BOTTLED WATER OPERATOR CERTIFICATION MANUAL

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Certification and Licensing Program

Mission

Promote responsible environmental stewardship.

Goal

Provide operators with the basic knowledge required to manage drinking water, wastewater and solid waste systems.

The Division of Compliance Assistance offers free compliance assistance. Our services are available to all individuals, communities and businesses regulated by the Kentucky Department for Environmental Protection. We want to help you succeed!

Hotline and Website for regulatory, technical or operational concerns
800-926-8111
dca.ky.gov

Other programs administered by the Division of Compliance Assistance:

Kentucky Excel Program
Kentucky Brownfield Program
Kentucky Environmental Compliance Assistance Program

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Chapter 1: THE BOTTLED WATER OPERATOR

Chapter 1 Objectives

1. Explain when and why operator certification came into existence.
2. Determine what constitutes a public water system.
3. Understand and be able to notate the size parameters relative to certification classifications of treatment facilities.
4. Recall the number of continuing education hours necessary to renew operator certifications.
5. Remember the grace period and monetary penalty for failing to renew operator certification on time.
6. Explain the notions of professionalism and ethical behavior.

History

When the Cuyahoga River in Cleveland, Ohio, caught fire for the fifth time on June 22, 1969, people began complaining about the abysmal condition of the waters in the United States. Publicity from this event was a major impetus for the passage of the Clean Water Act (CWA) in 1972. This statute employs a variety of regulatory and non-regulatory tools to sharply reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities and manage polluted runoff.

The CWA was followed up by the Safe Drinking Water Act (SDWA) in 1974, in order to protect the quality of both actual and potential drinking water in the United States. This statute requires the United States Environmental Protection Agency (EPA) to regulate all "public water systems." This regulation included Maximum Contaminant Levels (MCL) and Maximum Contaminant Level Goals (MCLG) for each regulated contaminant. The SDWA was amended in 1986 to address, among other things, the regulation of lead levels in solder and flux and defined "lead-free" pipes. In 1996, the act was further amended to emphasize sound science and risk-based standard setting, small water supply system flexibility and technical assistance, community-empowered source water assessment and protection, public right-to-know and water system infrastructure assistance through a state revolving loan fund (SRF). Further revisions to the SDWA in 1996 included the following:

Consumer Confidence Reports (CCR) that all community water systems must distribute annually about the water they provide, including information on detected contaminants, possible health effects and the water's source;

Cost-Benefit Analysis, which mandates that the EPA conduct a thorough cost-benefit analysis for every new standard to determine whether the benefits of a drinking water standard justify the costs associated with them;

Drinking Water State Revolving Funds (SRF), which states can use to help water systems make infrastructure or management improvements or to help systems assess and protect their source water;

Microbial Contaminants and Disinfection Byproducts (DBP), which required the EPA to strengthen protection for microbial contaminants, including cryptosporidium, while strengthening control over the byproducts of chemical disinfection.

Operator Certification where water system operators must be certified to ensure that systems are operated safely. In 1999, the EPA issued guidelines specifying minimum standards for the certification and recertification of the operators of community and non-transient, non-community water systems. All states are currently implementing EPA-approved operator certification programs.

Public Information and Consultation: The SDWA emphasizes that consumers have a right to know what is in their drinking water, where it comes from, how it is treated and how to help protect it and established a Drinking Water Hotline among other resources.

Small water systems are given special consideration and resources under the SDWA, to make sure they have the managerial, financial and technical ability to comply with drinking water standards.

Public water systems (PWS) are defined by the EPA as "a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such a system has at least 15 service connections or regularly serves at least 25 individuals."

Why Should I Become a Certified Operator?

Wastewater and drinking water system operators are front-line environmental professionals who ensure the quality of Kentucky's water resources and protect the public's health. Only operators that are certified by the Kentucky Certification and Licensing Branch can be in responsible charge of a wastewater or drinking water system.

Working in the water and wastewater industry can be extremely rewarding as you will be providing a critical service to your community. It just might be one of the most important positions in the world since no one can live without water. It takes knowledgeable, conscientious people to deliver clean, potable water and ensure that wastewater is treated and returned as clean water to the environment.

Certification Process

Certification is obtained by meeting minimum education and experience requirements, submitting the appropriate forms and fee and by passing the certification examination with at least a 70%. Regulations pertaining to the certification of drinking water and wastewater system operators are located in 401 KAR Chapter 11.

System Classifications

A Subclass "BW" system is a system that treats Surface water or groundwater under the direct influence of surface water; or Groundwater not under direct influence of surface water that uses gravity filtration.	
Class I-BW	Water treatment plant used for bottling water for sale.

Regulatory Education and Experience

Class I-BW	High School Diploma or GED and one (1) year of acceptable operation of a bottled water facility with any design capacity shall be required.

Operators in Training (OIT) Certifications

Operators in training certifications are available for each certification type. An individual can apply for an OIT license that is one level higher and of the same type as the certification that the individual currently holds. An individual may also apply for an entry-level OIT certification. OITs must pass the appropriate operator certification exam and work under the responsible charge of a mentor. To apply for the exam, individuals must submit the following to the Certification and Licensing Branch:

- Education and Experience Documentation Form;
- Registration Form for Exams and Training;
- The appropriate fee; and
- A letter from the applicant's mentor. The letter from the mentor must include:
    - A commitment to oversee the applicant's work after the applicant becomes an OIT;
    - A commitment to mentor the applicant as long as the applicant is under the mentor's direct responsible charge;
    - Verification that the mentor is not currently mentoring any other OITs; and
    - Confirmation that the mentor holds a certification license that is equal to or greater than the certification level required to serve in primary responsibility of the facility where the mentor and prospective OIT works.

Wastewater Treatment Class I-OIT who operates a wastewater treatment plant owned by the operator that serves only one residence may have primary responsibility for that plant. All other OITs may not be in responsible charge of a facility unless they hold an additional certification license that does not have an OIT designation.

Certification Renewal or Maintenance

Drinking water treatment, distribution and bottled water system certifications expire on June 30 of even-numbered years. Certifications shall remain valid until the expiration date, unless suspended, revoked or replaced by a higher classification certificate before that date. Certificates issued between Jan. 1 and June 30 of a renewal year will be issued to include the next two-year renewal period. Failure to renew before July 1 of the renewal year will result in the expiration of certification and a late fee assessment. The certificate shall terminate if not renewed on or before Dec. 31 of the year the certification expired. Certified operators with expired certificates shall not be in responsible charge of a drinking water or wastewater facility.

Certified operators (excluding OIT certificates) may renew their license(s) electronically through the cabinet website using the E-Search link or by submitting the

Application for Certification Renewal and appropriate fee to the Division of Compliance Assistance, Certification and Licensing Branch, 300 Fair Oaks Lane, Frankfort, KY 40601.

Certified operators who are designated an Operator in Training may renew a certification without examination if the operator has:

- Satisfied the continuing education requirements;
- Earned the required years of operational experience;
- Submitted an Education and Experience Documentation form verifying his or her experience;
- Submitted a letter of recommendation from a mentor; and
- Submitted a completed Application for Certification Renewal form and the renewal fee to the cabinet or has renewed the certification electronically on the cabinet's website.

Drinking water treatment, distribution and bottled water certified operators' training hours shall be completed for each renewal during the two (2)-year period immediately prior to the certificate expiration date. Certified operators holding a treatment, distribution and/or bottled water certificate shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for both certificates.

Reminder -- Continuing education hours earned prior to certification shall not count toward certificate renewal.

Operator Ethics – Standards of Professional Conduct for Certified Operators

In order to safeguard the life, health and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, standards of professional conduct apply to persons certified in accordance with 401 KAR Chapter 11. These standards state that:

(a) A certified operator shall, during the performance of operational duties, protect the safety, health and welfare of the public and the environment;
(b) A certified operator shall use reasonable care and judgment in the performance of operational duties;
(c) If a certified operator's judgment is overruled by an employer under circumstances in which the safety, health and welfare of the public or the environment are endangered, the certified operator shall inform the employer of the possible consequences;

(d) A certified operator shall be objective, truthful and complete in applications, reports, statements and testimony provided to the cabinet; and
(e) A certified operator shall ensure the integrity of the samples that the operator collects, prepares or analyzes so that results shall be a true representation of water quality.

The full set of standards is located in 401 KAR 11:020.

Certified operators who violate the standards in 401 KAR 11:020 are subject to disciplinary actions which include but are not limited to:

(a) Probation of the operator's certification for a specified period of time, not to exceed one (1) year;
(b) Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;
(c) Revocation of the operator's certification;
(d) Civil or criminal penalties; or
(e) A combination of the disciplinary actions listed above.

Disciplinary actions are outlined in 401 KAR 11:050, Section 4.

All regulations related to the certification of wastewater and drinking water operators are located in 401 KAR Chapter 11. A copy of the regulations is located in this manual, and it is recommended that you become familiar with the regulations that govern your profession.

Professionalism

Professionalism is the skill, competence or character expected of a member of a highly trained profession and the use of professionals instead of amateurs.

We are in a low-visibility PROFESSION and our customers don’t know how important our work is to their well-being.

We operators need to regard our profession as a PROFESSION, not just a job, and take our cues from other professionals.

Be proud of your profession. You, as an operator, provide one of the resources that human beings need to survive.

The purpose of treatment is to provide POTABLE WATER fit for human consumption to our customers.

KNOWLEDGE + YOUR DILIGENCE = POTABLE WATER

SOURCE WATER QUALITY + TREATMENT = FINISHED WATER QUALITY

Monitor Closely Controlled Change Set Goals

This formula for treating water is true and accurate for all systems.

SOURCE WATER + FACILITIES = TREATMENT TECHNIQUE

Since source waters are so different, treatment facilities and techniques will be different, as well. For this reason there is no "one size fits all" or quick fix that will work for all source waters or facilities. What works at one treatment facility will not necessarily work at another. Furthermore, what works at your facility today may not work nearly as well tomorrow when the source water changes.

The focus of operation should be to:

- Set finished water goals.
- Monitor closely all affective raw water quality changes.
- Understand the operational theory and design characteristics of your facility.
- Monitor and evaluate all factors that affect each treatment process.
- Take into account the big picture; recognize the interaction between processes.
- Measure and evaluate the results of all changes.
- Continuously strive to improve yourself as an operator.

"You can't build a reputation on what you are going to do."

– Henry Ford

List of Key Acronyms

AWWA	American Water Works Association
AwwaRF	American Water Works Research Foundation
BAC	Biologically Active Carbon
BAT	Best Available Treatment
BMP	Best Management Practice
CPE	Comprehensive Performance Evaluation
CTAP	Kentucky DOW Comprehensive Technical Assistance Program
DBP	Disinfection By-Product
D/DBP	Disinfectant and Disinfection By – Product
D/DBPR	Disinfectant and Disinfection By-Product Rule
DO	Dissolved Oxygen
DOW	Division of Water (Kentucky)
ES	Effective Size
ESWTR	Enhanced Surface Water Treatment Rule
GAC	Granular Activated Carbon
GWR	Ground Water Rule
GWUDI	Ground Water Under the Direct Influence of Surface Water
IESWTR	Interim Enhanced Surface Water Treatment Rule
IFE	Individual Filter Effluents
LCR	Lead and Copper Rule
LTESWTR	Long-Term Enhanced Surface Water Treatment Rule
LT2	Long-Term 2 (Enhanced Surface Water Treatment Rule)
MIEX	Magnetic Resin (trademark acronym for a resin specific for DOC removal)
MIOX	Mixed Oxidants
MGD	Million Gallons per Day
MOR	Monthly Operating Report
MRDL	Maximum Residual Disinfectant Level
NOM	Natural Organic Matter
NPDES	National Pollutant Discharge Elimination System
O & M	Operations and Maintenance
ORP	Oxidation Reduction Potential
PWS	Public Water System
QA	Quality Assurance
QC	Quality Control
RCAP	Rural Community Assistance Partnership
RTCR	Revised Total Coliform Rule
SCADA	Supervisory Control and Data Acquisition
SG	Specific Gravity
SOC	Synthetic Organic Carbon
SUVA	Specific Ultraviolet Absorbance
SWTR	Surface Water Treatment Rule
TC	Total Coliform
TCR	Total Coliform Rule
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
UC	Uniformity Coefficient
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WTP	Water Treatment Plant
WHPA	Well Head Protection Area

Review Questions for Chapter 1 – The Bottled Water Operator

1. Identify when the SDWA was enacted?
2. Identify when the operator certification process was federally mandated?
3. Operators have how many months to renew their license without having to retest?
4. What are operators bound by regulation to do if they are told to do something illegal?

Answers to Review Questions for Chapter 1 – The Bottled Water Operator

1. 1974

2. 1996

3. Six months

4. Inform whoever gave the order of the consequences.

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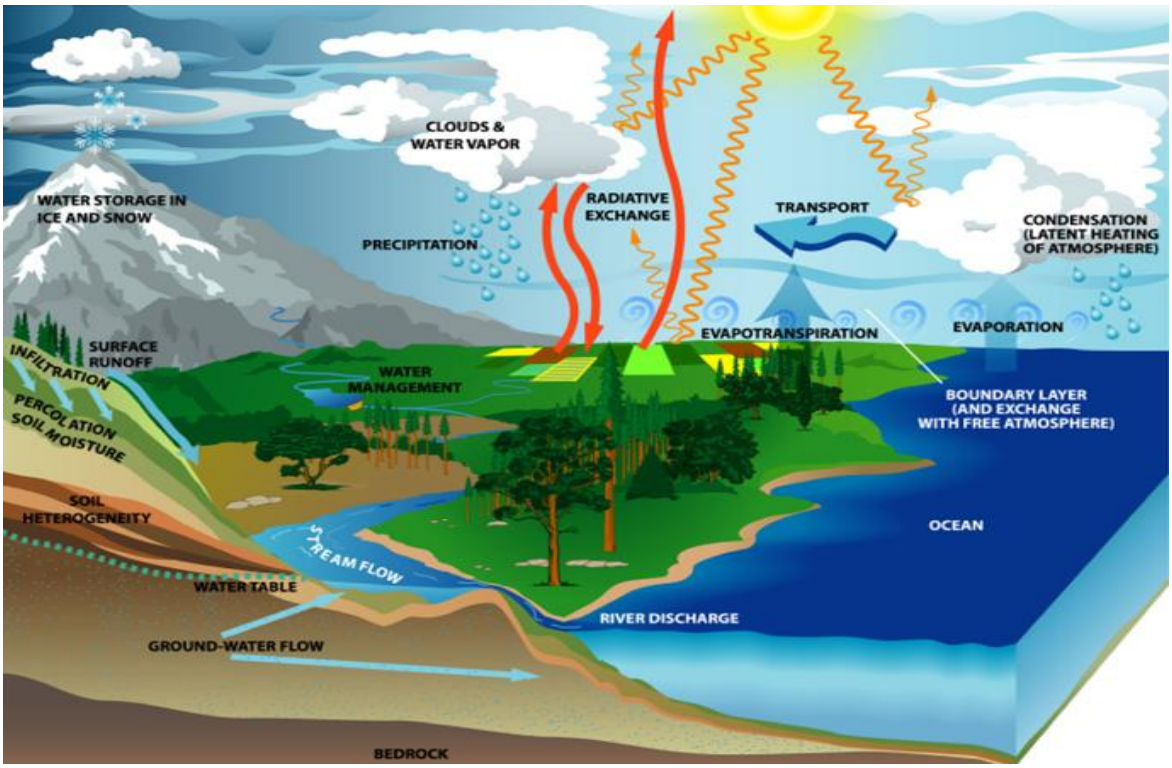
Chapter 2: WATER SOURCES

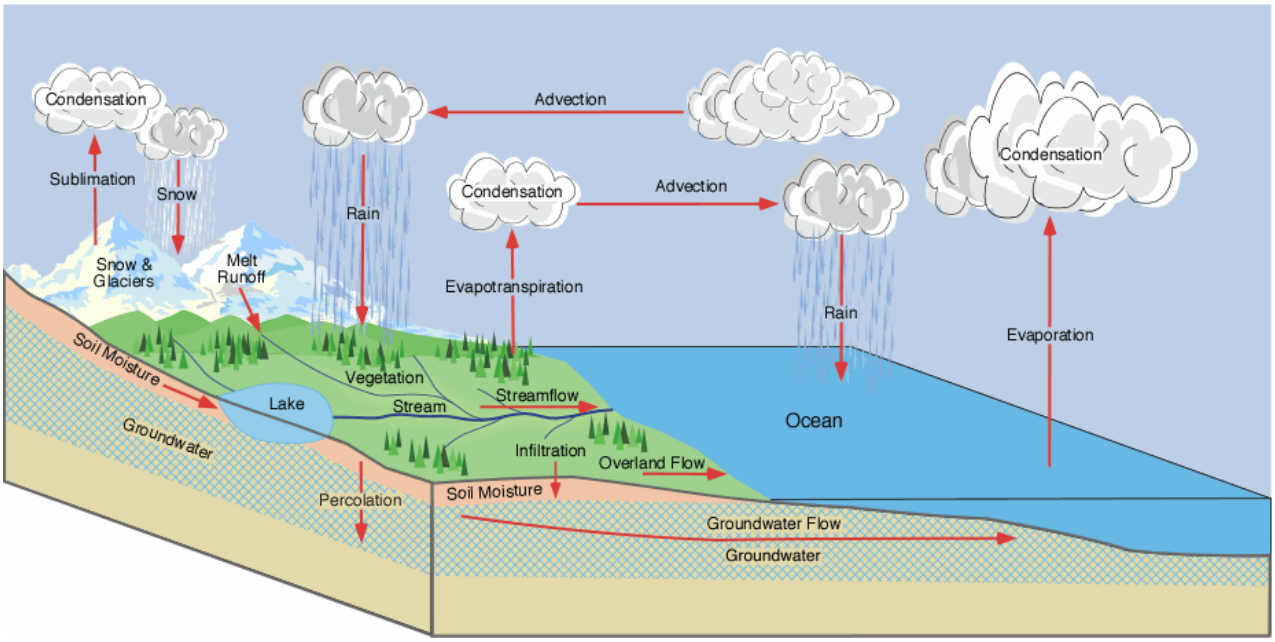


The Hydrologic Cycle

Chapter 2 Objectives

1. Define the hydrologic cycle and be able to recall the movements of water that are entailed within.
2. Delineate the three types of source water and the differences between them.
3. Determine what entities make up the EPA "Multiple Barrier Approach" to water quality.
4. Determine which type of source water is the easiest to remediate.

5. *The Hydrologic Cycle*



Evaporation – A process in which something is changed from a liquid to a vapor without its temperature reaching the boiling point.

Precipitation – The formation of rain, snow, hail, etc., from moisture in the air.

Runoff – Water, sometimes carrying agricultural or industrial wastes, that is carried by rainfall and melting snow into surface waters.

Infiltration - Water passing through the soil and recharging aquifers.

Percolation – Making a liquid pass through a filter (soil and rock) or porous substance.

Transpiration – A process where water vapor is given off to the atmosphere by a plant's surface (leaves, exposed roots, etc.).

Current federal drinking water regulations define **three distinct and separate sources of water**: 1) surface water, 2) groundwater under the direct influence of surface water, and 3) groundwater.

Surface Water

Surface water is water that is open to the atmosphere and results in overland flow. Much of this water is the result of surface runoff. Specific sources of supply include rivers, lakes, streams, springs, shallow wells and manmade impoundments.

Surface waters are easily polluted (or contaminated) with harmful chemicals and pathogenic microorganisms that cause diseases in humans. These harmful entities can enter surface water sources from runoff and upstream discharges.

The **turbidity** of surface water often fluctuates relative to the amount of precipitation that can increase treatment requirements, costs and the need of operator diligence.

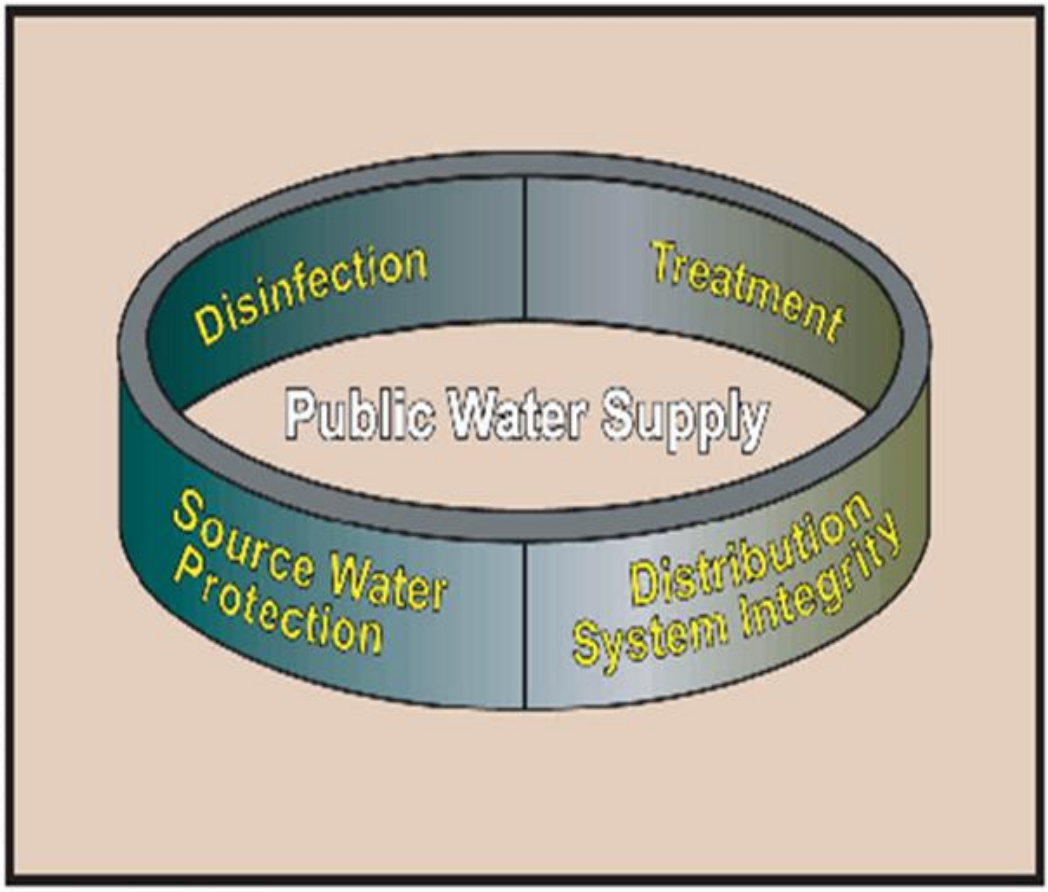
The **temperature** of surface water vacillates with the ambient temperature. This fluctuation in temperature impacts all chemical and physical treatment processes and makes consistent water quality more difficult to achieve.

Decomposing plant and animal life (organics) are prevalent in surface water. Organics can affect the taste, odor and color of water, and these organics have shown themselves to be precursors of disinfection by-products. Organics can also accelerate corrosion rates and greatly increase treatment requirements and associated costs.

Water-quality problems, such as hardness, or iron and manganese discoloration as a result of dissolved minerals, occur infrequently in surface water supplies, but can occasionally be problematic with some waters.

Surface water sources are easier to access, pollute and remediate than groundwater, and quantity can be unstable during droughts.

Because surface water supplies are so susceptible to pollution and pathogenic contamination, higher levels of treatment that will include **coagulation**, **flocculation** and **filtration** will likely be necessary. These processes are a part of the EPA ***multiple barrier concept of water treatment.***



4.3 Figure 1: Multiple barrier concept

Source Water Protection – Protecting the water before it gets to the treatment facility means less time and money to treat it when it gets to the plant.

Distribution – Provide both the quantity and quality of water to our customers.

Treatment – Remove potentially harmful chemicals and aesthetically displeasing contaminants

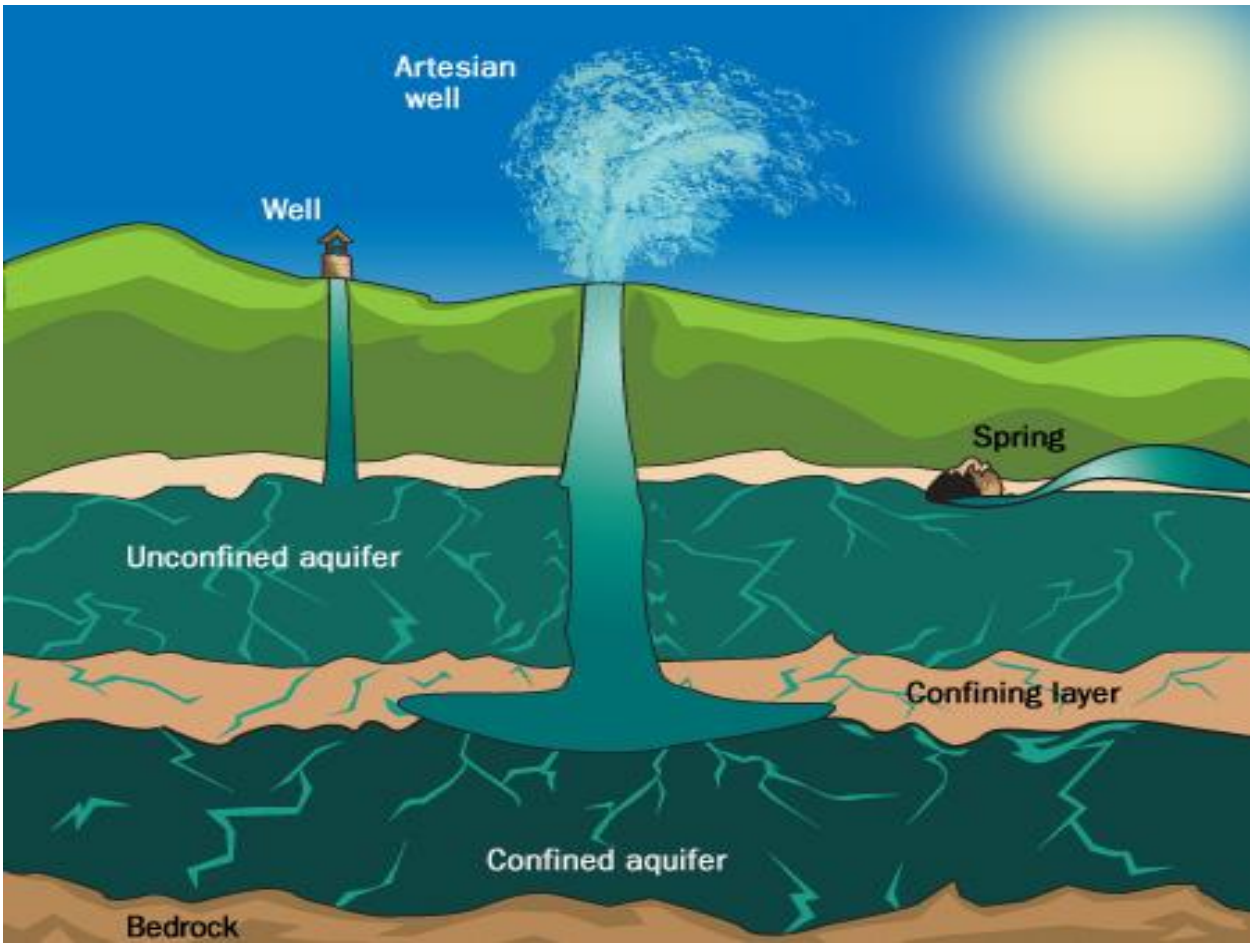
Groundwater Under the Direct Influence of Surface Water

Groundwaters under the direct influence (GWUDI) are affected by the same parameters as surface water, so the levels of treatment are much the same as surface water.

Groundwater

Groundwater is considered to be water that is below the earth's crust, which has been stored within an aquifer and does not change in character relative to precipitation events. An aquifer is an underground layer of water-bearing material. Groundwater is usually brought to the surface by a well.

Because of the earth's abilities to filter water as it travels down to the aquifer, the water quality of groundwater is generally good. Because of its lack of exposure to the atmosphere, contamination issues are usually much less than those of surface water. Because of its characteristics and the lack of outside influences, groundwater usually requires less treatment than surface water.



Purified water – This is water that has been produced by distillation, deionization, reverse osmosis or other suitable processes while meeting the definition of purified water in the US. Can contain no more then 10 ppm TDS by federal standards.

Sparkling Bottled Water – This is water that after treatment, and possible replacement with carbon dioxide, contains the same amount of carbon dioxide that it had as it emerged from the source.

Artesian water / artesian well water – This bottled water is from a well that taps a confined aquifer in which the water-level stands at some height above the top of the aquifer.

Spring water - Spring water is derived from an underground formation from which water flows naturally to the surface of the earth. It must be collected only at the spring or at a borehole tapping the underground formation feeding the spring.

Well water – This is bottled water from a hole bored, drilled or otherwise constructed in the ground, which taps the water aquifer.

Mineral water –Bottled water of this type contains not less than 250 ppm total dissolved solids. No minerals can be added to this product.

Review Questions for Chapter 2 – Water Sources

1. What are the six hydrologic cycle processes that transport water around our planet?

2. An underground layer of water bearing material is called what?

3. Which source water, ground or surface, is easier to remediate?

Answers to Review Questions for Chapter 2 – Water Sources

1. Evaporation, condensation, runoff, infiltration, precipitation, transpiration

2. An aquifer

3. Surface

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Chapter 3: WATER CHARACTERISTICS and CHEMISTRY

Chapter 3 Objectives

1. Define an MCL, MCLG and associated action levels
2. Define an inorganic contaminant and what differentiates it from organic contaminants. Explain what role both play in drinking water treatment.
3. Define pH, and explain its significance in water treatment, how it is measured and the effects of the differences in measurements, and how to alter or change pH levels.
4. Define alkalinity and what role it plays in water treatment as well as ways to change alkalinity levels
5. Determine how temperature variances could impact both the water being treated and the treatment processes and how to adapt to such changes.
6. Explain how a treatment facility can adapt to significant temperature change.
7. Define turbidity and explain its significance in the treatment process as well as how it is measured.
8. Define hardness.
9. Delineate the types of color and their potential impact on the treatment process, disinfection by-products and customers' perceptions of their water.
10. List the most predominate causes of taste and odor in drinking water and how they relate to TOC, NOM and DOC.
11. Define TDS and its impact on the treatment process.
12. Explain the importance of intake structures to the treatment process, which intake level would be superior and the means available to instigate inexpensive solutions to intake issues.
13. Explain what significance stratification has to raw water.

Water Characteristics and Chemistry

One of the first things water treatment operators should learn is the source of the water entering their plant. The water source affects both the quantity and quality of the raw water to be treated. A basic understanding of how raw water acquires its characteristics and how these characteristics will affect human health and necessary treatment techniques will help operators effectively treat their water.

Potable water is water that is safe for drinking purposes from the standpoint of its chemical, physical and biological characteristics. Public water systems' (PWS) product (potable water), must meet certain federal and state water-quality standards enforced by the EPA and the Kentucky Division of Water (DOW).

Before any system in Kentucky begins offering water for human consumption, it first must perform a series of tests on its raw water source(s) to determine 1) what type of contaminants are present in the raw water 2) how pervasive these contaminants are and 3) the likelihood of the numbers of these contaminants changing over time. This information is then used to determine what treatment processes are required, CT calculations, monitoring frequencies and design parameters for plant expansions or for new treatment facilities.

Periodically, water systems undergo sanitary surveys. Sanitary surveys evaluate source water characteristics, treatment process effectiveness, distribution system efficiencies, certified operator availabilities and capacity development guidelines.

Basic knowledge of water quality, characteristics and treatment processes are necessary to competently perform the duties of a certified treatment operator. After gaining this knowledge, using it on a regular basis will hone your skills and improve your performance as well as the performance of the plant.

Maximum Contaminant Levels

Maximum Contaminant Levels (MCLs) are

PRIMARY MCLs		SECONDARY MCLs	
NITRATE	10.0 mg/L	**SULFATE**	250 mg/L
FLUORIDE	4.0 mg/L	**FLUORIDE**	2.0 mg/L
LEAD	0.05 mg/L *	**IRON**	0.3 mg/L
COPPER	1.3 mg/L **	**MANGANESE**	0.05 mg/L
TURBIDITY	0.3 NTU ***		

* Action Level 0.015 mg/L ** Action Level 1.3 mg/L *** As an average of monthly samples

Lead and Copper Rule

"The treatment technique for the rule requires systems to monitor drinking water at customer taps. If lead concentrations exceed an action level of 15 ppb or copper concentrations exceed an action level of 1.3 ppm in more than 10% of customer taps sampled, the system must undertake a number of additional actions to control corrosion. If the action level for lead is exceeded, the system must also inform the public about steps they should take to protect their health and may have to replace lead service lines under their control." http://water.epa.gov/lawsregs/rulesregs/sdwa/lcr/index.cfm

When MCLs are exceeded, the consuming public MUST be informed as dictated by the Public Notification Rule and Consumer Confidence Reporting.

MAXIMUM CONTAMINANT LEVEL GOALS (MCLG) represents the level of a contaminant that would pose no detrimental health effect to humans. It is often less than the MCL for that individual contaminant. As technology and/or compliance treatment costs improve, the MCL will gradually be lowered by the EPA until it equals the MCLG.

TREATMENT TECHNIQUES – Some recent regulatory additions and changes necessitate the implementation of new or different treatment techniques for the removal of certain contaminants in drinking water. Some of these treatment challenges are as follows:

- **CT for Giardia** (3-log removal), viruses (4-log removal) and cryptosporidium (up to 6-log removal);
- **TOC** percent removal requirement based on upon raw water TOC and alkalinity levels;
- **DBP's** flushing and cleaning requirements for distribution systems; and
- **Lead and Copper** removal and public notification requirements whenever action levels are exceeded.

There are different techniques and methods used to treat the contaminants in water. The type of treatment used is dependent on monetary considerations, source water quality and engineering recommendations. Choosing the proper application requires diligence.

Water Quality Problem	Treatment
1. **Coliforms or icrobiological contamination**	1a. disinfection (chlorination) 1b. disinfection (other oxidants – ozone, chlorine dioxide, chloramination) 1c. coagulation, flocculation, sedimentation, filtration and disinfection
2. **Turbidity**	2. coagulation, flocculation, sedimentation and filtration
3. **Odors**	3a. clarification (coagulation, flocculation, sedimentation and filtration 3b. oxidation (chlorination or permanganate) 3c. special oxidation (chlorine dioxide) 3d. adsorption (GAC or PAC) 3e. aeration
4. **Iron and/or manganese**	4a. sequestration (poly or ortho phosphates) 4b. removal by special ion exchange 4c. permanganate and greensand 4d. oxidation by aeration* 4e. oxidation with chlorine* 4f. oxidation with permanganate *filtration must follow oxidation
5. **Excessive hardness**	5a. ion exchange softening 5b. lime (and soda) softening
6. **Dissolved minerals (high total dissolved solids**)	6a. ion exchange 6b. reverse osmosis
7. **Corrosivity**	7a. pH adjustment with chemicals 7b. corrosion inhibitor addition (zinc phosphate, silicate)
8. **Preventative treatment** **a. fluoridation** **b. trihalomethanes (THMs**)	8a. add fluoride chemicals 8b. (1) do not prechlorinate, disinfect with ozone, chlorine dioxide or chloramines 8b. (2) remove THM precursors 8b. (3) remove THMs after they form

Inorganics

Non-life forms, such as sand, clay, silt, salts and metals, comprise the majority of the inorganics we see in the treatment plant. In addition there are some manmade chemical compounds developed from non-life materials that appear from time to time in our source water as a result of the erosion and dissolving of minerals or as by-products of industrial processes and pollution.

Some of the more common inorganic contaminants are lead, copper, barium, cadmium, nitrates and arsenic, and all of these are toxic to humans. Treatment for inorganic substances usually involves a combination of processes and is dependent upon which inorganic contaminant needs to be removed. Some of the more commonly used processes for inorganic removal include oxidation, coagulation combined with settling and filtration, carbon adsorption, lime softening, ion exchange, reverse osmosis, stabilization and chlorine and UV disinfection.

A very prevalent drinking water problem relative to inorganics is the presence of iron or manganese, calcium or magnesium hardness and total dissolved solids (TDS).

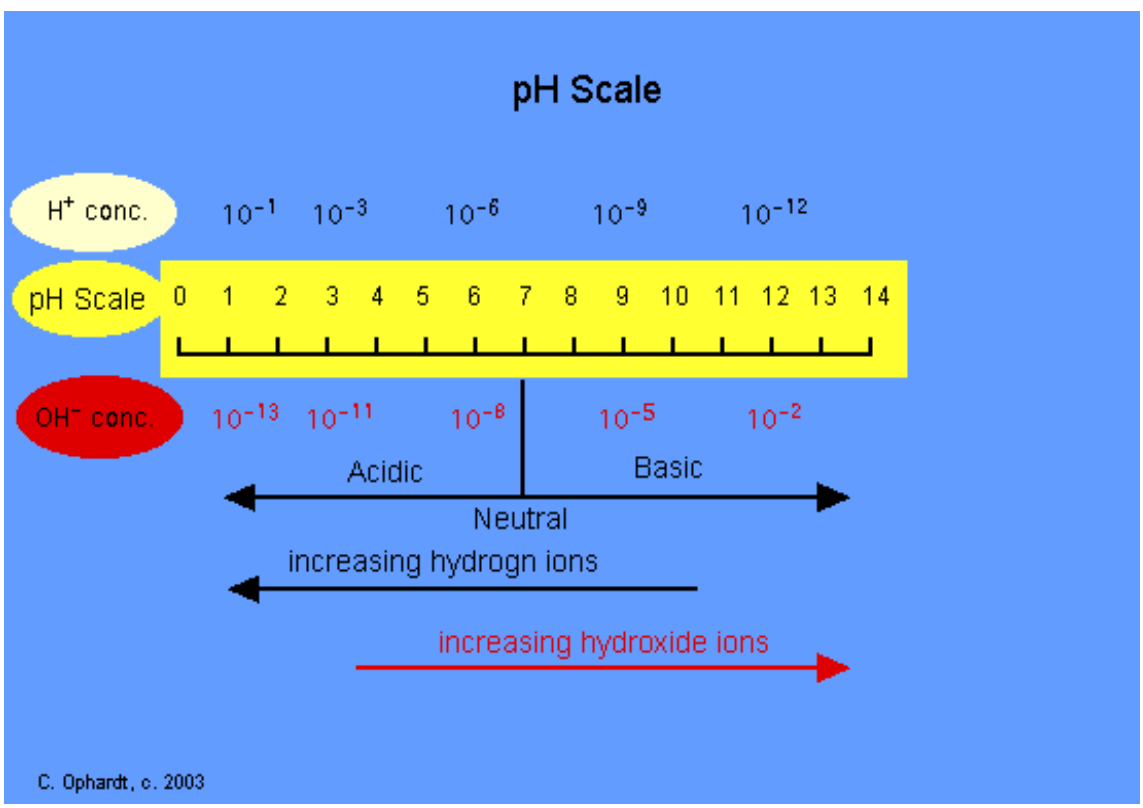
Without proper restoration, mining can have severe impacts upon stream hydrology, morphology, biota and water quality.

Surface Water Characteristics and Monitoring Parameters

Some monitoring of surface source water is done frequently to better understand the significance and bearing on the successful operation of the treatment facility.

Among them are the following:

pH actually describes the hydrogen ion concentration in a water sample. pH is measured on a scale from 0 to 14 with a reading of 7 being neutral. The pH meter measures the relative amount of hydrogen ions versus hydroxyl ions in a solution. The lower the pH value, the greater the proportion of hydrogen to hydroxyl ions in the solution and the more *acidic* the solution. As pH values rise on the scale, the relative amount of hydroxyl ions proportionate to hydrogen ions becomes larger and the solution becomes more *basic*. A pH measurement of 7.0 is considered neutral and represents the point on the scale where the amount of hydrogen and hydroxyl ions are equal. Each numerical change on the pH scale is actually indicative of a tenfold change in the hydrogen ion concentration. Frequently, a change in pH indicates a change in water quality. Monitoring and understanding the effect pH has on treatment processes can significantly improve the optimization of these processes. The measurement of pH is established using a calibrated ph meter.



Alkalinity describes the ability of a substance to neutralize an acid. Alkalinity is a buffer to pH, which means that the higher the level of alkalinity is in a solution, the more acid it will take to lower the pH. Chemicals used to increase the alkalinity level in water (lime, caustic soda, soda ash, etc.) have the effect of adding hydroxyl ions to a solution. When this addition of alkalinity creates an excess of hydroxyl ions in relation to hydrogen ions in the solution, the pH of the solution will increase accordingly. When acids are added to a solution (the addition of hydrogen ions) containing alkalinity, the hydrogen ions bind with the hydroxyl ions in solution (essentially forming water molecules) and reduce the alkalinity level in the solution without substantially affecting pH.

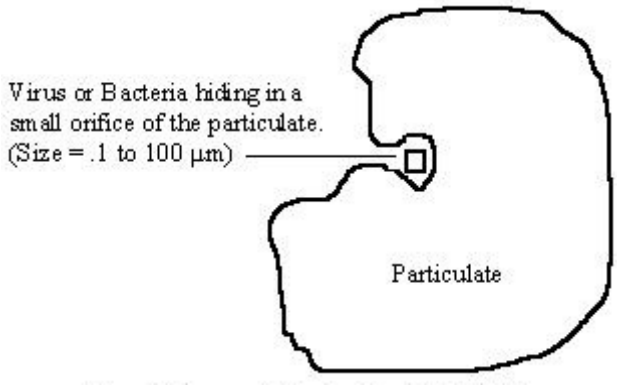
This is the buffering effect. As more acid is added to the solution, the alkalinity will gradually be used up and the pH will then decrease accordingly. When more alkalinity is once more added to the water, it again creates an excess of hydroxyl ions and the pH will begin to rise dependent upon the amount of alkalinity added. Alkalinity is determined mathematically after observing a color change while titrating a weak acid into a solution.

Temperature is measured as degrees Fahrenheit or degrees Celsius. Temperature impacts every treatment process, but it is the parameter of least control for an operator. Chemical reactions occur faster in warmer waters and particles settle out more quickly in warmer waters. Warmer waters are more conducive to the growth of organic substances and taste and odor issues are more noticeable in warmer temperatures. Measured by a thermometer, temperature affects the recommended filter backwash rates. Sometimes it is necessary to convert temperatures in Fahrenheit to Celsius and vice versa.

^{o} Fahrenheit = (^{o} Celsius X 1.8) + 32 Celsius = (^{o} Fahrenheit – 32) ÷ 1.8

Turbidity is a measure of suspended matter in a water sample. It can be comprised of a myriad of entities including organic and inorganic substances. Turbidity can be a viable indicator of the amount of contamination or pollution in water, and as such, turbidity levels should be minimized throughout the treatment process. Turbidity can also interfere with disinfection efforts by shielding pathogens from disinfection efforts.

Simplified Diagram of a Pathogen Encapsulated by a Particulate

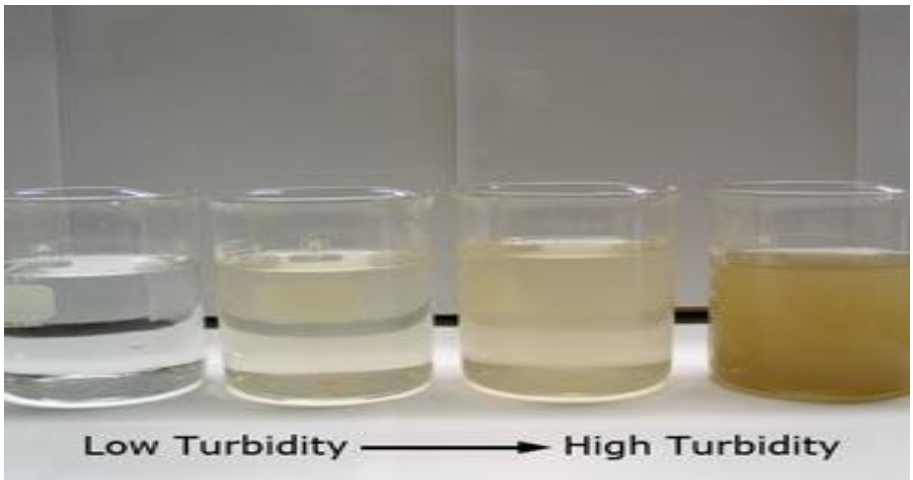


Courtesy of *Eric Karch and David Loftis*

Regulation requires water purveyors to achieve monthly average turbidity levels to be below 0.3 NTU measured in the combined filter effluent every four hours of plant operation. No treated water should ever exceed 1.0 NTU.

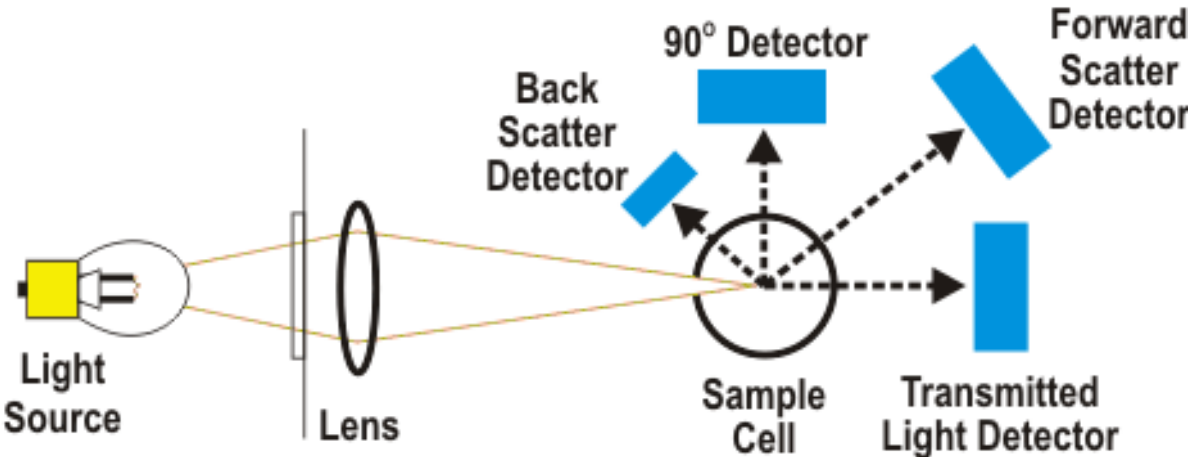
Settled water turbidity should be maintained below 1.0 NTU and finished water turbidity should be maintained below 0.1 NTU. Individual filters shall be continuously monitored and notated for performance and inspection and maintenance. Measurement of turbidity is obtained using a calibrated and standardized turbidimeter.

Turbidimeters measure the reflective properties of the particulate in a sample. The results are shown as NTUs (nephelometric turbidity units). Differently shaped and colored particulate will produce varied results on the turbidimeter.



HACH
2100N Turbidimeter
NTU
EBC
NEPH
CALIBRATE
EDIT
ENTER
CAL
RANGE
SIGNAL AVG
RATIO
PRINT

12.46
NTU
READ ENTER
CAL
WATERPROOF
OAKTON
Turbidimeter
T-100


90° Detector
Forward Scatter Detector
Back Scatter Detector
Light Source
Lens
Sample Cell
Transmitted Light Detector

Hardness describes water containing a high level of calcium and magnesium ions. Excessive hardness in water causes soap not to lather and scale deposition on pipes, valves, meters, boilers, dishes, cookware and water heaters. Hardness can sometimes impart objectionable tastes to water, as well as damaging some industrial processes. Softened water delivered to customers in Kentucky usually has a hardness level between 80 and 90 mg/L as calcium carbonate (CaCO3). Hardness levels are determined by titrating a weak acid into a solution while observing a color change.

Color relative to water is water that is aesthetically objectionable or it can be any water not deemed to be clear. There are **two types** of color:

- **True color**
  - True color is caused by decomposing organic materials in the water.
  - Since true color is composed of organics, these may aid in the formation of disinfection by-products (DBPs), as well as biofilms and biological regrowth in distribution systems.
  - Measured in color units (CU) by using a spectrophotometer.

- **Apparent color**
  - Apparent color is caused by precipitated inorganics, frequently iron (Fe) and manganese (Mn) in the water.
  - This type of color produces discoloration in the water as well as staining basins, tubs and laundry. Iron at levels greater than (>)0.3 mg/L causes red water, and manganese greater than (>) 0.05 frequently causes black water.
  - Apparent color is measured in mg/L using a spectrophotometer or a reagent method.

Taste and odor is aesthetically objectionable water that possesses any taste and odor outside of what the customer is used to. These issues can be caused by many major influences, such as algae, reservoir stratification, decaying organics, wastewater, industrial wastes, minerals, dissolved gasses, incompatible chemical combinations and, last but certainly not least, treatment plant and distribution system shortcomings. Measurement is done by using the Threshold Odor Number

(TON method) where samples are diluted and arranged in order for detection by a panel of human observers. Average level of detection is used to describe the sample.

Total Organic Carbon (TOC) describes the organic composition of a water sample. TOCs are precursors to disinfection-by-product (DBP) formation. The most effective traditional removal of TOC is accomplished by enhanced coagulation, which is coagulation at a low pH. Activated carbon adsorption is also an effective method of removal. Regulatory removal requirements are based on raw water levels and alkalinity levels. Due to the costs associated with TOC analysis, samples are generally sent to an approved laboratory. Dissolved Organic Carbon (DOC) may be used as a surrogate for TOC for in-plant process control and levels can be determined by a spectrophotometer using the UV – 254 method.

Volatile Organic Carbon (VOC) are organic chemicals that have a high vapor pressure at ordinary, room-temperature conditions. VOCs are numerous and varied and are both manmade and naturally occurring chemical compounds. They can pose health problems including damage to the reproductive system, liver, nervous system and other organs. Common VOCs come from household products through septic systems, gasoline compounds (such as MTBE and benzene) and industrial solvents. Current regulatory procedures establish MCLs, MCLGs, and mandated treatment technologies based on ingestion of 2 liters per day. Water treatment operations subject to the SDWA must implement treatment and monitoring systems to ensure SDWA requirements are being met.

Your source water will frequently contain volatile organic compounds or chemicals (VOCs). Some of the more frequently encountered VOCs are Benzene, Toluene, Formaldehyde, Xylene, Chloride, Ethylene glycol, fuel oil, vehicle exhaust and gasoline. Most VOCs are absorbable to some extent. More weakly adsorbing compounds can often be removed by air stripping.

Synthetic Organic Carbons (SOC) enter drinking water from pesticides and herbicides. Synthetic Organic Chemicals (compounds) (SOCs) are also commonly found in surface water. Some commonly found SOCs are Adipate, Lindane, Atrazine, 2, 4-D, Toxaphene, Diquat, Weed-B-Gone, Scotts 4XD and Bladex B.

Some organics in drinking water are caused by the decay of naturally occurring vegetation. These decay compounds are called lignins or tannins. A much larger group of organic contaminants are the thousands of manmade organic chemicals that have been created in the last 50 years. The EPA regulates some of these contaminants as health risks in the Safe Drinking Water Act (SDWA). These manmade organic contaminants can be grouped into subcategories that are often more recognized (and more easily pronounced) than the more formal chemical name. These subcategories are given below, along with a few illustrations of specific contaminants in each subcategory.

1. Industrial solvents, such as trichloroethylene, carbon tetrachloride
2. Hydrocarbons, such as benzene, xylene, toluene
3. Pesticides such, as aldicarb and chlordane
4. Herbicides such, as alachor and silvex

Trihalomethanes are the by-products of the chemical reaction between chlorine and the naturally occurring organics in drinking water. These naturally occurring carbon compounds are not hazardous by themselves, but when combined with chlorine, produce by-product reactants, which have a health concern.

TREATMENT OPTIONS

There are three treatment methods that have been shown to be effective in removing organics from drinking water. They are aeration, adsorption using activated carbon and oxidation.

Activated Carbon Treatment: Advantages and Disadvantages

Activated carbon has an enormous surface area for the volume it displaces. One pound has the surface area of more than a football field. Activated carbon is a material that attracts many types of organic contaminants onto its surface. Once the carbon's removal capacity is used up, the carbon may be returned to the manufacturer for

rejuvenation (for very large users) or can be disposed of appropriately. Activated carbon can foster the growth of bacteria by concentrating the food the bacteria needs to live. A final concern with activated carbon is the possible release of contaminants already adsorbed. This is known as “dumping” and could occur when the carbon is nearly saturated with contaminants, and a contaminant of higher preference displaces another with lower adsorption preference.

Aeration: Advantages and Disadvantages

Aeration treatment consists of passing large amounts of air through the contaminated water. The efficiency of the device is improved by breaking up the water flow into many small droplets. The goal is to maximize the water's surface area to allow the contaminants to volatilize into the air stream. Aerator configurations include packed tower and low-profile bubble tray styles. Where aeration is used, two operational problems are possible:

Where there are elevated levels of iron or manganese, rusty staining of water use fixtures and clothing is possible.

Bacterial slime may grow in aerators requiring continuous or periodic chlorination.

The advantage of aeration is that there is no disposal of radioactive waste or regeneration of the treatment system necessary.

Oxidation: Advantages and Disadvantages

Certain organic contaminants will chemically react with oxygen and oxygen-like compounds. After this treatment is accomplished, the resultant compounds may be either fully neutralized or will have a lower level of hazard. Further treatment may still be necessary. Oxidizing chemicals include ozone, potassium permanganate, hydrogen peroxide and hypochlorite.

The Safe Drinking Water Act (SDWA) of 1974 required the administrator of the EPA to establish minimum national standards for controlling the presence of contaminants in drinking water. This means that any technology used to remove SOCs from drinking water must be at least as effective as GAC. The SDWA amendments declare granular activated carbon (GAC) as the "best available control

technology" (BAT) for removing synthetic organic chemicals (SOCs) from drinking water.

Dissolved Oxygen (DO) is the amount of oxygen dissolved in water, and it can impact water treatment operators in a number of ways. The amount of oxygen water can support in its dissolved state is temperature-dependent. Iron (Fe) and manganese (Mn) will exist in their reduced (colorless) form when dissolved oxygen levels are low or nonexistent. Colder water can hold more dissolved oxygen than warmer water. Dissolved oxygen levels at or near 100 percent saturation can release oxygen into filters in the winter and could be a cause of air binding of the filters. Low or zero dissolved oxygen levels at the bottom of lakes or reservoirs often cause taste and odor problems. The presence of dissolved oxygen in water can contribute to the rate of corrosion in piping systems. Dissolved oxygen levels can be determined with the use of a DO meter with values expressed in mg/L.

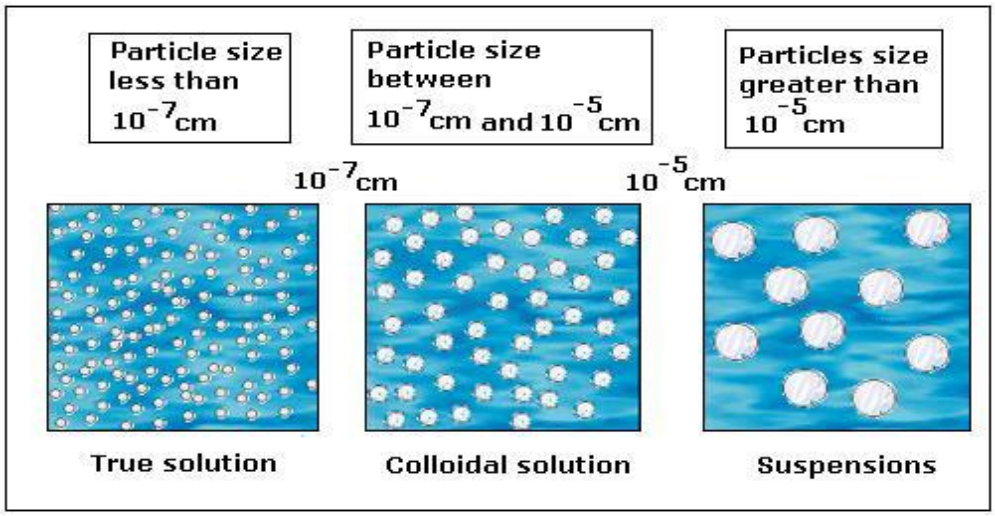
Total Dissolved Solids (TDS) are all the solids that are dissolved in water. In potable water, total dissolved solids consist mainly of inorganic salts, minute amounts of organic matter and dissolved gases. Total dissolved solids can be reduced with oxidation/settling/filtration and can be removed by distillation or membrane filtration. The higher the total dissolved solid concentration, the greater the likelihood of taste and odor issues, as well as scale deposition on pipes and fixtures. The total dissolved solid concentration is measured on a sample of water that has passed through a fine mesh filter to remove the suspended solids.

The water that passes through the filter is evaporated, and the remaining residue represents the total dissolved solid level. Generally, waters with a TDS content < 50 mg/L are the most desirable for domestic uses.

Surface water sources that are polluted by man and nature are likely to contain quite a variety of pollutants. Biological organisms, such as bacteria, viruses and protozoa as well as suspended and dissolved organic and inorganic materials, are usually prevalent in surface water. By-products of land erosion and runoff, dissolved minerals, decomposed plant and animal materials, airborne contaminants, industrial discharges and the ever–present human and animal waste continue to contaminate our surface water sources.

For conventional treatment purposes, particulate impurities can be divided **into two general classifications**:

- **Settable solids:** larger-sized particles, such as sand and heavy silts that can be easily removed from water by slowing down the flow enough to allow natural gravity settling to occur.
- **Nonsettleable solids** (colloidal matter): smaller-sized particles, such as fine clays and silts, bacteria and organic residues that do not readily settle out and require chemical treatment to produce larger particles that are settleable.



If you, as an operator, don't know the characteristics of your raw water, how can you effectively treat it?

- What contaminants are present?
- How prevalent are these contaminants?
- How frequently and how much will these parameters change?

"Potable water" is water that is safe for human consumption and must meet certain federal and state water quality standards.

Public Health Protection Challenges

- There is an increase in the frequency, intensity and duration of extreme weather events (droughts, rain events, ice storms, etc.).

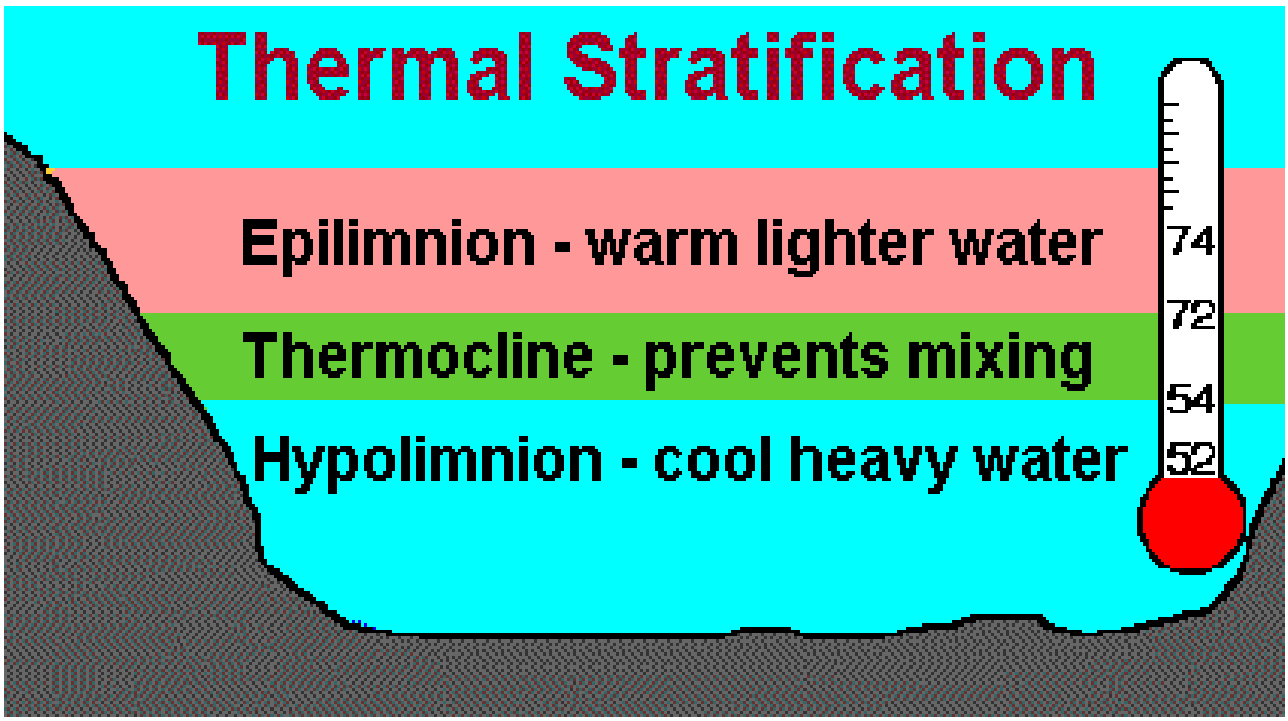
- Some pathogens are acquiring resistance to conventional disinfection.

    - 0.2 log or less of inactivation of Cryptosporidium with free chlorine at 5 – 15 mg/L for 60 – 240 minutes. (Finch, 1995)

- Meeting existing compliance levels is not always effective in preventing disease.

Cryptosporidium Outbreaks vs. Finished Water Turbidity

Location of Outbreak	Year	General Plant Information	Turbidity Information
Las Vegas, Nevada (CDC, 1996)	1993-1994	No apparent deficiencies; SWTR compliant; performed chlorination, filtration (sand & anthracite)	Average raw 0.14 NTU 1/93-6/95 Maximum of 0.3 Reg 0.17 NTU
Milwaukee, Wisc. (CDC, 1996 Logsdon, 1996)	1993	SWTR compliant; deteriorated source quality & decreased coag/floc process effectiveness	Dramatic temporary finished turbidity, high of 2.7 NTU
Jackson County, Oregon (USEPA, 1997)	1992	Poor plant performance (excessive levels of algae & debris) no pre-chlorination	When outbreak occurred, filtered water averaged 1 NTU
Carrolton, Georgia (USEPA, 1997 Logsdon, 1996)	1987	Conventional filtration plant; sewage overflow into intake, filters placed into service without backwash	Filtered turbidity reached 3 NTU from one filter



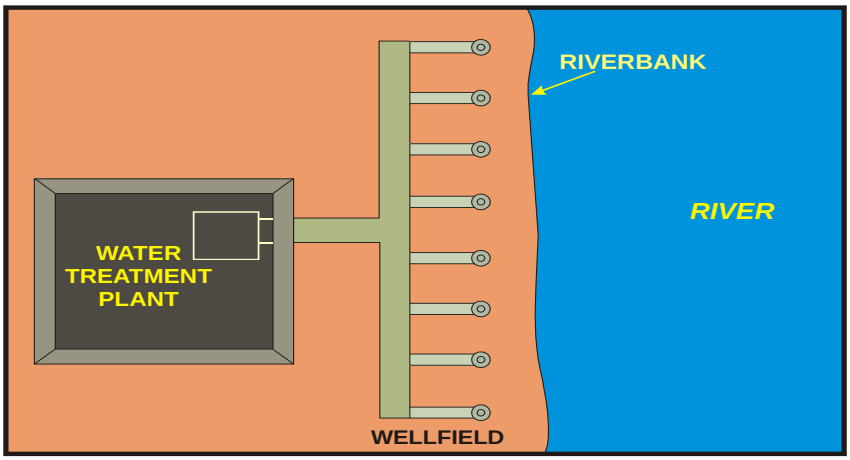
When lakes or reservoirs "stratify," as in the illustration above, all the entities that have settled out since the last turnover come to the upper regions of the body of water. This layer of settled material can include iron, manganese, organics and any number of other substances that can increase the time, cost and attention necessary to treat this water and make it potable.

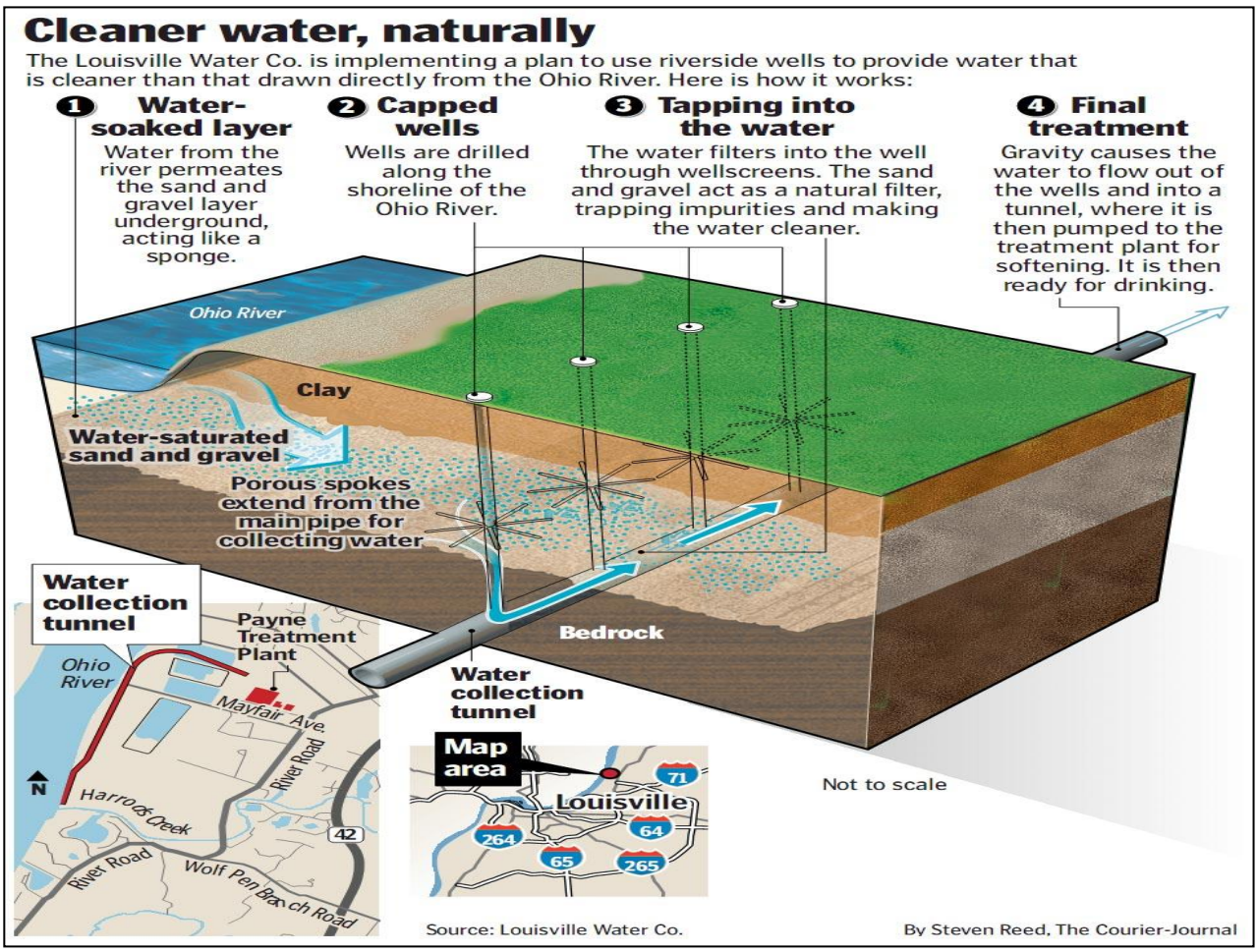
INTAKES

Because of stratification and changing water levels throughout the year, many treatment facilities have multilevel intakes. Some facilities employ floating intake structures, but most are fixed in place. It is important to keep all of the intakes clear so they are available when needed. In multilevel intakes, the top and middle intakes usually provide the best water for treatment.

Some facilities are employing riverbank filtration to allow nature to "clean" the water before arriving at the treatment facility. If done successfully, this will greatly decrease the entities present in surface water and because of this natural filtration, cut treatment costs. Louisville has recently employed this method with the use of Ranney collector wells.

Louisville Water Company
Riverbank Filtration Project
Collector Wells (4) and Tunnel
OHIO
RIVER
SAND &
GRAVEL
AQUIFER
LATERALS
BEDROCK
Water Supply Tunnel
to Plant


RIVERBANK
RIVER
WATER
TREATMENT
PLANT
WELLFIELD


Cleaner water, naturally
The Louisville Water Co. is implementing a plan to use riverside wells to provide water that is cleaner than that drawn directly from the Ohio River. Here is how it works:
1 Water-soaked layer
Water from the river permeates the sand and gravel layer underground, acting like a sponge.
2 Capped wells
Wells are drilled along the shoreline of the Ohio River.
3 Tapping into the water
The water filters into the well through wellscreens. The sand and gravel act as a natural filter, trapping impurities and making the water cleaner.
4 Final treatment
Gravity causes the water to flow out of the wells and into a tunnel, where it is then pumped to the treatment plant for softening. It is then ready for drinking.
Ohio River
Clay
Water-saturated sand and gravel
Porous spokes extend from the main pipe for collecting water
Bedrock
Water collection tunnel
Water collection tunnel
Payne Treatment Plant
Ohio River
Mayfair Ave.
River Road
Harrods Creek
42
River Road
Wolf Pen Branch Road
N
Map area
71
Louisville
64
264
65
265
Not to scale
Source: Louisville Water Co.
By Steven Reed, The Courier-Journal

Review Questions for Chapter 3 – Water Characteristics and Chemistry

1. Differentiate between health and aesthetic issues.
2. Each transition on the pH scale, for instance from a 6 to a 7, is actually how much of a difference?
3. _____ is the ability of water to neutralize acids.
4. What very important parameter of the treatment process is one the operator has no control over? Explain the parameter of the treatment process that the operator has no control over.
5. What is measured numerically by the calcium carbonate concentration of water?
6. What is the cloudy appearance of water is called? Identify the cloudy appearance of water.
7. What are the two types of color? Name them.
8. TOC, when in contact with free chlorine, produces what? Describe what TOC produces when it comes in contact with free chlorine.
9. One way many of our customers judge the quality of their drinking water is the absence of _____ and _____. Describe those ways.
10. Water that is cold can hold more _____ _____ than water that is considerably warmer. Differentiate between cold and hot water characteristics.

Answers to Review Questions for Chapter 3 – Water Characteristics and Chemistry

1. Health is illness or death. Aesthetic is objectionable to the senses but not the cause of illness.
2. 10 times
3. alkalinity
4. temperature
5. hardness
6. turbidity
7. true and apparent
8. DBPs
9. taste and odor
10. dissolved oxygen

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Chapter 4: STORAGE

Chapter 4 Objectives

1. Describe the state regulations related to drinking water storage, operation and maintenance.
2. Explain the difference between the two types of maximum contaminant levels (MCLs).
3. Describe the three types of storage and the associated design features.
4. Explain why excessive water age is one of the most important factors related to water quality deterioration.
5. Explain the two ways to address water age issues.
6. Identify the chemical, biological and physical issues related to water quality problems.
7. Demonstrate the ability to calculate conversions, area, and volume related to water storage.

Traditionally, finished water storage facilities have been designed to equalize water demands; reduce pressure fluctuations in the distribution system and provide reserves for firefighting, power outages and other emergencies. Some storage facilities have been operated to provide adequate pressure and have been kept full in order to be prepared for emergency conditions. Additionally, some storage facilities have been designed such that the high-water level is below the hydraulic grade line of the system, making water turnover extremely difficult. If the hydraulic grade line of the system drops significantly, very old water may enter the system. If tanks are kept full yet are underutilized, the stored water ages and water quality is frequently compromised.

Purpose of Storage: To meet all consumer demands

Storage Quantity: Ensure an adequate supply for fire protection, peak usage periods, distribution maintenance, plant shutdown, major leaks, pressure maintenance or any other consumer needs.

Quality: Provide pathogen-free water that is also free from inorganic precipitates, biological activity, corrosion by-products, taste, odor, color, turbidity, disinfection-by-products and any other factor that is detrimental to the health or aesthetic properties of the water.

Under-storage: Limits the ability to get the necessary quantity of water to the consumer when needed. Can allow pressure drops during peak usage if sufficient quantities aren't maintained.

Over-storage: Can lead to water-quality degradation due to the water age or lack of turnover.

Ideally, the operator needs to maintain the minimal amount of water necessary to meet demand on a daily basis in order to prevent water-quality degradation and residual chlorine depletion due to a lack of turnover.

Types of Storage

- Underground
- Ground Level
- Elevated Storage

Design Features

Storage tanks should be:

- ✓ Covered to prevent contamination
- ✓ Vented to relieve vacuum conditions
- ✓ Screened to prevent entry of birds, rodents, etc.
- ✓ Screened and flappered overflows that extend to or below ground level and be directed away from the tank foundation, businesses, homes, etc.
- ✓ Protected against corrosion and its by-products.
- ✓ Built and maintained to ensure structural integrity

Operation and Maintenance

Inspection: Coatings (paint), security, safety, corrosion protection, stratification, vents, overflows, telemetry, valve operation, etc. Inspection can be accomplished by draining the facility, diving, remote sensing or float down.

Monitoring: Total coliform, disinfectant residuals, pH, temperature, DBPs, bacteria concentration (heterotrophic or standard plate counts), corrosion, scale, nitrification (especially in systems using chloramines), taste, odor, iron, manganese, turbidity, gases, etc.

Cleaning and Disinfection: Draining and cleaning of tanks should be performed when necessary and should be considered on an annual basis. Painting and coatings should be evaluated at least every five to 10 years.

Storage Tank Disinfection

Kentucky Administrative Regulations concerning Disinfection of New and Repaired Water Lines:

(1) New Construction Projects and Line Extensions

(a) Disinfection of water lines. A water distribution system, including storage distribution tanks or all extensions to existing systems, shall be thoroughly disinfected before being placed in service.

(b) A water distribution system shall disinfect with chlorine or chlorine compounds, in amounts as to produce a concentration of at **least fifty (50) ppm** and a residual of at least **twenty-five (25)** ppm at the end of **twenty-four (24) hours**, and the disinfection shall be followed by a thorough flushing.

(c) Other methods and testing procedures that provide an equivalent level of protection may be used if the cabinet grants prior written approval.

Continuous Method

1. Drain and clean tank.
2. As tank is refilling, inject chlorine into the flow to produce 50 ppm.
3. Hold for 24 hours and then measure the free residual (must be > 25 ppm).
4. Drain and dechlorinate the chlorinated water in the tank.
5. Refill with treated water and measure total coliforms and chlorine residual.
6. Return to service.*
7. Record and maintain records for a minimum of five (5) years.

Spray/Swab Method

1. Drain and clean tank.
2. Fill tank with a measured volume (i.e. 1 ft. deep).
3. Dose premeasured volume at 250 ppm.
4. Swab or spray interior walls and ceiling with the chlorine solution.
5. Repeat process no sooner than one hour later.
6. Allow an additional 30 minutes contact time.
7. Drain and dechlorinate the chlorinated water.
8. Refill with treated water and measure total coliforms and chlorine residual.
9. Return to service.*
10. Record and maintain records for a minimum of five years after fulfilling bacteriological sample requirements.

** If a new installation is involved, the continuous method must be used and negative coliform results must be obtained before being placed into service.*

Operational Issues

- ✓ Calibrate and maintain the accuracy of the telemetry and valving systems.
- ✓ Drawdown tanks as far as feasible before refilling so water turnover is achieved.
- ✓ Design the tank with a smaller diameter riser to increase velocity and increase mixing.
- ✓ Contemplate retrofitting older designs with separate inlets and outlets to induce water circulation and mixing.

Water Age

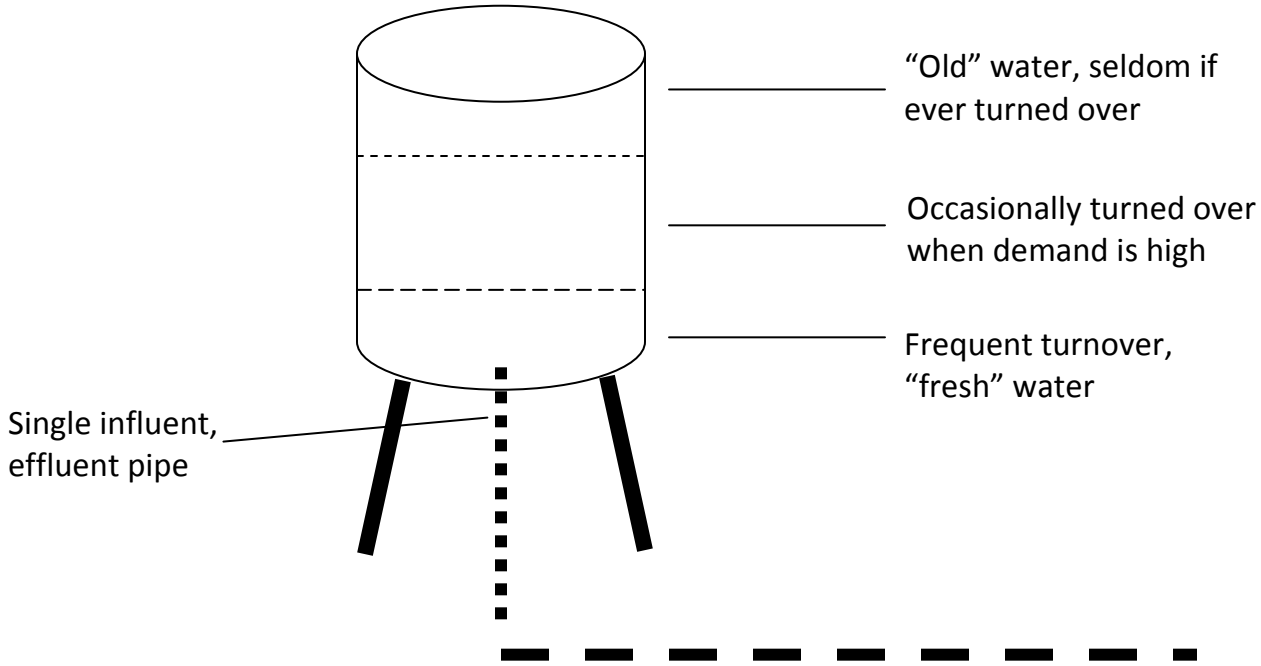
Traditionally, many water storage facilities were built with a common inlet and outlet. Water-quality problems associated with water storage can be classified as chemical, microbiological or physical.

Excessive water age is probably the most important factor related to water-quality deterioration. Long detention times can be conducive to microbial growth and chemical changes. Excessive water age is usually caused by 1) underutilization and 2) short circuiting within the storage facility. Poor mixing (including stratification) can make water-quality problems worse by creating zones within the water storage facility where the water age significantly exceeds the average water age throughout your system.

Summary of Water-Quality Problems Associated with Finished Water Storage Facilities

CHEMICAL ISSUES	BIOLOGICAL ISSUES	PHYSICAL ISSUES
Disinfectant Decay	Microbial Regrowth*	Corrosion
Chemical Contaminants*	Nitrification*	Temperature/Stratification
DBP Formation*	Pathogen Contamination*	Sediment*
Taste and Odors	Taste and Odors	

** Water-quality issues with direct potential health impact*



Guidelines on Water Turnover Rate

SOURCE	GUIDELINE	COMMENTS
Georgia Environmental Protection Division	Daily turnover goal equals 50% of storage facility volume; minimum desired turnover equals 30% of storage facility volume.	As part of this project, state regulators were interviewed by telephone.
Virginia Dept of Health, Water Supply Engineering Division, Richmond, Va	Complete turnover recommended every 72 hours	As part of this project, state regulators were interviewed by telephone.
Ohio EPA	Required daily turnover of 20%; recommended daily turnover of 25%	Code of state regulations; turnover should occur in one continuous period rather than periodic water level drops throughout the day
Baur and Eisenbart, 1988	Maximum 5-7 day turnover	German source, cement-based internal surface
Braid 1994	50% reduction of water depth during a 24-hour cycle	Scottish source
Houlmann 1992	Maximum 1-3 day turnover	Swiss source

Information taken from Kirmeyer, et. al., 1999

Summary

- Microbiological, chemical and physical water quality problems can occur in finished water facilities due to poor mixing or underutilization.
- Poor mixing can result from poor design and/or operational practices.
- Health-related water quality issues associated with water age or lack of water turnover:
    - DBP formation
    - Nitrification
    - Pathogen contamination
    - Increases VOC/SOC concentrations
    - Loss of disinfectant residual

Area and Volume

Area: A two-dimensional measurement (length X width). Area is a measurement of the amount of space on the surface on an object. Since the square is the basis by which these measurements are made, the units used to express this surface space are in square feet (ft^2).

feet X feet = square feet (ft^2)

Volume: A three-dimensional measurement (length X width X height). Volume is used to measure the holding capacity of an object. The basis of measuring this capacity is the cube expressed as cubic feet (ft^3).

feet X feet X feet = cubic feet (ft^3)

OBJECT	AREA (ft^2)	VOLUME (ft^3)
Rectangle	Length' x Width'	Length' x Width' x Height'
Circle	.785 x D' x D'	
Triangle	1/2 (Base' x Altitude')	
Cylinder		.785 x D' x D' x Length'
Sphere		.5236 x D' x D' x D'

Perimeter = Sum of All Sides
Diameter (D) = 2 x radius
Circumference = π (3.14) x D

Volume Examples

1. The cross-sectional area of a 12-inch pipe is _____.
   .785 x 1 ft x 1 ft = .785 ft^2

2. The volume of a standpipe that is 20 feet in diameter and 60 feet in height is _____.
   .785 x 20 ft x 20 ft x 60 ft = 18,840 ft^3

Conversions

In our industry, we don't usually use measurements in cubic feet. In order to convert cubic feet to gallons, we multiply the number of cubic feet by 7.48 gallons. To use the previous problem as an example, we would multiply 18, 840 ft^3 by 7.48 gallons.

18,840 ft^3 X 7.48 gallons = 140,923.2 gallons

CONVERSIONS		
1 psi	=	2.31 ft. of head
1 ft. of head	=	.433 psi
1 cu.ft of water	=	7.48 gallons
1 cu.ft of water	=	62.4 lbs.
1 cu.yrd	=	27 cu.ft
1 gallon	=	8.34 lbs.
1 gallon	=	3,785 ml
1 Liter	=	1,000 ml
1 Liter	=	1,000 grams
1 mg/L	=	8.34 lbs/MG
1 ppm	=	1 mg/L
1 ml	=	1 gram
1 pound	=	453.6 grams
1 pound	=	7,000 grains
1 kilogram	=	1,000 grams
1 cu.ft/sec	=	448.8 gpm
1 MGD	=	1.55 cu.ft/sec
1 MGD	=	694.5 gpm
1 HP	=	33,000 ft.lbs./min
1 HP	=	.746 kilowatt
1 mile	=	5,280 feet

We use conversions every day. Conversions are a change from one measuring or calculating system to another. Sometimes, we must convert certain measurements in order to determine dosages, volumes, velocities, etc. The key to using the conversion portion of the formula sheet (above) is to find the two entities you need to solve the problem and then decide whether to multiply or divide.

Conversion Examples

If you are given cuft/sec (ft^3/sec) and you need gallons per minute (gpm), there is only one line under the conversions header that gives you both forms of measurement you need. What you know is on the left side and what you don't know is on the right side, so you would multiply to obtain the answer.

1. Convert 15 cuft/sec to gpm → *15 cuft/sec X 448.8 gpm = 6,732 gpm*

If you are given gpm and need to convert them to MGD there is only one line that has both gpm and MGD. What we are given is on the right side and what we need to know is on the left so we would divide.

2. Convert 2,500 gpm to MGD → *2,500 gpm/694.5 gpm = 3.599 or 3.6 MGD*

Math Review

If we need to find the area (a two-dimensional measurement) in a rectangle, we simply multiply length x width.

OBJECT	AREA (ft^2)	VOLUME (ft^3)
Rectangle	Length' x Width'	Length' x Width' x Height'
Circle	.785 x D' x D'	
Triangle	1/2 (Base' x Altitude')	
Cylinder		.785 x D' x D' x Length'
Sphere		.5236 x D' x D' x D'

Perimeter = Sum of All Sides
Diameter (D) = 2 x radius
Circumference = π (3.14) x D

If we need the cross–sectional area of a circle, we multiply .785 x diameter in feet x diameter in feet, which gives us an answer in **square feet (ft^2).**

2-d Area Examples

1. What would the area be of a basin that measures 6 feet wide by 10 feet long?
   Area = Length in feet X Width in feet
   Area = 6 ft X 10 ft
   Area = 60 square feet (ft^2)

2. What would the cross-sectional area of a 24-inch circle be?
   Area = .785 X diameter in feet X diameter in feet
   Area = .785 X 2 ft X 2 ft
   Area = 3.14 ft^2

To find volume (the size of a three–dimensional space enclosed within or occupied by an object) in a rectangle, we account for the third measurement which would be height or depth.

OBJECT	AREA (ft^2)	VOLUME (ft^3)
Rectangle	Length' x Width'	Length' x Width' x Height'
Circle	.785 x D' x D'	
Triangle	1/2 (Base' x Altitude')	
Cylinder		.785 x D' x D' x Length'
Sphere		.5236 x D' x D' x D'

Perimeter = Sum of All Sides
Diameter (D) = 2 x radius
Circumference = π (3.14) x D

To find the volume of a pipe or cylinder, we multiply .785 x diameter in feet x diameter in feet x height or depth in feet.

3-d Area Examples

1. A sedimentation basin measures 18 feet wide by 26 feet long by 12 feet in depth. What is the volume of this basin?
   Volume = Length (in feet) X Width (in feet) X Depth or Height (in feet)
   Volume = 26 ft X 18 ft X 12 ft
   Volume = 5,616 cubic feet (ft^3)

2. How many cubic feet of water would a 24-inch pipeline that measures 1500 feet in length contain?
   Volume = .785 X diameter (in feet) X diameter (in feet) X length (in feet)
   Volume = .785 X 2 ft X 2 ft X 1500 ft
   Volume = 4,710 cubic feet (ft^3)

Flow Rate Calculations

Q = A X V
Q = FLOW expressed as ft^3/sec (cubic feet/second—sometimes presented as cfs)
V = VELOCITY expressed as fps (feet per second)
A = CROSS-SECTIONAL AREA expressed as ft^2

Flow is volume/time. Can be expressed as:

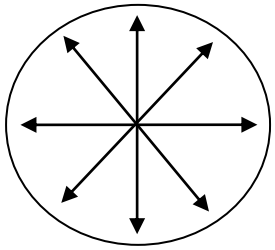
- gallons per minute (gpm)
- million gallons a day (MGD)

Velocity is speed or time/distance. Can be expressed as:

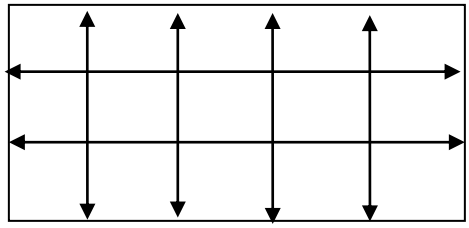
- feet per second (fps)
- yards per hour
- blocks per day

Area is a two-dimensional measurement. In this equation, we calculate the cross-sectional area. All we are concerned with in this equation relative to area is a two-dimensional measurement.

.785 X D (ft) X D (ft) for a



Length X Width for a rectangle



Anytime you have a measurement notated in inches, we must convert it to feet in order for us to calculate a correct answer. All that is needed to convert inches to feet is to divide by 12, which is how many inches are contained in a foot. Here are some examples:

8 inches is .666 feet	(8 inches ÷ 12 inches)
2 inches is .166 feet	(2 inches ÷ 12 inches)
42 inches is 3.5 feet	(42 inches ÷ 12 inches)

Area Examples

1. What is the cross-sectional area of a 16-inch pipe?

   The formula to obtain this is .785 X D (in feet) X D (in feet)

   Area = .785 X (16 inches ÷ 12 inches) X (16 inches ÷ 12 inches)
   Area = .785 X 1.33 ft X 1.33 ft
   Area = 1.4 ft^2 (actually 1.3885865 rounded up)

   So, the cross-sectional area for a 16-inch pipe is 1.4 ft^2.

2. Water is flowing through a 4 feet long by 2 feet wide by 3 feet deep trench at 1.9 feet per second. What is the flow?

   Q = A X V
   Q (flow) expressed as ft^3/sec = (4 ft X 2 ft) X 1.9 fps
   Q (flow) expressed as ft^3/sec = 8 ft^2 X 1.9 fps

   A = 15.2 ft^3 (cubic feet per second)

   Since we are figuring area (a two-dimensional measurement), we do not need to use the depth into the equation for the question above.

3. The flow through a 10-inch water line is 4.4 ft^3/sec. What is the velocity of this water?

   V = Q ÷ A
   V (velocity) expressed as feet per second (fps) = Q (flow) ft^3/sec ÷ A (area) ft^2
   V = 4.4 ft^3/sec (flow) ÷ (.785 X (10" ÷ 12") X (10" ÷ 12"))
   V = 4.4 ft^3/sec ÷ (.785 X .83' (ft) X .83' (ft))
   V = 4.4 ft^3/sec ÷ .54 ft^2

   V = 8.1 fps (feet per second)

4. The flow through a 22-inch pipe is 3142 gpm. What is the velocity?

$$V = Q \div A$$

In order to satisfy the equation, we have to convert 3142 gpm into ft^3/sec.

The conversion sheet shows that 1 ft^3/sec = 448.8 gpm

$$V = (3142 \text{ gpm} \div 448.8 \text{ gpm}) \div .785 \text{ X } (22'' \div 12'') \text{ X } (22'' \div 12'')$$

$$V = 7 \text{ ft}^3/\text{sec} \div (.785 \text{ X } 1.83' \text{ X } 1.83')$$

$$V = 7 \text{ ft}^3/\text{sec} \div 2.6 \text{ ft}^2$$

V = 2.69 or 2.7 fps

Practice Examples

1. The flow through the 36-inch main transmission line in the community of Getz is 3.6 MGD. What is the velocity of the water through this pipeline?

2. Water is traveling through a 4-inch pipe at 0.7 fps. What is the flow in this pipe expressed as gpm?

3. You are preparing to attach a line extension to a 12-inch pipe when the track hoe operator punctures the existing line. It took 3 minutes for water to travel through the trench, which was 4 feet deep, 3 feet wide and 200 feet long. What is the velocity of this water?

4. Water is flowing through a completely filled 24-inch water main at 75 feet per minute. What is the flow in this pipeline?

5. In order for your new pump to work efficiently, it needs a minimum of 700 gpm to be pumped through it. The line attached to the pump is 18 inches, and the water is flowing at 1.1 fps. How many gallons per minute are moving through the new pump?

Solutions

1) V = Q ÷ A
V = (3.6 MGD X 1.55 ft^3/sec) ÷ .785 X (36" ÷ 12") X (36" ÷ 12")
V = 5.58 ft^3 ÷ (.785 X 3' X 3')
V = 5.58 ft^3/sec ÷ 7.07 ft^2
V = 0.8 (actually 0.789) fps

2) Q = A X V
Q = .785 X (4" ÷ 12") X (4" ÷ 12") X 0.7 fps
Q = (.785 X .33' X .33') X 0.7 fps
Q = 0.085 ft^2 X 0.7 fps
Q = .0595 ft^3/sec How many gallons per minute would that be? 26.7 gpm

3) If it takes 3 minutes (180 seconds) for the water to travel 200 feet, then we could say that the water was traveling at a rate of 1.1 fps (200 feet ÷ 180 seconds).

4) Q = A X V
Q = (.785 X 2' X 2') X 1.25 fps, which has been converted from 75 feet per minute
Q = 3.14 ft^2 X 1.25 fps
Q = 3.9 ft^3/sec

5) Q = A X V
Q = (.785 X (18" ÷ 12") X (18" ÷ 12")) X 1.1 fps
Q = .785 X 1.5' X 1.5' X 1.1 fps
Q = 1.94 ft^3/sec
Q= Converting to gpm 1.94 ft^3/sec X 448.8 gpm = 870.6 gpm
Q = 870.6 gpm

Review Questions for Chapter 4– Storage

1. Chemical reactions occur more quickly in _____water.

2. Tank _____is an important consideration in reducing water age.

3. A lack of water turnover causes a rapid depletion of _____ residuals.

4. A storage facility should turn the water completely over every _____ hours.

5. Every time a tank is taken out of service for repair or cleaning, it must be disinfected at a dosage of _____ ppm, held for _____ hours and maintain a residual of _____ ppm.

6. Monkeys Eyebrow's 4,800 residents use on average 190,000 gallons of water a day. What would the average daily water demand per resident be for the month of June?
    a. 40 gallons
    b. 175 gallons
    c. 1187.5 gallons
    d. 467.6 gallons

Answers to Review Questions for Chapter 4 – Storage

1. Warmer
2. Turnover
3. Chlorine
4. 72
5. 50, 24, 25
6. a

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Chapter 5: DISINFECTION

Chapter 5 Objectives

1. Answer the question "Why do treatment operators disinfect the water"?
2. Define log removal, CT calculations, and breakpoint.
3. Determine at what range of proximity the disinfectant chlorine needs to be relative to a pathogen to impact it.
4. Decide how it is possible to determine whether or not breakpoint has been reached.
5. List the four forms of chlorine commonly used for the disinfection of water and their strengths and weaknesses.
6. Describe how UV accomplishes the task of disinfection.
7. Determine at what pH measurement the amount of hypochlorous acid is at its highest level.
8. Determine what factors affect disinfection.
9. Calculate dosage relative to demand and residual, lbs., dosage and ml relative to percent available disinfectant.
10. Define specific gravity.
11. Calculate gallons of chemical needed with a specific gravity both above and below 1.
12. Define and calculate percent solution strength.
13. Explain the significance of disinfection by-products and determine the potential health effects of disinfection by-products and how they are formed.
14. Determine what steps or practices could be undertaken to control or remove disinfection by-products.
15. Determine what significance 2012 has relative to disinfection by-products.

Purpose of Disinfection

- TO KILL or INACTIVATE PATHOGENS
- TO PROVIDE A RESIDUAL SAFEGUARD

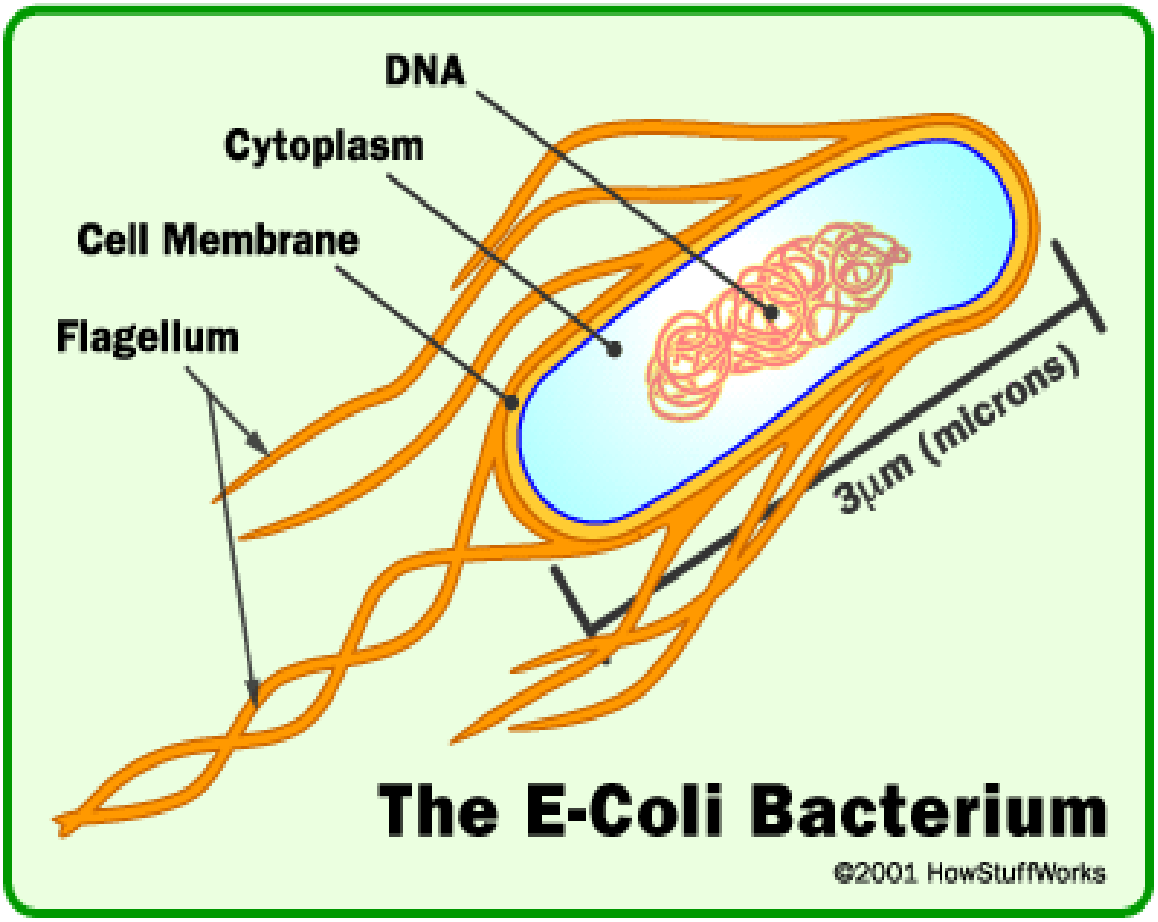
The primary reason we disinfect our water is to kill or inactivate pathogens. Pathogens are disease-causing organisms. Examples of diseases caused by waterborne pathogens are:

- Cholera
- Typhoid
- Salmonella
- Hepatitis
- Dysentery
- Polio
- Giardiasis
- Cryptosporidiosis

Waterborne illnesses in the past have eradicated entire populations and, even today, kill thousands of people every year. The treatment processes of coagulation, flocculation and sedimentation that we use today were developed originally to remove or control pathogenic organisms in drinking water. Pathogens, which can take the form of bacteria, viruses or protozoa, are not totally destroyed by disinfectants. Some of them are killed, some are temporarily inactivated, some are genetically mutated so reproduction is impossible and some are not affected at all by the disinfectant in the time they are in contact with it. With possible life or death consequences a possibility, all our treatment processes, including disinfection, need to be fully optimized.

Pathogen Reduction from Various Treatment Processes	
UNIT PROCESS	PERCENT REDUCTION
Storage *	Significant Amounts
Sedimentation*	0 – 99
Coagulation *	Significant Amounts
Filtration *	0 – 99
Chlorination	99

* These methods do not, by themselves, provide adequate pathogen reduction. However, their use prior to disinfection may significantly lower the costs associated with disinfection.



The secondary purpose of disinfection is to provide a residual safeguard. Water quality degrades after it leaves the treatment plant and travels through the distribution system on its way to the customer's tap. The amount of degradation is relative to the physical, chemical and biological composition of the treated water and, the physical, chemical and biological condition of the distribution system through which it travels, and how the treated water and the distribution system interact with each other. The disinfectant residual we impart to our distribution system hopefully provides a safeguard against pathogenic contamination that may originate or regrow within our systems.

We also sometimes use disinfectants as chemical oxidants. If fed early in the treatment process, the disinfectant pre-oxidizes certain compounds that are dissolved in the water allowing subsequent treatment processes to effectively remove these precipitated compounds. Pre-oxidation can aid in the treatment and removal of taste, color, odor, dissolved gasses and some disinfection by-product organic precursors.

401 KAR 8:150. Disinfection, filtration and recycling. (The complete regulation can be located at www.lrc.ky.gov.)

Section 1. Disinfection. A public and semipublic water system shall provide disinfection, except as provided in this section. A semipublic water system shall comply with the requirements of this section for public water systems or meet the requirements of Section 2(2) of this administrative regulation.

(1) A public water system using groundwater or surface water as a source.

(a) A public water system that uses chlorine shall:

1. Use continuous automatic disinfection by chlorination;

2. Provide a minimum free chlorine residual of two-tenths (0.2) milligrams per liter, or ppm, throughout the distribution system measured as described in subsection (2) of this section;

3. Check free chlorine residuals daily at representative points throughout the system; and

4. Report the free chlorine residuals monthly pursuant to 401 KAR 8:020, Section 2(7)(a)2.

(b)1. Disinfecting agents other than chlorine may be used pursuant to 40 C.F.R. 141.172(c).

2. If chloramination is used, a minimum combined residual of five-tenths (0.5) milligrams per liter, or ppm, shall be provided throughout the distribution system.

(2) A public water system using surface water as a source or groundwater under the direct influence of surface water shall provide disinfection treatment as established in 40 C.F.R. 141.72(b).

(3) If adisinfection residual fails to comply with Section 1(1) of this administrative regulation, the public shall be notified in accordance with 401 KAR 8:020, Section 2(9).

(4) Variances or exemptions shall not be granted for subsection (2) of this section.

Section 4. Disinfection of Treatment and Distribution System Facilities, New and Repaired Water Lines. (1) New construction projects and line extensions.

(a) Disinfection. A water treatment plant or distribution system, including storage distribution tanks, or extensions to existing systems, shall be thoroughly disinfected before being placed in service.

(b) A water distribution system shall disinfect with chlorine or chlorine compounds in amounts that shall produce a concentration of at least fifty (50) ppm and a residual of at least twenty-five (25) ppm at the end of twenty-four (24) hours, and the disinfection shall be followed by a thorough flushing.

Log Removal

In addition to selecting the proper dosage to feed, the operator must determine if the amount of contact time is sufficient for the disinfection of pathogens. The ESWTR requires that the disinfection process be effective for a 3–log removal of Giardia cysts and a 4–log removal of viruses. In our business, the term "log" basically means 9. Hence, a 2-log removal is 99%, a 3-log removal is 99.9%, and a 4-log removal is 99.99% and so on.

	microorganisms removed	microorganisms remaining
2 log removal 99%	9900	100
3 log removal 99.9%	9990	10
4 log removal 99.99%	9999	1

Ruth Lancaster Illustration

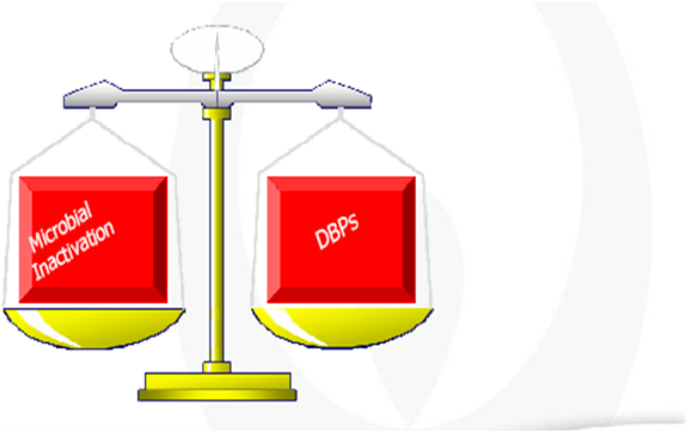
Above is a delicious pitcher of Ohio River water during flood season. If there are approximately 10,000 microorganisms in the water and we started our disinfection process, a 2-log removal would leave 100 microorganisms remaining, a 3-log removal would leave 10 microorganisms, and 4-log removal would leave 1 microorganism. What percent of removal would you care to drink?

Concentration Over Time (CT)

Mathematical models were developed to assist operators in determining how well their disinfection process meets removal or eradication standards. These models are the CT calculations. The CT takes into account all the factors that affect the viability of the disinfection process and determines the probability that the entire treatment process achieves the necessary removal or inactivation of pathogens in your water that would make it safe for human consumption. The "C" stands for residual disinfectant concentration and the "T" stands for contact time, which are the two most important factors in the disinfection process. Among the criteria considered relative to CT could be:

- the performance of the coagulation/flocculation/sedimentation process,
- filter performance,
- the type of disinfectant used,
- baffling,
- the pH and the water temperature, and
- the qualification of the operator.

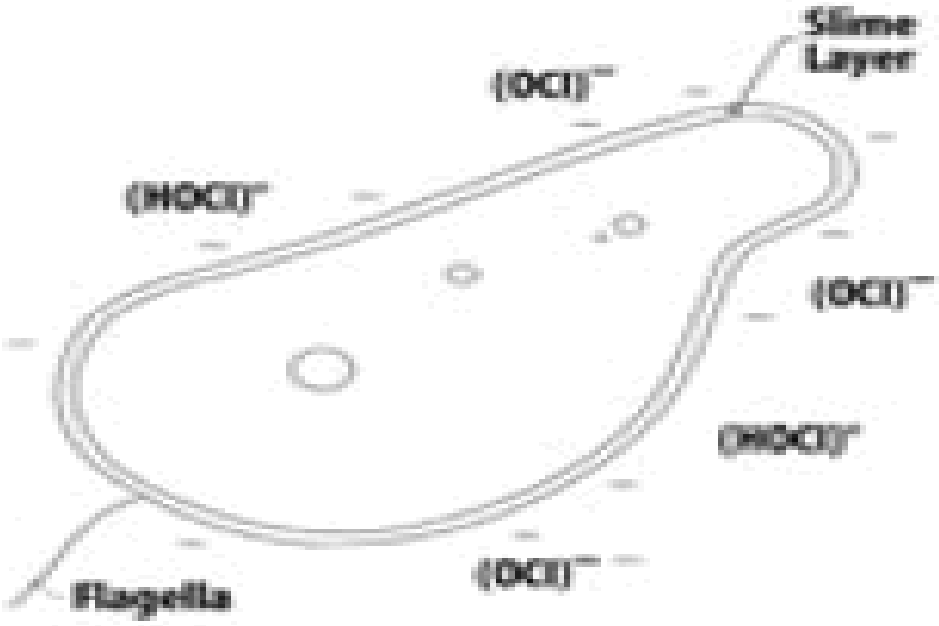
After calculating CT, the necessary adjustments to the disinfection process can be performed that would reduce disinfection by-products while still not compromising pathogen control, so the water sent to our consumers is safe to drink. If the CT calculated is too high, disinfectant dosages could be lowered to achieve enough pathogen inactivation as well as keep disinfection by-products to a minimum. Too low a CT would mean the quality of the water has been compromised and a change would be necessary quickly in order not to jeopardize consumers' safety. Possible CT-enhancing changes that could be made to the treatment facility could be slowing down the flow of the water through the plant and allowing the plant to operate as it was designed, installing baffles in the basins to increase contact time, altering the treatment process so a lower pH could develop during disinfection contact and lastly, increase the chlorine dose to meet CT.

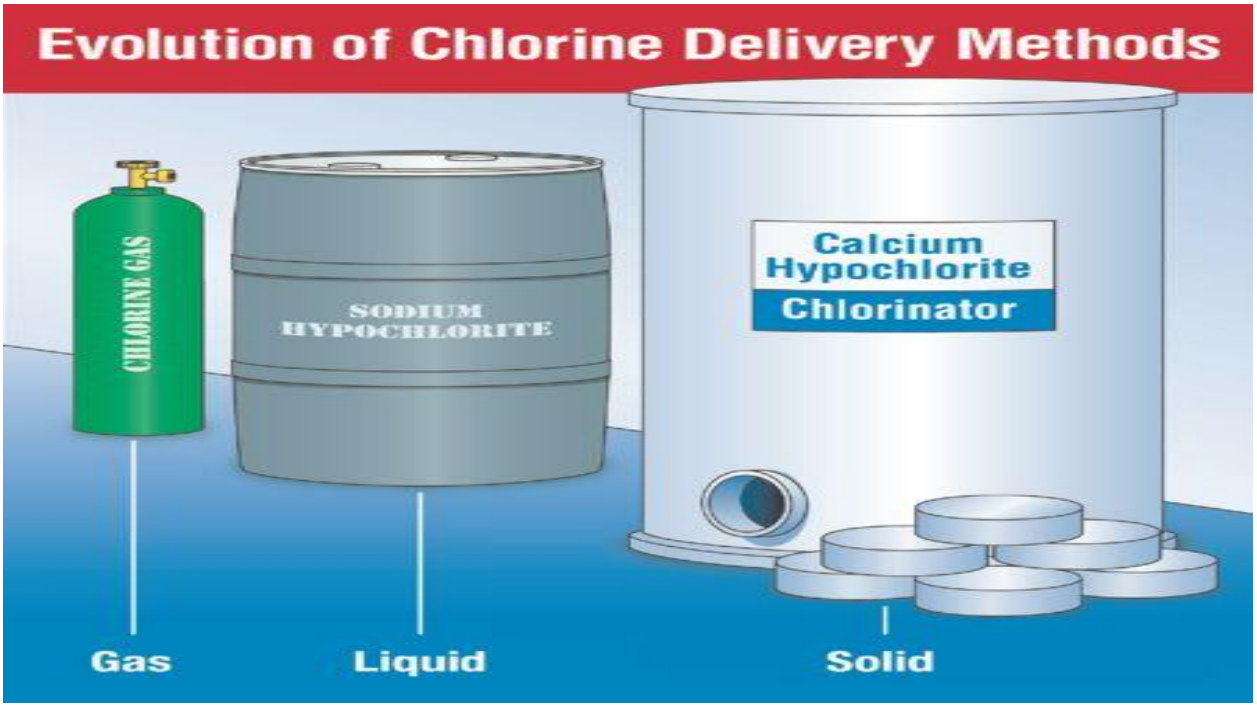


Disinfectants Commonly Used in Potable Water Applications

Chlorine

This is the most commonly used disinfectant for potable water. It is available in three forms, and diluted forms are being used more frequently because of security concerns. Chlorine (Cl_2) has shown its effectiveness in pathogen inactivation and also satisfies the need for a residual disinfectant safeguard against contamination in our distribution systems. As an oxidant, chlorine precipitates such substances as iron and manganese, prior to settling or filtration. It volatizes gasses, such as hydrogen sulfide, methane and benzene, and reduces many organic-related taste, odor and color-causing compounds. Because of its many forms, chlorine is available to be used in many applications, such as raw water, wells, pipelines and storage tanks, as well as the many fittings used in the distribution system and in disinfecting water leak sites. With the advent of the information of the potentially carcinogenic properties of halogenated disinfection by-products, due diligence is appropriate in the use of chlorine as a primary disinfectant. When chlorine is combined with organic compounds present due to a lack of treatment optimization or distribution system maintenance, Trihalomethanes (THM) and haloacetic acids (HAA5s) may be formed. THMs and HAAs are by-products of the disinfection process. Because of the suspected carcinogenic properties, chlorine use an a pre-oxidant has declined, and many facilities are using other means to oxidize their water.





Forms of Chlorine

Gas (100% available)

Chlorine (Cl_2) gas is fed out of pressurized tanks or cylinders that contain both a gas and a liquid. The amount of liquid to gas is temperature-dependent, with higher temperatures yielding a higher concentration of liquid. The atmospheric expansion ratio from liquid to gas is 460:1. Since liquid leaks are so dangerous, a fusible plug is designed to melt between 154º F - 165º F in order to exhaust the chlorine as a gas. Chlorine gas is a greenish yellow color and is 2.5 times heavier than air. While chlorine gas is not flammable, with oxygen it will support combustion. Chlorine gas is corrosive when in combination with moisture and has a tendency to lower the pH of the water. There are regulations in place regarding the chlorine room in a treatment facility to ensure the safety of the operators. Small leaks can be located with the use of a 10 percent ammonium hydroxide vapor solution that when in contact with chlorine gas produces a white cloud. When chlorine is fed at a rate of greater than 40 pounds a day, freezing in the cylinder can occur. Every time a cylinder is replaced, it is necessary to replace the lead washer to ensure the seal is air tight. Because of the potentially dangerous nature of chlorine, an up-to-date emergency response plan is necessary.

Calcium Hypochlorite (65 – 70%)

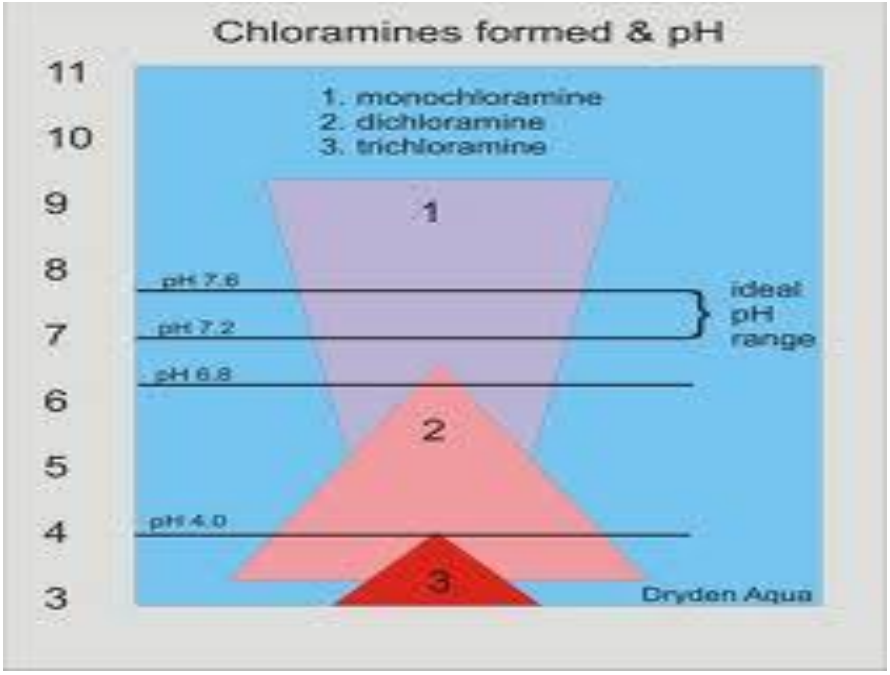
This product is manufactured in powder, granular and tablet form. Many of us know this product as HTH which is a trade name. Calcium hypochlorite $Ca(ClO)_2$ tends to raise the pH of the water and is a weaker disinfectant than gaseous chlorine. Flammable hazards exist when in contact with oxidizers. This product should be stored in a cool, dark area because it degrades when exposed to light or heat and carries a shelf life of 2 years. It is frequently used in distribution system disinfection applications but more treatment facilities are using it as a primary disinfectant because of safety concerns concerning chlorine.

Sodium hypochlorite (5.25 – 15%)

This liquid (NaOCl) is frequently referred to as bleach. Formerly used extensively in well systems and for the disinfection of distribution system pipes and fittings, but more and more surface water treatment facilities are using sodium hypochlorite as their primary disinfectant. As with HTH, sodium hypochlorite should be stored in a cool, dark place because of the degradation effects of heat and light. This product has a shelf life from 60–90 days.

Chloramine (NH2Cl)

Chloramine is formed by the addition of ammonia with chlorine. Chloramines are approximately 80 times weaker than chlorine gas as a primary disinfectant and require very long contact time to achieve pathogen inactivation. Chloramine lasts much longer in solution than chlorine with documented cases where it has been shown to last for up to 27 days in the distribution system. Since the chlorine is in the combined form, the formation of THMs and HAAs is limited. Also, because chloramines never reach breakpoint, the minimum disinfectant residual for chloraminated systems is 0.5 mg/L. The chlorine to ammonia ratio, pH and the rate of decay must be carefully monitored and controlled to prevent nitrification, taste and odor, increased lead and copper levels and biological regrowth in the distribution system. Currently, Kentucky American Water and Louisville Water Company are using chloramines for disinfection.



Ozone (O_3)

Ozone must be produced on-site by subjecting oxygen molecules to a high-voltage, low-amperage charge. This action imparts a third oxygen molecule to the oxygen atom. It is an extremely strong oxidizer and the strongest disinfectant available for potable water treatment, so CT can be easily met.

Ozone is sometimes used in conjunction with biologically active filters with granular activated carbon (GAC) media, but this application requires a high level of operator attention. Ozone, like every disinfectant, produces its own disinfection by-products, mainly bromate. The MCL for bromate is 0.1 mg/L, which limits its use for some systems. Ozone used for disinfection can also form assimilable organic compounds, which are low molecular-weight dissolved organic carbons. Ozone, like chlorine, is corrosive when in contact with moisture. Ozone has been used for municipal water disinfection for over 100 years in Europe and one of the largest treatment facilities in the world, the 600-MGD Los Angeles Aqueduct Treatment Plant has used ozone for over a decade. Reduced coagulant dosages are a by-product of ozone use in water treatment. Since ozone quickly dissipates, it cannot be used as a residual safeguard, so its use must be supplemented with the use of chlorine or chloramine.

Chlorine Dioxide ($ClO)_2$

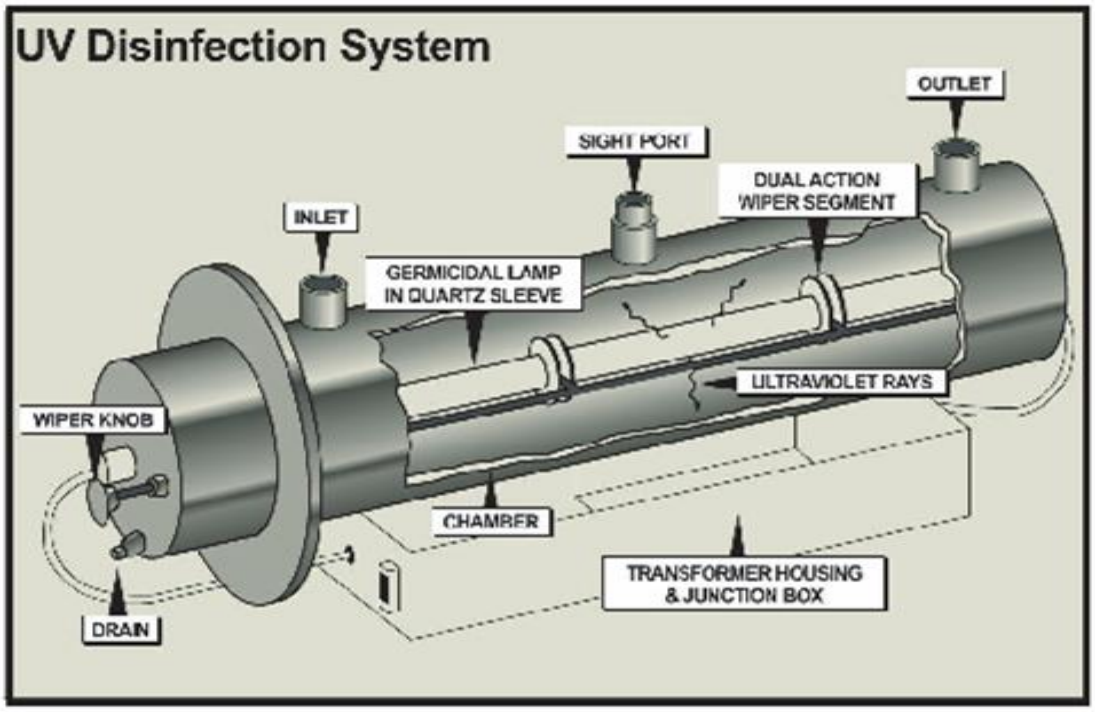
Chlorine dioxide, which results from the addition of sodium chlorite with chlorine, is a strong oxidant that may be used as a primary disinfectant. Because it does not form THMs or HAAs, chlorine dioxide may be fed early in the treatment process and used as a pre-oxidant. This makes it very useful in the control of iron and manganese, color and many tastes and odors in the raw water. The ability to add the chemical early in the treatment process greatly reduces the CT required for pathogen inactivation. Chlorine dioxide produces its own disinfection by-products, chlorite and chlorate, which must not be present as a residual greater than 1.0 mg/L before exiting the treatment facility. Because of this, chlorine dioxide has no use as a residual disinfectant, and therefore must be supplemented with some other form of residual disinfectant. It must be generated on-site. Currently, Dawson Springs and Henderson use chlorine dioxide as a disinfectant.

Miox

Miox is an acronym for mixed oxidants. It is generated on-site with brine or salt subjected to an electrical charge. It is a strong oxidant and produces fewer halogenated disinfection by-products (THMs and HAAs) than does chlorine. Reportedly, and from personal experience, Miox reduces biofilm formation in distribution system piping. The use of Miox as an oxidant also reduces coagulant dosages. Because all that is needed to produce this disinfectant is salt and electricity, safety concerns are minimal. Currently, Prestonsburg and Lawrenceburg use Miox as a disinfectant.

TIME NEEDED (in minutes) TO ACHIEVE PATHOGEN INACTIVATION FOR FRQUENTLY USED DISINFECTANTS

ORGANISM	FREE Cl2 pH 6 - 7	Chloramines pH 8 - 9	Chlorine Dioxide pH 6-7	OZONE
E Coli	.034 - .05	95 - 180	0.4 – 0.75	0.02
Polio	0.1 – 2.5	768 - 3740	0.2 – 6.7	0.1 – 0.2
Rotavirus	0.01 – 0.05	3806 - 6476	0.2 – 2.1	0.006 - .06
Giardia Lamblia	47 – 150		- - - - - - - - -	0.5 – 0.6
Giardia muris	36 - 630	1400	- - - - - - - - -	1.8 – 2.0
Cryptosporidium	7200	7200	79	5 - 10



6.3 Figure 1: UV disinfection system

UV

Ultraviolet radiation (UV) is being used more frequently for potable water disinfection. UV accomplishes the task of disinfection a little differently than most other methods. UV disrupts the DNA of the pathogen.

NORMAL DNA

DNA AFTER UV EXPOSURE

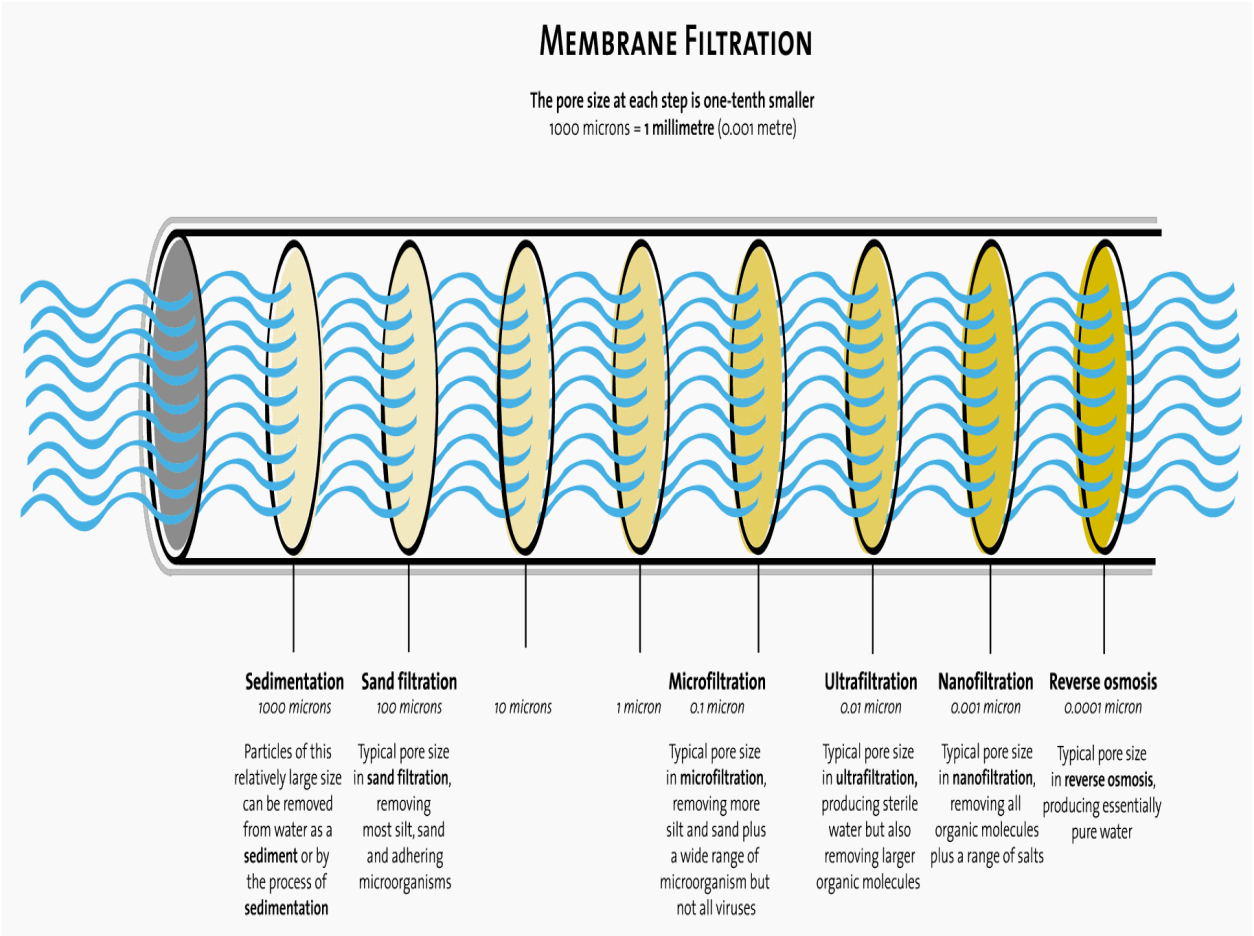
Ultraviolet is readily available as the bulbs used are glass-enclosed mercury vapor lamps, similar to the lamps we use every day, but without an opaque coating. UV needs short CTs to accomplish disinfection, and it produces no known toxic disinfection by-products. The bulbs are encased in quartz tubes, which are submerged in the flow. The success of the disinfection is dependent upon the ability of the light to permeate across the entire flow of water. To aid in this endeavor, wipers are outfitted on each quartz tube to ensure that it is always kept clean and allows the light to reach as far as needed. There is no residual disinfectant generated with this process so it must be supplemented with some chemical disinfectant to impart a residual safeguard.

Currently Northern Kentucky Water and Shelbyville use UV.

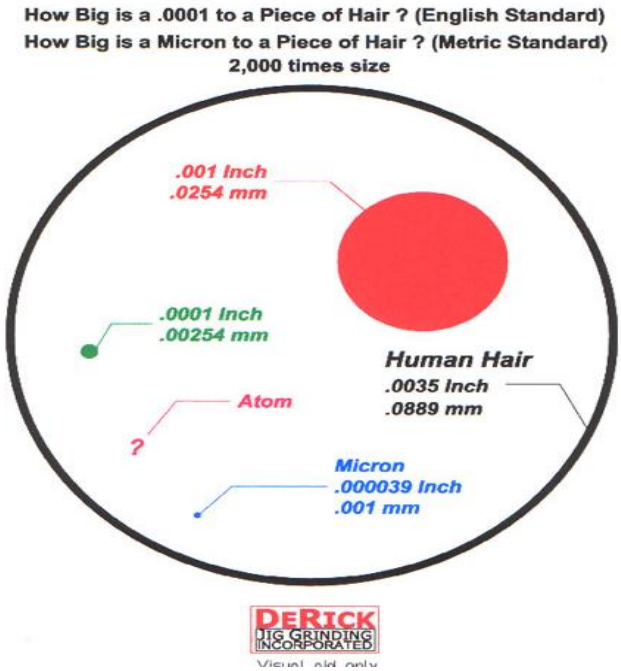
There are other disinfectants available to be used in water treatment, but as of this writing, few others are used.

Membrane Filtration

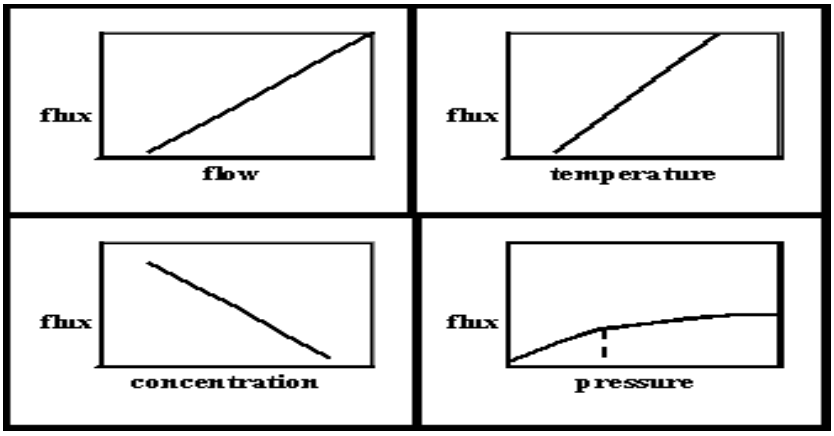
A membrane, or more succinctly described, a semi-permeable membrane is a thin piece of material capable of separating substances. Membrane processes have become more attractive for potable water treatment in recent years for many reasons. Some users like the fact that membranes' size exclusion technology show great promise for meeting current as well as future regulations, including natural organic matter (NOM), which can impart color, tastes, odors and in combination with chlorine can cause disinfection by-products. Others enjoy the fully automated controls that can eliminate guesswork by the operator. The first membranes used in potable water were pressure-driven, with vacuum-driven membranes being used more and more frequently.



As the previous illustration points out, sand filtration will effectively remove particles above the size of 100 microns. Some of the attraction to membrane filtration is garnered by the fact that some membranes remove particulate down to the size of 1/10,000 of a micron. The four types of membrane filtration used in water treatment are, by size of particulate exclusion from largest to smallest, microfiltration, ultrafiltration, nanofiltration and reverse osmosis.



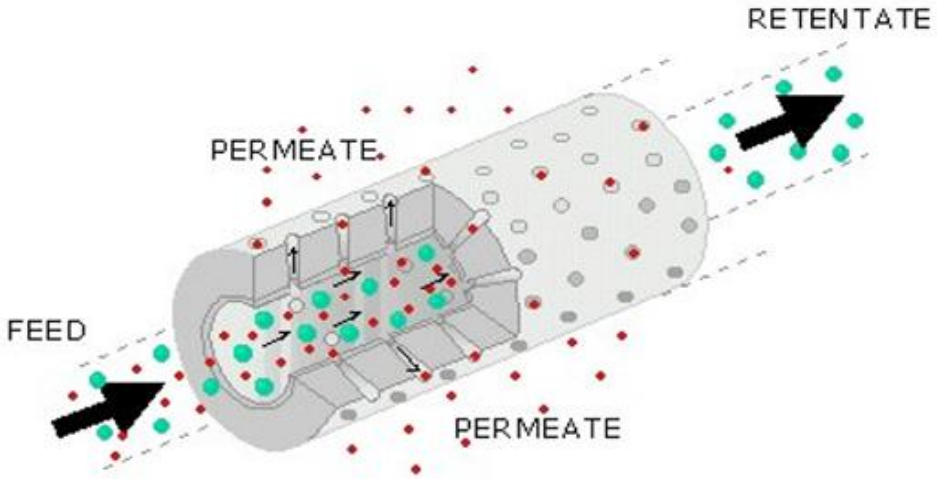
Another factor in determining the proper membrane for the correct application is the flux rate. In membrane applications, flux rate is pretty much synonymous with flow rate. There is a maximum amount of water that can pass over or through a membrane that will viably allow the water to be “filtered” so that size-exclusion processes work the way we want.

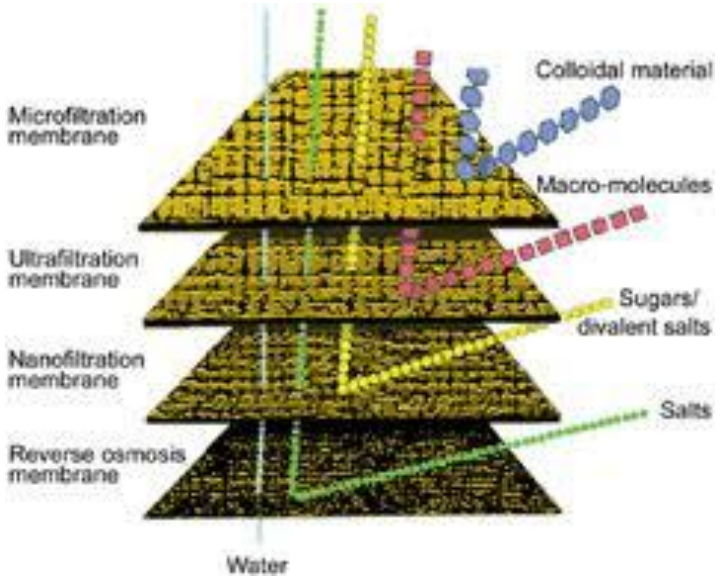


Again, there are four types of membrane filtration mentioned here:

Surface Water Treatment Compliance Technology

Unit Technologies	Removal: Log *Giardia* and Log Virus	Raw Water, Pretreatment and Other Water Quality Issues
Microfiltration (MF)	Very effective Giardia, > 5-6 log; Partial removal of viruses (disinfect for virus credit)	High-quality influent or pretreatment required. Same note regarding TOC
Ultrafiltration (UF)	Very effective Giardia, > 5-6 log; Partial removal of viruses (disinfect for virus credit)	High-quality influent or pretreatment required (e.g., MF). TOC rejection generally low, DBP precursors could be a concern
Nanofiltration (NF)	Very effective absolute barrier (cysts and viruses)	Very high-quality influent or pretreatment required
Reverse Osmosis (RO)	Very effective absolute barrier (cysts and viruses)	May require conventional or other pretreatment for surface water to protect membrane surfaces, such as may include turbidity or Fe/Mn removal, stabilization to prevent scaling, reduction of dissolved solids or hardness and pH adjustment



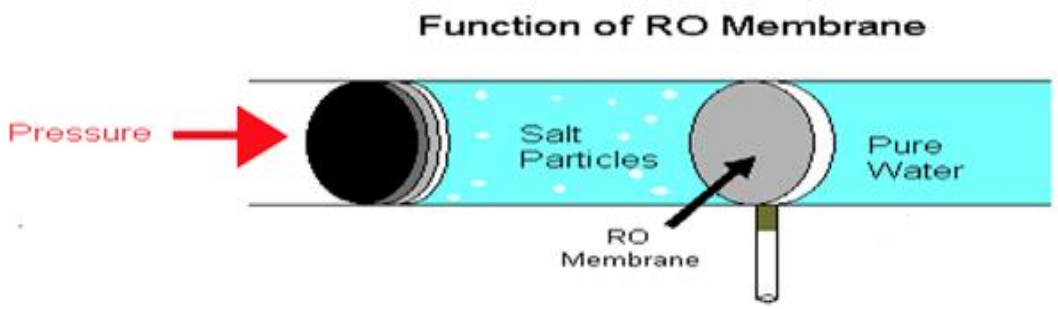


The membrane filtration spectrum ranges from reverse osmosis (RO), which allows the finest degree of separation, through nanofiltration, ultrafiltration, and finally microfiltration, which seperates submicron particles from dissolved material.

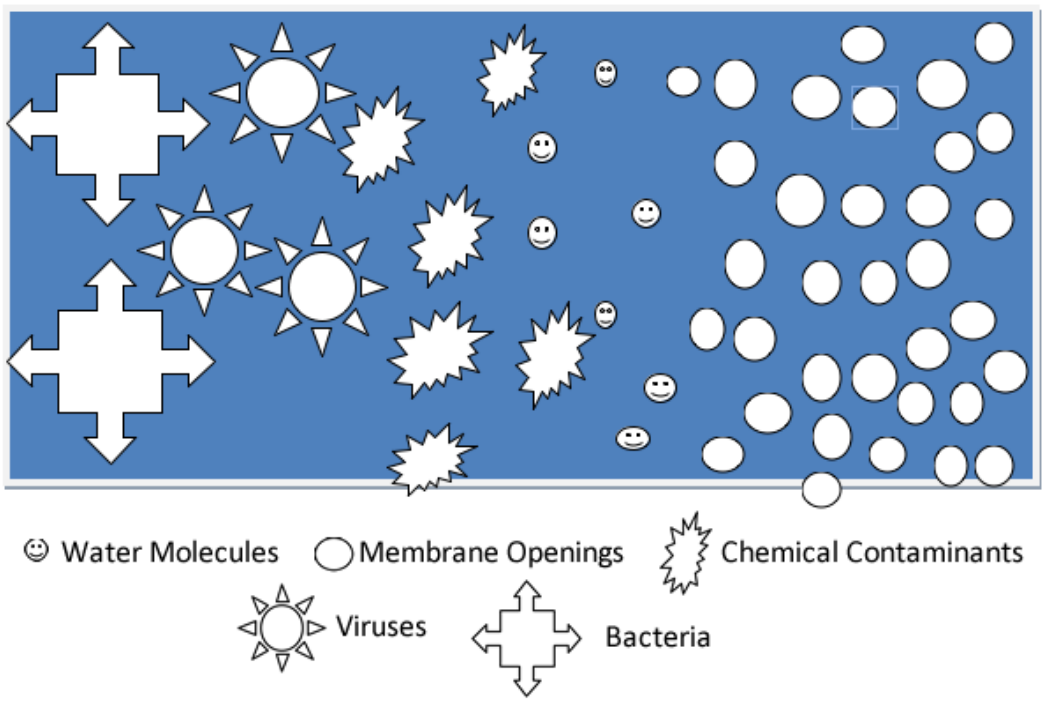
Most municipal membrane applications use micro or ultrafiltration membranes while many bottled water industrial applications seem to be reverse osmosis. Nanofiltration seems to be used more for process water.

Membrane Filtration Comparison

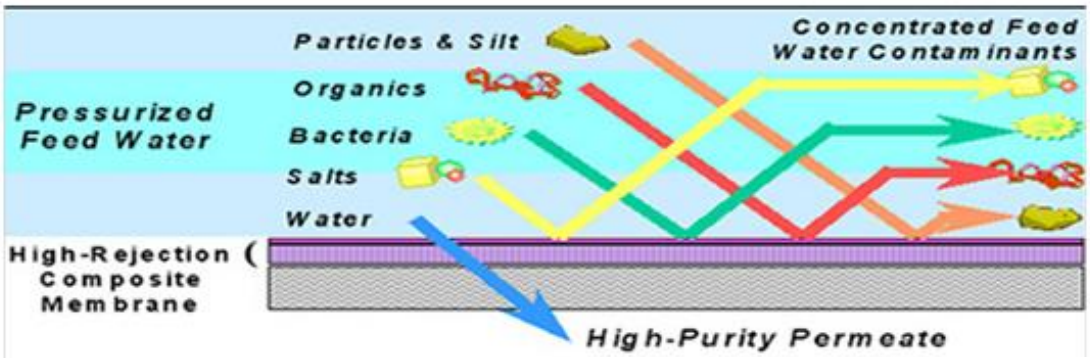
Unit Technologies	Complexity: Ease of Operation (Operator Skill Level)	Secondary Waste Generation	Other Limitations/ Drawbacks
Microfiltration (MF)	Basic: increases with pre/post treatment and membrane cleaning needs	Low-volume waste, may include sand, silt, clay, cysts and algae	Disinfection required for viral inactivation
Ultrafiltration (UF)	Basic: Increases with pre/post treatment and membrane cleaning needs	Concentrated waste: 5–20% by volume. Waste may include sand, silt, clays, cysts, viruses and humic material	Disinfection required for viral inactivation
Nanofiltration (NF)	Intermediate: increases with pre/post treatment and membrane cleaning needs	Concentrated waste: 5 – 20% by volume	Disinfection required under regulation, as recommended as a safety measure and residual protection.
Reverse Osmosis (RO)	Intermediate: increases with pre/post treatment and membrane cleaning needs	Brine waste. High volume, e.g., 25 – 50%. May be toxic to some species	Bypassing of water cannot be practiced at risk of increasing microbial concentrations in finished water. Post – disinfection required under regulation, is recommended as a safety measure and for residual maintenance



Initially, membranes used pumps to forcefully push water through the tiny openings or pores in the filters. The openings, in some cases, are so small that only water can pass through the pores in the membrane (reverse osmosis).



Even though the above illustration leaves something to be desired, the plain circles and ovals represent the openings in the semi-permeable membrane. Water molecules, the smiley faces, represent water molecules and would freely pass through the openings in the membrane. The jagged ovals represent chemical contaminants that could not fit through the openings. The stars represent viruses, which are too large to fit through the openings. The arrowed rectangles represent bacteria, and they are much too large to fit through the openings in the membrane.

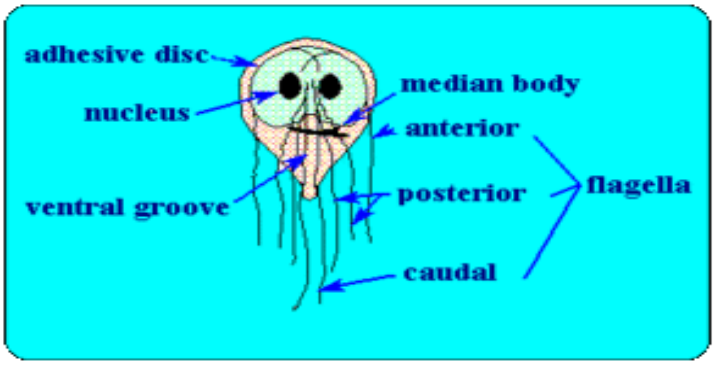


Graphic of interaction at membrane surface

Above: A strand of membrane in action
Below: A cassette housing membranes

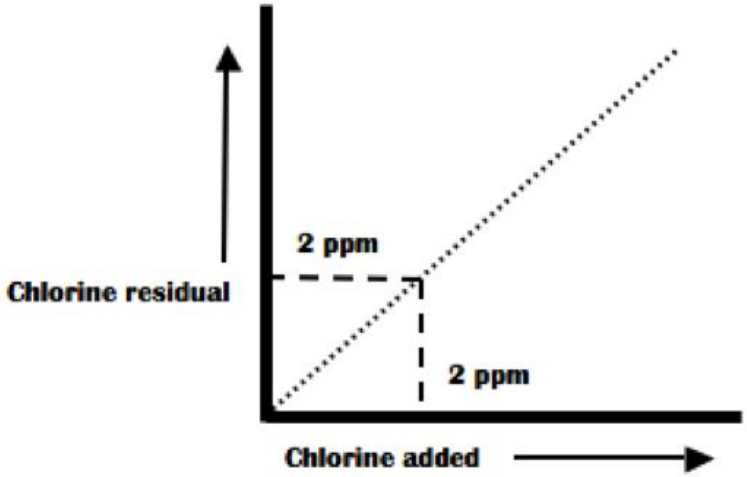
Vacuum-driven membranes are becoming more widely used for potable water treatment. Most of these vacuum-driven membranes pull the water through 2,700 or so thin membrane "strands" per bundle that separate the water from the contaminants. These bundles are arranged in racks and submerged in the raw water. Every 10 seconds or so, the water in the membrane tanks is aerated to scrub the membranes. Every 15 minutes, the vacuum pressure is reversed to back pulse clean water through the membranes pores to purge dirt from the membrane surface. These types of membranes come in single header (attached at the bottom only) and double header (attached both top and bottom) and then lowered into the raw water tank. In both single and double header configurations, the air flow is reversed to backwash the filter. The membranes are pictured below.

There are a number of membrane plants in operation here in Kentucky. Logan-Todd, Jamestown and Madisonville, among others, are already on-line, and Ohio County, Campton and Paintsville's new membrane plants are currently being constructed or planned.



Disinfection Chemistry

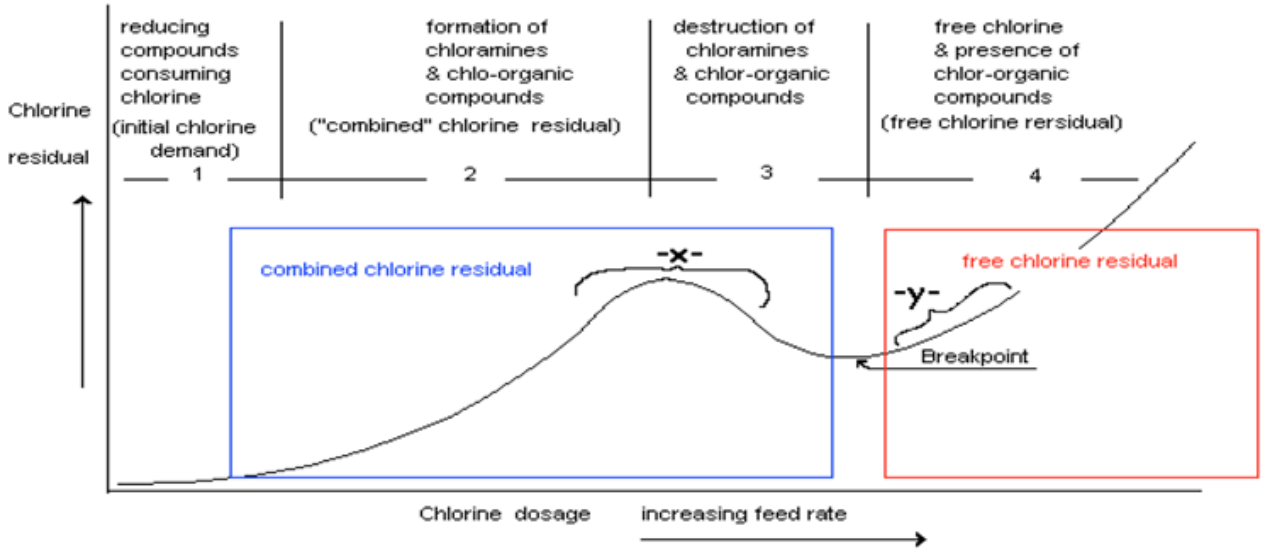
When chemical disinfectants, like chlorine, ozone, etc., are added to water, they react with all the substances that are in the water. Since water is the universal solvent, it chemically attracts all types of substances found in nature. Once these chemical reactions have completed, any remaining disinfectant in the water will exist as residual. If the water to be treated were free of all impurities, (i.e. distilled water), there would be nothing for the chlorine to react with. The chlorine added versus the chlorine residual relationship curve would be linear as shown below.



The reaction of chlorine in distilled water

Breakpoint

As an operator, we are faced with the task of treating natural water that is carrying substances that do react with the addition of chlorine. If we plotted the relationship of natural water and chlorine, it would look like this.



The curve at the bottom of the graphic above is commonly referred to as the **breakpoint curve**. The shape of the curve develops when we plot the chlorine added (dosage) versus the chlorine remaining (residual). From point 1 to point 2, the addition of chlorine results in no residual. At this point, the chlorine acts as an oxidizer where it precipitates dissolved substances (reducing agents) out of the water and is consumed via oxidation.

As more chlorine is added, from point 2 to point 3, chlorine reacts with the ammonia and organic matter in the water to form chloramines and chlororganic compounds. These are *combined* chlorine residuals. Since the chlorine is ***combined*** with other compounds, this residual is not free to react and therefore not available as free chlorine residual.

As more chlorine is added, it results in a decrease of residual as the additional chlorine in the water oxidizes some of the chlororganic compounds and ammonia. This additional chlorine also changes some of the monochloramine to dichloromine and trichloromine.

As additional chlorine is added, the amount of chloramine reaches a minimal value. Beyond this point, the point is reached where the further addition of chlorine results in ***free residual chlorine***. The point at which this occurs is known as the ***breakpoint***. To the

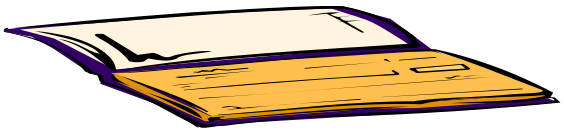
right of the breakpoint, an increase in the chlorine dosage will produce a proportionate increase in the residual. It is here where the curve begins to parallel the curve for distilled water, where the water has no demand for chlorine.

Another way to quickly determine whether you have reached breakpoint is to divide the residual chlorine reading by the total chlorine reading on your chlorine meter (DPD). If the chlorine meter shows a total chlorine of 1.2 ppm and a residual chlorine of 1.1 ppm, we would divide 1.1 by 1.2 and multiply the result by 100 to turn it into a percentage. (1.1 ppm ÷ 1.2 ppm) X 100 = 91.66 %. If this calculation results in a number near or above 85percent, you are most likely at breakpoint.

The chlorine dosage fed into the water must not only meet the chlorine demand the water has, but also produce the desired residual safeguard. To accurately determine demand, we can increasingly dose jars with chlorine and analyze the corresponding total residuals after an adequate contact time. The residuals are then plotted against their respective chlorine dosages to produce a breakpoint curve, which will indicate to the operator the chlorine demand for that particular water. The desired residual is added to that demand to determine the proper dosage. The chlorinators should be set accordingly.

DOSAGE = DEMAND + RESIDUAL

One way to keep these three numbers into perspective is to do what Ruth Lancaster related to me. Turn these three entities into a checkbook scenario.



Dosage will be the deposit put into your checking account.

Demand will be the amount of money spent by writing the checks to cover the expenses.

Residual is what is left over or the balance after all the checks are written.

Dosage (Deposit)	=	**Demand** (Expenses)	+	**Residual** (Balance)
Dosage is 3.5 ppm	=	**Demand** is 2.2 ppm	+	**Residual** is 1.3 ppm

As with any equation, if you know two of the variables, you can determine the third.

If demand is 1.8 ppm and the dosage is 2.2 ppm, then the residual is 0.4 ppm.

Dosage 2.2 ppm– Demand 1.8 ppm = 0.4 ppm Residual

If dosage is 3.5 ppm and the residual is 0.8 ppm, then the demand is 2.7 ppm.

Dosage 3.5 ppm– Residual 0.8 ppm = 2.7 ppm Demand

If demand is 2.9 ppm and the residual is 1.1 ppm, then the dosage is 4.0 ppm.

Demand 2.9 ppm + Residual 1.1 ppm = 4.0 ppm Dosage

The regulated disinfectant residual required to be maintained throughout the entire distribution system is:

FOR CHLORINE	0.2 mg/L (free chlorine)
FOR CHLORAMINE	0.5 mg/L (combined chlorine)

The purpose of maintaining residuals is to handle any disinfectant demand that comes about by way of the distribution system.

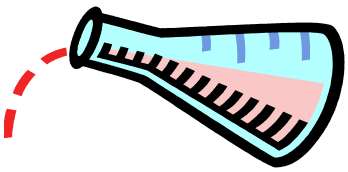
The quality of our consumable product (drinking water) is only as good as the container (our distribution system) it is delivered in. The quality of the treated drinking water is generally good to excellent when it leaves the water treatment facility. But as it travels from the treatment plant to the consumer, the quality of the water deteriorates relative to the condition of the distribution system. When distribution systems are exposed to the atmosphere, as in line installation or repair, contaminants can enter into our container (the piping). If the distribution system maintenance has been neglected, biofilms and other contamination can reproduce and flourish causing water quality issues. Our container, the distribution system, is basically a reusable container, and effort needs to be given in the area of maintenance by performing such tasks as unidirectional flushing, storage tank and line disinfection, corrosion control and backflow protection. Unfortunately, this is frequently an overlooked aspect of public drinking water systems.

When residual is lost in a distribution system, it signals an increase in disinfectant demand. This increased demand should be viewed as contamination developing in your system, and the source or reason for this increase in demand should be located and eliminated immediately. Diagnostic residual analysis can be used to locate and identify this additional demand.

In the past, operators simply increased the disinfectant dosage at the plant to obtain a residual in the distribution system. This doesn't resolve any problems; the demand on the disinfectant is still there. Since biofilms are resistant to biocides, their numbers will continue to increase and also increase the disinfectant demand. Increasing disinfectant dosages will usually bring about a commensurate increase in disinfection by-products, which will bring about compliance issues and no additional protection against pathogenic contamination. A much better approach would be to eliminate whatever is causing the increase in disinfectant demand so that desired residual levels can be obtained at lower dosage levels and minimize potential disinfection by-product increases.

The regulated maximum disinfectant residual level (MRDL) allowable by regulation is 4.0 mg/L for both chlorine and chloramine. This regulation was instigated to prevent the "old way" of achieving a disinfectant residual by throwing more disinfectant in the water at the plant and to encourage a "demand elimination" approach. Water quality degradation can be indirectly determined by calculating the disinfectant demand as shown previously. Loss of disinfectant residual in the distribution system is a result of greater demand. In order to control the disinfection process, the operator must control the factors that impact that process itself. It is important to understand not only what these factors are, but to also know how they impact the control of pathogenic organisms in our drinking water and distribution systems.

Factors Affecting the Disinfection Process



Dosage

The more disinfectant applied to the water within regulatory limits, the more effective the disinfection process will be. However, with chlorine, more disinfectant can lead to greater disinfection by-product production. Excessively high concentrations of disinfectants can also affect corrosion rates, tastes and odors and color issues. Because of the aforementioned reasons, it is important to determine what disinfectant level will achieve effective pathogen removal and continue to monitor to control this optimal level with correct dosage levels.

Contact Time

The longer the contact time, the more effective the disinfection process will be. The disinfectant must physically come in contact with the pathogen or contaminant of concern so the longer the disinfectant has to react with the water, the more effective it will be whether it is used as an oxidizer or a disinfectant. Since organics in combination with chlorine will produce halogenated disinfection by-products, THMs and HAAs, longer contact times could lead to greater disinfection by-products production at a given dosage. Conversely, inadequate contact time between chlorine and water may not allow breakpoint chlorination to transpire, which will reduce pathogen removal. Contact time and dosage are co-dependent upon one another. In order to achieve pathogen inactivation, CT calculations ensure the proper combination of dosage to contact time.

The effectiveness of depends primarily on two factors:

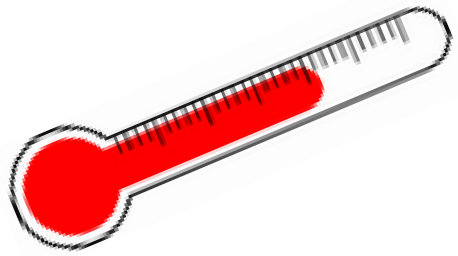
- **Concentration (C)**
- **Contact Time (T)**

THE DESTRUCTION OF ORGANISMS, OR "KILL," IS DIRECTLY RELATED TO THESE TWO FACTORS AS FOLLOWS:

"Kill" is proportional to C X T
Or
"Kill" = C X T

Temperature

The warmer the water, the faster the chemical reactions will occur. Therefore, in the warmer summer months when the water is warmer, breakpoint chlorination and CT can be more rapidly achieved. Yet, because the dissipation of chlorine in the distribution system is driven by a chemical reaction, free residuals will be harder to maintain in the summer than in the winter when the water is cooler. A change in water temperature will change the disinfection characteristics of the treated water.



pH

When chlorine is added to water, the following chemical reactions take place:

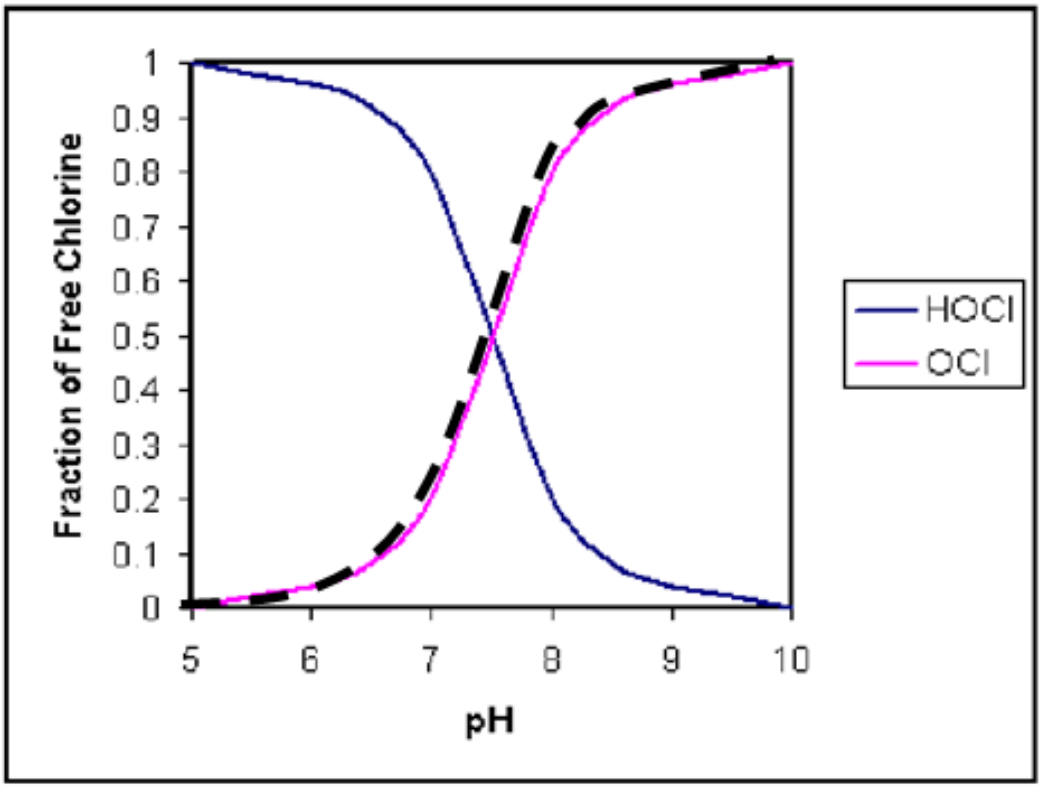
$$Cl_2 + H_2O \longrightarrow HOCl + HCl$$

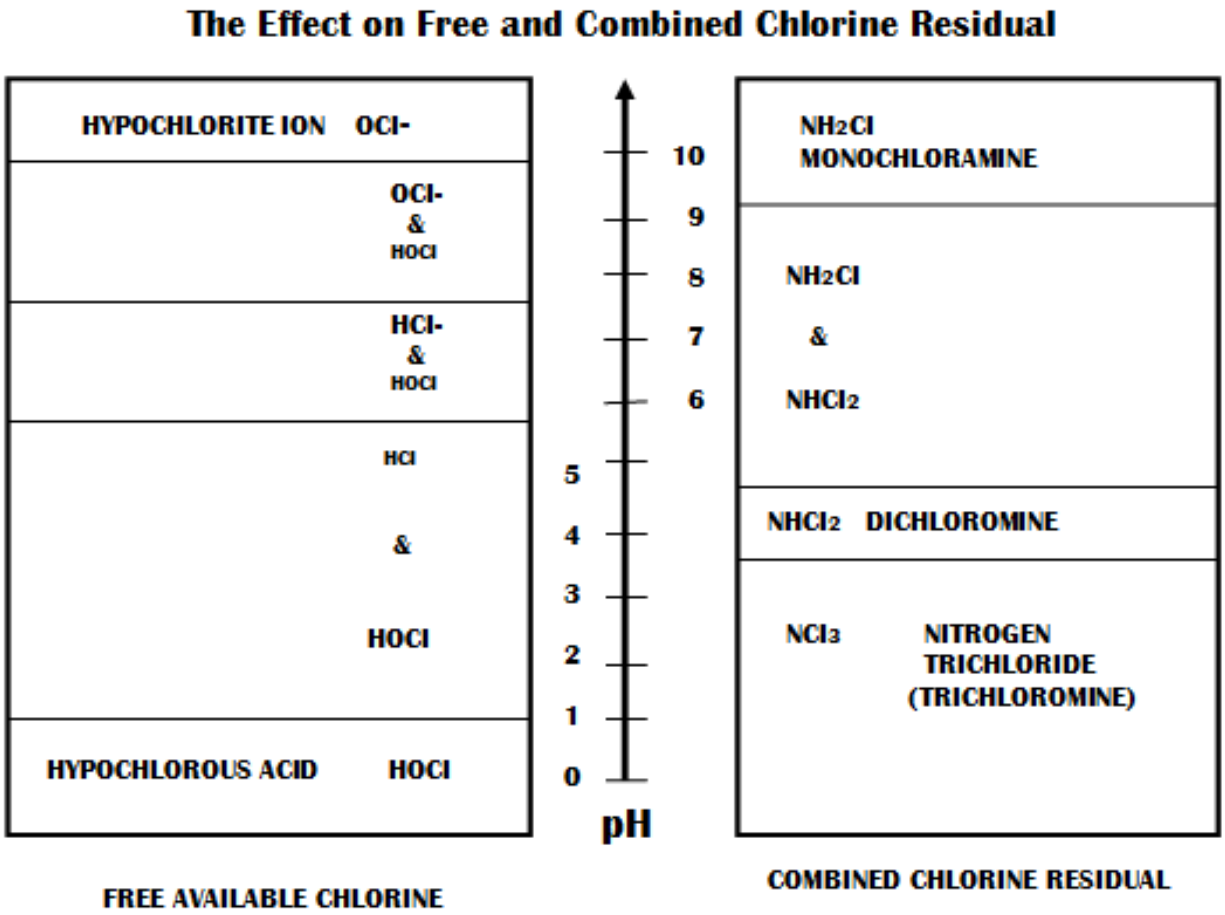
Chlorine + Water ⟶ *Hypochlorous Acid* + Hydrochloric Acid

$$HOCl \longleftrightarrow H^+ + OCl^-$$

Hypochlorous Acid ⟷ Hydrogen Ion + *Hypochlorite Ion*)

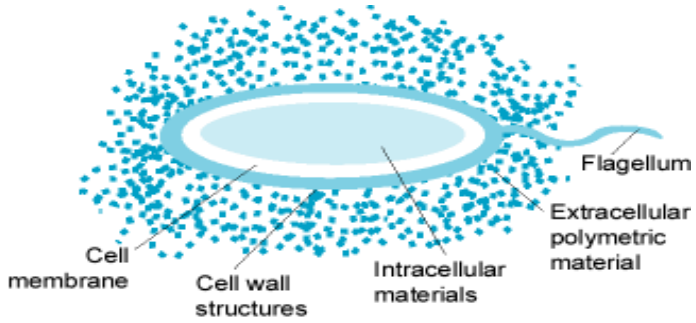
The hypochlorous acid and the hypochlorite ion are the compounds that kill or inactivate pathogens. Hypochlorous acid is 100 X more effective at pathogen inactivation than is the hypochlorite ion. Both occur simultaneously in water with the relative concentrations of each being pH-dependent. Generally, the lower the pH, the greater the concentration of hypochlorous acid and because of the higher hypochlorous concentration, the greater the disinfection potential. Waters with a higher pH will require greater chlorine dosages and/or longer contact times to achieve a given CT.





Interfering Substances

Since disinfectants must physically come in contact with the pathogens we're concerned with, turbidity and other interfering substances can and do provide a barrier or shield that makes the survival of the pathogen much more likely. Some of these interfering substances can actually serve as a food source for pathogens and must be kept at a minimum. Turbidity reduction, unidirectional flushing, storage tank cleaning, etc., all assist in the optimization of our disinfection process.



Point of Application

The point at which we apply our disinfectant is extremely important. If applied early in the treatment process, many of our disinfectants will provide oxidation characteristics that will greatly improve coagulation, settling or sedimentation and filtration. Conversely, along with oxidation characteristics, early application of disinfectants may also increase disinfection by-product formation. To minimize DBP formation, some operators will initially feed disinfectants post-filtration, which is hopefully after TOC reduction and has been optimized through our coagulation, flocculation and sedimentation processes. If a free residual isn't carried through the filters, there is a high probability that pathogens stored in the filter can grow, multiply and be released by the filter, making real pathogen control suspect. In order to maximize CT, chlorination should occur early in the treatment process, while simultaneously minimizing DBP production. With chloramination, chlorine is fed early in the treatment process to establish adequate contact time, while taking advantage of the stronger disinfectant. Ammonia is then fed to produce the more persistent disinfectant residual. Chlorine dioxide and ozone are both fed early in the treatment process and supplemented later with chlorine or chloramine to provide the residual safeguard.

Disinfection Monitoring and Control

The amount of disinfectant applied to the water is dependent upon the **DEMAND**, which is a combination of the amount required to react with any reducing agents that are in the raw water, the amount that will combine with NOM present in the water, the amount of disinfectant needed to debilitate or destroy the pathogens present in the water and the desired amount of free residual required to control pathogenic contamination in the distribution system. The sum of **DEMAND** plus **RESIDUAL** equals the **DOSAGE** required. Initial demand can be determined with jar tests and DPD analysis. Subsequent adjustments of the disinfectant dosage are made because of fluctuations or changes in the raw water and your analysis of them. Breakpoint chlorination should be a mandatory practice to ensure that all the demand is met and a free residual is established. Dosage can be calculated by using the following formulas.

lbs./day = dosage (mg/l, ppm) X 8.34 X MGD

If using a hypochlorite as your disinfectant, the percent purity must be accounted for.

lbs. of hypochlorite/day = dosage (mg/L, ppm) X 8.34 X MGD

% purity

If we need to disinfect a volume of water, such as a basin, storage tank, pipe, etc., at a described or prescribed by regulation dosage, the formula would be:

lbs. of disinfectant = dosage (mg/L, ppm) X 8.34 X MG

If a measured amount, by weight, of a disinfectant is added to a known volume of water, the dosage can be calculated using the following formula:

$$\text{dosage (mg/L, ppm)} = \frac{\text{lbs. of chemical}}{8.34 \text{ X MG}}$$

Again, if a hypochlorite is used in this type of application, we must differentiate the percent purity from 100 percent available chlorine. That amount could be calculated as follows:

$$\text{dosage (mg/L, ppm)} = \frac{\text{lbs. of chemical X \% purity}}{8.34 \text{ X MG}}$$

Examples:

Roland disinfects their 8 MGD flow with a chlorine disinfectant concentration (dosage) of 2.5 ppm. **How many pounds of disinfectant will this facility use in a day? How many pounds an hour?**

lbs. of chemical = ppm X 8.34 X MGD

lbs. of chemical = 2.5 ppm X 8.34 X 8 MGD

lbs. of chemical = 166.8 lbs./day

To determine how many pounds an hour is used, we just need to divide the total by how many hours are in a day.

$$\text{lbs. of chemical/hour} = \frac{\text{166.8 lbs.}}{\text{24 hours}}$$

lbs. of chemical/hour = 6.95 lbs./hr

To determine the same type of equation using a hypochlorite solution, the calculation just needs to account for the percent purity. The Kays Treatment Facility disinfects their 900,000 - gallon per day flow with a dosage of 3.5 mg/L of 12percent sodium hypochlorite. **How many pounds of sodium hypochlorite will this facility use in a day?**

$$\text{lbs. of chemical} = \frac{\text{ppm X 8.34 X MGD}}{\text{\% purity}}$$

$$\text{lbs. of chemical} = \frac{\text{3.5 ppm X 8.34 X 0.9 MGD}}{.12 \text{ (the decimal equivalent of 12\%)}} \text{ (900,000 gallons ÷ 1,000,000)}$$

$$\text{lbs. of chemical} = \frac{26.27}{.12}$$

lbs. of chemical = 218.9 or 219 lbs.

The Kays Treatment Plant needs to disinfect its sedimentation basin after removing all of the sludge by hand. As per regulation, the dosage needs to be an initial 50 ppm, held for a 24-hour interval and achieve a 25 ppm residual at the end of the 24 hours. The basin measures 30 feet by 75 feet and is 12 feet deep. **How many pounds of 70 percent available HTH would need to added to the water to disinfect the basin?**

$$\text{lbs. of chemical} = \frac{\text{ppm X 8.34 X MG}}{\text{\% purity (decimal equivalent)}}$$

$$\text{lbs} = \frac{\text{50 ppm X 8.34 X [(width (ft) X Length (ft) X Depth (ft)]X 7.48 gal converted to MG]}}{\text{\% purity (decimal equivalent)}}$$

$$\text{lbs.} = \frac{\text{50 ppm X 8.34 X [(30 ft X 75 ft X 12 ft) X 7.48 then converted to MG]}}{\text{\% purity}}$$

$$\text{lbs.} = \frac{\text{50 ppm X 8.34 X .20 MG}}{.70}$$

lbs. = 119.14 lbs.

Mr. Jones knows he has to disinfect the new line he and his crew have installed. His disinfectant tool is a grain scoop. If the scoop is full, it will hold 2 pounds of 65% available calcium hypochlorite. The new pipe is 1,500 feet long and 8 inches in diameter. Mr. Jones used 1 1/2 scoops of HTH. **Did he reach his 50 ppm regulatory requirement?**

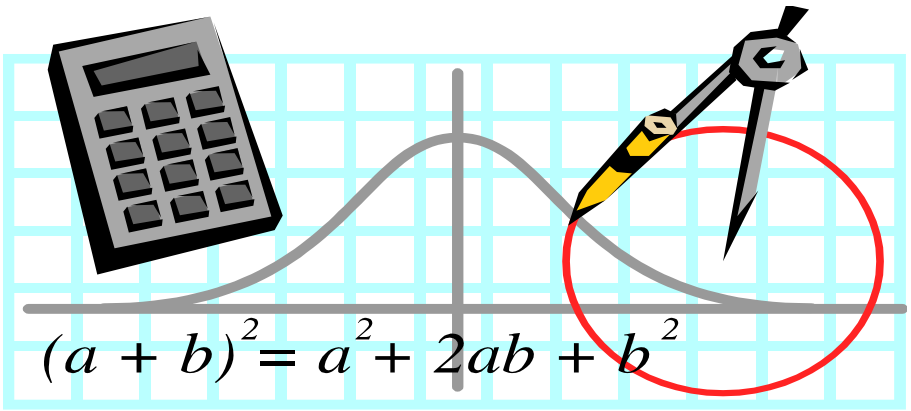
$$\text{ppm} = \frac{\text{lbs. of chemicals X \% Purity (decimal equivalent)}}{8.34 \text{ X MG}}$$

$$\text{ppm (mg/L)} = \frac{3 \text{ lbs. X } .65}{8.34 \text{ X } [(.785 \text{ X } .666 \text{ ft. X } .666 \text{ ft. X } 1500 \text{ ft}) \text{ X } 7.48 \text{ gallons then converted to MG}]}$$

$$\text{ppm} = \frac{1.95}{8.34 \text{ X } 0.0039\text{MG}}$$

$$\text{ppm} = \frac{1.95}{.033 \text{ (actually } 0.032526)}$$

ppm = 59 (actually 59.090909)



DON'T WORRY ABOUT CALCULATING PERCENT PURITY OR PERCENT AVAILABLE UNLESS IT IS MENTIONED IN THE BODY OF THE PROBLEM.

Practice

1. The Wilhoite Treatment Facility has a flow of 750 gpm during its 18 hours of daily operation. **How many pounds of chlorine will be needed to achieve the desired 3.75 ppm dosage rate?**

2. The Keatley Water Treatment Facility has switched from gaseous chlorine to sodium hypochlorite. This will be the first day it will use the 11% sodium hypochlorite in treating the 5.3 MGD flow at the plant to reach the desired dosage of 2.7 mg/L. **How many pounds of sodium hypochlorite will be need to be added to the water?**

3. The City of Ricketts treats 11 .7 MGD and currently uses a dosage of 2.2 mg/L of chlorine. It has added on to its distribution system and now needs a dosage of 3 mg/L to satisfy the residual requirements. **How many additional pounds of chlorine per hour will the city need to accomplish this?**

4. The Haynes Treatment Plant is thinking of converting its disinfection from chlorine to 70% calcium hypochlorite. The daily flow is 6 MGD and the dosage currently is 3.4 ppm. **How many additional pounds a month will the plant need to maintain its current dosage level, and what is the cost difference in calcium hypochlorite if it pays $0.80 a pound for chlorine and $0.48 a pound for the calcium hypochlorite?**

Where in the world do we start? I think we need to figure pounds for both and then do the costs.

1. lbs. of chemical = ppm X 8.34 X MGD

lbs = 3.75 ppm X 8.34 X [(60 minutes X 18 hours X 750 gpm) converted to MGD)

lbs. of chemical = 3.75 X 8.34 X 0.81 MG

lbs. of chemical = 25.3

2. $$\text{lbs. of chemical} = \frac{\text{ppm X 8.34 X MGD}}{\text{\% purity}}$$

$$\text{lbs. of chemical} = \frac{\text{2.7 ppm X 8.34 X 5.3 MGD}}{.11}$$

$$\text{lbs. of chemical} = \frac{119.34}{.11}$$

lbs. of chemical = 1084.9 or 1085

3. lbs. of chemical = ppm X 8.34 X MGD

lbs. of chemical = (3 mg/L – 2.2 mg/L) X 8.34 X MGD

lbs. of chemical = 0.8 mg/L X 8.34 X 11.7 MGD

lbs. of chemical = 78.06 (for 24 hours of operation)

lbs. of chemical/hr = 78.06 ÷ 24 hours

lbs. of chemical/hr =3.25

4. lbs. of chemical = ppm X 8.34 X MGD

lbs. of chemical = 3.4 ppm X 8.34 X 6 MGD

lbs. of chemical = 170.1 lbs. of chlorine @ $ .80/lb.

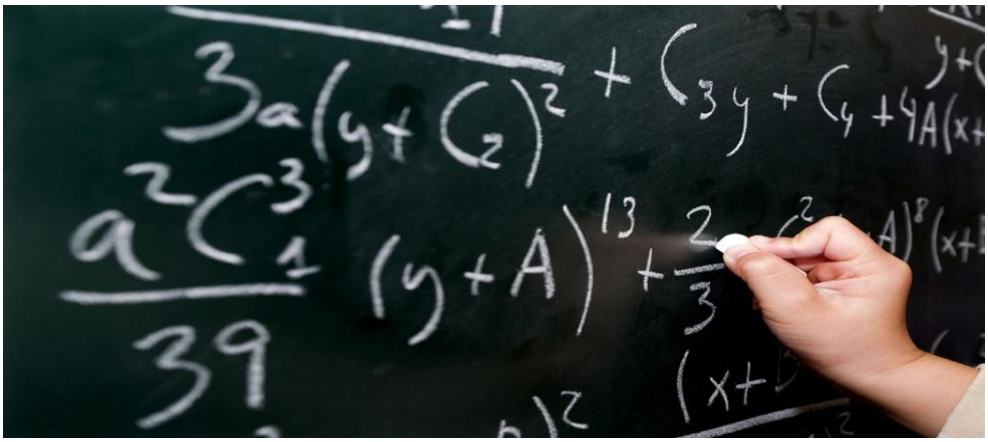
$$\text{lbs. of chemical} = \frac{3.4 \text{ ppm X } 8.34 \text{ X } 6 \text{ MGD}}{.70}$$

$$\text{lbs. of chemical} = \frac{3.4 \text{ ppm X } 8.34 \text{ X } 6 \text{ MGD}}{.70}$$

$$\text{lbs. of chemical} = \frac{170.1}{.70}$$

lbs. of chemical = 243 lbs. of 70% calcium hypochlorite @ $.48/lb

243 lbs. calcium hypochlorite	$116.64 calcium hypochlorite
- 170.1 lbs. chlorine	- $ 136.08 chlorine
72.9 lbs. more	$ -19.44 less



Specific Gravity

Specific gravity is nothing more than the weight of any liquid in comparison to an equal volume of water. Since some of the chemicals we need to treat our water do not weigh the same as an equal volume of water, we need to account for that difference since our formulas are based on the weight of water.

In the above illustration, kerosene has a specific gravity of 0.8, which means that it weighs 0.8 times the weight of water or 6.67 lbs./gal (.8 X 8.34 lbs.). Our super duper polymer weighs 1.3 times more than water, so it weighs 10.8 lbs./gal.

If we used a product that had a specific gravity of 1.6, what would it weigh per gallon?

8.34 lbs./gal water X 1.6 specific gravity = 13.34 lbs./gal

Example:

The Stump Treatment Plant disinfects its flow of 16.8 MGD with 8.25% available sodium hypochlorite with a specific gravity of 1.8 to obtain a dosage of 3.3 mg/L. **How many gallons of sodium hypochlorite will the plant use a day?**

All of our dosages are based on weight, so to determine gallons, we first have to determine pounds.

$$\text{lbs. of chemical} = \frac{\text{ppm X 8.34 X MGD}}{\text{\% purity}}$$

$$\text{lbs. of chemical} = \frac{\text{3.3 ppm X 8.34 X 16.8 MGD}}{.0825}$$

lbs. of chemical = 5604.48 lbs.

$$\text{gallons of chemical} = \frac{\text{5604.48 lbs.}}{\text{(8.34 X 1.8 SG)}}$$

$$\text{gallons of chemical} = \frac{5604.48}{\text{15 lbs/gal}}$$

gallons of chemical = 373.6 or 374 gallons of sodium hypochlorite

Strength of Solution

Strength of solution is the weight of a chemical divided by the weight of the water it was put into, PLUS, the weight of the water called the solution. When the calculation is performed, you will have a decimally notated number that when multiplied by 100, will give you an answer in a percentage notation.

$$\text{Strength of Solution} = \frac{\text{weight of chemical}}{\text{weight of solution}}$$

Examples:

If we were to put 25 pounds of alum in 300 pounds of water, we could calculate it in this way.

$$\text{Strength of Solution} = \frac{25}{\text{300 lbs./water + 30 lbs. alum}}$$

$$\text{Strength of Solution} = \frac{25}{\text{330 lbs.}}$$

Strength of Solution = 0.075

turned into a percentage multiply the sum by 100

Strength of Solution = 7.5 %

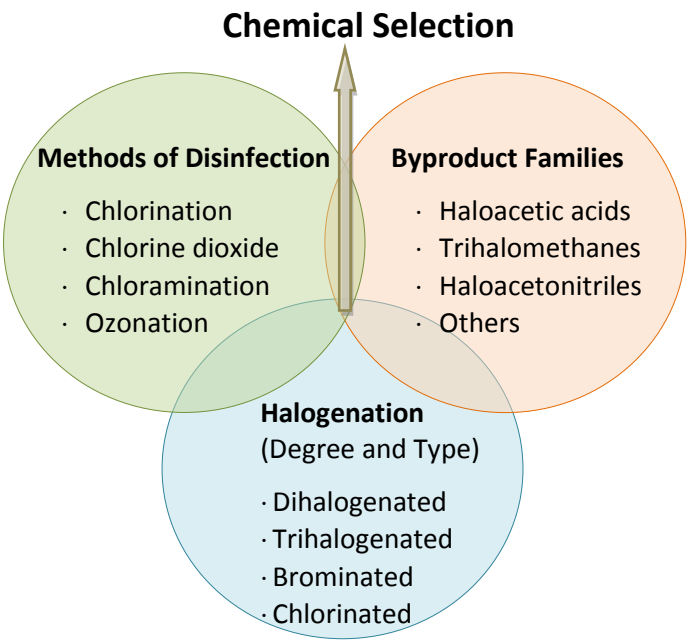
Harrod Treatment Plant has added 77 pounds of caustic soda to 1,000 gallons of water. What is the percent strength of solution?

$$\text{Strength of Solution} = \frac{\text{77 lbs. of caustic}}{\text{1000 gallons of water + 77 lbs. of caustic}}$$

$$\text{Strength of Solution} = \frac{\text{77 lbs. of caustic}}{\text{(1000 gal X 8.34 lbs/gal) + 77 lbs. caustic}}$$

$$\text{Strength of Solution} = \frac{\text{77 lbs. of caustic}}{\text{8417 lbs. of solution}}$$

Strength of Solution = 0.009 decimally or 0.9%



Disinfection By-products

Disinfection by-products (DBP) are formed when disinfectants used in water treatment and distribution react with natural organic matter (NOM). The main DBP that regulations have been established for include

- Trihalomethanes
- haloacetic acids
- bromate
- chlorite

Trihalomethanes (THM)

Trihalomethanes are a group of four chemicals that are formed when chlorine reacts with organic latter present in the water.

- chloroform
- bromodichloromethane
- dibromochloromethane
- bromoform

The Disinfection By-product Rule 2 sets the maximum allowable annual average **at 80 ppb**.

Haloacetic Acids (HAA)

These are also referred to as HAA5 because five different acids are formed when chlorine comes in contact with water.

- monochloroacetic acid
- dichloroacetic acid
- trichloroacetic acid
- monobromoacetic acid
- dibromoacetic acid

HAA5 are regulated at an annual average of **60 ppb**.

Chlorite

This is formed when chlorine dioxide is used as a disinfectant.

Chlorite is regulated at a monthly average of **1 ppm**.

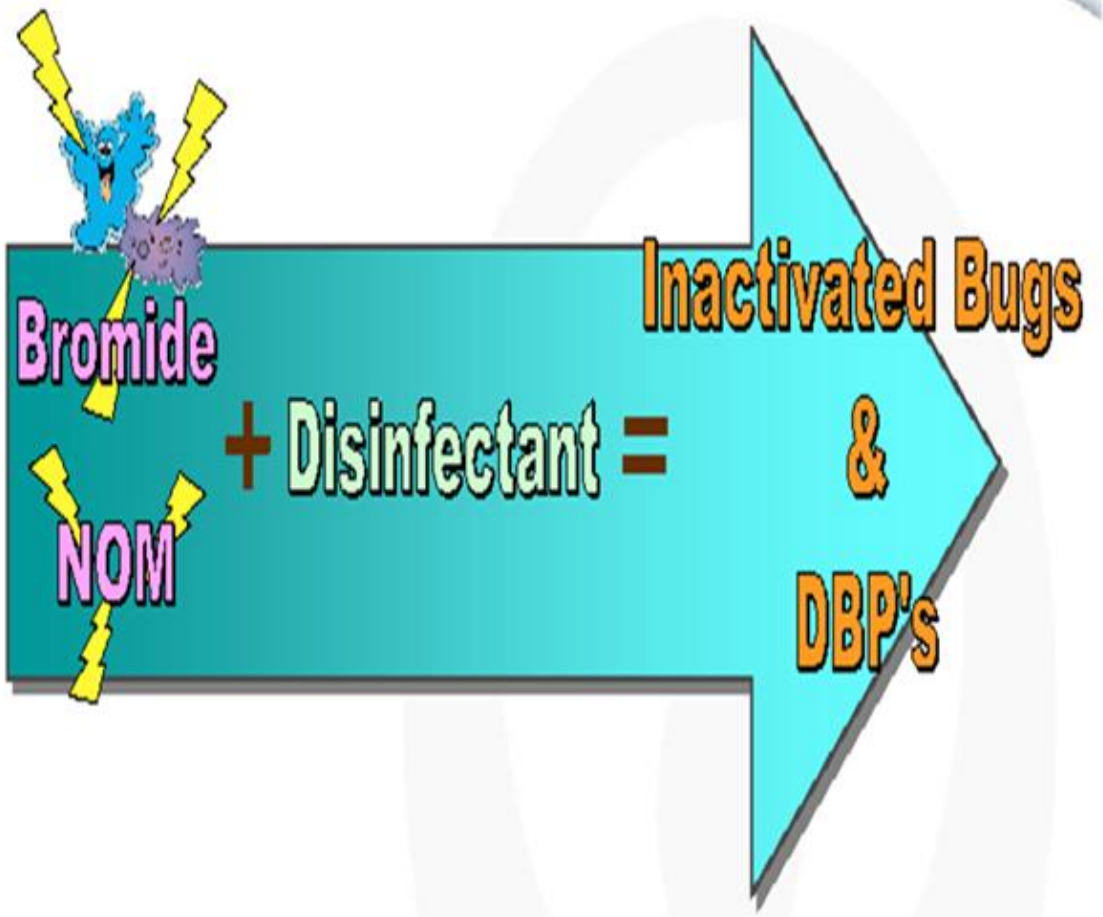
Bromate

Bromate is formed when ozone reacts with naturally occurring bromide found in source water. It is regulated at an annual average of **10 ppb.**

I am aware that this is redundant, but it warrants repetition. pH can dramatically impact the reactions between chlorine and NOM, resulting in very favorable conditions for the formation of total trihalomethanes (TTHM) and haloacetic acid (HAA). At a higher pH, more THM tend to form. Lower pH tends to favor HAA formation. Systems that have high TTHM levels but relatively low HAA formation might be able to reduce TTHM formation by lowering the pH. If your facility chooses this course of action, pay close attention to potential corrosion issues.

Besides the regulatory issues, DBP have been shown to be potentially carcinogenic, or cancer causing, so their control is in everyone's best interest. There are means available to control these substances, some of which do not require substantial investments of time or money. Optimizing the entire treatment process from beginning to end probably reduces the precursors of disinfection by-products, the organics, and allow your facility to meet regulatory guidelines, meet CT standards so viable disinfection is achieved and protect your consuming public. Being successful in this regard requires attention to detail, operator diligence, and in some systems, more management support.

Microbial Inactivation & Disinfection by-product (DBP) Formation



DBPs form due to disinfectant chemistry or from combining with natural organic matter (TOC)

Review Questions for Chapter 5 – Disinfection

1. Describe the reasons that disinfection of water is necessary.
2. Identify why a residual disinfectant in the distribution system is mandated by regulation.
3. Identify the three types of chlorine commonly used in municipal drinking water treatment.
4. Chloramines are formed when what two substances are combined?
5. What is the strongest disinfectant used in drinking water treatment?
6. Describe the process by which UV accomplishes disinfection.
7. Rate these chemical disinfectants from strongest to weakest: sodium hypochlorite, chlorine dioxide, gaseous chlorine, ozone, calcium hypochlorite and chloramines.
8. Explain how an operator determines chlorine in the water has reached breakpoint.
9. Identify the things that interfere with disinfection.
10. Which is the more effective disinfectant, hypochlorous acid or hypochlorite ion?
11. Explain the relationship between chlorine disinfection and pH level.
12. If you get customer complaint calls about the water smelling like Clorox, does this usually mean that there is too little or too much chlorine in the water?
13. If a liquid has a specific gravity of 1.4, is it lighter or heavier than the same volume of water?
14. TTHMs are formed when what two substances come in contact?
15. Could the point of application of chlorine make a difference in the production of DBPs?
16. The membrane filter with the smallest pore sizes is called what? Identify the pore sizes of each membrane filter.
17. The process by which membranes accomplish their task is actually _____ _____. Describe the process of how membranes accomplish their task.
18. Do membrane filtration systems require minimal or a great amount of pretreatment? Identify the level of pretreatment needed by a membrane filtration system.
19. Name the two types of membrane filtration most frequently used in municipal drinking water applications.

Answers to Review Questions for Chapter 5 –Disinfection

1. kill pathogens, provide residual safeguards
2. to kill any pathogens or to prevent pathogenic growths to flourish and reproduce
3. gaseous chlorine, calcium hypochlorite, sodium hypochlorite
4. chlorine and ammonia
5. ozone
6. changing or damaging the DNA of the pathogen, which prevents the pathogen from replicating or reproducing
7. ozone, chlorine dioxide, gaseous chlorine, calcium hypochlorite, sodium hypochlorite, chloramines
8. If the free chlorine is $\geq$ 75 percent of total and when all the chlorine added to the water shows as free chlorine.
9. turbidity, dosage, time, temperature, pH
10. Hypochlorous acid is 100 times a stronger disinfectant than the hypochlorite ion.
11. Low pH
12. If the water smells like Clorox, USUALLY this means that you haven't reached breakpoint and more chlorine is needed.
13. A specific gravity of 1.4 means that the liquid is 1.4 times heavier than water.
14. TTHMs are formed when free chlorine reacts with organics.
15. Yes
16. Reverse Osmosis
17. size exclusion
18. require substantial pretreatment
19. microfiltration and ultrafiltration

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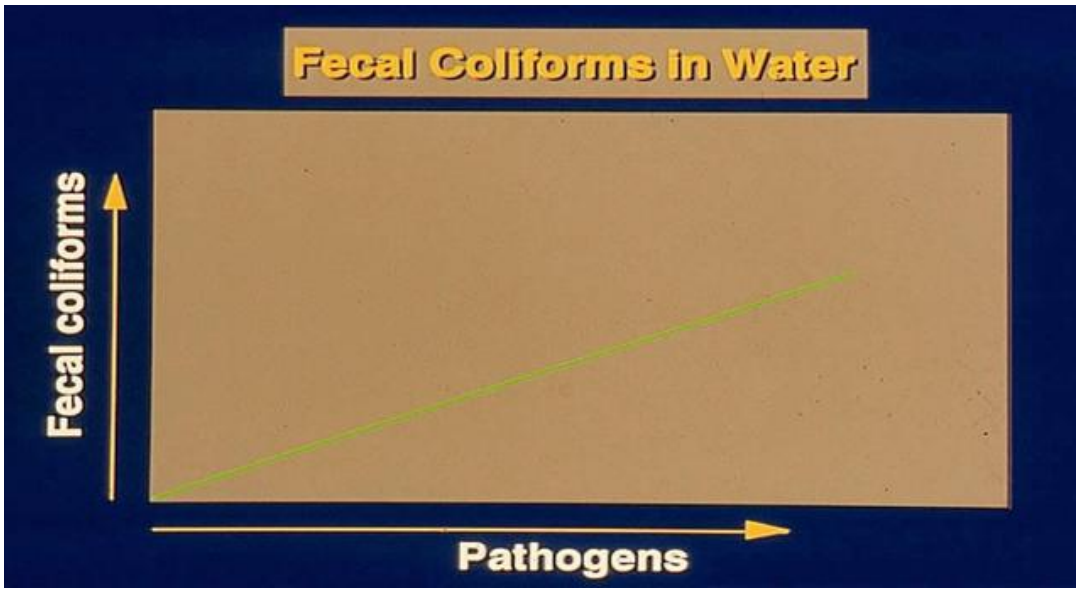
Chapter 6: BACTERIOLOGICAL MONITORING

Chapter 6 Objectives

1. Circumscribe the reason that sampling is mandated by regulation.
2. Notate the minimum number of samples required by regulation.
3. Determine the method that can be used as a substitute for chlorine residual sampling.
4. Explain why samples should be representative of your system.
5. Determine when check samples are necessary and where should they be taken.
6. Determine what volume of water is need for a bacteriological sample, the hold times for Bac-T samples and how long these records need to be kept.
7. Notate the hold times for bacteriological samples.
8. List what tests are performed to determine the presence of coliforms in the finished water.
9. Define coliforms, why they are used in our industry and how sampling is changing relative to coliforms.
10. Define heterotrophic plate counts, standard plate counts, what they enumerate and why they can be a valuable tool.

Purpose

Bacteriological sampling (Bac-T) is used to determine potential contamination problems, allowing the system to notify the public to boil their water while operators can locate and rectify the cause of the problem. The federal regulations regarding "Bac-T" sampling schedules set the minimum number of samples a water system must submit at one per month. As the size of the system increases so does the minimum number of samples required each month. Pathogens are disease causing organisms that have decimated entire populations and cultures. The pathogens of interest are bacteria, viruses, and protozoa. To determine if the propensity or likelihood that pathogens are present in our water we use an easy, inexpensive method to determine how likely the presence of pathogens might be. We use an indicator organism called a coliform. Coliforms are found in the intestinal tract of warm blooded animals but effective disinfection inactivates these organisms. Coliforms are easy to grow and relatively cheap and easy to identify. In February of 2013, EPA published in the Federal Register the revisions to the 1989 TCR. EPA anticipates greater public health protection under the Revised Total Coliform Rule (RTCR) requirements. The RTCR requires public water systems that are vulnerable to microbial contamination to identify and fix problems; and establishes criteria for systems to qualify for and stay on reduced monitoring, which could reduce water system burden and provide incentives for better system operation. If coliforms are present, there is a strong likelihood that pathogens are also present.



If fecal coliforms or E. coli are present in your water, an immediate boil water and public notice must be issued.

COLOR WHEELS MAY NO LONGER BE USED FOR COMPLIANCE SAMPLING.

Requirements

ALL public water suppliers must take samples of their water. **The minimum number of samples that any system, no matter how small, can take is two (2).** The population of your system will dictate the number of samples that need to be taken. If your system collects forty (40) or less samples a month, ALL must be negative to stay in compliance. If your system collects more than forty samples, the system can have 5 percent of the samples test positive without the system being out of compliance. A heterotrophic plate count (HPC), or as it is sometimes referred to, a standard plate count, can be used in lieu of chlorine residual for up to 5 percent of the distribution system samples.

Collection

At least 100 milliliters (ml) of water must be collected in, hopefully, a sterile container. Compliance samples should not be collected from fire hydrants, water fountains, hoses or swivel or leaky faucets. When using faucets for sampling, the faucet should not contain strainers or screens. The sample water should be run in at least pencil-sized streams for two – three minutes or until the temperature of the sample is constant. The reason for the two – three minute criteria is to ensure that the sample being taken is not from premise plumbing, but rather from the distribution system mains. The most numerous reasons for positive samples are operator error that could result from a lack of knowledge or a lack of concern by the operator. In the bottom of the collection bottle is usually found a small white tablet or a small amount of white powder. These substances are sodium thiosulfate, which is used as a dechlorination agent to determine what is left in the sample water after it has been exposed to the system's disinfection efforts.

Representative Samples

Samples should truly represent the quality of the water throughout the system. Water taken from "safe" sample points do nothing except satisfy compliance numbers. The sites that should be sampled are the dead ends, low-use areas and older lines that have been in service for a long time. Failure to sample the potentially problematic areas is to not diligently perform the duties of a certified operator, which is to protect the consuming public, all the consuming public. As the system expands, update the sampling plans to reflect these changes. Sampling plans should include residential, commercial, industrial and educational sample points. An addition or revision of your sampling sites must be done in writing to the DOW and approved before use. If a sampling site is abandoned or the site itself is no longer physically available, the number for that former sampling site may not be reused. When a water sample is taken and comes back negative, all it means is at that sample location and at that time, the water was safe. Immediately before or after the sample was taken the water could have been contaminated.

Check Sampling

After the notification from the lab of a positive sample, a system **must collect three (3) check samples**—one from within five upstream service connections, one from within five downstream service connections and one from the original sampling site.

Check samples are still considered compliance samples. If a system collects fewer than **five (5) samples a month** for compliance, the month after a check sample incident, the system **MUST submit five (5) compliance samples**. Special samples like new line installation, line extensions, etc., do not count toward compliance, but must be specified as a special sample. Even though they are not compliance samples, they too must be submitted on bacteriological analysis report forms (BARFs). Be sure to protect yourself and the system and include an accurate chain of custody document with each set of samples.

Hold Times

- Total coliform samples have a **30-hour hold time**.
- Heterotrophic (standard) plate counts have a **six-hour hold time**.

Methods

- Multiple Tube Fermentation
- Membrane Filtration
- MMO-MUG
- Heterotrophic Plate Count (Standard Plate Counts)

These are required for compliance samples that are **below the minimum chlorine residual of 0.2 mg/L.** This test counts the number of bacteria, not coliforms, not pathogens, only bacteria. Counts must be **less than 500 colony-forming units per 1 ml of the sample**.

Recordkeeping

Again, always fill out the **BARF** and chain of custody paperwork. These bacteriological records must be kept for a period of at least five (5) years. All chain of custody and BARFs **always include**

- Collection date and time;
- Location code chlorine residual;
- Type of disinfection;
- Name, address and PWSID; and
- The signature of the sampler.

Review Questions for Chapter 6 – Bacteriological Monitoring

1. The minimum number of samples any size system is regulated to obtain is ____.
2. An HPC can be used in lieu of a chlorine BAC-T sample in some circumstances. T or F
3. Standard plate counts or heterotrophic plate counts enumerate what?
4. How long must BAC-T records be kept?
5. What causes the majority of positive BAC-T samples?
6. If a positive BAC-T is received, how many check samples must be taken and where must they be taken?
7. Chlorine should be removed from disinfected water after flushing. T or F

Answers to Review Questions for Chapter 6 – Bacteriological Monitoring

1. 2
2. True
3. bacteria
4. 5 years
5. sampler error or poor technique
6. 3
7. True

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Chapter 7: CROSS CONNECTIONS

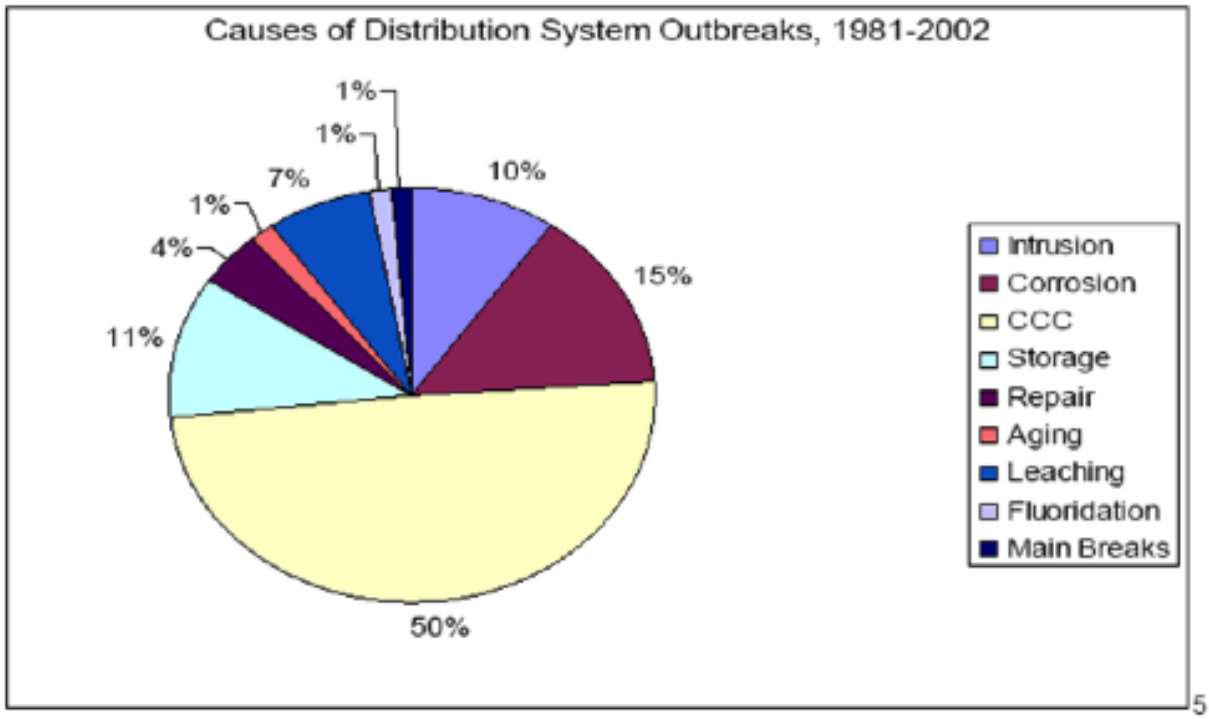
Chapter 7 Objectives

1. Define a cross connection, backflow, backsiphonage and backpressure.
2. Determine what is responsible for more waterborne illnesses than any other factor and whose responsibility it is if it occurs.
3. Determine how a cross-connection program should be implemented and what it should contain.
4. Determine the three levels of hazards of backflow.
5. Decide which form of backflow protection is the most foolproof or the most effective.
6. Decide which backflow prevention devices work only against backsiphonage.
7. Decide which backflow devices work against backpressure and backsiphonage.
8. Decide which backflow device(s) are approved for toxic substances.
9. Determine how frequently backflow prevention devices should be tested.
10. List some instances when backflow could occur.
11. Determine what device is frequently needed when a backflow prevention device is installed to counteract the effects of expansion due to the heating of water.
12. Delineate the two types of cross-connection prevention programs.

Cross-Connection Control

Backflow, which is accomplished through a cross connection has been shown to be responsible for more waterborne illnesses than any other factor.

WHY PAY SO MUCH ATTENTION TO CROSS CONNECTIONS?



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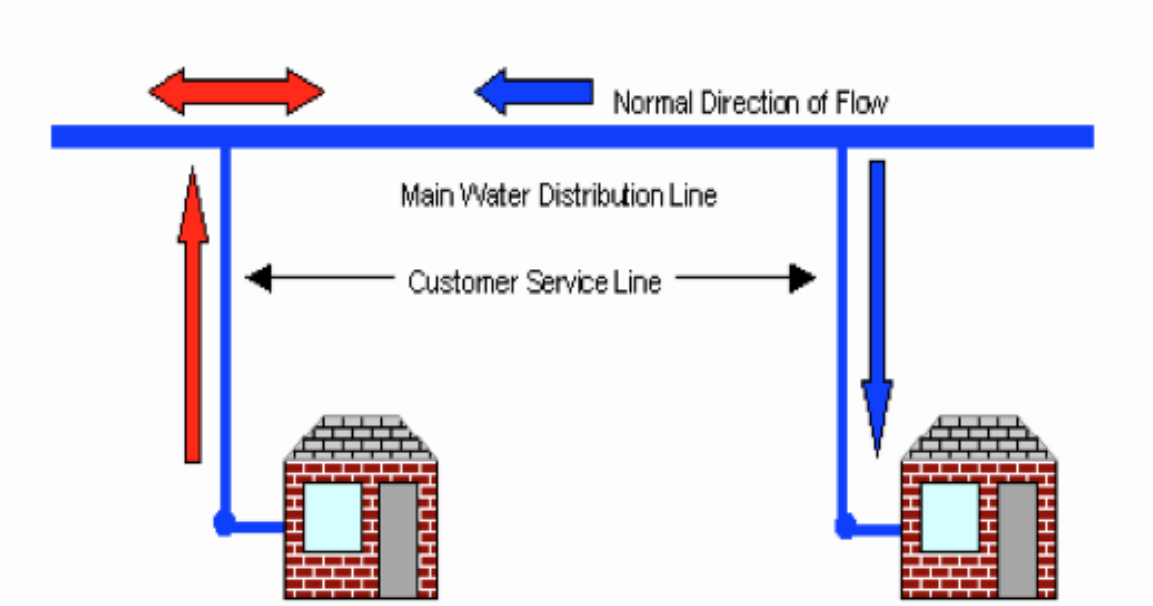
As the above chart illustrates, more people have gotten sick because of backflow than all of the other factors combined. But still there are no federal regulations mandating backflow prevention at the municipal level. Plumbing codes now demand them, but municipal water systems are not regulated to have a backflow prevention program in place. Why? In my opinion, it starts with the issue of funding. These devices are not cheap, and someone will have to pay for them.

Backflow, by definition, is a reverse flow condition whereby a nonpotable substance enters into the potable drinking water system, potentially exposing the water supply and everyone who consumes their water, to chemical or biological contaminants or pollutants.

The health hazards and the associated potential liability should make backflow prevention important to every water supplier, if not for financial reasons, then moral ones.



An increase in pressure due to pumps or water heating devices cause customer system water pressure to be greater than the water pressure of the distribution system. Result is a **Backflow** of contaminants into the distribution system.

A water distribution system that has a water pressure greater than that within the customers system will prevent the **Backflow** of contaminants into the distribution system.

"ENTIRE FOOTBALL TEAM CONTRACTS HEPATITIS FROM BACKFLOW INCIDENT"

"CHILDREN AND STAFF AT VBS SICKENED BY CHLORDANE FROM BACKFLOW INCIDENT"

"UPON INVESTIGATING COMPLAINTS FROM WATER CUSTOMERS, PESTICIDES FOUND FLOWING IN DRINKING WATER MAINS"

"NINE PEOPLE UNDERGOING KIDNEY DIALYSIS KILLED WHEN BACKFLOW INCIDENT OCCURS SIPHONING ETHELYNE GLYCOL INTO BUILDING'S WATER SUPPLY"

"MAN DRINKS BLOOD FROM FUNERAL HOME DRINKING FOUNTAIN"

At a funeral home in Georgia, people were paying their respects to the dearly departed. Simultaneously, the funeral director was embalming another body in preparation for viewing. A drop in system pressure resulted in bodily fluids being sucked back into the drinking water supply. This was discovered when a visitor to the funeral home found himself swallowing a large dose of blood and bodily fluids.

This incident and the headlines are not fabricated. They are taken directly from the U.S. Environmental Protection Agency (EPA) cross-connection book. Before these issues are dismissed, think about where the funeral homes in your area are located. I would guess at least some of them are in the larger, older, homes that were built long before plumbing codes mandated backflow prevention devices be installed where needed. What would the reaction in your area be if an incident like this occurred there?

The City of Georgetown had a backflow incident at a greenhouse where someone was affected by the substance that backflowed from the greenhouse. When representatives from the Division of Water appeared in Georgetown, their first question to Billy Jenkins, who at the time was in charge of the distribution system, was “Mr. Jenkins, do you have a written implemented cross-connection program in place?” His reply was “no.” The representatives then told Mr. Jenkins that the fine would be $25,000 a day until one was implemented. Could YOUR system afford that?

A backflow occurs because of a cross connection. A cross connection is any physical link between a potable water supply and one of unknown or questionable quality.

There are two conditions necessary for backflow to occur:

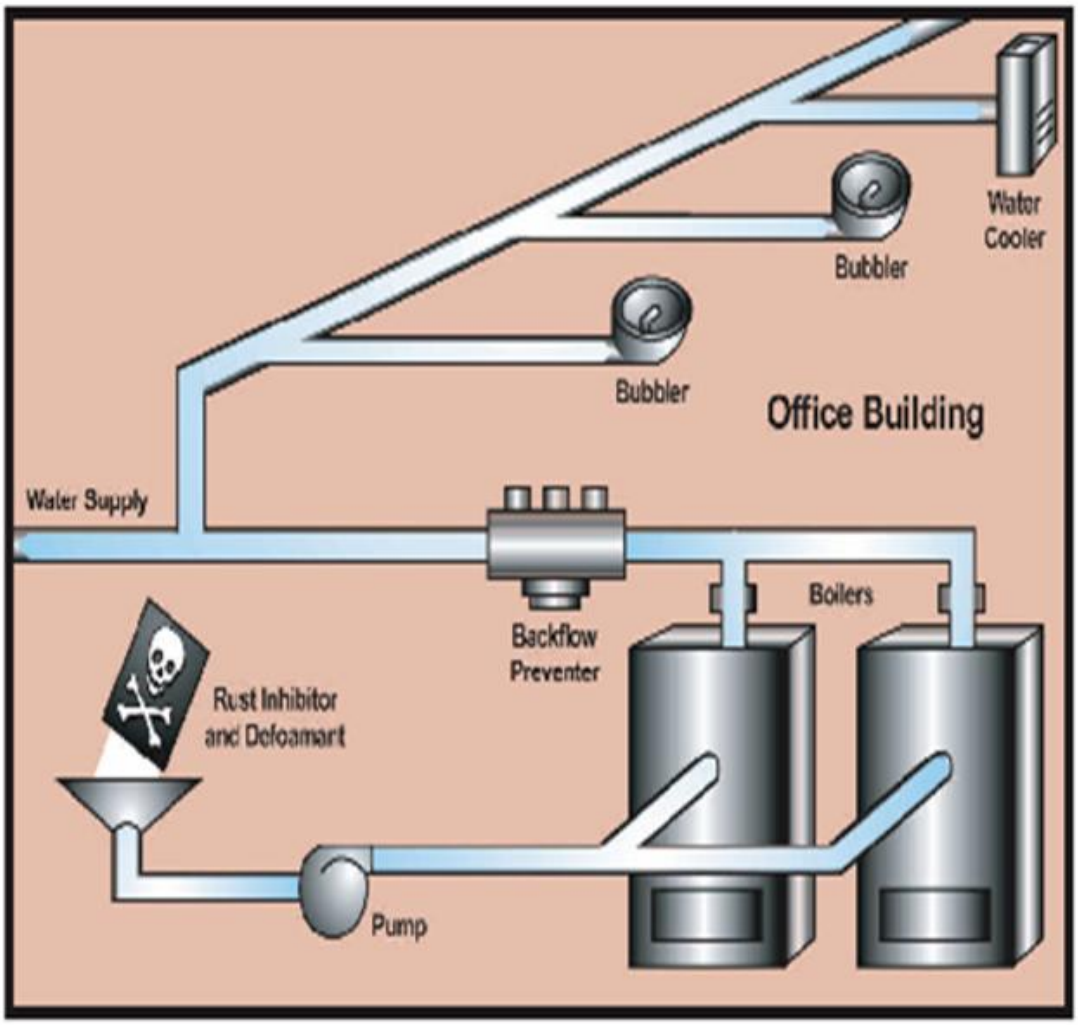
- Backpressure is where the nonpotable system pressure increases to where it is greater than the potable side that reverses the flow, OR
- Backsiphonage is where the potable system drops to a pressure lower than the nonpotable water system.

Cross-Connection Control Programs

There are two types of programs.

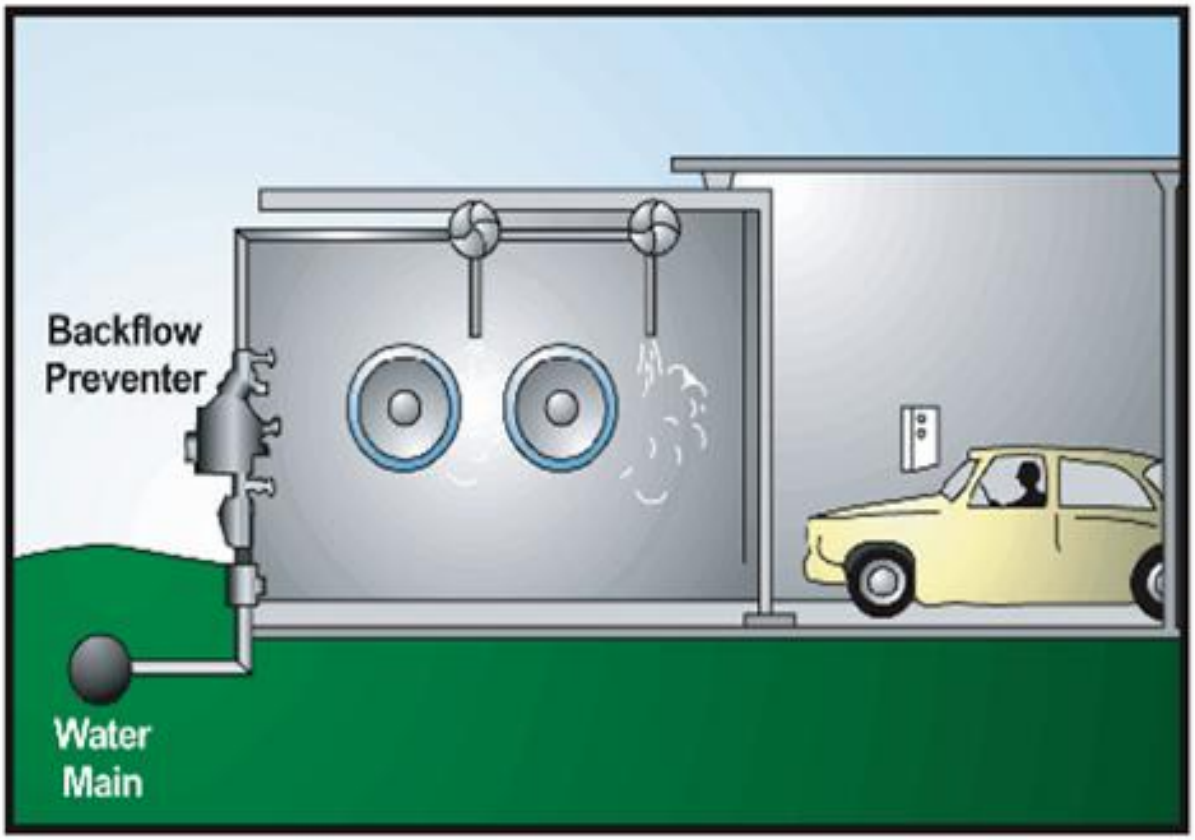
Isolation – protecting the consumer at the supply end.

Containment – protecting the water system at the service connection.



8.3 Figure 2: Isolation protects individual sites

Containment: Protecting the water system at the SERVICE CONNECTION.



8.3 Figure 1: Containment protects the public water system

Before embarking on a cross-connection control crusade, there are some considerations to be made. Voluntary compliance seldom works so some means to compel customers to install backflow prevention devices is needed.

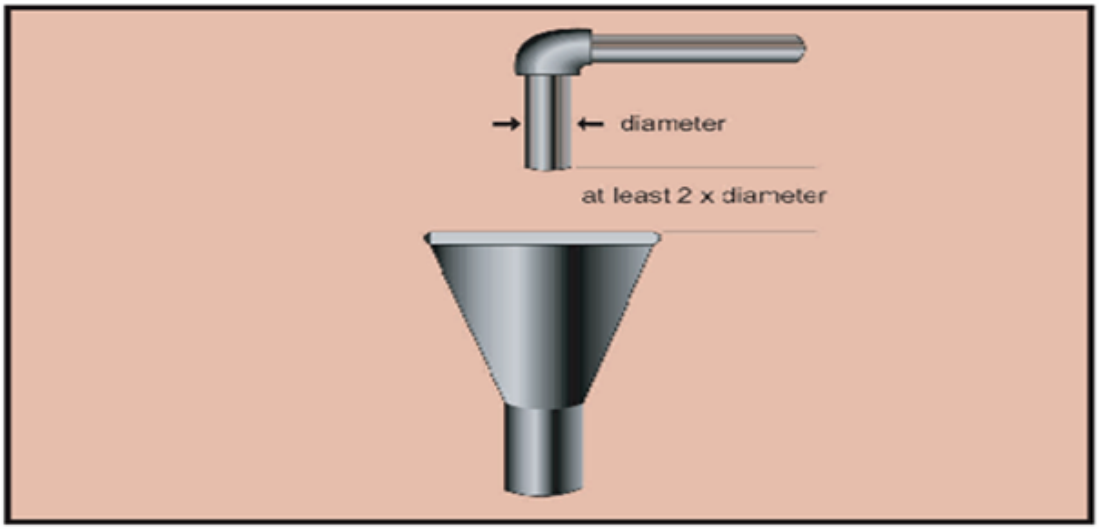
Your success could be dependent upon:

Local ordinances – defines the roles, responsibilities, penalties legalities, etc. Without this, you have no program.

Surveys – locate cross connections, assess the potential hazards, assign the appropriate devices

Certification – Train and certify the installers, testers, repairers, and certify the viability of the device at least annually.

Education – Educate everyone; the local officials for funding and support, staff and installation contractors for implementation and your consumers for understanding, acceptance and support.



8.4.1 Figure 1: Air gap

Backflow Prevention Devices

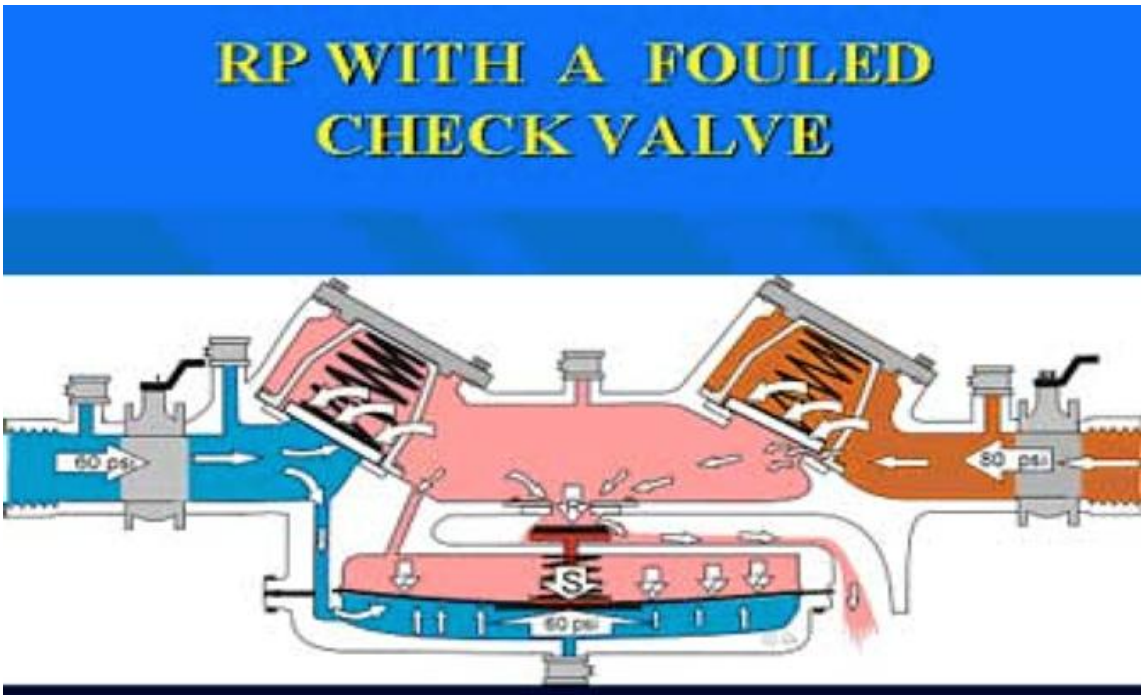
The most foolproof backflow prevention device is the air gap.

Air Gap

- An air gap is a physical separation from where the water leaves the pipe to where it is to end up.
- An air gap must be two times the inside diameter of the pipe or one inch, whichever is greater.
- It is the only viable device for highly toxic applications.
- It is the easiest to maintain, but also the easiest to defeat.

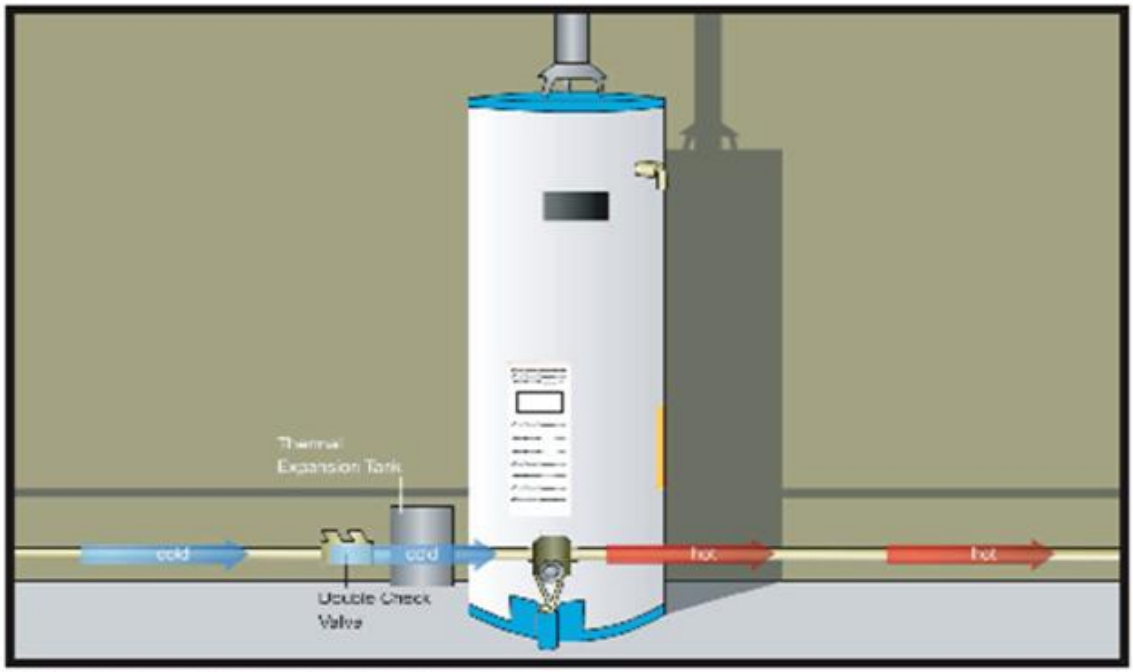
Reduced-Pressure Zone Backflow Preventer (RP, RPZ)

- It is recommended that these devices should be installed above ground at a height of 12 inches minimum and 30 maximum.
- Can also be used for toxic substances, but this device is not as reliable as an air gap.
- If the potentially contaminated water backflows and the water makes its way past the first valve, this device will send the contaminated water to the atmosphere by the use of a differential relief valve before the water gets to the first check valve.
- The relief valve should not be plugged, buried or submerged.
- Prevents backpressure and backsiphonage


RP WITH A FOULED CHECK VALVE
60 psi
50 psi
S
60 psi

RP IN NORMAL CONDITIONS
60 psi
52 psi
49 psi
S
60 psi

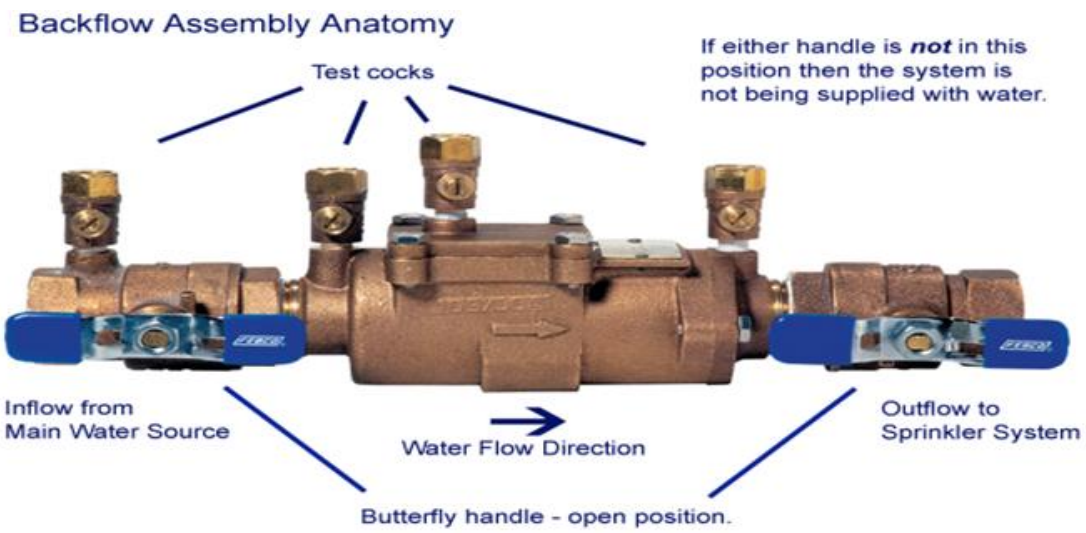
One issue that develops with the installation of a backflow prevention device is that a closed system now exists. When water is heated, it expands. Before the installation of the backflow prevention device, heated water could backflow through the premise plumbing, through the meter and out the service line to the main. We have now blocked the water's exit from the building. Because of this, it is necessary to install a thermal expansion device.

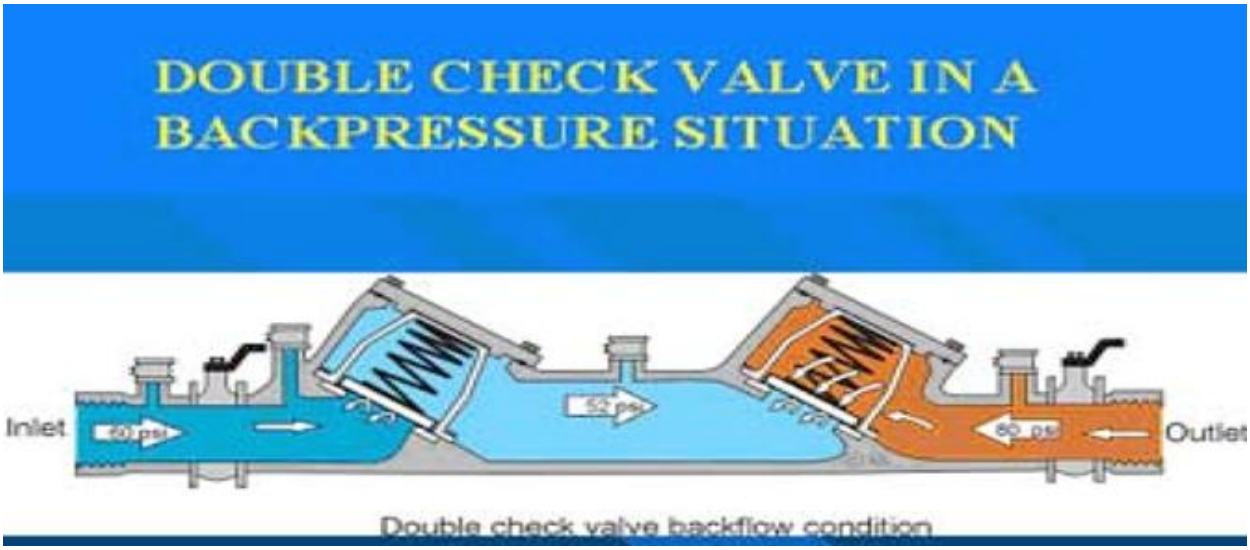


8.5 Figure 1: Allow for thermal expansion

Double Check Valve

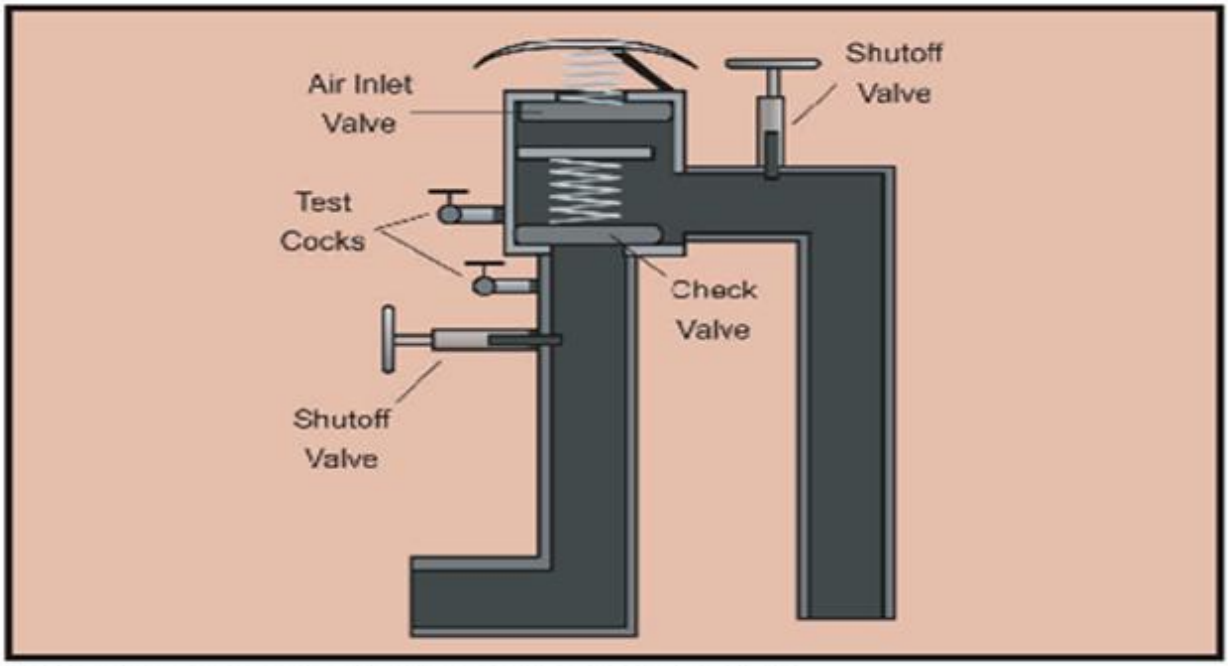
- Installed above ground
- Used for low-hazard applications
- Prevents backpressure and backsiphonage
- Most commonly used as a residential backflow prevention device





PRESSURE VACUUM BREAKER (PVB)

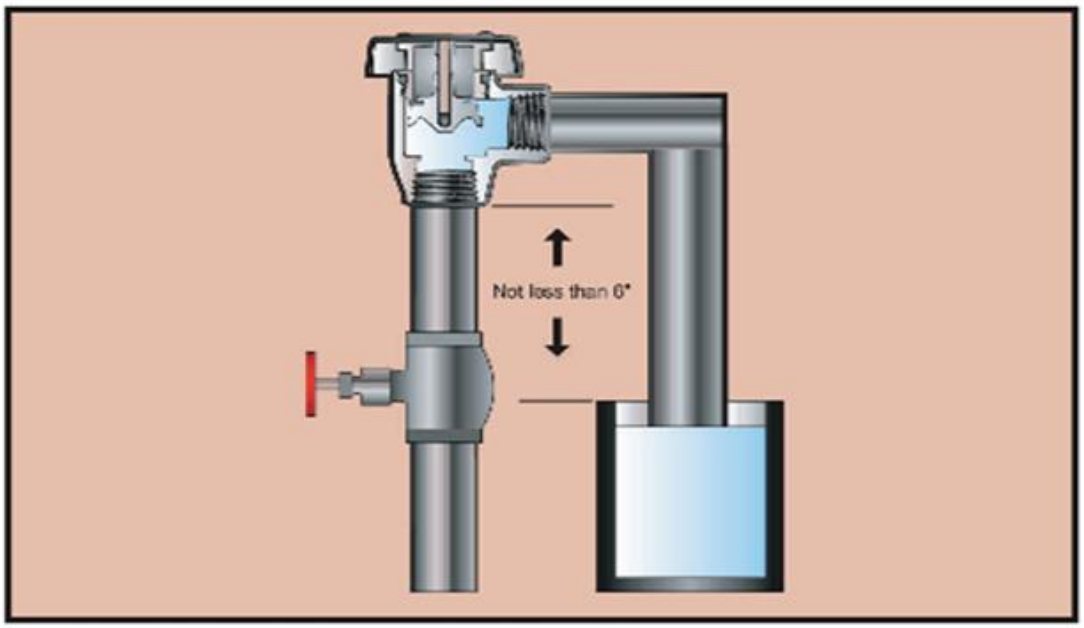
- Should be installed 12 inches above the highest downstream outlet
- May have a control valve downstream and can operate under continuous pressure
- Can be used for high-hazard contaminant or low-pressure pollutant
- Protects against backsiphonage only



8.4.3 Figure 1: Pressure vacuum breaker assembly (PVB)

ATMOSPHERIC VACUUM BREAKER (AVB)

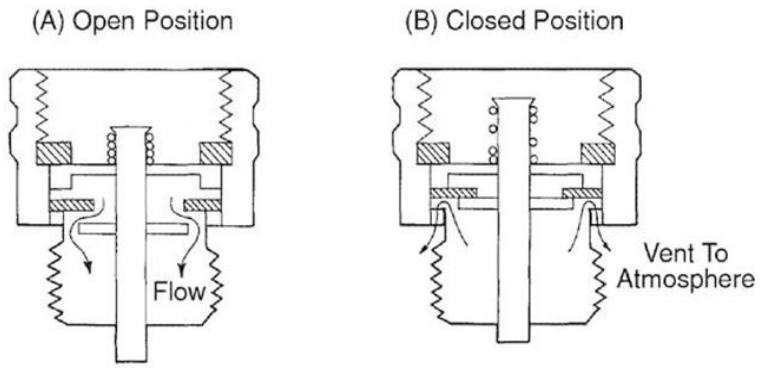
- Similar in design to a PVB
- Cannot be used in a continuous pressure application, 12 hours maximum
- Should not be installed in a pit or vault and needs to be exposed to the atmosphere
- Must be installed at least six inches above use
- Protects against backsiphonage only



8.4.2 Figure 1: Atmospheric vacuum breaker (AVB)

HOSE BIB VACUUM BREAKER

- Protects against backsiphonage only
- Inexpensive device to protect premise plumbing from backsiphonage emanating from a hose attached to your premise plumbing



The AWWARF (2561) sent out a questionnaire to water companies to determine the extent of backflow incidents. There were between 2,800 and 4,100 backflow incidents reported from those who responded to the questionnaire. Of those incidents, 1,100–1,750 are documented backflow incidents. But, only half of the water systems replied to the questionnaire. If we were to extrapolate or carry out that data to its logical numerical conclusion, it would mean that anywhere from 800,000–1,000,000 backflow incidents could have occurred since 1970.

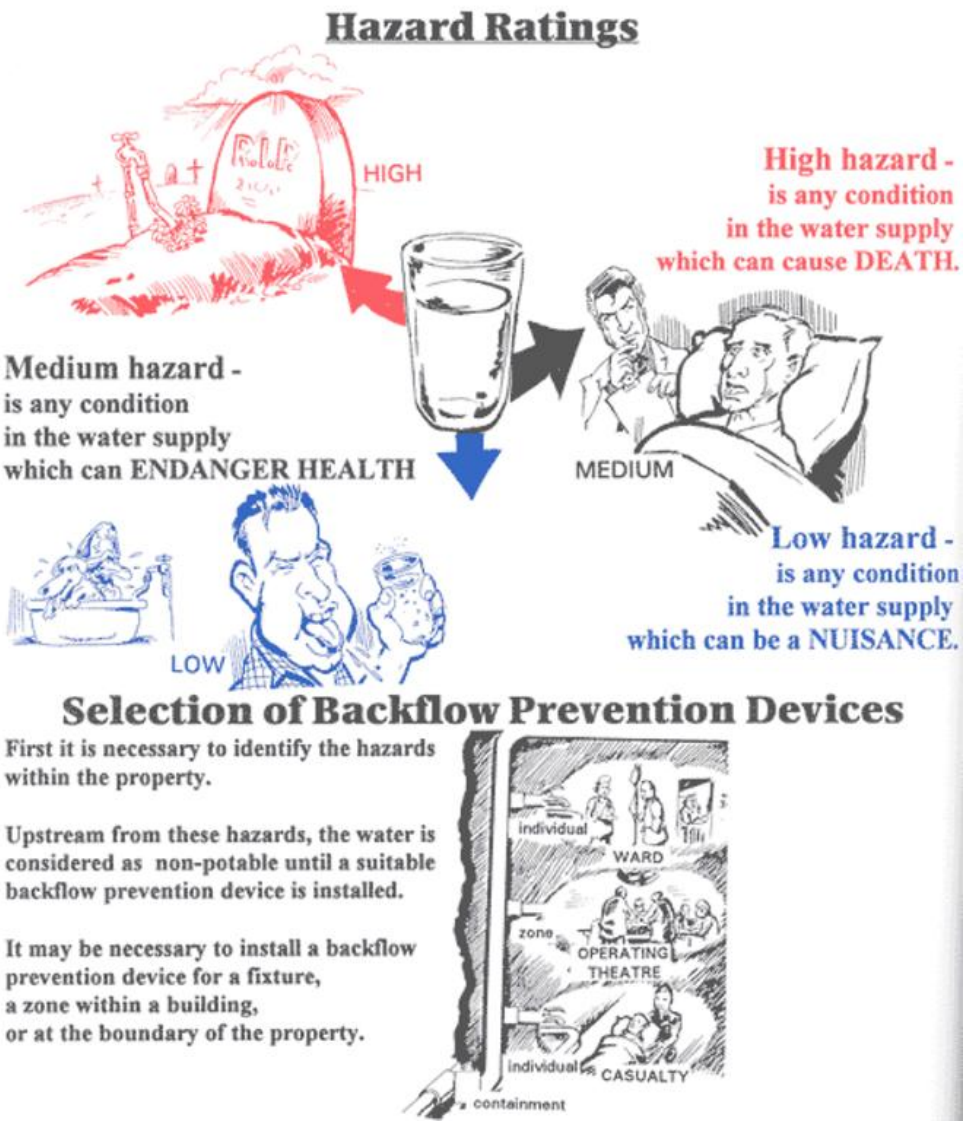
It is difficult to find something when you aren't looking. Many experts contend that most backflow incidents go unnoticed by the consumer. Most backflow events are transient in nature so they can easily go unnoticed. Backflow is very hard to trace to its origin. Backflow is real and happens much more frequently than we are aware. The reasons behind backflow occurrence are many:

- Power outages
- Broken mains
- "Displaced" fire hydrants, pumps, etc.
- Pump testing
- System flushing

If a backflow incident occurs in your system and some consumers of your water were sickened or died, who would be legally responsible? Public water purveyors (suppliers) fall under the **Safe Drinking Water Act,** which states that you, as a water supplier to the public, are to provide potable water to your customers. No doubt everyone would be sued, but the final responsibility is ours as public water systems. Our state regulations prohibit all cross connections. If one occurs in your system, you would hope you have a program in place.

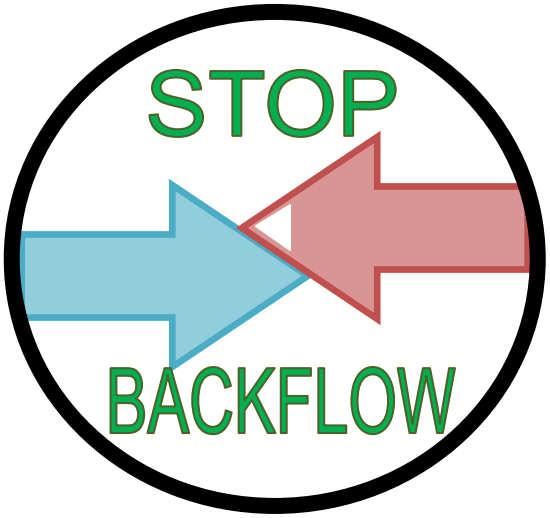
Backflow is real and happens all the time. It would seem it would be beneficial to be proactive as opposed to reactive regarding backflow.

The hazards of backflow fall into three categories.



	AIR GAP	REDUCED PRESSURE ZONE	DOUBLE CHECK VALVE	PRESSURE VACUUM BREAKER	ATMOSPHERIC VACUUM BREAKER	
Back Pressure	YES	YES	NO	NO	NO	Health Hazard
	YES	YES	YES	NO	NO	Non Health Hazard
Back - Siphonage	YES	YES	NO	YES	YES	Health Hazard
	YES	YES	YES	YES	YES	Non Health Hazard

All cross connections are prohibited. The use of automatic devices, such as reduced pressure zone backflow preventers and vacuum breakers, may be approved by the cabinet in lieu of proper air gap separation. A combination of air gap separation and automatic devices shall be required if determined by the cabinet to be necessary due to the degree of hazard to public health. Every public water system shall determine if or where cross connections exist and shall immediately eliminate them. (401 KAR 8:020 Sec 2 (2)



Examples of Cross-Connection Hazard Surveys

USC
UNIVERSITY OF SOUTHERN CALIFORNIA
Foundation for Cross Connection Control and Hydraulic Research

Prevalence of Cross-Connections in Household Plumbing

Survey Form

USC ID # _____

Survey Location

Name Mr. Mrs. Miss _____

Street Address _____

City _____ *State* _____ *Zip* _____

Phone (_____) _____ FAX (_____) _____

Contact person upon arrival Mr. Mrs. Miss _____

Arrival Time _____ am/pm Departure Time _____ am/pm

Service Connection(s) & Number — Water Meter Size

☐ Domestic _____ — ☐ 5/8" ☐ _" ☐ 1" ☐ other _____
☐ **Irrigation** _____ — ☐ 5/8" ☐ _" ☐ 1" ☐ **other** _____
☐ Fire _____ — ☐ 5/8" ☐ _" ☐ 1" ☐ other _____

Building Height - Number of Stories: ☐ One ☐ Two ☐ Three
Basement: ☐ Yes ☐ No

Water Usage		Cross-Connection? *No* *Yes - Direct or Indirect*			Protection ***AG, AVB, PVB, SVB RP, DC, DuCh, DCAP (1)***	Installation Acceptable (2)		Permanent or Temporary (3)	
		No	**Dir**	**Ind**		**Yes**	**No**	**Perm**	**Temp**
☐	Auxiliary water supply								
	☐ Water well- pressure tank	☐	☐	☐		☐	☐	☐	☐
	☐ Storage tank	☐	☐	☐		☐	☐	☐	☐
	☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:									
☐	**Fire Sprinkler System**								
	☐ Anti-freeze	☐	☐	☐		☐	☐	☐	☐
	☐ Storage tank	☐	☐	☐		☐	☐	☐	☐
	☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:									
☐	Irrigation System	☐	☐	☐		☐	☐	☐	☐
	☐ Chemical Injection	☐	☐	☐		☐	☐	☐	☐
	☐ Booster Pumps	☐	☐	☐		☐	☐	☐	☐
	☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:									

Prevalence of Cross-Connections in Household Plumbing Systems-University of Southern California Page 17 of 30

Water Usage	Cross-Conn			Type of Protection	Proper		Perm	Temp
	No	Dir	Ind		Yes	No		
☐ Heating/Cooling Equipment								
☐ Water Heater T& P Valve ☐Yes ☐No	☐	☐	☐		☐	☐	☐	☐
☐ Boiler	☐	☐	☐		☐	☐	☐	☐
☐ Geo-thermal heating	☐	☐	☐		☐	☐	☐	☐
☐ Heat Exchanger	☐	☐	☐		☐	☐	☐	☐
☐ Humidifier	☐	☐	☐		☐	☐	☐	☐
☐ Hydronic Heat	☐	☐	☐		☐	☐	☐	☐
☐ Snow Melt System	☐	☐	☐		☐	☐	☐	☐
☐ Solar Heating	☐	☐	☐		☐	☐	☐	☐
☐ Water cooled equip	☐	☐	☐		☐	☐	☐	☐
☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:								
☐ Kitchen Facilities								
☐ Faucet	☐	☐	☐		☐	☐	☐	☐
☐ Pull out spray head	☐	☐	☐		☐	☐	☐	☐
☐ Dishwasher - Inlet	☐	☐	☐		☐	☐	☐	☐
Outlet	☐	☐	☐		☐	☐	☐	☐
☐ Icemaker	☐	☐	☐		☐	☐	☐	☐
☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:								
☐ Laundry								
☐ Washing machine	☐	☐	☐		☐	☐	☐	☐
☐ Wash Sink	☐	☐	☐		☐	☐	☐	☐
☐ Portable Equipment	☐	☐	☐		☐	☐	☐	☐
☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:								
☐ Sewage System								
☐ Sewage Ejectors	☐	☐	☐		☐	☐	☐	☐
☐ RV Flushing Facilities	☐	☐	☐		☐	☐	☐	☐
☐ Bathroom #1 - Sink	☐	☐	☐		☐	☐	☐	☐
☐ Bathtub/Shower	☐	☐	☐		☐	☐	☐	☐
☐ Toilet/Bidet	☐	☐	☐		☐	☐	☐	☐
☐ Bathroom #2 - Sink	☐	☐	☐		☐	☐	☐	☐
☐ Bathtub/Shower	☐	☐	☐		☐	☐	☐	☐
☐ Toilet/Bidet	☐	☐	☐		☐	☐	☐	☐
☐ Bathroom #3 - Sink	☐	☐	☐		☐	☐	☐	☐
☐ Bathtub/Shower	☐	☐	☐		☐	☐	☐	☐
☐ Toilet/Bidet	☐	☐	☐		☐	☐	☐	☐
☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:								

Prevelence of Cross-Connections In Household Plumbing Systems-University of Southern California Page 18 of 30

Water Usage	Cross-Conn			Type of Protection	Proper		Perm	Temp
	No	Dir	Ind		Yes	No		
☐ Swimming Pool/Spa								
☐ Fill Line	☐	☐	☐		☐	☐	☐	☐
☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:								
☐ Tanks, Vats, other Vessels								
☐ Water Softener - Inlet	☐	☐	☐		☐	☐	☐	☐
Outlet	☐	☐	☐		☐	☐	☐	☐
☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:								
☐ Outdoor Hose bibbs								
☐ #1 -	☐	☐	☐		☐	☐	☐	☐
☐ #2 -	☐	☐	☐		☐	☐	☐	☐
☐ #3 -	☐	☐	☐		☐	☐	☐	☐
☐ #4 -	☐	☐	☐		☐	☐	☐	☐
☐ Other _____	☐	☐	☐		☐	☐	☐	☐
Comments:								

Other Actual or Potential Cross-Connections :

_____

_____

Type of Chemicals observed on-site:

_____

_____

All internal cross-connections protected? ☐ Yes ☐ No	Surveyor _____ Signature _____ **Date of Survey** _____

USC Research Team		Transferred to Data Base
Type of Cross-Conn _____	Hazard	Date:

Prevelence of Cross-Connections in Household Plumbing Systems-University of Southern California Page 19 of 30

Cross-Connection Survey Form

Date: _____

Name of Company, Corporation, or Business: _____

_____

Address: _____

Name of Contact: _____

Type of Use: Industrial _____ Commercial _____ Governmental _____ Other

Location of Service: _____

Size of Service: _____ Inch	Metered?	Yes ☐	No ☐
Require non-interrupted water service?		Yes ☐	No ☐
Does Boiler Feed utilize chemical additives?		Yes ☐	No ☐
Is Backflow protection incorporated?		Yes ☐	No ☐
Are air conditioning cooling towers utilized?		Yes ☐	No ☐
Is Backflow protection incorporated?		Yes ☐	No ☐
Is a Water Saver utilized on condensing lines or cooling towers?	N/A ☐	Yes ☐	No ☐
Is the make-up supply line backflow protected?		Yes ☐	No ☐
Is process water in use, and if so, is it potable supply water or "Raw" water		N/A ☐	Potable ☐
	Raw ☐	Protected ☐	Unprotected ☐
Is fire protection water separate from the potable supply?		Yes ☐	No ☐
Are Containment Devices in place?		Yes ☐	No ☐

Summary

Degree of Hazard:		High ☐	Low ☐
Type of Device recommended for containment:	RPZ ☐	DCV ☐	None ☐
Fixture Outlet protection required?		Yes ☐	No ☐

If so, where?

_____

Review Questions for Chapter 7 – Cross Connections

1. What has caused more waterborne illnesses than any other factor in the U.S. during the last 20 years?
2. Identify the two forms of backflow.
3. What are the two types of backflow protection programs or approaches?
4. Name three situations in which backflow could occur in almost any system.
5. What is the most reliable **mechanical** device for backflow protection?
6. Single-check valves can be used for backflow prevention. T or F
7. An air gap must be how many times the inside diameter of whatever pipe it serves?

Answers to Review Questions for Chapter 7 – Cross Connections

1. backflow (cross connections)
2. backsiphonage and backpressure
3. Isolation and Containment
4. power outages, broken water mains, malfunctioning or broken hydrants, pumps, pump testing, system flushing, etc.
5. RPZ (reduced pressure zone)
6. False
7. two times the ID

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GLOSSARY

- absorption – The uptake of water or dissolved chemicals by a cell or an organism.
- acidic – The condition of water or soil which contains a sufficient amount of acid substances to lower the pH below 7.0.
- acre-foot – A volume of water that covers one acre to a depth of one foot, or 43, 560 ft^3.
- action level – The level of lead or copper which, if exceeded, triggers treatment or other requirements that a water system must follow.
- acute health effect – An immediate (i.e. within hours or days) effect that may result from exposure to certain drinking water contaminants (e.g., pathogens).
- adsorption – The process by which chemicals are held on the surface of a mineral or soil particle.
- aeration – The process of adding air to water. Air can be added to water by either passing air through water or passing water through air.
- aerobic – A condition in which “free” (atmospheric) or dissolved oxygen is present in the water.
- air binding – A situation where air enters the filter media. Air can prevent the passage of water during the filtration process and cause a loss of filter media during the backwash cycle.
- air bladder – A flexible container located on the inside of a hydropneumatic tank to hold air.
- air gap – An open vertical drop, or vertical empty space, that separates a drinking (potable) water supply from another water system.
- air stripping – A treatment process used to remove dissolved gases and volatile substances from water. Large volumes of air are bubbled through the water being treated to remove (strip out) the dissolved gasses and volatile substances. (See packed tower aeration)

- algae – Microscopic plants which contain chlorophyll and live floating or suspended in water. Their biological activities appreciably affect the pH and dissolved oxygen content of the water because they produce oxygen during sunlight hours and use oxygen during the night.

- alkalinity – The capacity of water to neutralize acids.

- ambient – Environmental or surrounding conditions.

- anaerobic – A condition in which "free" (atmospheric) or dissolved oxygen is NOT present in water.

- anionic polymer – A polymer having negatively charged groups of ions; often used as a filter aid or for dewatering sludge.

- anode – The positive pole or electrode of an electrolytic system, such as a battery. The anode attracts negatively charged particles or ions. (anions)

- AOC – assimilable organic carbon – low molecular weight dissolved organic carbon (DOC)

- appurtenance – Structures and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.

- available chlorine – A measure of the amount of chlorine available in materials that are used as a source of chlorine when compared with that of elemental (gaseous or liquid) chlorine.

- aquifer – A natural underground layer of porous, water-bearing materials.

- artesian – Water held under pressure in porous rock or soil confined by impermeable geologic formations. An artesian well is free flowing.

- backpressure – A pressure that can cause water to backflow into the potable water supply when a customer's system is at a higher pressure than the public potable system.

- backflow – Flow in the opposite direction to the normal flow direction or the flowing back of a substance toward its source.

- backsiphonage – A type of backflow caused by negative pressure within a water system.
- backwashing – The process of reversing the flow of water back through the filter media to remove entrapped solids.
- baffles – A flat board or plate, deflector, or similar device constructed or placed in flowing water to cause more uniform flow velocities, to absorb energy, or to divert, guide, or agitate liquids.
- Best Available Technology – The water treatment(s) that the EPA certifies to be the most effective for removing a contaminant.
- Best Management Practices – Structural, nonstructural, and managerial techniques that are recognized to be the most effective and practical means to control the productive use of the resource to which they are applied.
- biofilm – An organic slime that grows on the inside of pipes, on filter media, or anywhere aqueous solutions are pervasive.
- biodegradation – decomposition of a substance into more elementary compounds by the actions of microorganisms such as bacteria
- brake horsepower – 1) the horsepower required at the top or end of a pump shaft (input to a pump). 2) The energy provided by a motor or other power source.
- breakpoint chlorination – Addition of chlorine to water until the chlorine demand has been satisfied. At this point, further additions of chlorine will result in free residual chlorine that is directly proportional to the amount of chlorine added beyond breakpoint.
- breakthrough – A crack or break in a filter bed allowing the passage of floc or particulate matter through a filter.
- $CaCO_3$ – calcium carbonate
- CO_2 – carbon dioxide

- C Factor – A factor of value used to indicate the smoothness of the interior of a pipe. The higher the C Factor, the smoother the pipe, the greater the carrying capacity, and the smaller the friction or energy losses occur from water flowing in the pipe.

- Capacity Development – A program developed by the USEPA and administered by the Kentucky DOW that determines the financial, technical, and managerial viability of water systems.

- capillary fringe – The porous material just above the water table which may hold water by capillarity (a property of surface tension that draws water upwards) in the smaller void.

- capital costs – Costs (usually long term) of financing construction and equipment.

- cathode – The negative pole or electrode of an electrolytic cell or system. The cathode attracts positively charged particles or ions (cations).

- cathodic protection – An electrical system for prevention of rust, corrosion, and pitting of metal surfaces which are in contact with water or soil. This practice can concentrate corrosion on auxiliary anodic parts which are deliberately sacrificed and allowed to corrode instead of letting the structure corrode.

- cationic polymer – A polymer having positively charged groups of ions; often used as a coagulant aid.

- cations – an ion that has a positive electric charge and is attracted toward the cathode in electrolysis

- cavitation – The formation and collapse of a gas pocket or bubble on the blade of an impeller. The collapse of this pocket or bubble drives water into the impeller with a terrific force that can cause pitting on the impeller. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller with a hammer.

- centrifugal pump – A pump consisting of an impeller fixed on a rotating shaft that is enclosed in a casing, and having an inlet and discharge connection.

- check valve – A valve with a hinged disc or flap that opens in the direction of flow and closing when the flow is reversed.

- chlorinate – The process of adding chlorine to water.

- chloramines – Compounds formed by the reaction of aqueous chlorine with ammonia.
- chlorine demand – The difference between the amount of chlorine added to water and the amount of residual chlorine remaining after a given contact time.
- chlororganic – Organic compounds combined with chlorine. These compounds generally originate from, or are associated with, life processes such as those of algae in water.
- chronic – Occurring over a long period of time.
- chronic health effect – The possible result of exposure over many years to a drinking water contaminant at levels above its MCL.
- circle of influence – The circular outer edge of a depression produced in the water table by the pumping of water from a well. (aka: zone of influence)
- clarification - to make a liquid clear either by settling or filtration.
- clarifier – A large circular or rectangular tank or basin in which water is held for a period of time, during which the heavier suspended solids settle to the bottom. (aka settling basins and sedimentation basins)
- class – The working pressure rating of a specific pipe for use in water distribution systems. This term is used for cast iron, ductile iron, asbestos cement and most plastic pipes.
- clear well – A reservoir for the storage of filtered water of sufficient capacity to prevent the need to vary the filtration rate with variations in demand. Also used to provide chlorine contact time for disinfection.
- coagulants – Chemicals that cause very fine particles to clump together into larger particles.
- coagulation – The clumping together of very fine particles caused by the use of chemicals (coagulants). The chemicals neutralize the electrical charges of the fine particles and cause destabilization of the particles.
- coliform – A group of related bacteria whose presence in drinking water may indicate contamination by disease-causing microorganisms.

- colloids – Very small particles that do not quickly dissolve that remain dispersed in a liquid for a long time due to their small size and electrical charge.

- combined available residual chlorine – The concentration of residual chlorine which is combined with ammonia (NH3) and/or organic nitrogen in water as a chloramine (or other chloro derivative) yet is still available to oxidize organic matter and utilize its bactericidal properties.

- community water system (CWS) – A water system which supplies drinking water to 25 or more of the same people year-round in their residences.

- composite sample – A composite sample is a collection of individual samples obtained at regular intervals during a 24 – hour time span.

- compliance – The act of meeting all state and federal drinking water regulations.

- compound – A substance composed of two or more elements whose composition is constant. i.e. table salt, sodium chloride, is a compound.

- cone of depression – The depression, roughly conical in shape, produced in the water table by pumping of water from a well.

- confined aquifer – an aquifer that is covered by an impermeable or semi-permeable layer of rock.

- contaminant – Anything found in water (including microorganisms, minerals, chemicals, radionuclides, etc.) which may be harmful to human health.

- corrosion – The gradual decomposition of a material by chemical action.

- corrosion inhibitor – Substances that slow the rate of corrosion by forming a protective film on the interior surface of the materials.

- cross connection – a physical link between potable water and one of unknown or questionable quality.

- Cryptosporidium – A microorganism commonly found in lakes and rivers which is highly resistant to disinfection.

- CT – The product of "residual disinfectant concentration" (C) in mg/L (ppm) determined before or at the first customer, and the corresponding "disinfectant contact time (T) in minutes.

- day tank – A tank used to store a chemical solution of known concentration for feed to a chemical feeder.

- dead end – The end of a water main which is not connected to other parts of the distribution system by means of a connecting pipe or loop.

- dechlorination – The deliberate removal of chlorine from water. The partial or complete reduction of residual chlorine by any chemical or physical process.

- denitrification – The biochemical conversion of nitrate and nitrite nitrogen dissolved in water to gaseous nitrogen.

- desalinization – The removal of dissolved salts from water by specific water treatment processes.

- Detention Time (DT) – 1) The theoretical (calculated) time required for a small amount of water to pass through a tank at a given rate of flow.
  Volume (gallons) ÷ Flow (gpm)

- discharge head – The pressure (in pounds per square inch or psi) measured at the centerline of a pump discharge converted into feet. (1 psi = 2.31 feet of head)

- disinfectant – Any oxidant – including but not limited to chlorine that is added to water in any part of the treatment or distribution process and is intended to kill or inactivate pathogenic microorganisms

- disinfectant contact time (The "T" in CT calculation) - The time in minutes that it takes for water to move from the point of disinfection application or the previous point of disinfectant residual measurement to a point before or at the point where residual disinfectant concentration (C) is measured. Disinfectant contact time in pipelines must be calculated based on plug flow by dividing the internal volume of the pipe by the maximum hourly flow rate through that pipe.

- disinfection – A chemical or physical process that kills or interrupts the life cycle of microorganisms such as bacteria, viruses, and protozoa.

- dissolved oxygen (DO) – A measure of water quality indicating free oxygen dissolved in water.
- distribution system – A network of pipes leading from a treatment plant to customers' plumbing systems.
- divalent – a divalent ion or molecule has a valence of two and thus can form two covalent bonds with other ions or molecules
- dosage – The quantity of a chemical administered to an organism.
- dose – The actual quantity of a chemical added to the water to which an organism is exposed.
- DPD – DPD stands for N, N-diethyl-p-phenylene-diamine A method of measuring the chlorine residual in water.
- eductor – A hydraulic device used to create a negative pressure (suction) by forcing or drawing liquid through a restrictor, such as a Venturi meter.
- effluent – A fluid flowing from a process or storage facility.
- electrolysis – the conduction of electricity through something dissolved in order to induce decomposition of the dissolved chemical into its components
- electron – An extremely small, negatively charged particle, the part of an atom that determines its chemical properties.
- enteric – Of intestinal origin, especially applied to wastes or bacteria.
- Environmental Protection Agency (EPA) – The Federal agency that determines and enforces, among other things, drinking water standards for the United States and its territories.
- epilimnion – The upper layer of water in a thermally stratified lake or reservoir.
- eutrophic – Reservoirs and lakes which are rich in nutrients and very productive in terms of aquatic animal and/or plant life.

- extrapolation – The estimation of unknown values by extending or projecting from known values.
- fecal coliform bacteria – Bacteria found in the intestinal tracts of animals. Their presence in water is an indicator of possible contamination by pathogens.
- ferric – containing iron, with a valence of three
- ferrous – relating to or containing iron
- filtration – A process for removing particulate matter from water by passage through porous media.
- finished water – Water that has been treated and is ready to be delivered to customers.
- first draw – The water that immediately comes out when a tap is first opened.
- floc – Clumps of bacteria and particulate impurities that have grouped together and formed a cluster.
- flocculation – The gathering together of fine particles in water by gentle mixing after the addition of coagulant chemicals to form larger particles.
- flushing – A method used to clean water distribution lines.
- flux – A flowing or flow.
- foot valve – A type of check valve located at the bottom end of the suction pipe on a pump.
- free available residual chlorine – That portion of total available residual chlorine remaining in water after chlorination.
- free residual chlorination – The application of chlorine to water to produce a free available chlorine residual equal to at least 80 percent of the total residual chlorine (sum of free and combined available chlorine residual).
- freeboard – 1) The vertical distance from the normal water surface to the top of the confining wall. 2) The vertical distance from the sand surface to the underside of a trough in a sand filter.

- friction losses – The 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, or any other restriction to flow such as fittings. Water flowing in a pipe loses energy as a result of friction losses.

- gauge pressure – The pressure within a closed container measured without the addition of the 14.7 pounds of atmospheric pressure added in. Most pressure gauges read in gauge pressure or psig (pounds per square inch gage pressure).

- galvanic series – A list of metals and alloys presented in the order of their tendency to corrode.

- garnet – Hard, reddish, glassy mineral sands made up of silicates of base metals (calcium, magnesium, iron and manganese).

- Giardia lamblia – A microorganism frequently found in rivers and lakes, which, if not treated properly, may cause diarrhea, fatigue, and cramps after ingestion.

- grab sample – A single sample collected at a particular time and place which represents the composition of the water at only that time and place.

- GW – Ground Water – The supply of fresh water found beneath the earth's surface, usually in aquifers.

- GWUDI – ground water under the direct influence (of surface water) – Any water found beneath the earth's surface with: 1) significant occurrence of insects or other macroorganisms from algae or large diameter pathogens such as Giardia lamblia or, 2) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, or pH.

- HAA 5 - Haloacetic Acids (chloroacetic acid, dichloroacetic acid, trichloroacetic acid, bromoacetic acid, dibromoacetic acid)

- hard water – Alkaline water containing dissolved salts that interfere with some industrial processes and that prevent soap from lathering.

- head – The distance (in feet) equal to the pressure (in psi) at a specific point. 1 foot of head is equivalent to .433 psi.

- head loss – The head, pressure or energy (they are synonymous) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity (speed) of the flowing water and the roughness of the pipe, channel walls or restrictions caused by fittings.

- HPC – Heterotrophic Plate Count (also known as standard plate count) – The number of colonies of heterotrophic bacteria grown on selected solid media at a given temperature and incubation period, usually expressed in number of bacteria per milliliter of sample.

- hydraulic grade line (HGL) – The level water would rise to in a freely vented standpipe under
  pressure.

- hydropneumatic – powered by air and water

- hydropneumatic tank – A small, less than 1,000 gallon tank used by a hydropneumatic system. The tank contains air and water, typically in a 1:2 ratio air to water, i.e. 1/3 to 2/3 water.

- hydrostatic pressure – 1) The pressure at a specific elevation exerted by a body of water at rest or, 2) In the case of ground water, the pressure at a specific elevation due to the weight of water at higher levels in the same zone of saturation.

- hypochlorinators – Chlorine pumps, chemical feed pumps or devices used to dispense chlorine solutions made from hypochlorites such as sodium hypochlorite or calcium hypochlorite.

- hypolimnion – The lowest layer in a thermally stratified lake or reservoir. This layer consists of colder, denser water that has a constant temperature where no mixing occurs.

- impeller – A rotating set of vanes in a pump designed to pump water.

- impermeable – Not easily penetrated. The property of a material or soil that does not allow, or allows with great difficulty, the passage of water.

- in-line filtration – The addition of chemical coagulants directly to the filter inlet pipe commonly used in pressure filter installations.

- inorganic contaminants – Mineral-based compounds such as metals, nitrates, and asbestos that are naturally-occurring in some water. These contaminants can also get into water through farming, chemical manufacturing, and other human activities.

- insoluble – incapable of being dissolved in a liquid

- Ions – an atom or group of atoms or molecules that has acquired an electric charge by losing or gaining one or more electrons

- jar test – A laboratory procedure that simulates a water treatment plant's coagulation/flocculation units with differing chemical doses and also energy of rapid mix, energy of slow mix, and settling time.

- kinetic energy – Energy possessed by a moving body of water as a result of its motion.

- Langelier index, Langelier Saturation Index (LSI) – An index reflecting the equilibrium pH of particular water with respect to calcium, alkalinity, and temperature.

- LSI pH = pHA (actual) – pHS (saturation) A negative sum indicates the likelihood the water is corrosive and a positive number indicates the water has the propensity to be scale forming.

- laundering weir – Sedimentation basin overflow weir. Usually a plate with V-notches along the top to assure a uniform flow rate and avoid short-circuiting.

- leachate – a derivative from the decomposition of inorganic and organic substances.

- leaching – To remove soluble or other constituents from by action of a percolating liquid.

- µ - micro, one millionth

- µg/L – microgram per liter, one millionth of a gram per liter.

- manganous – containing or derived from manganese

- Maximum Contaminant Level (MCL) – The highest level of a contaminant that the EPA allows in drinking water at which there are no known or anticipated adverse effect on human health.

- Maximum Contaminant Level Goal (MCLG) – See MCL. These are goals that the EPA would like to see reached for each contaminant. Maximum contaminant level goals are non-enforceable health goals.

- media migration – the movement of filter media from either where is was originally or intended in a filter bed to somewhere in the bed that is not intended

- mg/g - milligrams/gram

- microgram per liter – A unit equal to parts per billion (ppb) since one liter of water is equal in weight to one billion micrograms. A microgram dissolved in one liter of water.

- micron – A unit of length that equals 0.00004 of an inch. One millionth of a meter (39.37 inches).

- microorganisms – Tiny living organisms that can be seen only with the aid of a microscope. Also known as microbes.

- milligrams per liter (mg/L) – A measure of concentration of a dissolved substance. One milligram (one-thousandth of a grain, 3.5 X 10 – 1 oz or 0.000035 oz) means that one milligram of a substance is dissolved in each liter of water. For practical purposes, this unit is equal to parts per million (ppm) since one liter of water is equal in weight to one million milligrams.

- Million Gallons per Day (MGD) – A measure of water flow.

- disinfection generated on-site from salt brine and an electrical charge.

- monitoring – Testing that water systems must perform to detect and measure contaminants. A water system that does not follow EPA's monitoring methodology or schedule is in violation, and may be subject to legal action.

- motor efficiency – The ratio of energy delivered by a motor to the energy supplied to it during a fixed period or cycle.

- mounding – filter media bunching up atop other media in a filter bed

- mudballs – Material that forms in filters and gradually increases in size when not removed by the backwashing process. This material is frequently semi-round in shape and varies from pea-sized to several inches or more in diameter.

- multi-stage pump – A pump that has more than one impeller.

- Natural Organic Matter (NOM) – Organic compounds that are formed from decomposing plant, animal, and microbial material. They can react with disinfectants to form disinfection by products. Total organic carbon (TOC) is often measured as an indicator of natural organic matter.

- nephelometric – A means of measuring turbidity in a sample using a device called a nephelometer. A nephelometer passes light through a sample and the amount of light deflected (usually at a 90-degree angle) is then measured.

- nephelometric turbidity units (NTU) – the measurement of light passing through a sample of water when using a nephelometer.

- nitrification – The biochemical transformation of ammonium nitrogen to nitrate nitrogen.

- non-community water system (NCWS) – A public water system that is not a community water system. There are two types of NCWS's: transient and non-transient

- non-transient, non-community water system (NTNCWS) – A water system which supplies water to 25 or more of the same people at least six months per year in places other than residences. Some examples are schools, factories, office buildings, and hospitals which have their own water systems.

- organics – 1) Any form of animal or plant life. 2) A term used to refer to chemical compounds made from carbon molecules.

- organic contaminants – Carbon-based chemicals, such as solvents and pesticides, which can get into water through runoff from croplands or discharges from factories.

- overall pump efficiency – Also called wire to water efficiency. The combined efficiency of a pump and a motor together.

- overflow rate – One of the guidelines for the design of settling tanks and clarifiers in treatment plants. Used by operators to determine if tanks and clarifiers are hydraulically over or under loaded. Also called surface loading.

- Surface Overflow Rate = Flow (gpm) ÷ Area (sq ft)

- Oxidation-Reduction Potential (ORP) – The electrical potential required to transfer electrons from one compound or element (the oxidant) to another compound or element (the reductant); used as a qualitative measure of the state of oxidation in water treatment.

- pathogen – A disease-causing organism.

- ppb – parts per billion

- percolation – 1) The slow seepage of water into and through the ground. 2) The slow passage of water through a filter medium.

- permeability – The ability of rock or soil to transmit water.

- pH – A logarithmic expression of the intensity of the basic or acid condition of a liquid. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration, (H+). The pH range is from 0 to 14 where 0 is the most acidic, 14 most basic and 7 being neutral.

- phenolic compounds – Organic compounds that are derivatives of benzene.

- photosynthesis - The process in which organisms, with the aid of chlorophyll, convert carbon dioxide into oxygen, using sunlight for energy.

- pitless adaptor – A device installed in the upper portion of the well casing that allows the pump discharge line to exit the casing below the frost line.

- plug flow – A type of flow that occurs when a slug of water moves through a structure (i.e. pipe) without ever dispersing or mixing with the rest of the water.

- point-of-entry (POE) treatment device – A treatment device applied to the drinking water entering a house or building.

- point-of-use (POU) treatment device – A treatment device applied to a single tap.

- point source – A stationary location or fixed facility from which pollutants are discharged.

- pollutant – Any substance introduced into the environment that adversely affects the usefulness of that resource.

- polyelectrolyte – A high molecular weight substance having points of positive or negative electrical charges. Used with other coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water.

- polymer – A chemical formed by the union of many monomers (a molecule of low molecular weight). Used with other coagulants to aid in binding small suspended particles to larger chemical flocs for their removal from water. All polyelectrolytes are polymers but not all polymers are polyelectrolytes.

- potable water – Water that is safe for human consumption and aesthetically pleasing.

- precipitate – to cause a solid to separate out from a solution as a result of a chemical reaction

- precursor – Natural organic compounds found in all surface and ground waters. The compounds MAY react with halogens (such as chlorine) to form trihalomethanes.

- pressure head – The distance (in feet) equal to the pressure (in psi) at a specific point.

- pressure relief valve – A valve that opens automatically to release water in a pipeline when the pressure reaches an assigned limit.

- pressure zones – An area within a distribution system in which the pressure in the mains is maintained within certain limits.

- Primacy State – A State that has the responsibility and authority to administer the EPA's drinking water regulations within its borders. The rules must be at least as stringent as the EPA's.

- prime – The action of filling a pump casing with water to remove the air. Most pumps must be primed before startup or they will not pump water.

- public notification – An advisory that the EPA requires a water system to distribute to affected consumers when the system has violated MCL's or other regulations. The

notice advises consumers what precautions, if any, they should take to protect their health.

- Public Water Systems (PWS) – Any water system which provides water to at least 25 people for at least 60 days a year.
- purveyor – seller, supplier, vendor
- radionuclides – Any man-made or natural element that emits radiation and that may cause cancer after many years of exposure through drinking water.
- raw water – Water in its natural state, prior to any treatment for drinking.
- recharge area – An area that is connected with an aquifer by a highly porous soil or rock layer.
- recharge rate – The quantity of water per unit of time that replenishes or refills an aquifer(s).
- representative sample – A sample of water that is as nearly identical in content and consistency as possible to that in the larger body of water being sampled.
- residual chlorine – The amount of free and/or available chlorine after a given contact time and allowed to react with all substances present in the water.
- reverse osmosis – The application of pressure or a vacuum which causes the passage of the water across a semi=permeable membrane. The membrane allows the passage of the water but not the dissolved solids (solutes).
- runoff – The part of precipitation that runs off the land into streams or other surface water.
- Safe Drinking Water Act (SDWA) – The federal law that authorizes and requires the EPA and state agencies to monitor drinking water quality.
- sample – The water that is analyzed for the presence of EPA-regulated drinking water contaminants.
- sanitary seal – A watertight seal on top of the well casing that prevents water or other liquids from entering the well.

- sanitary survey – 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.

- saturated zone – The area below the water table where all open spaces are filled with water.

- secchi disc – A flat white disc (sometimes black and white) lowered into the water until it is just visible to determine the depth of the water.

- 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.

- septic – A condition produced by bacteria when all oxygen supplies are depleted. Usually accompanied by a foul odor and a black color in the water.

- Service line sample – A one liter sample of water collected in accordance with CFR Section 141.86(b)(6) of the code of Federal Regulations, that has been standing for at least six hours in the service line.

- short-circuiting – 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 can result in shorter contact times or settling times in comparison with the theoretical (calculated) detention times.

- single or three phase power – single phase – two sources of power 120° out of phase with each other. Three phase is three sources of power that are 120° out of phase with each other.

- slurry – a liquid mixture of water and an insoluble material

- sole source aquifer – An aquifer that supplies 50 percent or more of the drinking water of a particular area.

- specific gravity – The weight of a particle, substance, or chemical solution in relation to the weight of water (8.34 lbs/gallon).

- specific yield – The quantity of water that a unit volume of saturated permeable rock or soil will yield when drained by gravity. Specific yield may be expressed as a ratio or as a percentage by volume.

- spoil pile – Excavated material such as soil from a trench or excavation. OSHA regulations dictate that spoil piles must be kept at least two feet away from the edge of the trench.

- sounding tube – A pipe or tube used for measuring the depths of water.

- source water – Water in its natural state, prior to any treatment for drinking.

- static head – The distance, when water is not moving, from a specific point to the water surface.

- static pressure – The static pressure is the static head expressed as pressure. See above. One foot of head is equivalent to 0.433 psi.

- static water level – 1) The elevation or level of the water table in a well when the pump is not operating. 2) The level or elevation to which water would rise in a tube connected to an artesian aquifer or pipeline (conduit) under pressure.

- submergence – The distance between the water surface and the media surface in a filter.

- surface loading – see overflow rate

- surface water – The water that systems pump and treat from sources open to the atmosphere, such as rivers, lakes, and streams.

- THM – trihalomethane

- threshold odor – The minimum odor of a water sample that can just be detected after successive dilutions with odorless water. Also called odor threshold.

- thrust block – A mass of concrete or other similar material appropriately placed at a pipe to prevent the pipe from moving whenever the flow of the water changes direction or the momentum of the water is interrupted.

- titration – The process of adding the chemical reagent in increments until the completion of the reaction, as signaled by the end point.

- Total Coliform Rule (TCR) – A rule of the SDWA requiring systems to monitor for coliform bacteria on a monthly basis.

- total residual chlorine – The amount of available chlorine remaining after a given contact time. The sum of the combined available residual chlorine and the free available residual chlorine.

- total trihalomethanes (TTHM) – The sum of the concentration in milligrams per liter of the trihalomethane compounds (trichloromethane (chloroform), dibromochloromethane, bromodichloromethane and tribromomethane (bromoform), rounded to two significant digits.

- transient, non-community water systems (TNCWS) – 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.

- transmissivity – The ability of an aquifer to transmit water.

- transpiration – The process by which water vapor is released to the atmosphere by living plants.

- treatment technique – A required process intended to reduce the level of a contaminant in drinking water.

- trihalomethane – One of a family of organic compounds named as derivatives of methane. THMs are generally the by-product from chlorination of water that contains organic matter. The resulting compounds are suspected of causing cancer.

- TTHM – total trihalomethanes

- tube settlers – A device that uses configurations of small (2 – 3 inches) tubes installed on an incline as an aid to sedimentation. As water rises within the tubes, settling solids fall to the tube surface. As the sludge from the settled solids in these tubes gain

weight, it moves down the tubes and settles to the bottom of the basin for removal by conventional sludge collection processes.

- tubercle – A crust of corrosion products (rust) that build up over a pit caused by the loss of metal due to corrosion.

- tuberculation – The formation of small mounds of corrosion products (rust) on the inside of iron pipe. These mounds increase the roughness of the inside of the pipe and reduce the capacity of the pipe to carry the same volume of water (carrying capacity) as when the pipe was free of the tuberculation.

- turbidity – The cloudy appearance of water caused by the presence of tiny particles. Turbidity particles can also shield pathogens from disinfection.

- unconfined aquifer – An aquifer containing water that is not under pressure; the water level in a well is the same as the water table outside the well.

- unsaturated zone – The area between the land surface and water table in which the pore spaces are only partially filled with water.

- UV – ultraviolet light – mercury filled lamps used to disinfect water by altering the DNA of pathogens.

- valence – the combining power of atoms or groups measured by the number of electrons the atom or group will receive, give up or share in forming a compound.

- variance – State or EPA permission not to meet a certain drinking water standard.

- Venturi – The effect when velocity increases, pressure decreases in a pipeline or educator.

- violation – A failure to meet any state or federal drinking water regulation.

- virus – The smallest form of microorganisms capable of causing disease.

- Volatile Organic Contaminant (VOC) – an organic compound that contributes to water pollution e.g. ethylene, benzene, styrene, etc.

- Vortexing – a whirling mass of water that draws everything in close proximity towards its center

- watershed – The land area from which water drains into a stream, river, or reservoir.

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APPENDIX

Certified Drinking Water Operator Regulations

401 KAR 11:001. Definitions for 401 KAR Chapter 11.

RELATES TO: KRS 223.160-220, 224.01-010(9), 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.200, 224.10-100, 224.10-110, 224.73-110, EO 2009-538

NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of wastewater operators. KRS 223.200 requires the cabinet to promulgate administrative regulations concerning the certification of water treatment and distribution system operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes definitions applicable to the certification of wastewater and water operators.

Section 1. Definitions. (1) "Applicant" means a person who has submitted an application to take an examination for certification.

(2) "Board" means:

(a) The Kentucky Board of Certification of Wastewater System Operators; or

(b) The Kentucky Board of Certification of Water Treatment and Distribution System Operators.

(3) "Cabinet" is defined by KRS 224.01-010(9).

(4) "Certificate" means a certificate of competency issued by the cabinet stating that the operator has met the requirements for the specified operator classification as established by 401 KAR Chapter 11.

(5) "Certified operator" means an individual that holds an active certified operator's certificate issued in accordance with 401 KAR 11:050.

(6) "Core content" means the information identified as essential by the board for purposes of certification examination and continuing education training.

(7) "Direct responsible charge" means personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the drinking water treatment plant or distribution system is operated in accordance with accepted practices and with KRS Chapters 223 and 224 and 401 KAR Chapters 8 and 11.

(8) "Operator" means a person involved in the operation of a wastewater treatment plant, wastewater collection system, drinking water treatment plant, or drinking water distribution system.

(9) "Primary responsibility" means personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the wastewater treatment plant or wastewater collection system is operated in accordance with accepted practices and with KRS Chapter 224 and 401 KAR Chapters 5 and 11. (35 Ky.R. 473; Am. 1210; eff. 3-6-2009; 36 Ky.R. 449; 1047; eff. 2-5-2010.)

401 KAR 11:010. Boards of certification.

RELATES TO: KRS 223.160-220, 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-200, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the board of certification of wastewater system operators and the certification of wastewater operators. KRS 223.160-220 authorizes the cabinet to promulgate administrative regulations concerning the board of certification for water treatment and distribution operators and the certification of water treatment and distribution system operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes the duties of the Kentucky Board of Certification of Wastewater System Operators and the Kentucky Board of Certification of Water Treatment and Distribution System Operators.

Section 1. Duties of the Board. The board shall:
(1) Evaluate the qualifications of applicants and recommend qualified applicants to the cabinet for certification examination;
(2) Review and provide comments to the cabinet on proposed administrative regulations regarding operator certification;
(3) Review and make recommendations to the cabinet on core content for certification examinations and continuing education training for certification renewal;
(4) Review and make recommendations to the cabinet on training proposed to provide continuing education to certified operators. During the evaluation of training courses and seminars, the board shall consider:
(a) The consistency of training material with the core content;
(b) The ability of the training to provide information that supports effective water conveyance, treatment, and quality; and
(c) The ability of the instructor to properly present the training;
(5) Assist the cabinet in drafting examinations for the certification of operators;
(6) Review and provide comments to the cabinet on proposed fees for the training and certification of operators;

(7) Review applications for reciprocity and recommend to the cabinet the acceptance or denial of the application based on the criteria established in 401 KAR 11:050, Section 1(8); and

(8) Review evidence and advise the cabinet regarding disciplinary actions for certified operators who fail to comply with KRS Chapters 223 and 224 or 401 KAR Chapter 5, 8, or 11. (35 Ky.R. 474; Am. 1211; 1746; eff. 3-6-2009; 36 Ky.R. 450; 1049; eff. 2-5-2010.)

401 KAR 11:020. Standards of professional conduct for certified operators.

RELATES TO: KRS 223.160-220, 224.73-110, EO 2009-538

STATUTORY AUTHORITY: KRS 224.10-100, 224.10-110, 224.73-110, EO 2009-538

NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of water and wastewater operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes standards for the performance of certified water and wastewater operator duties.

Section 1. Standards of Professional Conduct. (1) In order to safeguard the life, health, and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, the following standards of professional conduct apply to persons certified in accordance with 401 KAR Chapter 11:

(a) A certified operator shall, during the performance of operational duties, protect the safety, health, and welfare of the public and the environment;

(b) A certified operator shall use reasonable care and judgment in the performance of operational duties;

(c) If a certified operator's judgment is overruled by an employer under circumstances in which the safety, health, and welfare of the public or the environment are endangered, the certified operator shall inform the employer of the possible consequences;

(d) A certified operator shall be objective, truthful, and complete in applications, reports, statements, and testimony provided to the cabinet; and

(e) A certified operator shall ensure the integrity of the samples that the operator collects, prepares, or analyzes so that results shall be a true representation of water quality.

(2) Proof of certification. While on duty, a certified operator shall carry the cabinet-issued wallet card showing the operator's current certification status.

(3) Maintenance of records. If information related to the operator's employment or mailing address changes from that provided in the application for certification, the certified operator shall provide written notification to the cabinet within thirty (30) days. (35 Ky.R. 475; Am. 1212; 1747; eff. 3-6-2009; 36 Ky.R. 452; 1051; eff. 2-5-2010.)

401 KAR 11:040. Water treatment and distribution system operators; classification and qualifications.

RELATES TO: KRS 223.160-220, 224.10-100, 224.10-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-220, 224.10-100, 224.10-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-100 and 224.10-110 authorize the cabinet to promulgate administrative regulations concerning the certification of water operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes classification of water treatment and distribution operator certifications and establishes the qualifications for certification.

Section 1. Classification of Water Operator Certifications. (1) Water treatment certifications.
(a) Limited certification. As provided in KRS 223.160(2), an operator issued a limited certificate may have primary responsibility for a water treatment facility for a school and for a semipublic water supply.
(b) Class IA-D treatment certification.
1. A Class IA-D treatment operator may be in direct responsible charge for a Class IA-D or Class IB-D water treatment plant as established in 401 KAR 8:030, Section 2.
2. A Class IA-D treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.
(c) Class IB-D treatment certification.
1. A Class IB-D treatment operator may be in direct responsible charge for a Class IB-D water treatment plant, as established in 401 KAR 8:030, Section 2.
2. A Class IB-D treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.
(d) Class IIA treatment certification.
1. A Class IIA treatment operator may be in direct responsible charge for a Class IIA water treatment plant or a Subclass A or B water treatment plant of an equal to or smaller design capacity, as established in 401 KAR 8:030, Section 2.
2. A Class IIA treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.
(e) Class IIB-D treatment certification.
1. A Class IIB-D treatment operator may be in direct responsible charge for a Class IIB-D water treatment plant or a Subclass B water treatment plant of a smaller design capacity, as established in 401 KAR 8:030, Section 2.
2. A Class IIB-D treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.
(f) Class IIIA treatment certification.

1. A Class IIIA treatment operator may be in direct responsible charge for a Class IIIA water treatment plant or a Subclass A or B water treatment plant of an equal to or smaller design capacity, as established in 401 KAR 8:030, Section 2.

2. A Class IIIA treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.

(g) Class IIIB treatment certification.

1. A Class IIIB treatment operator may be in direct responsible charge for a Class IIIB water treatment plant or a Subclass B water treatment plant of a smaller design capacity, as established in 401 KAR 8:030, Section 2.

2. A Class IIIB treatment operator shall not be in direct responsible charge for a water treatment plant with a larger design capacity.

(h) Class IVA treatment certification.

1. A Class IVA treatment operator may be in direct responsible charge of any Subclass A or B water treatment plant, as established in 401 KAR 8:030, Section 2.

(i) Class IVB treatment certification.

A Class IVB treatment operator may be in direct responsible charge of any Subclass B water treatment plant, as established in 401 KAR 8:030, Section 2.

(2) Water distribution certifications.

(a) Class ID distribution certification.

1. A Class ID distribution operator may be in direct responsible charge for a Class ID water distribution system, as established in 401 KAR 8:030, Section 2.

2. A Class ID distribution operator shall not be in direct responsible charge for a water distribution system serving a larger population.

(b) Class IID distribution certification.

1. A Class IID distribution operator may be in direct responsible charge for a Class IIID water distribution system, as established in 401 KAR 8:030, Section 2.

2. A Class IID distribution operator shall not be in direct responsible charge for a water distribution system serving a larger population.

(c) Class IIID distribution certification.

1. A Class IIID distribution operator may be in direct responsible charge for a Class IIID water distribution system, as established in 401 KAR 8:030, Section 2.

2. A Class IIID distribution operator shall not be in direct responsible charge for a water distribution system serving a larger population.

(d) Class IVD distribution certification.

1. A Class IVD distribution operator may be in direct responsible charge of any water distribution system.

(3) Bottled water certification. A bottled water operator may be in direct responsible charge for a bottled water system that bottles water for sale.

(4) Operator in Training designations.

(a) Except as provided in paragraph (c) of this subsection, a certified operator with an Operator in Training designation shall not serve in direct responsible charge of a water treatment plant or distribution system.

(b) A certified operator with an Operator in Training designation shall work under the direct supervision of a certified operator who works at the same facility and has obtained a certification level that is equal to or greater than the certification level required to serve in direct responsible charge of the facility.

(c) If a certified operator also has been issued a water treatment, distribution, or bottled water certification without an Operator in Training designation, the operator may serve in direct responsible charge a water treatment plant, distribution system or bottled water system as provided by this Section for the certifications that do not have an Operator in Training designation.

Section 2. Water Operator Qualifications: Experience, Education, and Equivalencies. An individual desiring to become a certified operator shall meet the following minimum qualifications prior to the cabinet approving the individual to take a certification examination as established in 401 KAR 11:050.

(1) The education and experience requirement for each class of water treatment certifications shall be as follows:

(a) Limited certification:

1. Education. A minimum level of education shall not be required.

2. Experience. A minimum level of experience shall not be required.

(b) Class IA-D treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a Subclass A public water system, as established in 401 KAR 8:030, Section 2, with any design capacity

(c) Class IB-D treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a Subclass A or B public water system, as established in 401 KAR 8:030, Section 2, with any design capacity shall be required.

(d) Class IIA treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a water treatment plant, with six (6) months in a Class IIA, IIIA, or IVA water treatment plant, as established in 401 KAR 8:030, Section 2, shall be required.

(e) Class IIB-D treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a public water system with six (6) months in a Class IA-D, II B-D, or higher water treatment plan, as established in 401 KAR 8:030, Section 2, shall be required.

(f) Class IIIA treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a public water treatment plant with one (1) year in a Class IIA, IIIA, or IVA water treatment plant, as established in 401 KAR 8:030, Section 2, shall be required.

(g) Class IIIB treatment certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a public water treatment plant with one (1) year in a Class IIA, IIB-D, IIIA, IIIB, IVA, or IVB water treatment plant, as established in 401 KAR 8:030, Section 2, shall be required.

(h) Class IVA treatment certification:

1. Education. A baccalaureate degree in engineering, science, or equivalent shall be required; and

2. Experience. One (1) year of acceptable operation of a Class IIIA or IVA public water treatment plant, as established in 401 KAR 8:030, Section 2, shall be required.

(i) Class IVB treatment certification:

1. Education. A baccalaureate degree in engineering, science, or equivalent shall be required; and

2. Experience. One (1) year of acceptable operation of a Class IIIA, IIIB, IVA, or IV public water treatment plant shall be required.

(2) The educational and experience qualifications for water distribution certifications shall be as follows:

(a) Class ID distribution certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a water distribution system shall be required.

(b) Class IID distribution certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a water distribution system shall be required.

Six (6) months of the required experience shall be in a water distribution system serving a population greater than or equal to 1,500.

(c) Class IIID distribution certification:

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a water distribution system shall be required.

One (1) year of the required experience shall be in a water distribution system serving a population greater than or equal to 1,500.

(d) Class IVD distribution certification:

1. Education. A baccalaureate degree in engineering, science, or equivalent shall be required; and

2. Experience. One (1) year of acceptable operation of a water distribution system serving a population greater than or equal to 15,000 shall be required.

(3) Bottled water certification. The educational and experience qualifications for bottled water certifications shall be as follows:

(a) Education. A High school diploma or general education development (GED) certificate shall be required; and

(b) Experience. One (1) year of acceptable operation of a bottled water system shall be required.

(4) The educational and experience qualifications for Operator in Training designations shall be as follows:

(a) Class IA-D Treatment, Class IB-D Treatment, Class ID Distribution, and Bottled Water certifications.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Experience shall not be required.

(b) All other applicants for the classifications identified in subsections 1(1) and 1(2) of this administrative regulation;

1. Shall have successfully qualified for and passed the certification exam of the same type classification at one (1) level lower than the Operator in Training designation being pursued; and

2. Shall not have been subject to disciplinary action as provided by 401 KAR 11:050, Section 4.

(5) Substitutions. The cabinet shall allow the following substitutions for the qualifications established in subsections (1), (2), and (3) of this section:

(a) Education in environmental engineering; environmental technology; and biological, physical, or chemical sciences shall be substituted if the substitution does not exceed fifty (50) percent of the required experience.

1. An associate degree shall be considered equivalent to two (2) years of experience.

2. A baccalaureate degree shall be considered equivalent to four (4) years of experience.

3. Education that did not result in a degree in a related field may be substituted for the required experience as follows:

a. Ten (10) contact hours, one (1) Continuing Education Unit, or one (1) post-secondary education quarter hour with a passing grade shall be considered equivalent to 0.022 years of experience.

b. One (1) postsecondary education semester hour with a passing grade shall be considered equivalent to 0.033 years of experience.

4. Education applied to the experience requirements specified in subsections (1) and (2) of this section shall not be applied to the education requirement.

(b) Experience may be substituted for the educational requirement as follows:

1. One (1) year of operational experience at a water system may substitute for one (1) year of education.

2. The cabinet may allow partial substitution of the education requirement by experience in maintenance, laboratory analysis, or other work related to the collection, treatment, or distribution of drinking water or wastewater. To establish how much experience shall be accepted, the cabinet shall determine the degree of technical knowledge needed to perform the work and the degree of responsibility the applicant had in the operation of the system.

3. Experience applied to the education requirement specified in subsections (1) and (2) of this section shall not be applied to the experience requirement.

(c) Water treatment and distribution experience may be substituted as follows:

1. Two (2) years of distribution system experience shall be considered equivalent to one (1) year of treatment experience.

2. One (1) year of treatment experience shall be considered equivalent to one (1) year of distribution system experience. (36 Ky.R. 1055; 1457; eff. 2-5-2010.)

401 KAR 11:050. Operator certification.

RELATES TO: KRS 223.160-220, 224.10-420(2), 224.73-110, EO 2009-538

STATUTORY AUTHORITY: KRS 223.160-220, 224.10-100, 224.10-110, 224.73-110, EO 2009-538

NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of water and wastewater operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes application and examination procedures; provisions relating to certificate issuance, renewal, and termination; reciprocity; training; and disciplinary actions.

Section 1. Application and Examination for Certification. (1) An individual desiring to become a certified operator shall first meet the qualifications established in 401 KAR 11:030 or 11:040 and then pass an examination administered by the cabinet.

(2)(a) An applicant for certification shall complete the Registration Form for Exams and Training and Education and Experience Documentation Form and shall submit them and the certification application fee to the cabinet.

(b) In addition to the requirements of paragraph (a) of this subsection, an applicant desiring to obtain an Operator in Training designation shall submit a signed letter for a certified operator located at the facility where the applicant will work. The letter shall include:

1. A statement from the certified operator indicating that the certified operator shall oversee the work of the applicant seeking an Operator in Training designation;

2. A commitment that the certified operator shall serve as a mentor to the applicant seeking an Operator in Training designation as long as the applicant is under the certified operator's direct responsible charge;

3. Verification that the certified operator is not currently the mentor for any other individuals with an Operator in Training designation; and

4. Confirmation that the certified operator has obtained a certification level that is equal to or greater than the certification level required to serve in primary responsibility of the facility.

(c) An application shall not be submitted to the cabinet unless the applicant has met the qualifications for examination.

(3)(a) After receipt of the application items established in subsection (2) of this section, the cabinet, considering the recommendation of the board, shall determine if the applicant meets the qualifications established in 401 KAR 11:030 or 11:040.

(b) If the applicant meets the qualifications, the cabinet shall approve the application and notify the applicant of the scheduled exam date.

(4)(a) Upon the applicant's completion of the examination, the cabinet shall notify the applicant of the applicant's examination score.

(b) A score of at least seventy (70) percent shall be required to pass the examination.

(5)(a) The cabinet shall issue a certificate and a wallet card to an applicant who successfully passes the certification examination.

(b) The certificate and wallet card shall designate the certification classification for which the operator has demonstrated competency.

(6) An applicant who fails to pass an examination may apply to take the examination again by resubmitting the Registration Form for Exams and Training and the application fee to the cabinet.

(7)(a) An examination shall not be returned to the applicant, but results may be reviewed by the applicant with a member of the cabinet.

(b) A request for a review shall be submitted to the cabinet in writing.

(8) A certificate shall be issued in a comparable classification, without examination, to a person who holds a valid certificate in a state, territory, or possession of the U.S. if:

(a) The requirements for certification under which the certificate was issued are not less stringent than the requirements for certification established in KRS 223.160-220, 224.73-110, and 401 KAR Chapter 11; and

(b) The applicant submits an Application for Reciprocity form and the reciprocity fee to the cabinet.

(9)(a) A certified operator who holds an Operator in Training designation may upgrade the certification by removing the Operator in Training Designation without examination if the operator:

1. Has satisfied the requirements of Section 3(1)(a) and (b) of this administrative regulation;

2. Has acquired the minimum experience required for the certification being pursued as required by 401 KAR 11:030 or 11:040; and

3. Submits a letter from the certified operator who has served as the applicant's mentor during the Operator in Training period that recommends the removal of the Operator in Training designation.

(b) A certified operator with an Operator in Training designation who is unable to comply with the requirements established in paragraph (a) of this subsection shall apply for and retake the certification exam to upgrade the operator's certification.

Section 2. Duration of Certification. (1)(a) Wastewater certifications shall expire on June 30 of an odd-numbered year unless suspended, revoked, or replaced by a higher classification certificate before that date.

(b) Wastewater certifications issued on or after January 1 and on or before June 30 of an odd-numbered year shall expire on June 30 of the next odd-numbered year.

(2)(a) Water certifications shall expire on June 30 of an even-numbered year unless suspended, revoked, or replaced by a higher classification certificate before that date.

(b) Water certifications issued on or after January 1 and on or before June 30 of an even-numbered year shall expire on June 30 of the next even-numbered year.

(3)(a) An expired certification shall continue in force pending the administrative processing of a renewal if the certified operator has complied with the renewal requirements of Section 3 of this administrative regulation.

(b) A certification continued in accordance with this subsection shall remain fully effective and enforceable.

(4) A certification shall terminate if not renewed on or before December 31 of the year the certification expired.

Section 3. Continuing Education and Certification Renewal. (1) A certified operator who is not designated an Operator in Training may renew a certification without examination if the operator has:

(a) Accumulated the training hours required in subsection (5) of this section; and

(b) Submitted a completed Application for Certification Renewal form and the renewal fee to the cabinet or has renewed the certification electronically on the cabinet's Web site.

(2)(a) A certified operator seeking to renew a certification with an Operator in Training designation shall apply for and retake the certification exam as provided in Section 1 of this administrative regulation.

(b) The cabinet shall not approve an operator to take an exam to renew a certification with Operator in Training designation unless the applicant has accumulated the training hours required in subsection (5) of this section.

(3) If the Application for Certification Renewal form and the renewal fee are not received by the cabinet or submitted electronically by June 30 of the year the certification expires, a late renewal fee as established in 401 KAR 8:050, Section 3 or 11:060, Section 1 shall be paid.

(4)(a) A terminated certification shall not be renewed.

(b) An operator whose certification is terminated and who wishes to become recertified shall reapply for and pass an examination in accordance with Section 1 of this administrative regulation.

(5)(a) Prior to applying for certification renewal, a certified operator shall complete the required number of cabinet-approved training hours.

(b) A certified operator holding multiple wastewater certifications issued in accordance with this administrative regulation shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for each certificate.

(c) A certified operator holding multiple water certifications issued in accordance with this administrative regulation shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for each certificate.

(d) Hours earned prior to initial certification shall not count toward certification renewal.

(e) Wastewater training hours shall expire two (2) years from the date earned.

(f) Water training hours shall be completed for each renewal during the two (2) year period immediately prior to the certificate expiration date.

1. Certified operators with a Bottled Water, Limited, Class I or II Treatment, Collection, or Distribution certification shall complete twelve (12) hours of approved training; or

2. Certified operators with a Class III or IV Treatment, Collection, or Distribution certification shall complete twenty-four (24) hours of approved training.

(6)(a) A training provider seeking approval of certified operator training shall submit to the cabinet a completed Application for Approval of Courses for Continuing Education Credit form.

(b) Upon completion of the approved training, the provider shall submit to the cabinet a completed Continuing Education Activity Report form.

(c) A certified operator who has attended training that has not been submitted to the cabinet for approval may apply for training approval as established in paragraph (a) of this subsection.

(d) A certified operator who provides approved training shall receive hour-for-hour credit for actual instruction time.

(7)(a) Cabinet approval of training shall expire two (2) years following the date of approval.

(b) The cabinet, in consultation with the board, shall extend the approval expiration date if:

1. The provider requests the extension in writing; and
2. The training has not changed from the previous approval.

Section 4. Disciplinary Action. (1) A certified operator shall be subject to disciplinary action if the cabinet, in consultation with the board, determines that the certified operator has not satisfactorily performed the operator's duties in accordance with 401 KAR 11:020.

(2)(a) A written complaint received by the board or cabinet regarding a certified operator, unless duplicitous or frivolous, and violations of 401 KAR 11:020 that are identified by the cabinet shall be evaluated by the board.

(b) The certified operator shall appear before the board if requested by the board

(3) The board shall make a recommendation to the cabinet regarding disciplinary action. The board may recommend that disciplinary action not taken or recommend that a disciplinary action be taken if the board determines that the certified operator has not satisfactorily performed operator duties in compliance with 401 KAR 11:020.

(4)(a) Upon receiving a recommendation from the board, the cabinet shall review the available evidence.

(b) After completing the review, the cabinet shall initiate the recommended disciplinary action or notify the board as to why an alternative disciplinary action was taken.

(5) A disciplinary action shall be commensurate with the severity, duration, and number of the violations. Disciplinary actions may include:

(a) Probation of the operator's certification for a specified period of time, not to exceed one (1) year;

(b) Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;

(c) Revocation of the operator's certification;

(d) Civil or criminal penalties; or

(e) A combination of the disciplinary actions established in paragraphs (a) through (d) of this subsection.

(6) If disciplinary action is taken, the cabinet shall notify the certified operator and the operator's employer by certified mail of the action, the reasons outlined for the action, and the length of time for which the disciplinary action shall apply.

(7)(a) A certified operator whose certification has been suspended shall not have primary responsibility during the period that the suspension remains in effect.

(b) Experience gained during a suspension shall not be included toward meeting the requirements of 401 KAR 11:030 or 11:040.

(8) If a certification is revoked, the operator shall be ineligible for future certification.

(9) A certified operator who is aggrieved by a disciplinary action may file a petition for hearing with the cabinet pursuant to KRS 224.10-420(2).

Section 5. Incorporation by Reference. (1) The following material is incorporated by reference:

(a) "Registration Form for Exams and Training", August 2009;

(b) "Education and Experience Documentation Form", July 2009;

(c) "Application for Certification Renewal", August 2009;

(d) "Application for Approval of Courses for Continuing Education Credit", August 2009;

(e) "Continuing Education Activity Report", August 2009; and

(f) "Application for Reciprocity", July 2009.

(2) This material may be inspected, copied, or obtained, subject to applicable copyright law, at the Division of Compliance Assistance, 300 Fair Oaks Lane, Frankfort, Kentucky 40601, Monday through Friday, 8 a.m. to 4:30 p.m. (35 Ky.R. 479; Am. 1216; eff. 3-6-2009; eff. 2-5-2010.)

401 KAR 8:050. Drinking water program fees.

RELATES TO: KRS 223.220, 224.10-100, 224.10-110, 40 C.F.R. 142.10, Pub. L. 104-182, EO 2008-507, 2008-531

STATUTORY AUTHORITY: KRS 223.220, 224.10-100(20), 224.10-110

NECESSITY, FUNCTION, AND CONFORMITY: KRS Chapter 224.10-100(20) authorizes the cabinet to establish, by administrative regulation, a fee or schedule of fees for the cost of processing applications for permits authorized by KRS Chapter 224. EO 2008-507 and 2008-531, effective June 16, 2008, abolish the Environmental and Public Protection Cabinet and establish the new Energy and Environment Cabinet. This administrative

regulation establishes fees for reviewing plans and specifications of public water systems, for operator certification, and for laboratory certification.

Section 3. (1) Fees for certification of water treatment plant and water distribution system operators.

(a) Certification application fee shall be $100.

(b) A renewal application fee shall be:

1. Fifty (50) dollars if renewed through the cabinet Web site; or

2. $100 if not renewed through the cabinet Web site.

(c) A renewal late fee shall be $250.

(d) A reciprocity fee shall be $500.

(2) Each year the cabinet, in consultation with the board, shall establish fees for operator training conducted by the cabinet.

(3)(a) The fees established in subsection (1) of this section shall be nonrefundable.

(b) Fifty (50) percent of the fees established in subsection (2) of this section shall be refundable if registration is canceled at least two (2) business days prior to the beginning of the training event.

(c) The fees in subsection (2) of this section shall be fully refunded if the training event is cancelled by the cabinet. (17 Ky.R. 599; eff. 11-15-1990; 35 Ky.R. 1847; eff. 7-6-2009.)

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