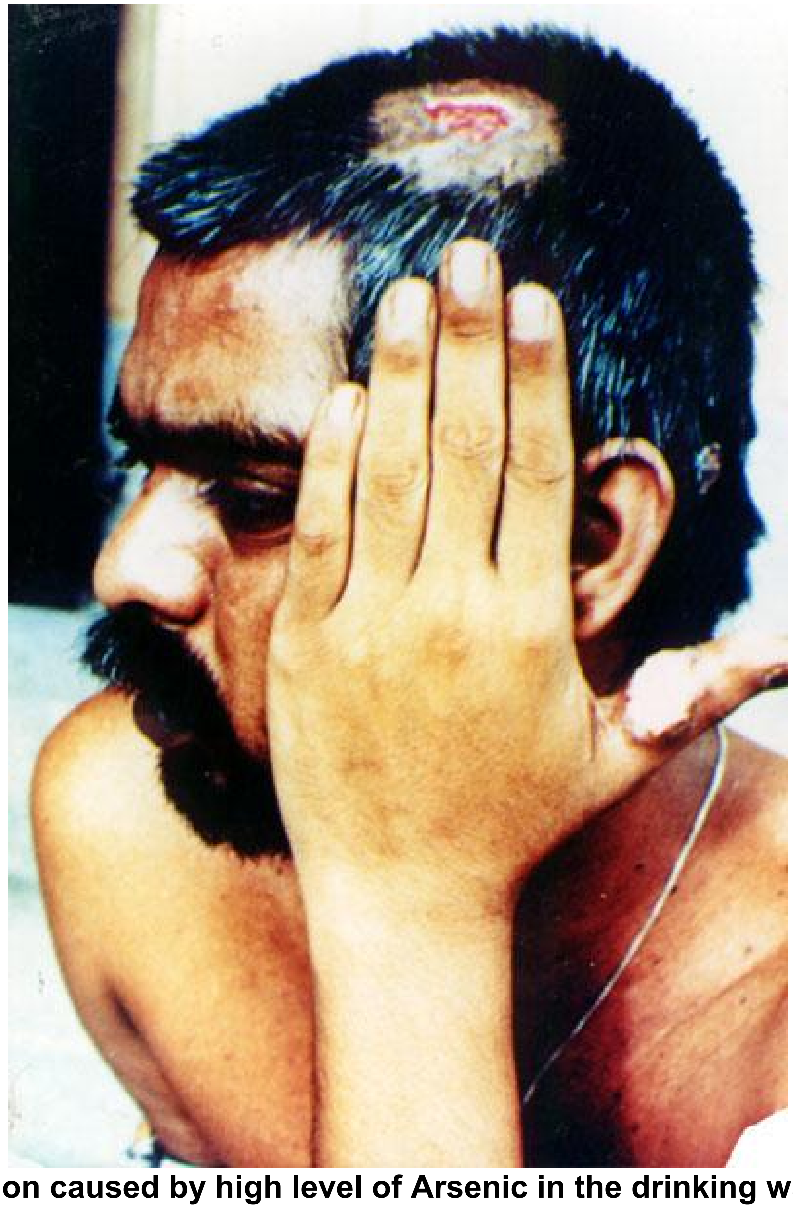
Where can the public get more information about this final rule?

For general information on arsenic in drinking water, contact the Safe Drinking Water Hotline, at (800) 426-4791, or visit the EPA's Safewater website at http://www.epa.gov/safewater or the arsenic website at http://www.epa.gov/safewater/arsenic.html.

In addition to this technical fact sheet, the following documents and fact sheets will be available to the public at the EPA web site on arsenic in drinking water:

- Federal Register notice of the final arsenic regulation
- Detailed technical support documents on Arsenic in Drinking Water
- Consumer Fact Sheet on Arsenic in Drinking Water

A copy of the Federal Register notice of the final regulation or any of the technical and consumer facts sheets can be obtained by contacting the Safe Drinking Water Hotline at (800) 426-4791 and (703) 285-1093. The Safe Drinking Water Hotline is open Monday through Friday, excluding federal holidays, from 9:00 a.m. to 5:30 p.m. Eastern Time.



Lesion caused by high level of Arsenic in the drinking water.

Exemptions & the Arsenic Rule

The EPA's goal is to have all water systems comply with the 10 ppb arsenic maximum contaminant level (**MCL**) by January 23, 2006.

The EPA understands, however, that additional time may be necessary for some systems to comply with the revised MCL, and believes that exemptions under §1416 of the Safe Drinking Water Act (**SDWA**) are an appropriate mechanism to provide this additional time. Exemptions can help ensure that systems which are unable to comply with the revised arsenic MCL will have the opportunity to gain the resources or take the steps needed to comply with the rule in an appropriate period of time. The use of exemptions will also allow systems time to develop a plan for long-term capacity. States can act before the revised arsenic MCL goes into effect and move water systems more expeditiously toward compliance.

All public water systems (**PWSs**) that meet the minimum criteria outlined in the SDWA are eligible for an exemption of up to three years. For smaller water systems, exemptions can provide up to nine additional years beyond the compliance date of the MCL to achieve compliance. The EPA anticipates that States will grant systems only as much additional time as is needed to build capacity and come into compliance. Without exemptions, water systems might not begin to move toward compliance until 2006.

Exemptions encourage water systems to start down the path to compliance now, so that public health is better protected. Exemptions are administrative tools that States can use in their long-term strategies to build capacity in drinking water systems. The use of exemptions gives eligible systems additional time to build capacity in order to achieve and maintain regulatory compliance, while continuing to provide acceptable levels of public health protection.

States can use exemptions during the implementation of the Arsenic Rule. The use of exemptions can help ensure that systems which are unable to comply with the arsenic MCL by January 23, 2006 will have the opportunity to gain the resources needed to comply with the rule in an appropriate period of time.

The EPA encourages the use of exemptions as a means of providing additional time to eligible systems. There are a number of criteria which systems must meet to be eligible for an exemption. First, the State must have adopted the August 14, 1998 Variance and Exemptions Regulation (63 FR 43835). Since some States may choose not to allow exemptions, systems under their jurisdiction will not be able to obtain an exemption.

For States with exemptions provisions, systems must meet certain eligibility criteria as outlined in SDWA §1416. Systems that meet these eligibility requirements may qualify for different exemption durations depending on system size, arsenic concentrations, system needs, and other State requirements, if any. Finally, the State must provide notice and opportunity for a public hearing.

If the exemption is approved, the State must prescribe a compliance schedule. This document shows how exemptions can be granted in a straightforward and streamlined manner. It is divided into 2 sections.

Section 1 explains in a question and answer (**Q&A**) format how the applicable laws and regulations can be translated into a workable set of exemption guidelines. Section 2 is a "***How To***" guide demonstrating how straightforward the granting of an exemption can be. Section 2 also includes two forms that can simplify the exemption process. The first form is for systems to use when requesting an exemption. The second form is for States to use when determining whether to grant an exemption. Both forms are accompanied by line-by-line instructions that explain the information needed and the types of paperwork necessary to document an exemption.

Arsenic Sources

There are many small abandoned mines in the US that produce acid mine drainage effluent which contains up to 20ppm of arsenic, and many heavy metals such as copper and zinc. This one on the right is in Montana.

The dissolved iron which occurs naturally in acid mine drainage streams will be activated by sunlight so that it can catalyze the oxidation of both arsenic and iron.

Alternatively a commercially manufactured UV lamp reactor can be used to achieve faster oxidation of acid mine water as well as for the stabilization of flue dust. These demonstrations were conducted with MSE and funded by the USEPA.

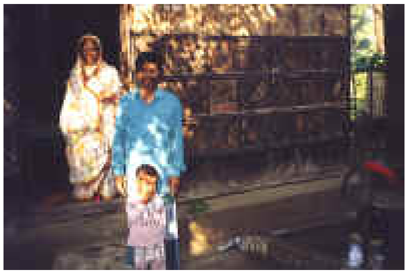
Patent 2 Sulfite and Short Wavelength Ultraviolet light

Drinking Water Treatment in Small WTP for Rural Townships

This 10 gpm reactor used to demonstrate the oxidation of arsenic in a small town's water supply in Northern California. After oxidation the arsenic was removed with iron hydroxide to produce clean water which contained less arsenic than the new stringent health limits.

Applications in Bangladesh

Patent 1 Iron and Sunlight or UV light



Families across Bangladesh rely on hand dug water for drinking. The tubewell of this family, like many others (50-70 million people) has been painted red signifying that the water naturally contains a dangerous amount of arsenic. Many thousands of villagers who have drunk the water for several years have developed skin cancers from the water.

AusAID has funded a demonstration Project in Bangladesh. The first step of the process involves dissolving a few grams of iron salt into forty liters of tubewell water and leaving it exposed to sunlight for a few hours.

After solar oxidation the arsenic contaminated water is transferred into the CRC-ANSTO designed settling urn. After settling overnight, the urn provides the convenience of 'clean drinking water on tap' to a Krishnapur villager.

No electricity is needed for this low-tech process which is planned for use in rural areas of Bangladesh

Comparison of Arsenic Treatment Technologies

What Technologies Are Used to Treat Arsenic?
This section identifies 13 technologies applicable to arsenic-contaminated soil, waste, and water. Technologies are considered applicable if they have been used at full scale to treat arsenic.

The media treated by these technologies can be grouped into two general categories: soil and waste; and water.

Technologies applicable to one type of soil and waste are typically applicable to other types. For example, solidification/stabilization has been used to effectively treat industrial waste, soil, sludge, and sediment.

Similarly, technologies applicable to one type of water are generally applicable to other types. For example, precipitation/co-precipitation has been used to effectively treat industrial wastewaters, groundwater, and drinking water.

Arsenic Treatment Technologies
Soil and Waste Treatment Technologies
- Solidification/Stabilization
- Vitrification
- Soil Washing/Acid Extraction
- Pyrometallurgical Recovery
- In Situ Soil Flushing

Water Treatment Technologies
- Precipitation/Co-precipitation
- Membrane Filtration
- Adsorption
- Ion Exchange
- Permeable Reactive Barriers

Soil, Waste, and Water Treatment Technologies
- Electrokinetics
- Phytoremediation
- Biological Treatment

What Technologies Are Used Most Often to Treat Arsenic?
This section provides information on the number of treatment projects identified for each technology and estimates of the relative frequency of their application.

The most frequently used technology for soil and waste containing arsenic is solidification/stabilization. The available data show that this technology can effectively meet regulatory cleanup levels, is commercially available to treat both soil and waste, is usually less expensive, and generates a residual that typically does not require further treatment prior to disposal.

Other arsenic treatment technologies for soil and waste are typically used for specific applications.

Vitrification may be used when a combination of contaminants are present that cannot be effectively treated using solidification/stabilization. It has also been used when the vitrification residual could be sold as a commercial product.

However, vitrification typically requires large amounts of energy, can be more expensive than S/S, and may generate off-gasses containing arsenic.

Soil washing/acid extraction is primarily used to treat soil. However, it is not applicable to all types of soil or to waste.

Pyrometallurgical treatment has been used primarily to recycle arsenic from industrial wastes containing high concentrations of arsenic from metals refining and smelting operations. These technologies may not be applicable to soil and waste containing low concentrations of arsenic.

In situ soil flushing treats soil in place, eliminating the need to excavate soil. However, no performance data were identified for the limited number of full-scale applications of this technology to arsenic.

For water containing arsenic, the most frequently used technology is precipitation/co-precipitation. Based on the information gathered for this report, precipitation/co-precipitation is frequently used to treat arsenic contaminated water, and is capable of treating a wide range of influent concentrations to the revised MCL for arsenic.

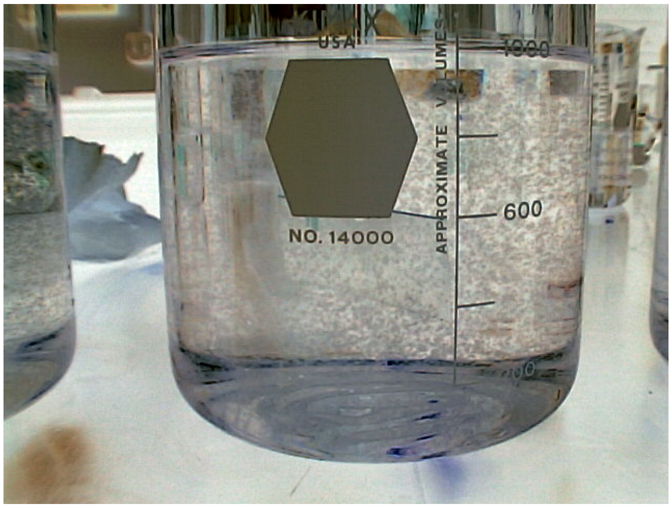
The effectiveness of this technology is less likely to be reduced by characteristics and contaminants other than arsenic, compared to other water treatment technologies. It is also capable of treating water characteristics or contaminants other than arsenic, such as hardness or heavy metals.

Systems using this technology generally require skilled operators; therefore, precipitation/ co-precipitation is more cost effective at a large scale where labor costs can be spread over a larger amount of treated water produced.

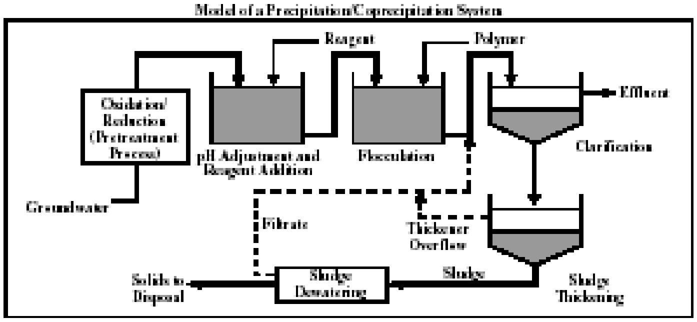
The effectiveness of adsorption and ion exchange for arsenic treatment is more likely than precipitation/co-precipitation to be affected by characteristics and contaminants other than arsenic.

Precipitation/Co-precipitation Process

- **Oxidation/Reduction**
- **(Pretreatment Process)**
- **Groundwater Solids to**
- **Disposal**
- **Sludge**
- **Dewatering**
- **Filtrate**
- **Sludge Sludge**
- **Thickening**
- **Thickener**
- **Overflow**
- **Flocculation pH Adjustment and**
- **Reagent Addition**
- **Polymer Reagent**
- **Effluent**
- **Clarification**



Model of a Precipitation/Co-precipitation System



Precipitation/co-precipitation has been the most frequently used method to treat arsenic contaminated water, including groundwater, surface water, leachate, mine drainage, drinking water, and wastewater in numerous pilot- and full-scale applications. Based on the information collected to prepare this report, this technology typically can reduce arsenic concentrations to less than 0.050 mg/L and in some cases has reduced arsenic concentrations to below 0.010 mg/L.

Technology Description

Precipitation uses chemicals to transform dissolved contaminants into an insoluble solid. In co-precipitation, the target contaminant may be dissolved or in a colloidal or suspended form.

Dissolved contaminants do not precipitate, but are adsorbed onto another species that is precipitated. Colloidal or suspended contaminants become enmeshed with other precipitated species, or are removed through processes such as coagulation and flocculation.

Many processes to remove arsenic from water involve a combination of precipitation and co-precipitation. The precipitated/co-precipitated solid is then removed from the liquid phase by clarification or filtration. Arsenic precipitation/co-precipitation can use combinations of the chemicals and methods listed below.

Media Treated

- **Drinking water**
- **Groundwater**
- **Wastewater**
- **Surface water**
- **Leachate**
- **Mine drainage**

Chemicals and Methods Used for Arsenic Precipitation/Co-precipitation

- Ferric salts, (e.g., ferric chloride), ferric sulfate, ferric hydroxide
- Ammonium sulfate
- Alum (aluminum hydroxide)
- pH adjustment
- Lime softening, limestone, calcium hydroxide
- Manganese sulfate
- Copper sulfate
- Sulfide

Technology Description and Principles

For this report, technologies were considered precipitation/co-precipitation if they involved the following steps:

- Mixing of treatment chemicals into the water.
- Formation of a solid matrix through precipitation, co-precipitation, or a combination of these processes, and
- Separation of the solid matrix from the water.

Technologies that remove arsenic by passing it through a fixed bed of media, where the arsenic may be removed through adsorption, precipitation/co-precipitation, or a combination of these processes, are discussed in the adsorption treatment section.

Precipitation/co-precipitation usually involves pH adjustment and addition of a chemical precipitant or coagulant; it can also include addition of a chemical oxidant. Oxidation of arsenic to its less soluble As(V) state can increase the effectiveness of precipitation/co-precipitation processes, and can be done as a separate pretreatment step or as part of the precipitation process. Some pretreatment processes that oxidize As(III) to As(V) include ozonation, photo oxidation, or the addition of oxidizing chemicals such as potassium permanganate, sodium hypochlorite, or hydrogen peroxide.

Clarification or filtration is commonly used to remove the solid precipitate.
Precipitation/co-precipitation is frequently used to treat water contaminated with metals.

The references identified for this report contained information on its application to industrial wastewater, groundwater, surface water, leachate, and mine drainage.

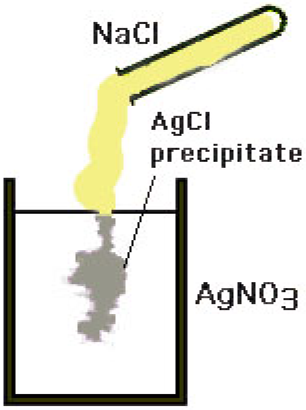
Precipitation/Co-precipitation Chemistry

Precipitation Reactions

A **precipitate** is a solid that forms out of solution.

A common example of a precipitation reaction happens when mixing the following two clear solutions:

(1) silver nitrate ($AgNO_3$)
and
(2) sodium chloride (NaCl)



The chemical equation for this reaction is ...

$$AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$$

The precipitate forms because the solid <u>product</u> of the reaction (**AgCl**) is ***insoluble*** in water.

That is true for all precipitates - the solids are insoluble in aqueous solutions.

Precipitation reactions occur all around us. For example, sometimes the pipes in our homes get clogged because precipitates of magnesium and calcium oxides have deposited themselves within the pipes. This can happen with "***hard***" water.

Another example is a kidney stone. A kidney stone is nothing more than a precipitate - often of calcium ions (from cheese) and oxalates. It is often suggested that a good way to avoid kidney stones is to drink a lot of water. This helps because the solubility of the precipitate increases with the amount of water - thus avoiding the formation of the kidney stone to begin with.

Complex
The chemistry of precipitation/co-precipitation is often complex, and depends upon a variety of factors, including the speciation of arsenic, the chemical precipitants used and their concentrations, the pH of the water, and the presence of other chemicals in the water to be treated. As a result, the particular mechanism that results in the removal of arsenic through precipitation/co-precipitation treatment is process-specific, and in some cases is not completely understood.

For example, the removal mechanism in the treatment of As(V) with Fe(III) has been debated in the technical literature.

It is beyond the scope of this course to provide all possible chemical reactions and mechanisms for precipitation/co-precipitation processes that are used to remove arsenic. More detailed information on the chemistry involved in specific processes can be found in the references listed at the end of this section.

The effectiveness of this technology can be evaluated by comparing influent and effluent contaminant concentrations. All of the 12 environmental media projects for which both influent and effluent arsenic concentration data were available had influent concentrations greater than 0.050 mg/L.

The treatments achieved effluent concentrations of less than 0.050 mg/L in eight of the projects and less than 0.010 mg/L in four of the projects. Information on the leachability of arsenic from the precipitates and sludges was available for three projects.

For all of these projects, the concentration of leachable arsenic as measured by the toxicity characteristic leaching procedure (**TCLP**) (the RCRA regulatory threshold for identifying a waste that is hazardous because it exhibits the characteristic of toxicity for arsenic) was below 5.0 mg/L.

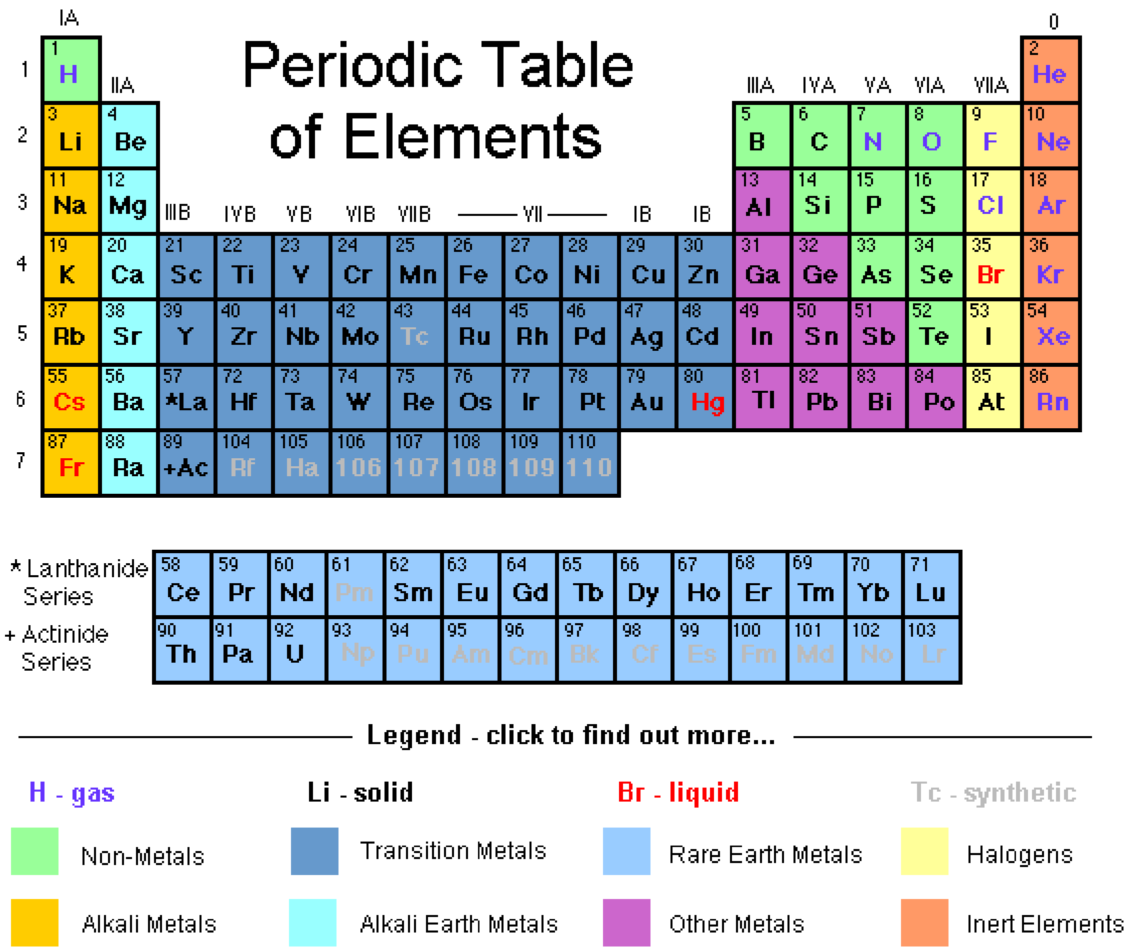
Factors Affecting Precipitation/Co-precipitation Performance

- **Valence state of arsenic** - The presence of the more soluble trivalent state of arsenic may reduce the removal efficiency. The solubility of arsenic depends upon its valence state, pH, the specific arsenic compound, and the presence of other chemicals with which arsenic might react (Ref. 9.12). Oxidation to As(V) could improve arsenic removal through precipitation/co-precipitation (Ref. 9.7).

- **pH** - In general, arsenic removal will be maximized at the pH at which the precipitated species is least soluble. The optimal pH range for precipitation/co-precipitation depends upon the waste treated and the specific treatment process (Ref. 9.7).

- **Presence of other compounds** - The presence of other metals or contaminants may impact the effectiveness of precipitation/co-precipitation. For example, sulfate could decrease arsenic removal in processes using ferric chloride as a coagulant, while the presence of calcium or iron may increase the removal of arsenic in these processes (Ref. 9.7).

A Water Operator's Lab



Periodic Table of Elements

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

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

Legend - click to find out more...

H - gas	**Li - solid**	**Br - liquid**	**Tc - synthetic**
🟩 Non-Metals	🟦 Transition Metals	🟦 Rare Earth Metals	🟨 Halogens
🟧 Alkali Metals	🟦 Alkali Earth Metals	🟪 Other Metals	🟧 Inert Elements

History of the Periodic Table

Dimitri Mendeleev created the periodic table when he first listed the elements in order of atomic mass in 1869. He found that the elements with similar properties occur in a periodic manner. Mendeleev was able to arrange the elements in a table form where similar elements are found in same column.

How is the Periodic Table Organized?

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

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

What are the Eight Groups of the Periodic Table?

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

- ✓ **Group II: Alkaline Earth Metals-Be, Mg, Ca, Sr, Ba, Ra**
  known as alkaline earth metals
  react with nonmetals, but more slowly than the Group I metals
  solids at room temperature
  have typical metallic properties
  harder than the Group I metals
  higher melting points than the Group I metals

- ✓ **Group III: B, Al, Ga, In, Tl**
  boron is a semimetal; all the others are metals

- ✓ **Group IV: C, Si, Ge, Sn, Pb**
  carbon is a nonmetal; silicon and germanium are semimetals; tin and lead are metals

- ✓ **Group V: N, P, As, Sb, Bi**
  nitrogen and phosphorus are nonmetals; arsenic and antimony are semimetals; bismuth is a metal

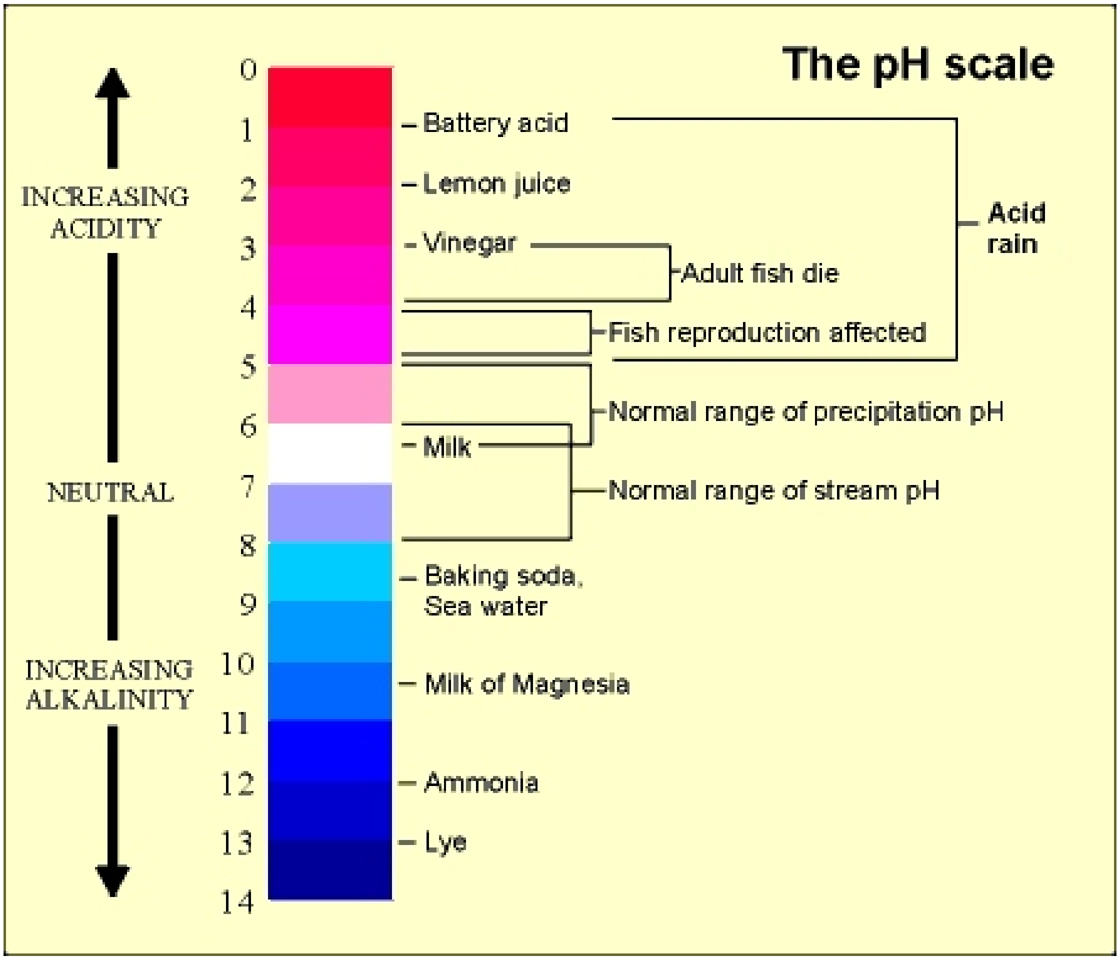
- ✓ **Group VI: O, S, Se, Te, Po**
  oxygen, sulfur, and selenium are nonmetals; tellurium and polonium are semimetals

- ✓ **Group VII: Halogens-F, Cl, Br, I, At**
  very reactive nonmetals

- ✓ **Group VIII: Noble Gases-He, Ne, Ar, Kr, Xe, Rn**
  very unreactive

Assignment
How do the properties of metals and nonmetals differ?

The pH Scale



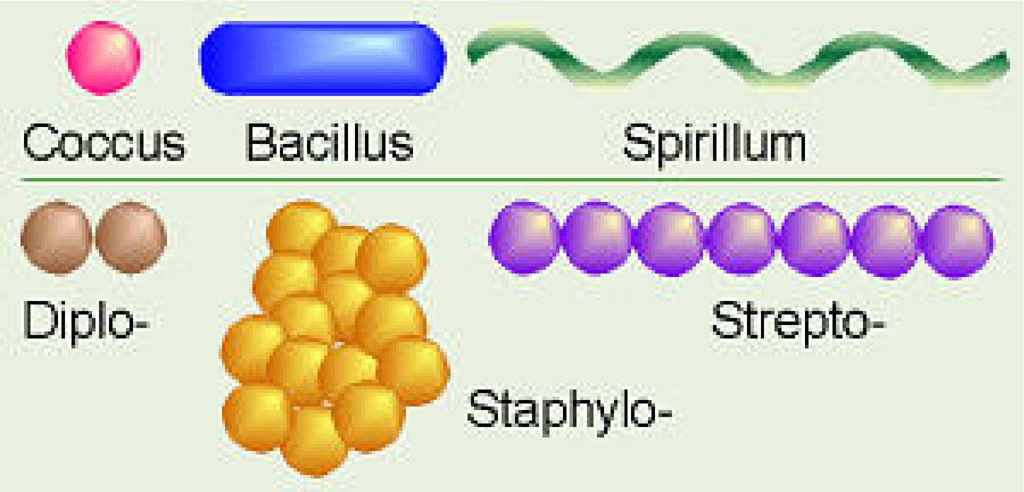
pH: A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest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

pH = (**Power of Hydroxyl Ion Activity**).

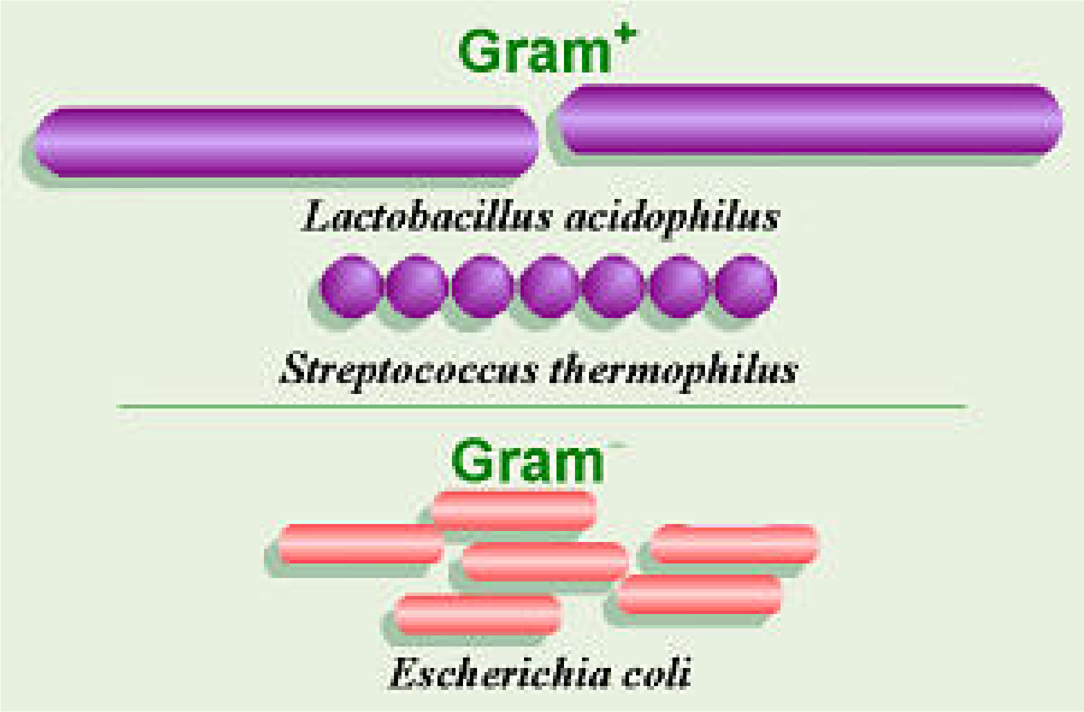
The acidity of a water sample is measured on a pH scale. This scale ranges from **0** (maximum acidity) to **14** (maximum alkalinity). The middle of the scale, **7**, represents the neutral point. The acidity increases from neutral toward **0**.

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

Normal rain has a pH of **5.6** – slightly acidic because of the carbon dioxide picked up in the earth's atmosphere by the rain.



Different types of bacteria



Gram Stain information for E. Coli

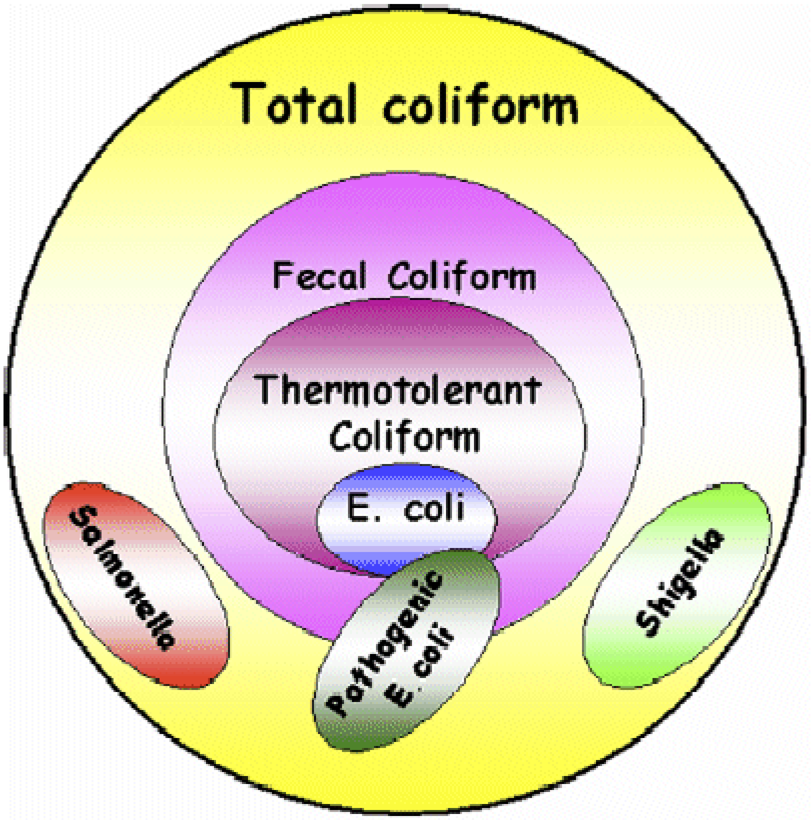
Bacteriological Monitoring Section

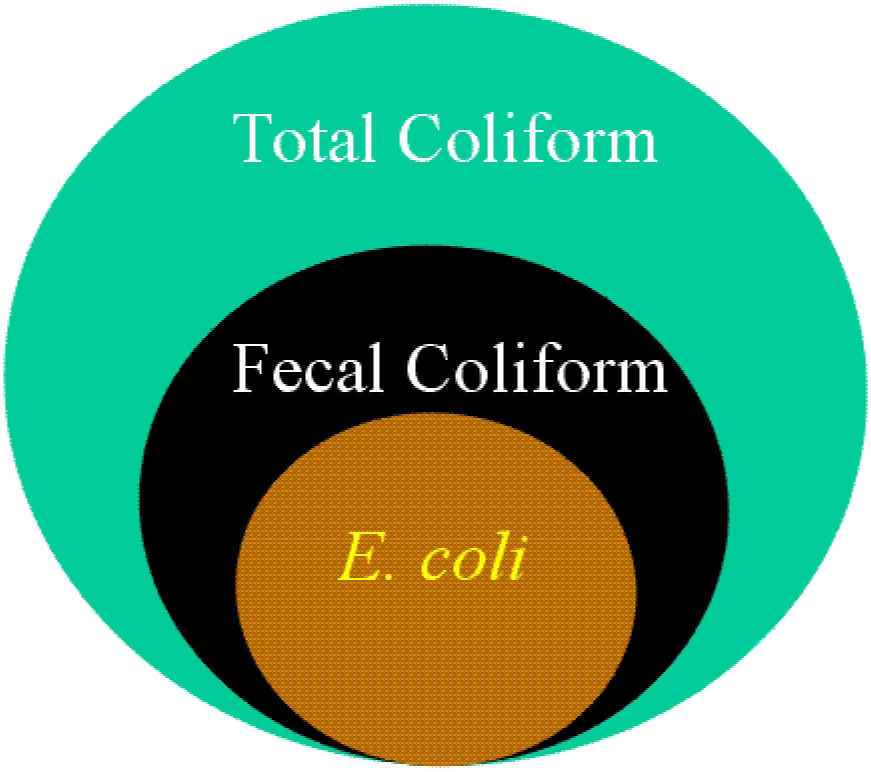
Looking under a black light to identify E.Coli

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

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

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


Total coliform
Fecal Coliform
Thermotolerant Coliform
E. coli
Salmonella
Pathogenic E. coli
Shigella


Total Coliform
Fecal Coliform
E. coli

Bacteriological Monitoring Section

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

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

Bacteria Sampling

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

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

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

Laboratory Procedures

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

Methods

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

Types of Water Samples

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

The three (3) types of samples are:

1. **Routine:** Samples collected on a routine basis to monitor for contamination. Collection should be in accordance with an approved sampling plan.

2. **Repeat:** Samples collected following a '***coliform present'*** routine sample. The number of repeat samples to be collected is based on the number of routine samples you normally collect.

3. **Special:** Samples collected for other reasons.
Examples would be a sample collected after repairs to the system and before it is placed back into operation or a sample collected at a wellhead prior to a disinfection injection point.

Routine Coliform Sampling

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

Noncommunity and nontransient noncommunity public water systems will sample at the same frequency as a like sized community public water system if:

1. It has more than 1,000 daily population and has ground water as a source, or
2. It serves 25 or more daily population and utilizes surface water as a source or ground water under the direct influence of surface water as its source.

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

Water Quality Review Statements

- ✓ What are disease causing organisms such as bacteria and viruses called? Pathogens
- ✓ Name the 4 broad categories of water quality. Physical, chemical, biological, radiological.
- ✓ What does a positive bacteriological sample indicate? The presence of bacteriological contamination.
- ✓ When must source water monitoring for lead and copper be preformed? When a public water system exceeds an action level for lead of copper.

No. of Samples per System Population

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

Repeat Sampling

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

1. If only one routine sample per month or quarter is required, four (4) repeat samples must be collected.
2. For systems collecting two (2) or more routine samples per month, three (3) repeat samples must be collected.
3. Repeat samples must be collected from:
   a. The original sampling location of the coliform present sample.
   b. Within five (5) service connections upstream from the original sampling location.
   c. Within five (5) service connections downstream from the original sampling location.
   d. Elsewhere in the distribution system or at the wellhead, if necessary.
4. If the system has only one service connection, the repeat samples must be collected from the same sampling location over a four-day period or on the same day.
5. All repeat samples are included in the MCL compliance calculation.
6. If a system which normally collects fewer than five (5) routine samples per month has a coliform present sample, it must collect five (5) routine samples the following month or quarter regardless of whether an MCL violation occurred or if repeat sampling was coliform absent.

Positive or Coliform Present Results

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

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

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

Some examples of typical corrective measures to coliform problems are:

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

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

Maximum Contaminant Levels (MCLS)

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

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

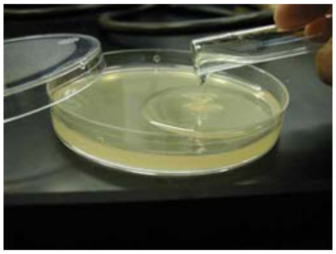
There are two types of MCL violations for coliform bacteria. The first is for total coliform; the second is an acute risk to health violation characterized by the confirmed presence of fecal coliform or E.coli.

Heterotrophic Plate Count

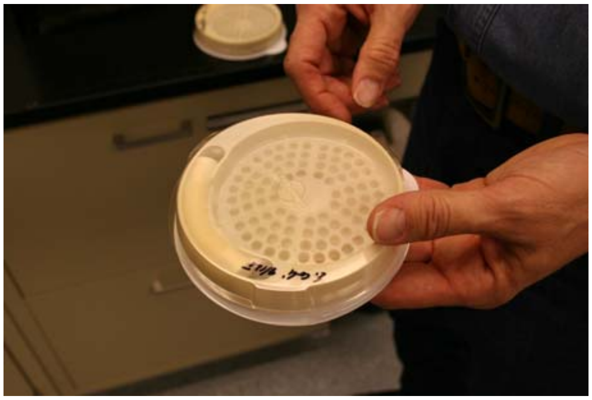
Heterotrophic Plate Count (**HPC**) --- formerly known as the standard plate count, is a procedure for estimating the number of live heterotrophic bacteria and measuring changes during water treatment and distribution in water or in swimming pools. Colonies may arise from pairs, chains, clusters, or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

Method:

There are three methods for standard plate count:



1. **Pour Plate Method**
The colonies produced are relatively small and compact, showing less tendency to encroach on each other than those produced by surface growth. On the other hand, submerged colonies often are slower growing and are difficult to transfer.
2. **Spread Plate Method**
All colonies are on the agar surface where they can be distinguished readily from particles and bubbles. Colonies can be transferred quickly, and colony morphology can be easily discerned and compared to published descriptions.
3. **Membrane Filter Method**
This method permits testing large volumes of low-turbidity water and is the method of choice for low-count waters.



Material

- i) Apparatus
  - Glass rod
  - Erlenmeyer flask
  - Graduated Cylinder
  - Pipette
  - Petri dish
  - Incubator
- ii) Reagent and sample
  - Reagent-grade water
  - Nutrient agar
  - Sample

Procedure*

1. Boil mixture of nutrient agar and nutrient broth for 15 minutes, then cool for about 20 minutes.
2. Pour approximately 15 ml of medium in each Petri dish, let medium solidify.
3. Pipette 0.1 ml of each dilution onto surface of pre-dried plate, starting with the highest dilution.
4. Distribute inoculum over surface of the medium using a sterile bent glass rod.
5. Incubate plates at 35°C for 48h.
6. Count all colonies on selected plates promptly after incubation, consider only plates having 30 to 300 colonies in determining the plate count.

*Duplicate samples

Computing and Reporting:

Compute bacterial count per milliliter by the following equation:

CFU/ml = colonies counted / actual volume of sample in dish a)If there is no plate with 30 to 300 colonies, and one or more plates have more than 300 colonies, use the plate(s) having a count nearest 300 colonies.

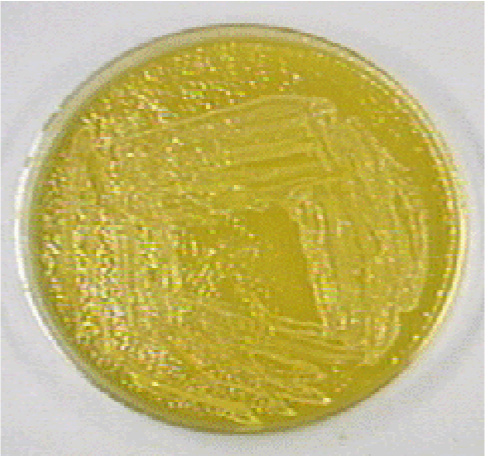
b) If plates from all dilutions of any sample have no colony, report the count as less than 1/actual volume of sample in dish estimated CFU/ml.

c) Avoid creating fictitious precision and accuracy when computing CFU by recording only the first two left-hand digits.

Heterotrophic Plate Count

(Spread Plate Method)

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



Laboratory Equipment Needed

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

Reagents

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

2) Ethanol: As needed for flame sterilization.

Preparation of Spread Plates

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

Sample Preparation

Mark each plate with sample type, dilution, date and any other information before sample application. Prepare at least duplicate plates for each volume of sample or dilution examined. Thoroughly mix all samples by rapidly making about 25 complete up-and-down movements.

Sample Application

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

Record Volume of Sample Used.

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

Counting and Recording

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

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

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

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

Assignment

1. Report the number of colony forming units (**CFU**) found on each plate.

2. Calculate the CFU per mL for each plate.

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

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

Data Table for Samples

Sample ID	Volume of Sample, mL	Colonies Counted per plate

Total Coliforms

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

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

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

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

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

2. A routine analysis shows total and fecal coliform or E. coli present and is followed by a repeat analysis which indicates total coliform present. An acute health risk violation requires the water system to provide public notice via radio and television stations in the area. This type of contamination can pose an immediate threat to human health and notice must be given as soon as possible but no later than 72 hours after notification from your laboratory of the test results.

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

Public Notice

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

A public notice is also required whenever a water system fails to comply with its monitoring and/or reporting requirements or testing procedure. Each public notice must contain certain information, be issued properly and in a timely manner and contain certain mandatory language.

The timing and place of posting of the public notice depends on whether an acute risk is present to users. Check with your state drinking water section or health department for further instructions.

The following are Acute Violations

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

General Contaminant Information

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

Contaminants that may be present in sources of drinking water include:
Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations and wildlife;
Inorganic contaminants, such as salts and metals, which can be naturally occurring or result from urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining or farming;
Pesticides and herbicides, which may come from a variety of sources such as agriculture, urban stormwater run-off and residential uses;
Organic chemical contaminants, including synthetic and volatile organic chemicals, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban stormwater run-off and septic systems;
Radioactive contaminants, which can be naturally occurring or be the result of oil and gas production and mining activities.

Background

Coliform bacteria and chlorine residual are the only routine sampling and monitoring requirements for small ground water systems with chlorination. The coliform bacteriological sampling is governed by the Total Coliform Rule (**TCR**) of the SDWA. Although there is presently no requirement for chlorination of groundwater systems under the SDWA, State regulations require chlorine residual monitoring of those systems that do chlorinate the water.
TCR The TCR requires all Public Water Systems (**PWS**) to monitor their distribution system for coliform bacteria according to the written sample siting plan for that system. The sample siting plan identifies sampling frequency and locations throughout the distribution system that are selected to be representative of conditions in the entire system. Coliform contamination can occur anywhere in the system, possibly due to problems such as; low pressure conditions, line breaks, or well contamination, and therefore routine monitoring is required. A copy of the sample siting plan for the system should be kept on file and accessible to all who are involved in the sampling for the water system.

Number of Monthly Samples

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

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

Sampling Procedures
The sample siting plan must be followed and all operating staff must be clear on how to follow the sampling plan. In order to properly implement the sample siting plan, staff must be aware of how often sampling must be done, the proper procedures and sampling containers to be used for collecting the samples, and the proper procedures for identification, storage and transport of the samples to an approved laboratory.

In addition, proper procedures must be followed for repeat sampling whenever a routine sample result is positive for total coliform. The following diagram outlines the requirements for responding to a positive Total Coliform sample.

Troubleshooting Table for Sampling Monitoring

Problem

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

Possible Causes

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

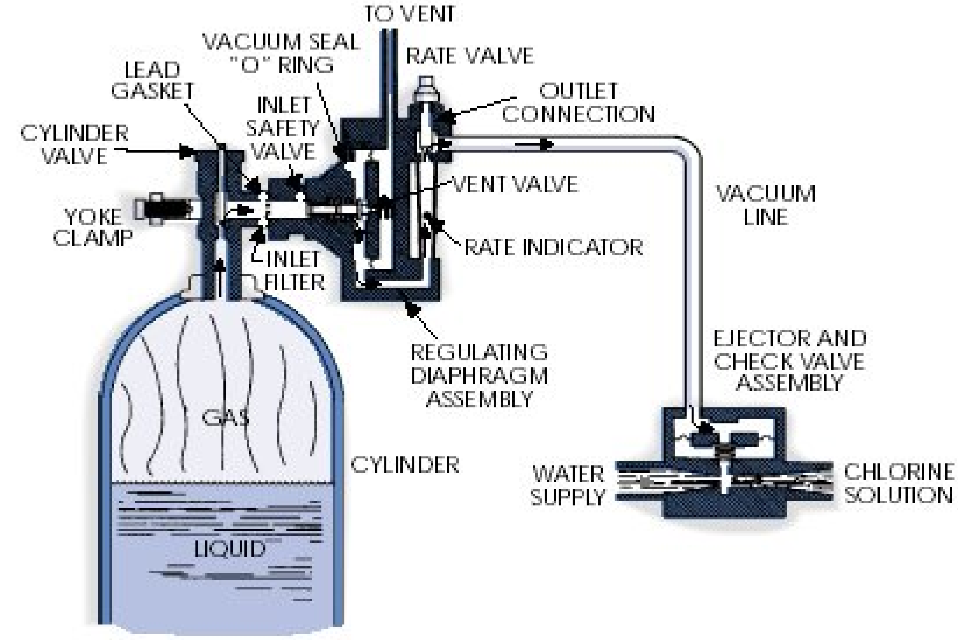
Possible Solutions

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

Chlorine Section Chapter 6

150 pound cylinder

Cylinder-Mounted Chlorinator

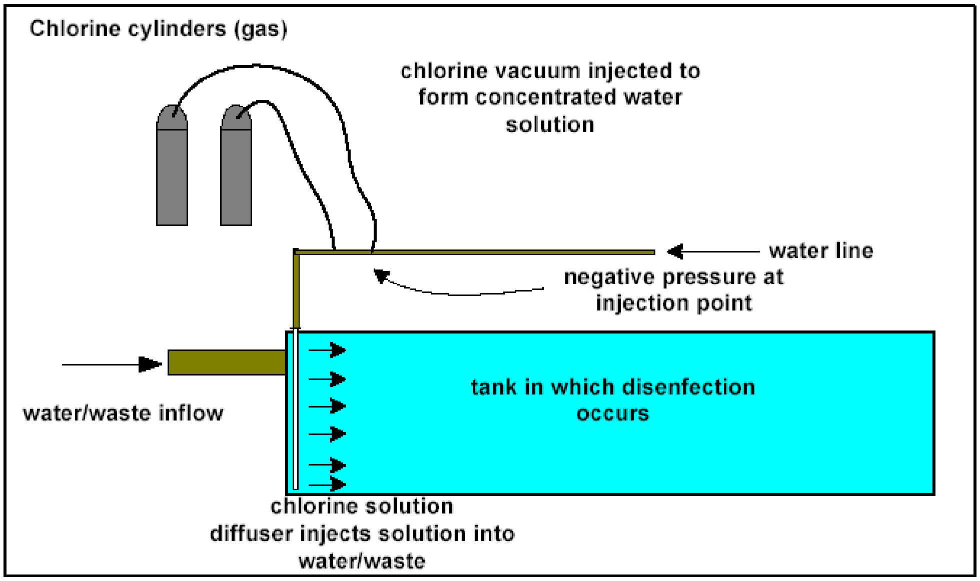


Chlorine Gas

Background

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

Chlorine is the most common chemical used to disenfect water and wastewater. It is added as a gas to most large installations. At very small facilities sodium hypochlorite (bleach) is added as a powder (tablets).



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

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

Pathophysiology

Chlorine is a greenish-yellow, noncombustible gas at room temperature and atmospheric pressure. The intermediate water solubility of chlorine accounts for its effect on the upper airway and the lower respiratory tract. Exposure to chlorine gas may be prolonged because its moderate water solubility may not cause upper airway symptoms for several minutes. In addition, the density of the gas is greater than that of air, causing it to remain near ground level and increasing exposure time.

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

Mechanism of Activity

The mechanisms of the above biological activity are poorly understood and the predominant anatomic site of injury may vary, depending on the chemical species produced. Cellular injury is believed to result from the oxidation of functional groups in cell components, from reactions with tissue water to form hypochlorous and hydrochloric acid, and from the generation of free oxygen radicals. Although the idea that chlorine causes direct tissue damage by generating free oxygen radicals was once accepted, this idea is now controversial.

The cylinders on the right contain chlorine gas. The gas comes out of the cylinder through a gas regulator. The cylinders are on a scale that operators use to measure the amount used each day. The chains are used to prevent the tanks from falling over.

Chlorine gas is stored in vented rooms that have panic bar equipped doors. Operators have the equipment necessary to reduce the impact of a gas leak, but rely on trained emergency response teams to contain leaks.

Solubility Effects

Hydrochloric acid is highly soluble in water. The predominant targets of the acid are the epithelia of the ocular conjunctivae and upper respiratory mucus membranes.

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

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

Early Response to Chlorine Gas

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

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

Immediate Effects

The immediate effects of chlorine gas toxicity include acute inflammation of the conjunctivae, nose, pharynx, larynx, trachea, and bronchi. Irritation of the airway mucosa leads to local edema secondary to active arterial and capillary hyperemia.

Plasma exudation results in filling the alveoli with edema fluid, resulting in pulmonary congestion.

Pathological Findings

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

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

1 Ton Chlorine Containers.
Unbelievably, this facility uses between 20 and 30 containers per day.

Chemical Equations, Oxidation States and Balancing of Equations

Before we break down Chlorine and other chemicals, let's start with this review of basic chemical equations.

Beginning
The common chemical equation could be A + B --> C + D. This is chemical A + chemical B, the two reacting chemicals will go to products C + D etc.

Oxidation
The term "oxidation" originally meant a reaction in which oxygen combines chemically with another substance, but its usage has long been broadened to include any reaction in which electrons are transferred.

Oxidation and reduction always occur simultaneously (redox reactions), and the substance which gains electrons is termed the oxidizing agent. For example, cupric ion is the oxidizing agent in the reaction: Fe (metal) + Cu++ --> Fe++ + Cu (metal); here, two electrons (negative charges) are transferred from the iron atom to the copper atom; thus the iron becomes positively charged (is oxidized) by loss of two electrons while the copper receives the two electrons and becomes neutral (is reduced).

Electrons may also be displaced within the molecule without being completely transferred away from it. Such partial loss of electrons likewise constitutes oxidation in its broader sense and leads to the application of the term to a large number of processes which at first sight might not be considered to be oxidation. Reaction of a hydrocarbon with a halogen, for example, CH_4 + 2 Cl --> CH_3Cl + HCl, involves partial oxidation of the methane; halogen addition to a double bond is regarded as an oxidation.

Dehydrogenation is also a form of oxidation, when two hydrogen atoms, each having one electron, are removed from a hydrogen-containing organic compound by a catalytic reaction with air or oxygen, as in oxidation of alcohol to aldehyde.

Oxidation Number
The number of electrons that must be added to or subtracted from an atom in a combined state to convert it to the elemental form; i.e., in barium chloride ($BaCl_2$) the oxidation number of barium is +2 and of chlorine is -1. Many elements can exist in more than one oxidation state.

Now, let us look at some common ions. An ion is the reactive state of the chemical, and is dependent on its place within the periodic table.

Have a look at the "periodic table of the elements". It is arranged in columns of elements, there are 18 columns. You can see column one, H, Li, Na, K, etc. These all become ions as H^+, L^{i+}, K^+, etc. The next column, column 2, Be, Mg, Ca etc. become ions Be^{2+}, Mg^{2+}, Ca^{2+}, etc. Column 18, He, Ne, Ar, Kr are inert gases. Column 17, F, Cl, Br, I, ionize to a negative F^-, Cl^-, Br^-, I^-, etc.

What you now need to do is memorize is the table of common ions, both positive ions and negative ions.

Table of Common Ions

Positive Ions

Valency 1		**Valency 2**		**Valency 3**	
lithium	Li^+	magnesium	Mg^{2+}	aluminum	Al^{3+}
sodium	Na^+	calcium	Ca^{2+}	iron III	Fe^{3+}
potassium	K^+	strontium	Sr^{2+}	chromium	Cr^{3+}
silver	Ag^+	barium	Ba^{2+}		
hydronium	H_3O^+	copper II	Cu^{2+}		
(or hydrogen)	H^+	lead II	Pb^{2+}		
ammonium	NH_4^+	zinc	Zn^{2+}		
copper I	Cu^+	manganese II	Mn^{2+}		
mercury I	Hg^+	iron II	Fe^{2+}		
		tin II	Sn^{2+}		

Negative Ions

Valency 1		**Valency 2**		**Valency 3**	
fluoride	F^-	oxide	O^{2-}	phosphate	PO_4^{3-}
chloride	Cl^-	sulfide	S^{2-}		
bromide	Br^-	carbonate	CO_3^{2-}		
iodide	I^-	sulfate	SO_4^{2-}		
hydroxide	OH^-	sulfite	SO_3^{2-}		
nitrate	NO_3^-	dichromate	$Cr_2O_7^-$		
bicarbonate	HCO_3^-	chromate	CrO_4^{2-}		
bisulphate	HSO_4^-	oxalate	$C_2O_4^{2-}$		
nitrite	NO_2^-	thiosulfate	$S_2O_3^{2-}$		
chlorate	ClO_3^-	tetrathionate	$S_4O_6^{2-}$		
permanganate	MnO_4^-	monohydrogen phosphate	HPO_4^{2-}		
hypochlorite	OCl^-				
dihydrogen phosphate	$H_2PO_4^-$				

Positive ions will react with negative ions, and vice versa. This is the start of our chemical reactions. For example:

Na+ + OH- --> NaOH (sodium hydroxide)
Na+ + Cl- --> NaCl (salt)
$3H^+ + PO_4^{3-}$ --> H_3PO_4 (phosphoric acid)
$2Na^+ + S_2O_3^{2-}$ --> $Na_2S_2O_3$

You will see from these examples, that if an ion of one (+), reacts with an ion of one (-) then the equation is balanced. However, an ion like PO_4^{3-} (phosphate) will require an ion of 3+ or an ion of one (+) (but needs three of these) to neutralize the 3- charge on the phosphate. So, what you are doing is balancing the charges (+) or (-) to make them zero, or cancel each other out.

For example, aluminum exists in its ionic state as Al^{3+}, it will react with many negatively charged ions, examples: Cl^-, OH^-, SO_4^{2-}, PO_4^{3-}.

Let us do these examples and balance them.
$Al^{3+} + Cl^- \text{-->} AlCl$ **(incorrect)**
$Al^{3+} + 3Cl^- \text{-->} AlCl_3$ **(correct)**

How did we work this out?
Al^{3+} has three positives (3+)
Cl- has one negative (-)
It will require **3 negative charges** to cancel out the **3 positive charges** on the aluminum (Al^{3+}).

When the **left hand side** of the equation is written, to balance the number of chlorine's (Cl-) required, the number 3 is placed in front of the ion concerned, in this case Cl-, becomes $3Cl^-$.

On the **right hand side** of the equation, where the ions have become a compound (a chemical compound), the number is transferred to after the relevant ion, Cl_3.

Another example:
$Al^{3+} + SO_4^{2-} \text{-->} AlSO_4$ (**incorrect**)
$2Al^{3+} + 3SO_4^{2-} \text{-->} Al_2(SO_4)_3$ (**correct**)

Let me give you an easy way of balancing:
Al is 3+
SO4 is 2-
Simply transpose the number of positives (or negatives) for each ion, to the other ion, by placing this value of one ion, in front of the other ion. That is, Al^{3+} the 3 goes in front of the SO_4^{2-} as $3SO_4^{2-}$, and SO_4^{2-}, the 2 goes in front of the Al^{3+} to become $2Al^{3+}$. Then on the **right hand side** of the equation, this same number (now in front of each ion on the **left side** of the equation), is placed after each "ion" entity.

Let us again look at:
$Al^{3+} + SO_4^{2-} \text{-->} AlSO_4$ **(incorrect)**
$Al^{3+} + SO_4^{2-} \text{-->} Al_2(SO_4)_3$ **(correct)**
Put the three from the Al in front of the SO_4^{2-} and the 2 from the SO_4^{2-} in front of the Al^{3+}.

Equation becomes:
$2Al^{3+} + 3SO_4^{2-} \text{-->} Al_2(SO_4)_3$. You simply place the valency of one ion, as a whole number, in front of the other ion, and vice versa. **Remember** to encase the SO_4 in brackets. **Why?** Because we are dealing with the sulfate ion, SO_4^{2-}, and it is this ion that is 2- charged (not just the O_4), so we have to ensure that the "ion" is bracketed. Now to check, the 2 times 3^+ = 6^+, and 3 times 2^- = 6^-. We have equal amounts of positive ions, and equal amounts of negative ions.

Another example:
$NaOH + HCl \dashrightarrow ?$
Na is Na^+, OH is OH^-, so this gave us NaOH. Originally the one positive canceled the one negative.

HCl is $H^+ + Cl^-$, this gave us HCl.

Reaction is going to be the Na^+ reacting with a negatively charged ion. This will have to be the chlorine, Cl^-, because at the moment the Na^+ is tied to the OH^-. **So:** $Na^+ + Cl^-$ --> NaCl
The H+ from the HCl will react with a negative (-) ion this will be the OH^- from the NaOH.
So: $H^+ + OH^-$ --> H_2O (water).

The complete reaction can be written:
NaOH + HCl --> NaCl + H_2O. We have **equal amounts** of all atoms **each side** of the equation, so the equation is **balanced**.
or
$Na^+OH^- + H^+Cl^-$ --> $Na^+Cl^- + H^+OH^-$

Something More Difficult:
$Mg(OH)_2 + H_3PO_4$ --> ? (equation on left **not** balanced)
$Mg^{2+}\ 2OH^- + 3H^+PO_4^{3-}$ --> ? (equation on left **not** balanced), so let us rewrite the equation in **ionic form**.

The Mg^{2+} **needs to react with a negatively charged ion**, this will be the PO_4^{3-}, **so:** $3Mg^{2+} + 2PO_4^{3-}$ --> $Mg_3(PO_4)_2$
(**Remember** the **swapping** of the positive or negative charges on the ions in the **left side** of the equation, and placing it in front of each ion, and then placing this number after each ion on the **right side** of the equation)

What is left is the H^+ from the H_3PO_4 and this will react with a negative ion, we only have the OH^- from the $Mg(OH)_2$ left for it to react with.
$6H^+ + 6OH^-$ --> $6H_2O$

Where did I get the 6 from? When I balanced the Mg^{2+} with the PO_4^{3-}, the equation became $3Mg^{2+} + 2PO_4^{3-}$ --> $Mg_3(PO_4)_2$

Therefore, I must have required $3Mg(OH)_2$ to begin with, and $2H_3PO_4$, (because we originally had $(OH)_2$ attached to the Mg, and H_3 attached to the PO_4. I therefore have $2H_3$ reacting with $3(OH)_2$. We have to write this, on the **left side** of the equation, as $6H^+ + 6OH^-$ because we need it in ionic form.
The equation becomes:
$6H^+ + 6OH^-$ --> $6H_2O$

The full equation is now balanced and is:
$3Mg(OH)_2 + 2H_3PO_4$ --> $Mg_3(PO_4)_2 + 6H_2O$
I have purposely split the equation into segments of reactions. This is showing you which ions are reacting with each other. Once you get the idea of equations you will not need this step. The balancing of equations is simple. You need to learn the valency of the common ions (see tables).

The rest is pure mathematics--you are balancing valency charges, positives versus negatives. You have to have the **same number** of **negatives**, or **positives**, on each side of the equation, and the **same number** of **ions** or **atoms** on each side of the equation.

If one ion, example Al^{3+}, (3 positive charges) reacts with another ion, example OH^- (one negative ion) then we require 2 more negatively charged ions (in this case OH^-) to counteract the 3 positive charges the Al^{3+} contains.

Take my earlier hint, place the 3 from the Al^{3+} in front of the OH^-, now reads $3OH^-$, place the 1 from the hydroxyl OH^- in front of the Al^{3+}, now stays the same, Al^{3+} (the 1 is **never** written in chemistry equations).
$Al^{3+} + 3OH^- \text{-->} Al(OH)_3$

The 3 is simply written in front of the OH^-, a recognized ion, there are no brackets placed around the OH^-. On the right hand side of the equation, all numbers in front of each ion on the left hand side of the equation are placed after each same ion on the right side of the equation. Brackets are used in the right side of the equation because the result is a compound. Brackets are also used for compounds (reactants) in the left side of equations, as in $3Mg(OH)_2 + 2H_3PO_4$ --> ?

Hard to tell, but these are one ton cylinders. Notice the five gallon bucket of motor oil in the bottom picture. Also notice that this picture is the only eye wash station that we found during our inspection of 10 different facilities. Do you have an eye wash and emergency shower?

Chemistry of Chlorination

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

Cl 2 + H 2 O → HOCl + HCl
(chlorine gas) (water) (hypochlorous acid) (hydrochloric acid)

CaOCl + H 2 O → 2HOCl + Ca(OH)
(calcium hypochlorite) (water) (hypochlorous acid) (calcium hydroxide)

NaOCl + H 2 O → HOCl + Na(OH)
(sodium hypochlorite) (water) (hypochlorous acid) (sodium hydroxide)

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

(OCl -): HOCl H + + OCl – Also expressed HOCl → H + + OCl –
(hypochlorous acid) (hydrogen) (hypochlorite ion)
The hypochlorite ion is a much weaker disinfecting agent than hypochlorous acid, about 100 times less effective.

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

Types of Residual

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

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

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

Total residual is all chlorine that is available for disinfection.

Total chlorine residual = free + combined chlorine residual.

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

Break-point chlorination is where the chlorine demand has been satisfied; any additional chlorine will be considered ***free chlorine*****.**

Residual Concentration/Contact Time (CT) Requirements

Disinfection to eliminate fecal and coliform bacteria may not be sufficient to adequately reduce pathogens such as Giardia or viruses to desired levels. Use of the ***"CT"*** disinfection concept is recommended to demonstrate satisfactory treatment, since monitoring for very low levels of pathogens in treated water is analytically very difficult.

The CT concept, as developed by the United States Environmental Protection Agency (Federal Register, 40 CFR, Parts 141 and 142, June 29, 1989), uses the combination of disinfectant residual concentration (mg/L) and the effective disinfection contact time (in minutes) to measure effective pathogen reduction. The residual is measured at the end of the process, and the contact time used is the T10 of the process unit (time for 10% of the water to pass).

CT = Concentration (mg/L) x Time (minutes)

500 pound container and 150 pound cylinders. The 1/2 ton is on a scale. Cylinders stand up right and containers on their sides.

The effective reduction in pathogens can be calculated by reference to standard tables of required CTs (see Appendices A and B).

Required Giardia/Virus Reduction
All surface water treatment systems shall ensure a minimum reduction in pathogen levels:
3-log reduction in Giardia and 4-log reduction in viruses. These requirements are based on unpolluted raw water sources with Giardia levels of = 1 cyst/100 L, and a finished water goal of 1 cyst/100,000 L (equivalent to 1 in 10,000 risk of infection per person per year). Higher raw water contamination levels may require greater removals as shown on Table 4.1.

TABLE 4.1
LEVEL OF GIARDIA REDUCTION

Raw Water Giardia Levels*	**Recommended Giardia Log Reduction**
< 1 cyst/100 L	3-log
1 cyst/100 L - 10 cysts/100 L	3-log - 4-log
10 cysts/100 L - 100 cysts/100 L	4-log - 5-log
> 100 cysts/100 L	> 5-log

*Use geometric means of data to determine raw water Giardia levels for compliance.

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

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

Results shall be reported as a reduction Ratio, along with the appropriate pH, temperature, and disinfectant residual.

The reduction Ratio must be greater than 1.0 to be acceptable. Users may also calculate and record actual log reductions. **Reduction Ratio = CT actual ÷ CT required**

Checking for leaks with Ammonia.

Using DPD Method for Chlorine Residuals
N, N – diethyl-p-phenylenediame

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

Measuring Chlorine Residual

Chlorine residual is the amount of chlorine remaining in water that can be used for disinfection. A convenient, simple and inexpensive way to measure chlorine residual is to use a small portable kit with pre-measured packets of chemicals that are added to water. (Make sure you buy a test kit using the ***DPD method***, and not the outdated orthotolodine method.)

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

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

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

Chlorine (DDBP)

Today, most of our drinking water supplies are free of the micro-organisms — viruses, bacteria and protozoa — that cause serious and life-threatening diseases, such as cholera and typhoid fever. This is largely due to the introduction of water treatment, particularly chlorination, at the turn of the century.

Living cells react with chlorine and reduce its concentration while they die. Their organic matter and other substances that are present convert to chlorinated derivatives, some of which are effective killing agents. Chlorine present as Cl, HOCl, and OCl^{-} is called ***free available chlorine***, and that which is bound but still effective is ***combined chlorine***. A particularly important group of compounds with combined chlorine is the chloramines formed by reactions with ammonia.

One especially important feature of disinfection using chlorine is the ease of overdosing to create a "**residual**" concentration. There is a constant danger that safe water leaving the treatment plant may become contaminated later. There may be breaks in water mains, loss of pressure that permits an inward leak, or plumbing errors. This residual concentration of chlorine provides some degree of protection right to the water faucet. With free available chlorine, a typical residual is from 0.1 to 0.5 ppm. Because chlorinated organic compounds are less effective, a typical residual is 2 ppm for combined chlorine.

There will be no chlorine residual unless there is an excess over the amount that reacts with the organic matter present. However, reaction kinetics complicates interpretation of chlorination data. The correct excess is obtained in a method called **"*Break Point Chlorination* ".**

Chlorine By-Products

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

The Principal Trihalomethanes are:

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

Health Effects

Laboratory animals exposed to very high levels of THMs have shown increased incidences of cancer. Also, several studies of cancer incidence in human populations have reported associations between long-term exposure to high levels of chlorination by-products and an increased risk of certain types of cancer. For instance, a recent study conducted in the Great Lakes basin reported an increased risk of bladder and possibly colon cancer in people who drank chlorinated surface water for 35 years or more.

Possible relationships between exposure to high levels of THMs and adverse reproductive effects in humans have also been examined recently. In a California study, pregnant women who consumed large amounts of tap water containing elevated levels of THMs were found to have an increased risk of spontaneous abortion. The available studies on health effects do not provide conclusive proof of a relationship between exposure to THMs and cancer or reproductive effects, but indicate the need for further research to confirm their results and to assess the potential health effects of chlorination by-products other than THMs.

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

Risks and Benefits of Chlorine

Current evidence indicates that the benefits of chlorinating our drinking water — reduced incidence of water-borne diseases — are much greater than the risks of health effects from THMs.

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

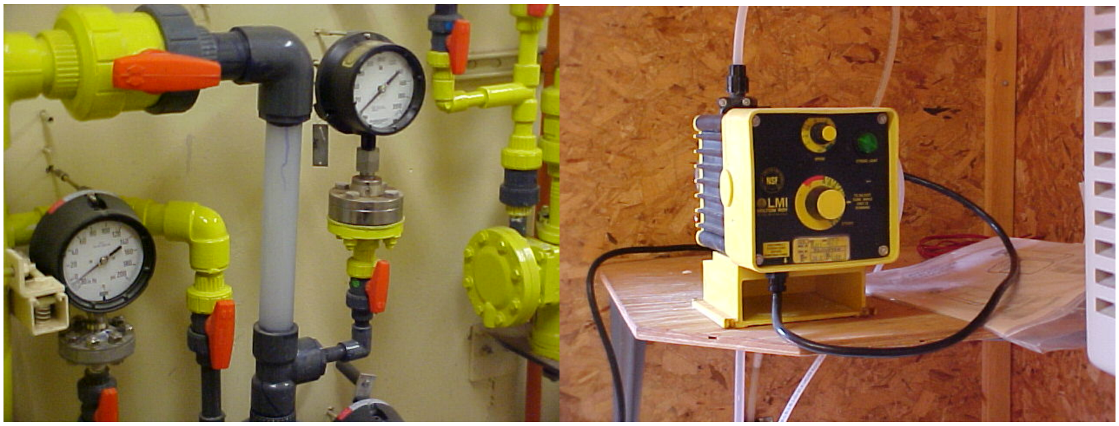
A number of cities use ozone to disinfect their source water and to reduce THM formation. Although ozone is a highly effective disinfectant, it breaks down quickly, so that small amounts of chlorine or other disinfectants must be added to the water to ensure continued disinfection as the water is piped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

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

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

In general, the preferred method of controlling chlorination by-products is removal of the naturally occurring organic matter from the source water so it cannot react with the chlorine to form by-products. THM levels may also be reduced through the replacement of chlorine with alternative disinfectants.

A third option is removal of the by-products by adsorption on activated carbon beds. It is extremely important that water treatment plants ensure that methods used to control chlorination by-products do not compromise the effectiveness of water disinfection.

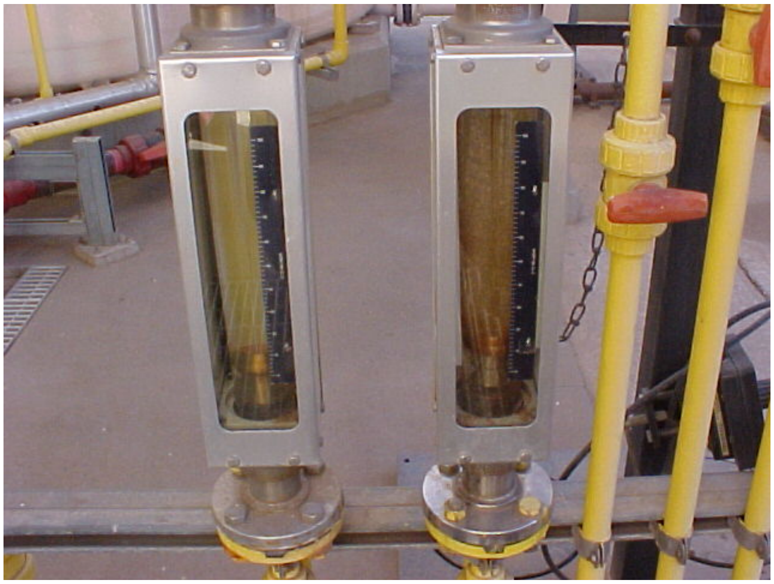


Chlorine Piping

Water Softener needed when your source water is too hard for successful chlorination using HTH.

Chlorinator Parts

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



Chlorine measurement devices or Rotameters

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

Chlorination Equipment Requirements

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

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

The gas pressure relief system shall vent pressurized gas to the atmosphere at a location that is not hazardous to plant personnel; the vent line should be run in such a manner that moisture collecting traps are avoided. The vacuum regulating valve(s) shall have positive shutdown in the event of a break in the downstream vacuum lines. As an alternative to chlorine gas, it is permissible to use hypochlorite with positive displacement pumping. Anti-siphon valves shall be incorporated in the pump heads or in the discharge piping.

Capacity

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

Methods of Control

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

Standby Provision

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

Weigh Scales

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

Securing Cylinders

All chlorine cylinders shall be securely positioned to safeguard against movement. Tag the cylinder "***empty***" and store upright and chained. Ton containers may not be stacked.

Chlorine Leak Detection

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

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

Consideration should also be given to the provision of caustic soda solution reaction tanks for absorbing the contents of leaking one-ton cylinders where such cylinders are in use. Chlorine leak detection equipment may not be required for very small chlorine rooms with an exterior door (e.g., floor area less than $3m^2$).You can use a spray solution of Ammonia or a rag soaked with Ammonia to detect a small Cl2 leak. If there is a leak, the ammonia will create a white colored smoke.

Safety Equipment

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

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

Chlorine Room Design Requirements

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

Ventilation

Gas chlorine rooms shall have entirely separate exhaust ventilation systems capable of delivering one (1) complete air change per minute during periods of chlorine room occupancy only - there shall be no continuous ventilation. The air outlet from the room shall be 150 mm above the floor and the point of discharge located to preclude contamination of air inlets to buildings or areas used by people. The vents to the outside shall have insect screens. Air inlets should be louvered near the ceiling, the air being of such temperature as to not adversely affect the chlorination equipment.

Separate switches for fans and lights shall be outside the room at all entrance or viewing points, and a clear wire-reinforced glass window shall be installed in such a manner as to allow the operator to inspect from the outside of the room.

Heating

Chlorine rooms shall have separate heating systems, if a forced air system is used to heat the building. Hot water heating system for the building will negate the need for a separate heating system for the chlorine room. The heat should be controlled at approximately 15°C. Cylinders or containers shall be protected to ensure that the chlorine maintains its gaseous state when entering the chlorinator.

Access

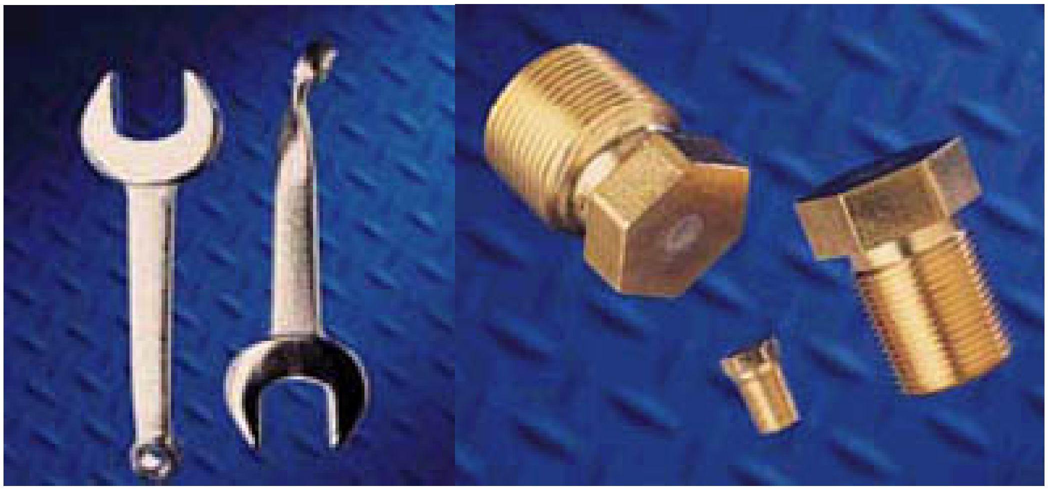
All access to the chlorine room shall only be from the exterior of the building. Visual inspection of the chlorination equipment from inside may be provided by the installation of glass window(s) in the walls of the chlorine room. Windows should be at least 0.20 m2 in area, and be made of clear wire reinforced glass. There should also be a ***'panic bar'*** on the inside of the chlorine room door for emergency exit.

Storage of Chlorine Cylinders

If necessary, a separate storage room may be provided to simply store the chlorine gas cylinders, with no connection to the line. The chlorine cylinder storage room shall have access either to the chlorine room or from the plant exterior, and arranged to prevent the uncontrolled release of spilled gas. Chlorine gas storage room shall have provision for ventilation at thirty air changes per hour. Viewing glass windows and a panic button on the inside of door should also be provided. In very large facilities, entry into the chlorine rooms may be through a vestibule from outside.

Scrubbers

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



Chlorine wrenches and chlorine cylinder fusible plugs.

Troubleshooting Hypochlorination Problems

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

Possible Causes
1A. No power.
1B. Electrical problem with signal from well pump or flow sensor.
1C. Motor failure.
2A. Improper procedure for running chlorine residual test or expired chemical reagents.
2B. Pump not feeding an adequate quantity of chlorine.
2C. Change in raw water quality.
2D. Pump **air bound**.
2E. Chlorine supply tank empty.
2F. Reduced effectiveness of chlorine solution.
2G. Damaged suction or discharge lines. (cracks or crimps)
2H. Connection at point of **injection** clogged or leaking.
3A. Speed and stroke setting inadequate.
3B. Suction lift too high due to feed pump relocation.
3C. Discharge pressure too high.
3D. Suction fitting clogged.
3E. Trapped air in suction line.
3F. Suction line not submerged in solution.
4A. Solution tank empty.
4B. Air leaks in suction fittings.
4C. Foot valve not in vertical position.
4D. Air trapped in suction tubing.

Possible Solutions
1A. Check to see if plug is securely in place.
Insure that there is power to the outlet and control systems.
1B. Check pump motor starter. Bypass flow sensor to determine if pump will operate manually.
1C. Check manufacturer’s information.
2A Check expiration date on **chemical reagents**. Check test procedure as described in test kit manual. Speed or stroke setting too low.
2B. Damaged **diaphragm** or suction leak.
2C. Test raw water for constituents that may cause increased chlorine demand. (i.e. iron, manganese, etc.)
2D. Check foot valve.
2E. Fill supply tank.
2F. Check date that chlorine was received. Sodium hypochlorite solution may lose effectiveness after 30 days. If that is the case, the feed rate must be increased to obtain the desired residual.
2G. Clean or repair lines with problems.

2H. Flush line and connection with mild acid such as **Acetic** or **Muriatic**. Replace any damaged parts that may be leaking.
3A. Check manufacturers' recommendations for proper settings to prime pump.
3B. Check maximum suction lift for pump and relocate as necessary.
3C. Check well pump discharge pressure.
Check pressure rating on chemical feed pump.
3D. Clean or replace screen.
3E. Insure all fittings are tight.
3F. Add chlorine solution to supply tank.
4A. Fill tank.
4B. Check for cracked fittings.
4C. Adjust foot valve to proper position.
4D. Check connections and fittings.

Chlorine Titration

These chlorine cylinders are unprotected and not fenced in. This is a huge violation.

Alternate Disinfectants

Chloramine

Chloramine is a very weak disinfectant for Giardia and virus reduction. It is recommended that it be used in conjunction with a stronger disinfectant. It is best utilized as a stable distribution system disinfectant.

In the production of chloramines, the ammonia residuals in the finished water, when fed in excess of the stoichiometric amount needed, should be limited to inhibit growth of nitrifying bacteria.

Chlorine Dioxide

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

Chlorine dioxide provides good Giardia and virus protection, but its use is limited by the restriction on the maximum residual of 0.5 mg/L ClO2/chlorite/chlorate allowed in finished water. This limits usable residuals of chlorine dioxide at the end of a process unit to less than 0.5 mg/L.

Where chlorine dioxide is approved for use as an oxidant, the preferred method of generation is to entrain chlorine gas into a packed reaction chamber with a 25% aqueous solution of sodium chlorite ($NaClO^2$).

Warning

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

Ozone

Ozone is a very effective disinfectant for both Giardia and viruses. Ozone CT values must be determined for the ozone basin alone; an accurate T10 value must be obtained for the contact chamber, residual levels measured through the chamber and an average ozone residual calculated.

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

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

Ozone may also be used as an oxidant for removal of taste and odor or may be applied as a pre-disinfectant.

Amperometric Titration

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

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

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

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

Free chlorine reacts readily with ammonia and certain nitrogenous compounds to form combined chlorine. With ammonia, chlorine reacts to form the chloramines: monochloramine, dichloramine, and nitrogen trichloride.
The presence and concentrations of these combined forms depend chiefly on pH, temperature, initial chlorine-to-nitrogen ratio, absolute chlorine demand, and reaction time. Both free and combined chlorine may be present simultaneously. Combined chlorine in water supplies may be formed in the treatment of raw waters containing ammonia or by the addition of ammonia or ammonium salts.

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

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

- Forward titration: USEPA-accepted methods for free and total chlorine and chlorine dioxide with chlorite
- Back titration: USEPA-accepted method for total chlorine in wastewater
- Accurate, yet convenient, the easiest way to complete ppb-level amperometric titration

If you're dechlorinating, modifying your current disinfectant delivery, changing over to another chlorine species, or adjusting disinfection processes to meet new regulations, this is the workhorse system that yields the fast, accurate residual readings you need.

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

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

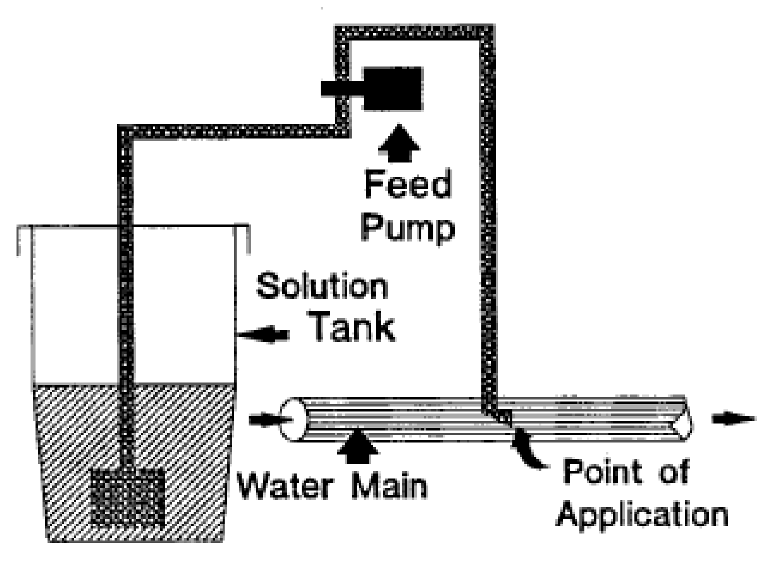
Chlorine Dioxide Methods

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

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

Recommendations for Preparing/Handling/Feeding Sodium Hypochlorite Solutions

Fig 4-2. Continuous chlorination



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

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

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

There are three ways in which NaOCl solutions degrade:
- Chlorate-forming reaction due to age, temperature, light and minor reduction in pH.
- Oxygen-producing reaction that occurs when metals, such as iron, copper or nickel, or metal oxides are brought into contact with the solution.
- Chlorine-producing reaction when solution pH falls below 6.

There are many factors that effect the stability of a NaOCl solution:
- Initial solution strength.
- pH solution.
- Temperature of the solution.
- Exposure of the solution to sunlight.

Shock Chlorination — Well Maintenance
Shock chlorination is a relatively inexpensive and straightforward procedure used to control bacteria in water wells. Many types of bacteria can contaminate wells, but the most common are iron and sulfate-reducing bacteria.

Health Problems

Although not a cause of health problems in humans, bacteria growth will coat the inside of the well casing, water piping and pumping equipment, creating problems such as:

- Reduced well yield
- Restricted water flow in distribution lines
- Staining of plumbing fixtures and laundry
- Plugging of water treatment equipment
- *"Rotten egg"* odor.

Bacteria may be introduced during drilling of a well or when pumps are removed for repair and laid on the ground. However, iron and sulfate-reducing bacteria (as well as other bacteria) can exist naturally in groundwater. A well creates a direct path for oxygen to travel into the ground where it would not normally exist. When a well is pumped, the water flowing in will also bring in nutrients that enhance bacterial growth.

Note: All iron staining problems are not necessarily caused by iron bacteria. The iron naturally present in the water can be the cause.

Ideal Conditions for Iron Bacteria

Water wells provide ideal conditions for iron bacteria. To thrive, iron bacteria require 0.5-4 mg/L of dissolved oxygen, as little as 0.01 mg/L dissolved iron and a temperature range of 5 to 15°C. Some iron bacteria use dissolved iron in the water as a food source.

Signs of Iron and Sulfate-Reducing Bacteria

There are a number of signs that indicate the presence of iron and sulfate-reducing bacteria. They include:

- Slime growth
- Rotten egg odor
- Increased staining.

Slime Growth

The easiest way to check a well and water system for iron bacteria is to examine the inside surface of the toilet flush tank. If you see a greasy slime or growth, iron bacteria are probably present. Iron bacteria leave this slimy by-product on almost every surface the water is in contact with.

Rotten Egg Odor

Sulfate-reducing bacteria can cause a rotten egg odor in water. Iron bacteria aggravate the problem by creating an environment that encourages the growth of sulfate-reducing bacteria in the well. Sulfate-reducing bacteria prefer to live underneath the slime layer that the iron bacteria form. Some of these bacteria produce hydrogen sulfide as a by-product, resulting in a "***rotten egg***" or sulfur odor in the water. Others produce small amounts of sulfuric acid which can corrode the well casing and pumping equipment.

Increased Staining Problems

Iron bacteria can concentrate iron in water sources with low iron content. It can create a staining problem where one never existed before or make an iron staining problem worse as time goes by. Use the following checklist to determine if you have an iron or sulfate-reducing bacteria problem. The first three are very specific problems related to these bacteria. The last two problems can be signs of other problems as well.

Checklist to Determine an Iron or Sulfate-Reducing Bacteria Problem

- Greasy slime on inside surface of toilet flush tank
- Increased red staining of plumbing fixtures and laundry
- Sulfur odor
- Reduced well yield
- Restricted water flow

Mixing a Chlorine Solution

Add a half gallon of bleach to a clean pail with about 3 gallons of water. This is generally sufficient to disinfect a 4 inch diameter well 100 feet deep or less. For wells greater than 100 feet deep or with a larger casing diameter, increase the amount of bleach proportionately.

If you have a dug well with a diameter greater than 18 inches, use 2 to 4 gallons of bleach added directly to the well. Please note that many dug wells are difficult or impossible to disinfect due t o their unsanitary construction.

Shock Chlorination — Well Maintenance

Shock Chlorination Method

Shock chlorination is used to control iron and sulfate-reducing bacteria and to eliminate fecal coliform bacteria in a water system. To be effective, shock chlorination must disinfect the following:

- The entire well depth
- The formation around the bottom of the well
- The pressure system
- Some water treatment equipment
- The distribution system.

To accomplish this, a large volume of super chlorinated water is siphoned down the well to displace all the water in the well and some of the water in the formation around the well.

Effectiveness of Shock Chlorination

With shock chlorination, the entire system (from the water-bearing formation, through the well-bore and the distribution system) is exposed to water which has a concentration of chlorine strong enough to kill iron and sulfate reducing bacteria. Bacteria collect in the pore spaces of the formation and on the casing or screened surface of the well. To be effective, you must use enough chlorine to disinfect the entire cased section of the well and adjacent water-bearing formation. The procedure described below does not completely eliminate iron bacteria from the water system, but it will hold it in check.

To control the iron bacteria, you may have to repeat the procedure each spring and fall as a regular maintenance procedure. If your well has never been shock chlorinated or has not been done for some time, it may be necessary to use a stronger chlorine solution, applied two or three times, before you notice a significant improvement in the water. You might also consider hiring a drilling contractor to thoroughly clean and flush the well before chlorinating in order to remove any buildup on the casing. In more severe cases, the pump may have to be removed and chemical solutions added to the well and vigorous agitation carried out using special equipment. This is to dislodge and remove the bacterial slime, and should be done by a drilling contractor.

Shock Chlorination Procedure for Small Drilled Wells

A modified procedure is also provided for large diameter wells.

Caution: If your well is low-yielding or tends to pump any silt or sand, you must be very careful using the following procedure because over pumping may damage the well. When pumping out the chlorinated solution, monitor the water discharge for sediment.

Follow these Steps to Shock Chlorinate your Well.

Store sufficient water to meet water demand needs for 8 to 48 hours.

Pump the recommended amount of water (see Amount of Chlorine Required to Obtain a Chlorine Concentration of 1000 PPM) into clean storage. A clean galvanized stock tank or pickup truck box lined with a 4 mil thick plastic sheet is suitable. The recommended amount of water to use is twice the volume of water present in the well casing. To measure how much water is in the casing, subtract the non-pumping water level from the total depth of the well. See the example below.

Shock Chlorination — Well Maintenance
5 1/4% 12% Industrial **1**70%
Casing Diameter Volume of Water Needed Domestic Sodium High Test Chlorine Bleach Hypochlorite Hypochlorite L needed L need Dry weight**1**

Water needed per 1 ft. (30 cm) per 1 ft. (30 cm) of water in the casing of water of water of water

(in) (mm)	(gal.) (L) (L) (L)	(g)
4 (100)	1.1 5.0 .095 .042	7.2
6 (150)	2.4 10.9 .21 .091	15.6
8 (200)	4.2 19.1 .36 .16	27.3
24 (600)	**2** extra 200 gal. extra 1000 L 1.7 .74	127
36 (900)	**2** extra 200 gal. extra 1000 L 3.8 1.7	286

12% industrial sodium hypochlorite and 70% high test hypochlorite are available from:
- **Water treatment suppliers**
- **Drilling contractor**
- **Swimming pool maintenance suppliers**
- **Dairy equipment suppliers**
- **Some hardware stores.**

Amount of Chlorine Required to Obtain a Chlorine Concentration of 1000 PPM
Since a dry chemical is being used, it should be mixed with water to form a chlorine solution before placing it in the well.

Calculate the amount of chlorine that is required. Mix the chlorine with the previously measured water to obtain a 1000 ppm chlorine solution.

Calculating Amount of Chlorine Example
If your casing is 6 in. and you are using 12% industrial sodium hypochlorite, you will require .091 L per ft. of water in the casing. If you have 100 ft. of water in the casing, you will use 0.091 L x 100 ft. = 9.1 L of 12% chlorine.
Using Table 1, calculate the amount of chlorine you will need for your well.

Casing diameter_______ Chlorine strength_______
L needed per 1 ft. of water_______ x _______ ft. of water in casing = _______ L of chlorine.

Caution: Chlorine is corrosive and can even be deadly.
If your well is located in a pit, you must make sure there is proper ventilation during the chlorination procedure. Well pits are no longer legal to construct. Use a drilling contractor who has the proper equipment and experience to do the job safely.

Shock Chlorination — Well Maintenance

Siphon this Solution into the Well.
Open each hydrant and faucet in the distribution system (including all appliances that use water such as dishwasher, washing machine, furnace humidifier) until the water coming out has a chlorine odor. This will ensure all the plumbing fixtures are chlorinated. Allow the hot water tank to fill completely.

Consult your water treatment equipment supplier to find out if any part of your water treatment system should be bypassed, to prevent damage. Leave the chlorine solution in the well and distribution system for 8 to 48 hours. ***The longer the contact time, the better the results.***

- Open an outside tap and allow the water to run until the chlorine odor is greatly reduced. Make sure to direct the water away from sensitive plants or landscaping.

- Flush the chlorine solution from the hot water heater and household distribution system. The small amount of chlorine in the distribution system will not harm the septic tank.

Backwash and Regenerate any Water Treatment Equipment.
If you have an old well that has not been routinely chlorinated, consider hiring a drilling contractor to thoroughly clean the well prior to chlorinating. Any floating debris should be removed from the well and the casing should be scrubbed or hosed to disturb the sludge buildup.

Modified Procedure for Large Diameter Wells
Due to the large volume of water in many bored wells the above procedure can be impractical. A more practical way to shock chlorinate a bored well is to mix the recommended amount of chlorine right in the well. The chlorinated water is used to force some of the chlorine solution into the formation around the well. Follow these steps to shock chlorinate a large diameter bored well.

Pump 200 gal. (1000 L) of water into a clean storage tank at the well head.

Mix 20 L of 5 1/4% domestic chlorine bleach (or 8 L of 12% bleach or 1.4 kg of 70%
calcium hypochlorite) into the 200 gal. of stored water.

Calculate the amount of chlorine you require per foot of water in the casing and add directly into the well. (Note that the 70% hypochlorite powder should be dissolved in water to form a solution before placing in the well.)

Circulate chlorine added to the water in the well by hooking a garden hose up to an outside faucet and placing the other end back down the well. This circulates the chlorinated water through the pressure system and back down the well. Continue for at least 15 minutes. Siphon the 200 gal. bleach and water solution prepared in Steps 1 and 2 into the well. Complete the procedure as described in Steps 5 to 9 for drilled wells.

Don't mix acids with chlorine. This is dangerous.

Chlorine Exposure Limits

This information is necessary to pass your certification exam.

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

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

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

HOCl and OCl-; the **OCL-** is the hypochlorite ion and the both of these two species are known as free available chlorine, they are the two main chemical species formed by chlorine in water and they known by collectively as hypochlorous acid and the hypochlorite ion. When chlorine gas is added to water, it rapidly hydrolyzes. The chemical equations best describes this reaction is **Cl2 + H2O --> H+ + Cl- + HOCl.** Hypochlorous acid is the most germicidal of the chlorine compounds with the possible exception of chlorine dioxide.

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

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

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

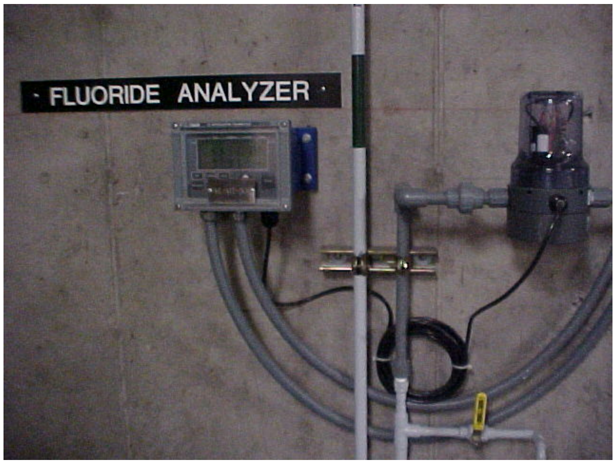
In water treatment, chlorine is added to the effluent before the contact chamber (before the clear well) for complete mixing. One reason for not adding it directly to the chamber is that the chamber has very little mixing due to low velocities.

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

Here are several symptoms of chlorine exposure: Burning of eyes, nose, and mouth, coughing, sneezing, choking, nausea and vomiting, headaches and dizziness, fatal pulmonary edema, pneumonia and skin blisters. A little Cl^2 will corrode the teeth and then progress to throat cancer.

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

Fluoride



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 in the 20 to 80 percent range of the 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,
8. All protective devices, whether for routine or emergency use, shall be inspected periodically and maintained in good operating condition.

Repair and Maintenance

Upon notifying the appropriate local board of health, a fluoridation program may be discontinued when necessary to repair or replace equipment, but shall be placed in operation immediately after the repair replacement is complete. Records shall be maintained and submitted during the period that the equipment is not in operation.

Competent Person Duties and Responsibilities

- Performs daily inspections of the protective equipment, trench conditions, safety equipment and adjacent areas.
- Inspections shall be made prior to the start of work and as needed throughout the shift.
- Inspections shall be made after every rainstorm or other hazard occurrence.
- Knowledge of emergency contact methods, telephone or radio dispatch.
- Removes employees and all other personnel from hazardous conditions and makes all changes necessary to ensure their safety.
- Insures all employees have proper protective equipment, hard-hats, reflective vests, steel-toed boots, harnesses, eye protection, hearing protection and drinking water.
- Categorize soil conditions and conduct visual and manual tests.
- Determine the appropriate protection system to be used.
- Maintain on-site records of inspections and protective systems used.
- Maintain on site a Hazard Communication program, Material Safety Data Sheets and a Risk Management Plan if necessary.
- Maintain current First Aid and CPR certifications. Maintain current Confined Space certification training.

Distribution System Design

System design depends on the area where you live. You may be a flatlander, like in Texas, and the services could be spread out for miles. You may live in the Rocky Mountain area and have many fluctuating elevations. Some areas may only serve residents on a part time basis and water will sit for long periods of time, while other areas may have a combination of peaks and valleys with short and long distances of service. Before you design the system, you need to ask yourself some basic questions.

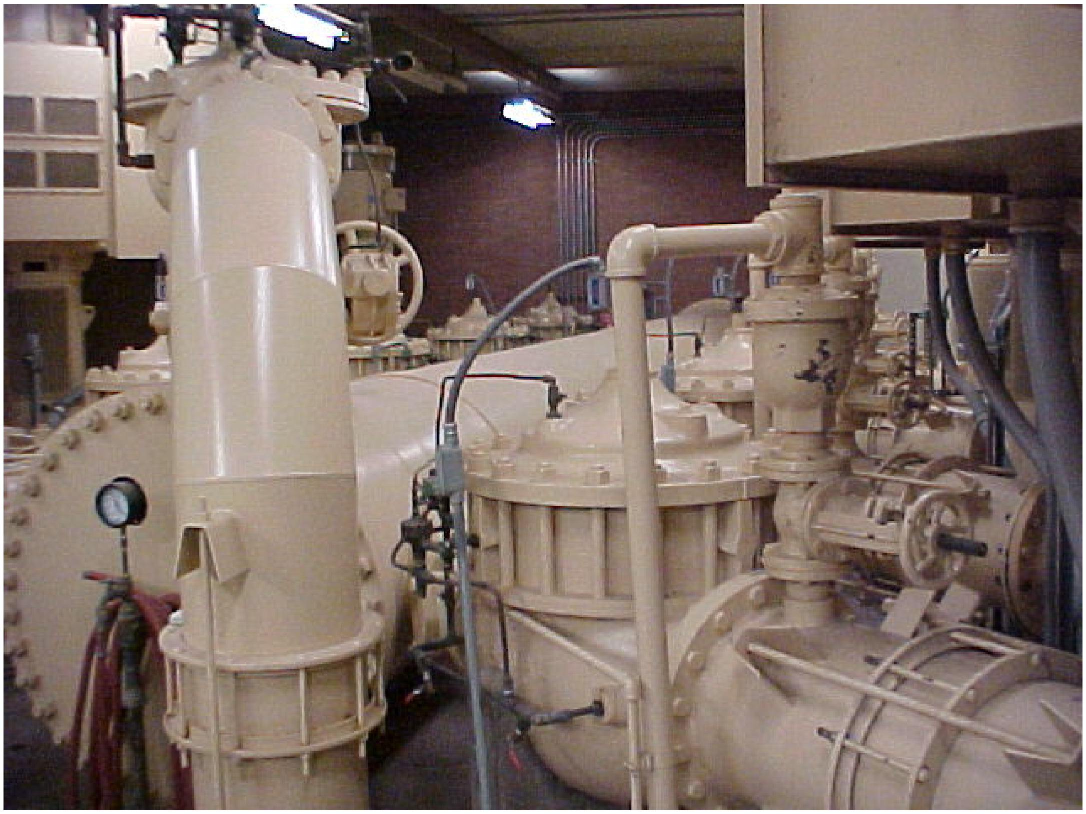
1. ***What is the source of water?***
2. ***What is the population?***
3. ***What kind of storage will I need for high demand and emergencies?***
4. ***How will the pressure be maintained?***

System Elements
The elements of a water distribution system include: distribution mains, arterial mains, storage reservoirs, and system accessories. These elements and accessories are described as follows:

Distribution Mains Distribution mains are the pipelines that make up the distribution system. Their function is to carry water from the water source or treatment works to users.

Arterial Mains Arterial mains are distribution mains of large size. They are interconnected with smaller distribution mains to form a complete gridiron system.

Storage Reservoirs Storage reservoirs are structures used to store water. They also equalize the supply or pressure in the distribution system. A common example of a storage reservoir is an aboveground water storage tank.



Booster Pump

System Accessories Include the Following

Booster stations are used to increase water pressure from storage tanks for low-pressure mains.

Valves control the flow of water in the distribution system by isolating areas for repair or by regulating system flow or pressure.

Different types of Gate Valves (Linear)

Top picture is valve ready for a valve re-placement. It has a Mechanical Type Joint.

Bottom picture is OS&Y commonly found on fire lines. This is a Flange type joint. (Outside Screw and Yoke) As the gate is lifted or opened, the stem will rise.

Gate valves should be used in the distribution system for main line isolation, only. Gate Valve is a linear type of valve. Gate valves should be stored upright with the gate down.

Butterfly Valve

These are rotary type of valves usually found on large transmission lines. They may also have an additional valve beside it known as a "*bypass*" to prevent a water hammer.

Some of these valves can require 300-600 turns to open or close.

Most Valvemen will use a machine to open or close a Butterfly Valve. The machine will count the turns required to open or close the valve.

Broken closed Gate Valve with nasty tuberculation.

Distribution Valves

The purpose of installing shutoff valves in water mains at various locations within the distribution system is to allow sections of the system to be taken out of service for repairs or maintenance without significantly curtailing service over large areas.

Valves should be installed at intervals not greater than 5,000 feet in long supply lines and 1,500 feet in main distribution loops or feeders. All branch mains connecting to feeder mains or feeder loops should have valves installed as close to the feeders as practical. In this way, branch mains can be taken out of service without interrupting the supply to other locations. In the areas of greatest water demand or when the dependability of the distribution system is particularly important, valve spacing of 500 feet maybe appropriate.

At intersections of distribution mains, the number of valves required is normally one less than the number of radiating mains. The valve omitted from the line is usually the one that principally supplies flow to the intersection. Shutoff valves should be installed in standardized locations (that is, the northeast comer of intersections or a certain distance from the center line of streets), so they can be easily found in emergencies. All buried small- and medium-sized valves should be installed in valve boxes. For large shutoff valves (about 30 inches in diameter and larger), it may be necessary to surround the valve operator or entire valve within a vault or manhole to allow repair or replacement.

Gate Valves

Gate valves are used when a straight-line flow of fluid and minimum flow restriction are needed. Gate valves are so-named because the part that either stops or allows flow through the valve acts somewhat like a gate.

The gate is usually wedge-shaped. When the valve is wide open the gate is fully drawn up into the valve bonnet. This leaves an opening for flow through the valve the same size as the pipe in which the valve is installed. Therefore, there is little pressure drop or flow restriction through the valve. Gate valves are not suitable for throttling purposes. The control of flow is difficult because of the valve's design, and the flow of fluid slapping against a partially open gate can cause extensive damage to the valve. Except as specifically authorized, gate valves should not be used for throttling.

Ball Valves

Most ball valves are the quick-acting type. They require only a 90-degree turn to either completely open or close the valve. However, many are operated by planetary gears. This type of gearing allows the use of a relatively small handwheel and operating force to operate a fairly large valve. The gearing does, however, increase the operating time for the valve. Some ball valves also contain a swing check located within the ball to give the valve a check valve feature. Ball valves should be either fully-on or fully-off.

Valve Exercising

Valve exercising should be done once per year (especially main line valves) to detect malfunctioning valves and to prevent valves from becoming inoperable due to freezing or build-up of rust or corrosion. A valve inspection should include drawing valve location maps to show distances (ties) to the valves from specific reference points (telephone poles, stonelines, etc.).

Hydrants are designed to allow water from the distribution system to be used for fire-fighting purposes.

Bottom of a dry barrel fire hydrant, there is a drainage hole on the back of this hydrant, sometimes referred to as a "weep hole".

Notice the corrosion inside this cast iron main.

This corrosion is caused by chemical changes produced by electricity or electrolysis.

We call this type of corrosion tuberculation. It is a protective crust of corrosion products that have built up over a pit caused by the loss of metal due to corrosion or electrolysis.

This type of corrosion will decrease the C-Factor and the carrying capacity in a pipe.

Crenothrix bacteria or Red-Iron bacteria will live in the bioslime in this type of tuberculation.

More on Water Distribution Valves

Water distribution valves are provided in the design of the water systems to allow for the isolation and shut-off of water when emergency conditions occur. It is important to recognize that these valves are a critical link in the management of emergencies that occur in the distribution system. Additionally, these valves are usually operated infrequently and therefore the establishment of an annual valve exercising program is essential to the viability of an utility emergency operations plan.

Emergency operations of water valves presumes that the system operators are familiar with the exact locations of many key water valves within the water system. Equal in importance is the knowledge that when these valves need to be operated in order to isolate a section of the distribution system they will operate and close effectively in order to prevent a large loss of the water recourse and excessive property damage.

Routine valve inspections should be conducted on the water system valves and the following tasks are accomplished:

- The accuracy of all valves and valve boxes is verified against existing records. If inconsistencies are found, the records are updated to reflect accurate information.
- An inspection is performed on each valve stem and nut to determine if any damage exists.
- The valve is fully closed and the number of turns necessary to accomplish a full closing is recorded.
- The valve is re-opened, and the system flows are re-established.
- The valve box and cover is cleaned, inspected for damaged and painted blue.

Exercising of all valves should be accomplished at the same time as the valve inspection. The exercising program assures that the valve operates and loosens any encrustation from valve seats and gates. Many valve manufacturers recommend that the valve stem be completely opened and then backed off by one complete turn.

Valve Exercising Machine

Distribution System Hydrant Maintenance/Flushing

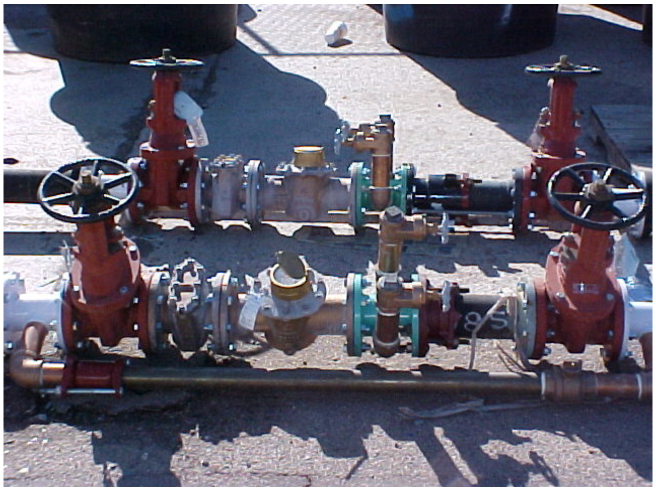
Fire hydrants provide not only fire protection, but also a method of moving large amounts of water out of various portions of the water system if microbiological and/or chemical contamination occurs and an emergency is declared. As a result, fire hydrant maintenance is conducted on all fire hydrants to assure their viability at all times.

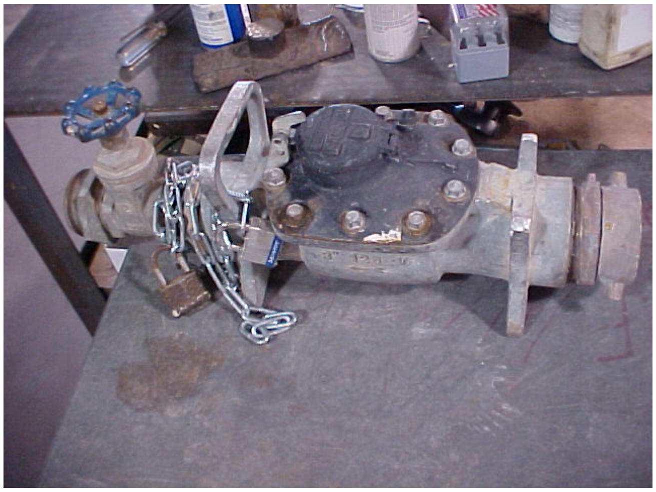
Fire hydrant maintenance includes the following specific procedures:

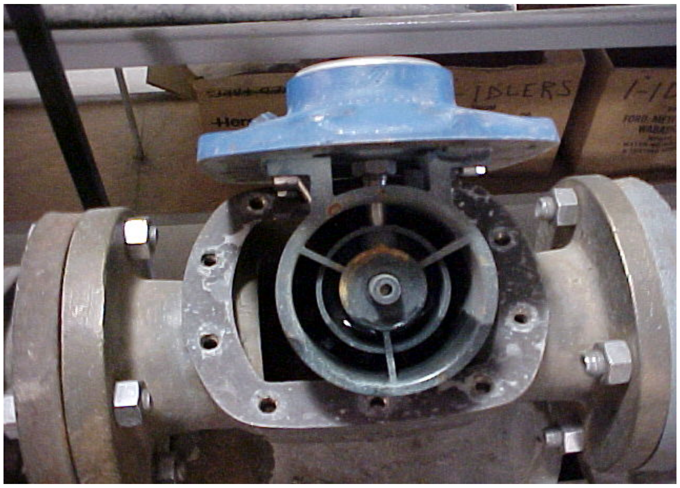
- All fire hydrants are inspected for leakage and repairs are made when necessary.
- The fire hydrant is fully opened and the ease of operation is noted.
- The hydrant flow is directed to waste. During this procedure, care is taken to direct and/or disperse the flow to minimize property damage.
- All fire hydrant nozzle caps are inspected for thread damage and lubricated to provide ease of operation.
- All fire hydrant nozzle cap thread gaskets are inspected and replaced as necessary.
- If a fire hydrant is found to be inoperable, a tag is placed on the hydrant, and the "***out of service"*** is immediately reported to the Fire Department.
- Accurate records related to the maintenance procedures performed on the fire hydrants are maintained by the water department.

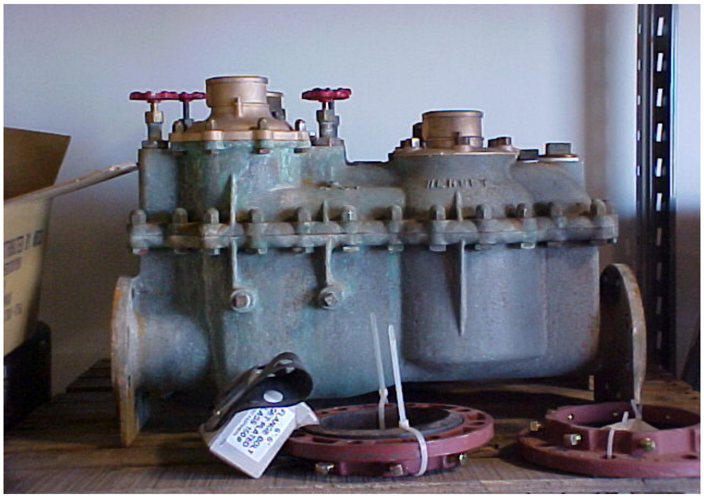
Airport Runway fire hydrant, hidden below the ground surface.

Water Meters record the flow of water in a part of the distribution system. Bypass, Compound, Turbine or Propeller meters.









Water Meters

It is important to account for the water produced and supplied. A master meter should be installed on each source, with service meters placed at each point of use. These should be read and recorded periodically. Totals from the master meters should be compared to totals from the service meters to compute the amount of water lost in the distribution system. This information is important in locating and eliminating leaks and unauthorized taps.

Losses of 10 to 20 percent are not uncommon in many distribution systems. Also, it has been shown that a system which is not metered is likely to have a water usage up to three times as great as a metered system.

Un-metered water users tend to use water freely and have little incentive to repair plumbing leaks.

Computerized handheld electronic meter reader "*station*"

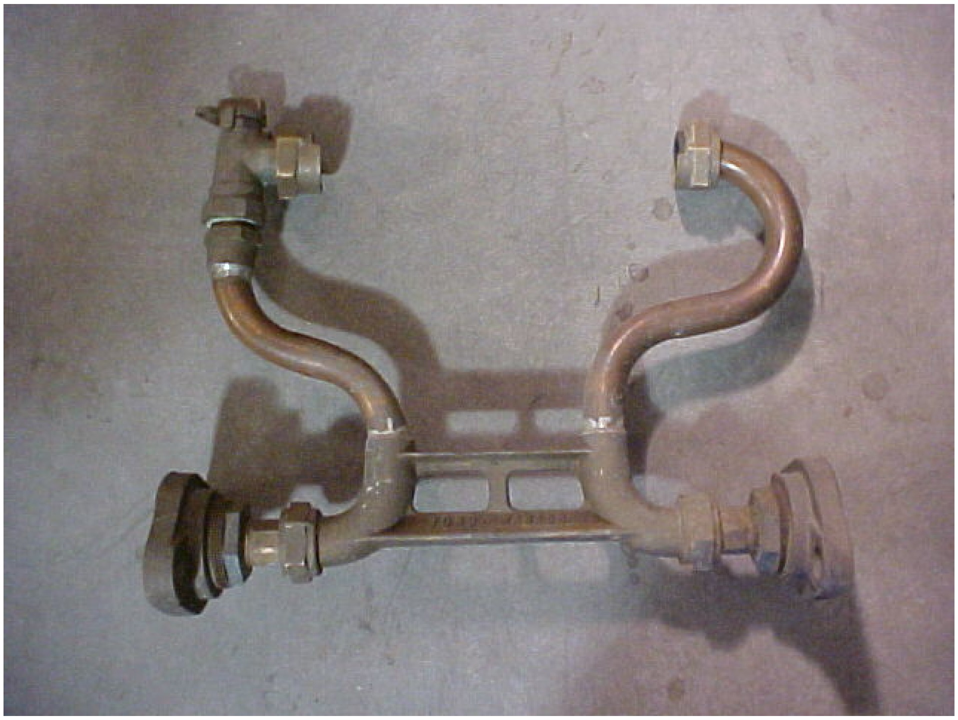
Meter Shop

Equipment used for meter calibration. Most meters will read lower than normal, never higher. All meters will create "**head loss**" on the water service except for a ***"Magnetic Meter***". The large tanks are used to measure the water in gallons that is used to calibrate or check the water meter.

Most water utilities will charge the customer a fee to check the accuracy of the meter.

Service Connections

Service connections are used to connect individual buildings or other plumbing systems to the distribution system mains.

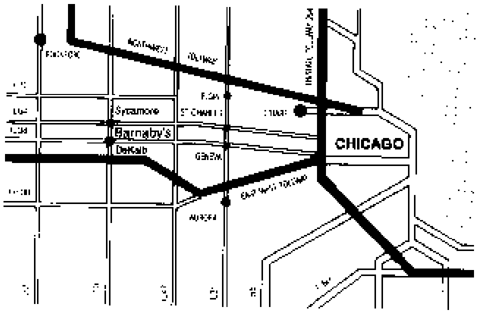


Water Meter Re-setter, riser or sometimes referred to as a copper yoke.

Common distribution fittings. Single check valve, Poly Pig, 1-inch repair clamp, 4-inch full circle clamp, T- Bolt and a corp. and saddle.

System Layouts

There are three general ways systems are laid out to deliver water (picture your quarter section layouts). They include:



A. **Tree systems**

B. **Loop or Grid systems**

C. **Dead-end systems: *Undesirable, taste and odor problems.***

Tree System

Older water systems frequently were expanded without planning and developed into a treelike system. This consists of a single main that decreases in size as it leaves the source and progresses through the area originally served. Smaller pipelines branch off the main and divide again, much like the trunk and branches of a tree.

A treelike system is not desirable because the size of the old main limits the expansion of the system needed to meet increasing demands. In addition, there are many dead ends in the system where water remains for long periods, causing undesirable tastes and odors in nearby service lines.

The most reliable means to provide water for fire fighting is by designing redundancy into the system. There are several advantages gained by laying out water mains in a loop or grid, with feeder and distributor mains interconnecting at roadway intersections and other regular intervals.

Friction Loss

Water will still be distributed through the system if a single section fails. The damaged section can be isolated and the remainder of the system will still carry water. Water supplied to fire hydrants will feed from multiple directions. Thus, during periods of peak fire flow demand, there will be less impact from "***friction loss***" in water mains as the velocity within any given section of main will be less since several mains will be sharing the supply.

The system shall be designed to maintain a minimum positive pressure of 25 psi. in all parts of the system at all times, 35 psi. is desirable.. Water pipe shall conform to applicable specifications and standards for the type of pipe to be used. The following shall govern the separation of water lines from possible sources of pollution:

1. Whenever possible, a water line shall be laid at least 10 feet horizontally from any existing or proposed sewer line.

2. Whenever water lines must cross sewers, the water line shall be laid at such an elevation that the bottom of the water line is 18 inches above the top of the sewer. This vertical separation shall be maintained for that portion of the water line located within 10 feet horizontally of any sewer or drain it crosses, said 10 feet to be measured as the normal distance from the water line to the drain or sewer. The sewer shall be constructed of cast iron pipe, type K copper, or Drain, Waste and Vent (**DWV**) plastic pipe (Schedule 40) with water-tight joints for a distance of 10 feet from each side of the water line. All crossings shall be made at right angles.
3. Where conditions prevent the minimum horizontal and/or vertical separation specified above, special consultation shall be obtained from the Department to determine other routes of water piping.

4. No water line shall pass through, or come into contact with, any part of a sewer manhole.

5. There shall be no physical connection between a community water system and a non-community or private water system, unless the non-community or private water system conforms to community water system requirements.

6. Lines for potable water shall be laid at least 25 feet horizontally from any underground sewage seepage field.

Plumbing Fixture Backflow Protection

The water supply lines shall have no physical connection with nonpotable water supplies. All plumbing shall be in accord with the Uniform Plumbing Code available from this Department. All plumbing fixtures and other equipment connected to the water system shall be so constructed and installed so as to safeguard the water system from the possibility of contamination through cross-connections or backsiphonage. Laundry units and equipment shall be so constructed and installed so as to prevent the contamination of the contents by the backflow of sewage.

Water main breaks are common and that is primary reason to keep a free chlorine residual of at least .2 mg/l in the distribution system, another reason is backflow.

Disinfection of Repaired Pipeline Sections

You should recognize that the protection of the public health of its water customers is the primary role of a water provider. Accordingly, the disinfection of all repaired water appurtenances is paramount to the return of the water system to its normal operation mode. Prior to initiating the disinfection process, a thorough cleaning of all repaired pipes and or reservoirs must be accomplished. The following table indicates the amount of Sodium Hypochlorite and Calcium Hypochlorite that is necessary to disinfect 100,000 gallons of water.

Disinfection Table For 100,000 Gallons Of Water

Desired Chlorine Dose in MG/L	Pounds of Liquid Chlorine Required	Gallons of Sodium Hypo Chlorite Required 5% Available Chlorine	10% Available Chlorine	15% Available Chlorine	Pounds of Calcium Hypo Chlorite Required. 65% Available
2	1.7	3.9	2.0	1.3	2.6
10	8.3	19.4	9.9	12.8	12.8
50	42	97	49.6	64	64

Spare Parts Inventory

You should maintain a complete inventory of spare parts for the maintenance and repair of all water transmission and distribution lines. The water lines in the system range in size between ¾ inch and 16 inches in diameter. Additionally, you should maintain spare motor controls, pump ends, and motors for all wells and booster stations. Water system personnel can repair the entire range of water lines without assistance from outside contractors. Stand-by warehouse personnel should be available twenty four hours per day to assist in the delivery of spare parts in instances requiring emergency repair.

Preventative maintenance can extend the life of any water pipeline. Pipes can deteriorate on the inside as a result of corrosion and on the outside as a result of aggressive soil and moisture. The Water Department should maintain an intense leak detection program to effectively reduce operating costs and provide revenue savings by reducing lost and unaccounted for water. Leaks can originate in joints and fittings or any corroded portion of a pipeline.

Additionally, leaks will undermine the pavement and water soak the area around the leaking section of pipeline. When leaks are discovered, they should be repaired within twenty-four hours after properly locating all underground utilities through the Underground Service Alert or "***Blue Stake***" procedure.

Types of Pipes Used in the Distribution Field

Several types of pipe are used in water distribution systems, but only the most common types used by operators will be discussed. These piping materials include copper, plastic, galvanized steel, and cast iron. Some of the main characteristics of pipes made from these materials are presented below.

Plastic Pipe (PVC)

Plastic pipe has seen extensive use in current construction. Available in different lengths and sizes, it is lighter than steel or copper and requires no special tools to install. Plastic pipe has several advantages over metal pipe. It is flexible, it has superior resistance to rupture from freezing, it has complete resistance to corrosion and, in addition, it can be installed above ground or below ground.

One of the most versatile plastic and polyvinyl resin pipes is the polyvinyl chloride (**PVC**). PVC pipes are made of tough, strong thermoplastic material that has an excellent combination of physical and chemical properties. Its chemical resistance and design strength make it an excellent material for application in various mechanical systems.

Sometimes polyvinyl chloride is further chlorinated to obtain a stiffer design, a higher level of impact resistance, and a greater resistance to extremes of temperature. A CPVC pipe (a chlorinated blend of PVC) can be used not only in cold-water systems, but also in hot-water systems with temperatures up to 210°F. Economy and ease of installation make plastic pipe popular for use in either water distribution and supply systems or sewer drainage systems.

Various types and sizes of coupons or tap cut-outs. You will want to date and collect these cut-outs to determine the condition of the pipe or measure the corrosion.

Plastic Pipe (PVC)

This is currently the most common type of pipe used in distribution systems. It is available in diameters of 1/2" and larger, and in lengths of 10', 20', and 40'. A main advantage is its light weight, allowing for easy installation. A disadvantage is its inability to withstand shock loads. Since it is non-metallic, a tracer wire must be installed with the PVC water main so that it can be located after burial.

The National Sanitation Foundation (**NSF**) currently lists most brands of PVC pipe as being acceptable for potable water use. This information should be stamped on the outside of the pipe, along with working pressure and temperature, diameter and pipe manufacturer. PVC pipe will have the highest C Factor of all the above pipes. The higher the C factor ,the smoother the pipe.

Cast Iron (CIP)

This is another type of piping material that has been in use for a long time. It is found in diameters from 3" to 48". Advantages of this material are its long life, durability and ability to withstand working pressures up to 350 psi. Disadvantages include the fact that it is heavy, difficult to install and does not withstand shock loading. Although it is not currently the material of choice, there is still a lot of it in the ground.

Ductile Iron Pipe (DIP)

This was developed to overcome the breakage problems associated with cast iron pipe. It can be purchased in 4" to 45" diameters and lengths of 18' to 20'. Its main advantage is that it is nearly indestructible by internal or external pressures. It is manufactured by injecting magnesium into molten cast iron. It is sometimes protected from highly corrosive soils by wrapping the pipe in plastic sheeting prior to installation. This practice can greatly extend the life of this type of pipe.

Steel Pipe

This pipe is often used in water treatment plants and pump stations. It is available in various diameters and in 20' or 21' lengths. Its main advantage is the ability to form it into a variety of shapes. It also exhibits good yielding and shock resistance. It has a smooth interior surface and can withstand pressures up to 250 psi. A disadvantage is that it is easily corroded by both soil and water.

To reduce corrosion problems, steel pipe is usually galvanized or dipped in coal-tar enamel and wrapped with coal-tar impregnated felt. At present, however, coal-tar products are undergoing scrutiny from a health standpoint and it is recommended that the appropriate regulatory agencies be contacted prior to use of this material.

Asbestos Cement Pipe (ACP)

This pipe is manufactured from Portland cement, long fibrous asbestos and silica. It is available in diameters from 3" to 36" and in 13' lengths. Its main advantages are its ability to withstand corrosion and its excellent hydraulic flow characteristics due to its smoothness. A major disadvantage is that it is brittle and is easily broken during construction or by shock loading. There is some concern regarding the possible release of asbestos fibers in corrosive water and there has been much debate over the health effects of ingested asbestos. Of greater certainty, however, is the danger posed by inhalation of asbestos fibers. Asbestos is considered a hazardous material, and precautionary measures must be taken to protect water utility workers when cutting, tapping or otherwise handling this type of pipe.

Galvanized Pipe

Galvanized pipe is commonly used for the water distributing pipes inside a building to supply hot and cold water to the fixtures. This type of pipe is manufactured in 21-ft lengths. It is **GALVANIZED** (coated with zinc) both inside and outside at the factory to resist corrosion. Pipe sizes are based on nominal **INSIDE** diameters. Inside diameters vary with the thickness of the pipe. Outside diameters remain constant so that pipe can be threaded for standard fittings.

Copper

Copper is one of the most widely used materials for tubing. This is because it does not rust and is highly resistant to any accumulation of scale particles in the pipe. This tubing is available in four different types: **K, L, and M for water and DWV for sewer applications.**

K has the thickest walls, and M, the thinnest walls, with L's thickness in between the other two. The thin walls of copper tubing are soldered to copper fittings. Soldering allows all the tubing and fittings to be set in place before the joints are finished. Generally, the result will be faster installation.

Type K copper tubing is available as either rigid (hard temper) or flexible (soft temper) and is primarily used for underground service in the water distribution systems.

Soft temper tubing is available in 40- or 60-ft coils, while hard temper tubing comes in 12- and 20-ft straight lengths. Type L copper tubing is also available in either hard or soft temper and either in coils or in straight lengths. The soft temper tubing is often used as replacement plumbing because of the tube's flexibility, which allows easier installation.

Type L copper tubing is widely used in water distribution systems.

Type M copper tubing is made in hard temper only and is available in straight lengths of 12 and 20 ft. It has a thin wall and is used for branch supplies where water pressure is low, but it is ***NOT*** used for mains and risers. It is also used for chilled water systems, for exposed lines in hot-water heating systems, and for drainage piping.

Notice that the pipe has been illegally cut with a powersaw blade. Please check with OSHA on details on handling this common water pipe. ACP will not corrode like metal pipe but will become slow and stained by iron over time. It is easily cracked by heavy loads, but easily repaired with a clamp.

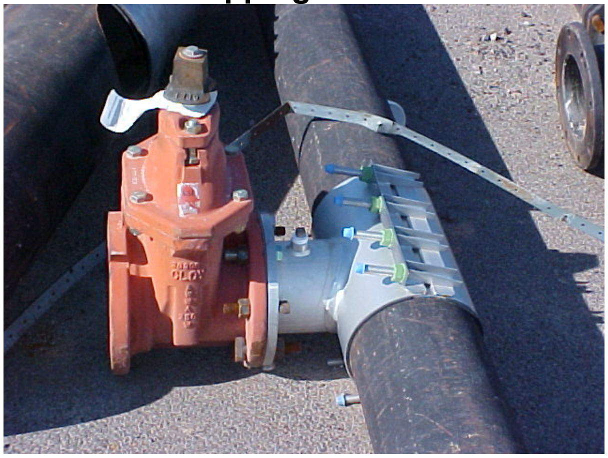
ACP Pipe with saw marks.

Joints and Fittings

Fittings vary according to the type of piping material used. The major types commonly used in water service include elbows, tees, unions, couplings, caps, plugs, nipples, reducers, and adapters.

Besides bell-and-spigot joints, cast-iron water pipes and fittings are made with either flanged, mechanical, or screwed joints. The screwed joints are used only on small-diameter pipe.

Tapping Sleeve



A Gate Valve is used to isolate sections of water mains. Not to be used to throttle or regulate the flow. A Globe valve should be used to regulate the flow. Be sure to chlorinate or disinfect all distribution parts such as valves and piping!

Caps

A pipe cap is a fitting with a female (inside) thread. It is used like a plug, except that the pipe cap screws on the male thread of a pipe or nipple.

Couplings

The three common types of couplings are straight coupling, reducer, and eccentric reducer. The **STRAIGHT COUPLING** is for joining two lengths of pipe in a straight run that do not require additional fittings. A run is that portion of a pipe or fitting continuing in a straight line in the direction of flow.

A **REDUCER** is used to join two pipes of different sizes. The **ECCENTRIC REDUCER** (also called a **BELL REDUCER**) has two female (inside) threads of different sizes with centers so designed that when they are joined, the two pieces of pipe will not be in line with each other, but they can be installed to provide optimum drainage of the line.

Elbows (or ELLS) 90° and 45°

These fittings (fig. 8-5, close to middle of figure) are used to change the direction of the pipe either 90 or 45 degrees. **REGULAR** elbows have female threads at both outlets. **STREET** elbows change the direction of a pipe in a close space where it would be impossible or impractical to use an elbow and nipple.

Both 45 and 90-degree street elbows are available with one female and one male threaded end. The **REDUCING** elbow is similar to the 90-degree elbow except that one opening is smaller than the other is.

Nipples

A nipple is a short length of pipe (12 in. or less) with a male thread on each end. It is used for extension from a fitting. At times, you may use the **DIELECTRIC** or **INSULATING TYPE** of fittings. These fittings connect underground tanks or hot-water tanks. They are also used with pipes of dissimilar metals. These help slow down corrosion that starts inside the pipe and works to the outside of the pipe.

Do not heat or solder dielectric fittings. You may melt the plastic coating on them.

Zinc is a coating on the outside and inside of pipes to slow corrosion. This process is called ***"Galvanization".***

Tees

A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. A common type of pipe tee is the **STRAIGHT** tee, which has a straight-through portion and a 90-degree takeoff on one side.

Notice the type of pipe connection device.
This is known as a "Restraining Flange".

All three openings of the straight tee are of the same size. Another common type is the **REDUCING** tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the other.

Water Main Installation

Installation of new or replacement pipe sections should be in accordance with good construction practices. The line must be buried a minimum of 30" below the ground surface to prevent freezing. The line must be bedded and backfilled properly, ensuring protection from weather and surface loadings. Also, thrust blocking (***Kickers***) at all bends, tees, and valves is essential to hold the pipe in place and prevent separation of line sections. Thrust blocking is not necessary if the pipe is welded.

Disinfection of new installations or repaired sections is required prior to placing them in service. This can be accomplished by filling the line with a 25 mg/1 free chlorine solution and allowing it to stand for 24 hours. Valves and fittings used in the waterworks industry are made of cast iron, steel, brass, stainless and fiberglass. Enough gate valves should be placed throughout the system to enable problem areas (leaks, etc.) to be isolated and repaired with minimal service disruption. Air relief valves should be installed at highpoints in the system. Valves should be installed with valve boxes and covers.

Regardless of the type of pipe installed, certain maintenance routines should be performed on the distribution system to maintain water quality and optimal service. These programs should be scheduled and performed on a regular basis.

Flushing at blowoffs on dead end lines and at fire hydrants throughout the system should be done at least twice per year. Flushing is needed to remove stagnant water in dead ends and to remove accumulated sediment that results from turbidity, iron, manganese, etc.

This should also help minimize customer complaints of water quality. Flushing should always be done from the source to the ends of the system. Affected customers should be notified of this process in advance. To do an adequate job of flushing, the flow should reach a velocity of at least 2.5 feet per second, known as the "***minimum cleansing velocity***" of the system (at hydrant locations).

These tests are important to determine the adequacy of the distribution system in transmitting water, particularly during days of peak demand. Also, these tests can help determine if pipe capacity is decreasing over time due to internal corrosion or deposits.

Pressure tests should be done at various locations in the distribution system several times per year. This helps to monitor the performance of the system and alert the operator to problems such as leaks or internal deposits. It is sometimes advantageous to have certain points in the system continuously monitored to provide a constant evaluation of the system.

Troubleshooting Table for Distribution System

Problem
1. Dirty water complaints
2. Red water complaints
3. No or low water pressure
4. Excessive water usage.

Possible Causes
1A. Localized accumulations of debris, solids/particulates in distribution mains.
1B. Cross connection between water system and another system carrying non-potable water.
2A. Iron content of water from source is high. Iron precipitates in mains and accumulates.
2B. Cast iron, ductile iron, or steel mains are corroding causing *"rust"* in the water.
3A. Source of supply, storage or pumping station interrupted.
3B. System cannot supply demands.
3C. Service line, meter or connections shutoff or clogged with debris.
3D. Broken or leaking distribution pipes.
3E. Valve in system closed or broken.
4A. More connections have been added to the system.
4B. Excessive leakage (>15% of production)is occurring, meters are not installed or not registering properly.
4C. Illegal connections have been made.

Possible Solutions
1A. Collect and preserve samples for analysis if needed. Isolate affected part of main and flush.
1B. Collect and preserve samples for analysis if needed. Conduct survey of system for cross connections. Contact State Drinking Water Agency.
2A. Collect and test water samples from water source and location of complaints for iron. If high at both sites, contact regulatory agency, TA provider, consulting engineer or water conditioning company for assistance with iron removal treatment.
2B. Collect and analyze samples for iron and corrosion parameters. Contact State Drinking Water Agency , TA provider, consulting engineer or water conditioning company for assistance with corrosion control treatment.
3A. Check source, storage and pumping stations. Correct or repair as needed.
3B. Check to see if demands are unusually high. If so, try to reduce demand. Contact State Drinking Water Agency, TA provider or consulting engineer.
3C. Investigate and open or unclog service.
3D. Locate and repair break or leak.
3E. Check and open closed isolation and pressure-reducing valves. Repair or contact contractor if valves are broken.
4A. Compare increase in usage over time with new connections added over same period. If correlation evident take action to curtail demand or increase capacity if needed. Contact State Drinking Water Agency , TA provider or consulting engineer.
4B. Conduct a water audit to determine the cause. If leakage, contact regulatory agency, and consulting engineer or leak detection contractor.
4C. Conduct survey to identify connections.

Distribution and Storage Summary

Safe entry into a confined space requires that all entrants wear a harness and safety line.

If an operator is working inside a storage tank and suddenly faints or has a serious problem, there should be two people outside standing by to remove the injured operator.

During an inspection of your water storage facility, you should inspect the Cathodic protection system including checking the anode's condition and the connections.

The concentration of polyphosphates that is used for corrosion control in storage tanks is typically 5 mg/L or less.

External corrosion of steel water storage facilities can be reduced with Zinc or aluminum coatings.

All storage facilities should be regularly sampled to determine the quality of water that enters and leaves the facility. One tool or piece of measuring equipment is the Jackson turbidimeter, which is a method to measure cloudiness in water.

The effects of water freezing in storage tanks can be minimized by alternating water levels in the tank.

The venting of air is not a major concern when checking water levels in a storage tank.

If an overflow occurs on a storage tank, the operator should first check the altitude-control valve.

The Altitude-Control Valve is designed to 1.) Prevent overflows from the storage tank or reservoir, or 2.) Maintain a constant water level as long as water pressure in the distribution system is adequate.

Pressure Regulation Valves control water pressure and operate by restricting flows. They are used to deliver water from a high pressure to a low-pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening.

Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In other words, something is ***"sucked"*** into the system because the main is under a vacuum.

The following are common pressure sensing devices: Helical Sensor, Bourdon Tube, and Bellows Sensor.

The most frequent problem that affects a liquid pressure-sensing device is air accumulation at the sensor.

A diaphragm element being used as a level sensor would be used in conjunction with a Pressure Sensor.

Inspection of magnetic flow meter instrumentation should include checking for corrosion or insulation deterioration.

Transmitting equipment requires installation where temperature will not exceed 130°F.

Telemetering systems must often transmit more than one signal. You can use several types of systems including: Polling, Scanning and Multiplexing.

The Strain Gauge is a common measuring device used for a variety of changes such as head. As the pressure in the system changes, the diaphragm expands, which changes the length of the wire attached. This changes the Resistance of the wire, which is then converted to head.

Float mechanisms, diaphragm elements, bubbler tubes, and direct electronic sensors are common types of level sensors.

Distribution system water quality can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. The common customer complaint of Milky Water is sometimes solved by the installation of these air relief valves.

When inspecting the plans for a new ground water storage tank, the superintendent should pay attention to the outlet and inlet and be sure that they are on opposite sides of the tank.

Surge tanks are used to control Water Hammer.

A limitation of hydropneumatic tanks is that they do not provide much storage to meet peak demands during power outages and you have very limited time to do repairs on equipment.

The maximum momentary load placed on a water treatment plant, pumping station or distribution system is the Peak Demand.

General & Safety Information

One of the roles of a distribution system supervisor is to inform the operators of SOPs concerning public relations. This can be accomplished by regular informational staff meetings.

Sprains and strains are the most frequent type of accident(s) encountered by water distribution personnel.

If a thrust block of another utility is discovered in your path while excavating, you should not alter the existing thrust block in any way.

Right to Know Laws state that the employer has the responsibility to provide the employees with information about the information about health hazards and chemical handling.

Uniforms and proper credentials aid meter readers and operators that work close to private property because they help readily identify personnel.

The Building Inspector is responsible for the enforcement of building regulations.

For a dead-end line of over 2,000 feet, the design criteria would dictate a minimum pipe diameter of 8 inches.

Any equipment that utilizes water for cooling, lubrication, washing or as a solvent is always susceptible to Cross-connections.

When installing a vacuum breaker backflow device, the operator must make sure that it is 12 inches above the highest discharge outlet. A double check will stop backsiphonage and backpressure of low contamination threats.

The relief valve will open and drain if a pressure differential occurs between the two checks; this best describes the operation of a reduced pressure principal backflow assembly device.

The water utility has the responsibility for ensuring that water contamination due to cross connections does not occur.

Pesticide mixing tanks have one of the greatest potential hazards of contamination if a cross connection occurs.

The most likely consequence if a backsiphonage condition causes a cross connection and pressure is then restored to the system is that the distribution system downstream of the cross connection will be contaminated.

An operator places a screen before a backflow prevention assembly to prevent debris from fouling the assembly.

Water audits can be performed in order to account for the water in the system. A 24-hour measure of all the water entering the system should be the first step in a water audit.

When you are shutting a large valve, a bypass valve will reduce high pressure that can be present.

If the pH of water from a dead-end line begins to drop, it is most likely an indication that anaerobic conditions are present.

The Hazen-Williams formula is used to determine pipe size.

Negative pressure in parts of the system may occur during periods of high flow or a fire when the waterline pressure has dropped drastically.

Wells and Pump Section   Chapter 8

Drilling a new groundwater production well.

Wells

Introduction

The purpose of this section is to provide background information about wells: types of wells, construction and main components, and the common problems associated with wells, their likely causes, and ways to proceed with their correction. (First, however, it is important to discuss how well problems can affect the health and safety of the Water Department.)

Operators usually learn of well problems when complaints are received about no water or low pressure, or the water smells, tastes, or looks bad. Whatever the problem, the operator is responsible for identifying the cause of the problem and for correcting it as soon as possible. The lack of a safe and adequate water supply requires an immediate response. Public health officials regard the lack of a safe and adequate water supply for more than 24 hours as a serious health hazard. The lack of an adequate and safe supply of water means the users are unable to wash, flush away bodily wastes, or safely prepare food and beverages. When tap water is discolored, or has a disagreeable taste or odor, users may reject it and may obtain drinking water from a source that is unsafe.

Background Information

Well structures may be dug, driven, bored, jetted, or drilled depending on the geological formations through which they must pass and the depth to which they must reach. Sinking methods--dug, driven, bored, and jetted wells--are usually confined to relatively soft soils overlaying rock and to shallow depths normally less than 50 feet (15 meters). Wells using these sinking methods should not be constructed for use as public water sources unless specifically approved by the state regulatory agency. Drilled wells are preferred for potable water supplies and can be used in both soft and hard soil and in rock and may be sunk to depths of several hundred or more feet. Drilled wells can be constructed in all instances where driven, jetted, dug and bored wells are constructed. The larger diameter of a drilled well, compared with a driven or jetted well, allows the use of larger pumping equipment that can develop the full capacity of the aquifer.

Casing

Well casing is installed in wells to prevent the collapse of the walls of the bore hole, to prevent pollutants (either surface or subsurface) from entering the water source and to provide a column of stored water and a support housing for the pump mechanisms and pipes. The top of the casing should be extended above the ground level around the well so that it will not be flooded.

Grout

Cement grout is used to fill the annular open space left around the outside of the well casing during construction to prevent undesirable water and contamination from entering the well.

Screens

Screens are installed at the intake point of the well to hold back unstable aquifer material and permit free flow of water into the well. The well screen should be of good quality (corrosion-resistant, hydraulically efficient, and with good structural properties).

Sanitary Seal

Well head covers or seals are used at the top of the casing or pipe sleeve connections to prevent contaminated water or other material from entering the well. A variety of covers and seals are available to meet the variety of conditions encountered, but the principles and the objective of excluding contamination are the same.

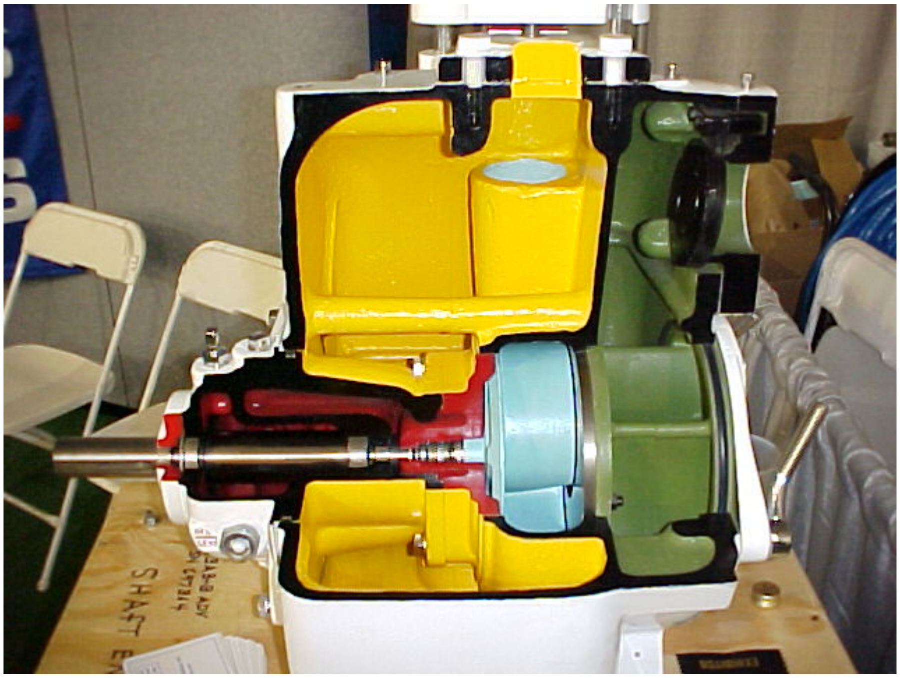
Pitless Units

Pitless units are used to eliminate the need for a well pit. Because of the flooding and pollution hazards involved, a well pit to house the pumping equipment or to permit accessibility to the top of the well is not recommended. Some states prohibit its use. These units vary in design but generally include a special fitting designed for placement on the side of the well casing. The well discharge piping is screw-threaded into the fitting, providing a tight seal. The pitless system permits the connection of the well piping to the casing underground below frost depth and, at the same time, provides for good accessibility to the well casing for repairs without excavation.

Pump

A submersible pump is normally used to lift water from inside the well casing to the ground surface. In most small systems with minimal treatment of the raw water, the pump also delivers the water to the point of application of chemical treatment, such as chlorination, and then into the storage and distribution system. This is accomplished without exposing the pumped water to the atmosphere.

Troubleshooting Pumps



Experience has shown that many well problems are related to electricity. Well pumps require electricity to run, and when the electrical supply is interrupted, so is the water supply. What this tells us is that lack of water in the system, or low pressure complaints probably means that electricity is not reaching the well pump. See the Troubleshooting Table that lists this and other problems, and identifies corrective actions.

Pump Review Statements

- ✓ What causes pump cavitation? A suction line may be clogged
- ✓ What does continuous leakage from a mechanical seal on a pump indicate? The Mechanical seal needs to be replaced.
- ✓ What happens to the viscosity of most lubricants as the temperature increases? The viscosity decreases.
- ✓ What is a possible cause of a scored shaft sleeve? The packing has broken down
- ✓ What is one disadvantage of a centrifugal pump? It is not self-priming.
- ✓ How long is the typical operating life of a mechanical seal? 5,000 to 20,000 hours
- ✓ When should a reciprocating pump or piston pump not be operated? Pump discharge valve
- ✓ An air compressor generates heat during the compression cycle. What is the most common type of damage caused by heat generated during operation? The lubricating oil tends to break down quickly requiring frequent replacement.

Pump Operations

Pump Objectives

- ★ **What is a pump?**
- ★ **Identify different types of pumps and related parts**
- ★ **Identify the main purpose of a motor starter.**
- ★ **Describe the main use of AC and DC motors in the plant.**
- ★ **Describe the operations of level sensor controls.**
- ★ **Identify and describe the most commonly used pumps.**
- ★ **Identify the suction and discharge valving.**
- ★ **Distinguish between discharge head, total head, suction head, and suction lift.**
- ★ **Describe information to be obtained from pump performance graphs.**
- ★ **Identify types of couplings, bearings, seals and other pump components.**
- ★ **Describe the importance of alignment of coupling.**
- ★ **Indicate when packing seals need to be replaced.**
- ★ **Describe cavitation.**
- ★ **Describe water hammer.**
- ★ **State the basic principles of positive displacement pumps.**

Pump Definitions *(Larger Glossary in the rear of this manual)*

Fluid: Any substance that can be pumped, such as oil, water, refrigerant, or even air.

Gasket: Flat material that is compressed between two flanges to form a seal.

Gland follower: A bushing used to compress the packing in the stuffing box and to control leakoff.

Gland sealing line: A line that directs sealing fluid to the stuffing box.

Horizontal pumps: Pumps in which the Center line of the shaft is horizontal.

Impeller: The part of the pump that increases the speed of the fluid being handled.

Inboard: The end of the pump closest to the motor.

Inter-stage diaphragm: A barrier that separates stages of a multi-stage pump.

Key: A rectangular piece of metal that prevents the impeller from rotating on the shaft.

Keyway: The area on the shaft that accepts the key.

Kinetic energy: Energy associated with motion.

Lantern ring: A metal ring located between rings of packing that distributes gland sealing fluid.

Leak-off: Fluid that leaks from the stuffing box.

Mechanical seal: A mechanical device that seals the pump stuffing box.

Mixed flow pump: A pump that uses both axial-flow and radial-flow components in one Impeller.

Multi-stage pumps: Pumps with more than one impeller.

Outboard: The end of the pump farthest from the motor.

Packing: Soft, pliable material that seals the stuffing box.

Positive displacement pumps: Pumps that move fluids by physically displacing the fluid inside the pump.

Radial bearings: Bearings that prevent shaft movement in any direction outward from the center line of the pump.

Radial flow: Flow at 90° to the center line of the shaft.

Retaining nut: A nut that keeps the part in place.

Rotor: The rotating parts, usually including the impeller, shaft, bearing housings and all other parts between the bearing housing and the impeller.

Score: To cause lines, grooves or scratches.

Shaft: A cylindrical bar that transmits power from the driver to the pump impeller.

Shaft sleeve: A replaceable tubular covering on the shaft.

Shroud: The metal covering over the vanes of an impeller.

Slop drain: The drain from the area that collects leak-off from the stuffing box.

Slurry: A thick viscous fluid, usually containing small particles.

Stages: Impellers in a multi-stage pump.

Stethoscope: A metal device that can amplify and pinpoint pump sounds.

Strainer: A device that retains solid pieces while letting liquids through.

Stuffing box: The area of the pump where the shaft penetrates the casing.

Suction: The place where fluid enters the pump.

Suction eye: The place where fluid enters the pump impeller.

Throat bushing: A bushing at the bottom of the stuffing box that prevents packing from being pushed out of the stuffing box into the suction eye of the impeller.

Thrust: Force, usually along the center line of the pump.

Thrust bearings: Bearings that prevent shaft movement back and forth in the same direction as the center line of the shaft.

Troubleshooting: Locating a problem.

Vanes: The parts of the impeller that push and increase the speed of the fluid in the pump.

Vertical pumps: Pumps in which the center line of the shaft runs vertically.

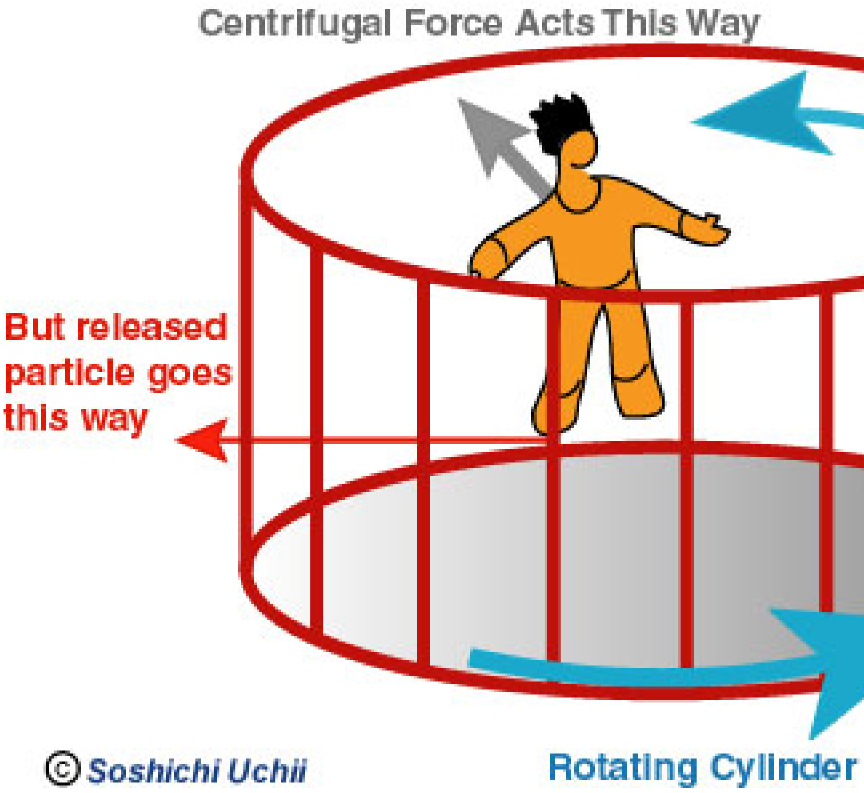
Volute: The part of the pump that changes the speed of the fluid into pressure.

Wearing rings: Replaceable rings on the impeller or the casing that wear as the pump operates.

Centrifugal pumps do not generate suction unless the impeller is submerged in water. If a pump is located above the level of water what must be provided on the suction piping to hold the prime? A foot valve

Basic Water Pump

The water pumps in distribution systems are centrifugal pumps. These pumps work by spinning water around in a circle inside a cylindrical pump housing. The pump makes the water spin by pushing it with an impeller. The blades of this impeller project outward from an axle like the arms of turnstile and, as the impeller spins, the water spins with it. As the water spins, the pressure near the outer edge of the pump housing becomes much higher than near the center of the impeller.

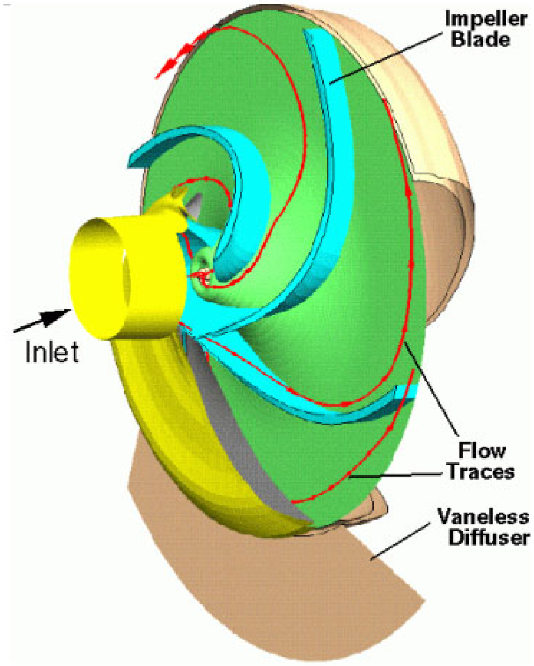


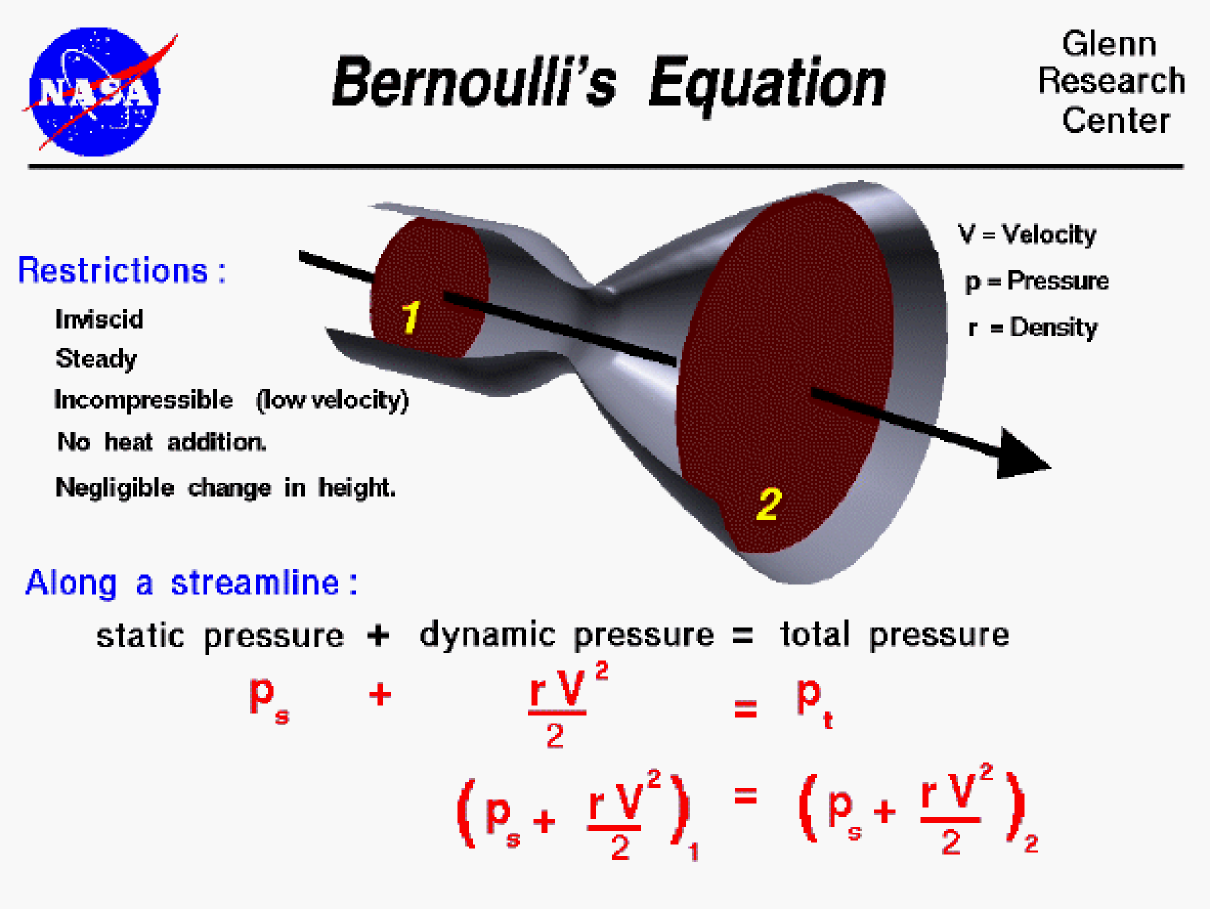
There are many ways to understand this rise in pressure, and here are two:
First, you can view the water between the impeller blades as an object traveling in a circle. Objects do not naturally travel in a circle--they need an inward force to cause them to accelerate inward as they spin. Without such an inward force, an object will travel in a straight line and will not complete the circle. In a centrifugal pump, that inward force is provided by high-pressure water near the outer edge of the pump housing. The water at the edge of the pump pushes inward on the water between the impeller blades and makes it possible for that water to travel in a circle. The water pressure at the edge of the turning impeller rises until it is able to keep water circling with the impeller blades.

You can also view the water as an incompressible fluid, one that obeys Bernoulli's equation in the appropriate contexts. As water drifts outward between the impeller blades of the pump, it must move faster and faster because its circular path is getting larger and larger. The impeller blades do work on the water so it moves faster and faster. By the time the water has reached the outer edge of the impeller, it is moving quite fast. However, when the water leaves the impeller and arrives at the outer edge of the cylindrical pump housing, it slows down.

Here is where Bernoulli's equation figures in. As the water slows down and its kinetic energy decreases, that water's pressure potential energy increases (*to conserve energy*). Thus, the slowing is accompanied by a pressure rise. That is why the water pressure at the outer edge of the pump housing is higher than the water pressure near the center of the impeller.

When water is actively flowing through the pump, arriving through a hole near the center of the impeller and leaving through a hole near the outer edge of the pump housing, the pressure rise between center and edge of the pump is not as large.





Bernoulli's Equation

Glenn
Research
Center

Restrictions :

- Inviscid
- Steady
- Incompressible (low velocity)
- No heat addition.
- Negligible change in height.

V = Velocity
p = Pressure
r = Density

Along a streamline :

static pressure + dynamic pressure = total pressure

$$p_s + \frac{r V^2}{2} = p_t$$

$$\left(p_s + \frac{r V^2}{2}\right)_1 = \left(p_s + \frac{r V^2}{2}\right)_2$$

Vertical Turbine Pump

Large Diameter Submersible Pump, Motor and Column Pipe

Larger check valve installed on submersible pump to prevent water hammer (notice motor shaft splines)

Types of Water Well Pumps

The most common type of water well pumps used for municipal and domestic water supplies are *variable displacement* pumps. A variable displacement pump will produce at different rates relative to the amount of pressure or lift the pump is working against. *Centrifugal* pumps are variable displacement pumps that are by far used the most. The water production well industry almost exclusively uses *Turbine* pumps, which are a type of centrifugal pump.

The turbine pump utilizes *impellers* enclosed in single or multiple *bowls (or stages)* to lift water by *centrifugal force*. The impellers may be of either a *semi-open or closed type*. Impellers are rotated by the *pump motor,* which provides the horsepower needed to overcome the pumping head. A more thorough discussion of how these and other pumps work is presented in the pump section of this course. The size and number of stages, horsepower of the motor, and pumping head are the key components relating to the pump's lifting capacity.

Vertical turbine pumps are commonly used in groundwater wells. These pumps are driven by a shaft rotated by a motor on the surface. The shaft turns the impellers within the pump housing while the water moves up the column. This type of pumping system is also called a *line-shaft turbine*. The rotating shaft in a line shaft turbine is actually housed within the column pipe that delivers the water to the surface. The size of the column, impeller, and bowls are selected based on the desired pumping rate and lift requirements.

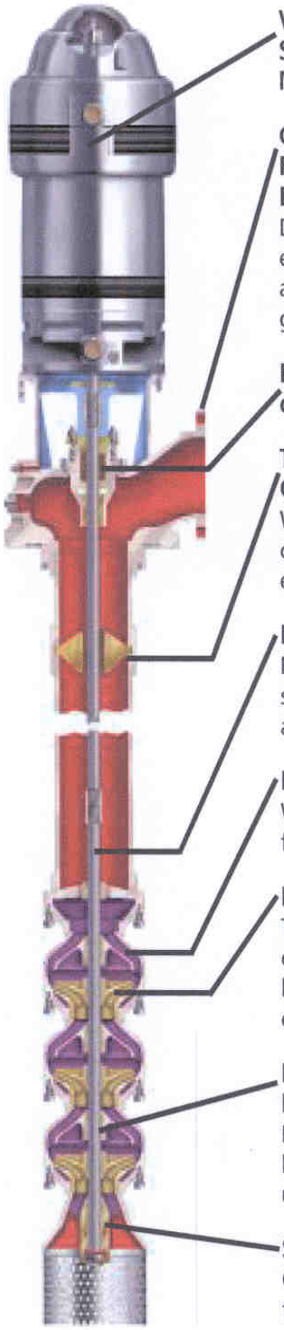
Column pipe sections can be threaded or coupled together, while the drive shaft is coupled and suspended within the column by *spider bearings*. The spider bearings provide both a seal at the column pipe joints and keep the shaft aligned within the column. The water passing through the column pipe serves as the lubricant for the bearings. Some vertical turbines are lubricated by oil rather than water. These pumps are essentially the same as water lubricated units only the drive shaft is enclosed within an *oil tube*.

Food grade oil is supplied to the tube through a gravity feed system during operation. The oil tube is suspended within the column by *spider flanges* while the line shaft is supported within the oil tube by *brass or redwood bearings*. A continuous supply of oil lubricates the drive shaft as it proceeds downward through the oil tube. A small hole located at the top of the pump bow unit allows excess oil to enter the well. This results the formation of an oil film on the water surface within oil-lubricated wells. Careful operation of oil lubricated turbines is needed to ensure that the pumping levels do not drop enough to allow oil to enter the pump.

Both water and oil lubricated turbine pump units can be driven by electric or fuel powered motors. Most installations use an electric motor that is connected to the drive shaft by a keyway and nut. However, where electricity is not readily available, fuel powered engines may be connected to the drive shaft by a right angle drive gear.

Also, both oil and water lubricated systems will have a strainer attached to the intake to prevent sediment from entering the pump. When the line shaft turbine is turned off water will flow back down the column, turning the impellers in a reverse direction. A pump and shaft can easily be broken if the motor were to turn on during this process. This is why a *time delay* or *ratchet* assembly is often installed on these motors to either prevent the motor from turning on before reverse rotation stops or simply not allow it to reverse at all.

Common Elements of Vertical Turbines



Vertical Hollow Shaft or Solid Shaft Motors

Cast Iron or Fabricated Discharge Head
Designed for mounting electric motor, right angle or combination gear.

Packed Stuffing Box or Mechanical Seal

Threaded or Flanged Column Assemblies
With bronze or cast iron bearing retainers.

Lineshaft
Polished high strength stainless steel. Other alloys available.

Intermediate Bowls
Waterways glass lined for maximum efficiency.

Impellers
Taperlocked or keyed construction. Precision balanced for smooth operation.

Intermediate Bowl Bearings
Bronze, rubber or carbon for long pump life under any conditions.

Suction Bell Bearing
Grease-packed for long trouble-free life.

Vertical Turbine

Pump Being Removed →

(notice line shaft)

Closed Pump Impeller→

Submersible Pumps

Submersible pumps are in essence very similar to turbine pumps. They both use impellers rotated by a shaft within the bowls to pump water. However, the pump portion is directly connected to the motor. The pump shaft has a keyway in which the splined motor end shaft inserts. The motor is bolted to the pump housing. The pump intake is located between the motor and the pump and is normally screened to prevent sediment from entering the pump and damaging the impellers.

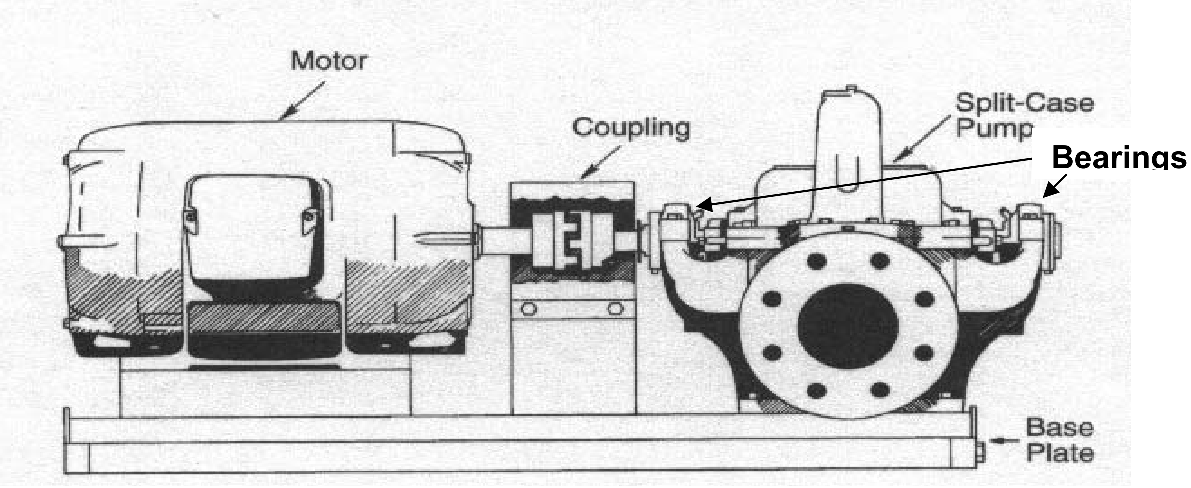
The efficient cooling of submersible motors is very important so these types of pumps are often installed such that flow through the well screen can occur upwards past the motor and into the intake. If the motor end is inserted below the screened interval or below all productive portions of the aquifer it will not be cooled, resulting in premature motor failure. Some pumps may have ***pump shrouds*** installed on them to force all the water to move past the motor to prevent overheating.

The shroud is a piece of pipe that attaches to the pump housing with an open end below the motor. As with turbine pumps the size of the bowls and impellers, number of stages, and horsepower of the motor are adjusted to achieve the desired production rate within the limitations of the pumping head.

Insertion of motor spline into pump keyway

←Cut away of a small submersible pump

The picture below illustrates the components that are common to all pump assemblies.



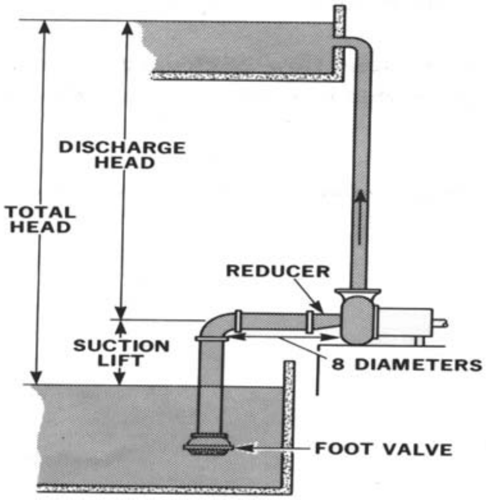


Illustration A

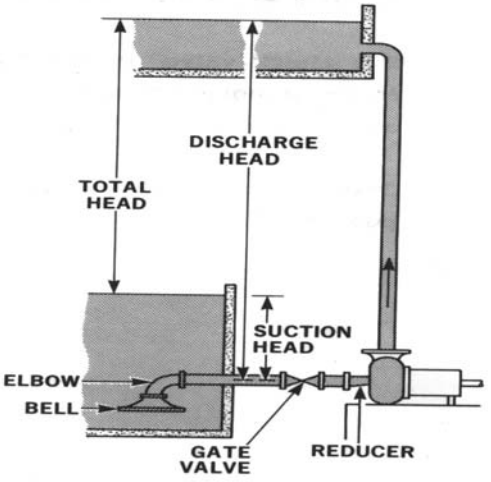


Illustration B

General Water Pumping Fundamentals

Here are the important points to consider about suction piping when the liquid being pumped is below the level of the pump.

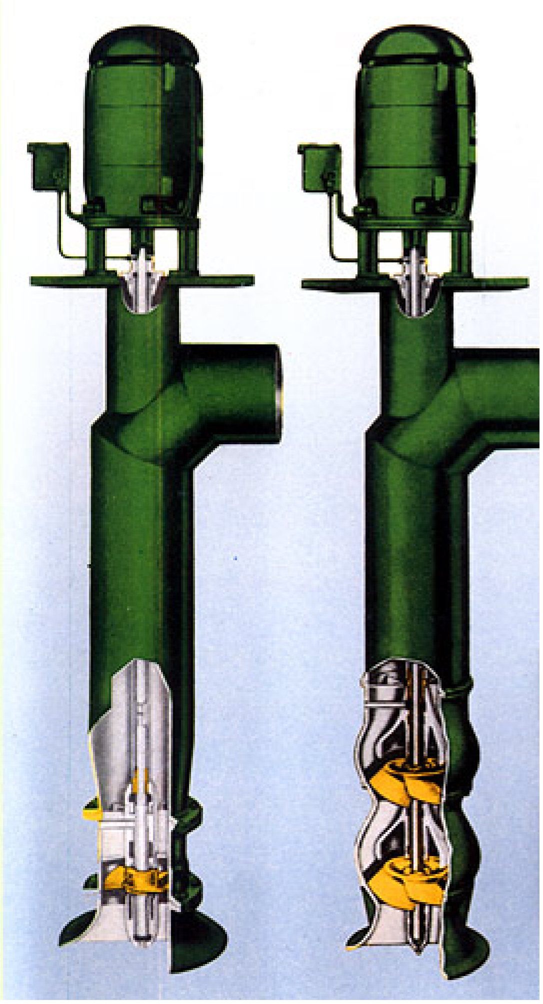
- First, the term suction lift is when the level of water to be pumped is below the centerline of the pump. Sometimes suction lift is also referred to as '**negative suction head'**.
- The ability of the pump to lift water is the result of a partial vacuum created at the center of the pump.
- This works similar to sucking soda from a straw. As you gently suck on a straw, you are creating a vacuum or a pressure differential. Less pressure is exerted on the liquid inside the straw, so that the greater pressure is exerted on the liquid around the outside of the straw causing the liquid in the straw to move up. By sucking on the straw this allowed atmospheric pressure to move the liquid.
- The foot valve is located at the end of the suction pipe of a pump. It opens to allow water to enter the suction side, but closes to prevent water from passing back out of the bottom end.
- The suction side of pipe should be one diameter larger than the pump inlet. The required eccentric reducer should be turned so that the top is flat and the bottom tapered.

The liquid is above the level of the pump. Sometimes this is referred to as 'flooded suction' or 'suction head' situations.

Points to note are:
If an elbow and bell are used, they should be at least one pipe diameter from the tank bottom and side.

This type of suction piping must have a gate valve which can be used to prevent the flow when the pump has to be removed.

The discharge head is from the centerline of the pump to the level of the discharge water. The total head is the difference between the two liquid levels.



Motor, Coupling and Bearings

We will now refer to the motor, coupling, and bearings. The power source of the pump is usually an electric motor. The motor is connected by a coupling to the pump shaft. The purpose of the bearings is to hold the shaft firmly in place, yet allow it to rotate. The bearing house supports the bearings and provides a reservoir for the lubricant. An impeller is connected to the shaft.

The pump assembly can be a vertical or horizontal set up. The components for both are basically the same.

Motors

The purpose of this discussion on pump motors is to identify and describe main types of motors, starters, enclosures and motor controls, as well as to provide you with some basic maintenance and troubleshooting information.

Although pumps could be driven by diesel or gasoline engines, pumps driven by electric motors are commonly used in our industry.

There are two general categories of electric motors:

- D-C motors, or direct current.
- A-C motors, or alternating current.

You can expect most motors at facilities to be A-C type.

D-C Motors

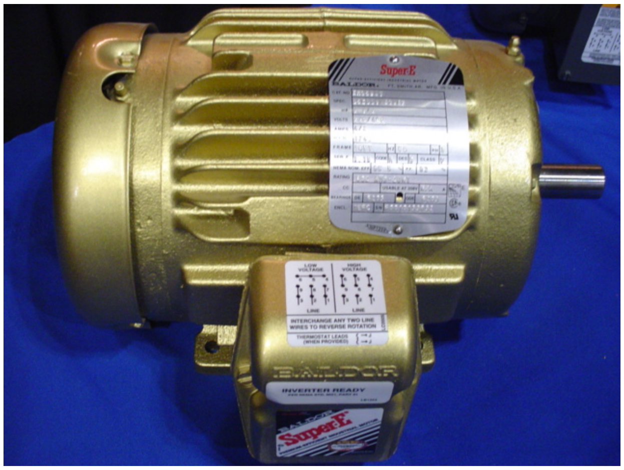
The important characteristic of the D-C motor is that its speed will vary with the amount of current used. There are many different kinds of D-C motors, depending on how they are wound and on their speed/torque characteristics.

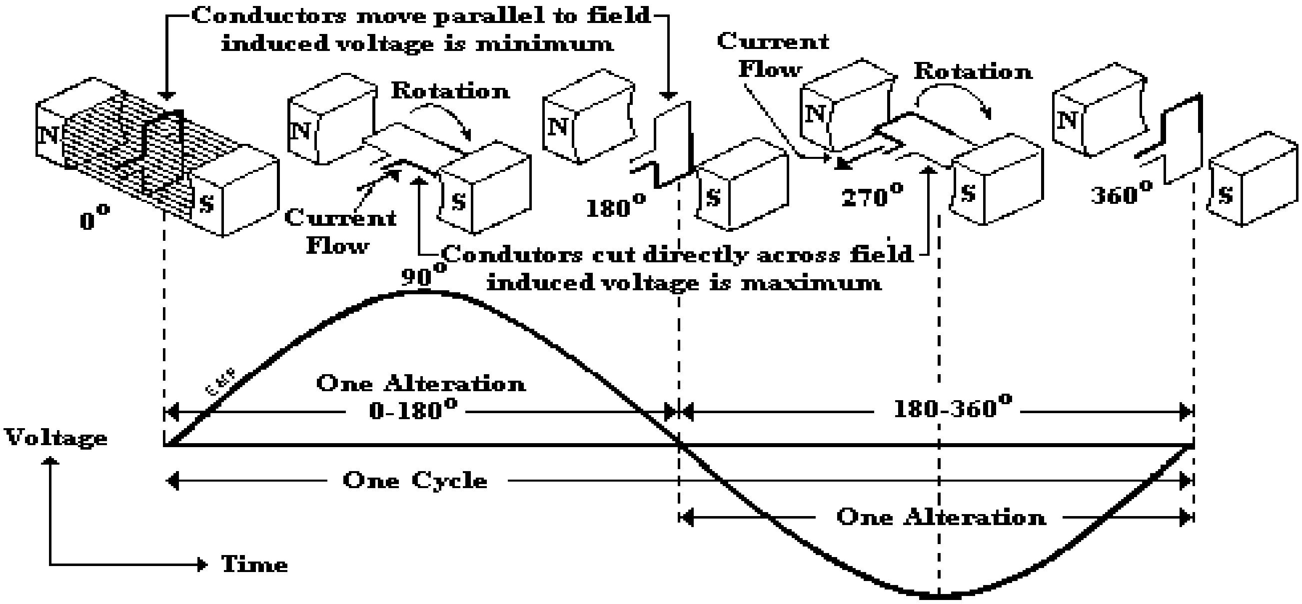
A-C Motors

There are a number of different types of alternating current motors, such as synchronous and induction; wound rotor and squirrel cage.

The synchronous type of A-C motor requires complex control equipment, since they use a combination of A-C and D-C. This also means that the synchronous type of A-C motor is used in large horsepower sizes, usually above 250 HP.

The induction type motor uses only alternating current. The squirrel cage motor provides a relatively constant speed and the wound rotor type could be used as a variable speed motor.





Define the following:

Voltage:

EMF:

Power:

Current:

Resistance:

Conductor:

Phase:

Single Phase:

Three Phase:

Hertz:

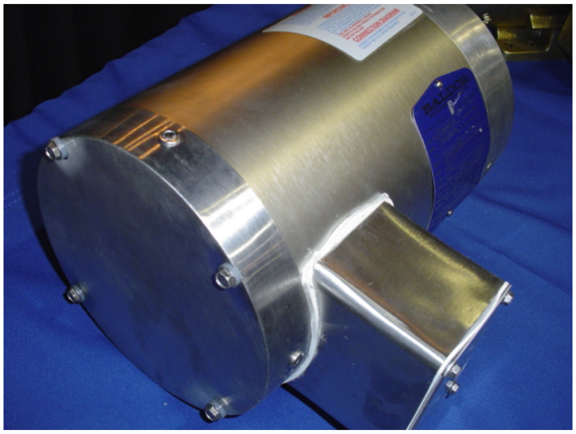
Motor Starters

All electric motors, except very small ones such as chemical feed pumps, are equipped with starters, either full voltage or reduced voltage. This is because motors draw a much higher current when they are starting and gaining speed. The purpose of the reduced voltage starter is to prevent the load from coming on until the amperage is low enough.

How do you think keeping the discharge valve closed on a centrifugal pump could reduce the start up load?

Motor Enclosures

Depending on the application, motors may need special protection. Some motors are referred to as open motors. They allow air to pass through to remove heat generated when current passes through the windings. Other motors use specific enclosures for special environments or safety protection. Can you think of any locations within your facility that require special enclosures?



Two types of totally enclosed motors commonly used are:

- **TENV**, or totally enclosed non-ventilated motor.
- **TEFC**, or totally enclosed fan cooled motor.

Totally enclosed motors include dust-proof, water-proof and explosion-proof motors. An explosion proof enclosure must provided on any motor where dangerous gases might accumulate.

Motor Controls

All pump motors are provided with some method of control, typically a combination of manual and automatic. Manual pump controls can be located at the central control panel at the pump or at the suction or discharge points of the liquid being pumped.

There are a number of ways in which automatic control of a pump motor can be regulated:

- Pressure and vacuum sensors
- Preset time intervals
- Flow sensors
- Level sensors

Two typical level sensors are the float sensor and the bubble regulator. The float sensor is pear-shaped and hangs in the wet well. As the height increases, the float tilts and the mercury in the glass tube flows toward the end of the tube that has two wires attached to it. When the mercury covers the wires, it closes the circuit. A low pressure air supply is allowed to escape from a bubbler pipe in the wet well. The back-pressure on the air supply will vary with the liquid level over the pipe. Sensitive air pressure switches will detect this change and use this information to control pump operation.

Motor Maintenance

Motors should be kept clean, free of moisture, and lubricated properly. Dirt, dust, and grime will plug the ventilating spaces and can actually form an insulating layer over the metal surface of the motor.

What condition would occur if the ventilation becomes blocked?

In the space provided below, list step-by-step ways that you would perform cleaning the motor.

Moisture

Moisture harms the insulation on the windings to the point where they may no longer provide the required insulation for the voltage applied to the motor. In addition, moisture on windings tends to absorb acid and alkali fumes, causing damage to both insulation and metals. To reduce problems caused by moisture, the most suitable motor enclosure for the existing environment will normally be used. It is recommended to run stand by motors to dry up any condensation which accumulates in the motor.

Motor Lubrication

Friction will cause wear in all moving parts, and lubrication is needed to reduce this friction. It is very important that all your manufacturer's lubrications are strictly followed. You have to be careful not to add too much grease or oil--this could cause more friction and generate heat.

To grease the motor bearings, this is the usual approach:

1. Remove the protective plugs and caps from the grease inlet and relief holes.
2. Pump grease in until fresh grease starts coming from the relief hole.

If fresh grease does not come out of the relief hole, this could mean that the grease has been pumped into the motor windings. The motor must then be taken apart and cleaned by a qualified service representative.

To change the oil in an oil lubricated motor, this is the usual approach:

1. Remove all plugs and let the oil drain.
2. Check for metal shearing.
3. Replace the oil drain.
4. Add new oil until it is up to the oil level plug.
5. Replace the oil level and filter plug.

Never mix oils, since the additives of different oils, when combined, can cause breakdown of the oil.

Couplings

The pump coupling serves two main purposes:

- It couples or joins the two shafts together to transfer the rotation from motor to impeller.
- It compensates for small amounts of misalignment between the pump and the motor.

Remember that any coupling is a device in motion. If you have a 4-inch diameter coupling rotating at 1800 rpm, its outer surface is traveling about 20 mph. With that in mind, can you think of safety considerations?

There are three commonly used types of couplings: ***Rigid, Flexible, and V-belts.***

Rigid Coupling

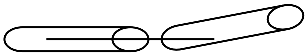
Rigid couplings are most commonly used on vertically mounted pumps. The rigid coupling is usually specially keyed or constructed for joining the coupling to the motor shaft and the pump shaft. There are two types of rigid couplings: the flanged coupling, and the split coupling. Another type of coupling is the flexible coupling. The flexible coupling provides the ability to compensate for small shaft misalignments. Shafts should be aligned as close as possible regardless. The greater the misalignment, the shorter the life of the coupling. Bearing wear and life are also affected by misalignment.

Alignment of Flexible and Rigid Couplings

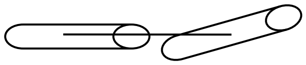
Both flexible and rigid couplings must be carefully aligned before they are connected.

Misalignment will cause excessive heat and vibration, as well as bearing wear. Usually, the noise from the coupling will warn you of shaft misalignment problems.

Three types of shaft alignment problems are shown in the pictures below:



ANGULAR MISALIGNMENT



ANGULAR AND PARALLEL

PARALLEL MISALIGNMENT

Different couplings will require different alignment procedures. We will look at the general procedures for aligning shafts.

1. Place the coupling on each shaft.
2. Arrange the units so they appear to be aligned. (place shims under the legs of one of the units to raise it.)
3. Check the run-out or difference between the driver and driven unit by rotating the shafts by hand.
4. Turn both units so that the maximum run-out is on top.

Now you can check the units for both parallel and angular alignment. Many techniques are used, such as straight edge, needle deflection (dial indicators), calipers, tapered wedges, and Laser alignment.

V-Belt Drives

V-belt drives connect the pump to the motor. A pulley is mounted on the pump and motor shaft. One or more belts are used to connect the two pulleys. Sometimes a separately mounted third pulley is used. This idler pulley is located off centerline between the two pulleys, just enough to allow tensioning of the belts by moving the idler pulley. An advantage of driving a pump with belts is that various speed ratios can be achieved between the motor and the pump.

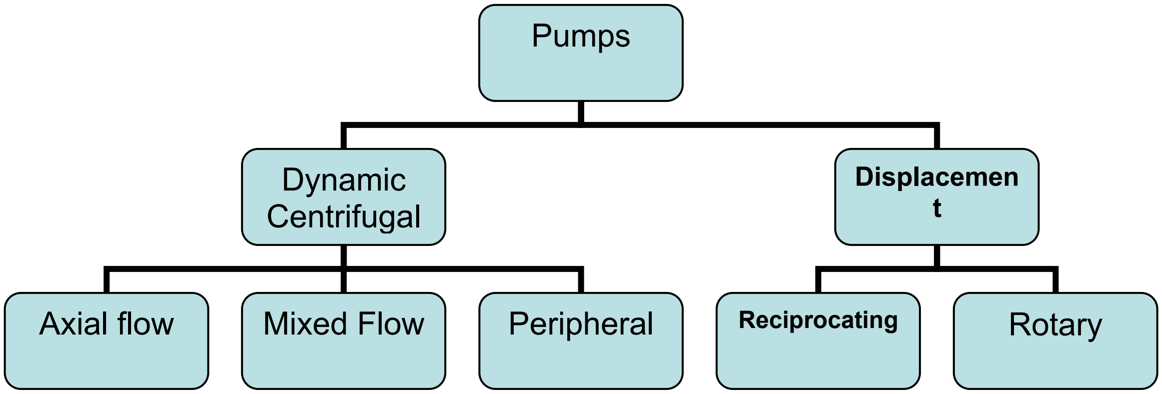
Shaft Bearings

There are three types of bearings commonly used: ball bearings, roller bearings, and sleeve bearings. Regardless of the particular type of bearings used within a system, whether it is ball bearings, a sleeve bearing, or a roller bearing, the bearings are designed to carry the loads imposed on the shaft.

Bearings must be lubricated. Without proper lubrication, bearings will overheat and seize. Proper lubrication means using the correct type and the correct amount of lubrication. Similar to motor bearings, shaft bearings can be lubricated either by oil or by grease.

Pump Categories

Pumps may be classified on the basis of the application they serve. All pumps may be divided into two major categories: (1) dynamic, in which energy is continuously added to increase the fluid velocities within the machine, and (2) displacement, in which the energy is periodically added by application of force.



Centrifugal pumps may be classified in several ways. For example, they may be either **SINGLE STAGE** or **MULTI-STAGE.** A single-stage pump has only one impeller. A multi-stage pump has two or more impellers housed together in one casing.

Multi-Stage Bowls

As a rule, each impeller acts separately, discharging to the suction of the next stage impeller. This arrangement is called series staging. Centrifugal pumps are also classified as **HORIZONTAL** or **VERTICAL**, depending upon the position of the pump shaft.

The impellers used on centrifugal pumps may be classified as **SINGLE SUCTION** or **DOUBLE SUCTION**. The single-suction impeller allows liquid to enter the eye from one side only. The double-suction impeller allows liquid to enter the eye from two directions. Impellers are also classified as **CLOSED** or **OPEN**.

Impellers

Closed impellers have side walls that extend from the eye to the outer edge of the vane tips. Open impellers do not have these side walls. Some small pumps with single-suction impellers have only a casing wearing ring and no impeller ring. In this type of pump, the casing wearing ring is fitted into the end plate. Recirculation lines are installed on some centrifugal pumps to prevent the pumps from overheating and becoming vapor bound in case the discharge is entirely shut off or the flow of fluid is stopped for extended periods. Seal piping is installed to cool the shaft and the packing, to lubricate the packing, and to seal the rotating joint between the shaft and the packing against air leakage. A lantern ring spacer is inserted between the rings of the packing in the stuffing box.

Seal piping leads the liquid from the discharge side of the pump to the annular space formed by the lantern ring. The web of the ring is perforated so that the water can flow in either direction along the shaft (between the shaft and the packing). Water flinger rings are fitted on the shaft between the packing gland and the pump bearing housing. These flingers prevent water from the stuffing box from flowing along the shaft and entering the bearing housing.

Leakage

During pump operation, a certain amount of leakage around the shafts and casings normally takes place. This leakage must be controlled for two reasons: (1) to prevent excessive fluid loss from the pump, and (2) to prevent air from entering the area where the pump suction pressure is below atmospheric pressure. The amount of leakage that can occur without limiting pump efficiency determines the type of shaft sealing selected. Shaft sealing systems are found in every pump. They can vary from simple packing to complicated sealing systems.

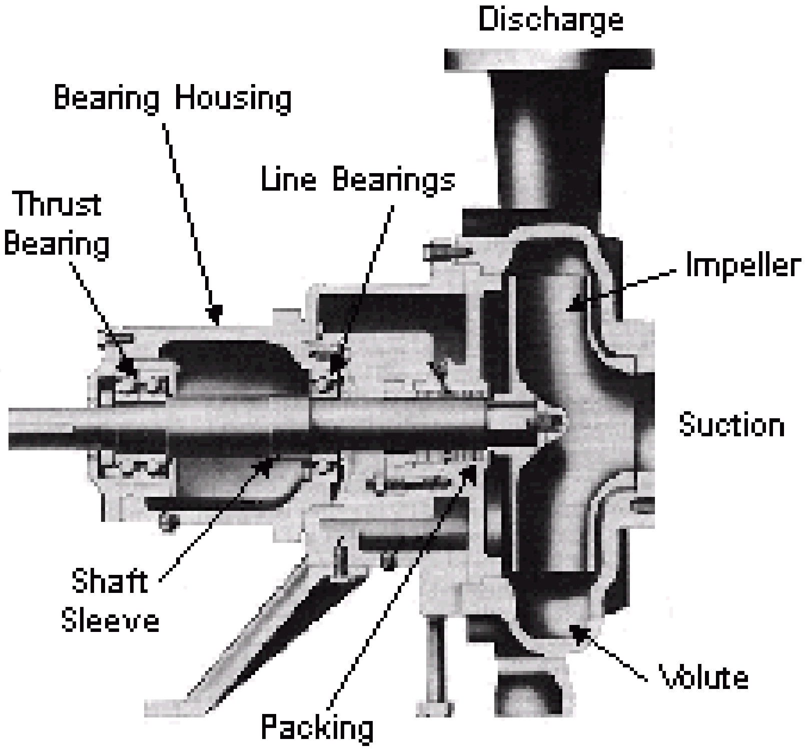
Packing is the most common and oldest method of sealing. Leakage is checked by the compression of packing rings that causes the rings to deform and seal around the pump shaft and casing. The packing is lubricated by liquid moving through a lantern ring in the center of the packing. The sealing slows down the rate of leakage. It does not stop it completely since a certain amount of leakage is necessary during operation. Mechanical seals are rapidly replacing conventional packing on centrifugal pumps.

Some of the Reasons for the Use of Mechanical Seals are as Follows:
1. Leaking causes bearing failure by contaminating the oil with water. This is a major problem in engine-mounted water pumps.
2. Properly installed mechanical seals eliminate leakoff on idle (vertical) pumps. This design prevents the leak (water) from bypassing the water flinger and entering the lower bearings.

Leakoff Causes Two Types of Seal Leakage:
1. Water contamination of the engine lubrication oil.
2. Loss of treated fresh water that causes scale buildup in the cooling system.

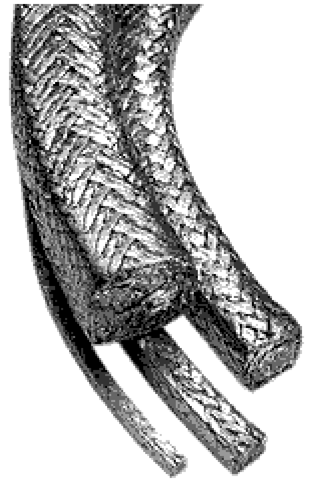
Centrifugal pumps are versatile and have many uses. This type of pump is commonly used to pump all types of water and wastewater flows, including thin sludge.

We will look at the components of the centrifugal pump.



As the impeller rotates, it sucks the liquid into the center of the pump and throws it out under pressure through the outlet. The casing that houses the impeller is referred to as the volute, the impeller fits on the shaft inside. The volute has an inlet and outlet that carries the water as shown above.

How can we prevent the water from leaking along the shaft?



A special seal is used to prevent liquid leaking out along the shaft. There are two types of seals commonly used:

- **Packing seal**
- **Mechanical seal**

Packing Seals
Should packing have leakage?

Lantern rings are used to supply clean water along the shaft. This helps to prevent grit and air from reaching the area. Another component is the slinger ring. The slinger ring is an important part of the pump because it is used to protect the bearings.

Mechanical Seals

Mechanical seals are commonly used to reduce leakage around the pump shaft. There are many types of mechanical seals.

Similar to the packing seal, clean water is fed at a pressure greater than that of the liquid being pumped. There is little or no leakage through the mechanical seal. The wearing surface must be kept extremely clean. Even fingerprints on the wearing surface can introduce enough dirt to cause problems.

What care should be taken when storing mechanical seals?

Wear Rings

Not all pumps have wear rings. However, when they are included, they are usually replaceable. Wear rings can be located on the suction side and head side of the volute. Wear rings could be made of the same metal but a different alloy. The wear ring on the head side is usually a harder alloy.

It's called a ***"WEAR RING"*** and what would be the purpose?

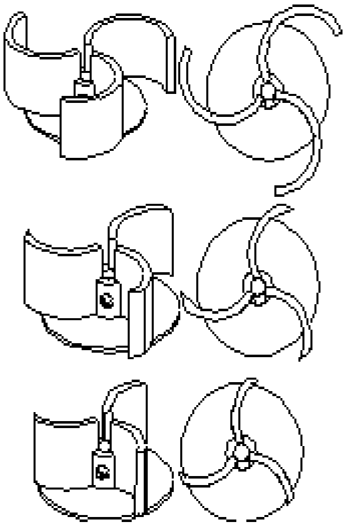
Pump Casing

There are many variations of centrifugal pumps. The most common type is an end suction pump. Another type of pump used is the split case. There are many variations of split case such as, two-stage, single suction, and double suction. Most of these pumps are horizontal.

There are variations of vertical centrifugal pumps. The line shaft turbine is really a multistage centrifugal pump.

Impeller

In most centrifugal pumps, the impeller looks like a number of cupped vanes on blades mounted on a disc or shaft. Notice in the picture below how the vanes of the impeller force the water into the outlet of the pipe.



The shape of the vanes of the impeller is important. Because the water is being thrown out of the pump, you can run centrifugal pumps with the discharge valve closed for a **SHORT** period of time. Remember the motor sends energy along the shaft and if the water is in the volute too long it will heat up and create steam. Not good!

Impellers are designed in various ways. We will look at:

- **Closed impellers**
- **Semi-open impellers**
- **Opened impellers, and**
- **Recessed impellers**

The impellers all cause a flow from the eye of the impeller to the outside of the impeller. These impellers cause what is called **radial flow**, and they can be referred to as radial flow impellers.

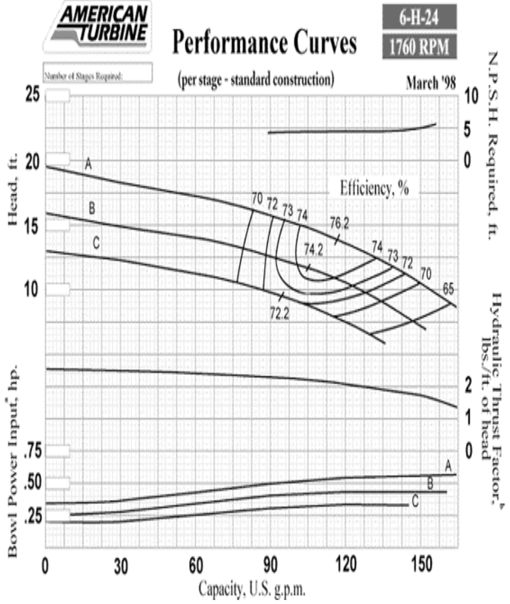
The **critical distance** of the impeller and how it is installed in the casing will determine if it is high volume / low pressure or the type of liquid that could be pumped.

An **Axial flow** impeller looks like a propeller and creates a flow that is parallel to the shaft.

Pump Performance and Curves

Lets looks at the big picture. Before you make that purchase of the pump and motor you need to know the basics such as:

- **Total dynamic head, the travel distance**
- **Capacity, how much water you need to provide**
- **Efficiency, help determine the impeller size**
- **HP, how many squirrels you need**
- **RPM, how fast the squirrels run**



Mechanical Seals

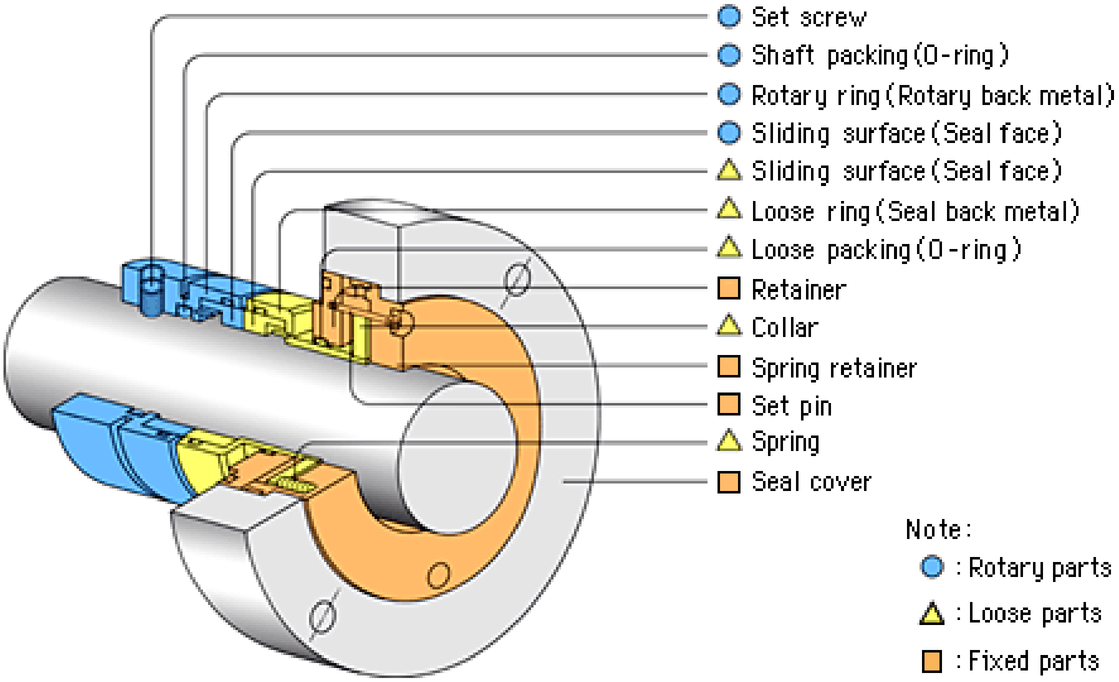
Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on rotary and positive-displacement pumps. Mechanical seals eliminate the problem of excessive stuffing box leakage, which causes failure of pump and motor bearings and motor windings.

Mechanical seals are ideal for pumps that operate in closed systems (such as fuel service and air-conditioning, chilled-water, and various cooling systems). They not only conserve the fluid being pumped but also improve system operation.

The type of material used for the seal faces will depend upon the service of the pump. Most water service pumps use a carbon material for one of the seal faces and ceramic (tungsten carbide) for the other. When the seals wear out, they are simply replaced.

You should replace a mechanical seal whenever the seal is removed from the shaft for any reason or whenever leakage causes undesirable effects on equipment or surrounding spaces. Do not touch a new seal on the sealing face because body acid and grease or dirt will cause the seal to pit prematurely and leak.

Mechanical shaft seals are positioned on the shaft by stub or step sleeves. Mechanical shaft seals must not be positioned by setscrews. Shaft sleeves are chamfered (beveled) on the outboard ends for easy mechanical seal mounting. Mechanical shaft seals serve to ensure that position liquid pressure is supplied to the seal faces under all conditions of operation. They also ensure adequate circulation of the liquid at the seal faces to minimize the deposit of foreign matter on the seal parts.



Positive Displacement Pump

There are many types of positive displacement pumps.
We will look at:

- **Plunger pumps**
- **Diaphragm pumps**
- **Progressing cavity pumps, and**
- **Screw pumps**

What kind of mechanical device do you think is used to provide this positive displacement in the:

Plunger Pump?

Diaphragm Pump?

In the same way, the progressing cavity, and the screw are two other types of mechanical action that can be used to provide movement of the liquid through the pump.

Plunger Pump

The plunger pump is a positive displacement pump that uses a plunger or piston to force liquid from the suction side to the discharge side of the pump. It is used for heavy sludge. The movement of the plunger or piston inside the pump creates pressure, so you have to be careful that this kind of pump is never operated against any closed discharge valve. All discharge valves must be open before the pump is started, to prevent any fast build-up of pressure that could damage the pump.

Diaphragm Pumps

In this type of pump, a diaphragm provides the mechanical action used to force liquid from the suction to the discharge side of the pump. The advantage the diaphragm has over the plunger is that the diaphragm pump does not come in contact with moving metal. This can be important when pumping abrasive or corrosive materials.

There are three main types of diaphragm pumps available:

- Diaphragm sludge pump
- Chemical metering or proportional pump
- Air-powered double-diaphragm pump

Progressive Cavity Pumps

In this type of pump, components referred to as a rotor and an elastic stator provide the mechanical action used to force liquid from the suction to the discharge side of the pump.

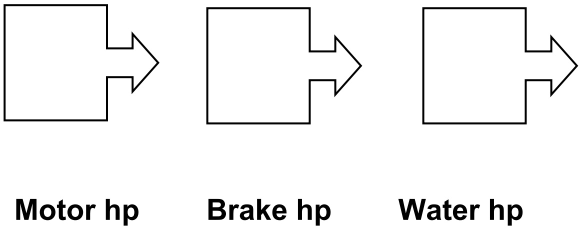
Progressive cavity pumps are used to pump material very high in solids content. The progressive cavity pump must never be run dry, because the friction between the rotor and stator will quickly damage the pump.

Screw Pumps

In this type of pump, a large screw provides the mechanical action to move the liquid from the suction to the discharge side of the pump. Here are some typical characteristics of screw pumps:

- Most screw pumps rotate in the 30 to 60 rpm range, although some screw pumps are faster.
- The slope of the screw is normally either 30° or 38°.
- The maximum lift for the larger diameter pumps is about 30 feet. The smaller diameter pumps have lower lift capabilities.

Motor and Pump Calculations



Horsepower

Work involves the operation of force over a specific distance. The rate of doing work is called power.

The rate in which a horse could work was determined to be about 550 ft-lbs/sec or 33,000 ft-lbs/min.

1 hp = 33,000 ft-lbs/min

Motor Horsepower (mhp)

1 hp = 746 watts or .746 Kilowatts

MHP refers to the horsepower supplied in the form of electrical current. The efficiency of most motors range from 80-95%. (manufacturers will list efficiency %)

Brake Horsepower (bhp)

$$\text{Brake hp} = \frac{\text{Water hp}}{\text{Pump Efficiency}}$$

BHP refers to the horsepower supplied to the pump from the motor. As the power moves through the pump, additional horsepower is lost, resulting from slippage and friction of the shaft and other factors.

Water Horsepower

$$\text{Water hp} = \frac{(\text{flow gpm})(\text{total hd})}{3960}$$

Water horsepower refers to the actual horse power available to pump the water.

Horsepower and Specific Gravity

The specific gravity of a liquid is an indication of its density or weight compared to water. The difference in specific gravity, include it when calculating ft-lbs/min pumping requirements.

$$\frac{(\text{ft})(\text{lbs/min})(\text{sp.gr.})}{33{,}000\ \text{ft-lbs/min/hp}} = \text{whp}$$

MHP and Kilowatt Requirements

$$1\ \text{hp} = 0.746\ \text{kW} \quad \text{or} \quad \frac{(\text{hp})\ (746\ \text{watts/hp})}{1000\ \text{watts/kW}}$$

Well Calculations

1. Well drawdown

Drawdown ft = Pumping water level, ft - Static water level, ft

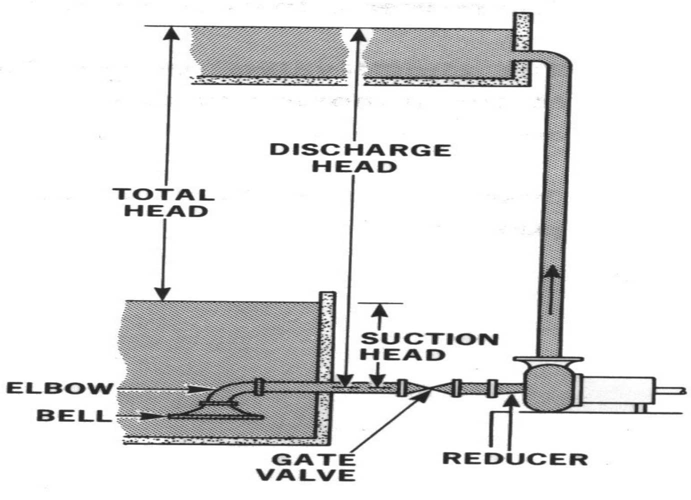
2. Well yield

$$\text{Well yield, gpm} = \frac{\text{Flow, gallons}}{\text{Duration of test, min}}$$

3. Specific yield

$$\text{Specific yield, gpm/ft} = \frac{\text{Well yield, gpm}}{\text{Drawdown, ft}}$$

4. Deep well turbine pump calculations



Discharge head, ft = (pressure measured) (2.31 ft/psi)

Field head, ft = pumping water + discharge head, ft

Bowl head, ft = field head + column friction

1 psi = 2.31 feet of head 1 foot of head = .433 psi

Example 1

A centrifugal pump is located at an elevation of 722 ft. This pump is used to move water from reservoir **A** to reservoir **B**. The water level in reservoir **A** is 742 ft and the water level in reservoir **B** is 927 ft. Based on these conditions answer the following questions:

1. **If the pump is not running and pressure gauges are installed on the suction and discharge lines, what pressures would the gauges read?**

   Suction side:

   Discharge side:

2. **How can you tell if this is a suction head condition?**

3. **Calculate the following head measurements:**

SSH:

SDH:

TSH:

4. **Convert the pressure gauge readings to feet:**

6 psi:

48 psi:

110 psi:

5. **Calculate the following head in feet to psi:**

20 ft:

205 ft:

185 ft:

SCADA

What is SCADA ?

SCADA stands for Supervisory Control And Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs), or other commercial hardware modules.

Contemporary SCADA systems exhibit predominantly open-loop control characteristics and utilize predominantly long distance communications, although some elements of closed-loop control and/or short distance communications may also be present.

Systems similar to SCADA systems are routinely seen in treatment plants and distribution systems. These are often referred to as Distributed Control Systems (DCS). They have similar functions to SCADA systems, but the field data gathering or control units are usually located within a more confined area. Communications may be via a local area network (LAN), and will normally be reliable and high speed. A DCS system usually employs significant amounts of closed loop control.

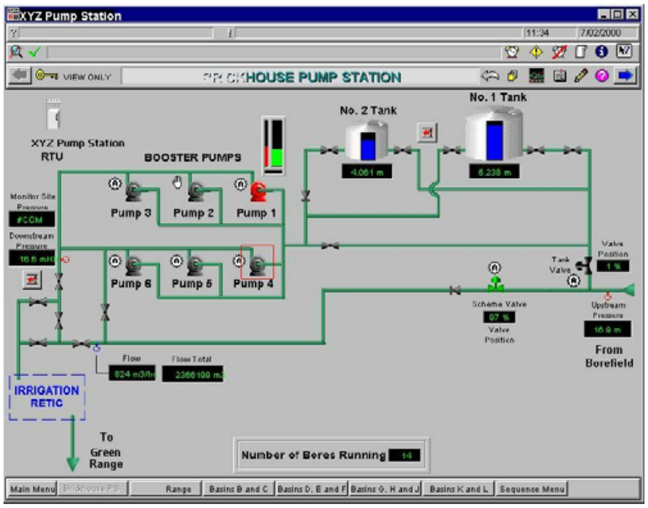
What is Data Acquisition ?

Data acquisition refers to the method used to access and control information or data from the equipment being controlled and monitored. The data accessed are then forwarded onto a telemetry system ready for transfer to the different sites. They can be analog and digital information gathered by sensors, such as flowmeter, ammeter, etc. It can also be data to control equipment such as actuators, relays, valves, motors, etc.

So Why or Where Would You Use SCADA?

SCADA can be used to monitor and control plant or equipment. The control may be automatic, or initiated by operator commands. The data acquisition is accomplished firstly by the RTU's (remote Terminal Units) scanning the field inputs connected to the RTU (RTU may also be called a PLC - programmable logic controller). This is usually at a fast rate. The central host will scan the RTU's (usually at a slower rate.)

The data is processed to detect alarm conditions, and if an alarm is present, it will be displayed on special alarm lists. Data can be of three main types. Analogue data (i.e. real numbers) will be trended (i.e. placed in graphs). Digital data (on/off) may have alarms attached to one state or the other. Pulse data (e.g. counting revolutions of a meter) is normally accumulated or counted.



The primary interface to the operator is a graphical display (mimic) usually via a PC Screen which shows a representation of the plant or equipment in graphical form. Live data is shown as graphical shapes (foreground) over a static background. As the data changes in the field, the foreground is updated. A valve may be shown as open or closed. Analog data can be shown either as a number, or graphically.

The system may have many such displays, and the operator can select from the relevant ones at any time.

Electrical Glossary

ALTERNATING CURRENT (AC) - A current which reverses in regularly recurring intervals of time and which has alternative positive and negative values, and occurs a specified number of times per second. The number is expressed in cycles per second or Hertz (Hz).
ALARM LIGHT - A light which is used to attract attention when a problem occurs in the system.
ALTERNATOR - A relay device designed for alternating the run cycle or duplexing action of two or more motors automatically. There are two basic types. One mechanically changes its contacts each time the operating coil is de-energized. The second is a solid state unit with an output relay. The alternator is used in the automatic control circuit to the motor starters to rotate the duty cycle of each motor.
AMBIENT TEMPERATURE - Temperature of the surroundings in which the equipment is used or operated.
AMMETER - Meter for measuring the current in an electrical circuit, measured in amperes.
AMPERE - The unit of electric current flow. One ampere will flow when one volt is applied across a resistance of one ohm.
AUDIBLE ALARM - Horn, siren, bell, or buzzer which is used to attract the attention of the operator when a problem occurs in the system.
AUXILIARY CONTACTS - Contacts of a switching device in addition to the main current contacts that operate with the movement of the latter. They can be normally open (NO) or normally closed (NC) and change state when operated.
CAPACITOR - A device which introduces capacitance into an electrical circuit. The capacitor, when connected in an alternating current circuit, causes the current to lead the voltage in time phase. The peak of the current wave is reached ahead of the peak of the voltage wave. This is the result of the successive storage and discharge of electric energy.
CIRCUIT BREAKER - A mechanical switching device capable of making, carrying, and breaking currents under normal conditions. Also making, carrying for a specific time, and automatically breaking currents under specified abnormal circuit conditions, such as those of short circuit. Circuit breakers have an ampere trip rating for normal overload protection and a maximum magnetic ampere interrupting capacity (AIC) for short circuit protection.
COMMERCIAL POWER - The term applied to power furnished by an electric power utility.
CONDENSATION HEATER - A device that warms the air within an enclosure and prevents condensation of moisture during shut-down periods. Also known as a space heater.
CONDUCTOR - A wire, cable or bus bar designed for the passage of electrical current.
CONTACTOR - An electro-mechanical device that is operated by an electric coil and allows automatic or remote operation to repeatedly establish or interrupt an electrical power circuit. A contactor provides no overload protection as required for motor loads. Sometimes called a power relay.
CONTACTS - Devices for making and breaking electrical circuits, which are a part of all electrical switching devices.
CURRENT - The amount of electricity, measured in amperes which is flowing in a circuit.
CYCLE - A given length of time (See Alternating Current). In the U.S., most electric current is 60 cycle (60 Hz).
CYCLE TIMER - A timer that repeatedly opens and closes contacts according to pre-set time cycles.
DELTA CONNECTION - A common three phase connection shaped schematically like the Greek Delta. The end of one phase is connected to the beginning of the next phase, or vice versa.
DESIGN LETTER - A letter that is shown on the motor nameplate indicating NEMA's classification of that motor. Classification encompasses characteristics such as full-voltage starting, locked rotor torque, breakdown torque, and others that determine electrical type.
DISCONNECTING MEANS (DISCONNECT) - A device or group of devices, or other means whereby all the ungrounded conductors of a circuit can be disconnected simultaneously from their source of supply.
ELAPSED TIME METER - An instrument used to record the amount of time each pump runs. One elapsed time meter is used per pump.
ELECTRIC UTILITIES - All enterprises engaged in the production and/or distribution of electricity for use by the public.

EMERGENCY POWER (ALTERNATE SOURCE OF POWER) - An independent reserve source of electric power which, upon failure or outage of the normal power source, provides stand-by electric power.
ENCLOSURE - The cabinet or specially designed box in which electrical controls and apparatus are housed. It is required by the National Electrical Code (NEC) to protect persons from live electrical parts and limit access to authorized personnel. It also provides mechanical and environmental protection. An enclosure should be designed to provide the required protection and sized to provide good, safe wire access and replacement of components. It can be manufactured of steel, galvanized or stainless steel, aluminum, or suitable non-metallic materials including fiberglass.
EXPLOSION-PROOF MOTOR - A motor in a special enclosure. The purpose of the enclosure is twofold:

1) If an explosive vapor (gas) should explode inside the motor, the frame of the motor will not be affected.
2) The enclosure is so constructed that no such explosion will ignite vapors outside the motor.

FACTORY MUTUAL (FM) - Independent U.S. agency associated with the insurance industry which tests for safety.
FREQUENCY - The number of complete cycles of an alternating voltage or current per unit of time and usually expressed in cycles per second or Hertz (Hz).
FULL LOAD CURRENT - The greatest current that a motor or other device is designed to carry under specific conditions; any additional is an overload.
FULL LOAD AMPS (FULL LOAD CURRENT) - The current flowing through a line terminal of a winding when rated voltage is applied at rated frequency with rated horsepower.
FUSE - An over-current protective device which consists of a conductor that melts and breaks when current exceeds rated value beyond a predetermined time.
GENERAL PURPOSE RELAY - A relay that is adaptable to a wide variety of applications as opposed to a relay designed for a specific purpose or specific application.
GENERATOR - A machine for converting mechanical energy into electrical energy or power.
GENERATOR RECEPTACLE - A contact device installed for the connection of a plug and flexible cord to supply emergency power from a portable generator or other alternate source of power. Receptacles are rated in voltage, amps, number of wires, and by enclosure type.
GROUND - A connection, either intentional or accidental, between an electric circuit and the earth or some conducting body serving in place of the earth.
GROUND FAULT INTERRUPTION (GFI) - A unit or combination of units which provides protection against ground fault currents below the trip levels of the breakers of a circuit. The system must be carefully designed and installed to sense low magnitude insulation breakdowns and other faults that cause a fault ground current path. The GFI system must be capable of sensing the ground fault current and disconnecting the faulted circuit from the source voltage.
GROUNDED NEUTRAL - The common neutral conductor of an electrical system which is intentionally connected to ground to provide a current carrying path for the line to neutral load devices.
GROUNDING CONDUCTOR - The conductor that is used to establish a ground and that connects equipment, a device, a wiring system, or another conductor (usually the neutral conductor) with the grounding electrode.
HAND-OFF-AUTOMATIC (HOA) - Selector switch determining the mode of system operation. H is the hand mode only. 0 is system Off. A is automatic operation, normally with pump alternation.
HAZARDOUS LOCATIONS - Those areas as defined in the NEC where a potential for explosion and fire exist because of flammable gasses, vapors, or finely pulverized dusts in the atmosphere, or because of the presence of easily ignitable fibers or flyings.
HERTZ (Hz) - A unit of frequency equal to one cycle per second.
HIGH POTENTIAL TEST - A test which consists of the application of a voltage higher than the rated voltage between windings and frame, or between two or more windings, for the purpose of determining the adequacy of insulating materials and spacing against breakdown under normal conditions. It is not the test of the conductor insulation of any one winding.
HORSEPOWER - A method of rating motors whereby values are determined by factors including rotational speed and torque producing capability as well as other factors.
IN-RUSH CURRENT - See Locked Rotor Current.

INTERLOCK - Interrelates with other controllers. An auxiliary contact. A device connected in such a way that the motion of one part is held back by another part.

INTRINSICALLY SAFE - A term used to define a level of safety associated with the electrical controls used in some lift stations. Intrinsically safe equipment and wiring is incapable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a hazardous atmospheric mixture - without the need for explosion-proof enclosures in the hazardous area. Any associated devices must be outside the hazardous area with an approved seal-off fitting used as an isolating barrier.

KILOWATT (KW) - A unit of measure of electrical power. One kilowatt equals 1000 watts. Used where larger units of electrical power are measured.

LOCKED ROTOR CURRENT - (See Starting Amps).

LOCKOUT - A mechanical device which may be set to prevent the operation of a push-button or other device.

MANUAL TRANSFER SWITCH - A switch designed so that it will disconnect the load from one power source and reconnect it to another source while at no time allowing both sources to be connected to the load simultaneously.

MEGGER OR MEGOHMETER - A high resistance range ohmmeter utilizing a power source for measuring insulation resistance.

MEGOHM - A unit of resistance equal to one million ohms.

MOTOR CIRCUIT PROTECTOR - A molded case disconnect switch specifically designed for motor circuits. It has a trip unit that operates on the magnetic principle only, sensing current in each of the three poles with an adjustable trip point. It provides short circuit protection, required by the National Electrical Code (NEC). It differs from a standard breaker in that it does not have a thermal overload unit.

MOTOR EFFICIENCY - A measure of how effectively a motor converts electrical energy into mechanical energy. Motor efficiency is never 100 percent. It is a variable that depends on a given motor's performance. Tabulated at 100, 75 and 50 percent load, it is the ratio of power output to power input.

MOTOR, ELECTRIC - A rotating device which converts electrical power into mechanical power.

MOTOR HORSEPOWER RATING - The motor horsepower nameplate rating fully-loaded at the ambient temperature.

NEC - The National Electrical Code (NEC) is the standard of the National Board of Fire Underwriters for electric wiring and apparatus, as recommended by the National Fire Protection Association.

NEC CODE LETTER - Motors with 60 and 50 Hertz ratings shall be marked with a code letter designating the locked-rotor KVA per horsepower on 60 Hertz.

NEMA - National Electrical Manufacturers Association, a non-profit trade association supported by the manufacturers of electrical apparatus and supplies. NEMA promulgates standards to facilitate understanding between the manufacturers and users of electrical products.

NFPA - National Fire Protection Association. Sponsors and publishes the National Electrical Code (NEC).

NEUTRAL - The point common to all phases of a polyphase circuit, a conductor to that point, or the return conductor in a single phase circuit. The neutral in most systems is grounded at or near the point of service entrance only and becomes the grounded neutral.

NORMALLY OPEN and NORMALLY CLOSED - The terms "Normally Open" and "Normally Closed" when applied to a magnetically operated switching device - such as a contactor or relay, or to the contacts thereof - signify the position taken when the operating magnet is de-energized. These terms pertain to all switches.

OHM - Unit of electrical resistance. One volt will cause a current of one ampere to flow through a resistance of one ohm.

OHMMETER - A device for measuring electrical resistance expressed in ohms.

OVERLOAD PROTECTION - Overload protection is the effect of a device operative on excessive current, but not necessarily on short circuit, to cause and maintain the interruption of current flow to the device being governed. Re-set may be manual or automatic.

OVERLOAD RELAY - A relay that responds to electric load and operates at a pre-set value of overload. The unit senses the current in each line to the motor and is either bimetallic, melting alloy or solid state actuated. It may be of the non-compensated or ambient-compensated type, and of a standard or fast-trip design.

PHASE (THREE PHASE CIRCUIT) - A combination of circuits energized by alternating electromotive forces which differ in phase by one-third of a cycle (120 degrees). In practice, the phases may vary several degrees from the specified angle.

PHASE MONITOR - A device in the control circuit of motors which monitors the three phase voltage and protects against a phase loss (single phasing), under voltage (brown outs) and phase reversal (improper phase sequence). Most are adjustable to set the nominal voltage and some have a LED indicator to indicate acceptable voltage and phase conditions. The output contacts are used to control the motor starters and provide signaling for telemetering.

PILOT DEVICE - Directs operation of another device:

Float switch - A pilot device responding to liquid levels.
Limit switch - A pilot device operated in response to a mechanical operation.
Pressure switch - A pilot device operated in response to pressure levels.
Temperature switch - A pilot device operated in response to temperature values.
All of the above switches cause a contact change of the switch at pre-set or adjustable points.

PILOT LIGHT - A lamp available with various colored lenses designed to operate on a control voltage. They are each turned On and Off to provide the required indication for specific functions or alarm conditions. They are available in various sizes and voltage ratings. They are each designed for a specific bulb style and base configuration and some have an integral transformer to allow the use of low voltage bulbs. Full voltage incandescent bulbs are most common, but neon bulbs are also used.

POWER FACTOR - The ratio of the true power to the volt-amperes in an alternating current circuit. Power factor is expressed in a percent of unity either lagging for inductive loads or leading for capacitive loads. Resistive loads produce a unity power factor.

PUSHBUTTON - Part of an electrical device, consisting of a button that must be pressed to effect an operation.

RATED VOLTAGE - The voltage of electrical apparatus at which it is designed to operate.

REDUCED VOLTAGE AUTO-TRANSFORMER STARTER - A starter that includes an auto-transformer to furnish reduced voltage for starting an alternating current motor. It includes the necessary switching mechanism. This is the most widely used reduced voltage starter because of its efficiency and flexibility.

RELAY - An electric device that is designed to interpret input conditions in a prescribed manner and, after specified conditions are met, to respond and cause contact operation or similar abrupt changes in associated electric control circuits.

RELAY, ELECTROMAGNETIC - A relay controlled by electromagnetic means, to open and close electric contacts.

RELAY, SOLID STATE - A completely electronic switching device with no moving parts or contacts.

RPM - Revolutions per minute of the motor/pump rotating assembly.

REMOTE CONTROL - Control function initiation or change of electrical device from a remote point.

RESISTANCE - The non-reactive opposition which a device or material offers to the flow of direct or alternating current. Usually measured in ohms.

SAFETY SWITCH - An enclosed, manually-operated disconnecting switch, which is horsepower and current rated. Disconnects all power lines simultaneously.

SEAL FAILURE ALARM - The sensing and indication of the intrusion of water into the oil-filled seal chamber between the inner and outer shaft seal of a submersible pump.

SELECTOR SWITCH - A multi-position switch which can be set to the desired mode of operation.

SERVICE FACTOR - A safety factor designed and built into some motors which allows the motor, when necessary, to deliver greater than its rated horsepower.

SINGLE PHASE - A circuit that differs in phase by 180 degrees. Single phase circuits have two conductors, one of which may be a neutral, or three conductors, one of which is neutral.

STANDBY POWER SUPPLY - The power supply that is available to furnish electric power when the normal power supply is not available.

STAR CONNECTION - Same as a "Y" or "Wye" connection. This three-phase connection is so called because, schematically, the joint of the "Y" points looks like a star.

STARTER - A device used to control the electrical power to motors and provide overload protection as required by the NEC. The starter can be operated manually, electrically, or by automatic pilot devices. A starter has two basic parts - a contactor for power switching and an overload relay for protection.
STARTING AMPS (LOCKED ROTOR) - The maximum current drawn by the motor during the starting period.
STARTING RELAY - A relay - actuated by current, voltage or the combined effect of current and voltage - which is used to perform a circuit-changing function in the primary winding of single phase induction motor within a pre-determined range of speed as the motor accelerates; and to perform the reverse circuit-changing operation when the motor is disconnected from the supply line. One of the circuit changes that is usually performed is to open or disconnect the auxiliary winding (starting) circuit.
SUBMERSIBLE MOTOR - A motor whose housing and terminal box is so designed that the motor can run underwater - completely submerged at an allowable temperature.
SURGE ARRESTER - A protective device for limiting surge voltages on equipment by discharging or bypassing surge current; it prevents continued flow of follow current to ground, and is capable of repeating these functions as specified.
SWITCH - A device for making, breaking, or changing connections in a circuit.
TELEMETERING - The transmitting of alarm and control signals to and from remote lift station controls and a central monitoring location.
TERMINAL BLOCK - An insulating base equipped with terminals for connecting wires.
THERMAL OVERLOAD PROTECTOR - Device, either a bimetal element or electric circuit, which protects motor windings from excessive temperature by opening a set of contacts. This device may reach its' pre-set trip point as a result of ambient temperature, current, or both. May be automatic or manually set.
THREE PHASE CIRCUIT - A combination of circuits energized by alternating electromotive sources which differ in phase by one third of a cycle - that is, 120 degrees. A three phase circuit may be three wire or four wire with the fourth wire being connected to the neutral point of the circuit which may be grounded.
TIME CLOCK - A device used to schedule electrical On/Off cycling operations. The device may be solid state or mechanical designed using a synchronous motor. The cycling operation must be programmed manually. The time clocks may operate in any increments of days, weeks, minutes, or hours.
TIME DELAY RELAY (TDR) - A device with either mechanical or solid state output contacts that performs a timing function upon energization or control signal.
TRANSDUCER - A device to condition and transform an analog signal to a specific variable output electrical signal proportional to the input signal. Typical inputs include variable pressure, level, voltage or current. Some common outputs are O to 1ma, 4 to 20 ma, and various MVDC signals. A transducer must be specifically designed to be compatible with the input/output requirements of the total system.
TRANSFORMER - A static electric device consisting of a single winding, or two or more coupled windings, used to transfer power by electromagnetic induction between circuits at the same frequency, usually with changed values of voltage and current.
UNDERWRITERS LABORATORIES, INC. (UL) - An independent, non-profit U.S. organization that tests products for safety.
VFD - Variable frequency drive.
VOLTAGE (NOMINAL A) - A nominal value assigned to a circuit or system for the purpose of conveniently designating its voltage class (as 120/240, 480/240, 600, etc.). The actual voltage at which a circuit operates can vary from the nominal within a range that permits satisfactory operation of equipment.
VOLTMETER - An instrument for measuring voltage.
WATT - A unit of measure of electrical power.
WYE CONNECTION - See Star Connection.

Pump Troubleshooting Section

As an Operator, some of the operating troubles you may encounter with centrifugal pumps, together with the probable causes, are discussed in the following paragraphs.

If a centrifugal pump **DOES NOT DELIVER ANY LIQUID**, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, such as might be caused by a partially closed valve or some other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation (this may occur after motor overhaul); (7) clogged suction screen (if used); (8) ruptured suction line; or (9) loss of suction pressure.

If a centrifugal pump delivers some liquid but operates at **INSUFFICIENT CAPACITY**, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes in pumps operating at less than atmospheric pressure; (3) insufficient pump speed; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves.

If a pump **DOES NOT DEVELOP DESIGN DISCHARGE PRESSURE**, the trouble may be caused by (1) insufficient pump speed; (2) air or gas in the liquid being pumped; (3) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves; or (4) reversed rotation of the impeller (3-phase electric motor-driven pumps).

If a pump **WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID,** the trouble may be caused by (1) air leakage into the suction line; (2) air leakage in the stuffing boxes; (3) clogged water seal passages; (4) insufficient liquid on the suction side; or (5) excessive heat in the liquid being pumped.

If a motor-driven centrifugal pump **DRAWS TOO MUCH POWER**, the trouble will probably be indicated by overheating of the motor. The basic causes may be (1) operation of the pump to excess capacity and insufficient discharge pressure; (2) too high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure may also cause vibration, as well as noisy operation and fluctuating discharge pressure, particularly in pumps that handle hot or volatile liquids.

If the pump fails to build up pressure when the discharge valve is opened and the pump comes up to normal operating speed, proceed as follows:

1. **Shut the pump discharge valve.**
2. **Secure the pump.**
3. **Open all valves in the pump suction line.**
4. **Prime the pump (*fill casing with the liquid being pumped*) and be sure that all air is expelled through the air cocks on the pump casing.**
5. **Restart the pump. If the pump is electrically driven, be sure the pump is rotating in the correct direction.**

6. Open the discharge valve to *“**load**”* the pump. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller may be broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump and continue troubleshooting according to the technical manual for that unit.

Maintenance of Centrifugal Pumps

When properly installed, maintained and operated, centrifugal pumps are usually trouble-free. Some of the most common corrective maintenance actions that you may be required to perform is discussed in the following sections.

Repacking - Lubrication of the pump packing is extremely important. The quickest way to wear out the packing is to forget to open the water piping to the seals or stuffing boxes. If the packing is allowed to dry out, it will score the shaft. When operating a centrifugal pump, be sure there is always a slight trickle of water coming out of the stuffing box or seal.

How often the packing in a centrifugal pump should be renewed depends on several factors, such as the type of pump, condition of the shaft sleeve, and hours in use. To ensure the longest possible service from pump packing, make certain the shaft or sleeve is smooth when the packing is removed from a gland. Rapid wear of the packing will be caused by roughness of the shaft sleeve (or shaft where no sleeve is installed). If the shaft is rough, it should be sent to the machine shop for a finishing cut to smooth the surface. If it is very rough, or has deep ridges in it, it will have to be renewed. It is absolutely necessary to use the correct packing.

When replacing packing, be sure the packing fits uniformly around the stuffing box. If you have to flatten the packing with a hammer to make it fit, **YOU ARE NOT USING THE RIGHT SIZE.**

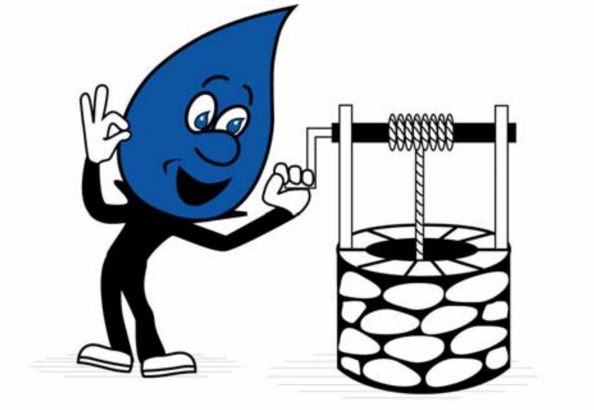
Pack the box loosely, and set up the packing gland lightly. Allow a liberal leak-off for stuffing boxes that operate above atmospheric pressure. Next, start the pump. Let it operate for about 30 minutes before you adjust the packing gland for the desired amount of leak-off. This gives the packing time to run-in and swell. You may then begin to adjust the packing gland. Tighten the adjusting nuts one flat at a time. Wait about 30 minutes between adjustments. Be sure to tighten the same amount on both adjusting nuts.

If you pull up the packing gland unevenly (or cocked), it will cause the packing to overheat and score the shaft sleeves. Once you have the desired leak-off, check it regularly to make certain that sufficient flow is maintained.

Troubleshooting Table for Well/Pump Problems

1. Well pump will not start.
2. Well pump will not shut off.
3. Well pump starts and stops too frequently (excessive cycle rate).
4. Sand sediment is present in the water.
5. Well pump operates with reduced flow.
6. Well house flooded without recent precipitation.
7. Red or black water complaints.
8. Raw water appears **turbid** or a light tan color following rainfall.
9. **Coliform** tests are positive.

Possible Causes



1A. Circuit breaker or overload relay tripped.
1B. Fuse(s) burned out.
1C. No power to switch box.
1D. Short, broken or loose wire.
1E. Low voltage.
1F. Defective motor.
1G. Defective pressure switch.
2A. Defective pressure switch.
2B. Cut-off pressure setting too high.
2C. Float switch or pressure transducer not functioning.
3A. Pressure switch settings too close.
3B. Pump foot valve leaking.
3C. Water-logged hydropneumatic tank.
4A. Problems with well screen or gravel envelope.
5A. Valve on discharge partially closed or line clogged.
5B. Well is over-pumped.
5C. Well screen clogged.
6A. **Check valve** not operating properly.
6B. Leakage occurring in discharge piping or valves.
7A. Water contains excessive **iron** (red brown) and/or **manganese** (black water).
7B. Complainant's hot water needs maintenance.
8A. Surface water entering or **influencing** well.
9A. Sample is invalid.
9B. **Sanitary protection** of well has been **breached.**

Possible Solutions

1A. Reset breaker or manual overload relay.
1B. Check for cause and correct, replace fuse(s).
1C. Check incoming power supply. Contact power company.
1D. Check for shorts and correct, tighten terminals, replace broken wires.
1E. Check incoming line voltage. Contact power company if low.
1F. Contact electrical contractor.
1G. Check voltage of incoming electric supply with pressure switch closed. Contact power company if voltage low. Perform maintenance on switch if voltage normal.
2A. Check switch for proper operation. Replace switch.
2B. Adjust setting.

2C. Check and replace components or cable as needed.
3A. Adjust settings.
3B. Check for **backflow**. Contact well contractor.
3C. Check air volume. Add air if needed. If persistent, check air compressor, relief valve, air lines and connections, and repair if needed.
4A. Contact well contractor.
5A. Open valve, unclog discharge line.
5B. Check **static water level** and compare to past readings. If significantly lower, notify well contractor.
5C. Contact well contractor.
6A. Repair or replace check valve.
6B. Inspect and repair/replace as necessary.
7A. Test for iron and manganese at well. If levels exceed 0.3 mg/L iron or 0.005mg/L manganese, contact regulatory agency, TA provider or water treatment contractor.
7B. Check hot water heater and flush if needed.
8A. Check well for openings that allow surface water to enter. Check area for **sinkholes**, **fractures**, or other physical evidence of surface water **intrusion** Check water **turbidity**. Notify regulatory agency if >0.5 **NTU**. Check raw water for coliform **bacteria**. Notify regulatory agency immediately if positive.
9A. Check sampling technique, sampling container, and sampling location and tap.
9B. Notify regulatory agency immediately and re-sample for re-testing.

Megger

Safety Section Chapter 9

Respiratory Protection

General

In the Respiratory Protection program, hazard assessment and selection of proper respiratory PPE is conducted in the same manner as for other types of PPE. In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used. References: OSHA Standards ***Respiratory Protection*** (**29 CFR 1910.134**)

Why Respirators Are Needed

Respirators protect against the inhalation of dangerous substances (vapors, fumes, dust, gases). They can also provide a separate air supply in a very hazardous situation.

Some of the health hazards that respirators prevent include

- Lung damage
- Respiratory diseases
- Cancer and other illnesses.

The employee is responsible for:

- Properly using respirators
- Maintaining respirator properly
- Reporting malfunctions
- Reporting medical changes

Selection of Respiratory Protection

When choosing the correct respiratory protection for your work environment, it is important to consider:

- Identification of the substance or substances for which respiratory protection is necessary
- A substance's material safety data sheet (**MSDS**) (it will state which type of respirator is most effective for the substance)
- Activities of the workers
- Hazards of each substance and its properties
- Maximum levels of air contamination expected
- Probability of oxygen deficiency
- Period of time workers will need to use the respiratory protection devices
- Capabilities and physical limitations of the device used

Types of Respirators The following is a description of different types of respirators.

Commonly Used Respirators (*Air Purifying*)

- **Disposable Dust masks** are worn over the nose and mouth to protect the respiratory system from certain nuisance dusts, mists, etc. They can only provide protection against particular contaminants as specified by the manufacturer (e.g., general dust, fiberglass, etc.). These dust masks cannot be fit tested, and are generally single use. They are not recognized as respiratory protection and may not be worn if a potential for overexposure exists. They are not included in most company's Respiratory Protection Program.
- **Half-Face Respirators** with interchangeable filter cartridges can protect the respiratory system from hazardous dusts, fumes, mists, etc. They can only provide protection against certain contaminants up to limited concentrations specified by the manufacturer for the particular cartridge type used (e.g., toluene, acetone). These generally operate under negative pressure within the respirator which is created by the wearer's breathing through the filter cartridges. As the protection is only gained if there is a proper seal of the respirator face piece, this type requires fit testing prior to respirator assignment and a fit check prior to each use.
- **Full-Face Respirators** operate under the same principle and requirements as the half-face type, however, they offer a better facepiece fit and also protect the wearer's eyes from particularly irritating gases or vapors.
- **Full-face, helmet or hood type powered air purifying respirators** (**PAPRs**) operate under positive pressure inside the facepiece using a battery operated motor blower assembly to force air through a filter cartridge into the wearer's breathing zone. Use of these respirators is also subject to the manufacturers' guidelines.

Less Commonly Used Types Respirators (Air Supplying)

- **Air-Line Respirators** supply clean air through a small diameter hose from a compressor or compressed air cylinders. The wearer must be attached to the hose at all times, which limits mobility. Use of these respirators is subject to the manufacturers' guidelines.
- **Self-Contained Breathing Apparatus** (**SCBA**) respirators supply clean air from a compressed air tank carried on the back of the wearer. These types of respirators are highly mobile and are used primarily for emergency response or rescue work, since only a limited amount of air can be supplied by a single tank, generally 20-60 minutes. Units must be thoroughly inspected on a monthly basis and written records must be kept of all inspections, operator training, etc. Use of these respirators is subject to the manufacturer's guidelines

Basic Types of Respirators

Air-purifying or filtering respirators. Such respirators are used when there is enough oxygen (at least 19.5 percent) and contaminants are present below IDLH level. The respirator filters out (or chemically "**scrubs**") contaminants, usually with a replaceable filter. Use color-coded filter cartridges or canisters for different types of contaminants. It's important to select the right filter for the situation.

Air-supplying Respirators These respirators are required when air-purifying respirators aren't effective. Air-purifying respirators are not sufficient in the following settings:

- When there is not enough oxygen
- In Confined spaces
- When contaminants cannot be filtered out
- When contaminants are at or above IDLH level.

Different Kinds of Air-Supplying Respirators Include:

- Those connected by hose to stationary air supply (air line)
- Portable tank self-contained breathing apparatus (**SCBA**).

Donning a SCBA

A ten minute emergency escape pack. Every treatment facility that has Chlorine gas should have this device stationed throughout the facility.

Hazard Communication *HazCom*

OSHA has estimated that more than 32 million workers are exposed to 650,000 hazardous chemical products in more than 3 million American workplaces. This poses a serious problem for exposed workers and their employers.

The basic goal of a Hazard Communication Program is to be sure employers and employees know about work hazards and how to protect themselves; this should help reduce the incidence of chemical source illness and injuries.

General

Chemicals pose a wide range of health hazards (such as irritation, sensitization, and carcinogenicity) and physical hazards (such as flammability, corrosion, and reactivity). OSHA's Hazard Communication Standard (HCS) is designed to ensure that information about these hazards and associated protective measures is disseminated to workers and employers.

This is accomplished by requiring chemical manufacturers and importers to evaluate the hazards of the chemicals they produce or import, and to provide information about them through labels on shipped containers and more detailed information sheets called material safety data sheets (MSDSs).

All employers with hazardous chemicals in their workplaces must prepare and implement a written hazard communication program, and must ensure that all containers are labeled, employees are provided access to MSDSs, and an effective training program is conducted for all potentially exposed employees.

The HCS provides workers the right-to-know the hazards and identities of the chemicals they are exposed to in the workplace. When workers have this information, they can effectively participate in their employers' protective programs and take steps to protect themselves.

In addition, the standard gives employers the information they need to design and implement an effective protective program for employees potentially exposed to hazardous chemicals.

Together these actions will result in a reduction of chemical source illnesses and injuries in workplaces.

OSHA's Hazard Communication Standard

OSHA's Hazard Communication Standard (29 CFR 1910.1200**) can help keep workplaces-and workers-safe and healthy when engaged in work with chemicals. It must be followed by all employers whose employees are or could be exposed to hazardous chemicals in the workplace.**

The standard states that employees have the "**right to know*****":***

- ***What hazards they face on the job***
- ***How to protect themselves from those hazards***

The standard requires employers to have a written Hazard Communication Program that***:***

- ***Tells employees about the Hazard Communication Standard***
- ***Explains which chemicals are used in the workplace***
- ***Explains how chemicals are used in the workplace***
- ***Explains the labeling requirements for hazardous chemical containers***

- ***Explains how MSDSs are maintained at the facility and how to access them***
- ***Provides training about the dangers presented by those hazardous chemicals and how employees can protect themselves from those dangers***

Right-to-Know

A. Employees have a right to know about chemical hazards in their workplace. With the help of the Hazard Communication Standard, they can protect themselves from chemical injuries and hazards.

B. Employees should practice these safety rules every day on the job:

- ✓ ***Know where to find the company's written HazCom program and MSDSs.***
- ✓ ***Identify hazards before starting a job.***
- ✓ ***Use correct personal protective equipment when handling hazardous substances.***
- ✓ ***Practice sensible, safe work habits; follow warnings and instructions.***
- ✓ ***Respect all precautions-don't take chances.***
- ✓ ***Ask the supervisor when in doubt.***
- ✓ ***Know in advance what could go wrong and what to do about it.***
- ✓ ***Know how and where to get help.***

Different Types of Chemical Hazards

Chemicals cause health hazards if they are:

- ✓ ***Target organ chemicals****—they injure specific organs in your body.*
- ✓ ***Toxic****—cause illness or death. Toxic chemicals are determined on the basis of tests on laboratory animals that are exposed to a given chemical through either inhalation, ingestion, or skin absorption.*
- ✓ ***Corrosive****—can destroy your skin or eyes.*
- ✓ ***Irritants****—cause reversible inflammation when they make contact with living tissue.*
- ✓ ***Carcinogens****—have been known to cause cancer or have the potential of causing cancer in humans.*
- ✓ ***Sensitizers****—can cause an allergic reaction on subsequent repeated exposures.*
- ✓ ***Neurotoxins****—produce toxic effects primarily on the central nervous system****.***
- ✓ ***Nephrotoxins****—Produce toxic effects on kidneys.*
- ✓ ***Reproductive toxins****—have the potential to adversely affect the reproductive system.*
- ✓ ***Hepatotoxins****—can adversely affect the liver.*
- ✓ ***Lung hazards****—can irritate or damage pulmonary tissue.*
- ✓ ***Skin hazards****—can affect the dermal layer of the body, resulting in rashes and irritation.*
- ✓ ***Eye hazards****—can adversely affect the eye or diminish the visual capacity of a human.*
- ✓ *Blood system hazards—caused by chemicals that decrease the hemoglobin function; depriving of oxygen. Chemicals that present physical hazards and are covered by the Hazard Communication Standard include combustible liquids, flammable materials, all compressed gases, explosives, organic peroxides, oxidizers, pyrophoric materials, unstable materials, and water-reactive materials.*
- ✓ ***Fire hazards****—chemicals that have the potential for creating a fire or aiding an ongoing fire.*

These materials are flammables, combustibles, oxidizers, pyrophoric materials, and organic peroxides.

- ✓ **Flammables**—catch fire quickly.
- ✓ **Oxidizers**—capable of initiating or promoting a fire in other compounds by the release of oxygen or other gases.
- ✓ **Pyrophoric materials**—can be ignited as a result of contact with oxygen in the absence of an ignition source at temperature below 130°F.
- ✓ **Organic peroxides**—contain both fuel, in the form of carbon, and excess oxygen, and thus can pose a severe fire hazard.
- ✓ **Compressed gases**—all compressed gases pose a physical hazard.
- ✓ **Explosive materials**—can be decomposed in a violent chemical reaction with the production of heat, pressure, and large quantities of gas.
- ✓ **Unstable materials**—certain compounds in their pure form can undergo vigorous decomposition or polymerization under moderate conditions of shock, pressure, or temperature.
- ✓ **Water-reactive compounds**—can react vigorously with water to produce a toxic or flammable gas.

Identifying Hazardous Chemicals

Chemical manufacturers have to let users know about hazards. They do this by providing for each product a container label, which gives a quick overview of the chemical, and an MSDS, which offers more complete information.

Label Information

Hazardous chemical containers are labeled by the manufacturer. The label format may differ from company to company, but all labels must contain the same information. This makes it easy to determine at a glance a chemical's possible hazards and the basic steps that employees must take to protect themselves.

The label may use words or symbols to tell you:

- ✓ **The chemical's identity and its components (unless they're part of the manufacturer's trade secrets, which do not have to be revealed)**
- ✓ **The name and address of the company that made or imported the chemical**
- ✓ **Specific hazard warnings, such as physical or health hazards Labels may also include:**
- ✓ **Precautionary measures, such as basic protective clothing, equipment, and procedures to work safely**
- ✓ **Proper handling and storage instructions**
- ✓ **First-aid instructions**
- ✓ **Special instructions concerning children**

MSDS Information

Each company should have on file an MSDS for every chemical and hazardous product in the workplace. An MSDS describes everything an employee needs to know about the chemical.

Employees must read the MSDS before starting a job to know what they're working with and how to handle it safely. Though an individual MSDS may give a different amount of information, they all contain similar types of information.

MSDSs Explain

- ✓ ***Identity of the chemical**. This includes its chemical and common names, manufacturer, etc. If the chemical is a mixture, each ingredient in the mix will be listed along with its hazards. The only time the components won't be covered is when they're a trade secret, but the MSDS will still tell about the hazards and required safety measures.*
- ✓ ***Physical and chemical characteristics.** The MSDS provides information such as the chemical's boiling point, vapor pressure, vapor density, melting point, evaporation point, evaporation rate, water solubility, flash point, and appearance and odor under normal conditions.*
- ✓ ***Physical hazards**. This covers such possible hazards as fire and explosion and what means should be used to prevent and to combat them.*
- ✓ ***Health hazards.** For example, the MSDS will reveal whether the chemical is believed to be a carcinogen and whether the hazards are acute (*short-term*) or chronic (*long-term*). It will give any permissible exposure limits set by OSHA or other agencies.*
- ✓ ***Signs and symptoms of exposure.** The chemical could cause eye irritation, nausea, dizziness, headaches, skin rashes, or aggravate existing medical conditions.*
- ✓ ***How the chemical enters the body**. It's important to know how exposure occurs: swallowing, inhaling, or contacting skin or eyes.*
- ✓ ***Reactivity**. The MSDS reports on the substance's stability as well as chemicals and situations that could make the substance unstable.*
- ✓ ***Protective equipment**. Any PPE such as respirators, gloves, goggles, etc. that are recommended to prevent exposure will be listed, along with ventilation requirements.*
- ✓ ***Spills, leaks, and disposal**. If the substance is accidentally released, the MSDS explains how to handle such an incident and dispose of the substance properly.*
- ✓ ***Handling and storage**. The proper ways of handling and storing the substance are covered by the MSDS.*
- ✓ ***Other.** The MSDS may also go into other topics related to the substance's hazards, such as toxicity to fish if spilled, transport requirements, etc.*

The MSDS is every worker's guide to safe handling of hazardous substances. An individual chemical's hazards determine exactly what information the MSDS contains. However, it always contains the information needed to avoid accidents and illness when handling that substance. Stress to employees the importance of reading the MSDS before starting a job.

Notification of a Chemical Release

Alarm or signal. Some companies have a monitoring system that activates an alarm when it senses a spill or a leak.

Witness. An employee may sense (see, smell, or hear) a release by chance or on a scheduled inspection, or an employee may accidentally release a substance while handling it.

MSDS Terminology

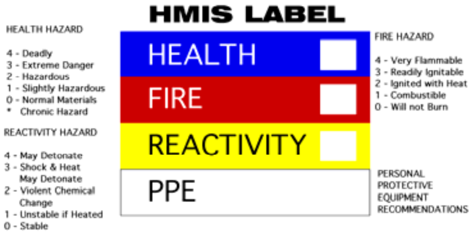
The Hazard Communication Standard requires employees to understand chemical hazards, labels, and MSDSs and to use them on the job. Before starting jobs involving possible exposure to hazardous substances, employees must read MSDSs to know what they're working with and procedures for safe handling.

Hundreds, perhaps thousands, of terms could be included in a listing like the one provided in this session. The list of terms and definitions included in this session is not comprehensive or all-inclusive.

The intent is to provide users with a brief list of some of the terms that may appear in common MSDSs. Additional terms specific to the substances your company uses or keeps on-site should be added to the list.

The list of terms and definitions included in this session has been divided into three categories:

- ✓ **Health hazards**
- ✓ **Physical hazards**
- ✓ **Hazardous limits.**



1. Where are labels used? (On the container of every hazardous chemical in the workplace. Hazardous chemicals can pose a danger to people or the environment.)

2. What does a label tell you? (It lists the chemical's identity, who made it, its hazards, and protections against those hazards.)

3. When should employees read the label for a hazardous chemical? (Before starting the job every time that chemical is used—its hazards or protections could change or an employee could forget or confuse it with other chemicals.)

The Hazard Communication Standard (29 CFR 1910.1200) specifically requires every hazardous chemical container to have a label. Labels are part of the company's Hazard Communication Program, which gives employees the Right to Know about the chemical hazards they face on the job.

Each Label Will Tell the Worker

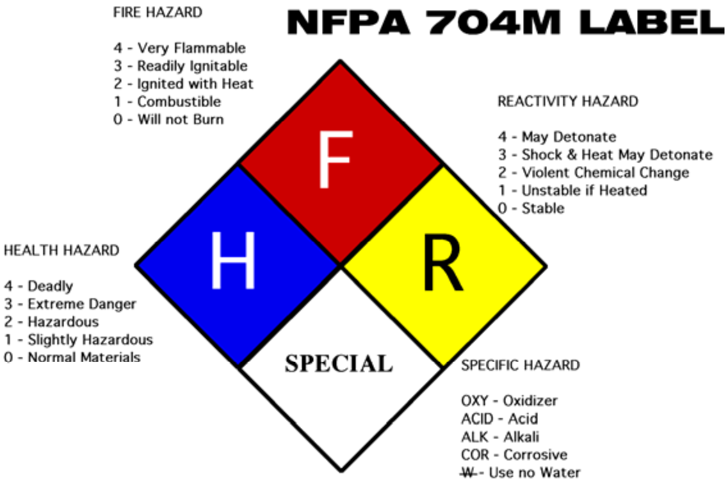
- ✓ **What a chemical's identity is**
- ✓ **Who made it**
- ✓ **Why it's hazardous**
- ✓ **How to protect himself or herself.**

Every person who comes in contact with a container, from receiving clerks to operations workers to maintenance personnel, should check the label automatically and BEFORE starting a job.

The Standard also requires that labels be legible, be in English, and be properly displayed.

Labels are required on cans, cylinders, barrels, drums, pipes, tanks, boxes—on any container that holds a hazardous chemical, even a common household chemical.

Labels don't always have to be the kind that stick to containers, though. They can be signs, placards, process sheets, batch tickets, and other identifiers—as long as they are near the container and provide information about the chemical and its hazards.



Confined space entry procedures and proper ventilation examples.

Personal Protective Equipment PPE Section

Purpose

Your Employer is required to provide all Employees with required PPE to suit the task and known hazards. This Chapter covers the requirements for Personal Protective Equipment with the exception of PPE used for respiratory protection or PPE required for hazardous material response to spills or releases. Applicable OSHA Standards are 1910 Subpart 1 App B and 1910.120 App B, 132, 133, 136, and 138.

General Rules

Design

All personal protective equipment shall be of safe design and construction for the work to be performed.

Hazard Assessment and Equipment Selection

Hazard analysis procedures shall be used to assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of personal protective equipment (**PPE**). If such hazards are present, or likely to be present, the following actions will be taken:

1) Select, and have each affected Employee use, the proper PPE
2) Communicate selection decisions to each affected Employee
3) Select PPE that properly fits each affected employee.

Defective and Damaged Equipment

Defective or damaged personal protective equipment shall not be used.

Training

All Employees who are required to use PPE shall be trained to know at least the following:
1) When PPE is necessary;
2) What PPE is necessary;
3) How to properly don, remove, adjust, and wear PPE;
4) The limitations of the PPE
5) The proper care, maintenance, useful life and disposal of the PPE.

Each affected Employee shall demonstrate an understanding of the training and the ability to use PPE properly, before being allowed to perform work requiring the use of PPE.

Certification of training for PPE is required by OSHA and shall be accomplished by using the Job Safety Checklist to verify that each affected Employee has received and understood the required PPE training.

Personal Protective Equipment Selection
Controlling Hazards

PPE devices alone should not be relied on to provide protection against hazards, but should be used in conjunction with guards, engineering controls, and sound manufacturing practices.

Selection Guidelines

The general procedure for selection of protective equipment is to:

a) become familiar with the potential hazards and the type of protective equipment that is available, and what it can do; i.e., splash protection, impact protection, etc.
b) compare the hazards associated with the environment; i.e., impact velocities, masses, projectile shape, radiation intensities, with the capabilities of the available protective equipment;
c) select the protective equipment which ensures a level of protection greater than the minimum required to protect employees from the hazards

d) fit the user with the protective device and give instructions on care and use of the PPE. It is very important that end users be made aware of all warning labels for and limitations of their PPE.

Fitting the Device

Careful consideration must be given to comfort and fit. PPE that fits poorly will not afford the necessary protection. Continued wearing of the device is more likely if it fits the wearer comfortably. Protective devices are generally available in a variety of sizes. Care should be taken to ensure that the right size is selected.

Devices with Adjustable Features

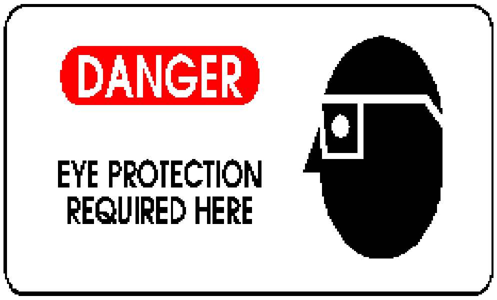
Adjustments should be made on an individual basis for a comfortable fit that will maintain the protective device in the proper position. Particular care should be taken in fitting devices for eye protection against dust and chemical splash to ensure that the devices are sealed to the face. In addition, proper fitting of helmets is important to ensure that it will not fall off during work operations. In some cases a chin strap may be necessary to keep the helmet on an employee's head. (Chin straps should break at a reasonably low force, however, so as to prevent a strangulation hazard). Where manufacturer's instructions are available, they should be followed carefully.

Eye and Face Protection

- ✓ Each affected employee shall use appropriate eye or face protection when exposed to eye or face hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation.
- ✓ Each affected employee shall use eye protection that provides side protection when there is a hazard from flying objects. Detachable side protectors are acceptable.
- ✓ Each affected employee who wears prescription lenses while engaged in operations that involve eye hazards shall wear eye protection that incorporates the prescription in its design, or shall wear eye protection that can be worn over the prescription lenses without disturbing the proper position of the prescription lenses or the protective lenses.
- ✓ Eye and face PPE shall be distinctly marked to facilitate identification of the manufacturer.
- ✓ Each affected employee shall use equipment with filter lenses that have a shade number appropriate for the work being performed for protection from injurious light radiation. The following is a listing of appropriate shade numbers for various operations.

Filter Lenses for Protection Against Radiant Energy			
Operations	**Electrode Size 1/32 in**	**Arc Current**	**Protective Shade**
Shielded metal arc welding	Less than 3	Less than 60	7
	3-5	60-160	8
	5-8	160-250	10
	More than 8	250-550	11
Torch brazing			3
Torch soldering			2
Note: as a rule of thumb, start with a shade that is too dark to see the weld zone. Then go to a lighter shade which gives sufficient view of the weld zone without going below the minimum. In oxyfuel gas welding or cutting where the torch produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line in the visible light of the (spectrum) operation.			

Eye Protection is a Requirement When Working With Hazardous Materials



Safety Glasses (Spectacles)

Safety glasses (spectacles) with side shields are the minimum level of eye protection required for any type of work with or around hazardous chemicals or chemical products.

- Prescription glasses (with or without side shields) are not an acceptable substitution for safety glasses. Prescription safety glasses are available.
- Safety glasses do not provide complete protection against splash or spray because they do not fit tightly to your face.
- Safety glasses must meet ANSI Z87.1 standards (It will be marked on the frame).
- Safety glasses must be worn anytime chemicals or chemical products are handled.

Goggles, Splash (Indirect Venting)

Splash goggles are your next level of defense against chemical eye injury. Splash goggles have indirect ventilation and form a tight seal to the face.

- Splash goggle must be worn anytime there is the chance of a chemical splash or spray.
- Safety glasses are not an acceptable substitution for goggles and do not provide complete protection against splash or spray because they do not fit tightly to your face.
- Operations requiring goggles include but are not limited to pouring, scrubbing, rinsing, spraying (aerosols), washing, and dispensing.
- Splash goggles must also meet ANSI Z87.1 standards.

Face Shield

Face shields protect the eyes, face, and neck from chemical splashes and spray as well as flying particles.

- Face shields will not be worn independently. In other words, safety glasses or goggles must be worn underneath face shields for complete protection.
- Face shields are necessary anytime there is a severe risk of splash or spray or if the material in use is highly hazardous, for example highly corrosive alkaline material.

Selection Chart Guidelines for Eye and Face Protection

The following chart provides general guidance for the proper selection of eye and face protection to protect against hazards associated with the listed hazard "source" operations.

Source	Hazard	Protection
IMPACT - Chipping, grinding machining, masonry work, woodworking, sawing, drilling, chiseling, powered fastening, riveting, and sanding	Flying fragments, objects, large chips, particles, sand, dirt, etc.	Spectacles with side protection, goggles, face shield For severe exposure, use face shield
HEAT-Furnace operation and arc welding	Hot sparks	Face shields, spectacles with side. For severe exposure use face shield.
CHEMICALS-Acid and chemical handling, degreasing, plating	Splash	Goggles, eyecup and cover types. For severe exposure, use face shield.
DUST - Woodworking, buffing, general, buffing, general dusty conditions.	Nuisance dust	Goggles, eye cup and cover type

Selection Guidelines for Head Protection

All head protection is designed to provide protection from impact and penetration hazards caused by falling objects.

- ✓ Head protection is also available which provides protection from electric shock and burn. When selecting head protection, knowledge of potential electrical hazards is important.
- ✓ **Class A helmets**, in addition to impact and penetration resistance, provide electrical protection from low-voltage conductors (they are proof tested to 2,200 volts).
- ✓ **Class B helmets**, in addition to impact and penetration resistance; provide electrical protection from high-voltage conductors (they are proof tested to 20,000 volts).
- ✓ **Class C helmets** provide impact and penetration resistance (they are usually made of aluminum which conducts electricity), and should not be used around electrical hazards.

Where falling object hazards are present, helmets must be worn. Some examples include: working below other workers who are using tools and materials which could fall; working around or under conveyor belts which are carrying parts or materials; working below machinery or processes which might cause material or objects to fall; and working on exposed energized conductors.

Foot Protection
General Requirements

Each affected employee shall wear protective footwear when working in areas where there is a danger of foot injuries due to falling or rolling objects, or objects piercing the sole, and where employee's feet are exposed to electrical hazards.

Selection Guidelines for Foot Protection

- ✓ Safety shoes and boots provide both impact and compression protection. Where necessary, safety shoes can be obtained which provide puncture protection. In some work situations, metatarsal protection should be provided, and in other special situations electrical conductive or insulating safety shoes would be appropriate.
- ✓ Safety shoes or boots with impact protection would be required for carrying or handling materials such as packages, objects, parts or heavy tools, which could be dropped; and, for other activities where objects might fall onto the feet.
- ✓ Safety shoes or boots with compression protection would be required for work activities involving skid trucks (manual material handling carts) around bulk rolls (such as paper rolls) and around heavy pipes, all of which could potentially roll over an employee's feet.
- ✓ Safety shoes or boots with puncture protection would be required where sharp objects such as nails, wire, tacks, screws, large staples, scrap metal etc., could be stepped on by employees, causing a foot injury.

Hand Protection

General Requirements

Hand protection is required when employees' hands are exposed to hazards such as those from skin absorption of harmful substances; severe cuts or lacerations; severe abrasions; punctures; chemical burns; thermal burns; and harmful temperature extremes.

Selection Guidelines for Hand Protection

Selection of hand PPE shall be based on an evaluation of the performance characteristics of the hand protection relative to the task(s) to be performed, conditions present, duration of use, and the hazards and potential hazards identified. Gloves are often relied upon to prevent cuts, abrasions, burns, and skin contact with chemicals that are capable of causing local or systemic effects following dermal exposure.

There is no glove that provides protection against all potential hand hazards, and commonly available glove materials provide only limited protection against many chemicals. Therefore, it is important to select the most appropriate glove for a particular application and to determine how long it can be worn, and whether it can be reused.

It is also important to know the performance characteristics of gloves relative to the specific hazard anticipated; e.g., chemical hazards, cut hazards, flame hazards, etc.

Before purchasing gloves, request documentation from the manufacturer that the gloves meet the appropriate test standard(s) for the hazard(s) anticipated. Other factors to be considered for glove selection in general include:

(A) As long as the performance characteristics are acceptable, in certain circumstances, it may be more cost effective to regularly change cheaper gloves than to reuse more expensive types.

(B) The work activities of the employee should be studied to determine the degree of dexterity required, the duration, frequency, and degree of exposure of the hazard, and the physical stresses that will be applied.

Selection of Gloves for Protection Against Chemical Hazards

(A) The toxic properties of the chemical(s) must be determined; in particular, the ability of the chemical to cause local effects on the skin and/or to pass through the skin and cause systemic effects.

(B) Generally, any "**chemical resistant**" glove can be used for dry powders;

(C) For mixtures and formulated products (unless specific test data are available), a glove should be selected on the basis of the chemical component with the shortest breakthrough time, since it is possible for solvents to carry active ingredients through polymeric materials.

(D) Employees must be able to remove the gloves in such a manner as to prevent skin contamination.

✔	Personal Protective Equipment[1]
	Chemical and disease protection
	Aprons
	Eye/Face splash guards
	Gloves (vinyl and/or latex or nitrile). Sizes: S M L XL
	Protective suits. Sizes: S M L XL
	Respirators (certification required for use)
	Climatic and UV protection
	Boots
	Fluids (for example, water and sports drinks)
	Hat, wide-brimmed
	Insect repellent (unscented)
	Rain gear
	Sunglasses
	Sunscreen
	Temperature-modifying clothing
	Flotation and reflective protection
	Orange flotation vests and jackets
	Safety harness
	Protection for working around heavy objects and machinery
	Back belt
	Hardhat
	Hearing protection
	Safety glasses
	Steel-toed safety boots
	Work gloves

[1] PPE must be selected based on the hazards likely to be encountered. The USGS is required to supply appropriate PPE, and field personnel are required to use it.

Standard Operating Safety Procedures *Example*

D1. General

- Follow all safety instructions carefully. Use equipment only for its designed purpose.
- Become thoroughly acquainted with the location and use of safety equipment such as safety showers, fire blankets, eyewash fountains, fire extinguisher, and exits.
- Know the safety rules and procedures that apply to the work being done. Determine the potential hazards and precautions before undertaking any operation.
- Be alert to any unsafe conditions and work practices and call attention to them immediately, so that appropriate corrections can be made as soon as possible.
- Horseplay, practical jokes, or other behavior which might confuse, startle, or distract other workers in the laboratory is forbidden.
- Be certain all chemicals are correctly and clearly labeled. Post warning signs when unusual hazards, such as radiation, laser, use of carcinogens, or highly toxic chemicals exist.

D2. Personal Protective Equipment

A. Eyes

Everyone in the laboratory including visitors **MUST** wear appropriate eye protection at all times, even when not performing a chemical operation. All protective eye wear used in the laboratory must meet the ANSI Z87.1 standard.

Regular prescription eye glasses (with or without side shields) are not allowed as a substitution for safety glasses or splash goggles. Faculty and staff may obtain prescription safety glasses (with side shields). See our Prescription Safety Glasses Program for more information.

Faculty and staff who don't obtain prescription safety glasses must wear safety glasses (for impact hazard) or goggles (for splash hazard) designed to go over their prescription glasses.

Full face shields with safety glasses or goggles underneath will be worn when conducting an operation that may result in a violent reaction.

Contact lenses can be worn without increased risks in most laboratory environments. Contact lenses will not be substituted for appropriate eye protection. In other words, if the use of contacts is allowed by the laboratory supervisor, approved eye protection will also be worn.

Contact lens wearers will be identified prior to beginning any laboratory operations. Laboratory supervisors who allow contact lens use and the contact lens wearers must be familiar with emergency procedures. Faculty and staff who wear contact lenses should consider obtaining a pair of prescription safety glasses.

B. Clothing

Clothing will offer protection from splashes and spills, should be easily removed in case of an accident, and should be fire resistant. HIGH HEELED OR OPEN TOED SHOES, SANDALS, AND FLIP-FLOPS **WILL NOT BE WOR**N in the laboratory. SHORTS, SHORT DRESSES, MINISKIRTS, TANK TOPS, AND HALTER TOPS ARE ALSO **PROHIBITED**. Long hair and loose clothing will be constrained.

Jewelry such as rings, bracelets, and watches will not be worn.

C. Gloves

Gloves are an important part of personal protection when used correctly. Check to make sure there are no cracks, breaks, or small holes prior to use. Gloves will be removed before handling telephones, doorknobs, writing instruments, and notebooks to prevent the unintentional spread of chemicals.

Gloves will be changed on a periodic basis depending on the nature of work and the chemicals used. Glove material must be appropriate for the chemicals being handled and the operation being performed. A chemical resistance chart that lists the material or materials that you are using should be consulted.

See also Personal Protective Equipment for chemical handling.

D3. Personal Hygiene

- Do not prepare, store, or consume food or beverages in the laboratory.
- Do not apply cosmetics in the laboratory.
- Wash hands and lower arms before leaving the lab even if gloves were worn. Do not use solvents to wash skin. Solvents remove the protective oils from the skin and cause drying, redness, and irritation.
- Never wear or bring lab coats or aprons in areas where food is stored or consumed.
- Never pipette or siphon by mouth.
- Food will not be stored in a refrigerator used for chemical storage. Refrigerators used for chemical storage will clearly labeled ***"Chemicals Only - No Food".*** Conversely refrigerators used for food storage, which will be located outside the laboratory area, will be labeled ***"Food Only -No Chemicals."***

D4. Housekeeping

In the laboratory and elsewhere, keeping things clean and neat generally leads to a safer environment. When housekeeping standards fall, safety performance inevitably deteriorates.

Therefore

- Work areas will be kept clean and free from obstructions. Keep isles free of chairs, boxes, equipment, and waste receptacles.
- Lab benches and floors will be cleaned regularly and kept free of clutter.
- Hazardous chemicals on the floor or above eye level.
- Access to emergency equipment, exits, control panels, and outlets will be kept clear at all times.
- Drawers and cabinets will be closed when not in use.
- Full hazardous waste collection containers will be removed from the laboratory.
- Unneeded or unwanted reagents will be returned to the division stockroom.
- Spilled chemicals will cleaned up immediately and disposed of properly.

D5. Unattended Operations

Reactions that are left to run unattended overnight or at other times are prime sources for fire, floods, or explosions. Plan for interruptions in electrical, gas, or water service. Equipment such as power stirrers, hot plates, heating mantles, and water condensers will not run unattended without fail-safe provisions.

Unattended operations will be checked regularly. Appropriate signs will be posted indicating that a laboratory operation is in progress. The sign will include any hazards associated with the operation and a telephone number of the person(s) to be contacted in an emergency.

Working Alone Policy *Example*

No one will work in a laboratory building alone. If a laboratory supervisor determines that an employee or student can work alone in a laboratory room, arrangements will be made for frequent contact with someone in the immediate area.

Contact will be maintained with Security during work outside of normal hours.

Security

- All laboratories will be locked when unattended and not in use to protect employees, students, equipment, supplies, and the public.
- Locked storage cabinets will be utilized for expensive, hazardous, or sensitive items.
- All suspicious persons or actions will be reported to Security immediately.

Glassware

Careful handling and storage procedures are necessary to avoid damaging glassware.

- Damaged or broken glassware will be discarded. Broken glass will be placed in designated containers. Broken glass collection containers will be labeled, "**CAUTION - Broken Glass**" to prevent injury to custodians and garbage handlers.
- Adequate hand protection will be worn when inserting glass tubing into rubber stoppers or corks, or when placing rubber tubing on glass connections.
- Glass apparatus under vacuum will be handled with extreme care to prevent implosion. Glassware under vacuum will be taped or shielded and only glassware designed for vacuum use such as Dewar flasks will be used for that purpose.
- Glassware will be cleaned at the laboratory sink or in a laboratory dishwasher. The use of strong oxidizer agents such as nitric, chromic, or sulfuric acid will be minimized.
- Proper hand protection will be worn when handling broken glass.
- Glassware or bottles used in laboratory operations will not be used to prepare or store food or beverages.

Systems Under Pressure.

- Reactions under pressure will be carried out in apparatus that is designed to withstand the full pressure of the system.
- All pressurized apparatus will have appropriate relief devices.

Compressed Gases

- Gas cylinders will be strapped or chained securely to a wall or bench top.
- Gas cylinders will be capped when not in use.
- Flammable compressed gases will be stored away from heat, oxygen, and sources of ignition.
- The appropriate regulator will be used.
- Gas cylinders will not be bled completely empty.
- Empty gas cylinders will be labeled as such and separated from full ones.
- Gas cylinders will be transported using gas cylinders carts specifically designed for this purpose.

Chemical Storage

General

- Every chemical container in the laboratory will have a definite storage place and must be returned to that location after each use. Containers will not be left on bench tops overnight.
- Do not store chemicals on desks, bench tops, or in hoods that are used for chemical manipulations.
- Storage trays or secondary containers will be used to minimize the spread of material should a container break or leak.

- Chemicals will be stored by hazard class, not alphabetically. At the very least acids will be separated from bases and flammables will be separated from oxidizers.
- Chemical containers will be inspected periodically. Worn or faded labels will be repaired. Unneeded or unwanted items will be donated to the surplus chemicals inventory, and deteriorated or unusable chemicals will be disposed of.
- Chemical containers will be dated when opened. The receiving date will recorded in ChIM.

Toxic Substances

- Chemicals known to be highly toxic will be stored in well ventilated areas in chemically resistant secondary containers.
- Only minimum working quantities will be present in the work area.
- Containers of suspected carcinogens or acutely toxic chemicals will carry a label such as the following**: "CAUTION - Carcinogen or CAUTION - Highly Toxic."**

Peroxide Forming Chemicals

Specific chemicals that can form dangerous concentrations of peroxides on exposure to air include cyclohexene, cycloctene, decalin (decahydronaphthalene), p-dioxane, ethyl ether anhydrous, diisopropyl ether, tetrahydrofuran, and tetralin (tetrahydronaphthalene).

- The quantity of peroxide-forming chemicals purchased will be limited to the minimum quantity required. Unused material will not be returned to the original container.
- Containers of peroxide-forming chemicals will be dated when opened, tested after 6 months, and disposed of before their expiration date.
- Peroxide forming chemicals will be stored at the lowest possible temperature consistent with their freezing point to prevent decomposition, but will not be allowed to freeze.

Controlling Chemical Exposures

The basic routes for a chemical to enter the body in a laboratory setting are: inhalation, skin and eye contact, ingestion, and injection. The prevention of entry by one of these routes can be accomplished by control mechanisms such as engineering controls, personal protective equipment, and administrative controls. Each route can be minimized by a variety of control measures depending on the hazard and operation.

Employing administrative controls is the most desirable method for controlling chemicals exposures and must be used whenever plausible. Administrative controls include but are not limited to:

- ✓ Hazard information and education.
- ✓ Substitution of a non-hazardous or less hazardous chemical, procedure, or equipment.
- ✓ Reducing the volumes of experiments or quantities used.
- ✓ Control and minimize individual exposure times. Rotate responsibilities.
- ✓ Restrict access to an area where a hazardous chemical is in use.
- ✓ Conduct operations that produce nuisance odors outside of typical hours.
- ✓ Place proper signs on doors to indicate the hazards within and the name and phone numbers of appropriate individuals to contact in an emergency.

Inhalation

Inhalation of hazardous chemicals is the most common route of entry to the body in laboratory operations. The American Conference of Governmental Industrial Hygienists (**ACGIH**) produces annual lists of Threshold Limit Values (**TLVs**) and Short Term Exposure Limits (**STELs**) for common chemicals and biological agents used in the laboratory. These values are guides, not legal standards, and are defined as follows:

- **TLV**: Time-weighted average concentration for a normal 8-hour workday to which nearly all workers may be repeatedly exposed without adverse effect.
- **STEL**: Maximum concentration to which workers can be exposed for periods of up to 15 minutes. Such exposures should be limited to no more than 4 per day with at least 60 minutes between exposures; and the total time-weighted average should not exceed the TLV value.

Most of the 1968 TLVs were adopted by OSHA as Permissible Exposure Levels (**PELs**). To avoid significant inhalation exposures and to limit exposure to concentrations below PEL values, there are a number of control measures that can be used.

Substituting a less toxic or less volatile chemical is the most desirable measure. If substitution is not practical, ventilation will be used to reduce exposure. Dilution ventilation may be used to reduce exposure to nonhazardous nuisance vapor and odor.

All hazardous chemicals should be used in a properly functioning chemical fume hood.

For extremely toxic substances, such as those classified as poison inhalation hazards by the Department of Transportation, the use of closed systems such as a glove box may be required. If necessary, personal protective equipment will be worn to limit chemical exposures. Dust masks or half face air purifying respirators may be utilized to this end. Respirators will not be worn in laboratories without first meeting the requirements of the OSHA Respirator Standard (1910.134).

The requirements include training on proper use, selection, cleaning, and storage of respirators as well as fit testing and medical testing and surveillance to ensure that the user is physically capable of wearing a respirator. See our Respiratory Protection Program for more information.

Skin and Eye Contact

Contact with the skin is a frequent mode of chemical injury. To reduce the risk of chemicals entering the body via skin and eye contact or skin absorption, controls include substitution and ventilation as described above.

If this doesn't control the exposure, the next step is the wearing of personal protective equipment such as gloves, eye protection, lab coats, aprons, appropriate shoes, and special protective equipment as required by the specific hazard present. The laboratory supervisor should consult references to determine the proper protective material for the chemicals being used.

Administrative Controls to Reduce Skin/Eye Contact Exposure Include:

- ✓ Setting up hazardous and non-hazardous areas in the laboratory.
- ✓ Enforcing sound chemical hygiene procedures such as no eating or drinking in the lab and washing hands and face after handling chemicals.

Ingestion

Most of the chemicals used in the laboratory are toxic if they enter the body by ingestion. The relative toxicity of a chemical can be determined by its LD_{50}, which is the quantity of material that, in a single dose, will cause the death of 50% of the test animals. It is usually expressed in grams or milligrams per kilograms of bodyweight.

Ingestion should not be a route of exposure in a laboratory setting. The best way to eliminate exposure by ingestion is to limit actual contact with all chemicals. Wear gloves and practice good hygiene measures.

Food and drink will not be stored in areas where chemicals are being used or stored. Label all chemical containers, and replace worn or faded labels ASAP.

Chemicals will not be tasted, and pipetting and siphoning of liquids will not be done by the mouth.

Highly Toxic Chemicals

Acutely toxic chemicals are substances falling into any of the following categories:

- A chemical that has a median lethal dose (LD50) of 50 mg or less per kg of body weight, when administered to albino rats weighing 200 to 300 g each.
- A chemical that has a median lethal dose (LD50) of 200 mg or less per kg of body weight, when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) to the bare skin of albino rabbits weighing 2 and 3 kg each.
- A chemical that has a median lethal concentration (LC50) in air of 200 parts per million by volume or less of gas or vapor, or 2 mg per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing 200 to 300 g each.

J4. Handling Procedures Policy Example

For the cases of substances that present special hazards the following procedures will be used to minimize risk. These procedures must be followed in laboratory operations with substances believed to be highly toxic or carcinogenic, even when used in small amounts. The extent of precaution depends on the hazards of the particular substance.

Factors such as physical form and volatility of the substance, type and duration of exposure, and the amount to be used should be considered.

All plans for experimental work and waste disposal must be approved by the laboratory supervisor in consultation with the Departmental Chemical Hygiene Officer or equivalent.

The overall objective is to minimize exposure to toxic substances, by any route of exposure. The general precautions outlined elsewhere in this plan should normally be followed whenever a toxic substance is transferred from one container to another or is subject to some chemical or physical manipulation.

The following procedures must also always be followed:

Record Keeping

Accurate records that include the amounts of chemicals used and names of researchers or employees involved should be kept as part of the laboratory notebook record of the experiment.

Storage

Substances having high chronic toxicity should be stored in a well ventilated area in a secondary container or tray.

Labels and Signs

All containers in the high chronic toxicity category will include a warning such as: **WARNING! CANCER SUSPECT AGENT**. All newly purchased containers should already contain this warning, but batch containers and solutions must also be labeled. Any area used for storage should have a label identifying the special toxicity hazard that exists.

Designated Areas

All experiments with and transfers of particularly hazardous substances or mixtures containing such substances must be done in a designated area. A designated area is defined as a laboratory, a portion of a laboratory, or a facility such as an exhaust hood or glove box that is designated for the use of highly toxic substances. Its use need not be restricted if all personnel who have access to the controlled area are aware of the nature of the substances being used and the precautions that are necessary.

Designated areas will be clearly marked with a conspicuous sign such as the following:

WARNING!
HIGHLY TOXIC SUBSTANCE IN USE: AUTHORIZED PERSONNEL ONLY.

The working surface of the hood can be fitted with removable liner of absorbent material. Surfaces can be protected from contamination with chemically resistant trays or plastic backed disposable paper.

Protective Equipment
In some cases, the laboratory supervisor may deem it advisable to wear special protective equipment when working with particularly hazardous substances.

Examples include long gloves or an apron covered by a disposable coat.

Decontamination

On leaving a controlled area, remove any protective apparel, thoroughly wash hands and arms, face, and neck. If disposable apparel or absorbent paper have been used, place these items in a closed impervious bag or container for disposal. Work surfaces will be thoroughly washed and rinsed.

All equipment that is known or suspected to have been in contact with particularly hazardous substances will also be washed and rinsed.

Waste Disposal
All general waste disposal procedures will be followed. Certain additional precautions must also be observed when waste materials are known to contain amounts of highly toxic substances. Volatile toxic substances must never be disposed of by evaporation in the hood. If practical, waste materials should be decontaminated as the last step in the experiment by some procedure that can reasonably be expected to convert the toxic substance to nontoxic substances.

Consult ***Prudent Practices for Disposal of Chemicals from Laboratories*** (available in EHS Office) for specific destruction procedures. If decomposition is not feasible, the waste will be stored in closed, impervious containers such that personnel handling the containers will not be exposed to its contents. All waste containers must be labeled to indicate the contents (constituents and approximate amounts or percentages) and the type of hazard that contact may pose.

For instance, if a waste stream is known to contain appreciable amounts of a carcinogen, the container should be labeled: **CANCER SUSPECT AGENT**. The generation of acutely hazardous waste (**P-waste**) must be closely monitored. As a small quantity generator, our Laboratory is allowed to store no more than 1 kg (2.2 lbs) of acutely hazardous waste. All wastes and residues that have not been chemically decontaminated will be disposed of in accordance with Laboratory's Hazardous Waste Procedures.

Spills And Emergency Procedures *Policy Example*

L1. Chemical Spills

The time to prepare to handle a spill is long before it occurs. Appropriate precautions and the proper equipment will alleviate many of the potential complications associated with the spill of a hazardous material. The following principles will decrease the likelihood of a spill:

- Substitute a less hazardous chemical, procedure, or piece of equipment such as alcohol thermometers instead of mercury thermometers.
- Always store chemical containers with closed caps.
- Use secondary containment whenever possible. Trays and wash basins work well. Coated safety bottles should be used when possible.
- Do not store chemicals on the floor, desks, or counter tops.
- Check shelving; watch for overloading or overcrowding. Excess chemicals can be stored in the division stockroom.
- Practice good housekeeping. Clutter increases the likelihood of a spill or accident.
- Minimize chemical storage in the laboratory. Purchase only the amount needed.

Anticipate chemical spills by having appropriate cleanup and safety equipment on hand.
These cleanup supplies should be consistent with the hazards and quantities of substances used.
Paper towels and sponges may be used as absorbent type cleanup aids but this should be done cautiously. Paper used to clean up oxidizers can later ignite and appropriate gloves should be worn when cleaning toxic materials with towels. Sponges should be chemically resistant.
Commercial clean-up kits are available that have instructions, absorbents, neutralizers, and protective equipment, but these kits are usually expensive and may not cover everything used in a particular lab. Individuals or departments may want to assemble their own kits. The EHS Office can offer assistance in this process. These kits should be located strategically around the laboratory or department area.

If a spill does occur, the following general procedures should be followed:

- Attend to contaminated personnel.
- Alert personnel in adjacent areas.
- Confine the spill, and evacuate nonessential personnel from spill area.
- If spilled material is flammable, extinguish flames and all other sources of ignition.
- Maintain fume hood ventilation.
- Secure appropriate cleanup supplies.
- During cleanup, wear appropriate personal protection.
- Notify the Supervisor of Chemical Management, if the spill involves a regulated substance.

When the nature of the spill constitutes a more serious hazard or involves the release of gas or fumes, the following procedures should be followed:

- Activate the emergency alarm system.
- Rescue injured personnel, if possible.
- Evacuate the building; move to the assembly area.
- Notify Security with the details of the situation.

L2. Emergency Procedures

All laboratory personnel must be familiar with the Emergency Response Plan. The following additional procedures are intended to limit injuries and minimize damage should an accident occur:
Render assistance to persons involved and remove them from exposure to further injury, if necessary.

- Warn personnel in adjacent areas of potential hazards to their safety.
- Render immediate first aid such as washing in safety shower, administering CPR, or special first aid (such as the use of a cyanide kit if cyanide exposure is involved).

- Extinguish small fires by using a portable fire extinguisher. Turn off nearby apparatus and remove flammable materials from the area. In case of larger fires, contact Security immediately.

In the case of a medical emergency, remain calm and do only what is necessary to protect life.

- Call Security immediately.
- Do not move an injured person unless they are in further danger.
- Keep the injured person warm. If feasible, designate one person to remain with the injured person.
- If clothing is on fire, knock the person on the ground and roll them around to smother the flames or douse under a safety shower. A fire blanket should only be used as a last resort.

L3. Fires and Explosions Policy Example

Small fires can easily be extinguished without evacuating the building or calling the fire department. However, even a small fire can quickly become a serious problem. The first few minutes are critical to preventing a larger emergency. The following actions should be taken by personnel in the event of a minor fire:

- Alert other people in the laboratory and send someone to call Security.
- Attack the fire immediately, but never attempt to fight a fire alone. A fire in a small vessel can often be suffocated by placing a larger beaker or watch glass over the top. Use the proper extinguisher, directing discharge of the extinguisher at the base of the flame:
    - ***class A fires***- ordinary combustible solids such as paper, wood, rubber, and textiles.
    - ***class B fires-*** petroleum hydrocarbons and volatile flammable solvents.
    - ***class C fires-*** electrical equipment.
    - ***class D fires***- combustible or reactive metals such as sodium, potassium, or magnesium, metal hydrides, or organometallics.
    - Avoid entrapment, always fight a fire from a position accessible to an exit.

If there is any doubt whether the fire can be controlled locally by available personnel or equipment, the following actions should be taken:

- Activate the emergency alarm system.
- Confine the fire (close hood sashes, doors between laboratories, and fire doors) to prevent further spread of the fire.
- Assist injured personnel.
- Evacuate the building; move to an assemble point for accountability.

Personal Contamination

Chemical Spill to a Large Portion of the Body

- Immediately flood the contaminated area with sufficient running water.
- Remove all contaminated clothing.
- Continue to rinse with cold water for 15 minutes. Wash chemical from contaminated areas with the water but do not apply creams or lotions.
- Get medical attention promptly.

Chemicals on the Skin in a Confined Area

- Flush the exposed skin with cold water.
- If the skin is not burned, wash the area with soap.
- Seek profession medical attention if necessary.

Chemical in the Eyes

- Flush the eyeball and inner eyelid with cold water for 15 minutes. Forcibly hold the eye open to wash thoroughly behind the eyelids.
- Get professional medical attention promptly.
- For caustic splash, continue to irrigate during transportation.

For Contact Lenses

- Copiously irrigate the eye with irrigation solution or water (do not use neutralizing solutions) while holding the lids apart as described above.
- Do not worry about losing the contact lens.
- If the lens remains after the initial flushing, remove it or slide it onto the conjunctiva and re-irrigate.
- Seek professional emergency management. Let them know if the contact lenses are still in the eyes.

Smoke or Fume Inhalation

- Remove from the contaminated air to fresh air.
- Treat for shock, if necessary.
- Get professional medical attention promptly.

Chemical Ingestion

- Administer antidote, if known and available.
- Wrap in blanket to prevent shock.
- Notify Security.
- Identify the chemical(s), and obtain the MSDS for the hospital.

Excavation & Trenching Safety Section

This section outlines procedures and guidelines for the protection of employees working in and around excavations and trenches. This section requires compliance with OSHA Standards described in Subpart P (**CFR 1926.650**) for the construction industry.

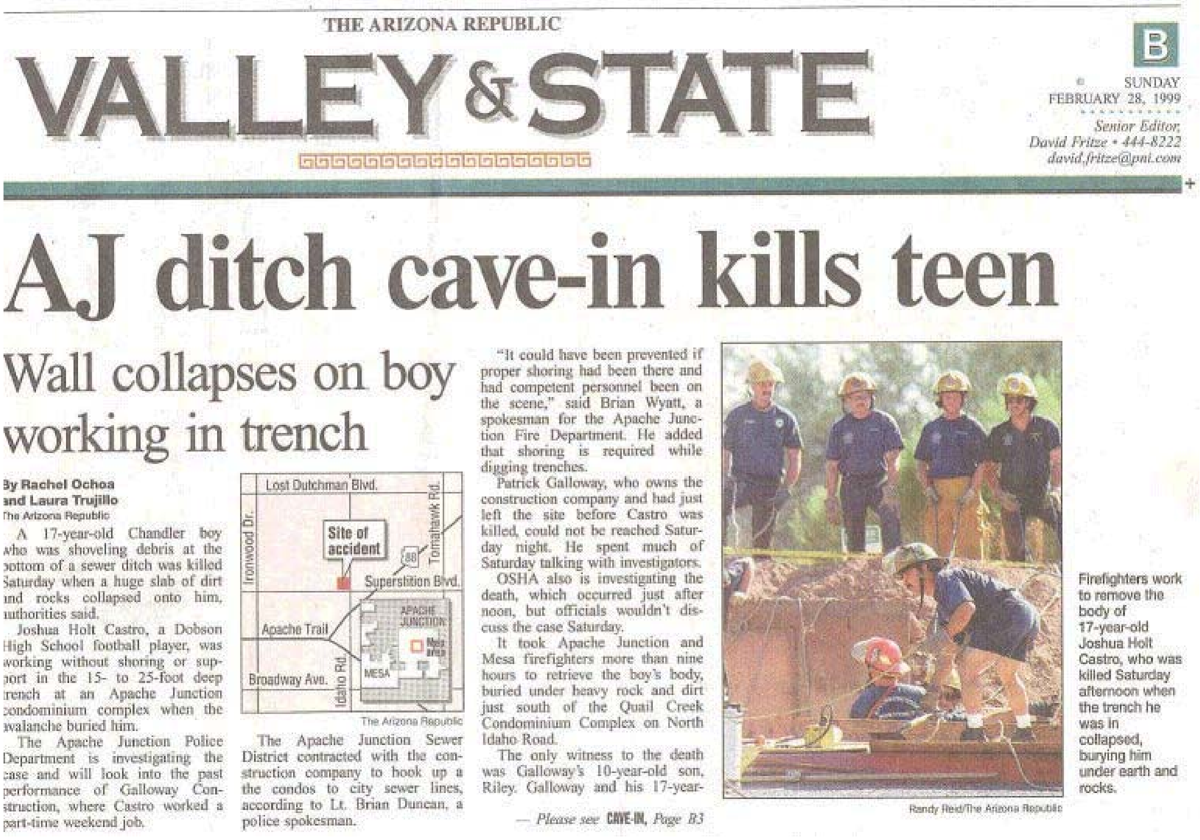
Safety compliance is mandatory to ensure employee protection when working in or around excavations.

The competent person(s) must be trained in accordance with the OSHA Excavation Standard, and all other programs that may apply (examples Hazard Communication, Confined Space, and Respiratory Protection), and must demonstrate a thorough understanding and knowledge of the programs and the hazards associated.

All other employees working in and around the excavation must be trained in the recognition of hazards associated with trenching and excavating.

REFERENCES

- **29 CFR 1926.650, Subpart P - Excavations**
- **Excavation Equipment Manufacturer Safety Procedures**



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AJ ditch cave-in kills teen

Wall collapses on boy working in trench

By Rachel Ochoa
and Laura Trujillo
The Arizona Republic

A 17-year-old Chandler boy who was shoveling debris at the bottom of a sewer ditch was killed Saturday when a huge slab of dirt and rocks collapsed onto him, authorities said.

Joshua Holt Castro, a Dobson High School football player, was working without shoring or support in the 15- to 25-foot deep trench at an Apache Junction condominium complex when the avalanche buried him.

The Apache Junction Police Department is investigating the case and will look into the past performance of Galloway Construction, where Castro worked a part-time weekend job.

The Arizona Republic

The Apache Junction Sewer District contracted with the construction company to hook up a the condos to city sewer lines, according to Lt. Brian Duncan, a police spokesman.

"It could have been prevented if proper shoring had been there and had competent personnel been on the scene," said Brian Wyatt, a spokesman for the Apache Junction Fire Department. He added that shoring is required while digging trenches.

Patrick Galloway, who owns the construction company and had just left the site before Castro was killed, could not be reached Saturday night. He spent much of Saturday talking with investigators.

OSHA also is investigating the death, which occurred just after noon, but officials wouldn't discuss the case Saturday.

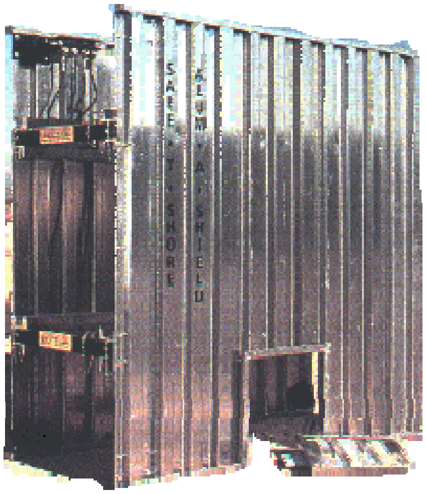
It took Apache Junction and Mesa firefighters more than nine hours to retrieve the boy's body, buried under heavy rock and dirt just south of the Quail Creek Condominium Complex on North Idaho Road.

The only witness to the death was Galloway's 10-year-old son, Riley. Galloway and his 17-year-

— *Please see* **CAVE-IN**, *Page B3*

Randy Reid/The Arizona Republic

Firefighters work to remove the body of 17-year-old Joshua Holt Castro, who was killed Saturday afternoon when the trench he was in collapsed, burying him under earth and rocks.



Trench Shield

Hazards
One of the reasons OSHA requires a competent person on-site during excavation & trenching are the numerous potential hazardous that may be encountered or created. Hazards include:

Electrocution
Gas Explosion
Entrapment
Struck by equipment
Suffocation

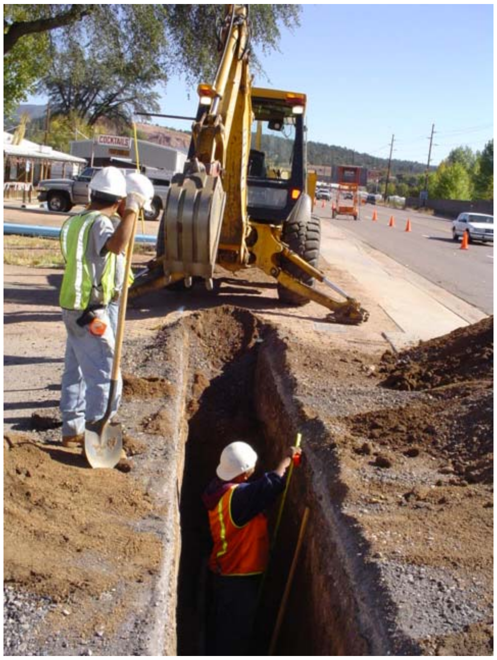
Hazard Controls
Before any work is performed and before any employees enter the excavation, a number of items must be checked and insured:

- Before any excavation, underground installations must be determined. This can be accomplished by either contacting the local utility companies or the local "**one-call'** center for the area. All underground utility locations must be documented on the proper forms. All overhead hazards (**surface encumbrances**) that create a hazard to employees must be removed or supported to eliminate the hazard.
- If the excavation is to be over 20 feet deep, it must be designed by a registered professional engineer who is registered in the state where work will be performed.
- Adequate protective systems will be utilized to protect employees. This can be accomplished through sloping, shoring, or shielding.
- The worksite must be analyzed in order to design adequate protection systems and prevent cave-ins. There must also be an excavation safety plan developed to protect employees.
- Workers must be supplied with and wear any personal protective equipment deemed necessary to assure their protection.
- All spoil piles will be stored a minimum of **two (2) feet from** the sides of the excavation. The spoil pile must not block the safe means of egress.
- If a trench or excavation is 4 feet or deeper, stairways, ramps, or ladders will be used as a safe means of access and egress. For trenches, the employee must not have to travel any more than 25 feet of lateral travel to reach the stairway, ramp, or ladder.
- No employee will work in an excavation where water is accumulating unless adequate measures are used to protect the employees.
- A competent person will inspect all excavations and trenches daily, prior to employee exposure or entry, and after any rainfall, soil change, or any other time needed during the shift. The competent person must take prompt measures to eliminate any and all hazards.
- Excavations and trenches 4 feet or deeper that have the potential for toxic substances or hazardous atmospheres will be tested at least daily. If the atmosphere is inadequate, protective systems will be utilized.

- If work is in or around traffic, employees must be supplied with and wear orange reflective vests. Signs and barricades must be utilized to ensure the safety of employees, vehicular traffic, and pedestrians.

Competent Person Responsibilities
The OSHA Standards require that the competent person must be capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and have authorization to take prompt corrective measures to eliminate them and, if necessary, to stop the work.

A Competent Person is Required to:
- Have a complete understanding of the applicable safety standards and any other data provided.
- Assure the proper locations of underground installations or utilities, and that the proper utility companies have been contacted.
- Conduct soil classification tests and reclassify soil after any condition changes.
- Determine adequate protective systems (sloping, shoring, or shielding systems) for employee protection.
- Conduct all air monitoring for potential hazardous atmospheres.
- Conduct daily and periodic inspections of excavations and trenches.
- Approve design of structural ramps, if used.



Excavation Safety Plan
An excavation safety plan is required in written form. This plan is to be developed to the level necessary to insure complete compliance with the OSHA Excavation Safety Standard and state and local safety standards.

Excavation Safety Plan Factors
- Utilization of the local one-call system.
- Determination of locations of all underground utilities.
- Consideration of confined space atmosphere potential.
- Proper soil protection systems and personal protective equipment and clothing.
- Determination of soil composition and classification.
- Determination of surface and subsurface water.
- Depth of excavation and length of time it will remain open.
- Proper adherence to all OSHA Standards, this excavation and trenching safety program, and any other coinciding safety programs.

Soil Classification and Identification
The OSHA Standards define soil classifications within the Simplified Soil Classification Systems, which consist of four categories: Stable rock, Type A, Type B, and Type C. Stability is greatest in stable rock and decreases through Type A and B to Type C, which is the least stable. Appendix A of the Standard provides soil mechanics terms and types of field tests used to determine soil classifications.

Stable rock is defined as natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A Soil is Defined as:

- Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (**TSF**) or greater.
- Cemented soils like caliche and hardpan are considered Type A.

Soil is NOT Type A if:

- It is fissured.
- The soil is subject to vibration from heavy traffic, pile driving or similar effects.
- The soil has been previously disturbed.
- The material is subject to other factors that would require it to be classified as a less stable material.
- The exclusions for Type A most generally eliminate it from most construction situations.

Type B Soil is Defined as:

- Cohesive soil with an unconfined compressive strength greater than .5 TSF, but less than 1.5 TSF.
- Granular cohesion-less soil including angular gravel, silt, silt loam, and sandy loam.
- The soil has been previously disturbed except that soil classified as Type C soil.
- Soil that meets the unconfined compressive strength requirements of Type A soil, but is fissured or subject to vibration.
- Dry rock that is unstable.

Type C Soil is Defined as:

- Cohesive soil with an unconfined compressive strength of .5 TSF or less.
- Granular soils including gravel, sand and loamy sand.
- Submerged soil or soil from which water is freely seeping.
- Submerged rock that is not stable.

Soil Test & Identification

The competent person will classify the soil type in accordance with the definitions in Appendix A based on at least one visual and one manual analysis. These tests should be run on freshly excavated samples from the excavation and are designed to determine stability based on a number of criteria: the cohesiveness, the presence of fissures, the presence and amount of water, the unconfined compressive strength, the duration of exposure, undermining, and the presence of layering, prior excavation and vibration. The cohesion tests are based on methods to determine the presence of clay. Clay, silt, and sand are size classifications, with clay being the smallest sized particles, silt intermediate and sand the largest. Clay minerals exhibit good cohesion and plasticity (can be molded). Sand exhibits no elasticity and virtually no cohesion unless surface wetting is present. The degree of cohesiveness and plasticity depend on the amounts of all three types and water.

When examining the soil, three questions must be asked: Is the sample granular or cohesive? Fissured or non-fissured? What is the unconfined compressive strength measured in TSF?

Methods of Testing Soils

- **Visual test:** If the excavated soil is in clumps, it is cohesive. If it breaks up easily, not staying in clumps, it is granular.
- **Wet manual test:** Wet your fingers and work the soil between them. Clay is a slick paste when wet, meaning it is cohesive. If the clump falls apart in grains, it is granular.
- **Dry strength test:** Try to crumble the sample in your hands with your fingers. If it crumbles into grains, it is granular. Clay will not crumble into grains, only into smaller chunks.

Pocket Penetrometer Test: This instrument is most accurate when soil is nearly saturated. This instrument will give unconfined compressive strength in tons per square foot. The spring-operated device uses a piston that is pushed into a coil up to a calibration groove. An indicator sleeve marks and retains the reading until it is read. The reading is calibrated in tons per square foot (**TSF**) or kilograms per cubic centimeter.

Thumb Penetration Test: The competent person attempts to penetrate a fresh sample with thumb pressure. If the sample can be dented, but penetrated only with great effort, it is Type A. If it can be penetrated several inches and molded by light pressure, it is Type C. Type B can be penetrated with effort and molded.

Shearvane: Measures the approximate shear strength of saturated cohesive soils. The blades of the vane are pressed into a flat section of undisturbed soil, and the knob is turned slowly until soil failure. The dial is read directly when using the standard vane. The results will be in tons per square foot or kilograms per cubic centimeter.

The competent person will perform several tests of the excavation to obtain consistent, supporting data along its depth and length. The soil is subject to change several times within the scope of an excavation and the moisture content will vary with weather and job conditions. The competent person must also determine the level of protection based on what conditions exist at the time of the test, and allow for changing conditions.

Excavation Protection Systems

The three basic protective systems for excavations and trenches are sloping and benching systems, shoring, and shields.

The protective systems shall have the capacity to resist without failure all loads that are intended or could reasonably be expected to be applied to or transmitted to the system. Every employee in an excavation shall be protected from cave-ins by an adequate protective system.

Exceptions to Using Protective System:

- Excavations are made entirely in stable rock
- Excavations are less than 5 feet deep and declared safe by a competent person

Sloping and Benching Systems

There are four options for sloping:

- Slope to the angle required by the Standard for Type C, which is the most unstable soil type.
- The table provided in Appendix B of the Standard may be used to determine the maximum allowable angle (after determining the soil type).
- Tabulated data prepared by a registered professional engineer can be utilized.
- A registered professional engineer can design a sloping plan for a specific job.

Sloping and benching systems for excavations five (5) to twenty (20) feet in depth must be constructed under the instruction of a designated competent person.

Sloping and benching systems for excavations greater than twenty (20) feet must be designed and stamped by a registered professional engineer.

Sloping and benching specifications can be found in Appendix B of the OSHA Standard (Subpart P).

Shoring Systems

Shoring is another protective system or support system. Shoring utilizes a framework of vertical members (uprights), horizontal members (whales), and cross braces to support the sides of the excavation to prevent a cave-in. Metal hydraulic, mechanical or timber shoring are common examples.

The different examples of shoring are found in the OSHA Standard under these appendices:

APPENDIX C - Timber Shoring for Trenches

APPENDIX D - Aluminum Hydraulic Shoring for Trenches

APPENDIX E - Alternatives to Timber Shoring

One-Call Center or Bluestakes

You are required to locate or call for proper buried utility locations before you dig or excavate. You will usually need a 48-hour notice before you excavate. Please check your local One-Call system.

Red-Electricity, Yellow-Gas, Blue-Water

Orange-Telephone & Fiber Optics

One Call Program

According to federal safety statistics, damage from unauthorized digging is the major cause of natural gas pipeline failures. To prevent excavation damage to all utilities, including pipelines, all 50 states have instituted ***"One Call"*** Programs. The programs provide telephone numbers for excavation contractors to call before excavation begins.

The One Call operator will notify a pipeline company of any planned excavation in the vicinity of its pipeline so that the company can flag the location of the pipeline and assign personnel to be present during excavation, if necessary.

In a related effort, a joint government-industry team has developed a public education program entitled *"**Dig Safely**".* The team involved representatives from the U.S. Department of Transportation, gas and liquid pipeline companies, distribution companies, excavators, the insurance industry, one-call systems and the telecommunications industry. This campaign provides information to the general public concerning underground utilities and the danger of unknowingly digging into buried lines and cables.

The program has posters, brochures and other printed materials available for use by interested organizations. For more information, contact www.digsafely.com.

Buried Telephone Cables

Confined Spaces are
-large enough to allow entry of any body part, and
-limited or restricted entry or exit, and
-not designed for continuous employee occupancy

Permit Required Confined Spaces are confined spaces that have any of the following
-potential hazardous atmosphere
-material inside that may engulf or trap you
-internal design that could trap or asphyxiate you
-***any other serious safety or health hazard***

Entry Permits are required before you enter any "**Permit Required Confined Space**"

Hazards include

- Fire & Explosion
- Engulfment
- Asphyxiation
- Entrapment
- Slips & Falls
- Electric Shock
- Noise & Vibration
- Chemical Exposure
- Toxic Atmospheres
- Thermal / Chemical Burns

Engineering Controls

- ☐ Ventilation
- ☐ Locked Access
- ☐ Lighting

Administrative Controls

- ☐ Controlled Access
- ☐ Hazard Assessments
- ☐ Entry Permits & Procedures
- ☐ Signs & Lockout Tagout
- ☐ Training

Smart Safety Rules

Know what you are getting into.

Know how to get out in an emergency.

Know the hazards & how they are controlled.

Only authorized & trained personnel may enter a Confined Space or act as an attendant.

No smoking in Confined Space or near entrance or exit area.

Attendant must be present at all times.

Constant visual or voice communication must be maintained between the attendant and entrants.

No bottom or side entry will be made, or work conducted, below the level any hanging material or material which could cause engulfment.

Air and oxygen Monitoring is required before entering a Permit-Required Confined Space.

Ventilation & oxygen monitoring is required when welding is performed.

Backflow Cross-Connection Section Chapter 10

A Certified Backflow Tester examining a Double Check Detector check fire line assembly. Notice the water meter which will detect any water usage that be used in the fire line.

Recent Backflow Situations

Oregon 1993
Water from a drainage pond, used for lawn irrigation, is pumped into the potable water supply of a housing development.

California 1994
A defective backflow device in the water system of the County Courthouse apparently caused a sodium nitrate contamination that sent 19 people to the hospital.

New York 1994
An 8-inch reduced pressure principle backflow assembly in the basement of a hospital discharged under backpressure conditions, dumping 100,000 gallons of water into the basement.

Nebraska 1994
While working on a chiller unit of an air conditioning system at a nursing home, a hole in the coil apparently allowed Freon to enter the circulating water and from there into the city water system.

California 1994
The blue tinted water in a pond at an amusement park backflowed into the city water system and causedcolored water to flow from homeowners' faucets.

California 1994
A film company shooting a commercial for television accidentally introduced a chemical into the potable water system.

Iowa 1994
A backflow of water from the Capitol Building chilled water system contaminated potable water with Freon.

Indiana 1994
A water main break caused a drop in water pressure allowing anti- freeze from an air conditioning unit to backsiphon into the potable water supply.

Washington 1994
An Ethylene Glycol cooling system was illegally connected to the domestic water supply at a veterinarian hospital.

Ohio 1994
An ice machine connected to a sewer sickened dozens of people attending a convention.

Backflow and Cross-Connection Principles

Atmospheric Pressure

The atmosphere is the entire mass of air that surrounds the earth. While it extends upward for about 500 miles, the section of primary interest is the portion that rests on the earth's surface and extends upward for about 7 1/2 miles. This layer is called the troposphere.

If a column of air 1-inch square extending all the way to the "***top***" of the atmosphere could be weighed, this column of air would weigh approximately 14.7 pounds at sea level. Thus, atmospheric pressure at sea level is approximately 14.7 psi.

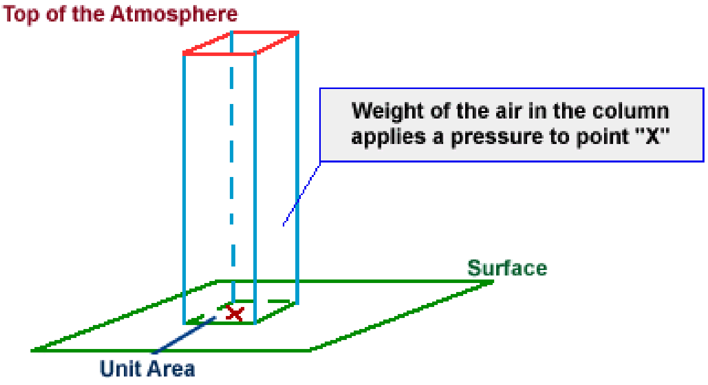
As one ascends, the atmospheric pressure decreases by approximately 1.0 psi for every 2,343 feet. However, below sea level, in excavations and depressions, atmospheric pressure increases. Pressures under water differ from those under air only because the weight of the water must be added to the pressure of the air.

Atmospheric pressure can be measured by any of several methods. The common laboratory method uses the mercury column barometer. The height of the mercury column serves as an indicator of atmospheric pressure. At sea level and at a temperature of 0° Celsius (**C**), the height of the mercury column is approximately 30 inches, or 76 centimeters. This represents a pressure of approximately 14.7 psi. The 30-inch column is used as a reference standard.

Another device used to measure atmospheric pressure is the aneroid barometer. The aneroid barometer uses the change in shape of an evacuated metal cell to measure variations in atmospheric pressure. The thin metal of the aneroid cell moves in or out with the variation of pressure on its external surface. This movement is transmitted through a system of levers to a pointer, which indicates the pressure.

The atmospheric pressure does not vary uniformly with altitude; it changes more rapidly. Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air above that surface. In the diagram below, the pressure at point "**X**" increases as the weight of the air above it increases.

The same can be said about decreasing pressure, where the pressure at point "X" decreases if the weight of the air above it also decreases.



Pressure may be referred to using an absolute scale, pounds per square inch absolute (psia), or gauge scale, (psiag). Absolute pressure and gage pressure are related. Absolute pressure is equal to gauge pressure plus the atmospheric pressure. At sea level, the atmospheric pressure is 14.7 psai.

Absolute pressure is the total pressure. Gauge pressure is simply the pressure read on the gauge. If there is no pressure on the gauge other than atmospheric, the gauge will read zero. Then the absolute pressure would be equal to 14.7 psi, which is the atmospheric pressure.

Vacuum

The term ***vacuum*** indicates that the absolute pressure is less than the atmospheric pressure and that the gauge pressure is negative. A complete or total vacuum would mean a pressure of 0 psia or –14.7 psig.

Since it is impossible to produce a total vacuum, the term vacuum, as used in this document, will mean all degrees of partial vacuum.

In a partial vacuum, the pressure would range from slightly less than 14.7 psia (0 psig) to slightly greater than 0 psia (-14.7 psig). Backsiphonage results from atmospheric pressure exerted on a liquid forcing it toward a supply system that is under a vacuum.

Water Pressure

The weight of a cubic foot of water is 62.4 pounds per square foot. The base can be subdivided into 144-square inches with each subdivision being subjected to a pressure of 0.433 psig.

Suppose you placed another cubic foot of water on top of the first cubic foot. The pressure on the top surface of the first cube which was originally atmospheric, or 0 psig, would now be 0.4333 psig as a result of the additional cubic foot of water. The pressure of the base of the first cubic foot would be increased by the same amount of 0.866 psig or two times the original pressure.

Hydraulics

The word ***hydraulics*** is based on the Greek word for water, and originally covered the study of the physical behavior of water at rest and in motion. Use has broadened its meaning to include the behavior of all liquids, although it is primarily concerned with the motion of liquids. Hydraulics includes the manner in which liquids act in tanks and pipes, deals with their properties, and explores ways to take advantage of these properties.

Hydraulics is a branch of engineering concerned mainly with moving liquids. The term is applied commonly to the study of the mechanical properties of water, other liquids, and even gases when the effects of compressibility are small.

Hydraulics can be divided into two areas, hydrostatics and hydrokinetics. Hydrostatics, the consideration of liquids at rest, involves problems of buoyancy and flotation, pressure on dams and submerged devices, and hydraulic presses.

Hydrodynamics The relative incompressibility of liquids is one of its basic principles.

Hydrodynamics, the study of liquids in motion, is concerned with such matters as friction and turbulence generated in pipes by flowing liquids, the flow of water over weirs and through nozzles, and the use of hydraulic pressure in machinery.

Development of Hydraulics

Although the modern development of hydraulics is comparatively recent, the ancients were familiar with many hydraulic principles and their applications. The Egyptians and the ancient people of Persia, India, and China conveyed water along channels for irrigation and domestic purposes, using dams and sluice gates to control the flow. The ancient Cretans had an elaborate plumbing system. Archimedes studied the laws of floating and submerged bodies. The Romans constructed aqueducts to carry water to their cities.

After the breakup of the ancient world, there were few new developments for many centuries. Then, over a comparatively short period, beginning near the end of the seventeenth century, Italian physicist Evangelista Torricelle, French physicist Edme Mariotte, and later, Daniel Bernoulli conducted experiments to study the elements of force in the discharge of water through small openings in the sides of tanks and through short pipes.

During the same period, Blaise Pascal, a French scientist, discovered the fundamental law for the science of hydraulics. Pascal's law states that increase in pressure on the surface of a confined fluid is transmitted undiminished throughout the confining vessel or system.

For Pascal's law to be made effective for practical applications, it was necessary to have a piston that ***"fit exactly."*** It was not until the latter part of the eighteenth century that methods were found to make these snugly fitted parts required in hydraulic systems.

This was accomplished by the invention of machines that were used to cut and shape the necessary closely fitted parts and, particularly, by the development of gaskets and packings. Since that time, components such as valves, pumps, actuating cylinders, and motors have been developed and refined to make hydraulics one of the leading methods of transmitting power.

Liquids are almost incompressible. For example, if a pressure of 100 pounds per square inch (**psi**) is applied to a given volume of water that is at atmospheric pressure, the volume will decrease by only 0.03 percent. It would take a force of approximately 32 tons to reduce its volume by 10 percent; however, when this force is removed, the water immediately returns to its original volume. Other liquids behave in about the same manner as water.

Another characteristic of a liquid is the tendency to keep its free surface level. If the surface is not level, liquids will flow in the direction which will tend to *make* the surface level.

Liquids at Rest

In studying fluids at rest, we are concerned with the transmission of force and the factors which affect the forces in liquids. Additionally, pressure in and on liquids and factors affecting pressure are of great importance.

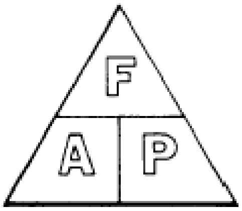
Pressure and Force

Pressure is the force that pushes water through pipes. Water pressure determines the flow of water from the tap. If pressure is not sufficient then the flow can reduce to a trickle and it will take a long time to fill a kettle or a cistern.

The terms ***force*** **and** ***pressure*** are used extensively in the study of fluid power. It is essential that we distinguish between the terms. Force means a total push or pull. It is the push or pull exerted against the total area of a particular surface and is expressed in pounds or grams. Pressure means the amount of push or pull (force) applied to each unit area of the surface and is expressed in pounds per square inch (lb/in2) or grams per square centimeter (gm/cm2). Pressure may be exerted in one direction, in several directions, or in all directions.

Computing Force, Pressure, and Area

A formula is used in computing force, pressure, and area in fluid power systems. In this formula, P refers to pressure, F indicates force, and A represents area. Force equals pressure times area. Thus, the formula is written



$$A = \frac{F}{P}$$

Pascal’s Law

The foundation of modern hydraulics was established when Pascal discovered that pressure in a fluid acts equally in all directions. This pressure acts at right angles to the containing surfaces. If some type of pressure gauge, with an exposed face, is placed beneath the surface of a liquid at a specific depth and pointed in different directions, the pressure will read the same. Thus, we can say that pressure in a liquid is independent of direction.

Pressure due to the weight of a liquid, at any level, depends on the depth of the fluid from the surface. If the exposed face of the pressure gauges, are moved closer to the surface of the liquid, the indicated pressure will be less. When the depth is doubled, the indicated pressure is doubled. Thus the pressure in a liquid is directly proportional to the depth. Consider a container with vertical sides that is 1 foot long and 1 foot wide. Let it be filled with water 1 foot deep, providing 1 cubic foot of water. 1 cubic foot of water weighs 62.4 pounds. Using this information and the equation, **P = F/A**, we can calculate the pressure on the bottom of the container.

Since there are 144 square inches in 1 square foot, this can be stated as follows: the weight of a column of water 1 foot high, having a cross-sectional area of 1 square inch, is 0.433 pound. If the depth of the column is tripled, the weight of the column will be 3 x 0.433, or 1.299 pounds, and the pressure at the bottom will be 1.299 lb/in^2 (psi), since pressure equals the force divided by the area. Thus, the pressure at any depth in a liquid is equal to the weight of the column of liquid at that depth divided by the cross-sectional area of the column at that depth. The volume of a liquid that produces the pressure is referred to as the fluid head of the liquid. The pressure of a liquid due to its fluid head is also dependent on the density of the liquid.

Gravity

Gravity is one of the four forces of nature. The strength of the gravitational force between two objects depends on their masses. The more massive the objects are, the stronger the gravitational attraction.

When you pour water out of a container, the earth's gravity pulls the water towards the ground. The same thing happens when you put two buckets of water, with a tube between them, at two different heights. You must work to start the flow of water from one bucket to the other, but then gravity takes over and the process will continue on its own.

Gravity, applied forces, and atmospheric pressure are static factors that apply equally to fluids at rest or in motion, while inertia and friction are dynamic factors that apply only to fluids in motion. The mathematical sum of gravity, applied force, and atmospheric pressure is the static pressure obtained at any one point in a fluid at any given time.

Static Pressure

Static pressure exists in addition to any dynamic factors that may also be present at the same time.

Pascal’s law states that a pressure set up in a fluid acts equally in all directions and at right angles to the containing surfaces. This covers the situation only for fluids at rest or practically at rest. It is true only for the factors making up static head.

Obviously, when velocity becomes a factor it must have a direction, and as previously explained, the force related to the velocity must also have a direction, so that Pascal’s law alone does not apply to the dynamic factors of fluid power. The dynamic factors of inertia and friction are related to the static factors. Velocity head and friction head are obtained at the expense of static head. However, a portion of the velocity head can always be reconverted to static head. Force, which can be produced by pressure or head when dealing with fluids, is necessary to start a body moving if it is at rest, and is present in some form when the motion of the body is arrested. Therefore, whenever a fluid is given velocity, some part of its original static head is used to impart this velocity, which then exists as velocity head.

Volume and Velocity of Flow

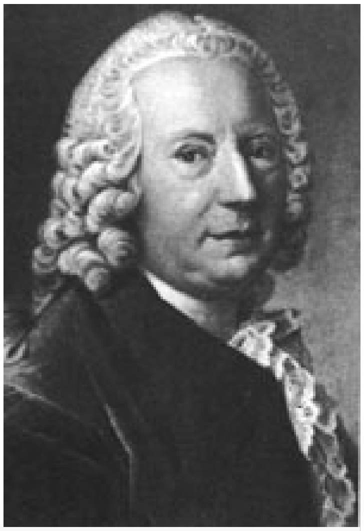
The volume of a liquid passing a point in a given time is known as its ***volume of flow*** or flow rate. The volume of flow is usually expressed in gallons per minute (gpm) and is associated with relative pressures of the liquid, such as 5 gpm at 40 psi.

The ***velocity of flow*** or velocity of the fluid is defined as the average speed at which the fluid moves past a given point. It is usually expressed in feet per second (fps) or feet per minute (fpm). Velocity of flow is an important consideration in sizing the hydraulic lines.

Volume and velocity of flow are often considered together. With other conditions unaltered—that is, with volume of input unchanged—the velocity of flow increases as the cross section or size of the pipe decreases, and the velocity of flow decreases as the cross section increases. For example, the velocity of flow is slow at wide parts of a stream and rapid at narrow parts, yet the volume of water passing each part of the stream is the same.

Bernoulli's Principle

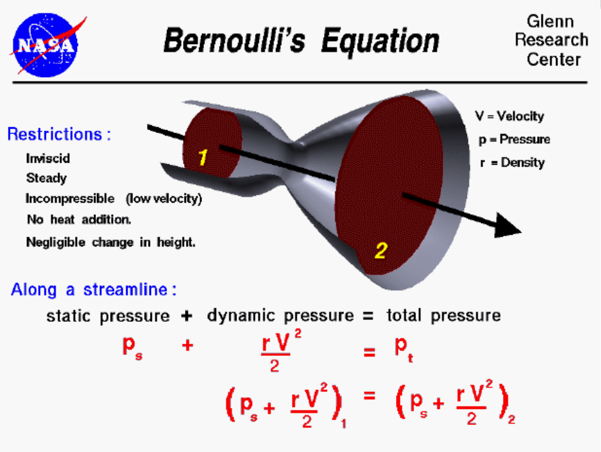
Bernoulli's principle thus says that a rise (fall) in pressure in a flowing fluid must always be accompanied by a decrease (increase) in the speed, and conversely, an increase (decrease) in the speed of the fluid results in a decrease (increase) in the pressure. This is at the heart of a number of everyday phenomena. As a very trivial example, Bernoulli's principle is responsible for the fact that a shower curtain gets ``***sucked inwards***" when the water is first turned on. What happens is that the increased water/air velocity inside the curtain (relative to the still air on the other side) causes a pressure drop.



The pressure difference between the outside and inside causes a net force on the shower curtain which sucks it inward. A more useful example is provided by the functioning of a perfume bottle: squeezing the bulb over the fluid creates a low pressure area due to the higher speed of the air, which subsequently draws the fluid up.

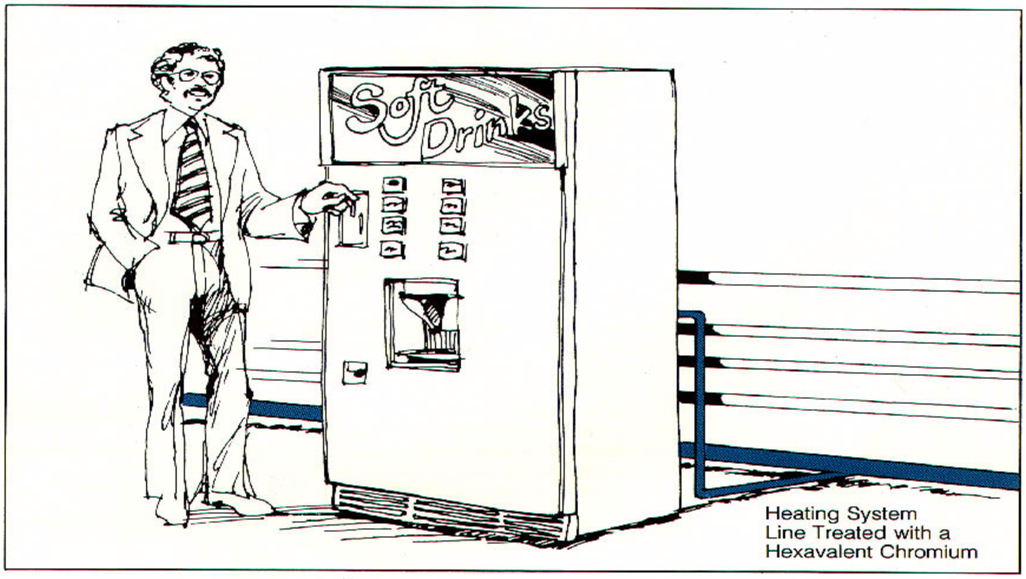
Bernoulli's Principle also tells us why windows tend to explode, rather than implode, in hurricanes. The very high speed of the air just outside the window causes the pressure just outside to be much less than the pressure inside, where the air is still. The difference in force pushes the windows outward, and hence they explode. If you know that a hurricane is coming, it is therefore better to open as many windows as possible, to equalize the pressure inside and out.

Another example of Bernoulli's principle at work is in the lift of aircraft wings and the motion of ``***curve balls"*** in baseball. In both cases the design is such as to create a speed differential of the flowing air past the object on the top and the bottom - for aircraft wings this comes from the movement of the flaps, and for the baseball it is the presence of ridges. Such a speed differential leads to a pressure difference between the top and bottom of the object, resulting in a net force being exerted, either upwards or downwards.



Cross-Connection Terms

Cross-Connection
A cross-connection is any temporary or permanent connection between a public water system or consumer's potable (i.e., drinking) water system and any source or system containing nonpotable water or other substances. An example is the piping between a public water system or consumer's potable water system and an auxiliary water system, cooling system, or irrigation system.



Contaminant: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.

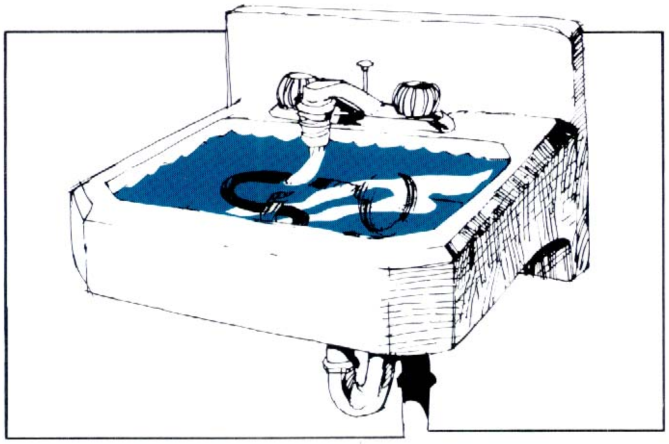
Contamination: To make something bad; to pollute or infect something. To reduce the quality of the potable (drinking) water and create an actual hazard to the water supply by poisoning or through spread of diseases.

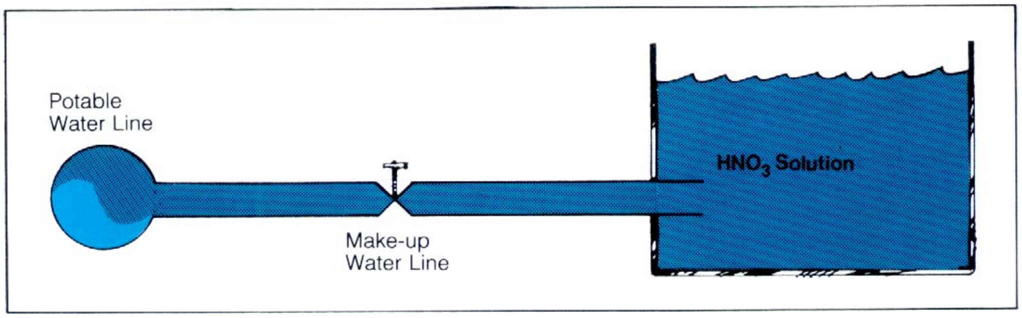
Corrosion: The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.

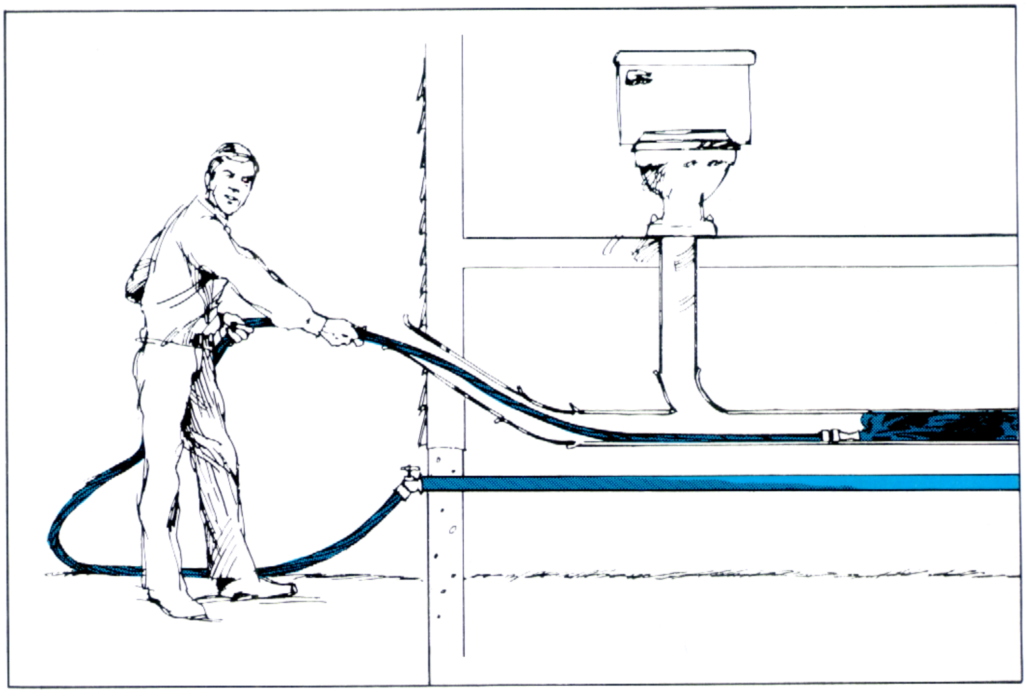
Cross-Connection Failure: Could be the source of an organic substance causing taste and odor problems in a water distribution system.

Cross-Connection: A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow. The mixing of two unlike qualities of water; for example, the mixing of good water with a polluting substance like a chemical.

Common Cross-Connections



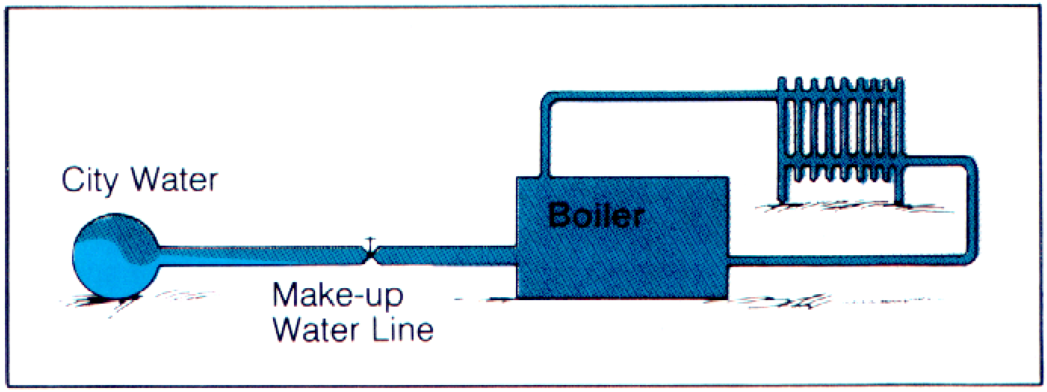




Backflow

Backflow is the undesirable reversal of flow of nonpotable water or other substances through a cross-connection and into the piping of a public water system or consumer's potable water system. There are two types of backflow--**backpressure** and **backsiphonage.**

Backsiphonage

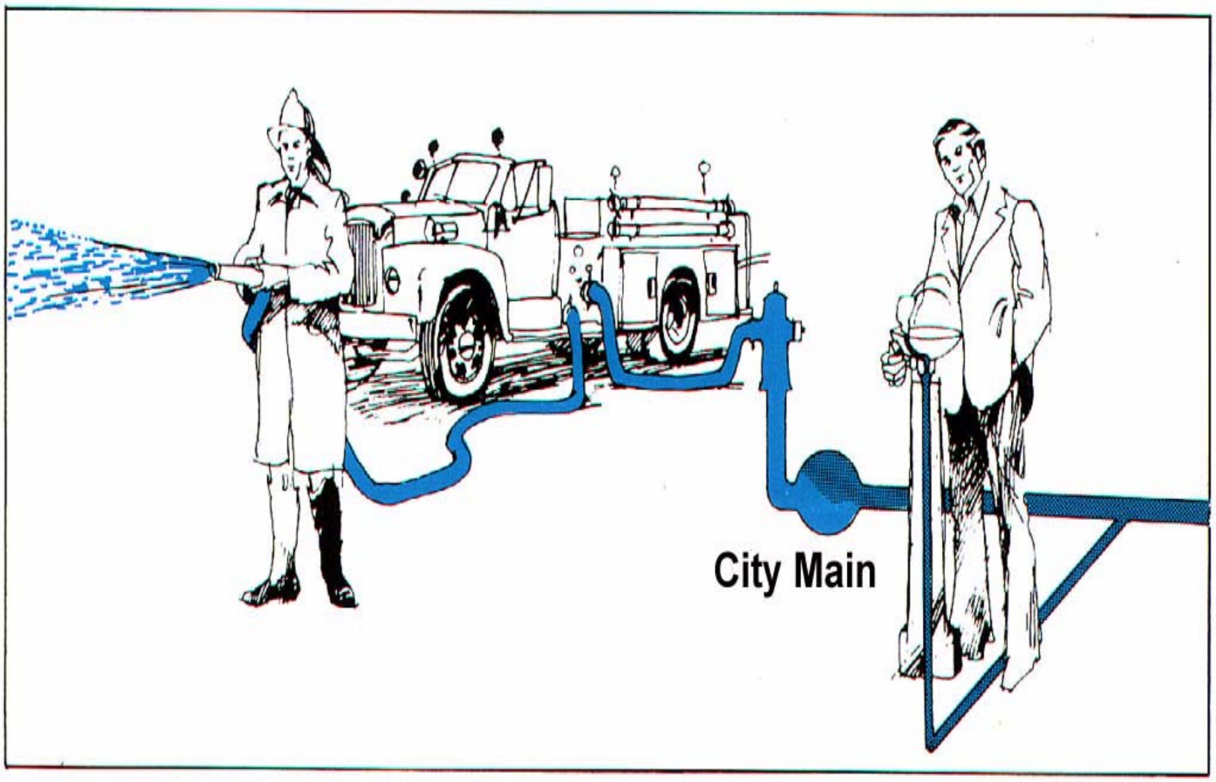


Backpressure

Backsiphonage

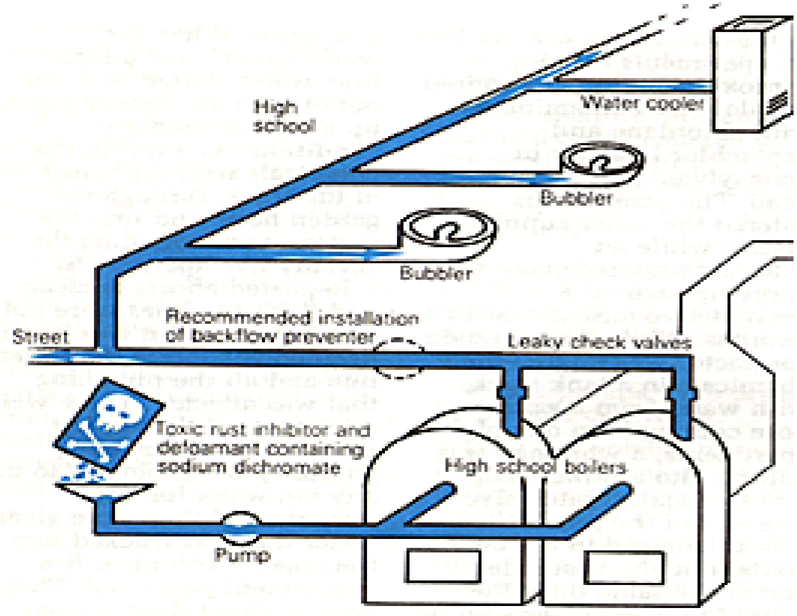
Backsiphonage is backflow caused by a negative pressure (i.e., a vacuum or partial vacuum) in a public water system or consumer's potable water system. The effect is similar to drinking water through a straw.

Backsiphonage can occur when there is a stoppage of water supply due to nearby fire fighting, a break in a water main, etc.



Backpressure

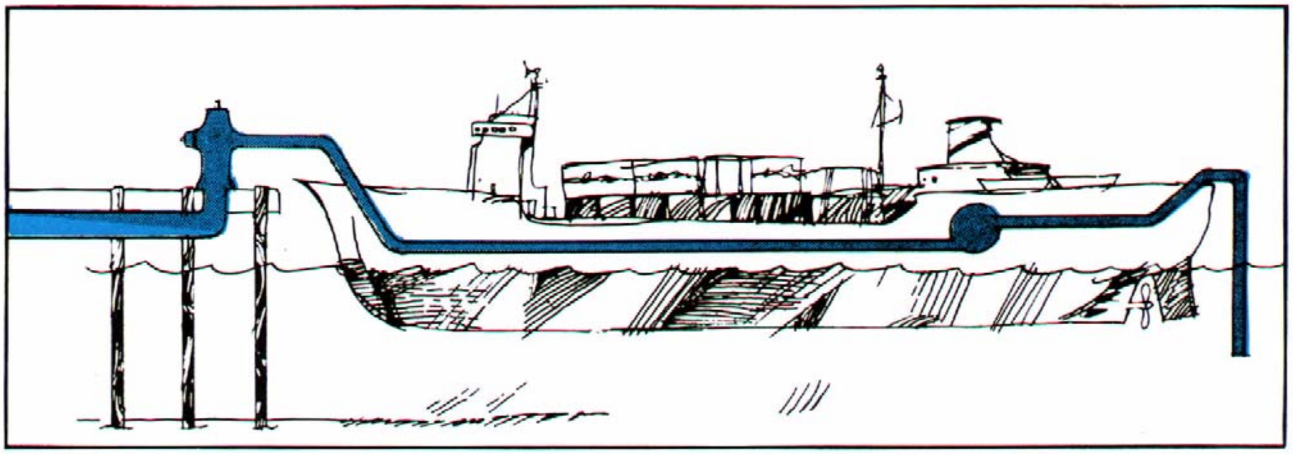
Backpressure backflow is backflow caused by a downstream pressure that is greater than the upstream or supply pressure in a public water system or consumer's potable water system. Backpressure (i.e., downstream pressure that is greater than the potable water supply pressure) can result from an increase in downstream pressure, a reduction in the potable water supply pressure, or a combination of both. Increases in downstream pressure can be created by pumps, temperature increases in boilers, etc.



Reductions in potable water supply pressure occur whenever the amount of water being used exceeds the amount of water being supplied, such as during water line flushing, fire fighting, or breaks in water mains.

Backpressure Example:

Booster Pumps, Pressure Vessels, Boilers



Backflow Review Statements

Backflow Condition: A continuous positive pressure in a distribution system is essential for preventing what event?

Backflow or Cross-Connection Failure: What might be the source of an organic substance causing taste and odor problems in a water distribution system?

Backflow Prevention: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquids, gases, or solid substances back in to the public potable (drinking) water supply. See Cross-connection control.

Backflow: Minimum water pressure must be maintained to ensure adequate customer service during peak flow periods. However, minimum positive pressure must be maintained in mains to protect against backflow or backsiphonage from cross-connections.

Backflow: Name the most common ***CAUSE*** for public water supply contamination. Backflow or cross-connection.

Backflow: To reverse the natural and normal directional flow of liquids, gases, or solid substances back in to the public potable (drinking) water supply. This is normally an undesirable effect.

Backflow: What does a backsiphonage condition usually cause? Reduced pressure or negative pressure on the service or supply side.

Backflow: What does a double check valve backflow assembly provide effective protection from? Both backpressure and backsiphonage of pollution only.

Backflow: What is equipment that utilizes water for cooling, lubrication, washing or as a solvent always susceptible to? A cross-connection.

Backflow: What is the definition of '***backflow***'? A reverse flow condition, that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system.

Backflow: What is the difference between a reduced pressure principle backflow device and a double check backflow device? The RP has a relief valve.

Backflow: What is the maximum time period between having a backflow device tested by a certified backflow tester? 1 year.

Backflow: What must an operator ensure when installing a pressure vacuum breaker backflow device? It must be at least 12 inches above the highest downstream outlet.

Cooling Tower - A common location of a cross-connection

Backflow Responsibility

The Public Water Purveyor

The primary responsibility of the water purveyor is to develop and maintain a program to prevent or control contamination from water sources of lesser quality or other contamination sources from entering into the public water system. Under the provisions of the Safe Drinking Water Act of 1974, (**SDWA**) and current Groundwater Protection rules the Federal Government, through the EPA (Environmental Protection Agency), set national standards of safe drinking water. The separate states are responsible for the enforcement of these standards as well as the supervision of public water systems and the sources of drinking water. The water purveyor or supplier is held responsible for compliance to the provisions of the Safe Drinking Water Act, to provide a warranty that water quality by their operation is in conformance with EPA standards at the source, and is delivered to the customer without the quality being compromised as it is delivered through the distribution system.

This is specified in the Code of Federal Regulations (Volume 40, Paragraph141.2 Section c)":
Maximum contaminant level, means the permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry (**POE**) to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

The Water Consumer

Has the responsibility to prevent contaminants from entering into the public water system by way of their individual plumbing system, and retain the expenses of installation, maintenance, and testing of the approved backflow prevention assemblies installed on their individual water service line.

The Certified General Backflow Tester

Has the responsibility to test, maintain, inspect, repair, and report/notify on approved backflow prevention assemblies as authorized by the persons that have jurisdiction over those assemblies.

Backflow into a public water system can pollute or contaminate the water in that system (i.e., backflow into a public water system can make the water in that system unusable or unsafe to drink), and each water supplier has a responsibility to provide water that is usable and safe to drink under all foreseeable circumstances. Furthermore, consumers generally have absolute faith that water delivered to them through a public water system is always safe to drink. For these reasons, each water supplier must take reasonable precautions to protect its public water system against backflow.

What should water suppliers do to control cross-connections and protect their public water systems against backflow?

Water suppliers usually do not have the authority or capability to repeatedly inspect every consumer's premises for cross-connections and backflow protection. Alternatively, each water supplier should ensure that a proper backflow preventer is installed and maintained at the water service connection to each system or premises that pose a significant hazard to the public water system.

Generally, this would include the water service connection to each dedicated fire protection system or irrigation piping system and the water service connection to each of the following types of premises:
(1) Premises with an auxiliary or reclaimed water system.
(2) Industrial, medical, laboratory, marine or other facilities where objectionable substances are handled in a way that could cause pollution or contamination of the public water system.
(3) Premises exempt from the State Plumbing Code and premises where an internal backflow preventer required under the State Plumbing Code is not properly installed or maintained.
(4) Classified or restricted facilities; and
(5) Tall buildings.

Each water supplier should also ensure that a proper backflow preventer is installed and maintained at each water loading station owned or operated by the water supplier.

Degrees of Hazards (HAZARD RATINGS) High, *Contaminant* and Low, *Pollutional*

Containment Protection, *Secondary protection*

This approach utilizes a minimum of backflow devices and isolates the customer from the water main. It virtually insulates the customer from potentially contaminating or polluting the public water supply system. Containment protection does not protect the customer within his own building, it does effectively remove him from the possibility public water supply contamination. Containment protection is usually a backflow prevention device as close as possible to the customer's water meter and is often referred to as "***Secondary Protection***". This type of backflow protection is excellent for water purveyors and is the least expense to the water customer, but does not protect the occupants of the building.

Internal Protection, *Primary protection*

The water purveyor may elect to protect his customers on a domestic internal protective basis and/or "***fixture outlet protective basis***," in this case cross-connection-control devices (backflow preventors) are placed at internal hazard locations and at all locations where cross-connections may exist, including the ***"last free flowing outlet."***

This type of protection entails extensive cross-connection survey work usually performed by a plumbing inspector or a Cross-Connection Specialist. In a large water supply system, internal protection in itself is virtually impossible to achieve and police due to the quantity of systems involved, the complexity of the plumbing systems inherent in many industrial sites, and the fact that many plumbing changes are made within commercial establishments that do not get the plumbing department's approval or require that the water department inspects when the work is completed.

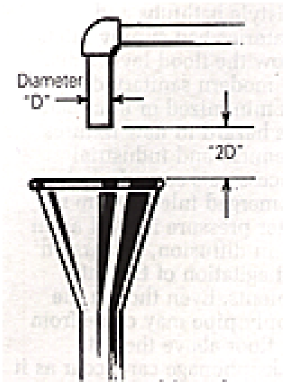
Internal protection is the most expensive and best type of backflow protection for both the water purveyor and the customer alike, but is very difficult to maintain. In order for the purveyor to provide maximum protection of the water distribution system, consideration should be given to requiring the owner of the premises to provide at his own expense, adequate proof that his internal water supply system complies with the local or state plumbing code(s).

Types of Backflow Prevention Methods and Assemblies

Approved Air Gap Separation (AG)

An approved air gap is a physical separation between the free flowing discharge end of a potable water supply pipeline, and the overflow rim of an open or non pressure receiving vessel. These separations must be vertically orientated a distance of at least twice the inside diameter of the inlet pipe, but never less than one inch.

An obstruction around or near an air gap may restrict the flow of air into the outlet pipe and nullify the effectiveness of the air gap to prevent backsiphonage. When the air flow is restricted, such as in the case of an air gap located near a wall, the air gap separation must be increased. Also, within a building where the air pressure is artificially increased above atmospheric, such as a sports stadium with a flexible roof kept in place by air blowers, the air gap separation must be increased.



Air gap or vacuum breaker: What should a potable water line be equipped with when connected to a chemical feeder for fluoride?

Air Gap Separation: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet.

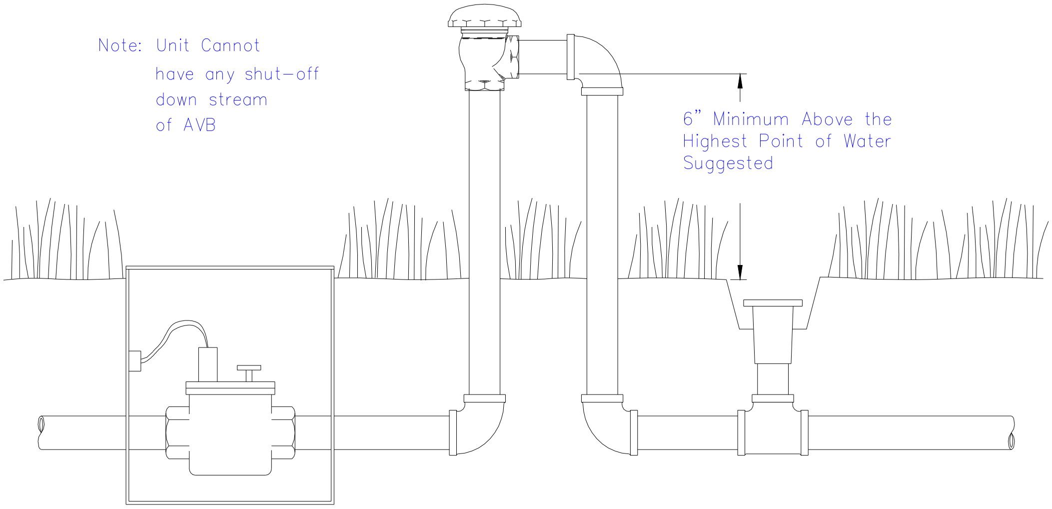
Which of these ice machine drains are approved air gaps?

Atmospheric Vacuum Breaker (AVB)

The Atmospheric Vacuum Breaker contains a float check (poppet), a check seat, and an air inlet port. The device allows air to enter the water line when the line pressure is reduced to a gauge pressure of zero or below. The air inlet valve is not internally loaded. To prevent the air inlet from sticking closed, the device must not be installed on the pressure side of a shutoff valve, or wherever it may be under constant pressure more than 12 hours during a 24 hour period. Atmospheric vacuum breakers are designed only to prevent backflow caused by backsiphonage from low health hazards.

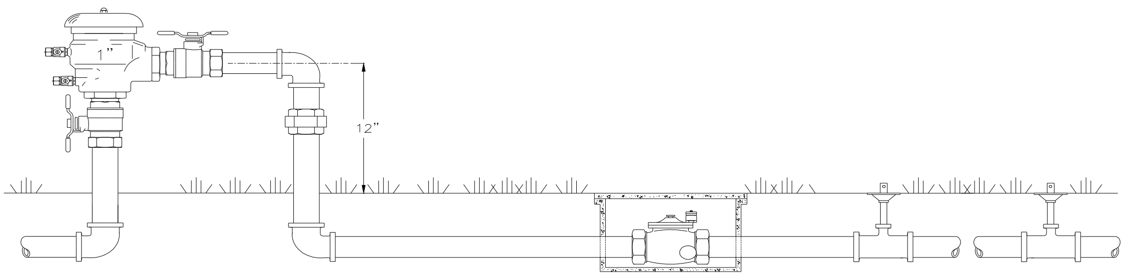
Atmospheric Vacuum Breaker Uses: Irrigation systems, commercial dishwasher and laundry equipment, chemical tanks and laboratory sinks (backsiphonage only, nonpressurized connections)

(Note: hazard relates to the water purveyor's risk assessment; plumbing codes may allow AVB for high hazard fixture isolation).



Pressure Vacuum Breaker Assembly (PVB)

The Pressure Vacuum Breaker Assembly consists of a spring-loaded check valve, an independently operating air inlet valve, two resilient seated shutoff valves, and two properly located resilient seated test cocks. It shall be installed as a unit as shipped by the manufacturer. The air inlet valve is internally loaded to the open position, normally by means of a spring, allowing installation of the assembly on the pressure side of a shutoff valve.



Double Check Valve Assembly (DC)

The Double Check Valve Assembly consists of two internally loaded check valves, either spring loaded or internally weighted, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit as shipped by the manufacturer. The double check valve assembly is designed to prevent backflow caused by backpressure and backsiphonage from low health hazards.

A DC on a fireline with OS& Y valve, notice the little DC with a water meter.

Reduced Pressure Backflow Assembly (RP)

The reduced pressure backflow assembly consists of two independently acting spring loaded check valves separated by a spring loaded differential pressure relief valve, two resilient seated full ported shutoff valves, and four properly located resilient seated test cocks. This assembly shall be installed as a unit shipped by the manufacturer.

During normal operation, the pressure between the two check valves, referred to as the zone of reduced pressure, is maintained at a lower pressure than the supply pressure. If either check valve leaks, the differential pressure relief valve maintains a differential pressure of at least two (2) psi between the supply pressure, and the zone between the two check valves, by discharging water to atmosphere. The reduced pressure backflow assembly is designed to prevent backflow caused by backpressure and backsiphonage from low to high health hazards.

Various RPs

Why do Backflow Preventers Have to be Tested Periodically?

Mechanical backflow preventers have internal seals, springs, and moving parts that are subject to fouling, wear, or fatigue. Also, mechanical backflow preventers and air gaps can be bypassed. Therefore, all backflow preventers have to be tested periodically to ensure that they are functioning properly. A visual check of air gaps is sufficient, but mechanical backflow preventers have to be tested with properly calibrated gauge equipment.

Backflow prevention devices must be tested annually to ensure that they work properly. It is usually the responsibility of the property owner to have this test done and to make sure that a copy of the test report is sent to the Public Works Department or Water Purveyor.

If a device is not tested annually, Public Works or the Water Purveyor will notify the property owner asking them to comply. If the property owner does not voluntarily test their device, the Water provider may be forced to turn off water service to that property. State law may require the Water provider to discontinue water service until testing is complete.

Troubleshooting Table for Cross Connection Problem
1. Sudsy or soapy water.
3. Positive Coliform.
3. Coloring in the water (unusual colors such as bright blue).
4. Organic odors.

Possible Causes
1A. Hose connected to an unprotected hose bib with the other end in a bucket or sink of soapy water.
2A. Hose connected to an unprotected hose bib with the other end lying on the floor of the pump house, on the ground in the car wash area, in the wading or swimming pool or other nonpotable liquid.
2B. Unprotected potable water line feeding a lawn irrigation system.
2C. Submerged inlet, e.g. faucet submerged.
3A. Backflow from toilet.
4A. Handheld pesticide/herbicide applicator attached to unprotected hose.

Possible Solutions
1A. Equip all hose bibs with an AVB.
2A. Equip all hose bibs with an AVB.
2B. Install a backflow preventer on the potable water line feeding the irrigation system.
2C. Relocate faucet above flood level.
3A. Get help. Bring in someone who understands cross connections to evaluate the system.
4A. Don't use these devices

This PVB is not 12 inches above the ground nor the highest downstream outlet.

Water Treatment Glossary

Excellent operator certification study tool.

0.2 mg/L: Should be the target value for the free chlorine residual in the distribution system.
10 ppm: The IDLH for Cl2 gas according to the NIOSH manual.
Absence of Oxygen: The complete absence of oxygen in water described as Anaerobic.
Accuracy: How closely an instrument measures the true or actual value.
Acid and a Base is Mixed: When an acid and a base are mixed, an explosive reaction occurs and decomposition products are created under certain conditions.
Acid Rain: A result of airborne pollutants.
Acid: Slowly add the acid to water while stirring. An operator should not mix acid and water or acid to a strong base.
Activated Charcoal: A treatment technique that is not included in the grading of a water facility.
Air Gap or Vacuum Breaker: A potable water line should be equipped with an air gap or vacuum breaker when connected to a chemical feeder for fluoride.
Air Gap: A physical separation space that is present between the discharge vessel and the receiving vessel, for an example, a kitchen faucet. Minimum 1 inch or twice the diameter, whatever is greater.
Air Hood: The most suitable protection when working with a chemical that produces dangerous fumes.
Alternative Disinfectants: Disinfectants - other than chlorination (halogens) - used to treat water, e.g. ozone, ultraviolet radiation, chlorine dioxide, and chloramine. There is limited experience and scientific knowledge about the by-products and risks associated with the use of alternatives.
Aluminum Sulfate: The chemical name for Alum. The molecular formula of Alum is Al2(SO4)3~14H2O. It is a cationic polymer.
Ammonia: A chemical made with Nitrogen and Hydrogen and used with chlorine to disinfect water. Most ammonia in water is present as the ammonium ion rather than as ammonia.
Anaerobic: An abnormal condition in which color and odor problems are most likely to occur.
Anaerobic conditions: When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with Reduction in the stratified waters.
Aquifer: An underground geologic formation capable of storing significant amounts of water. A permeable layer of the subsurface that allows the movement of groundwater.
As: The chemical symbol of Arsenic.
Atom: The general definition of an ion is an atom with a positive or negative charge. Electron is the name of a negatively charged atomic particle.
Backflow 12 inches: The required distance above ground that a double check backflow or RP assembly needs to be installed.
Backflow or Cross-connection Failure: Might be the source of an organic substance causing taste and odor problems in a water distribution system.
Backflow Prevention: To stop or prevent the occurrence of, the unnatural act of reversing the normal direction of the flow of liquids, gases, or solid substances back into the public potable (drinking) water supply. Continuous positive pressure in a distribution system is essential for preventing a backflow event. See Cross-connection control.
Backflow: A double check valve backflow assembly provides effective protection from both backpressure and backsiphonage of pollution only. Needs to be tested on an annual basis, needs to be installed 12 inches above the ground.
Backflow: A reverse flow condition that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system. To reverse the natural and normal directional flow of liquids, gases, or solid substances back into the public potable (drinking) water supply. This is normally an undesirable effect. The difference between a reduced pressure principle backflow device and a double check backflow device is that RP has a relief valve.1 year is the maximum time period between having a backflow device tested by a certified backflow tester. An operator must ensure when installing a pressure vacuum breaker backflow device that it must be at least 12 inches above the highest downstream outlet. This is different than 12 inches above the ground. Backsiphonage condition usually causes reduced pressure or negative pressure on the service or supply side. Equipment that utilizes water for cooling, lubrication, washing or as a solvent is always susceptible to a cross-

connection. Minimum water pressure must be maintained to ensure adequate customer service during peak flow periods. However, minimum positive pressure must be maintained in mains to protect against backflow or backsiphonage from cross-connections.

Backsiphonage: A liquid substance that is carried over a higher point. It is the method by which the liquid substance may be forced by excess pressure over or into a higher point.

Back-up Disinfection units: If a chlorination system goes out of operation you are required to have back-up.

Backwash: A surface wash system should be activated prior to the start of the backwash.

Backwashing: Backwash the filters more frequently can be used to increase water production if an increase in raw water turbidity and coagulation feed rate creates additional loading on the filter.

Bacteria: Small, one-celled animals too small to be seen by the naked eye. Bacteria are found everywhere, including on and in the human body. Humans would be unable to live without the bacteria that inhabit the intestines and assist in digesting food. Only a small percentage of bacteria cause disease in normal, healthy humans. Iron bacteria is undesirable in a water distribution system because the bacteria may cause red water and slime. Examples include; Salmonella, Shigella, Bacillus, Vibri Cholera and Cholera.

Battery: A source of direct current (**DC**) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.

Benching: A method of protecting employees from cave-ins by excavating the sides of an excavation to form one or a series of horizontal levels or steps, usually with vertical or near vertical surfaces between levels.

Breakpoint Chlorination: The process of chlorinating the water with significant quantities of chlorine to oxidize all contaminants and organic wastes and leave all remaining chlorine as free chlorine.

Bromine: This chemical disinfectant has been used only on a very limited scale for water treatment because of its handling difficulties. This chemical causes skin burns on contact, and a residual is difficult to obtain.

Bromine: Has a limited use for water treatment because of its handling difficulties. This is one of the chemical disinfectants (***HALOGEN***) that kills bacteria and algae.

Buffer: Chemical that resists pH change, e.g. sodium bicarbonate.

Bypass Valve: The name of a type of valve that reduces the differential pressure across a closed disk making the main valve easier to open and close.

Ca: The chemical symbol for calcium.

Cadmium: A contaminant that is usually not found naturally in water or in very small amounts.

Calcium Hardness: A measure of the calcium salts dissolved in water.

Calcium Ion: Divalent because it has a valence of +2.

Calcium, Magnesium, and Iron: Are the three elements that cause hardness in water.

CaOCl2.4H2O: The molecular formula of Calcium hypochlorite.

Capillary Fringe: The material immediately above the water table may contain water by capillary pressure in the small void spaces.

Carbon Dioxide Gas: The pH will decrease and alkalinity will change as measured by the Langelier index after pumping carbon dioxide gas into water.

Carbonate, Bicarbonate and Hydroxide: Chemicals that are responsible for the alkalinity of water.

Cathodic Protection: An operator should protect against corrosion of the anode and/or the cathode by painting the copper cathode.

Cathodic Protection: Cathodic protection interrupts corrosion by supplying an electrical current to overcome the corrosion-producing mechanism.

Cathodic Protection: Guards against stray current corrosion.

Caustic Soda: Also known as sodium hydroxide and is used to raise pH.

Ceiling Area: The specific gravity of ammonia gas is 0.60. If released, this gas will accumulate first at the ceiling are. Cl2 gas will settle on the floor.

Centrifugal Force: That force when a ball is whirled on a string pulls the ball outward. On a centrifugal pump, it is that force which throws water from a spinning impeller.

Centrifugal Pump: A pump consisting of an impeller fixed on a rotating shaft and enclosed in a casing, having an inlet and a discharge connection. The rotating impeller creates pressure in the liquid by the velocity derived from centrifugal force.

Check Valve: Allows water to flow in only one direction.

Chelation: A chemical process used to control scale formation in which a chelating agent "captures" scale-causing ions and holds them in solution.

Chemical Oxidizer: KMnO4 is used for taste and odor control because it is a strong oxidizer which eliminates many organic compounds.

Chemical Reaction Rate: In general, when the temperature decreases, the chemical reaction rate also decreases. The opposite is true for when the temperature increases.

Chloramination: Treating drinking water by applying chlorine before or after ammonia. This creates a persistent disinfectant residual called chloramines.

Chloramines: A group of chlorine and ammonia compounds formed when chlorine combines with organic wastes in the water. Chloramines are not effective as disinfectants and are responsible for eye and skin irritation as well as strong chlorine odors (***also known as Combined Chlorine).***

Chlorination: The process in water treatment of adding chlorine (gas or solid hypochlorite) for purposes of disinfection.

Chlorine Demand: Amount of chlorine required to react on various water impurities before a residual is obtained. Also, means the amount of chlorine required to produce a free chlorine residual of 0.1 mg/l after a contact time of fifteen minutes as measured by iodmetic method of a sample at a temperature of twenty degrees in conformance with Standard methods.

Chlorine Feeding: Chlorine may be delivered by vacuum-controlled solution feed chlorinators. The chlorine gas is controlled, metered, introduced into a stream of injector water and then conducted as a solution to the point of application.

Chlorine, Free: Chlorine available to kill bacteria or algae. The amount of chlorine available for sanitization after the chlorine demand has been met. Also known as chlorine residual.

Chlorine: A chemical used to disinfect water. Chlorine is extremely reactive, and when it comes in contact with microorganisms in water killing them. Chlorine is added to swimming pools to keep the water safe for swimming. Chlorine is available as solid tablets for swimming pools. Some public water system's drinking water treatment plants use chlorine in a gas form because of the large volumes required. Chlorine is very effective against algae, bacteria and viruses. Protozoa are resistant to chlorine because they have thick coats. Protozoa are removed from drinking water by filtration.

CL2 0.2 mg/L: If you are disinfecting to preserve water potability, the minimum concentration of free Cl2 residual in the distribution system.

CL2 10 mg/L: Small water storage tanks are commonly disinfected with a solution containing a Cl2 concentration of 50 mg/L. After 24 hours the minimum Cl2 concentration should be 10 mg/L.

CL2 A Fusible Plug: Considered a safety device on a Cl2 cylinder.

CL2 Chronic Exposure Corrosion of the Teeth: May occur due to chronic exposure to low concentrations of Cl2 gas. After long exposure, throat cancer will occur.

Cl2 Cylinder is Increased: If the temperature of a full Cl2 cylinder is increased by 50° F or 30° C, a rupture may occur.

Cl2 Demand: Cl2 combines with a wide variety of materials. These side reactions complicate the use of Cl2 for disinfecting purposes. Their demand for Cl2 must be satisfied before Cl2 becomes available to accomplish disinfection.

Cl2 Expands in Volume: Happens to Cl2 when the temperature of a Cl2 cylinder increases.

CL2 Free Concentration: If you are disinfecting to preserve water potability, the minimum concentration of free chlorine residual in the distribution system should be 0.2 mg/l.

CL2 Gas Exposure: Chlorine gas causes suffocation, constriction of the chest, tightness in the throat, and edema of the lungs. As little as 2.5 mg per liter (approximately 0.085 percent by volume) in the atmosphere causes death in minutes, but less than 0.0001 percent by volume may be tolerated for several hours. Chlorine gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining the respiratory tract when the tissue is exposed to chlorine. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of chlorine gas in air, causing acute discomfort that warns of the presence of the toxicant. Death is possible from asphyxia, shock, reflex spasm in the larynx, or massive pulmonary edema. Populations at special risk from chlorine exposure are individuals with pulmonary disease, breathing problems, bronchitis, or chronic lung conditions.

CL2 Gas IDLH: As soon as Cl2 gas enters the throat area, a victim will sense a sudden stricture—nature's way of signaling to prevent passage of the gas to the lungs. The victim must attempt to get out of the area of the leak, proceeding upwind, and to take only very short breaths through the mouth. Normal breathing will cause coughing, which must be prevented if possible. Chlorine gas causes suffocation, constriction of the chest, tightness in the throat, and edema of the lungs. As little as 2.5 mg per liter in the atmosphere causes death in minutes, but less than 0.01 percent by volume may be tolerated for several hours.

CL2 Gas Safety: Gas leak is the primary safety concern when using chlorine gas as opposed to calcium hypochlorite or sodium hypochlorite.

Cl2 Gas will Accumulate: If a Cl2 leak occurs, the Cl2 gas will accumulate on the floor.

CL2 Gaskets: Replace according to manufacturers recommendations should be done with the gaskets when making a new connection on a chlorine feed system.

CL2 General Statements: If an operator cannot open the valve on a Cl2 cylinder because it is too tight, first loosen the packing gland around the valve, and tap the valve gently with your hand.

17 is the atomic number of Cl2. 200 mg/l is the generally acceptable concentration of Cl2 solution that should be prepared to wash the inside of a storage facility. A device that has a transparent tube with a tapered bore containing a ball and is often used to measure the rate of a gas or liquid is called a Rotameter. After Cl2 gas is manufactured, it primarily transported and packaged as a liquefied gas under pressure in steel containers. As soon as CL2 gas enters the throat area, a victim will sense a sudden stricture in this area- Nature's way of signaling to prevent passage of the gas to the lungs. At this point, the victim must attempt to do two things: get out of the area of the leak, proceeding upwind, and to take only very short breaths through the mouth. Normal breathing will cause coughing, which must be prevented if possible. Before entering a Cl2 room to check on a leak don a self-contained breathing apparatus and check to see that the ventilation system is working. Be sure that no one enters the leak area without an adequate self-contained breathing apparatus. Breakpoint chlorination means adding Cl2 to the water until the Cl2 demand is satisfied. Chronic exposure to low concentrations of Cl2 gas may cause corrosion of the teeth. Cl2 combines with a wide variety of materials. These side reactions complicate the use of Cl2 for disinfecting purposes. Their demand for Cl2 must be satisfied before Cl2 becomes available to accomplish disinfection. Cl2 combines with water to form both hypochlorous and hydrochloric acids. Cl2 gas is highly corrosive in moist conditions. The only metals that are totally inert to moist Cl2 gas are Gold, Platinum, and Tantalum. Cl2 as with H2S gas produces olfactory fatigue. Cl2 gas reacts with water producing a strongly oxidizing solution causing damage to the moist tissue lining the respiratory tract when the tissue is exposed to Cl2. The respiratory tract is rapidly irritated by exposure to 10-20 ppm of Cl2 gas in air, causing acute discomfort that warns of the presence of the toxicant. Cl2 gas should only be used under a fume hood. Determine the ambient temperature in a Cl2 room by using a regular thermometer because ambient temperature is simply the air temperature of the room. Downstream from the point of post chlorination, the concentration of a free Cl2 residual should be 0.5 mg/L in a clear well or distribution reservoir. Even brief exposure to 1,000 ppm of Cl2 can be fatal. Free available Cl2 is very effective in killing bacteria. If an operator places water on a leaking Cl2 cylinder, corrosion will occur and the leak will get larger. Store an empty Cl2 cylinder upright, tagged as empty. The Cl2 storage ventilation equipment be checked on a daily basis. The CT values for disinfection are used to determine the disinfection efficiency based upon time and concentration of the disinfectant residual. The effectiveness of disinfection determined from the results of coliform testing. The first step when removing a hypochlorinator from service is to turn off the water supply pump. The fusible plug on a 150-pound Cl2 cylinder is designed to soften and melt at high temperatures. The physical and chemical properties of Cl2 are: A yellowish green, nonflammable and liquefied gas with an unpleasant and irritating smell. Can be readily compressed into a clear, amber colored liquid. A noncombustible gas, and a strong oxidizer, Cl2 is about 1.5 times heavier than water and gaseous Cl2 is about 2.5 times heavier than air. The purpose of an evaporator is to convert liquid Cl2 to gaseous Cl2 for use by gas chlorinators. The purpose of the bottom valve on a 1-ton Cl2 cylinder is to remove liquid Cl2.The purpose of the ejector on a hypochlorinator, is to draw in additional water for dilution of the hypochlorinate solution. The water temperature decreases from 70°F (21°C) to 40°F (4°C). Allow a longer contact time to maintain good disinfection of the water. When Cl2 is inhaled in high concentrations it causes emphysema and damage to the pulmonary blood vessels. When determining a Cl2 use rate, the scale or meter should be read at the same time each day. When hypochlorite is brought into contact with an organic material, the organic material decomposes releasing heat very rapidly. Where other factors are constant, the disinfecting action may be represented by: **Kill = C x T**.

Clear Well: A large underground storage facility sometimes made of concrete. A clear well or a plant storage reservoir is usually filled when demand is low.

ClO2: The molecular formula of Chlorine dioxide.

Coagulation: The best pH range for coagulation is between a pH of 5 and 7. Mixing is an important part of the coagulation process you want to complete the coagulation process as quickly as possible.

Coliform Bacteria: Bacteria that are normally found in the intestines of warm-blooded animals. Coliform bacteria are present in high numbers in animal feces. They are an indicator of potential contamination of water. Adequate and appropriate disinfection effectively destroys coliform bacteria.
Coliform Testing: The effectiveness of disinfection is usually determined by Coliform bacteria testing. A positive sample is a bad thing and indicates that you have bacteria contamination.
Colloidal Suspensions: Because both iron and manganese react with dissolved oxygen to form insoluble compounds they are not found in high concentrations in waters containing dissolved oxygen except as colloidal suspensions of the oxide.
Colorimetric Measurement: A means of measuring an unknown chemical concentration in water by measuring a sample's color intensity.
Combined Chlorine: The reaction product of chlorine with ammonia or other pollutants, also known as chloramines.
Community Water System: A water system which supplies drinking water to 25 or more of the same people year-round in their residences.
Competent Person: One who is capable of identifying existing and predictable hazards in the surroundings or working conditions, which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.
Compliance Cycle: A 9-calendar year time-frame during which a public water system is required to monitor. Each compliance cycle consists of 3 compliance periods.
Compliance Period: A 3-calendar year time-frame within a compliance cycle.
Composite Sample: A water sample that is a combination of a group of samples collected at various intervals during the day.
Condensation: The process called that changes water vapor to tiny droplets or ice crystals.
Contact Time, pH and Low Turbidity: Factors which are important in providing good disinfection using chlorine.
Contact Time: If the water temperature decreases from 70°F (21°C) to 40°F (4°C). The operator needs to increase the detention time to maintain good disinfection of the water.
Contains the Element Carbon: A simple definition of an organic compound.
Contaminant: Any natural or man-made physical, chemical, biological, or radiological substance or matter in water, which is at a level that may have an adverse effect on public health, and which is known or anticipated to occur in public water systems.
Contamination: To make something bad; to pollute or infect something. To reduce the quality of the potable (drinking) water and create an actual hazard to the water supply by poisoning or through spread of diseases.
Control Taste and Odor Problems: $KMnO^4$ Potassium permanganate is a strong oxidizer is commonly used to control taste and odor problems.
Copper: The chemical name for the symbol Cu.
Corrosion: The gradual decomposition or destruction of a material as it chemically reacts with water and is often referred to as corrosion. The removal of metal from copper, other metal surfaces and concrete surfaces in a destructive manner. Corrosion is caused by improperly balanced water or excessive water velocity through piping or heat exchangers.
Corrosivity: The Langelier Index measures corrosivity.
Coupon: Placed to measure corrosion damage in the water mains.
Cross-connection: A physical connection between a public water system and any source of water or other substance that may lead to contamination of the water provided by the public water system through backflow. Might be the source of an organic substance causing taste and odor problems in a water distribution system.
Cross-contamination: The mixing of two unlike qualities of water; for example, the mixing of good water with a polluting substance like a chemical.
Cryptosporidium: A disease-causing parasite, resistant to chlorine disinfection. It may be found in fecal matter or contaminated drinking water.
Diaphragm: Valves can be used to maintain a constant downstream pressure in a water distribution system, regardless of fluctuating demand. An integral component of these valves is a rubber diaphragm. Commonly found in a PRV.
Dangerous Chemicals: The most suitable protection when working with a chemical that produces dangerous fumes is to work under an air hood.
CWS: Community Water System.

Decibels: The unit of measurement for sound.
Decompose: To decay or rot.
Decomposition of Organic Material: The decomposition of organic material in water produces taste and odors.
Demineralization Process: Mineral concentration of the feed water is the most important consideration in the selection of a demineralization process. Acid feed is the most common method of scale control in a membrane demineralization treatment system.
Dental Caries Prevention in Children: The main reason that fluoride is added to a water supply.
Depolarization: The removal of hydrogen from a cathode.
Desiccant: When shutting down equipment which may be damaged by moisture, the unit may be protected by sealing it in a tight container. This container should contain a desiccant.
Detection Lag: The period of time between the moment of change in a chlorinator control system and the moment when the change is sensed by the chlorine residual indicator.
Detention Time: The minimum detention time range recommended for flocculation is 5 – 20 minutes for direct filtration and up to 30 minutes for conventional filtration.
Diatomaceous Earth: A fine silica material containing the skeletal remains of algae.
Direct Current: A source of direct current (**DC**) may be used for standby lighting in a water treatment facility. The electrical current used in a DC system may come from a battery.
Disinfect: To kill and inhibit growth of harmful bacterial and viruses in drinking water.
Disinfectant Residual: The CT values for disinfection are used to determine the disinfection efficiency based upon time and disinfectant residual.
Disinfection by-products (DBPs): The products created due to the reaction of chlorine with organic materials (e.g. leaves, soil) present in raw water during the water treatment process. The EPA has determined that these DBPs can cause cancer.
Disinfection: The treatment of water to inactivate, destroy, and/or remove pathogenic bacteria, viruses, protozoa, and other parasites. The effectiveness of disinfection determined by the results of coliform testing. Types of source water are required by law to treat water using filtration and disinfection are groundwater under the direct influence of surface water. Surface water sources.
Dissolved Oxygen: Can be added to zones within a lake or reservoir that would normally become anaerobic during periods of thermal stratification.
Distillation, Reverse Osmosis and Freezing: Processes can be used to remove minerals from the water.
Distribution 8 inches: The minimum pipe diameter for a dead end line exceeding 2,000 feet in length should be 8 inches.
Double Suction Pump: One advantage of a double suction pump is a reduction in the thrust load that the bearings must carry.
Dry Acid: A granular chemical used to lower pH and or total alkalinity.
E. Coli, *Escherichia coli* : A bacterium commonly found in the human intestine. For water quality analyses purposes, it is considered an indicator organism. These are considered evidence of water contamination. Indicator organisms may be accompanied by pathogens, but do not necessarily cause disease themselves.
Eccentric Valve: The plug on an eccentric valve contacts the valve seat when the valve is closed.
Effectiveness of Chlorination: The factors which influence the effectiveness of chlorination the most are pH, Turbidity and Temperature.
Effectiveness of the Chlorine Decreases: Will occur during disinfection in source water with excessive turbidity.
Electrical Problem: Moisture will cause the deterioration of oil in a transformer.
Electrical Resistance: Resistance of electrical equipment is affected by many variables including the thickness of the insulation and its total mass area.
Electrical: An operator using a voltage meter to test electrical equipment should first, make sure the main switch is off and the voltage tester is rated to handle the voltage expected in the circuit. If grease comes in contact with the winding of a motor the winding insulation may deteriorate. If the overload control on a motor has tripped and the motor has stopped running. An operator needs to wait for the overload to cool, then tries to start the motor again. If the motor does not start, the operator should first check the fuse.
Electricity: Rubber may be used to prevent the flow of electricity through a wire.
Electron: The name of a negatively charged atomic particle.

Elementary Business Plan: Technical Capacity, Managerial Capacity, and Financial Capacity make up the elementary business plan. To become a new public water system, an owner shall file an elementary business plan for review and approval by the Department.

Emergency Response Team: Get out of the area and notify your local emergency response team; this is the first thing that should be done in case of a large uncontrolled chlorine leak.

Enhanced Coagulation: The process of joining together particles in water to help remove organic matter.

Enterovirus: A virus whose presence may indicate contaminated water; a virus that may infect the gastrointestinal tract of humans.

F: The chemical symbol of Fluorine.

Faucet with an Aerator: When collecting a water sample from a distribution system, a faucet with an aerator should not be used as a sample location.

Fecal Coliform: A group of bacteria that may indicate the presence of human or animal fecal matter in water.

Filtration: A series of processes that physically removes particles from water. A water treatment step used to remove turbidity, dissolved organics, odor, taste and color.

Filter Clogging: An inability to meet demand may occur when filters are clogging.

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 filtration processes that involves a number of interrelated removal mechanisms. Demineralization is primarily used to remove total dissolved solids from industrial wastewater, municipal water, and seawater.

Finished Water: Treated drinking water that meets minimum state and federal drinking water regulations.

Flocculation: The process of bringing together destabilized or coagulated particles to form larger masses that can be settled and/or filtered out of the water being treated.

Floc Shearing: Likely to happen to large floc particles when they reach the flocculation process.

Flocculation Basin: A compartmentalized basin with a reduction of speed in each compartment. This set-up or basin will give the best overall results.

Flood Rim: The point of an object where the water would run over the edge of something and begin to cause a flood.

Flow must be Measured: A recorder that measures flow is most likely to be located in a central location.

Fluoride Feeding System: Always review fluoride feeding system designs and specifications to determine whether locations for monitoring readouts and dosage controls are convenient to the operation center and easy to read and correct.

Fluoride: High levels of fluoride may stain the teeth of humans. This is called Mottling. This chemical must not be overfed due to a possible exposure to a high concentration of the chemical. The most important safety considerations to know about fluoride chemicals is that all fluoride chemicals are extremely corrosive**.** These are the substances is most commonly used to furnish fluoride ions to water: Sodium fluoride, Sodium silicofluoride and Hydrofluosilicic acid.

Flux: The term flux describes the rate of water flow through a semipermeable membrane. The water flux decreases through a semipermeable membrane means that the mineral concentration of the water is increasing.

Formation of Tubercles: This condition is of the most concern regarding corrosive water effects on a water system. It is the creation of mounds of rust inside the water lines.

Free Chlorine Residual gives the best Disinfection: The reason for chlorinating past the breakpoint is to provide protection in case of backflow.

Free Chlorine Residual: Regardless of whether pre-chloration is practiced or not, a free chlorine residual of at least 10 mg/L should be maintained in the clear well or distribution reservoir immediately downstream from the point of post-chlorination.

Free Chlorine: In disinfection, chlorine is used in the form of free chlorine or as hypochlorite ion.

Frequency must a Remote Operator inspect a Grade 1 or grade 2 Water Treatment Plant: Monthly or as necessary a remote operator inspect a grade 1 or grade 2 water treatment plant or distribution system that produces and distributes groundwater.
Gate Valve: The most common type of valve used in isolating a small or medium sized section of a distribution system and is the only linear valve used in water distribution. All the other valves are in the rotary classification.
Giardia Lamblia: A pathogenic parasite, which may be found in, contaminated water.
Giardiasis, Hepatitis, or Typhoid: Diseases that may be transmitted through the contamination of a water supply but not AIDS.
GIS - Graphic Information System: Detailed information about the physical locations of structures such as pipes, valves, and manholes within geographic areas with the use of satellites.
Globe Valve: The main difference between a globe valve and a gate valve is that a globe valve is designed as a controlling device.
Good Contact Time, pH and Low Turbidity: These are factors that are important in providing good disinfection when using chlorine.
Grab Sample: A type of sample that should be collected to analyze for coliform bacteria, pH and Temperature. A snap shot of a certain location and time.
Gt : Represents (Detention time) x (mixing intensity) in flocculation.
H2SO4: The molecular formula of Sulfuric acid.
Hard Water: Hard water causes a buildup of scale in household hot water heaters.
Hazards of Polymers: Slippery and difficult to clean-up are the most common hazards associated with the use of polymers in a water treatment plant.
Head: The measure of the pressure of water expressed in feet of height of water. 1 PSI = 2.31 feet of water or 1 foot of head equals about a half a pound of pressure or .433 PSI. There are various types of heads of water depending upon what is being measured. Static (water at rest) and Residual (water at flow conditions).
Head Loss: A negative effect that a water meter has on a service.
Headworks: The facility at the "**head**" of the water source where water is first treated and routed into the distribution system.
Health Advisory: An EPA document that provides guidance and information on contaminants that can affect human health and that may occur in drinking water, but which the EPA does not currently regulate in drinking water.
Heat Damage to Air Compressor: An air compressor generates heat during the compression cycle. And is the most common type of damage caused by heat generated during operation.
Hertz: The term is used to describe the frequency of cycles in an alternating current (AC) circuit.
Heterotrophic Plate Count Bacteria: A broad group of bacteria including non-pathogens, pathogens, and opportunistic pathogens; they may be an indicator of poor general biological quality of drinking water. Often referred to as **HPC**.
HF: The molecular formula of Hydrofluoric acid.
High Turbidity Causing an Increased Chlorine Demand: May occur or be caused by the inadequate disinfection of water.
Hydrochloric and Hypochlorous Acids: The compounds that are formed in water when chlorine gas is introduced.
Hydrogen Sulfide or Chlorine: These chemicals can cause olfactory fatigue.
Hydrophobic: Does not mix readily with water.
Hypochlorite and Organic Material: Heat and a possible fire may happen when hypochlorite is brought into contact with an organic material.
Hypochlorous and Hydrochloric Acids: Chlorine combines with water to form hypochlorous and hydrochloric acids, HOCL and HCL or free available chlorine.
If a facility is re-graded to a higher grade, how long does the facility have to hire or train an operator with the applicable class and grade?: 12 months.
Impeller: A rotating set of vanes designed to impart rotation to a mass fluid.
Impervious: Not allowing, or allowing only with great difficulty, the movement of water.
Infectious Pathogens/Microbes/Germs: Considered disease-producing bacteria, viruses and other microorganisms.
Initial monitoring year: An initial monitoring year is the calendar year designated by the Department within a compliance period in which a public water system conducts initial monitoring at a point of entry.

Inorganic Contaminants: Mineral-based compounds such as metals, nitrates, and asbestos. These contaminants are naturally-occurring in some water, but can also get into water through farming, chemical manufacturing, and other human activities. The EPA has set legal limits on 15 inorganic contaminants.

Insoluble Compounds: Types of compounds cannot be dissolved. When iron or manganese reacts with dissolved oxygen (**DO**) insoluble compound are formed.

Intake Facilities: One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for cathodic protection.

Ion Exchange: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. The hardness of the source water affects the amount of water an ion exchange softener may treat before the bed requires regeneration.

Iron and Manganese: In water can be usually detected by observing the color of the inside walls of filters and the filter media. If the raw water is pre-chlorinated, there will be black stains on the walls below the water level and a black coating over the top portion of the sand filter bed. When significant levels of dissolved oxygen are present, iron and manganese exist in an oxidized state and normally precipitate into the reservoir bottom sediments. The presence of iron and manganese in water promote the growth of Iron bacteria. Only when a water sample has been acidified then you can perform the analysis beyond the 48 hour holding time. Iron and Manganese in water may be detected by observing the color of the of the filter media. Maintaining a free chlorine residual and regular flushing of water mains may control the growth of iron bacteria in a water distribution system.

Iron Bacteria: Perhaps the most troublesome consequence of iron and manganese in the water is they promote the growth of a group of microorganism known as Iron Bacteria.

Iron Fouling: You should look for an orange color on the resin and backwash water when checking an ion exchange unit for iron fouling.

Iron: The elements iron and manganese are undesirable in water because they cause stains and promote the growth of iron bacteria.

Kill=C x T: Where other factors are constant, the disinfecting action may be represented by: Kill=C x T.

Kinetic Energy: The ability of an object to do work by virtue of its motion. The energy terms that are used to describe the operation of a pump are pressure and head.

Langelier Index: A measurement of Corrosivity. The water is becoming corrosive in the distribution system causing rusty water if the Langelier index indicates that the pH has decreased from the equilibrium point. Mathematically derived factor obtained from the values of calcium hardness, total alkalinity, and pH at a given temperature. A Langelier index of zero indicates perfect water balance (i.e., neither corroding nor scaling).

Leaching: A chemical reaction between water and metals that allows for removal of soluble materials.

Lead and Copper: Initial tap water monitoring for lead and copper must be conducted during 2 consecutive 6-month periods.

Lime Soda Softening: In a lime soda softening process, the pH of the water is raised to 11.0. In a lime softening process, excess lime is frequently added to remove Calcium and Magnesium Bicarbonate. The minimum hardness which can be achieved by the lime-soda ash process is 30 to 40 mg/L as calcium carbonate. The hardness due to noncarbonate hardness is most likely to determine the choice between lime softening and ion exchange to remove hardness.

Lime: A chemical that may be added to water to reduce the corrosivity. When an operator adds lime to water, Calcium and magnesium become less soluble.

Lines: Lines in the distribution system should be flushed on a regular basis. The flushing should be done at night and the water pressure in the distribution system must be at least 25 PSI.

LOTO: In a good lock-out/tag out program, if a piece of equipment is locked out, the key to the lock-out device the key should be held by the person who is working on the equipment. The tag is an identification device and the lock is a physical restraint.

Magnesium Hardness: Measure of the magnesium salts dissolved in water – it is not a factor in water balance.

Magnetic Starter: A type of motor starter should be used in an integrated circuit to control flow automatically.

Marble and Langelier Tests: Used to measure or determine the corrosiveness of a water source.

Maximum Contaminant Level Goal (MCLG): The level of a contaminant at which there would be no risk to human health. This goal is not always economically or technologically feasible, and the goal is not legally enforceable.
Maximum Contaminant Levels (MCLs): The maximum allowable level of a contaminant that federal or state regulations allow in a public water system. If the MCL is exceeded, the water system must treat the water so that it meets the MCL.
MCL for Turbidity: Turbidity is undesirable because it causes health hazards. An MCL for turbidity was established by the EPA because turbidity does not allow for proper disinfection.
Measure Corrosion Damage: A coupon is a strip of metal and is placed to measure corrosion damage in the distribution system in a water main.
Mechanical Seal: A mechanical device used to control leakage from the stuffing box of a pump. Usually made of two flat surfaces, one of which rotates on the shaft. The two flat surfaces are of such tolerances as to prevent the passage of water between them. Held in place with spring pressure.
Medium Water System: More than 3,300 persons and 50,000 or fewer persons.
Megger: Used to test the insulation resistance on a motor.
M-Endo Broth: The media shall be brought to the boiling point when preparing M-Endo broth to be used in the membrane filter test for total coliform.
Methane: Classified as an organic compound.
mg/L: Milligrams per liter.
Microbe, Microbial: Any minute, simple, single-celled form of life, especially one that causes disease.
Microbial Contaminants: Microscopic organisms present in untreated water that can cause waterborne diseases.
Microbiological: A type of analysis in which a composite sample unacceptable.
mL: milliliter.
Moisture and Potassium Permanganate: The combination of moisture and potassium permanganate produces heat.
Moisture: If a material is hygroscopic it must it be protected from water.
Motor 3600 rpms: The maximum synchronous speed of an electric motor that has a frequency of 60 Hz.
Motor Overload Control: The overload control on a motor has tripped and the motor has stopped running. An operator waits for the overload to cool, then tries to start the motor again. If the motor does not start, the operator should first check the Motor overload control.
Motor: If a motor is rated for 10 amps the overload relays that should be used are 10 to 11 amps. A possible cause for a mechanical noise coming from a motor is there is an unbalance of a rotating mechanical part. And a possible result of over greasing a bearing is that there will be extreme friction in the bearing chamber.
Mottling: High levels of fluoride may stain the teeth of humans.
MSDS: A safety document must an employer provide to an operator upon request.
Mud Balls in Filter Media: A possible result of an ineffective or inadequate filter backwash.
Muriatic Acid: An acid used to reduce pH and alkalinity. Also used to remove stain and scale.
NaOCl: The molecular formula of Sodium hypochlorite.
NaOH: The molecular formula of Sodium hydroxide.
New Public Water System: Depending upon your state rule; Community water systems and non-transient non-community water systems that begin operations on or after October 1, 1999 must comply with Article 6, Capacity Development Requirements for a New Public Water System.
NH3: The molecular formula of Ammonia.
NH4+: The molecular formula of the Ammonium ion.
Nitrate and nitrite are prohibited: The Department will not grant a nitrate or nitrite waiver.
Nitrates: A dissolved form of nitrogen found in fertilizers and sewage by-products that may leach into groundwater and other water sources. Nitrates may also occur naturally in some waters. Over time, nitrates can accumulate in aquifers and contaminate groundwater.
Nitrogen and Phosphorus: Pairs of elements and major plant nutrients that cause algae to grow.
NO3-: The molecular formula of the Nitrate ion.
Non-Carbonate Hardness: The portion of the total hardness in excess of the alkalinity.
Noncarbonate Ions: Water contains Noncarbonate ions if it cannot be softened to a desired level through the use of lime only.

Non-point source pollution: Air pollution may leave contaminants on highway surfaces. This nonpoint source pollution adversely impacts reservoir water and groundwater quality.

Non-Transient, Non-Community Water System: A water system which supplies water to 25 or more of the same people at least six months per year in places other than their residences. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.

Normality: The number of equivalent weights of solute per liter of solution.

Notification and Safety of the Public: The most important concern to an owner/operator if a toxic substance contaminates a drinking water.

NTNCWS: Non-transient non-community water system.

NTU (nephelometric turbidity unit)**:** A measure of the clarity or cloudiness of water.

O^3: The molecular formula of ozone.

Oligotrophic: A reservoir that is nutrient-poor and contains little plant or animal life.

Organic Precursors: Natural or man-made compounds with chemical structures based upon carbon that, upon combination with chlorine, leading to trihalomethane formation.

Osmosis: The process by which water moves across a semi permeable membrane from a low concentration solute to a high concentration solute to satisfy the pressure differences caused by the solute.

Overrange Protection Devices: Mechanical dampers, snubbers and an air cushion chamber are examples of surging and overrange protection devices.

Oxidizing: The process of breaking down organic wastes into simpler elemental forms or by products. Also used to separate combined chlorine and convert it into free chlorine.

Oxygen Deficient Environment: Name one of the most dangerous threats to an operator upon entering a manhole.

Ozone does not provide a Residual in the Distribution System: One of the major drawbacks to using ozone as a disinfectant.

Ozone, Chlorine Dioxide or Chloramine O3, ClO2, or NH4Cl2: These chemicals may be used as alternative disinfectants.

PAC: A disadvantage of using PAC is it is very abrasive and requires careful maintenance of equipment. One precautions should be taken in storing PAC is that bags of carbon should not be stored near bags of HTH. Removes tastes and odors by adsorption only. Powered activated carbon frequently used for taste and odor control because PAC is non-specific and removes a broad range of compounds. Jar tests and threshold odor number testing determines the application rate for powdered activated carbon. Powdered activated carbon, or PAC, commonly used for in a water treatment plant for taste and odor control. Powdered activated carbon may be used with some success in removing the precursors of THMs.

Packing: Material, usually of woven fiber, placed in rings around the shaft of a pump and used to control the leakage from the stuffing box.

Pathogens: Disease-causing pathogens; waterborne pathogens A pathogen is a bacterium, virus or parasite that causes or is capable of causing disease. Pathogens may contaminate water and cause waterborne disease.

Pb: The chemical symbol of Lead.

pCi/L: Picocuries per liter. A curie is the amount of radiation released by a set amount of a certain compound. A picocurie is one quadrillionth of a curie.

Peak Demand: The maximum momentary load placed on a water treatment plant, pumping station or distribution system.

Permeate: The term for water which has passed through the membrane of a reverse osmosis unit.

pH of Saturation: The ideal pH for perfect water balance in relation to a particular total alkalinity level and a particular calcium hardness level, at a particular temperature. The pH where the Langelier Index equals zero.

pH (*Power of Hydroxyl Ion Activity*): A measure of the acidity of water. The pH scale runs from 0 to 14 with 7 being the mid point or neutral. A pH of less than 7 is on the acid side of the scale with 0 as the point of greatest acid activity. A pH of more than 7 is on the basic (alkaline) side of the scale with 14 as the point of greatest basic activity. Alkalinity and pH tell an operator with regards to coagulation how to determine the best chemical coagulant to be used. The definition of an acidic solution is a solution that contains a significant number of H+ ions. An operator should calibrate the instrument with a known buffer solution before using a pH meter. Rinse the electrodes with distilled water should be done with

the electrodes after measuring the pH of a sample with a pH meter. pH Temperature and Chlorine dosage are the factors that influence the effectiveness of chlorination the most.
Phenolphthalein /Total Alkalinity: The relationship between the alkalinity constituent's bicarbonate, carbonate, and hydroxide can be based on the P and T alkalinity measurement.
Phosphate, Nitrate, and Organic Nitrogen: Nutrients in a domestic water supply reservoir may cause water quality problems if they occur in moderate or large quantities.
Pipeline Appurtenance: Pressure reducers, bends, valves, regulators (which are a type of valve), etc.
Pneumatic systems are not reliable over transmission lines greater than 1000 feet: Is the primary characteristic which limits the use of a pneumatic data transmission system.
Point of Entry: POE.
Pollution: The duration of exposure to the contaminant affects the dose of a toxic contaminant in a water supply.
Pollution: To make something unclean or impure. See Contaminated.
Polyphosphates: Chemicals that may be added to remove low levels of iron and manganese.
Potable: Good water which is safe for drinking or cooking purposes. **Non-Potable:** A liquid or water that is not approved for drinking.
Potential Energy: The energy that a body has by virtue of its position or state enabling it to do work.
PPM: Abbreviation for parts per million.
Pre-chlorination: The addition of chlorine to the water prior to any other plant treatment processes.
Perikinesis: The aggregation resulting from random thermal motion of fluid molecules.
Pressure Head: The height to which liquid can be raised by a given pressure.
Pressure Measurement: Bourdon tube, Bellows gauge and Diaphragm are commonly used to measure pressure in waterworks systems.
Pressure: A Bellows-type sensor reacts to a change in pressure.
Prevention: To take action. Stop something before it happens.
Proton, Neutron, Electron: The 3 fundamental particles of an atom.
Public Notification: An advisory that EPA requires a water system to distribute to affected consumers when the system has violated MCLs or other regulations. The notice advises consumers what precautions, if any, they should take to protect their health.
Public Water System (PWS): Any water system which provides water to at least 25 people for at least 60 days annually. There are more than 170,000 PWSs providing water from wells, rivers and other sources to about 250 million Americans. The others drink water from private wells. There are differing standards for PWSs of different sizes and types.
Pump 5,000 to 20,000 hours: The typical operating life of a mechanical seal.
Pump Discharge Valve Off: A reciprocating pump or piston pump should not be operated.
Pump: A key and a tight fit is the common method used to secure an impeller to the shaft on double-suction pump. A mechanical seal is the best seal to use for a pump operating under high suction head conditions. A possible cause of a scored shaft sleeve is that the packing has broken down or the packing is too tight or over tightened. A reciprocating pump or piston pump should not be operated with the discharge valve in the closed position. An air compressor generates heat during the compression cycle. The most common type of damage caused by heat generated during operation: the lubricating oil tends to break down quickly requiring frequent replacement. Cavitation is caused by a suction line may be clogged or is above the water line. Centrifugal pumps do not generate suction unless the impeller is submerged in water. If a pump is located above the level of water a foot valve must be provided on the suction piping to hold the prime. Continuous leakage from a mechanical seal on a pump indicates that the mechanical seal needs to be replaced. One disadvantage of a centrifugal pump is that it is not self-priming. The main purpose of the wear rings in a centrifugal double suction pump is that the wear rings maintain a flow restriction between the impeller discharge and suction areas. The purpose of the foot valve on a pump is that it keeps the air relief opened. The viscosity decreases with most lubricants as the temperature increases. Two pumps of the same size can be operated alternately to equalize wear and distribute lubricant in bearings.
PWS: 3 types of public water systems. Community water system, non-transient non-community water system, transient non community water system.
Raw Water: Water that has not been treated in any way; it is generally considered to be unsafe to drink.
Recorder: A recorder that measures flow is most likely to be located anywhere in the plant where a flow must be measured and in a central location.

Reagent: A substance used in a chemical reaction to measure, detect, examine, or produce other substances.
Red Water and Slime: Iron bacteria are undesirable in a water distribution system because of red water and slime complaints.
Relay Logic: The name of a popular method of automatically controlling a pump, valve, chemical feeder, and other devices.
Reservoir: An impoundment used to store water.
Residual Disinfection/Protection: A required level of disinfectant that remains in treated water to ensure disinfection protection and prevent recontamination throughout the distribution system (i.e., pipes).
Rotameter: The name of transparent tube with a tapered bore containing a ball is often used to measure the rate of flow of a gas or liquid.
Rules: The objective of a vulnerability assessment is to determine weakness in the distribution or water system.
Runoff: Surface water sources such as a river or lake are primarily the result of natural processes of runoff.
Safe Yield: A possible consequence when the “safe yield” of a well is exceeded and water continues to be pumped from a well is land subsidence around the well will occur.
Safety: 2 Feet: The distance from the edge of a hole must you place the spoil from an excavation.
Safety Statements: A supervisor should warn an operator about the presence of a confined space by clearly posting the appropriate signage at all entries to a confined space. Before beginning an excavation, an “Underground Service Alert” center should be contacted to assist in determining the location of all underground utilities in the work area. Corrosive-This type of chemical classification may weaken, burn, or destroy a person’s skin or eyes and can be either acidic or basic. Ladders and climbing devices by inspected by a qualified individual once a year. The correct order for placing shorting equipment in a trench is starting at the top move to the bottom of the trench and reverse to remove it.
Salts are Absent: A strange characteristic that is unique to water vapor in the atmosphere.
Sample: The water that is analyzed for the presence of EPA-regulated drinking water contaminants. Depending on the regulation, the EPA requires water systems and states to take samples from source water, from water leaving the treatment facility, or from the taps of selected consumers.
Sand, Anthracite and Garnet: Mixed media filters are composed of these three materials.
Sanitary Survey: Persons trained in public health engineering and the epidemiology of waterborne diseases should conduct the sanitary survey. The importance of a detailed sanitary survey of a new water source can not be overemphasized. An on-site review of the water sources, facilities, equipment, operation, and maintenance of a public water systems for the purpose of evaluating the adequacy of the facilities for producing and distributing safe drinking water. The purpose of a non-regulatory sanitary survey is to identify possible biological and chemical pollutants which might affect a water supply.
Sanitizer: A disinfectant or chemical which disinfects (kills bacteria), kills algae and oxidizes organic matter.
Saturation Index: See Langelier's Index.
Saturator: A device which produces a fluoride solution for the fluoride process. Crystal-grade types of sodium fluoride should be fed with a saturator. Overfeeding must be prevented to protect public health when using a fluoridation system.
SCADA: A remote method of monitoring pumps and equipment. 130 degrees F is the maximum temperature that transmitting equipment is able to with stand. If the level controller may be set with too close a tolerance 45 could be the cause of a control system that is frequently turning a pump on and off.
Scale: Crust of calcium carbonate, the result of unbalanced water. Hard insoluble minerals deposited (usually calcium bicarbonate) which forms on pool and spa surfaces and clog filters, heaters and pumps. Scale is caused by high calcium hardness and/or high pH. The regular use of stain prevention chemicals can prevent scale.
Scroll and Basket: The two basic types of centrifuges used in water treatment.
Secondary Drinking Water Standards: Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.
Sectional Map: The name of a map that provides detailed drawings of the distribution system’s zones. Some times we call these quarter-sections.

Sedimentation Basin: This location is where the thickest and greatest concentration of sludge will be found. Twice a year sedimentation tanks should be drained and cleaned if the sludge buildup interferes with the treatment process.

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

Sensor: A float and cable system are commonly found instruments that may be used as a sensor to control the level of liquid in a tank or basin.

Shock: Also known as superchlorination or break point chlorination. Ridding a water of organic waste through oxidization by the addition of significant quantities of a halogen.

Shroud: The front and/or back of an impeller.

Single Phase Power: The type of power is used for lighting systems, small motors, appliances, portable power tools and in homes.

Sludge Basins: After cleaning sludge basins and before returning the tanks into service the tanks should be inspected, repaired if necessary, and disinfected.

Sludge Reduction: Organic polymers are used to reduce the quantity of sludge. If a plant produces a large volume of sludge, the sludge could be dewatered, thickened, or conditioned to decrease the volume of sludge. Turbidity of source water, dosage, and type of coagulant used are the most important factors which determine the amount of sludge produced in a treatment of water.

Small Water System: 3,300 or fewer persons.

SOC: A common way for a synthetic organic chemical such as dioxin to be introduced to a surface water supply is from an industrial discharge, agricultural drainage, or a spill.

Soda Ash: Chemical used to raise pH and total alkalinity (sodium carbonate). Chemical often used to soften water.

Sodium Bicarbonate: Commonly used to increase alkalinity of water and stabilize pH.

Sodium Bisulfate: Chemical used to lower pH and total alkalinity (dry acid).

Sodium Hydroxide: Also known as caustic soda, a by-product chlorine generation and often used to raise pH.

Softening Water: When the water has a low alkalinity it is advantageous to use soda ash instead of caustic soda for softening water.

Softening: The process that removes the ions which cause hardness in water.

Solar Drying Beds or Lagoons: Shallow, small-volume storage pond where sludge is concentrated and stored for extended periods.

Solar Drying Beds, Centrifuges and Filter Presses: Procedures used in the dewatering of sludge.

Solid, Liquid, Vapor: 3 forms of matter.

SPADNS: The lab reagent called SPADNS solution is used in performing the Fluoride test.

Split Flow Control System: This type of control system is to control the flow to each filter influent which is divided by a weir.

Spray Bottle of Ammonia: An operator should use ammonia to test for a chlorine leak around a valve or pipe. You will see white smoke if there is a leak.

Spring Pressure: What maintains contact between the two surfaces of a mechanical seal.

Standpipe: A water tank that is taller than it is wide. Should not be found in low point.

Stationing: The word stationing on a plan drawing refers to a representation of a location from a starting point or reference. A stoneline or benchmark.

Sterilized Glassware: The only type of glassware that should be used in testing for coliform bacteria.

Storage Tanks: Three types of water usage that determine the volume of a storage tank are fire suppression storage, equalization storage, and emergency storage. Equalization storage is the volume of water needed to supply the system for periods when demand exceeds supply. Generally, a water storage tank's interior coating (paint) protect the interior about 3-5 years.

Stuffing Box: That portion of the pump that houses the packing or mechanical seal.

Sulfate: Will readily dissolve in water to form an anion.

Sum of all the Atomic Weights of the Elements in a Molecule: Is the molecular weight of a compound.

Supernatant: The liquid layer which forms above the sludge in a settling basin.

Surface Water Sources: Surface water sources such as a river or lake are primarily the result of Runoff.

Surface Water: Water that is open to the atmosphere and subject to surface runoff; generally, lakes, streams, rivers.

Susceptibility Waiver: A waiver that is granted based upon the results of a vulnerability assessment.

Tapping Valve: The name of the valve that is specifically designed for connecting a new water main to an existing main that is under pressure.

Taste and Odor Problems in the Water: May happen if sludge and other debris are allowed to accumulate in a water treatment plant.

Taste and Odors: The primary purpose to use potassium permanganate in water treatment is to control taste and odors. Anaerobic water undesirable for drinking water purposes because of color and odor problems are more likely to occur under these conditions.

TCE, *trichloroethylene*: A solvent and degreaser used for many purposes; for example dry cleaning, it is a common groundwater contaminant.

TDS-Total Dissolved Solids: An expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular (colloidal sol) suspended form. Generally the operational definition is that the solids (often abbreviated TDS) must be small enough to survive filtration through a sieve size of two micrometers. Total dissolved solids are normally only discussed for freshwater systems, since salinity comprises some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes, although TDS is generally considered not as a primary pollutant (e.g. it is not deemed to be associated with health effects), but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants.

TDS: Ion exchange is an effective treatment process used to remove iron and manganese in a water supply. This process is ideal as long as the water does not contain a large amount of TDS. When determining the total dissolved solids, a sample should be filtered before being poured into an evaporating dish and dried. Demineralization may be necessary in a treatment process if the water has a very high value Total Dissolved Solids.

Telemetering: The use of a transmission line with remote signaling to monitor a pumping station or motors. Can be used to accomplish accurate and reliable remote monitoring and control over a long distribution system.

Temperature: This test should be performed immediately in the field, a grab sample.

The rate decreases: In general, when the temperature decreases, the chemical reaction rate decreases also.

Thickening, Conditioning, and Dewatering: Common processes that are utilized to reduce the volume of sludge.

Three-phase Motor: The incoming leads for a three-phase motor all have power. Large three-phase motors employs the use of a magnetic starter.

Time for Turbidity Breakthrough and Maximum Head Loss: The two factors which determine whether or not a change in filter media size should be made.

Titration: Method of testing by adding a reagent of known strength to a water sample until a specific color change indicates the completion of the reaction.

Titration: The common method of standardization of a solution determination in the lab.

Total Alkalinity: A measure of the acid-neutralizing capacity of water that indicates its buffering ability, i.e. measure of its resistance to a change in pH. Generally, the higher the total alkalinity, the greater the resistance to pH change.

Total Dissolved Solids (**TDS**)**:** The accumulated total of all solids that might be dissolved in water. See TDS.

Toxic substance contaminates a drinking water: Public Safety is the most important concern should an owner/operator allow a toxic substance to contaminate a drinking water.

Transient, Non-Community Water System: A water system which provides water in a place such as a gas station or campground where people do not remain for long periods of time. These systems do not have to test or treat their water for contaminants which pose long-term health risks because fewer than 25 people drink the water over a long period. They still must test their water for microbes and several chemicals, but are not required to sample for VOC's.

Treated Water: Disinfected and/or filtered water served to water system customers. It must meet or surpass all drinking water standards to be considered safe to drink.

Trihalomethanes (THM): Four separate compounds including chloroform, dichlorobromom-ethane, dibromochloromethane, and bromoform. The most common class of disinfection by-products created when chemical disinfectants react with organic matter in water during the disinfection process. *See Disinfectant Byproducts.*

Tubercles: The creation of this condition is of the most concern regarding corrosive water effects on a water system. Tubercles are formed due to joining dissimilar metals, causing electro-chemical reactions. Like iron to copper pipe. We have all seen these little rust mounds inside cast iron pipe.

Turbidimeter: Monitoring the filter effluent turbidity on a continuous basis with an in-line instrument is a recommended practice. Turbidimeter is best suited to perform this measurement.

Turbidity Interferes with Disinfection: The primary reason turbidity of water be minimized.

Turbidity: One physical characteristic of water. 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. An MCL for turbidity has been 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

U.S. Environmental Protection Agency: In the United States, this agency responsible for setting drinking water standards and for ensuring their enforcement. This agency sets federal regulations which all state and local agencies must enforce.

Under Pressure in Steel Containers: After chlorine gas is manufactured, it is primarily transported in steel containers.

Unit Filter Run Volume (UFRV): One of the most popular ways to compare filter runs. This technique is the best way to compare water treatment filter runs.

Valve 20 or 30 Feet Per Inch: The typical scale of a Valve and Hydrant map using an intersection method of indexing.

Valves: A gate valve should be operated in any position between fully open and fully closed.

Vane: That portion of an impeller that throws the water toward the volute.

Velocity Head: The vertical distance a liquid must fall to acquire the velocity with which it flows through the piping system. For a given quantity of flow, the velocity head will vary indirectly as the pipe diameter varies.

Venturi: If water flows through a pipeline at a high velocity, the pressure in the pipeline is reduced. Velocities can be increased to a point that a partial vacuum is created.

Volatile Organic Chemical: VOC.

Voltage: 1,000 volts is the maximum number of volts that electrical equipment can be insulated with a lower limit of 1 megaohm.

Volute: The spiral-shaped casing surrounding a pump impeller that collects the liquid discharge by the impeller.

Vulnerability Assessment: An evaluation of drinking water source quality and its vulnerability to contamination by pathogens and toxic chemicals.

Waivers: Monitoring waivers for nitrate and nitrite are prohibited.

Water Hammer: A surge in a pipeline resulting from the rapid increase or decrease in water flow. Water hammer exerts tremendous force on a system and can be highly destructive.

Water Level: The probe may be coated by calcium carbonate is a common problem with an electrical probe that is used to measure the level of water.

Water Meter: A water meter that is removed from service for repair should be handled by sealing the meter to retain water.

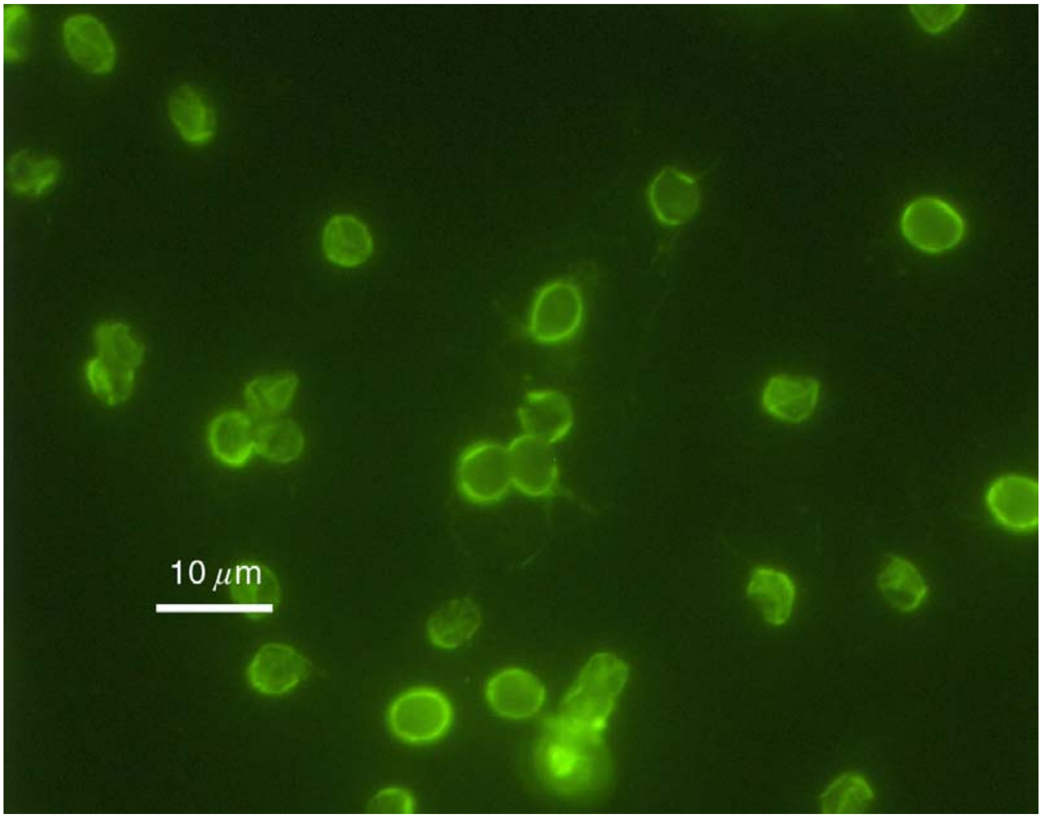
Water Meter: Head loss may occur with the use of a water meter. The three main classifications of water meters. Compound, Displacement, Velocity. Peak day demand is the greatest amount of water used for any one day in a calendar year.

Water Purveyor: The individual or organization responsible to help provide, supply, and furnish quality water to a community.

Water Quality: The 4 broad categories of water quality are: Physical, chemical, biological, radiological. Pathogens are disease causing organisms such as bacteria and viruses. A positive bacteriological sample indicates the presence of bacteriological contamination. Source water monitoring for lead and copper be preformed when a public water system exceeds an action level for lead of copper.

Water Vapor: A characteristic unique to water vapor in the atmosphere is that it does not contain salts.

Waterborne Disease: A disease, caused by a virus, bacterium, protozoan, or other microorganism, capable of being transmitted by water (e.g., typhoid fever, cholera, amoebic dysentery, gastroenteritis).
Watershed: An area that drains all of its water to a particular water course or body of water. The land area from which water drains into a stream, river, or reservoir.



Cryptosporidium

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Math Conversion Factors and Practical Exercise

If you are poor at math, come to a TLC review class.

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

LENGTH
12 Inches = 1 Foot
3 Feet = 1 Yard
5280 Feet = 1 Mile

AREA
144 Square Inches = 1 Square Foot
43,560 Square Feet = 1 Acre

VOLUME
1000 Milliliters = 1 Liter
3.785 Liters = 1 Gallon
231 Cubic Inches = 1 Gallon
7.48 Gallons = 1 Cubic Foot of Water
62.38 Pounds = 1 Cubic Foot of Water

Dimensions

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

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

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

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

SPHERE:

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

Circumference = 3.14 X Diameter

General Conversions

Flowrate

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

POUNDS PER DAY= Concentration (mg/L) X Flow (MG) X 8.34
AKA* Solids Applied Formula** = Flow X Dose X 8.34 ***Professor Jeff's Favorite Math Formula Please memorize.

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

TEMPERATURE: $^{0}F = (^{0}C \times 9/5) + 32$ $9/5 = 1.8$
$^{0}C = (^{0}F - 32) \times 5/9$ $5/9 = .555$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

POPULATION EQUIVALENT (PE):

1 PE = .17 Pounds of BOD per Day
1 PE = .20 Pounds of Solids per Day
1 PE = 100 Gallons per Day

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

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

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

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

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

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

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

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

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

If you are poor at math, don't be embarrassed come to a review class.

This section will present basic and complex math principals and formulas for water and wastewater system operators to include: area, volume, temperature conversions, flow rates, pressure, pounds and % efficiency. The objective for this class is to prepare the student to properly calculate complex mathematical formulas for: detention time, hydraulic loading rates, organic loading rates, horsepower, weir loading rates & treatment efficiency.

Proper calculation of concentration is contingent upon accurate determination of the volume of water to be treated. If you are uncertain as to the volume of water to be treated then take the time to measure the size of the tank or channel so that volume can be accurately determined. Ideally, all chemical treatments should be carried out in a special treatment or quarantine tank, but this is not always practical.

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Volume in Cubic Feet

Cube Formula
V= (L) (W) (D)
Volume= Length X Width X Depth

Cylinder Formula
V= (.785) (D^2) (d)

Build it, Fill it and Dose it.

1. Convert 10 cubic feet to gallons of water.

There are 7.48 gallons in one cubic foot.

2. A tank weighs 800 pounds, how many gallons are in the tank?

3. Convert a flow rate of 953 gallons per minute to million gallons per day.
There are 1440 minutes in a day.

4. Convert a flow rate of 610 gallons per minute to million of gallons per day.

5. Convert a flow of 550 gallons per minute to gallons per second.

6. Now, convert this number to liters per second.

7. A tank is 6’ X 15’ x 7’ and can hold a maximum of ____________ gallons of water.
V= (L) (W) (D) X 7.48 =

8. A tank is 25’ X 75’ X 10’. What is the volume of water in gallons?
V= (L) (W) (D) X 7.48 =

9. In Liters?
V= (L) (W) (D) X 7.48 =_________ X 3.785

10. A tank holds 67,320 gallons of water. The length is 60' and the width is 15'. How deep is the tank?

Gallons______ ÷ 7.48 = _______ 60 X 15 =

11. The diameter of a tank is 60' and the depth is 25'. How many gallons does it hold?

Cylinder Formula
V= (.785) (D^2) (d)

.785 X 60' X 60' X 25' X 7.48 =

Cubic Feet Information
There is no universally agreed symbol but the following are used:
cubic feet, cubic foot, cubic ft
cu ft, cu feet, cu foot
ft^3, $feet^3$, $foot^3$
$feet^3$, $foot^3$, ft^3
feet/-3, foot/-3, ft/-3

Water Treatment Production Math Numbering System
In water treatment, we express our production numbers in Million Gallon numbers. Example 2,000,000 or 2 million gallons would be expressed as 2 MG or 2 MGD.
Hints. A million has six zeros, you can always divide your final number by 1,000,000 or move the decimal point to the left six places. Example 528,462 would be expressed .56 MGD.

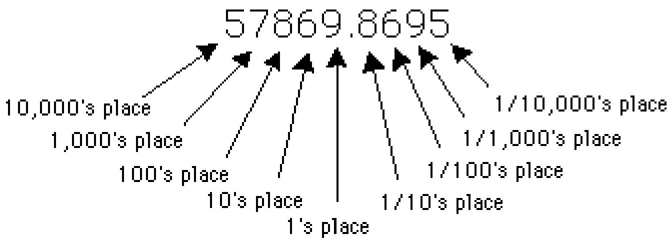
12. The diameter of a tank is 15 Centimeters or cm and the depth is 25 cm, what is the volume in liters?

2.54cm = 1 inch, 12 inches = 1 foot
15 cm ÷ 2.54 cm ÷ 12 inches = .492 feet

.785 X .492' X .492' X _____' =______ X 7.48 = _______ X 3.785 L =

Percentage and Fractions
Let's look again at the sequence of numbers 1000, 100, 10, 1, and continue the pattern to get new terms by dividing previous terms by 10:

.1 = 1/10
.01 = 1/100
.001 = 1/1000



So just as the digits to the left of the decimal represent 1's, 10's, 100's, and so forth, digits to the right of the decimal point represent 1/10's, 1/100's, 1/1000's, and so forth.

Let’s express 5% as a decimal. 5 ÷ 100 = 0.05 or you can move the decimal point to the left two places.

Changing a fraction to a decimal:

Divide the numerator by the denominator

A. 5/10 (five tenths) = five divided by ten:

```
     .5
    -----
10 ) 5.0
     5 0
    ----
```

So 5/10 (five tenths) = .5 (five tenths).

B. How about 1/2 (one half) or 1 divided by 2 ?

```
    .5
   -----
2 ) 1.0
    1 0
    ----
```

So 1/2 (one half) = .5 (five tenths)

Notice that equivalent fractions convert to the same decimal representation.

8/12 is a good example. 8 ÷ 12 =.66666666 or rounded off to .667

How about 6/12 or 6 inches? .5 or half a foot

Flow and Velocity

This depends on measuring the average velocity of flow and the cross-sectional area of the channel and calculating the flow from:

$Q(m^3/s) = A(m^2) \text{ X } V(m/s)$

Or

Q = A X V

Q CFM = Cubic Ft, Inches, Yards of time, Sec, Min, Hrs, Days

A = Area, squared Length X Width

V f/m = Inch, Ft, Yards, Per Time, Sec, Min, Ft or Speed

13. A channel is 3 feet wide and has water flowing to a depth of 2.5 feet. If the velocity through the channel is 2 fps or feet per second, what is the cfs flow rate through the channel? **Q = A X V**

Q = 7.5 sq. ft. X 2 fps What is Q?
A= 3' X 2.5' = 7.5
V= 2 fps

14. A channel is 40 inches wide and has water flowing to a depth of 1.5 ft. If the velocity of the water is 2.3 fps, what is the cfs flow in the channel? **Q = A X V**
First we must convert 40 inches to feet.
40 ÷ 12" = 3.333 feet

A = 3.333' X 1.5' = 4.999 or round up to 5
V = 2.3 fps
We can round this answer up.

15. A channel is 3 feet wide and has a water flow at a velocity of 1.5 fps. If the flow through the channel is 8.1 cfs, what is the depth of the water?

Q = 8.1 cfs
V = 1.5 fps
A = ?

8.1 ÷1.5 = _______ Total Area

16. The flow through a 6 inch diameter pipe is moving at a velocity of 3 ft/sec. What is the cfs flow rate through the pipeline?

Q =
A = .785 X .5' X .5' =
V = 3 fps

17. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the gpm flow rate through the pipe?

Q = ______ cfs X 60 sec/min X 7.48 = ___________ gpm
A = .785 X .667' X .667'
V = 3.4 fps

18. A 6 inch diameter pipe delivers 280 gpm. What is the velocity of flow in the pipe in ft/sec?

Take the water out of the pipe. 280 gpm ÷ 7.48 ÷ 60 sec/min = ________ cfs
Q =
A = .785 X .5' X .5' =
V =

19. A new section of 12 inch diameter pipe is to be disinfected before it is placed in service. If the length is 2000 feet, how many gallons of 5% NaOCl will be need for a dosage of 200 mg/L?

Cylinder Formula
V= (.785) (D^2) (d)

.785 X 1' X 1' X 2000' = _______ cuft X 7.48 = ______ ÷ 1,000,000 = ___________MG

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal if 100% concentrate. If not, divide the lbs/day by the given %

0.0117436 MG X 200 mg/L X 8.34 =_________ lbs/day ÷ .05 =

20. A section of 6 inch diameter pipe is to be filled with water. The length of the pipe is 1320 feet long. How many kilograms of chlorine will be needed for a chlorine dose of 3 mg/L?

.785 X .5' X .5' X 1320' X 7.48 =_____________ Make it MGD

Pounds per day formula = Flow X Dose X 8.34 X 45.4 Grams per pound

21. Determine the chlorinator setting in pounds per 24 hour period to treat a flow of 3.4 MGD with a chlorine dose of 3.35 mg/L?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

22. To correct an odor problem, you use chlorine continuously at a dosage of 15 mg/L and a flow rate of 85 GPM. Approximately how much will odor control cost annually if chlorine is $0.17 per pound?

85 gpm X 1440 min/day = _____________ gpd ÷ 1,000,000 = __________ MGD

______ MGD X 15 mg/L X 8.34 lbs/gal X $0.17 per pound X 365 days/year =

23. A wet well measures 8 feet by 10 feet and 3 feet in depth between the high and low levels. A pump empties the wet well between the high and low levels 9 times per hour, 24 hours a day. Neglecting inflow during the pumping cycle, calculate the flow into the pump station in million of gallons per day (MGD).

Build it, fill it and do what it says, hint: X 9 X 24

24. A sewage treatment plant has a flow of 0.7 MGD and a BOD of 225 mg/L. On the basis of a national average of 0.2 lbs BOD per capita per day, what is the approximate population equivalent of the plant?

25. What is the detention time of a clarifier with a 250,000 gallon capacity if it receives a flow of 3.0 MGD.

DT= Volume in Gallons X 24 Divided by MGD

.25 MG X 24 hrs ÷ 3.0 MGD =________ Hours of DT

Always convert gallons to MG

Crazy Math Section

The metric system is known for its simplicity. All units of measurement in the metric system are based on decimals—that is, units that increase or decrease by multiples of ten. A series of Greek decimal prefixes is used to express units of ten or greater; a similar series of Latin decimal prefixes is used to express fractions. For example, *deca* equals ten, *hecto* equals one hundred, *kilo* equals one thousand, *mega* equals one million, *giga* equals one billion, and *tera* equals one trillion. For units below one, *deci* equals one-tenth, *centi* equals one-hundredth, *milli* equals one-thousandth, *micro* equals one-millionth, *nano* equals one-billionth, and *pico* equals one-trillionth.

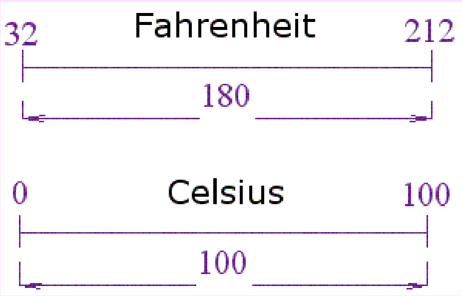
26. How many grams equal 4,500 mg?

Just simply divide by 1,000.

Temperature

There are two main temperature scales. The **Fahrenheit Scale** (used in the US), and the **Celsius Scale** (part of the Metric System, used in most other Countries)
They both measure the same thing (temperature!), just using different numbers.

- If you freeze water, it measures 0° in Celsius, but 32° in Fahrenheit
- If you boil water, it measures 100° in Celsius, but 212° in Fahrenheit
- The difference between freezing and boiling is 100° in Celsius, but 180° in Fahrenheit.

Freezing	... to ...	Boiling
		

Conversion Method
Looking at the diagram, notice:

- The scales start at a different number (32 vs 0), so we will need to add or subtract 32
- The scales rise at a different rate (180 vs 100), so we will also need to multiply

And this is how it works out:

To convert from Celsius to Fahrenheit, first multiply by 180/100, then add 32

To convert from Fahrenheit to Celsius, first subtract 32, then multiply by 100/180

Note: 180/100 can be simplified to **9/5**, and likewise 100/180=**5/9**.
^{0}F = (^{0}C X 9/5) + 32 9/5 =1.8

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

27. Convert 20 degrees Celsius to degrees Fahrenheit.

20 ° X 1.8 + 32 = F

28. Convert 4 degrees Celsius to degrees Fahrenheit.

4° X 1.8 + 32 = F

Water Treatment Filters

29. A 19 foot wide by 31 foot long rapid sand filter treats a flow of 2,050 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

GPM ÷ Square Feet

30. A 26 foot wide by 36 foot wide long rapid sand filter treats a flow of 2,500 gallons per minute. Calculate the filtration rate in gallons per minute per square foot of filter area.

Chemical Dose

31. A pond has a surface area of 51,500 square feet and the desired dose of a chemical is 6.5 lbs per acre. How many pounds of the chemical will be needed?

43,560 Square feet in an acre

51,500 ÷ 43,560 = _______ X 6.5 =

32. A pond having a volume of 6.85 acre feet equals how many millions of gallons?

33. Alum is added in a treatment plant process at a concentration of 10.5 mg/L. What should the setting on the feeder be in pounds per day if the plant is treating 3.5 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

Q=AV Review

34. An 8 inch diameter pipe has water flowing at a velocity of 3.4 fps. What is the GPM flow rate through the pipe?
Q = 1.18 CFS x 60 Seconds x 7.48 GAL/CU.FT = 532 GPM
A = .785 X .667 X .667 X 1 = .349 Sq. Ft.
V= 3.4 Feet per second

35. An 6 inch diameter pipe delivers 280 GPM. What is the velocity of flow in the pipe in Ft/Sec?
280 GPM ÷ 60 seconds in a minute ÷ 7.48 gallons in a cu.ft. = .623 CFS

Q = .623
A = .785 X.5 X .5 =.196 Sq. Ft.
V = 3.17 Ft/Second

Collections

36. A 24-inch sewer carries an average daily flow of 5 MGD. If the average daily flow per person from the area served is 110 GPCD (gallons per capita per day), approximately how many people discharge into the wastewater collection system?

5,000,000 divided by 110 =

37. Using a dose rate of 5 mg/L, how many pounds of chlorine per day should be used if the flow rate is 1.2 MGD?

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

38. What capacity blower will be required to ventilate a manhole which is 3.5 feet in diameter and 17 feet deep? The air exchange rate is 16 air changes per hour.
.785 X 3.5' X 3.5' X 17' X 16 = ____________ CFH

39. Approximately how many feet of drop are in 455 feet of 8-inch sewer with a 0.0475 ft/ft. slope?

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

455' X 0.0475 =

40. How much brake horsepower is required to meet the following conditions: 250 gpm, total head = 110 feet. The submersible pump that is being specified is a combined 64% efficient?

(250 X 110) ÷ (3960 X .64)

41. How wide is a trench at ground surface if a sewer trench is 2 feet wide at the bottom, 10 feet deep and the sides have been sloped at a 4/5 horizontal to 1 vertical (3/4:1) ratio?

(3/4:1) or 3 ÷ 4 = .75 X every foot of depth

42. A float arrives in a manhole 550 feet down stream three minutes and thirty seconds from its release point. What is the velocity in ft/sec.?
Velocity ft/sec = distance ÷ time

550’ ÷ 3 **min stop convert min to sec. 3 X 60 = 180 + 30 = 210 sec**
550’ ÷ 210 sec = ______ fps

43. A new sewer line plan calls out a 0.6% slope of the line. An elevation reading of 108.8 feet at the manhole discharge and an elevation of 106.2 feet at a distance of 200 feet from the manhole are recorded. What is the existing slope of the line that has been installed?

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

44. A triangular pile of spoil is 12 feet high and 14 feet wide at the base. The pile is 75' long. If the dump truck hauls 9 cubic yards of dirt, how many truck loads will it take to remove all of the spoil?

Given the base and the height of a triangle, we can find the area. Given the area and either the base or the height of a triangle, we can find the other dimension. The formula for area of a triangle is:

$A = \frac{1}{2} \cdot b \cdot h$ Or $A = \frac{b \cdot h}{2}$ where b is the base, h is the height.

14’ X 12’ ÷ 2 X 75’ = _________ cuft (27cuft/cuyrd)

45. A red dye is poured into an upstream manhole connected to a 12 inch sewer. The dye first appears in a manhole 400 feet downstream 3 minutes later. After 3 minutes and 40 seconds the dye disappears. Estimate the flow velocity in feet per second?
Velocity ft/sec = distance ÷ time
Make sure and convert time and average it.

46. Calculate the total dosage in pounds of a chemical. Assume the sewer is completely filled with the concentration. Pipe diameter: 18 inches, Pipe length: 420 feet, Dose: 120 mg/L.

Figure out the volume first.

.785 X 1.5' X 1.5' X 420' X 7.48 =___________ convert to MG

Pounds per day formula = Flow (MGD) X Dose (mg/L) X 8.34 lbs/gal

Answers

1. 7.48 X 10 = 74.8
2. 800 ÷ 8.34 = 95.92 gallons
3. 1372320 or 1.3 MGD
4. 610 X 1441 = 878400 or 0.87 MGD
5. 550 ÷ 60 = 9.167 gpm
6. 9.167 X 3.785 = 34.695 Liters
7. 630 Area 4712 gallons
8. 18,750 cu. ft. X 7.48 = 140250 gallons
9. 140250 X 3.785 = 530846 Liters
10. 10 feet deep
11. 528462 or .5 MG
12. 1.166 Gallons X 3.785 = 4.412 Liters
13. 15 cfs
14. 11.49 cfs
15. 1.8'
16. .58875 cfs
17. 533 gpm
18. 3.2 ft/sec
19. 46.9 gal
20. .002 kg
21. 94.9 lbs/day
22. $950.12
23. .387 MG
24. 6567.75
25. 2 hrs
26. 4.5 grams
27. 68° F
28. 39°F
29. 3.48 gpm/sqft
30. 2.67 gpm/sqft
31. 7.68 lbs
32. 2.231 MG
33. 306.495
34. 532 gpm
35. 3.2 fps
36. 45454.5 people
37. 50.04 lbs
38. 2615.6 cfh
39. 21.61 ft
40. 10.85 bhp
41. 17 ft
42. 2.62 fps
43. .013 or 1.3%
44. 26 trucks
45. 2 fps
46. 5.55 lbs

Teaching Math In 1960

A logger sells a truckload of lumber for $100. His cost of production is 4/5 of the price. What is his profit?

Teaching Math In 1970

A logger sells a truckload of lumber for $100. His cost of production is 4/5 of the price, or $80. What is his profit?

Teaching Math In 1980

A logger sells a truckload of lumber for $100. His cost of production is $80. Did he make a profit?

Teaching Math In 1990

A logger sells a truckload of lumber for $100. His cost of production is $80 and his profit is $20. Your assignment: Underline the number 20.

Teaching Math In 2000

A logger cuts down a beautiful forest because he is selfish and inconsiderate and cares nothing for the habitat of animals or the preservation of our woodlands. He does this so he can make a profit of $20. What do you think of this way of making a living? Topic for class participation after answering the question: How did the birds and squirrels feel as the logger cut down their homes? (There are no wrong answers.)

Water Distribution Review Section. *This is not your assignment.*

The answers to this section are in the rear of this section. This is an excellent study tool for an Operator Certification Exam or a finial review for the assignment.

1. In general, any ___________pump can be designed with a multistage configuration. Each stage requires an additional __________ and casing chamber in order to develop increased pressure, which adds to the pressure developed by the preceding stage. Two part question.
A. Submersible, Diffuser
B. Centrifugal, Impeller
C. Displacement, Volute
D. Centrifugal, Foot valve
E. None of the above

2. The axial-flow pump is often referred to as a ________________.
A. Propeller Pump
B. Submersible Pump
C. Hydraulic pump
D. None of the above

3. In all centrifugal pumps, there must be a flow restriction between the __________ discharge and _____________ areas that will prevent excessive circulation of water between the two parts.
A. Wear ring & Foot valve
B. Impeller & Suction
C. Lantern Ring & Shaft Sleeve
D. Packing rings & Shaft

4. This type of valve is designed to 1) Prevent overflows from the storage tank or reservoir, or 2) Maintain a constant water level as long as water pressure in the distribution system is adequate.
A. Double Check
B. PVB
C. Air Relief
D. Ball
E. Altitude-Control Valve

5. When a pump operates under suction, the impeller inlet is actually operating in a vacuum. Air will enter the water stream along the shaft if the packing does not provide an effective seal. It may be impossible to tighten the packing sufficiently to prevent air from entering without causing excessive heat and wear on the packing and shaft or shaft sleeve. To solve this problem, a _______ is placed in the Stuffing Box.
A. Lantern Ring
B. Packing Gland
C. Sanitary seal
D. Wye
E. None of the above

6. If the pump must operate under high suction head, the suction pressure itself will compress the packing rings regardless of the operator's care. Packing will then require frequent replacement. Most manufacturers recommend using ______________ for low-suction head conditions as well.
A. Mechanical Seals
B. Graphite
C. Vibration devices
D. Flow controls
E. All of the above

7. The mechanical seal is designed so that it can be hydraulically balanced. The result is that the wearing force between the machined surfaces does not vary regardless of the suction head. Most seals have an operating life of _____________.

A. 5,000 to 20,000 hours
B. 50,000
C. 75,000
D. 1 million hours

8. The speed at which the magnetic field rotates is called the motor's synchronous speed. It is expressed in revolutions per minute. For a motor that operates on an electric power system having a frequency of 60Hz, the maximum synchronous speed is 3,600 rpm, or 60 revolutions per second. In other words, because the electric current changes its flow direction 60 times a second, the rotor can rotate 60 times per second. This speed is achieved by:

A. The Starting Current
B. Squirrel cage
C. A two-pole motor
D. A three phase stator
E. All of the above

9. ____________ is a condition in which the pressure in the distribution system is less than atmospheric pressure. In other words, something is "sucked" into the system because the main is under a vacuum.

A. Backsiphonage
B. Backpressure

10. Float mechanisms, diaphragm elements, bubbler tubes, and direct electronic sensors are:

A. Types of valves
B. Methods of telemetry
C. Common types of level sensors
D. Out dated methods of measuring flows
E. All of the above

11. Which of the following is a correct statement concerning a single phase motor?

A. If it is a split-phase motor, the motor will not have windings.
B. A repulsion-induction motor is very simple and less expensive than other single phase motors.
C. Will have a capacitor start motor has a high starting torque and a high starting current.
D. All of the above
E. None of the above

12. A chlorine demand test from a well water sample produces a result of 1.2 mg/L. The water supplier would like to maintain a chlorine residual of 0.2 mg/L throughout the system. What should be the chlorine dose in mg/L from either a chlorinator or a hypochlorinator?

A. 1.2
B. 0.2
C. 1.0
D. 1.4

13. The vacuum created by a chlorine ejector moves through this device. This device prevents water from back feeding or entering the vacuum-regulator portion of the chlorinator.

A. Rate valve
B. The ejector
C. Interconnection manifold
D. Check valve assembly
E. Rotameter

14. Uniforms and proper credentials aid meter readers and operators that work close to private property because they help:
A. Readily identify personnel
B. Cash pay checks
C. Alter behavior
D. All of the above

15. Which of the following is responsible for the enforcement of building regulations?
A. The Crew Leader
B. The Building Inspector
C. The Supervisor
D. Depends if anyone is around

16. A water storage facility should be able to provide water for the ____________ and _____ demands.
A. Typical, Fire
B. Average, Peak
C. Fire, Peak
D. Maximum, Minimum
E. CMOM, CAFO

17. What is the peak demand?
A. The maximum momentary load placed on a water treatment plant, pumping station or distribution system.
B. The total demand for water during the period of time divided by the number of days in that time period.
C. None of the above

18. Surge tanks are used to control:
A. Water Hammer
B. Chlorine Demand
C. Backpressure
D. Backwash
E. CAFO

19. On most kilowatt meters, the current kilowatt load is indicated by:
A. The Primary or Binder dial
B. Current load dial
C. Disk revolutions
D. None of the above

20. This special type of check valve is located at the bottom end of the suction on a pump. This valve opens when the pump operates to allow water to enter the suction pipe, but closes when the pump shuts off to prevent water from flowing out of the suction pipe.
A. Prime Valve
B. Foot
C. Impeller

21. Distribution system water quality can be adversely affected by improperly constructed or poorly located blowoffs of vacuum/air relief valves. Air relief valves in the distribution system lines must be placed in locations that cannot be flooded. This is to prevent water contamination. What customer complaint is sometimes solved by the installation of air relief valves?
A. Taste and odors
B. Milky water
C. MIB
D. Constipation

22. What does HPC mean?
A. Halogenated Particle Count
B. Heterotrophic plate count
C. Hard Particle Count
D. Heterotrophic Particle Count

23. Which of the following pumps consists of an impeller fixed on a rotating shaft that is enclosed in a casing, and has an inlet and discharge connection? As the rotating impeller spins the liquid around, force builds up enough pressure to force the water through the discharge outlet.
A. Booster
B. Centrifugal
C. Submersible
D. Rotator

24. What is a limitation of hydropneumatic tanks?
A. Do not provide much storage during average demands
B. Do not provide much storage to meet peak demands during power outages
C. Very limited time to do repairs on equipment
D. Both B & C

25. Why would a pump engineer design a system that would use multiple pumps for a parallel operation?
A. To provide for a fluctuating demand
B. To provide an increased discharge head
C. To reduce the friction coefficient on a larger pump for greater efficiency
D. All of the above

26. When the superintendent is inspecting the plans for a new ground water storage tank, the superintendent should pay attention to the inlet and outlet of this tank. What design factor should be noticed?
A. The outlet and inlet should be on opposite sides of the tank
B. The inlet must be twice the size of the outlet
C. The outlet must be twice the size of the inlet
D. The outlet and inlet should be on the top
E. CMOM

27. Water quality in a storage facility could degrade due to excessive water age caused by low demands for water and short-circuiting within the distribution storage reservoir. Which of the following are not other reasons for water quality degradation?
A. Sampling program
B. Poor design
C. Inadequate maintenance
D. Improperly applied coating and linings

28. Transmitting equipment requires installation where temperature will not exceed:
A. 100°F.
B. 100°C.
C. 130°C.
D. 130°F.

29. For a dead-end line of over 2,000 feet, the design criteria would dictate a minimum pipe diameter of ________ inches.
A. 4
B. 8
C. 6

30. A diaphragm element being used as a level sensor would be used in conjunction with:
A. Pressure Sensor
B. Manometer
C. Rotameter
D. Redwood plug
E. HTH

31. Inspection of magnetic flow meter instrumentation should include:
A. Checking EMF on the hemisphere transducer
B. Checking for corrosion or insulation deterioration
C. Placing a bucket of water for your feet
D. Polarity multiplexing

32. The most frequent problem that affects a liquid pressure-sensing device is:
A. Air accumulation at the sensor
B. Greenhouse effect
C. Freezing
D. Sensing solenoid failure
E. CAFO

33. Which of the following is not a pressure sensing device?
A. Helical Sensor
B. Bourdon Tube
C. Campos Gauge
D. Bellows Sensor

34. Telemetering systems must often transmit more than one signal. Which of the following is not a means for transmitting multiple signals?
A. Pulse-duration modulation
B. Polling
C. Scanning
D. Multiplexing

35. The Strain Gauge is a common measuring device used for a variety of changes such as head. As the pressure in the system changes, the diaphragm expands which changes the length of the wire attached. This change of length of the wire changes the ________of the wire, which is then converted to head.
A. Resistance
B. Voltage
C. Current
D. None of the above

36. Any equipment that utilizes water for cooling, lubrication, washing or as a solvent is always susceptible to:
A. Cross connections
B. An operator falling in to it
C. Garden hoses and backpressure
D. All of the above

37. When installing a vacuum breaker backflow device, the operator must make sure that:
A. It is 12 inches above the lowest discharge outlet
B. It is 2 inches above the air gap
C. It is 12 inches above the highest discharge outlet
D. It is made of brass

38. Which of the following statements is true concerning a double check backflow assembly?
A. A Double Check is approved for high contamination/pollution and backpressure
B. A double check will stop backsiphonage
C. A double check has a relief valve
D. A double check is redundant

39. Which of the following statements best describe the operation of a reduced pressure principal backflow assembly device?
A. The relief valve will open and drain if a pressure differential occurs between the two checks
B. The spring loaded diaphragm is below the second check valve
C. The air relief will open at 15 PSI
D. All of the above

40. Which of the following has the greatest potential hazard of contamination if a cross connection occurs?
A. Sugar machine
B. Commercial food processors
C. Swimming pools
D. Pesticide mixing tanks

41. What is the most likely consequence if a backsiphonage condition causes a cross connection and pressure is then restored to the system?
A. Probably dirty water
B. There will be no contamination
C. Backpressure
D. The distribution system down stream of the cross connection will be contaminated

42. A common abbreviation on plan and profile drawings is “PI”. What does this stand for?
A. Point of Increase
B. Point of Tap
C. Point of Instruction
D. Point of Intersection

43. Galvanized pipes are unsuitable for most services because:
A. Easily bent
B. Improper threads
C. Galvanic corrosion
D. Palatability problems

44. If valve and hydrant maps are to be effective, the maps must:
A. Provide measurements to appurtenances from permanent references/tie and measure
B. Show as-builts
C. Have the Operator’s name on the each valve
D. Show the size the stem

45. An effective cross-connection control program should focus on two major sources of problems. These will include:
A. Fire fighting equipment/Pollutional sources
B. Garden Hoses/ Air Gaps
C. Customer plumbing problems/Auxiliary water sources
D. All of the above

46. What is the name of a map that an operator would use on a day to day basis that provides detailed drawings of distribution zones, but do not show all the system components?
A. Leak survey maps
B. Sectional Maps
C. Comprehensive maps

47. Intersection indexes can be prepared by:
A. Alphabetizing street names
B. Assigning numbers to each intersection
C. scada
D. SCATA
E. CMOM

48. What is the advantage of a "**Wet Tap**" over a "**Dry Tap**" ?
A. You have more chances of contamination
B. You do not need a shut down for a corp/saddle installation
C. A ball peen hammer is all you need
D. The installation time is increased.

49. Why would an operator place a screen before a backflow prevention assembly?
A. Prevent debris from fouling the assembly
B. Prevent small animals from entering the assembly
C. To allow the passage of air
D. To keep insects out of the air relief

50. A single-phase motor is receiving adequate power and the run windings are operable, but the motor will not start, what could be the problem?
A. The switch is closed
B. There is a problem with the stator
C. There is a problem with the start winding
D. There is a problem with the Rotor Monitor

51. Who has the responsibility for insuring that water contamination due to cross connections does not occur?
A. EPA
B. The Health Dept
C. Federal Government
D. The water utility
E. All of the above

52. Pigs traveling at speeds of 10 fps will likely result in:
A. Excessive wearing of the pig
B. SOCs and BOD reduction
C. Leaks in the water line
D. Complete removal of the tubercles
E. MIB

53. When cleaning or swabbing a water line, the velocity should be:
A. 2-4 fps
B. 10-20 fps
C. 20 PPM
D. 5 gallons per minute

54. Of the following answers, which is an acceptable way to launch pigs?
A. Using a fire hydrant
B. Using a taping tool
C. Tying the pig up, and having an Operator 1 using a backhoe
D. Using a high pressure air compressor, or PTO

55. Mechanical seals consist of two machined and polished surfaces which must contact each other. This contact is maintained by:
A. Spring pressure
B. Water pressure

56. What is the main reason for having an updated comprehensive map of the entire water distribution system?
A. To help identify and record sections that need improvement or development
B. To show all of the other utilities and their locations
C. To help develop a per capita use plan
D. To make work for the Valveman

57. Valve and hydrant maps using an intersection method of indexing will typically have a scale of:
A. 1 mile per inch
B. 1/25
C. 20-30 feet per inch
D. 1/2

58. Water audits can be performed in order to account for the water in the system. What should be the first step in a water audit?
A. Measure flow in to each quarter-section
B. Pump test
C. A 24 hour measure of all the water entering the system
D. Dye test

59. Which of the following types of motors would be expected to have the lowest demand for starting current?
A. Wound-rotor induction motor
B. Squirrel Cage induction motor
C. Rotor Synch motor
D. None of the Above

60. The purpose of a sump on a vertical turbine pump is used to maintain adequate:
A. Liquid above the suction level
B. Pressure for the foot valve
C. Backpressure
D. Cavitation diffusion

61. This term is used to describe head pressure or energy lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions by fittings.
A. C Factor
B. Friction Losses
C. Pressure
D. Pressure Head
E. None of the above

62. Continuous leakage from a mechanical seal indicates:
A. An abnormal condition
B. A normal condition
C. Packing needs to be tightened
D. Mechanical gland needs to be replaced
E. All of the above

63. When you are shutting a large valve, which of the following valves will reduce high pressure that can be present?
A. Gate valve
B. Bypass valve
C. Binder device
D. Inserting Valve

64. What is the most likely choice for the result of grease coming in to contact with the windings for a motor?
A. The winding insulation may deteriorate
B. The overloads will trip
C. There will be a phase monitor problem
D. The torque converter will fail

65. If the pH of water from a dead-end line begins to drop, it is most likely an indication that:
A. Anaerobic conditions are present
B. The main is being flushed regularly
C. There is a redwood plug in the main
D. None of the above

66. An electric motor that has a frequency of 60Hz will have a maximum synchronous speed of:
A. 600 rpms
B. 3600 rpms
C. 3000 rpms
D. None of the Above

67. As the wear ring inside a centrifugal pump looses tolerance between the impeller and wear ring, the efficiency of the pump will:
A. Remain the same
B. Fluctuates with the velocity of water
C. Increases
D. Decreases
E. None of the above

68. Multistage centrifugal pumps can discharge high pressure water. The pressure increases with the number of stages, but what happens to the capacity/flow of the pump?
A. The flow is decreased by 25% for each stage
B. The flow will remain the same through each stage
C. The flow will double with each stage
D. The flow is cut in half

69. What is the function of speed controls on valve actuators?
A. A SCADA function
B. To prevent a water hammer
C. To prevent backflow
D. A measuring device
E. All of the above

70. Dry-barrel fire hydrants with unplugged drains should be inspected:
A. Twice a year
B. Prior to installation
C. By placing a stethoscope on the stem
D. With the gate valve closed and pressure induced through an outlet nozzle

71. With remote manual control, the operator is also required to turn a switch or push a button to operate equipment. Control devices which actuate equipment by inducing a ___________in the device are commonly known as ___________.
A. Electric charge, SCADA
B. Magnetic field, Solenoids
C. Electric charge, Full Duplexing switches
D. EMF, Helical Sensors
E. Pressure change, Diaphragms

72. Thrust protection from thrust blocks should:
A. To kick the pipe in place
B. Partially cradle the protected pipe and to equally distribute the force
C. Be part all thread and 500 pounds of cement
D. Not poured in trenches near fire hydrants

73. Cement-mortar linings of water mains have been effectively used on nearly all pipe diameters. However, the most cost effective use of this procedure is generally for water lines of________ or greater.
A. 8 Inches
B. 12 Inches
C. 18 Inches
D. 48 Inches

74. What design criteria of water distribution systems is based upon the Hazen-Williams formula?
A. Pipe Size
B. Fire control capacities
C. Pressure head requirements
D. Never heard of this guy, all of the above

75. Which of the following problems may occur during periods of high flow or a fire when the waterline's pressure has dropped drastically?
A. Negative pressure in parts of the system
B. Water hammer
C. Low velocity throughout the system
D. All of the above

76. This type of valve which controls water pressure operates by restricting flows. They are used to deliver water from a high pressure to a low pressure system. The pressure downstream from the valve regulates the amount of flow. Usually, these valves are of the globe design and have a spring-loaded diaphragm that sets the size of the opening.
A. Pressure Regulation Valve
B. A Butterfly Valve
C. Reduced Pressure
D. Check Valve

77. What is the intent of a designer when multiple water pumps are installed for paralleled operation?
A. To increase the discharge head
B. To provide for a fluctuating demand/or for if one pump is out of service
C. To increase the water force
D. To help build the kingdom/spend the budget

78. During an inspection of your water storage facility, how should you inspect the Cathodic protection system?
A. Check the anode's condition and the connections
B. Check the system with a Megger
C. Check the dielectric converter
D. Check the voltage level

79. The concentration of polyphosphates that is used for corrosion control in storage tanks is typically _______ or less.
A. 5 mg/L
B. 15 mg/L
C. 20 mg/L
D. 50 PPM

80. The most accurate method of measuring chlorine residual concentrations is:
A. The Walker method
B. Combined residual analysis
C. The DPD procedure
D. Amperometric titration
E. CMOM

81. According to the manual, external corrosion of steel water storage facilities can be reduced with coating of:
A. Zinc or aluminum coatings
B. Lead coatings
C. Petroleum coatings
D. Latex coatings

82. All storage facilities should be regularly sampled to determine the quality of water which enters and leaves the facility. One tool or piece of measuring equipment is the Jackson turbidimeter. What is the function of this device?
A. A visual method to measure cloudiness in water
B. An instrumental method based on deflected light
C. Both 1 & 2
D. None of the above

83. The effects of water freezing in storage tanks can be minimized by:
A. Adding drinking water antifreeze
B. Adding solar heaters
C. Alternating water levels in the tank
D. Adding slaked lime
E. All of the above

84. Which of the following is a not a major concern when checking water levels in a storage tank?
A. The venting of air
B. Excessive water demands
C. Stale water
D. Backsiphonage

85. If an overflows occurs on a storage tank, the operator should first check:
A. Bac-t samples
B. Backpressure
C. The altitude-control valve
D. Pump velocity

86. What is most frequent type of accident(s) encountered by water distribution personnel?
A. Sprains and strains
B. An Operator 1 running a tamper over a foot
C. Slips and falls
D. Sunburns and hangovers
E. ERGO

87. If a thrust block of another utility is discovered in your path while excavation, you should:
A. Call the Engineer and place all thread on the thrust block
B. Be careful and alter the thrust block so that you can do the work
C. Do not alter the existing thrust block in any way
D. Do your work and pour concrete
E. File a NPDES

88. Right to Know Laws state that the employer has the responsibility to provide the employees with information about:
A. CDLs
B. The information about health hazards and chemical handling
C. The amount of each chemical to use in each application
D. The method of disposal for the product
E. CAFO

89. Safe entry into a confined space requires that:
SAC. Sec. 7.20 Topic SA
A. All entrants be First aid trained and able to hold their breaths
B. All entrants wear watches to remind them of the time limit
C. All entrants wear a harness and safety line
D. A rescue squad is standing by.
E. All of the above

90. If an operator is working inside a storage tank and suddenly faints or has a serious problem, there should be:
A. Smelling salts available
B. Two handheld radios
C. Two people outside standing by to remove the injured operator
D. LOTO
E. None of the above

Answers to Distribution Review Section

1. B
2. A
3. B
4. E
5. A
6. A
7. A
8. C
9. A
10. C
11. C
12. D
13. D
14. A
15. B
16. B
17. A
18. A
19. C
20. B
21. B
22. B
23. B
24. D
25. A
26. A
27. A
28. D
29. B
30. A
31. B
32. A
33. C
34. A
35. A
36. A
37. C
38. B
39. A
40. D
41. D
42. D
43. C
44. A
45. C
46. B
47. B
48. B
49. A
50. C
51. D
52. A
53. A
54. A
55. A
56. A
57. C
58. C
59. A
60. A
61. B
62. A
63. B
64. A
65. A
66. B
67. D
68. B
69. B
70. D
71. B
72. B
73. C
74. A
75. A
76. A
77. B
78. A
79. A
80. D
81. A
82. A
83. C
84. A
85. C
86. A
87. C
88. B
89. C
90. C

Water Treatment Review *Answers to this section in rear*

1. What does **MCL** stand for?
A. Minimum chlorine level
B. Minimum containment load
C. Maximum contaminant level
D. Maximum chlorine level

2. Within how many days must a certified operator notify the Department (in writing) that the operator either ceases or commences operation of another facility?
A. 5 Days
B. 1 Month
C. 10 Days
D. 2 Weeks

3. What does **CWS** mean?
A. Coastal water system
B. Contaminated water system
C. Community water system
D. None of the above

4. What is the definition of an "***On-site operator***" ?
A. An operator who visits a facility at least daily to ensure that it is operating properly.
B. An operator who lives near the facility.
C. An owner of a trailer park who is also the certified operator for the trailer park
D. An operator who is at their place of work.

5. What is the definition of a ***"facility"*** ?
A. Any public water system or sewage treatment plant
B. Any water system that serves potable water
C. Facility means a water treatment plant, wastewater treatment plant, distribution system or collection system.
D. Any device or structure used to improve the physical, chemical, or biological quality of the water of a public water system

6. This term means the aliquot of finished drinking water that is examined for the presence of coliform bacteria. This sample volume is 100 milliliters and is commonly referred to as ?
A. Surface Water Sample
B. Standard Sample
C. Eplilimnion
D. None of the Above

7. This term means 1 of the family of organic compounds, named as derivatives of methane, wherein 3 of 4 hydrogen atoms in methane are substituted by a halogen atom in the molecular structure.
A. Trihalomethanes
B. TTHM
C. VOC
D. SOC

8. What term best represents an oxidant, including chlorine, chlorine dioxide, chloramines, ozone, or an equivalent agent or process such as ultraviolet light, that kills or inactivates pathogenic organisms?
A. Halogen
B. Disinfectant
C. Dihydrogen Oxide

9. Reservoirs which are nutrient-poor and contain little plant or animal life are known as:
A. Littoral Zone
B. Threshold Reservoir
C. Mesotrophic
D. Stratification type
E. Oligotrophic

10. What is the definition of ***"backflow"*** ?
A. An impairment of the quality of drinking water
B. An assembly composed of two independently acting check valves
C. A reverse flow condition that causes water or mixtures of water and other liquids, gases, or substances to flow back into the distribution system.
D. An assembly composed of two independently acting check valves.

11. What is a compliance cycle?
A. When all the baseline sampling has been completed.
B. The year in which compliance sampling is conducted.
C. Sampling for 12 consecutive months.
D. A 9-calender year time-frame during which a public water system is required to monitor. Each compliance cycle consists of 3 compliance periods.

12. What is a compliance period?
A. The time between sample analysis and when the report is submitted to the Department.
B. The sampling conducted during one calendar year.
C. The time between sample collection and sample analysis.
D. A 3-calendar year time-frame within a compliance cycle.

13. Name the three types of public water systems.
A. Community water system, nontransient noncommunity water system, transient non community water system.
B. Semi-public water system, domestic water improvement district, community water system.
C. Community water system, private water system, municipalities.
D. Community water system, noncommunity water system, ACC regulated utilities.

14. How many persons does a small water system serve?
A. More than 3.300 and 50,000 or fewer persons.
B. 500 or fewer persons
C. 3,300 or fewer persons
D. 10,000 or fewer persons

15. How many persons does a medium water system serve?
A. 100,000 or fewer persons
B. More than 3,300 persons and 50,000 or fewer persons.
C. 500,00 or fewer persons
D. More than 10,000 persons

16. How many persons does a large water system serve?
A. More than 3,300 persons and 50,000 or fewer persons.
B. More than 10,000 persons.
C. 500,000 or fewer persons
D. More than 50,000 persons.

17. What is a **POE**?
A. Pair of electrons
B. Point of Exit
C. Point of Entry
D. Potential Oxygen Elimination

18. What is a **VOC**?
A. Volatile Organic Chemical
B. Volatile Oxidation Coupling
C. Very old Contaminant
D. Vinyl Chloride Oxidation

19. Many water quality problems in domestic water supply reservoirs occur in reservoirs containing moderate or large quantities of nutrients such as phosphate, ___________compounds.
A. Nitrate, and organic nitrogen
B. Iron, and oxygen
C. DO and calcium
D. Calcium and iron

20. ______________filtration rates and increased frequency of filter backwashing are reflected in an inability to meet system water demands and increased water treatment costs.
A. Reduced
B. Increased
C. Reverse
D. Greensand

21. A major problem associated with algal blooms is that certain species of algae tend to clog filters at water treatment plants and thereby reduce both filtration rates and the duration of filter runs. Normal filter runs will last _________ before cleaning is required.
A. 30 – 100 hours
B. 10-20 hours
C. 100-200 hours
D. 500 –1000 hours

22. When anaerobic conditions exist in either the metalimnion or hypolimnion of a stratified lake or reservoir, water quality problems may make the water unappealing for domestic use without costly water treatment procedures. Most of these problems are associated with this term in the stratified waters.
A. Precipitate
B. Turbidity
C. Reduction
D. Alkalinity
E. All of the above

23. When significant levels of dissolved oxygen are present, iron and manganese exist in an ___________state and normally precipitate into the reservoir bottom sediments.
A. Oxidized
B. Reduced
C. Precursor

24. One of the more important considerations in the construction of intake facilities is the ease of operation and maintenance over the expected lifetime of the facility. Every intake structure must be constructed with consideration for operator safety and for:
A. Fish habitat
B. Reagents
C. Cathodic protection
D. Supernatant
E. None of the above

25. The proper pH range must be maintained because coagulants generally react with the alkalinity in water. What is the pH range for the best coagulation?
A. 11-12
B. 7-9
C. 5-7
D. 3-5
E. 99

26. The information furnished by a sanitary survey is essential to evaluating the bacteriological and chemical quality data. Which of the following items are essential or considered in a sanitary survey?
A. Identify potential hazards
B. Determine factors which affect which affect water quality
C. Select treatment requirements.
D. All of the above

27. The minimum detention time recommended for flocculation ranges from about:
A. 30 - 40 minutes
B. 40 – 60 minutes
C. 120 minutes
D. 5 – 20 minutes for direct filtration and up to 30 minutes for conventional filtration
E. None of the above

28. This substance or mixture is a pure chemical substance that is used to make new products or is used in chemical tests to measure, detect, or examine other substances. Jar test _______ can be prepared at several concentrations, depending upon desired dosage.
A. Reagent
B. Cathodic protection
C. Supernatant
D. Logarithm

29. Which of the following terms best represents the definition of the property of a material or soil that permits considerable movement of water through it when it is saturated?
A. Media
B. Alluvial
C. Permeability
D. Reverse Omission
E. Frazzle

30. Which of the following are desirable filter media characteristics?
A. Hard and durable
B. Insoluble in water
C. Free of impurities
D. All of the above
E. None of the above

31. The volume of a reservoir is estimated to be 581,000 cubic feet. Estimate the volume in acre-feet.
A. 13.3 Acre feet
B. .133 Acre feet
C. 1 sore foot
D. 10 Acre feet

32. Determine the actual chemical feed in pounds per day from a dry chemical feeder. A. bucket placed under the chemical feeder weighed 0.3 pounds empty and 2.1 pounds after 30 minutes.
A. 86 lbs./day
B. 8.6 lbs./day
C. 860 lbs./day
D. 6.3 lbs./day

33. A small chemical feed pump lowered the chemical solution in a three-foot diameter tank one foot and seven inches during an eight-hour period. Estimate the flow delivered by the pump in gallons per minute.
A. 0.28 GPM
B. 28 GPM
C. .280 GPM
D. 0.17 GPM

34. The optimum liquid alum dose from the jar tests is 12 mg/L. Determine the setting on the liquid alum chemical feeder in milliliters per minute when the plant flow is 4.7 MGD. The liquid alum delivered to the plant contains 642.3 milligrams per milliliter of liquid solution.
A. 31 mL/min
B. 198 mL/min
C. 321 mL/min
D. 2.31 mL/min

35. Convert a flow of 800 gallons per minute to million gallons per day.
A. 800
B. .80
C. 0.8
D. 1.15

36. Determine the chlorinator setting in pounds per 24 hours to treat a flow of 2 MGD with a chlorine dose of 3.0 mg/L.
A. 50 lbs./day
B. 8.34 lbs./day
C. 60 lbs./day
D. .50 lbs./day

39. A reservoir has a volume of 6.8-acre feet. What is the reservoir in million gallons?
A. 1.1 Million gallons
B. 2.2 Million gallons
C. 3.3 Million gallons
D. 4.4 Million gallons

40. To check an ion exchange unit for iron fouling the operator should make careful observations during the backwash cycle and look for:
A. An orange color on the resin and backwash water
B. A black color on the filters
C. A black color on the resin surface
D. A fine shimmery powder
E. Lantern rings

41. Which of the following are physical characteristics of water?
A. Hardness
B. Turbidity
C. Alkalinity
D. All of the above

42. How is groundwater produced?
A. Through artesian pressure
B. Through percolation
C. Through evapotranspiration
D. Through impoundment intrusion
E. None of the above

43. Which of the following are plant nutrients which may cause an increase in the growth of algae?
A. Nitrogen and phosphorus
B. Sulfur and carbon
C. Water and fertilizer
D. None of the above

44. Fluoride is added to a water supply:
A. To prevent dental caries in children
B. To remove tastes and odors
C. To combine with chlorine
D. To hide other additives
E. To aid in flocculation

45. What are the essential factors that should be considered during a Sanitary Survey?
A. Factors which affect water quality
B. Identify potential hazards
C. Both A & B
D. None of the above

46. What is the chemical symbol for Chlorine ?
A. C
B. Cl
C. Cr
D. Ch

47. A rotameter measures gallons per hour or pounds per day, and is commonly used to determine chemical feed rates for:
A. GAC
B. Most fluids
C. VOCs
D. Powders

48. A cross-connection in a water supply is:
A. Connection between a chlorinator and fluorinator
B. Connection between safe and unsafe water
C. A four way water connection
D. Logarithm

49. Pneumatic systems are not reliable as transmission lines over:
A. 100 feet
B. 1000 feet
C. 5000 feet

50. Surface water such as rivers and lakes are the result of which of the following processes?
A. Evapotranspiration
B. Percolation
C. BOR
D. Runoff

51. Which of the following will result when calcium carbonate or limestone is added to water?
A. Corrosion will be inhibited
B. The pH will decrease
C. DO will increase
D. Photosynthesis

52. Before entering the chlorine room to check on a chlorine leak, the operator should?
A. Use a self-contained breathing apparatus and check to see that the ventilation system is working
B. Wear gloves, goggles and boots
C. Check the lights and ventilation systems
D. Use a gas canister mask and ventilate the room for fifteen minutes

53. What are the two forms of activated carbon which are used in water treatment?
A. Powdered and granular
B. Slurry and granular
C. Activated and GAC
D. Reduced and regular

54. Powdered Activated Carbon, or **PAC** is commonly used in water plants for what purpose?
A. Absorbing moister
B. Metalimnion
C. Turbidity
D. Taste and odor control

55. What is the chemical name of **Cu** ?
A. Chlorine
B. Copper
C. Chloride
D. Carbon
E. Gold

56. Which of the following pieces of labware may have a glass stopcock that must be lubricated?
A. A buret
B. A graduated cylinder
C. A boiling flask
D. A pipette

57. The simplest way to define an organic compound is that it:
A. Will not burn
B. Contains carbon
C. Is a halogen
D. All of the above

58. A water sample may be collected from a surface water or basin by hand. To do this, the sample bottle should be plunged mouth down below the surface then tilted upward to allow _____ to escape from the bottle.
A. Air
B. Preservative
C. Sodium Thiosulfate

59. The Safe Drinking Water Amendments include MCLs. *MCLs can be defined as:*
A. Maximum Chlorine Level
B. Maximum Carbon Level
C. Maximum Contaminant Level
D. None of the above

60. Excessive turbidity during disinfection will:
A. Reduce the effectiveness of the chlorine
B. Help the filter process
C. Decease the chlorine demand
D. Reduce the effectiveness of the water
E. Create Logarithm

61. What should be used to test for chlorine leaks around valves and piping?
A. An ammonia soaked rag
B. A spray bottle of sulfuric acid
C. Your nose
D. Lantern ring
E. Liquid Oxygen

62. When the temperature of a chlorine cylinder is increased, the chlorine will:
A. Expand in volume
B. Increase in density
C. Become flammable
D. All of the above.

63. Why do many operators chlorinate past the breakpoint?
A. It will form chloramines
B. It will form chlororganics
C. The free chlorine residual gives the best disinfection
D. To help decrease the demand

64. If you cannot open the valve on a chlorine cylinder because it is too tight, you should:
A. Use a pair of vise-grips
B. Loosen the packing gland around the valve, and tap the valve gently with your hand
C. Remove the valve and replace it
D. Spray a lubricant on it.

65. If there is a chlorine leak in the chlorine tank, the chlorine gas will accumulate:
A. Near the floor
B. Near the vents
C. Near the supervisor's office
D. Near the public
E. Near the ceiling

66. Which of the following laboratory tests should be done immediately with no holding time?
A. Bac-T
B. Copper
C. Nitrate
D. None of the above

67. The best place to take a water sample from the distribution system is from:
A. Front yard faucets which have allot of organic and vegetation matter around
B. Fire hydrant
C. Kitchen sinks
D. Front yard faucet on a short service

68. A **Grab Sample** should be used when testing for:
A. Dissolved gases
B. Residual Chlorine
C. Coliform bacteria, pH and Temperature
D. All of the above

69. You should never use a composite sample when testing for:
A. Chlorinated hydrocarbons
B. Oil and grease
C. Bacteriological examinations
D. BOD
E. TPH

70. If an operator was to put water on a leaking chlorine cylinder, which of the following is most likely to occur?
A. Corrosion will occur and the leak will get larger
B. A cloud of white smoke will occur
C. The water will neutralize the liquid
D. The water will temporally seal the leak

71. If the chlorination system goes out of service or operation, what should be done?
A. Service may be interrupted for a short time but add additional chlorine when the system is back on line
B. Notify the Operator 2 that the service may be interrupted
C. Back-up disinfection units should be brought on-line immediately with no interruption of service
D. Service may be interrupted for a short period

72. Chlorine gas enters the injector, this makes the chlorine:
A. A more dilute gas
B. A solution which is ready for application
C. A little warmer
D. Turn into water
E. Turn into HTH

73. What is the purpose of the ejector on a hypochlorinator?
A. Discharges chlorine into the atmosphere
B. Draws in additional water for dilution of the hypochlorinate solution
C. Regulates the chlorine dose
D. Provides an atmospheric break in the piping to prevent backflow
E. Open lantern rings

74. Which of the following is a safety device found on chlorine cylinders?
A. Seat belt
B. Fusible plug
C. Fusible link
D. Tripod
E. Air bag

75. Sodium Hypochlorite compounds have all of the following properties except:
A. 2.5 times heavier than air
B. Non-flammable
C. Corrosive
D. May cause fires when in contact with organic material
E. Lighter than air

76. What chemical may be added to water to reduce corrosivity?
A. Alum
B. Ferric chloride
C. Lime

77. Corrosive water may cause:
A. Red or dirty water
B. High levels of lead
C. Leaks in the distribution system
D. All of the above

78. When a hypochlorinator is taken out of service, the most important and very first step should be:
A. Turn off the water supply pump
B. Make sure the solution tank level is adequate to prevent backflow
C. Unplug the unit
D. Call the Distribution Supervisor/Water Master

79. What type of fittings and gaskets should be used when making connections to chlorine containers?
A. Fittings and gaskets supplied by the chlorine manufacturer
B. Standard plumbing fittings
C. Magnos system fittings
D. All of the above

80. When determining the chlorine use rate, the scales or meters should be read:
A. At the same time every day
B. During the average flow
C. During high demands
D. At a different time every other day

81. A major problem with air in aerobic water is when iron and manganese passes in solution. What will occur?
A. Oxidation
B. Reduction
C. Biofouling
D. Precipitation
E. None of the above

82. What is the purpose of a sanitary survey?
A. To identify possible biological and chemical pollutants which may affect a water supply
B. To measure the safe yield of a water supply
C. To identify the source of backflow

83. Which of the following condition may occur when filters are clogging ?
A. Reduction in chemicals
B. Increased corrosion in the system
C. Inability to meet demand
D. All of the above

84. Cascade systems and spray aerators may develop what types of maintenance problems?
A. Clogging
B. Water Hammer
C. Biological growth
D. All of the above

85. What will the combination of moisture and Potassium Permanganate produce?
A. A very corrosive environment
B. An explosive environment
C. A hostile environment
D. Greenhouse effect

86. What strong oxidant can be used to control taste and odor problems ?
A. Potassium permanganate
B. Alum
C. Sodium Chloride
D. Dihydrogen oxide

87. Which of the following chemicals removes tastes and odors by absorption only?
A. Chlorine
B. PAC
C. TOC
D. Ozone

88. Why is Potassium Permanganate used in water treatment?
A. Taste and odor control
B. pH adjustment
C. For favor
D. Corrosion control
E. To prevent backflow

89. Aeration can remove volatile substances from water. Increasing the aeration rate in such systems will:
A. Cause binding of the aeration system
B. Increase the removal of volatile compounds
C. Increase system efficiency at low temperatures
D. None of the above

90. A standard solution is a prepared chemical solution in which:
A. The exact chemical concentration is known
B. The pH is known
C. The alkalinity is known
D. The temperature and volume are known

91. What precautions are necessary when mixing dry polymer solutions?
A. A dust collector or closed system should be used to prevent dust from escaping
B. A cooling system is needed to prevent excessive heat build-up
C. Mixing should be done in a spark proof container to prevent fire
D. The polymer should be mixed slowly to prevent an explosion

92. Powdered activated carbon is frequently used for taste and odor control because:
A. It has no limitations on use
B. It is non-specific and removes a broad range of compounds
C. It readily mixes with water
D. It is a strong oxidant

93. What are the necessary emergency procedures in case of a large uncontrolled chlorine leak?
A. Notify the local emergency response team
B. Warn and evacuate people in adjacent areas
C. Be sure that no one enters the leak area without adequate self-contained breathing equipment
D. All of the above

94. The water temperature decreases from 70° F (21° C) to 40° F (4°C). To maintain good disinfection:
A. A shorter contact time is necessary
B. A longer contact time is necessary
C. A shorter filter run is necessary
D. Raise the temperature

95. Chlorine reacts with phenol, which can cause:
A. A drop in water alkalinity
B. A strong medicinal odor
C. A color in the water
D. Incrustation in the distribution system
E. Dihydrogen oxide

96. When making a new connection on a chlorine feed system, the gaskets should be:
A. Oiled
B. Dried
C. Inspected and knulled
D. Replaced

97. The best pH range for coagulation is:
A. Below a pH of 2
B. Between a pH of 5 and 7
C. Between a pH of 2 and 6
D. Above a pH of 9

98. Good coagulation and flocculation processes promote the removal of natural organic compounds from the water which also aids the treatment process by:
A. Increasing the water production capacity of the plant
B. Reducing the formation of THMs
C. Adding more dissolved gases to the water
D. All of the above

99. Large, light floc particles which are formed in the coagulation flocculation process are more likely to:
A. Remove color from the water
B. Settle quickly
C. Be subject to floc shearing
D. All of the above

100. ____________ is undesirable and may result in shortened filter runs and loss of media during backwash.
A. Air binding
B. Dihydrogen oxide
C. Hypolimnion
D. Epilimnion

101. The __________ detention time recommended for flocculation ranges from about _________ minutes for direct filtration systems and up to 30 minutes for conventional filtration.
A. Minimum, 5-20
B. Maximum, 60-90
C. Average 90-120
D. Minimum, 120-600

102. The two factors which determine whether or not a change in filter media size should be made are?
A. Time for turbidity breakthrough and maximum head loss
B. Type of coagulants and disinfectant used
C. Filter backwash rate and surface washing

103. If an increase in raw water turbidity and an increase in coagulation feed rate creates additional loading on the filter, which of the following operational changes may be helpful?
A. Increase the filtration rate
B. Backwash the filters more frequently
C. Increase the speed of the paddle rotation
D. "*Bump*" the filter in between backwash cycles

104. A detailed evaluation and inspection of a new water supply source should be made to identify and protect against sources of pollution. What would you call this type of evaluation?
A. A sanitary survey
B. A cross-connection survey
C. A pretreatment survey
D. A hydro-geological survey

105. If you exceed the "*safe yield*" what may happen?
A. Depletion of the aquifer
B. An OSHA violation
C. An Operator 1 may get a ticket
D. A watershed contour
E. All of the above

106. Organic chemicals such as pesticides may enter a surface water supply through?
A. Capillary discharges
B. Artesian pressure
C. Overflow from wells
D. Industrial discharges, agricultural drainage, and spills
E. All of the above

107. Acid rain is the result of:
A. Airborne pollutants
B. Runoff from abandoned mines
C. Fluorocarbon release
D. Ozone depletion

108. Under normal plant conditions the flow is 3.0 MGD and a one minute fast mixing in the jar test is adequate. If the plant flow increases to 4.0 MGD, how long of fast mix is needed in the jar test?
A. Less than one minute is necessary
B. One minute is still adequate
C. More than one minute is necessary
D. The speed should be increased by one third

109. An organic chemical is causing taste and odor problems in the water distribution system. What might cause these problems?
A. A backflow situation / a cross-connection
B. Backpressure and /or backsiphonage
C. All of the above

110. A very small percentage of chlorine in the air is most likely to:
A. Cause serve coughing
B. Be undetectable
C. Cause headaches and gout
D. Cause white smoke

111. The chlorine storage ventilation equipment should be checked:
A. Weekly
B. Before replacing or ordering new cylinders
C. Daily
D. On a logarithm

112. What would happen if the temperature of a full chlorine cylinder is increased by a temperature of 50°F (or 30°C)?
A. The cylinder will rupture
B. Corrosion will occur
C. This is an increased fire hazard
D. All of the above

113. The effectiveness of disinfection may be determined by?
A. Lack of consumer complaints
B. Turbidity of finished water
C. Results of coliform testing
D. By the thermocline
E. All of the above

114. The chlorine gas lines connected to the evaporator have been incorrectly connected to the liquid side of the liquid side of the chlorine container. When this happens the most likely result will be:
A. The chlorine flow will increase and the residual will double
B. The chlorine flow will be restricted and frost may appear on the valves
C. Nothing
D. None of the above

115. What should be the target value for the free chlorine residual in the distribution system?
A. There is no target value
B. 1.5 mg/L
C. 0.2 mg/L
D. 2.0 mg/L

116. Which of the following factors will influence the effectiveness of chlorination?
A. pH/Temperature
B. Chlorine dosage
C. All of the above
D. Logarithm
E. None of the above

Answer Key for Water Treatment Section

1. C
2. C
3. C
4. A
5. C
6. B
7. A
8. B
9. E
10. C
11. D
12. D
13. A
14. C
15. B
16. D
17. C
18. A
19. A
20. A
21. A
22. C
23. A
24. C
25. C
26. D
27. D
28. A
29. C
30. D
31. A
32. A
33. D
34. A
35. D
36. A
37. B
38. A
39. B
40. A
41. D
42. B
43. A
44. A
45. C
46. B
47. B
48. B
49. B
50. D
51. A
52. A
53. A
54. D
55. B
56. A
57. B
58. A
59. C
60. A
61. A
62. A
63. C
64. B
65. A
66. D
67. D
68. D
69. C
70. A
71. C
72. B
73. B
74. B
75. A

The rest are for you to find, the glossary is a great tool.

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