

T3/T4 Exam Prep

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Drinking Water Treatment Exams Expected Range of Knowledge

Exam Content	Number of questions			
Grade	T1	T2	T3	T4
Source Water	25	25	20	15
Water Treatment Processes	25	25	35	20
Operation/Maintenance	20	20	15	15
Laboratory Procedures	15	15	15	15
Regulations/Administrative Duties	15	15	15	35

Source Water

Watershed Protection, Wells / Groundwater, Surface Water / Reservoirs, Raw Water Storage, Clear Well Storage

Water Treatment Processes

Coagulation/Flocculation/ Sedimentation, Filtration, Disinfection, Corrosion Control, Taste and Odor, Iron and Manganese removal, Fluoridation, BAT (Best Available Technology)

Operation / Maintenance

Chemical feeders, Pumps and Motors, Blowers and Compressors, Water meters, Pressure gauges, Instrumentation, Electrical generators

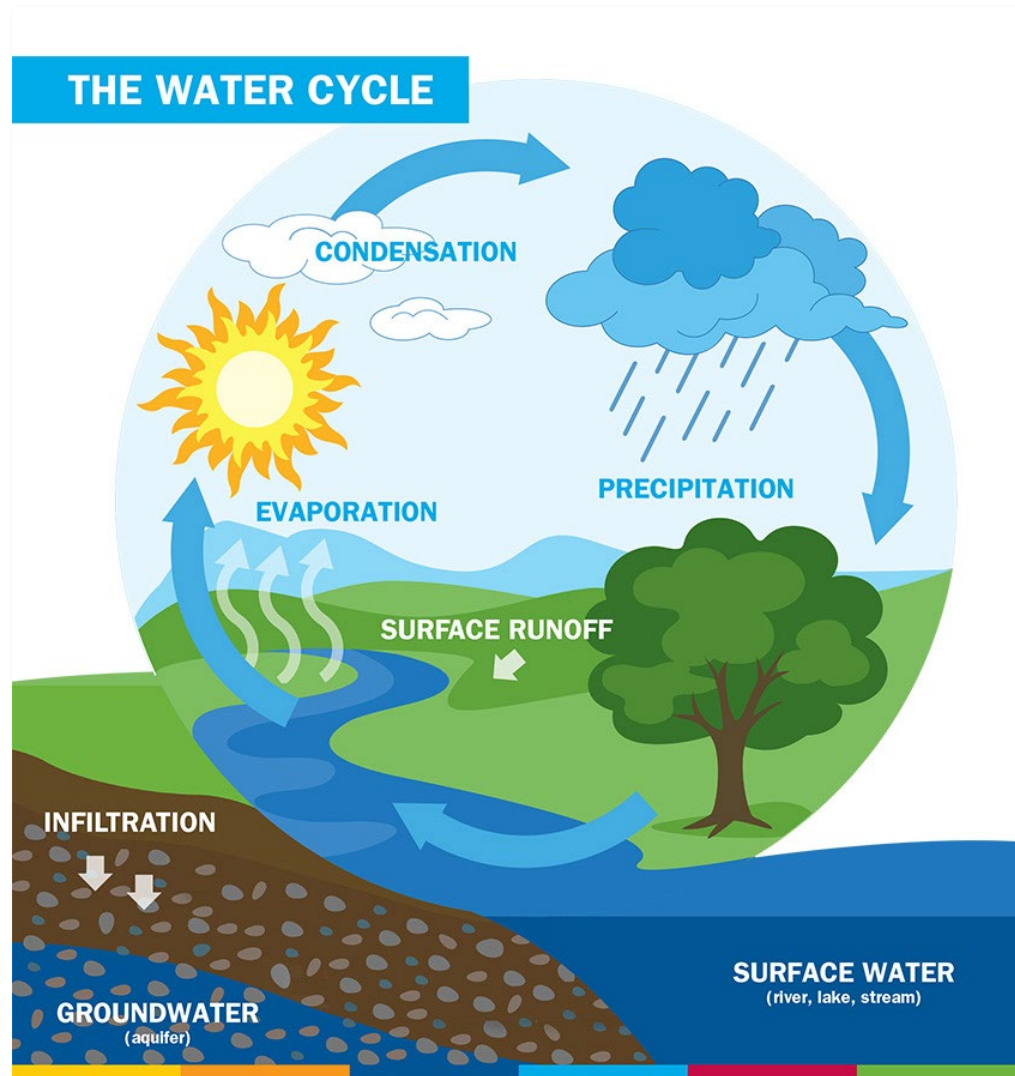
Laboratory Procedures

Sampling, General Lab Practices, Disinfectant analysis, Alkalinity analysis, pH analysis, Turbidity analysis, Specific Conductance, Hardness, Fluoride analysis, Color analysis, Taste and Odor analysis, Microbiological analysis

Regulations/Administrative Duties

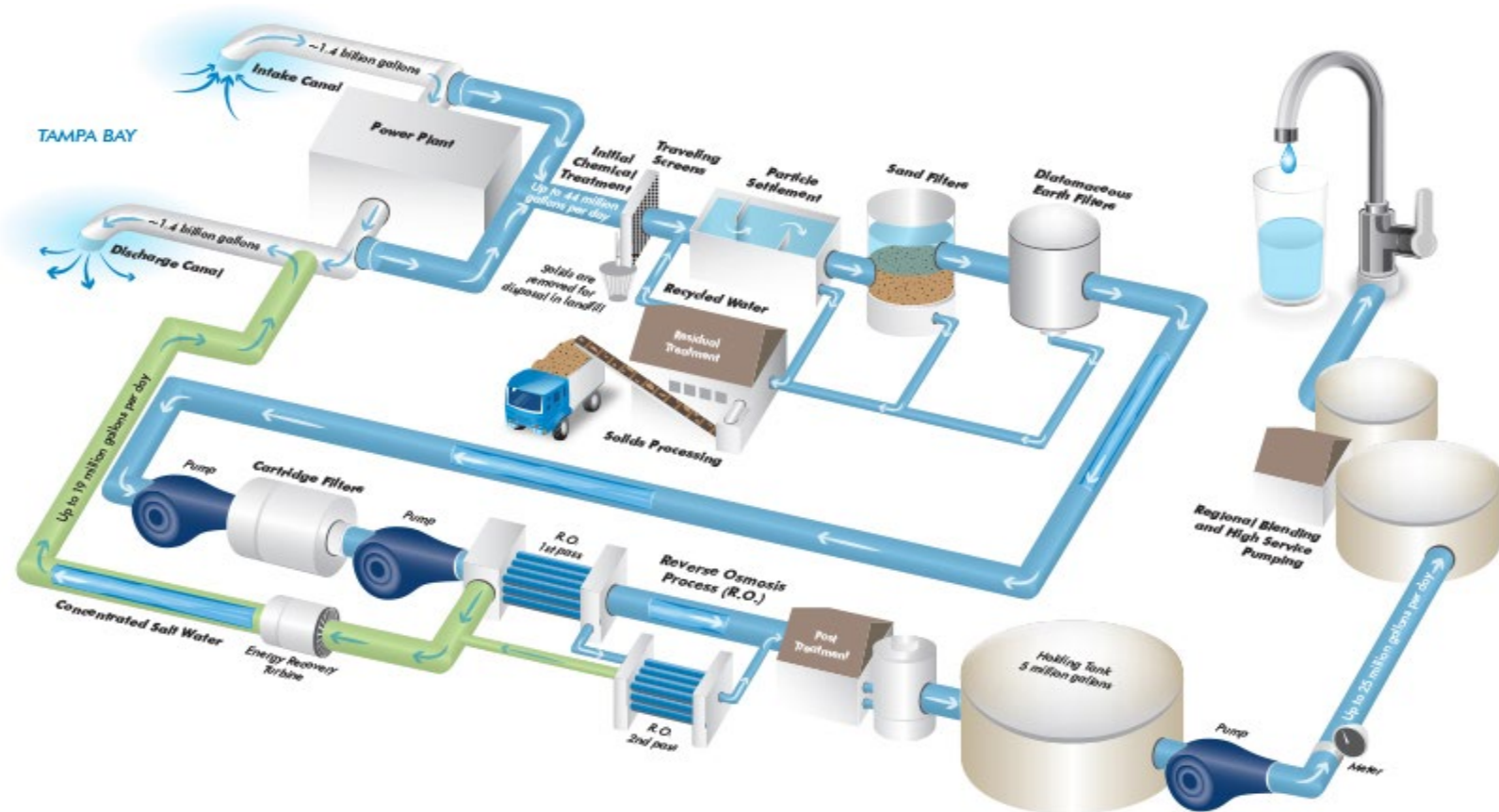
Safety, Planning, Organizing, Directing, Controlling, Implementing Regulations, Record keeping, California Waterworks Standards, Safe Drinking Water Act and amendments, Surface Water Treatment Rule and amendments, Primary Contaminants, Secondary Contaminants, Lead and Copper Rule, Total Coliform Rule, Operator Certification Regulations

Sources of Water



Sources of Water

- Desalination- Water treated from the ocean



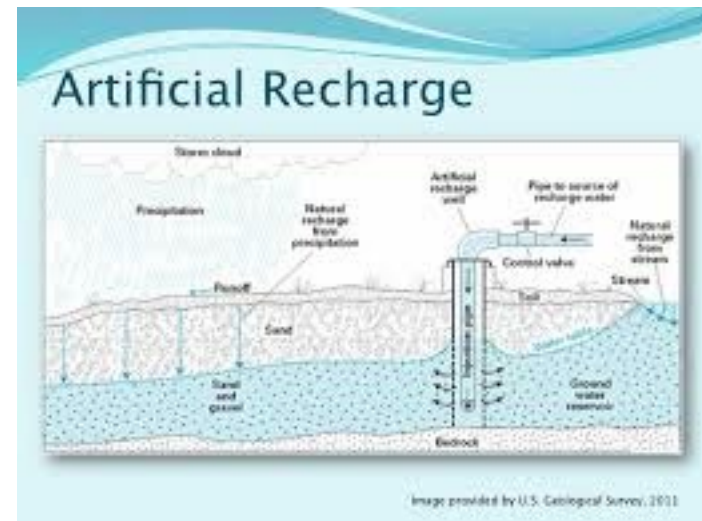
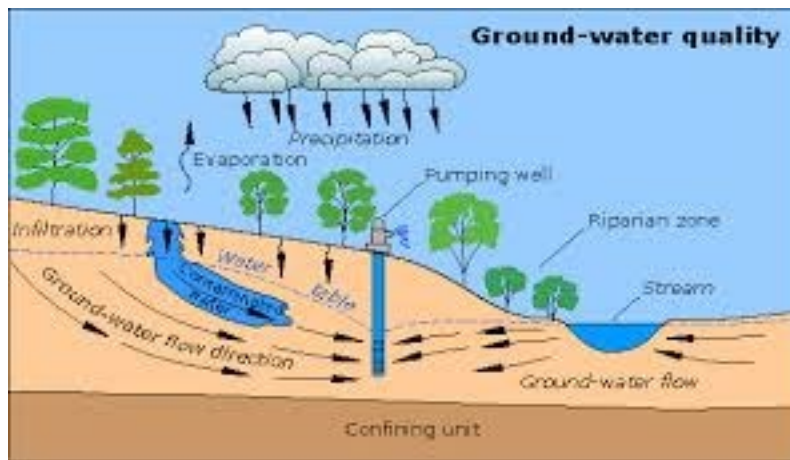
Sources of Water

- Surface Water



Sources of Water

- Groundwater



Water Rights

- Many potential drinking water sources are unavailable because the right to their use are already allocated.
- Depending on state laws, water rights may be sold, leased, or transferred like other property.

Sanitary Survey

- Even if the water rights are available, the source may not be appropriate for drinking water uses. Sanitary surveys are used to determine if a new source is appropriate or an existing supply continues to offer a safe and high-quality water.

Physical Characteristics of Water

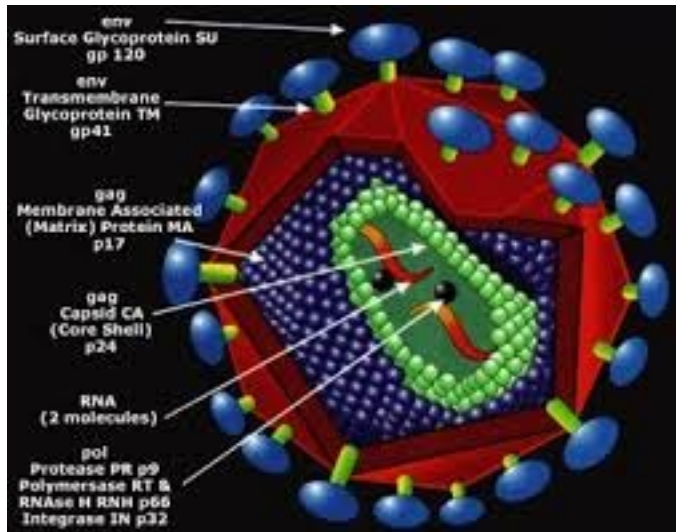
- Turbidity
- Color
- Temperature
- Tastes
- Odors



Does your
water taste or
smell bad?



Other Characteristics

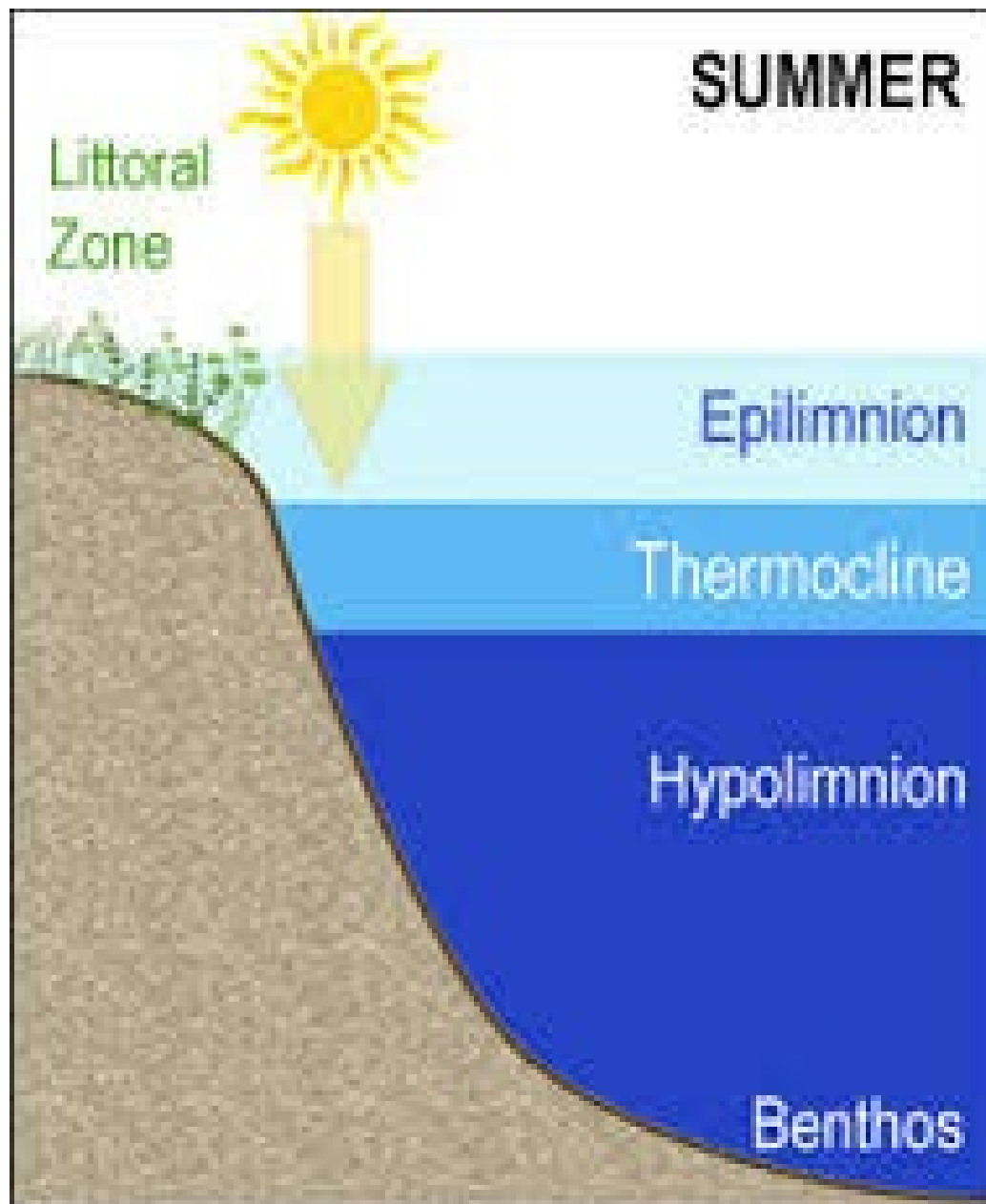


- Chemical Characteristics
- Biological Factors
- Radiological Factors

Reservoir Management

- Removal of Trees and Brush
- Copper Sulfate
- Livestock Grazing
- Use of Pesticides
- Wildfires
- Farming
- Use of fertilizers





Reservoir Overturn

- In the fall when the days are shorter and temperatures drop, the upper layer cools and sinks. The result is a mixed reservoir with no optimum layer.

Dissolved Oxygen Depletion

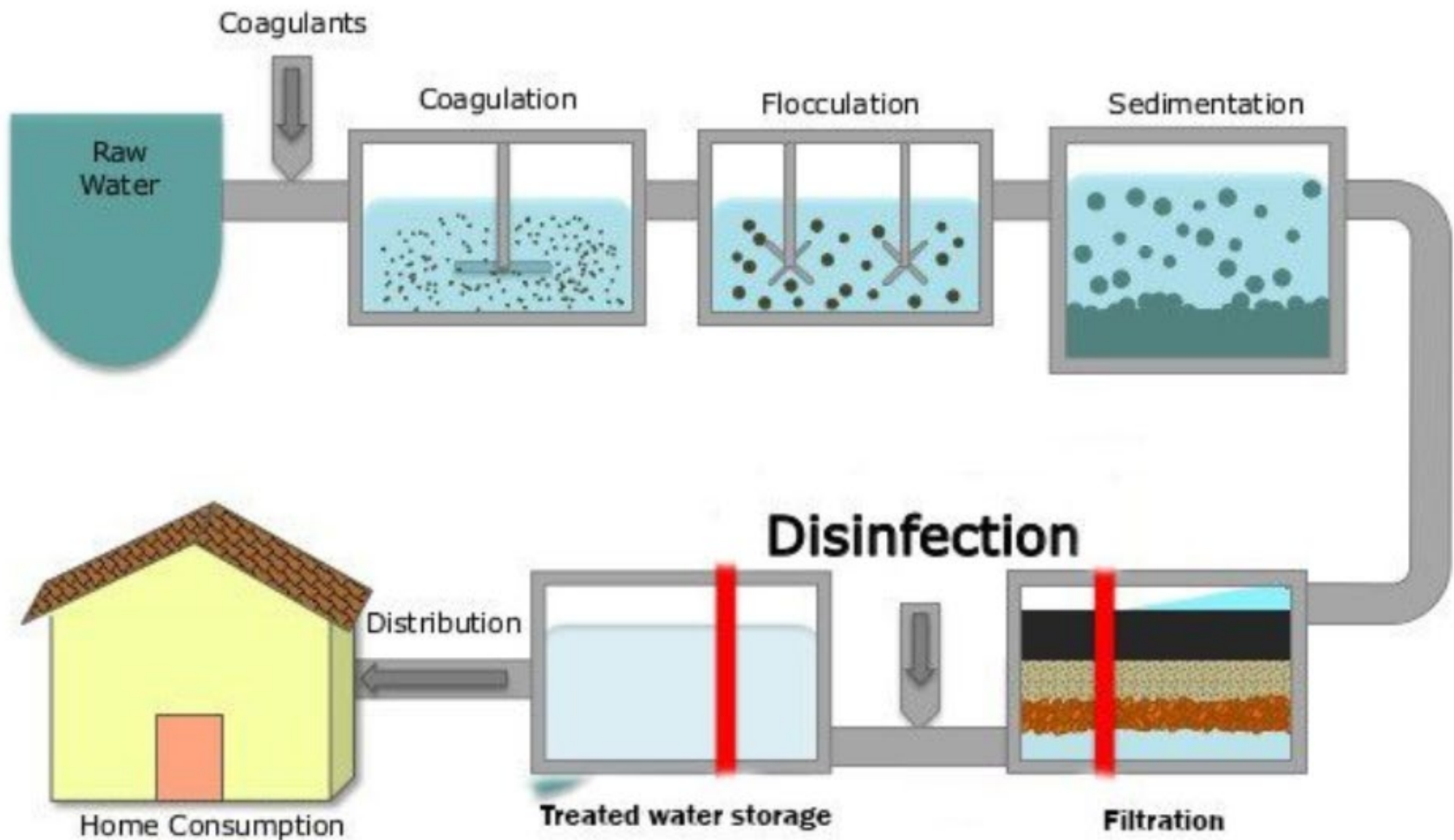
- Fish kills
- Odor problems with the water
- Iron and manganese issues



Water Treatment Process



Coagulation



What is Coagulation

- The clumping together of very fine particles into larger particles called floc caused by the use of chemicals (coagulants). The chemicals neutralize the electrical charges of the fine particles allowing them to come closer and form larger clumps. This clumping together makes it easier to separate the solids from the water by settling.
- As coagulants are introduced, small particles react and form larger/heavier floc.

Types of Coagulants

- Primary and Coagulant aids
 - Primary: Aluminum Sulfate, Ferric Sulfate, Ferrous Sulfate, Ferric Chloride, PACL
 - Coagulant aid: Cationic, Anionic, Non-ionic polymers
 - Metallic salts, and synthetic organic Polymers are commonly used as coagulation chemicals in water treatment because they are effective, relatively low in cost, available, and easy to handle, store, and apply

Primary Coagulant Selection

- Selection can be difficult because there are so many different types of chemicals and no universal evaluation method
- Consider:
 - Approval for drinking water use (NSF approved).
 - Cost
 - Availability
 - Source water characteristics

Coagulation Chemistry

- Particle Destabilization
- Most colloidal particles are negatively charged
- Most coagulant chemicals are positively charged

Alkalinity

- The alkalinity of a water sample is a measure of the water's capacity to neutralize acid.
- In natural and treated waters, alkalinity is caused mainly by bicarbonate, carbonate and hydroxide, which originate from calcium, magnesium, and sodium compounds.
- pH drops slowly as you add acid until all the hydroxide, carbonate, and bicarbonate is consumed by about pH 4.5
- Titrating down to pH 4.5 measures total alkalinity
- Titrating down to pH 8.3 measures the phenolphthalein alkalinity

pH

- Why is pH important?
 - The pH of the water determines which hydrolysis species (chemical compounds) predominate. Lower pH values tend to favor positively charged species, which are desirable for reacting with negatively charged colloids and particulates, forming insoluble flocs, and removing impurities from the water

Coagulant	Empirical Formula	pH Range (s)	Alkalinity Consumed*
Aluminum Sulfate	$\text{Al}_2(\text{SO}_4)_3 \cdot 14 \text{ H}_2\text{O}$	Theory 5.5 to 7.8	0.49 mg/l for each 1 mg/l of alum
		Typical 6.0 to 7.4	
Ferric Sulfate	$\text{Fe}_2\text{SO}_4 \cdot 9 \text{ H}_2\text{O}$	4.0 to 11.0	0.53 mg/l for each mg/l of ferric sulfate
Ferric Chloride	FeCl_3	4.0 to 11.0	0.92 mg/l for each mg/l of ferric chloride
* See Alkalinity Requirement for Aluminum and Iron Coagulants in the Appendix for calculation of the alkalinity requirements for alum, ferric sulfate and ferric chloride.			

Figure 5: pH ranges and alkalinity consumed for aluminum and iron coagulants

Enhanced Coagulation

- Enhanced Coagulation is a process designed to remove natural organic matter (NOM) from water by adjusting both the coagulant dosage and pH to produce the greatest possible reduction of dissolved or suspended matter.

- Enhanced coagulation is paramount to reducing TOC and thereby reducing DBP formation, TTHM's.
- pH reduction depends on the alkalinity of the source water

Flocculation

- A slow stirring process that causes the gathering together of small, coagulated particles into larger, settleable particles.

Sedimentation

The sedimentation process removes suspended solids that are denser than water in order to reduce filtration load

Filtration

- The purpose of filtration is the removal of particulate impurities and floc from the water being treated. Through filtration, water passes through materials, such as a bed of sand, coal, or other granular substances, to remove floc and particulate impurities.

- There are a number of interrelated removal mechanisms within the filter media itself that are relied upon to achieve high removal efficiencies. These removal mechanisms include the following processes:
 - Sedimentation on media (very important)
 - Adsorption (very important)
 - Think of tape
 - Biological action
 - Absorption (not to important after initial wetting)
 - Think of a sponge
 - Straining

Types of Filters

- Gravity filtration
- Pressure filtration
- Diatomaceous Earth filtration
- Slow sand filtration

Filter Media

- Sand, anthracite coal, and garnet are the filter media most often selected in gravity filtration
- Desirable characteristics
 - Good hydraulic characteristics
 - Does not react with substances in the water
 - Hard and durable
 - Free of impurities
 - Insoluble in water

- Filter media is usually characterized by
 - Effective size (ES)
 - Uniformity Coefficient
 - Specific Gravity
 - Hardness

- Proper selection of media size is important and based on two factors:
 - The time required for turbidity to break through the filter bed
 - The time required for the filter to reach limiting (terminal) headloss
- Properly sized media will result in both factors happening simultaneously

- If the limiting head loss is frequently a problem and turbidity breakthrough rarely occurs, then a larger media size may be considered
- If turbidity breakthrough is frequently a problem and limiting head loss is rarely encountered, then a smaller media size may be considered
- Optimized process/proper chemical addition is also a main contributor of premature turbidity breakthrough of premature headloss buildup

Disinfection



- Water naturally carries biological life forms that can cause diseases. These waterborne pathogenic organisms can cause the types of diseases that may cause harm to humans.



- One of the cleansing processes in the treatment of safe water is called disinfection. Disinfection is the process designed to kill or inactivate most microorganisms in water or wastewater, including essentially all pathogenic (disease-causing) bacteria. There are several ways to disinfect, with chlorination being the most frequently used in water and wastewater treatment plants.

Factors Influencing Disinfection

- pH
- Temperature
- Turbidity
- Reducing Agents
- Microorganisms

pH

- The pH of water being treated can alter the efficiency of disinfectants. Chlorine, for example, disinfects water much faster at a pH around 7.0 than at a pH over 8.0.

Temperature

- Temperature conditions also influence the effectiveness of the disinfectant. The higher the temperature of the water, the more efficiently it can be treated. Water near 70 to 85 degrees is easier to disinfect than water at 40 to 60 degrees.
- Longer contact times are required to disinfect water at lower temperatures.
- To speed up the process, operators often simply use larger amounts of chemicals. Be aware, that the higher the chlorine concentration, the greater the dissipation rate of chlorine into the atmosphere.

Turbidity

- Under normal operating conditions, the turbidity level of water being treated is very low by the time the water reaches the disinfection process. Excessive turbidity will greatly reduce the efficiency of the disinfecting chemical or process. Studies in water treatment plants have shown that when water is filtered to a turbidity of one unit or less, most of the bacteria have been removed.

Organic and Inorganic Matter

Organics found in the water can consume great amounts of disinfectants while forming unwanted compounds. Trihalomethanes (THMs) are an example of undesirable compounds formed by reactions between chlorine and certain organics. Disinfecting chemicals often react with organics and reducing agents. Then if any of the chemical remains available after this initial reaction, it can act as an effective disinfectant.

Inorganic compounds such as ammonia (NH_3) in the water being treated can create special problems. In the presence of ammonia, some oxidizing chemicals form side compounds causing a partial loss of disinfecting power. Silt can also create a chemical demand. The chemical properties of the water being treated can seriously interfere with the effectiveness of disinfecting chemicals.

Microorganisms

- The concentration of microorganisms is important because the higher number of microorganisms, the greater the demand for a disinfecting chemical. The resistance of microorganisms to specific disinfectants varies greatly. Cysts and viruses can be resistant to certain types of disinfectants.



Removal Processes

- Pathogenic organisms can be removed from water, killed, or inactivated by various physical and chemical water treatment processes. These processes are:
 - Coagulation: Chemical coagulation followed by sedimentation and filtration will remove 90 to 95 percent of the pathogenic organisms depending on which chemicals are used. Alum usage can increase virus removals up to 99 percent.
 - Sedimentation: Properly designed sedimentation processes can effectively remove 20 to 70 percent of the pathogenic microorganisms. This removal is accomplished by allowing them to settle out by gravity, assisted by chemical floc.
 - Filtration: Filtering water through granular filters is an effective means of removing pathogenic and other organisms from water. The removal rates vary from 20 to 99+ percent, depending on the coarseness of the filter media and the type and effectiveness of pretreatment
 - Disinfection: Disinfectant chemicals, such as chlorine, are added to water to kill or inactivate pathogenic microorganisms

Other Types of Disinfectants

- Ultraviolet (UV) can be used to destroy pathogenic microorganisms. To be effective, the rays must come in contact with each microorganism. The UV energy disrupts various organic components of the cell causing a biological change that is fatal to the microorganism.
 - These systems have not had widespread acceptance because of the lack of measurable residual and the cost of operation. Currently, use of ultraviolet rays is limited to small or local systems and industrial applications.
 - Advances in UV technology and concern about DBPs produced by chlorine have prompted renewed interest.
- Heat has been used for centuries to disinfect water. Boiling water for about 5 minutes will destroy essentially all microorganisms.
- Ultrasonic Waves have been used to disinfect water on a limited scale. Sonic waves destroy microorganisms by vibration.

Chemical Disinfectants other than chlorine

- Iodine, Bromine, Bases
- Ozone
 - Ozone has been used in the water industry since the early 1900s, particularly in France. In the US, it has been used primarily for taste and odor control. The limited use in the US has been due to its high costs, lack of residual, difficulty in storing, and maintenance requirements.
 - Although ozone is effective in disinfecting water, its use is limited by its solubility. The temperature and pressure of water being treated regulate the amount of ozone that can be dissolved in the water.
 - Many scientists claim that ozone destroys all microorganisms. Unfortunately, significant residual ozone does not guarantee that a water is safe to drink. Organic solids may protect organisms from the disinfecting action.

Chlorine

- Chlorine (CL₂) is a greenish-yellow gas with a penetrating and distinctive odor. The gas is two and a half times heavier than air. Chlorine has very high coefficient of expansion. Chlorine by itself is nonflammable and non-explosive, but it will support combustion.

Chlorine Residual

- Chlorine is not only an excellent disinfectant but also reacts with iron, sulfide, and many taste and odor producing compounds to help improve the quality of treated water.
- There are two types of chlorine residual
 - Free chlorine residual
 - Combined residual

- Free chlorine residual refers to chlorine gas (Cl_2), hypochlorous acid (HOCl), and the hypochlorite ion (OCl^-).
- Combined residual chlorine refers to the chlorine-ammonia compounds monochloramine (NH_2Cl), dichloramine (NHCl_2), and trichloramine (NCl_3).
- These are both types of disinfectants

Corrosion Control



Factors influencing corrosion

- Physical Factors
 - Material, system pressure, soil moisture, temperature and flow
- System Construction
 - Types of coatings on the material
- System Pressure
 - High pressure systems corrode more greatly, it increases the max concentration of corrosive gases like carbon dioxide and oxygen
- Soil Moisture
 - Moisture functions as the electrolyte, the same as water inside the pipe does in the case of internal corrosion
- Stray Electric Current
 - Grounding wires
- Temperature
 - Increased temperature usually increases the rate of the reaction
 - However with calcium carbonate deposition is enhanced

- Effects of chemical factors
- Various chemical factors greatly influence corrosion
 - pH
 - Alkalinity
 - Chlorine residual
 - Levels of dissolved solids
 - Dissolved gases

Methods of controlling corrosion

- Calcium Carbonate Saturation
 - Reducing corrosive water is almost always accomplished by treating the water with chemicals so that the water is saturated or slightly supersaturated with calcium carbonate.
 - These chemicals should be fed after filtration

Determination of chemicals

- Depends on water quality goals and ultimately price.
- Quicklime
 - Added to waters that have a low hardness and low alkalinity in order to form calcium carbonate barrier in distribution mains.
- Caustic Soda
 - Added to waters with high levels of hardness and alkalinity because there is already sufficient calcium alkalinity to form calcium carbonate, but the pH must be increased to reach saturation conditions.

Lime

- Difficult to handle (powder)
- Messy
- Cakes
- Inhalation hazards
- Requires a lime tower or gravity feed

Caustic Soda

- Accurate Feed
- Liquid
- Dangerous chemical
- Expensive

Chemical dose is dependent on pH desired

- pH desired is based on the Langelier Saturation Index.

Cathodic Protection Systems

- Used to reduce or inhibit corrosion of metal exposed to water or soil.
- Key to the system is the use of an auxiliary anode of expendable metal that is immersed or buried in the soil or water.
- All cathodic protection systems pass current through the soil or water from anodes connected to the structure that is to be protected. (pg 398)

Protection of flocculators, clarifiers, and filters

- Automatic cathodic protection control devices can provide precise corrosion control under nearly all conditions

Lead and Copper Rule

- Lead is a common, natural and often useful metal found throughout the environment in lead-based paint, air, soil, household dust, food, certain types of pottery etc.
- Lead in drinking water, although rarely the sole cause of lead poisoning can significantly increase a person's total lead exposure
- When water stands in lead pipes or plumbing systems containing lead for several hours or more, the lead may dissolve into your drinking water.

Lead and Copper Rule

- 1991
- Maximum contaminant level goals, actions levels are established for lead and copper
- Lead and copper monitoring
- Treatment technique for lead and copper, included optimal corrosion control techniques
- Public notification and education

Monitoring Requirements

- Lead and Copper monitoring must be taken from high risk areas
 - Homes with lead solder installed after 1982
 - Homes with lead pipes
 - Homes with lead service lines

Maximum Contaminant Level Goals

- 10 percent of samples taken in the system cannot exceed the action level:
- Lead- Action level of 0.015 mg/L
- Copper- Action level of 1.3 mg/L

Treatment Requirements

- pH and alkalinity adjustment
- Calcium adjustment (to form protective calcium carbonate films inside plumbing)
- Phosphate- or silica based inhibitor addition

Lead service line replacement

- All public water systems that continue to exceed the lead action level after installing optimal corrosion control treatment
- Replacement of seven percent of their lead service lines per year
- Total replacement of the entire lead service line unless it can demonstrate that it does not control the entire line.
- A maximum of 15 years to complete the lead service line replacement.

Public Education

- Mail out notices
- Announcements in major local daily and weekly newspapers, distribution, of pamphlets to schools, health care, and day care facilities, and submittal of public service announcements to at least five of the largest radio and television stations in the area.
- Flushing taps before use
- Cooking with cold rather than hot tap water
- Checking new plumbing for lead solder
- Testing their water for lead

CA Title 22

- https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/lawbook/dw_regulations_2019_04_16.pdf

The Safe Drinking Water Act

- 1974, the Safe Drinking Water Act (SDWA) was signed into law, giving the federal government, through EPA, the authority to:
 - Set national standards regulating the levels of contaminants in the drinking water
 - Require public water systems to monitor and report their levels of identified contaminants
 - Establish uniform guidelines specifying the acceptable treatment technologies for cleansing drinking water of unsafe levels of pollutants

- Primary Standards
 - Established maximum contaminant levels based on the health significance of the contaminants
- Secondary Standards
 - Established based on aesthetic considerations

- Public water system
 - 15 service connections
 - Regularly serves an average of 25 individuals daily at least 60 days out of the year

Surface Water Treatment Rule

- Established Turbidity Requirements
 - Combined effluent turbidity limit of 0.3 NTU 95% of the time
 - Never to exceed 1 NTU
- Disinfection requirement
 - 99.9 Percent (3 log) removal of Giardia lamblia
 - 99.99 Percent (4 log) removal of Virus

- Conventional

- Systems using either conventional or direct filtration must achieve a filtered water turbidity level of less than or equal to 0.3 NTU in 95% of the measurements taken for each month. This limit may be increased by the state to 1 NTU if the system proves it can effectively remove Giardia cysts at such turbidity levels. At no time can filtered water turbidity exceed 1 NTU.

Total Coliform Rule (TCR)

- Coliform must be absent in 95% of samples collected
- If a routine sample is positive the water supplier shall collect a repeat sample within 24 hours of being notified of the positive result.
 - Three samples are to be collected, one at the original sample location, one upstream and one downstream within 5 service connections.

Significant Rise in Bacterial Count

- A system collecting at least 40 samples per month has a total coliform positive routine sample followed by two total coliform positive repeat samples.
- A system has a sample which is positive for fecal coliform or E. Coli.
- A system fails the total coliform MCL

Total Coliform MCL

- Results of all samples collected in a calendar month shall be included in determining compliance with the total coliform MCL.
- A violation of the TCR MCL occurs when:
 - (1) For a public water system which collects at least 40 samples per month, more than 5.0 percent of the samples collected during any month are total coliform-positive; or
 - (2) For a public water system which collects fewer than 40 samples per month, more than one sample collected during any month is total coliform-positive; or
 - (3) Any repeat sample is fecal coliform-positive or E. coli-positive; or
 - (4) Any repeat sample following a fecal coliform-positive or E. coli-positive routine sample is total coliform-positive.

Public Notification

- Tier 1 Notification- As soon as possible within 24 hours
 - Acute and immediate risk to human health or unknown risk.
- Tier 2 Notification- Within 30 days after learning of a violation.
- Tier 3 Notification- Within one year, typically in the annual consumer confidence report.

Disinfectants and Disinfection Byproducts Rule (DBPR)

- Set maximum contaminant levels for disinfection byproducts

Table 64533-A
Maximum Contaminant Levels and Detection Limits for Purposes of Reporting Disinfection Byproducts

Disinfection Byproduct	Maximum Contaminant Level (mg/L)	Detection Limit for Purposes of Reporting (mg/L)
Total trihalomethanes (TTHM)	0.080	
Bromodichloromethane		0.0010
Bromoform		0.0010
Chloroform		0.0010
Dibromochloromethane		0.0010
Haloacetic acids (five) (HAA5)	0.060	
Monochloroacetic Acid		0.0020
Dichloroacetic Acid		0.0010
Trichloroacetic Acid		0.0010
Monobromoacetic Acid		0.0010
Dibromoacetic Acid		0.0010
Bromate	0.010	0.0050 0.0010 ¹
Chlorite	1.0	0.020

¹ For analysis performed using EPA Method 317.0 Revision 2.0, 321.8, or 326.0

- Results are based on locational running annual average. Also set maximum residual disinfectant level.

Table 64533.5-A
Maximum Residual Disinfectant Level

<i>Disinfectant Residual</i>	<i>MRDL (mg/L)</i>
Chlorine	4.0 (as Cl ₂)
Chloramines	4.0 (as Cl ₂)
Chlorine dioxide	0.8 (as ClO ₂)

Monitoring Requirements

- The LRAA is based on an average of the quarterly samples collected, per location in the distribution system
- Reported every quarter

Enhanced Coagulation

- Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual
- <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockkey=200021WV.txt>

TABLE 2-1
Required Removal of TOC by Enhanced Coagulation
For Plants Using Conventional Treatment:
Step 1 Removal Percentages^{a, b}

SOURCE WATER TOC (mg/L)	SOURCE WATER ALKALINITY (mg/L as CaCO ₃)		
	0 to 60	>60 to 120	>120 ^c
>2.0 - 4.0	35.0%	25.0%	15.0%
>4.0 - 8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

Notes:

- a. Enhanced coagulation and enhanced softening plants meeting at least one of the six alternative compliance criteria in Section 2.4 are not required to meet the removal percentages in this table.
- b. Softening plants meeting one of the two alternative compliance criteria for softening in Section 2.4 are not required to meet the removal percentages in this table.
- c. Plants practicing precipitative softening must meet the TOC removal requirements in this column.

Emerging Contaminants or new Laws

- Lead Copper Rule revisions
- PFAS
- Microplastics

Questions?