THE TAYLOR TUTORIAL STUDY GUIDE

WATER TREATMENT PLANT CERTIFICATION TRAINING SUPPLEMENT

Produced by the

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Introduction to The Taylor Tutorial Study Guide

Those preparing for their Water Treatment Plant C and D Certification Examination have frequently sought a concise compilation of treatment facts to help them prepare for these examinations. The Taylor Tutorial Study Guide has been successfully used by many water treatment plant operators for this purpose. The Florida Rural Water Association has reprinted the guide to assist certification exam applicants in their preparations.

This guide was originally compiled by Michael Taylor. Mr. Taylor is a water treatment plant operator at the City of Jacksonville Beach Water Treatment Plant. He has allowed the Florida Rural Water Association to reprint his work here to assist the many water treatment plant operators who are preparing for their water treatment plant certification examinations. The Guide highlights concepts important in the understanding of the water treatment process. We are very much indebted to Mr. Taylor for his excellent work. Small organizational edits have been made to make the Study Guide easier for applicants to use.

The Tutorial has been organized in sections to conform to the Florida Rural Water Association's Small Water Systems Training Guide. Operators taking the State of Florida Water Treatment Plant Operator's Certification Examination are encouraged to use the Florida Rural Water Association's Small Water System's Training Guide as the basic text to assist the operator in applying and understanding the many facts highlighted in the Taylor Tutorial. The Small Water Systems Training Guide can be obtained from The Florida Rural Water Association, by calling (850)-668-2746, by visiting the Florida Rural Water Association WEB site at http://www.fwra.net or by attending a Water Plant Certification Training Session hosted by the Florida Rural Water Association held at various locations around the State of Florida beginning 8 weeks prior to the February and August State Examinations.

Those operators that are responsible for Surface Water Plants are strongly encouraged to also obtain The Florida Rural Water Association's Surface Water Training Supplement which can be obtained through the processes mentioned above. This Training Supplement has additional detail applicable to Surface Water Treatment.

Water Sources for Drinking Water Supply

1. Purpose of Water Treatment
   - The first priority for operating a water treatment plant is the production of safe drinking water, one that is free of harmful bacteria and toxic materials.

2. Waterborne diseases are caused by:
   - Cholera
   - Dysentery
   - Gastroeteritis
   - Giardiasis
   - Hepatitis
   - Typhoid
   - Malaria is not a water borne illness!

3. Causes of Impurities in Water
   - Land erosion
   - Decay of plant material
   - Airborne contamination
   - Industrial discharges
   - Animal wastes

4. Causes of Surface Water Pollution
   - People
   - Nature
   - Suspended and dissolved organic (plant and animal origin)
   - Inorganic (mineral) material
   - Biological – Bacteria & plankton

5. Hydrological Cycle

   Precipitation infiltrates the soil. Water drains downward (percolates) below root zone and finally reaches a level at which all openings and voids in the earths materials are filled with water. This is known as the zone of saturation. Also known as Ground water.

6. Thermal Stratification of Lakes and Impoundments

   - Upper layer – Epilimnion (constant temp – warm)
   - Middle layer – Thermocline or metaumnion (Rapid temp decrease)
   - Lower layer – Hypolimnion (cooler denser water)
   - Summer: Water warm – less dense and stays in upper layer, with no mixing to lower layers
   - Turn over

In winter, upper layer cools and becomes equal with lower level of lake. Water density is uniform. Water is mixed with wind cooling more dense water and sinks and mixes with lower level water.
Monomictic – One mixing
Dimictic – Two mixing; Lakes and reservoirs which freeze over normally go through two stratifications and 2 mixings cycles per year

7. Algae Blooms and PH

- Algal blooms are often associated with fluctuations in PH of the water in the upper layers of a resevoir where blooms occur.
- PH is frequently raised from a level near 7 to near 9 or above.
- Chlorination efficiency greatly reduced at higher PH levels.
- Algae removes carbon dioxide from solution
- Converts carbon dioxide into cellular material as algae grows
- Carbonate equilibrium (balance) is affected
- Under favorable light conditions, in high concentrations of algae growth, PH levels values can rise as high as 9.8
- During daylight hours, PH will increase
- PH will lower at night
- Respiration by algae results in an increase in carbon dioxide in water (lower of PH)
- Photosynthesis decreases carbon dioxide in water (increasing PH)
- Fluctuations in PH affect both coagulation and disinfection.
- Chemicals used to control Algal growths are copper sulfate pentahydrate (bluestone) –algaecide; Treat in autumn
- Alkalinity, suspended matter and water temp affect copper sulfate as a algaecide
- Copper sulfate is fully effective when alkalinity is 0-50 mg/l
- Alkalinity above 150mg/l, copper sulfate is in-effective

8. Nutrients Considerations in Surface Water Sources

- Phosphate
- Nitrate
- Organic nitrogen compounds
- Nutrient RICH water sources – Eutrophic
- Nutrient POOR water sources – Oligotrophic
- Eutrophic – acts as a fertilizer and stimulates algae growth
- Mesotrophic – Moderate level of nutrients

9. Problems with Lack of Dissolved Oxygen and low pH

- Sulfate is reduced to Sulfide (stinky) causing odor problems
- Iron and Manganese
  High level of dissolved oxygen, iron & manganese is oxidizable and precipitates into the reservoirs bottom sediments (un-soluble)
  Low levels of dissolved oxygen, iron and manganese become soluble
  Iron becomes soluble Ferrous state
  Manganese becomes soluble manganous state

10. Types of Contaminants

- Organic: Substances that come from animal or plant sources. Organic substances always contain carbon. (inorganic materials are chemical substances of mineral origin)
- Inorganic: Materials such as sand, salt, iron, calcium salts and other mineral materials. Inorganic substances are of mineral origin, whereas organic substances are usually of animal or plant origin.
- Biological: Bacteria and Virus
- Radiological: Radon and Radionuclides

11. Ground Water Sources

- Water obtained from Zone of Saturation
- Can be protected by confining layers of lime rock and Clay
- Artesian Springs are (free flowing because of potentiometric pressure
- Typical water sources are Aquifers and UDI Under direct influence of surface water

Florida Rules and Safe Drinking Water Act Requirement for Water Systems

1. Definitions

- Maximum Contaminant Level (MCL.) The highest level of a contaminant that is allowed in drinking water. The MCL is the maximum contaminate level that is determined by health effects. MCLs are set as close to the MCLGs (see below) as feasible using the best available treatment technology. To understand the possible health effects described for many regulated constituents, a person would have to drink 2 liters of water every day at the MCL level for a lifetime to have a one-in-a-million chance of having the described health effect.
- Maximum Residual Disinfectant Level (MRDL.) The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for the control of microbial contaminants.
- Maximum Residual Disinfectant Level Goal (MRDLG). The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Action Level (AL) The concentration of a contaminant which, when exceeded, triggers treatment or other requirements which a water system must follow. Non-Detects (ND) - laboratory analysis indicates that the contaminant is not present.
- Treatment Technique (TT) The required process intended to reduce the level of a contaminant to acceptable levels.

2. Regulated Inorganic Compounds

- Nitrates and Nitrite (indicators of fecal contamination)

  Nitrite = 1.0 mg/l (eats up chlorine!)
  Nitrate = 10.0 mg/l Nitrate + Nitrite = 10 mg/l

- Action Levels for Lead and Copper (90 percentile or 10% in violation)

  Lead = .015 mg/l - 15 ppb
  Copper = 1.3 ppm

3. Secondary MCL's for Taste and Color

- Iron = 0..3 mg/l (causes staining at this level) Color = 15 units
- Manganese = .05 mg/l .02 mg/ l initiate flushing (to avoid complaints)

4. Public Water System Classification (PWS)

- Public Water System Definition

  Serves as at least 15 service connections
  Regularly serves an average of at least 25 individuals daily at least 60 days out of the year.

- Public Water System Types – Community (CWS) or Non Community Water Systems (NCWS)

- Community Water System (CWS)

  Has at least 15 service connections used by all year residents or
  Regularly serves at least 25 all year residents.
  Examples are cities, mobile home parks, subdivisions.

- Non-Community (NCWS)

  Serves over 25 different people each day,
  Examples are stores, plaza's, gas stations, restaurants, campgrounds and hotels, etc.

- Non Transient Non Community (NTNCWS)

  Serves over 25 of the same people at least 6 months of the year,
  Examples are schools, hospitals, large business, mostly same people everyday, but don't actually live there
  Must meet the same requirements as community water systems

- Transient Non-Community Water System (TNCWS)

  Does not regularly serve drinking water to at least 25 of the same persons over 6 months a year

5. Some Regulations to Know

- THM's = .08 mg/l or 80 ppb HAA5 = 0.06 mg/l or 60 ppb
- Fluoride = Primary 4.0, secondary 2.0 (Notification 2.0, violation 4.0)
- Flouride Range are: .8 – 1.2 mg/l (optimum range is .8 – 1.2 mg/l)
- The recommended MCL requirement for any known carcinogens = 0
- Sodium levels in water should be below 20 mg/l; MCL = 160 mg/l
- The Minimum Free Chlorine Residual is 0.2 mg/l; 0.6 mg/l for chloramine
- 4 log removal = 99.99% removal for Surface Water Filtration for Viruses
- 3 log removal = 99.9 % removal for Surface Water Filtration for Giardia

Well Requirements for Public Water Systems

1. Setback Distances

- Minimium set back, 200 ft from septic tank over 2000 gpd flow
- Minimum set back, 100 ft from septic tank under 2000 gpd flow

2. DEP Well Construction Requirments

- Well pad 6'x 6'x4" concrete sloped away from the casing
- Casing must extend 12 inches minimum above concrete slab and 100 yr flood

3. Well Operations Definitions

- Static level – Level of water when pump is not operating
- Pumping or Dynamic Level – Level of water when pump is operating
- Draw down – Drop of water level when water is pumped from well
- Pumping – Static = Drawdown

4. Well Operation Considerations

- Well pump packing gland lubrication – Water (aprox one drop per second)
- Well casing must be disinfected

5. Municipal Well Pump Types

- Submersible
- Centrifugal
- Turbine

6. Locating a Well

- Vulnerability is the most important factor to consider in locating a well site from the health point of view
- A well is acidized in order to increase yield
- The drawdown in a well is measured from the static water level to the pumping water level
- If volatile organic chemicals (VOC's) are detected, sampling must then be conducted quarterly

Water Storage

1. Types of Water Storage Tanks

- Gravity or elevated
- Ground Storage
- Hydropneumatic

2. Elevated or Gravity Tanks

- Less variation in pressure
- Large storage capacity
- 140 ft tank provides 60psi
- .433 x Ft = psi

3. Advantages Provided by Gravity Storage Tanks

- Less variation in pressure
- Storage for fire fighting use
- Greater storage to meet water requirement
- Greater flexibility to meet peak demands
- Use of lower capacity wells (pumping not necessary to meet peak system demand)
- Sizing of pumps to take better advantage of electric load factors
- Reduced on and off cycling of pumps
- Tie-in of several wells, each pumping at its optimal rate

4. Air Compressors

- Lubricants must be NSF approved
- Must be drained for moisture accumulation
- Dirty filters affect efficiencies and reduce life

Chlorination and Disinfection

1. Types of Disinfection

- Heat treatment – boil water
- Radiation – Ultraviolet – High cost and lack of residual and turbidity
- Chemical Treatment – includes:
  Chlorine – is the most widely used disinfectant in water treatment.
  Chloramines – Chlorine and ammonia mixed (less effective than Chlorine)
  Potassium Permanganate
  Ozone
  Chlorine Dioxide

2. Factors Affecting Chlorination

- PH – the lower the PH the faster the disinfection
- Contact time – longer chlorine contact means more pathogen inactivation
- Temperature – The higher the temperature, the more effective the treatment
- Presence of Reducing Agents – Hydrogen sulfide, Iron and Manganese, NH_3 are major demanding agents
- Organics – Organics in water consume of chlorine while forming unwanted disinfection byproducts such as THM's and HAA5's

3. Types of Chlorine Used in Water Treatment

- Liquid – Sodium Hypochlorite 5.25% Bleach, 12.5% Commercial
- Dry Powder – Calcium Hypochlorite 65 – 70% (HTH)
- Gas Chlorine – 150 lb and 1 ton cylinders – 100% available
- Gas Chlorine Lowers PH; other forms raise pH
- Gas Chlorine – Formation of Hypochlorous acid (more effective)
- Hypochlorite forms lose strength after about 2 weeks

4. Properties of Gas Chlorine

- Greenish – Yellow Gas and is 2.5 times heavier than air
- Expands 450 times from liquid to gas
- Containers are welded steel tanks with a chlorine capacity of 2000 lbs and a loaded weight of as much as 3650 lbs.
- Stamped with serial number, tare weight and date of most recent hydro test.
  3 fusible plugs on each end and are designed to melt between 158 deg F and 165 deg F

5. Liquid Chlorine 100% Solution

- Amber in color
- Is about 1 ½ times heavier than water
- Seldom seen as a liquid because it boils (converts to gas) at about -30 deg cen
- 1 pound or about 11 fluid ounces of liquid chlorine yields aprox 5.4 cubic feet of 100% chlorine gas.

6. Liquid Chlorine Solution (Sodium Hypochlorite Solution)

- Concentrations of 5 to 15% chlorine
- More expensive than chlorine Gas
- Easier to handle than chlorine Gas or Calcium Hypochlorite
- Very corrosive
- Hydrogen is given off as a by-product

7. Calcium Hypochlorite Solid

- Contains 65% available chlorine
- Dissolves easily in water
- Available in granular, powdered or tablet form
- Corrosive
- Strong odor
- Must be kept away from organic and petroleum products
- Can generate enough heat to cause fire or explosion

8. Chloramines

- Formed when water containing chlorine and ammonia are mixed
- Optimal mixing ratio is 3 to 5 parts chlorine to 1 part ammonia
- Three types are: monochloramine, dichlroramine and trichloramine
- Monochloramine desired, dichloramine causes taste and odor problems
- Chloramine = Combined Chlorine
- Produces fewer disinfection by products
- Chloramine is a weak disinfectant and need to maintain 0.6 ppm
- Much less effective against viruses and protozoa
- Best as a secondary disinfectant to prevent bacterial regrowth
- Nitrogen Trichloride is the only detrimental reaction formed at a PH below 5
- Dichloramine produced when ration exceed 5 to 1
- Free chlorine requires about a 10 to 1 ratio
- When people complain about a strong chlorine odor in the water, it’s often due to a chloramine buildup

9. Chlorine Facts that Every Operator Should Know

- Liquid Chlorine - Greenish – Yellow Gas
- Chlorine is 2.5 times heavier than air and gravitates to bottom of room
- Chlorine expands 450 times from liquid to gas
- Chlorine demand increases when organic matter increases
- Fusible Plugs melt at 158 to 165 degrees
- There are 6 fusible plugs on a two ton chlorine cylinder – 3 on each end
- There is 1 fusible plug on a 150 lbs chlorine cylinder
- Gas chlorine – lowers Ph and strips Alkalinity
- Gas chlorine increases hydrogen concentrations
- Gas chlorine is non flammable
- CL2 detectors are located at the lowest point where CL2 tanks are stored
- Initial concentration of chlorine applied to new water mains for disinfection is 50 mg/l
- One volume of liquid chlorine confined in a chlorine cylinder under pressure will yield about 460 volumes of gaseous chlorine.
- Daily consumption of gas chlorine is checked by a platform scale
- The permissible exposure limit (PEL) for chlorine is 0.5 ppm for 15 minutes
- The disinfection process is used to destroy or inactivate disease producing (pathogenic) organisms
- Disinfection is the selective destruction or inactivation of pathogenic organisms

Coagulation/Flocculation

1. Coagulation chemicals

   - Metallic Salts of Aluminum and Iron

     Aluminum Sulfate (alum)
     Ferric Sulfate
     Ferrous sulfate
     Ferric Chloride

2. Synthetic (manmade) Organic Polymers

   - Polymers – contain ionizable groups – (carboxyl, amino, sulfonic groups) referred to as polyelectrolytes.
   - Some polymers lose their effectiveness when used in the presence of a chlorine residual
   - Types of Polymers

     Cationic Polymers with positively charges groups attract Negative
     Anionic Polymers with negatively charged groups attract Positive
     Non-Ionic Polymers with balanced charged groups

   - Cationic polymers are used as both primary coagulant and as a coagulant aid (in conjunction with Alum) when alum is not used as a primary
   - Cationic polymers have the ability to absorb on negatively charged particles (Colloidal and turbidity Particles) and neutralize their charge

3. Primary Coagulants – Neutralize electrical charges of particles causing clumping

   - Aluminum Sulfate (Alum), $Al_2(SO_4)_3 \cdot 14H_2O$
   - Ferrous Sulfate
   - Ferric Sulfate
   - Ferric Chloride

4. Coagulant Aids – Ads density to slow settling flocs and stickiness to prevent breakup of flocs.

   - Lime (coagulant aid)
   - Sodium Aluminate
   - Bentonite (weighting agent)
   - Clay (weighting agent)
   - Sodium Silicate (weighting agent)
   - Various synthetic organic water soluble polyelectrolytes

5. Purpose of Coagulation and flocculation

  - Removes particulate impurities
  - Removes non-settlable solids
  - Removes color from water being treated
  - Chemicals cause particles to clump together forming floc
  - Forms larger heavier settling floc

6. Coagulation Process

  - Chemicals are added causing particles to become destabilized and clump together
  - Alum is the most commonly used coagulant

7. Flocculation Process

  - Particles are gently stirred causing collisions that bind them together to form larger floc particles.
  - Process takes 20 to 30 minutes for conventional treatment

8. Important Facts Concerning Coagulation

  - When the natural alkalinity in raw water is too low to produce complete precipitation of alum, addition of lime is often added to ensure complete precipitation (need at least 30 ppm alkalinity in effluent)
  - Lower PH values tend to favor positively charged species which are desirable for reacting with negatively charged colloids and particulates forming insoluable flocs
  - Residual alkalinity in water serves to buffer (prevent PH from changing)
  - Low alkalinity can cause problems with coagulation
  - Increase alkalinity with Lime or Soda ash
  - The best pH for alum coagulation usually falls in the range of PH 5 to 7
  - Removal of organic compounds with effective coagulation / flocculation reduces the formation of TRIHALOMETHANES after chlorine disinfection

8. Non-Settlable Solids or Colloids (Do not settle (easily) because of negative charge and require treatment to produce larger particles that settle)

  - Bacteria and viruses
  - Fine clays
  - Silts

10. Coagulation/Flocculation Process

- The purpose of coagulation and flocculation is to remove particulate impurities, especially non-settlable solids and color from water
- Coagulating chemicals cause the particles to clump together
- Form larger. Heavier floc and settle out
- Chemicals cause particles to destabilize and clump together
- Flocculation is gentle mixing motion to cause collisions
- Particles are removed by sedimentation and filtration

11. Flash Mixing

- The mixing of coagulant chemicals with raw water
- Rapidly mixes and equally distributes coagulant chemicals
- Entire process is completed in a very short time (several seconds)
- First results are the formation of very small particles

12. Primary Coagulants and Coagulant Aids

- Primary coagulants neutralize the electrical charge and causes particles to clump
- Coagulant aids – Add density to slow settling flocs and adds toughness so floc will not break up.
- Coagulant aids could be called flocculation or sedimentation aids

13. Coagulant Chemicals (Multi-valent Metallic Salts)

- Aluminum sulfate (alum)
- Ferric Sulfate
- Ferrous Sulfate
- When added to water form chemical action with alkalinity producing insoluble hydroxide compounds that cause agglomeration to occur
- Sufficient chemicals must be added to exceed the solubility limit of metal hydroxide, resulting in floc
- Floc formed will absorb on particles (turbity)

14. Polyelectrolytes or Polymers (Long chained organic molecules)

- Carboxyl
- Amino
- Sulfonic groups

15. Anionic and nonionic polymers

- Effective in certain applications
- As coagulant aids
- Filter aids

16. Polymer Overdosing

- Can result in accelerated head loss buildup
- Some polymers lose their effectiveness when used with chlorine residual

17. Chemistry of Coagulation

- Coagulation is a physical and chemical reaction between the alkalinity of water and the coagulant
- Lower PH values tend to favor positively charged particles which are desirable for reaction with negatively charged colloids and particulates
- PH for coagulation is best between 5 – 7
- Proper PH must be maintained
- Coagulants react with alkalinity
- Residual alkalinity in water serves as a buffer (prevents PH from changing)
- Alkalinity can be increased with lime or soda ash

18. Mixing Coagulation Chemicals

- Must be mixed in as short a time as possible (Several seconds)
- Hydrolic mixing
- Mechanical mixing
- Diffusers and grid systems
- Pumped blenders

19. Flash mixing

- Turbulence in the flowing water mixes the chemicals with the water

20. Flocculation

- Is a slow stirring process that causes
- The purpose of flocculation is to create floc of a good size, density and toughness for later removal in the sedimentation and filtration process
- Best size floc ranges **from 0.1mm to about 3.0mm,** appearance popcorn

21. Filtration Process

- Direct filtration or Conventional filtration
- Detention time = The right stirring time, stirring intensity, properly shaped basin and creating stirring action / movement
- Insufficient mixing will result in ineffective collisions (of particles) and poor floc formation
- Excessive mixing may tear apart the flocculated particles (shear) after they have been clumped together
- Detention time is required for the necessary chemical reaction to take place
- Minimum detention time is between 5-20 minutes for direct filtration
- Up to 30 minutes for conventional filtration
- Disinfection of water will be affected by poor coagulation – flocculation
- Effective coagulation/ flocculation removes natural organic compounds
- Removal of natural organic compounds reduce the formation of trihalomethanes (THM'S) following the use of chlorine for disinfection

22. Jar Testing

- Use clear plastic beakers instead of glass because temperatures will change less during the test Important Considerations
- Selection of the proper type and amount of coagulant chemicals
- Jar testing to determine type and quantity of coagulant
- Minimum performed at start of shift or water quality change
- Most of the suspended solids are removed in the sedimentation basins
- Filtration is the final step in the solids removal process
- Coagulation and flocculation should be controlled to improve filtration
- Grab samples and turbidity meter (turbidimeter) measures water turbidity
- Don't rely on turbity results as your sole process control, and water quality indicator
- Considerable time for water to travel from the various treatment process (2 to 6 hours)
- Any change in coagulant dosage at the front and will not be noticed in the final finished water quality for 2 to 6 hours
- Monitor all indicators in the process to detect poor process performance early and initiate corrective action:
  Turbidity
  PH
  Temp
  Chlorine demand
- Floc quality:
  A popcorn flake is a desirable floc appearance
  A milky appearance or a bluish tint means the alum dose is probably too high

Sedimentation

1. Settling of Larger Size Particles

   - Sand
   - Heavy silts
   - Removed by slowing down flow and allowing simple gravity settling
   - These are settleable solids

2. Sedimentation Considerations

   - Sedimentation – The settling rate of a particle becomes much slower as the temperature drops. The colder the water temperature becomes, the longer the particle takes to settle out.
   - When water becomes colder, perform jar tests and adjust coagulant dosage to produce a heavier floc and thus a faster settling floc.
   - The settled materials from coagulation or settling are referred to as sludge, and slurry refers to the suspended floc clumps in the clarifier. Sometime the terms sludge and slurry are use interchangeably.

Filters

Filtration Media Type	Maximum Loading Rate (GPM/Sq ft)	Media
Sand	2	Sand, Gravel
Dual Media	4	Sand, Anthracite
Deep Bed (multi media) (depth > 60")	4+	Sand, Anthracite, Garnet

Filter Monitoring

- Turbidity Monitoring, 15 min intervals using on-line turbidimeters at each filter.
- Particle Counters process only, (particularly effective for Giardia and Cryptosporidium cysts; 4 to 15 μ m range

- Filtration Rate
- meters for each filter very effective to ensure even flow through each filter

- Terminal Head Loss should not exceed 8 feet
- Terminal Head Loss (difference between static head and operating losses) should not be exceeded to prevent air binding

- Filter Wash Rate
- Seasonal rate adjustments necessary

- Length of Filter Run
  Prolonged filter runs result in compaction, media boils, chemical binding on media

Diatomaceous Earth Filtration Process

- Precoat (generally 1/16 to 1/8 inch coating with recycle)
- Body Feed (continuous, generally ~ 20 ppm)
- Filtration (generally operated up to 25 to 30 psi)
- Backwash (5 to 8 minutes and "air bumping is sometimes incorporated to remove material

Water Stabilization

1. Corrosive Water

- Normally, surface water and ground water have a PH Range of 6.8 to 8.5
- High concentrations of Carbon Dioxide is an indication of corrosive water
- High Dissolved Oxygen content makes the water corrosive
- Cathodic protects metal parts in water against Corrosion
- The amount of dissolved oxygen in cold water is more than in warm water
- A negative langelier index indicates that the water is corrosive
- A positive langelier index indicates that the water is scale forming

2. The Aeration Process

- removes undesirable gases such as Hydrogen sulfide and Carbon dioxide
- Oxidizes metals such as iron and manganese to insoluble compounds that precipitate
- Aeration removes volatile organic compounds
- Aeration unites must be screened and sealed
- Aeration (Oxidation) followed by filtration is used to remove high iron content; Ferrous is the most soluble form of iron in water and is oxidized
- Since Aeration adds oxygen to the water it will be corrosive

3. Chemical Oxidation

- Potassium Permanganate – Removes taste and odor from water by oxidation
- Also used in Iron / manganese treatment to oxidize any remaining iron and manganese after chlorination. Oxidizes iron & manganese to insoluble oxides.
- Chlorine – removes taste and odor from water by oxidation

4. Causes of Foul Taste and Odor Problems in Water (more noticeable in warm water)

- Iron and Manganese Slimes
- Algea
- Hydrogen sulfide

5. Red Water Complaints

- May be caused by corrosive water (Low PH) or iron bacteria in the water.
- Corrosive water frees ferrous ions from pipe that feed bacteria
- Addition of caustic to raise PH will help eliminate the corrosive water condition.. Maintaining a good free chlorine residual will eliminate iron bacteria and red water complaints.
- Flushing and maintenance of chlorine residual reduces complaints

Demineralization (Membrane Filtration, Ion Exchange and Dialysis)

1. Source Water for Demineralization Plants

- Most of the earths water supply is saline (high in dissolved minerals)
- Demineralization is the process that removes dissolved minerals (salts)
- Salts are inorganic
- Total Dissolve Solids (TDS) is a measure of the mineral content of water
- Minerals commonly found in nature consist of positive metallic ions (calcium, sodium) are bonded to negative ions (chloride, sulfate, carbonate)

2. Source Water Classifications

- TDS Limits:
- Fresh water – less than 1000mg/l TDS
- Brackish – 1000 – 10,000mg/l TDS (not used because of high mineral taste)
- Seawater – 35,000mg/l TDS (too expensive to process due high TDS)

3. Methods of Demineralizing Water

- Freezing or distillation (phase change)
  Reverse osmosis
  Electrodialysis
- Ion exchange (non phase change)
- Demineralization is primarily used to remove dissolved inorganic materials
- Some systems may also remove suspended solid/materials, organic material, bacteria and viruses

4. Reverse Osmosis Process

- Reverse osmosis – defined as the passage of a liquid from a weak solution to a more concentrated solution across a semipermeable membrane. The membrane allows passage of the water (solvent) but not the dissolved solids (solutes)
- Reverse Osmosis Operation:
  Concentrate is forced through a membrane to yield a less concentrated solution.
- The two types of semi-permeable membranes that are used most often for demineralization are cellulose acetate and thin film composites.
  Reverse Osmosis operated at a pH of 5.5 - Low pH is maintained so minerals will pass thru membrane; Demineralized water is called Permeate
- Recovery – defined as the percentage of feed flow which is recovered as product water.

- The term flux is the expression used to describe the rate of water flow through the semipermeable membrane

- Flux is expressed in GPD – Gallons per day per square foot of membrane surface or in grams per square centimeter
- Most reverse osmosis systems will require periodic cleaning dependent on the average membrane flux rate of the system
- Feedwaters are never pure and contain dissolve organic and inorganics, bacteria, algae and other potential foulants. Deposits can grow on the membrane surface and hinder water flow through the membrane.

5. Reverse Osmosis/Mineral Rejection

- Mineral rejection – The purpose of demineralization is to separate minerals from water: called mineral rejection.
- Higher mineral concentration increases the osmotic pressure
- Rejection improves as feed pressure increases.
- Typical rejection for most commonly encountered dissolved inorganics is usually between 92-99%
- Most demineralization (RO) plants require use of a membrane with high rejection rates (95%)
- Reverse osmosis operation Feedwater temperatures has a significant effect on membrane performance, as temperature of feedwater increases, flux increases

7. Hydrolysis in Reverse Osmosis Systems

- Cellulose acetate membranes are subject to long term failure called hydrolysis of the membrane which will breakdown into cellulose and acetate acid
- Hydrolysis results in lessening of mineral rejection capability. As the membrane hydrolyzes, both the amount of water and the amount of solute that permeate the membrane increase and the quality of the product deteriorates
- Hydrolysis is accelerated by increased feed temperature and pH
- Slightly acidic PH (5 – 6), lowers hydrolysis rate as do cooler temps
- Hydrolysis is at a minimum at a PH of about 4.7; standard practice is to inject sulfuric acid to adjust PH to 5.5
- Acid is added and pH is adjusted during pretreatment to lengthen the life of cellulose acetate membranes and to slow hydrolysis

7. Membranes in Reverse Osmosis Systems

- The 3 types of Membranes are: Spiral wound, Hollow fine fiber and Tubular
- Pre-treatment of feed water removes turbidity and suspended solids to protect the membrane and ensure maximum efficiency
- Pretreatment prevents scaling or fouling of membrane
- Disinfection is used to prevent biological growth
- Cartridge filters – function only as a particle safeguard, not as a primary particle removal device
- Turbidity to cartridge should be no greater than (1) one NTU
- Sodium hexamethaphosphate is sometimes added as precipitation inhibitor represses both calcium carbonate and calcium sulfate scaling

8. RO Plant Operation

- Pretreatment of source water
- Water to be mineralizedis pressurized by high pressure feed pumps to the RO pressure vessel membrane assemblies
- Membrane assemblies consist of a series of pressure vessels
- Typical operating pressure for brackish water varies between 150 – 400psi
- Demineralized water is called **Permeate**
- Reject is called **Concentrate**
- Recovery rate is controlled by increasing feed flow
- Brine flow valves are never fully closed

1. Ion Exchange or Zeolite Softening

   - The four stages of Ion exchange are: 1.) Service, 2.) Backwash, 3.) Brine, and Rinse.
   - Ion exchange – ideal bed expansion is 75 – 100%
   - Ion exchange – optimum brine solution is between 10 – 14% sodium chloride
   - Zeolite Ion Exchange – sulfonated polystyrene resins used as the exchange media.
   - Ion exchange units can be used to remove any charged (ionic) substance from water, but are usually used to remove hardness and nitrate from groundwater.
   - Ion exchange is best with water high in non carbonate hardness and where total hardness does not exceed 350mg/l
   - Ion exchange can produce a water of zero hardness
   - Lime softening cannot achieve a zero hardness in water
   - Ion exchange removes total hardness – the sum of carbonate and non carbonate hardness
   - Most ion exchange units use "sulfonated polystyrene resins" as an exchange media
   - Ion exchange softening can be defined as exchanging hardness causing ions (calcium and magnesium) for sodium ions that are attached to the ion exchange resins to create a soft water

2. Types of Ion Exchange Softeners

   - An upflow unit – water flows from the bottom to the top
   - Gravity rapid sand filter – Flows down and out the bottom
   - Pressure downflow ion exchange softener – most common
   - Vertical units are preferred to prevent short circuiting

1. Nanofiltration Softening

- Reverse Osmosis System
- Uses membranes with lower rejection rates (80%) and lower operating pressures. (150psi or less) commonly referred to as softening or nanofiltration membranes.
- These membranes produce the same quanity of water as RO standard membranes, but at a lower operating pressure.
- Softening and nanofiltration membranes are used when municipal water supplies require high rejection rates for hardness and THM formation and moderate TDS rejection.

1. Electrodialysis Demineralization Process

- Well established water treatment process since – 9/72
- Treats brackish well water and also used for industrial water demineralization
- Typical removals of inorganic salts from brackish water is 25 –40% of dissolved solids per stage
- Efficient removal of most inorganic constituents
- Waste brine contains only salts and a small amount of acid used for PH control Process
- Brackish water flows between alternating Cation – permeable and Anion – permeable membranes
- A direct electrical current provides the motive force
- Many alternating cation and anion membranes are assembled into membrane stacks
- Plastic spacers contain the water systems and direct the flow of water
- Equipment takes the form of a plate and frame assembly similar to that of a filter press
- Several hundred membranes are usually assembled between a single set of electrodes to form a membrane stack
- Membranes are placed between two salt solution and subject to direct electrical current
- Most of the current will be carried through membranes by ions
- Membrane is ION selective
- When current is continued for sufficient time, solution on the side of the membrane finishing ions becomes partially de salted
- Solution on the other side becomes concentrated 10 to 20 seconds to pass between a single stack of membranes, where entering minerals are removed
- Percentage of removal varies with water temp and type of ions present and flow rate
- Typical removal is 25 – 40%
- 1 to 6 stages

- ED systems operate at temps up to 110 degrees F
- Efficiency increases with increasing temps
- Expected life of membranes is aprox 10 years
- Most common problem is scaling (or fouling) of membranes by organic and inorganic materials
- Electrolyzed and hydroxide ions pass through the membrane and raise PH in the cell
- This increase (PH) is sufficient to cause precipitation of magnesium hydroxide or calcium carbonate
- This causes electrical resistance of the membrane, this can cause damage or destroy the membrane
- Offset by use of acid to concentrate water to maintain a negative Langelier index to ensure scale free operation

2. Principles of Electrodialysis

- When common salts, minerals, acids and alkalis are dissolved in water, each molecule splits into two oppositely charges particles called ions
- Positive charged ions are – Cations, i.e., Na+, Ca++, Mg++
- Negative charged ions are – Anions, i.e., Cl-, HCO3- (Bicarbonate)
- and SO4 -- (Sulfate)
- Apply (DC) direct current across a solution of salt water by inserting two electrodes in the solution
- The cations (positive) will move toward a negative electrode
- Known as the “CATHODE”
- The anions (negative) will move toward the positive electrode
- Known as the “ANODE”
- 2 types of membranes, Cation membranes for positive ions
- and anion membranes for negative ions

Softening

1. Hardness and Water Softening

- Hardness is caused by mainly by the salts of calcium and magnesium, such as bicarbonate, carbonates, sulfate, chloride and nitrate.
- Hardness causes soap curds, increased soap use, disposition of scale in boilers (HW heaters and tea kettles)
- Hardness can cause objectionable tastes and odors in drinking water.
- Calcium hardness Ca++
- Magnesium hardness Mg++
- Total hardness is the sum of the hardness caused by both calcium and magnesium ions = 2.5 x Ca mg/l + 4.12 x Mg mg/l
- Temporary hardness – Carbonate hardness – is caused by the alkalinity present in water up to the total hardness.
- Permanent hardness – Non carbonate hardness – is that portion of the total hardness in excess of the alkalinity.
- Dissolved minerals (calcium and magnesium) cause a coating to form inside the hot water heater similar to that of a tea kettle after repeated use.
- Hardness will shorten the life of fabrics when washed in hard water.
- Benefits of softening include:
- Removal of iron and manganese
- Disinfection due to high PH values when using lime
- Sometime a reduction of taste and odor
- Free chlorine is mostly hypochlorite at PH levels above 7.5 and is a less powerful disinfectant
- Disposal of process waste is landfill or agricultural application
- Soft water is aggressive which tends to corrode metal ions in water piping
- Hard water can cause scaling on the inside of pipes and restrict flow.
- Hard water does not have adverse effects on health
- The detergent consuming power of hard water can be very costly

2. Lime Softening Process

- Lime – soda ash
- PH is and expression of the intensity of the basic or acidic condition of water
- Natural waters usually have a PH of between 6.5 and 8.5
- Lime softening – The PH must be raised to 11 to remove Mg, around 10 to remove Ca for the desired chemical reactions to occur
- Alkalinity is not the same as PH because water does not have to be strongly base (high PH) to have high alkalinity
- Alkalinity is a measure of how much acid must be added to a liquid to lower the PH of the water to 4.5
- Calcium and magnesium become less soluble as PH increases

- Soda ash – Sodium carbonate Na_2CO_3
- Addition of lime to water increases PH
- Addition of lime to water also converts alkalinity from bicarbonate form to carbonate form (All carbonate hardness is in the bicarbonate form below a pH of 8.3.)

4. Types of Lime

- Quick lime (unslaked lime) is shipped in powdered form as Calcium Oxide
- Lime is Slaked by adding water and is converted to Hydrated Lime
- Hydrated lime or Calcium Hydroxide is used in water treatment

5. Principles of Hardness Removal

- Water Softening depends on whether the hardness is carbonate or non-carbonate.
- Carbonate hardness can be removed by use of lime.
- Non carbonate hardness removal requires both lime and soda ash.
- To remove calcium and magnesium bicarbonate, an excess of lime must be used.
- Calcium carbonate becomes insoluble and settles out at a hardness pH of 9.4.
- A higher PH is needed to remove the magnesium hardness.
- Magnesium carbonate is converted to magnesium hydroxide that becomes insoluble and settles out at a pH of 10.6.
- Excess lime needed to remove magnesium hardness results in supersaturated conditions and the residual of lime which will produce a PH of about 10.9.
- The excess lime is called caustic alkalinity

6. Recarbonation

- If PH is lowered, better precipitation of calcium carbonate and magnesium hydroxide will occur. Alkalinity will also be lowered.
- To lower PH, carbon dioxide gas is pumped into water, this process is called recarbonation. This lowers PH
- A second treatment of additional carbon dioxide gas removes noncarbonate hardness. This will lower PH to about 9.8
- Recarbonation prior to filtration prevents excess lime, calcium carbonate and magnesium hydroxide precipitates from building up on the filters
- Alternate methods in lime/soda ash process is the use of sodium hydroxide (caustic soda) in place of soda ash
- In summary, calcium and magnesium bicarbonate hardness can be softened by using lime only
- Recarbonation is used to lower PH
- If PH is above 9, the water will cause scale to form

- Recarbonation will lower PH to between 8.8 and 8.4 and the Langlier Index will be positive and there will be little or no corrosion
- The use of acids such a sulfuric or hydrochloric instead of recarbonation with carbon dioxide does not produce the same results
- Calcium and magnesium sludge removal. Most common method of disposal is landfill or land application for agricultural purposes.

7. Magnesium Carbonate Removal Process

- Lime reacts with bicarbonate to form calcium carbonate and settle out at a PH above 10
- Magnesium carbonate is converted to Magnesium hydroxide with additional lime.
- Magnesium hydroxide becomes insoluble at a pH of 10.6.

8. Alum Addition

- Alum and iron salts are acidic and react with the alkalinity in the water
- Cationic polymers are not very PH sensitive and are often used as coagulant aids in softening plants rather than alum or iron salts
- Alum is a good coagulant when treating highly colored water at low PH values

Disinfection and Disinfection Byproducts

1. Haloacetic Acids (HAA5)

    - HAA5 Detection Level: 1.0000 ug/l or .001 PPM

2. Five Regulated HAA5's

    - Dibromoacetic Acid
    - Dichloroacetic Acid
    - Monobromoacetic Acid
    - Monochloroacetic Acid
    - Trichloroacetic Acid

3. Chloramination and Alternative Disinfectants for Reducing DBP's

    - Chlorine and Ammonia together produce Chloramines
    - Higher the Temperature, the more effective treatment
    - THM's – formed when mixing chlorine and organic matter
    - THM's increase at higher temperatures
    - THM's produce faster at higher PH
    - Halogenated By-product Compounds are formed by the reaction of a disinfectant, such a chlorine with organic material in a water supply.
    - Ozone, Chloramines, and chlorine dioxide do not contain free chlorine

3. Four Regulated Total Trihalomethanes (TTHM)

    - Chloroform
    - Bromoform
    - Bromodichloromethane
    - Dibromochloromethane

Basic Math and Chemistry for Water Plant Operators

1. Measurement Conventions Used in Describing Chemical Concentrations

- Parts per million (ppm) or Milligrams per liter (mg/l) –Parts per billion (ppb) or Micrograms per liter - explained as a relation to time and money as one part per billion corresponds to one minute in 2,000 years, or a single penny in $10,000,000.
- Parts per trillion (ppt) or Nanograms per liter (nanograms/l) - explained as a relation to time and money as one part per trillion corresponds to one minute in 2,000,000 years, or a single penny in $10,000,000,000.
- Parts per quadrillion (ppq) or Picograms per liter (picograms/l) - explained as a relation to time and money as one part per quadrillion corresponds to one minute in 2,000,000,000 years or one penny in $10,000,000,000,000.
- Picocuries per liter (pCi/L) - picocuries per liter is a measure of the radioactivity in water.

2. Measurement Conventions Used in Describing Radioative Substances

- Millirems per year (mrem/yr) - measure of radiation absorbed by the body.
- Million Fibers per Liter (MFL) - million fibers per liter is a measure of the presence of asbestos fibers that are longer than 10 micrometers.

3. Measurement Conventions Used in Describing Turbididty

- Nephelometric Turbidity Unit (NTU) - nephelometric turbidity unit is a measure of the clarity of water.
- Turbidity in excess of 5 NTU is just noticeable to the average person.

4. Conversion Factors

- One pound of water weighs 8.34 lbs
- One cubic foot of water contains 7.48 gallons
- 1 cu ft water weighs 62.38 lbs (8.34lbs x 7.48gals = 62.38 lbs)
- .433 x height = psi
- 2.31 / height = psi
- 1 ft of water = .433 psi

5. Common Chemicals Used in Water Treatment

Calcium	(Ca)	Lead	(Pb)
Carbon	(C)	Magnesium	(Mg)
Chlorine	(Cl)	Manganese	(Mn)
Copper	(Cu)	Nitrogen	(N)
Fluorine	(F)	Oxygen	(O)
Hydrogen	(H)	Sodium	(Na)
Iron	(Fe)	Sulfur	(S)

6. Names and Formulas of Common Chemicals Used in Water Analyses

Acetic Acid	CH3COOH
Aluminum Sulfate	Al2(SO4)3 .14.3H2Oa
Ammonium Hydroxide	NH4OH
Calcium Carbonate	CaCO3
Chloroform	CHCL3
Copper Sulfate	CuSO4
Ferric Chloride	FeCl3
Nitric Acid	HNO3
Phenylarsine Oxide	C6H5AsO
Potassium Iodide	Kl
Sodium Bicarbonate	NaHCO3
Sodium Hydroxide	NaOH
Sulfuric Acid	H2SO4

7. PH Facts

- PH – Hydrogen Ion concentration in water
- The PH scale goes from 0 –14
- 0 being acidic and 14 being the most base or alkaline
- Water with a PH below 7 is considered acidic
- Water with a PH of 7 is neutral
- Water with a PH above 7 is considered Base or alkaline
- PH stands for the hydrogen ion
- Water should be stable, neither corrosive or scale forming
- Low PH causes corrosion
- High PH causes Scale
- The lower the PH the faster the disinfection
- A higher PH requires a higher chlorine residual
- Higher the PH, the faster the rate of oxidation of iron to insoluble ferric hydroxide.
- Water with a PH of 7 is considered pure water
- Calcium and magnesium become less soluble as PH increases

- Natural waters usually have a PH of between 6.5 and 8.5
- Free chlorine is mostly hypochlorite at PH levels above 7.5 and is a less powerful disenfectant
- If PH is above 9, the water will cause scale to form
- Recarbonation will lower PH to between 8.8 and 8.4 and the langelier index will be positive and there will be little or no corrosion
- Hydrolysis is at a minimum at a PH of about 4.7
- PH – Hydrogen Ion concentration in water
- The PH scale goes from 0 –14
- 0 being acidic and 14 being the most base or alkaline
- Water with a PH below 7 is considered acidic
- Water with a PH of 7 is neutral
- Water with a PH above 7 is considered Base or alkaline
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- Natural waters usually have a PH of between 6.5 and 8.5
- Free chlorine is mostly hypochlorite at PH levels above 7.5 and is a less powerful disenfectant
- If PH is above 9, the water will cause scale to form
- Recarbonation will lower PH to between 8.8 and 8.4 and the langelier index will be positive and there will be little or no corrosion
- Respiration by algae results in an increase in carbon dioxide in water (lower of PH)
- Photosynthesis decreases carbon dioxide in water (increasing PH)
- Respiration by algae results in an increase in carbon dioxide in water (lower of PH)

8. Chemicals that Raise pH

- Lime (Calcium Oxide and hydrated lime or Calcium hydroxide)
- Soda Ash
- Hypochlorination
- Sodium bicarbonate
- Caustic soda
- Calcium Hypochlorite
- Sodium hypochlorite

9. Chemicals that lower pH

- Gas chlorine – lowers Ph and strips Alkalinity
- Sulfuric acid
- Carbon dioxide – causes corrosion (used to recarbonate water and lower PH)
- Alum
- Ferric Chloride
- Hydrofluosilicic Acid
- Ferrous Sulfate

10. Chemicals Commonly Used in Water Treatment and Their Application

- Sodium Thiosulfate crystals – Neutralizes chlorine present in sample bottles used for bacteriological sample collection.
- Hypochlorous Acid and Hypochlorite Ion – Reacts chemically and biologically to the total residual chlorine remaining in water known as free available chlorine residual.
- Copper sulfate – kills algae
- Copper sulfate pentahydrate (bluestone) –algicide Treat in autumn
- Caustic Soda – (sodium hydroxide) Increases PH (can be used as a alternate method to soda ash)
- Soda Ash – Increases PH (use with lime to remove non carbonate hardness)
- Soda Ash and Lime - Increases alkalinity
- Lime – Increases PH (used to remove carbonate hardness)
- Lime - Increases alkalinity
- Lime – Coagulant Aid
- Gas chlorine – lowers Ph and strips Alkalinity
- Aluminum Sulfate (Alum) – Primary coagulant
- Aluminum Sulfate (Alum) - Alum is the most commonly used coagulant
- Ferrous Sulfate – Primary coagulant
- Ferric Sulfate – Primary coagulant
- Ferric Chloride – Primary coagulant
- Sodium Aluminate – Coagulant Aid
- Bentonite – Bentonite clay - Coagulant Aid
- Clay – Coagulant Aid
- Sodium Silicate – Coagulant Aid
- Carbon dioxide – used for recarbonation of water to lower PH
- Hydrogen sulfide H2S – Smells like rotton eggs – Eats up chlorine
- Ammonia – used to detect chlorine leaks, and produces chloramines when mixed with CL2
- Polyphosphate – keeps Ferrous Iron in suspension by sequestering

- available Chlorine solution
- Baking Soda is a buffer
- Sodium Bicarbonate is baking soda
- Ferrous (Fe^{++}) iron is most soluble in water; Fe^{+++} is insoluble
- Sodium hexamethaphosphate – precipitation inhibitor represses both calcium carbonate and calcium sulfate also called polyphosphate
- Orthophosphate is used to coat pipe surfaces to prevent ions from forming
- copper sulfate pentahydrate (bluestone) –algaecide; Treat in autumn

11. Processes and Chemicals used in Pre-treatment

- Oxidizing agents for color
- Activated carbon for tastes and odors
- Aeration for iron or hydrogen sulfide gas

13. Chemicals used in Flouridation

- Sodium fluoride (NaF) – Dry form of fluoride
- Sodium silicofluoride (Na2SiF6) – Dry form of fluoride
- Hydrofluorosilicic (H2SiF6) – Liquid form of fluoride
- Sometimes called (liquid form)
- Fluosilicic
- Hydroflusilicic acid
- The three compounds most commonly used to fluoridate water are Hydroflusilicic acid, sodium fluoride and sodium fluorosilicate.
- 1st symptom of floride poisoning by inhalation is a sharp biting pain in the nose and nose bleeds.

16. Common Ions in Water Treatment

- Common Ions in water: Fluoride, chloride, nitrite, nitrate, bicarbonate
- Calcium hardness Ca^{++}
- Magnesium hardness Mg^{++}
- Sodium Na^{+} (cations – positive)
- Calcium Ca^{++} (cations – positive)
- Chloride Cl^{-} (anions – negative)
- Bicarbonate HCO_3^{-} (anions – negative)
- Sulfate $(SO_4)_2^{\ -}$ (anions – negative)
- Ferrous (Fe^{++}) iron is most soluble in water

15. Some Important Acronyms

- NSF – National Sanitation Foundation
- THM – Trihalomethanes

- NTU – Nethomelthric Turbity Unit
- SDI – Sludge density index
- HPC – Hetertrophic Plate Count

16. Temperature Conversions

- Convert Fahrenheit to Celsius – Multiply 9 X temperature, divide by 5, them Add 32 degrees.
- Convert Celsius to Fahrenheit – Subtract 32 from Temperature, multiply that total by 5 and divide by 9.

Water Treatment Fundamentals

1. A list of Facts That All Operators Need to Know from tests in no Particular Order)

    - Normal per capita water use is 100 – 150 GPD, normal residential 2.5 times
    - Total Hardness is the total of the carbonate and non-carbonate hardness
    - Carbonate hardness (made up of bicarbonate + carbonate + hydroxide) is equal to the alkalinity
    - Non carbonate hardness is the portion of the total hardness in excess of the total alkalinity (sulfides and chlorides)
    - Alkalinity is the capacity of water to neutralize acids
    - The Minimum Free Chlorine Residual 0.2 mg/l; for Chloramine it is 0.6 mg/l
    - DEP requires a minimum of 20 psi throughout the distribution system
    - Calcium hypochlorite is a dry powder
    - Hard water is caused by Calcium and Magnesium (over 100 as $CaCO_3$ is hard)
    - Hardness = 17.1 mg/l = 1 hardness grain per gallon; 5 grains = hardness of 86
    - Soft water is between 5 grains of hardness; below 5 it is corrosive
    - Water with zero hardness is very corrosive
    - Water pressure is maintained with the elevated tank
    - Ammonia can be used to detect chlorine leaks. It produces a smoky cloud when chlorine is present; use rag not spray bottle to prevent corrosion.
    - Organic compounds- Are defined as those compounds that contain Carbon atom such as Proteins and carbohydrates.
    - Agglomeration – The process of bringing positive and negative charged particles together to form a floc that has a neutral charge, and is large enough to settle.
    - Polyphosphate keeps Iron in suspension in water (Sequestering).
    - Dissolved carbon dioxide causes corrosion in water.
    - Volatile organic chemicals cause cancer
    - Hypochlorous Acid has a PH of 5 (acidic)
    - Hydrogen sulfide gas causes corrosion of structures and equipment
    - Hydrogen sulfide gas has a rotten eggs odor; can be detected at ~0.5 ppm
    - A higher PH requires a higher chlorine residual
    - Chlorine reacts with nitrogenous compounds to form Chloramines.
    - Higher the PH, the faster the rate of oxidation of iron to insoluble ferric hydroxide.
    - The lower the PH the faster the disinfection rate
    - Chlorine (Cl_2) is an oxidizer
    - Hydrogen Sulfide is a reducing agent
    - Demand = Dose minus Residual
    - Residual = Dose minus Demand
    - Water can be de-chlorinated by use of reducing agents such as sulfur dioxide, sodium bisulfate (least expensive) and Sodium sulfite.

- Flocculation – Slow stirring process – gathers small coagulated particles into larger settleable ones
- Lime softening – Selective carbonate hardness removal above 9.6 PH
- Lime softening – Manganese hardness removal above 10.4 PH
- Lime reacts with bicarbonate alkalinity below pH 8.3
- Corrosive chemicals are usually pumped with a plunger type pump
- The primary health risk associated with volatile organic chemicals (VOC) is reduced IQ in children and cancer
- The discharge rate of a piston type pump is constant at a constant speed.
- Positive sample for fecal coliform or E-coli notice to public is within 72 hours.
- Flow of electrical current is measured in amperes
- A primary health risk associated with microorganisms in drinking water is acute gastrointestinal disease.
- Dissolved Carbon dioxide causes corrosion.
- Ferrous (fe+2) iron is most soluble in water
- An atmosphere is considered oxygen deficient when the oxygen level is below 19.5%
- Breakpoint chlorination is achieved when chlorine dosage is increased and a corresponding Free Residual is detected, Combined Chlorine is Chloramine.
- Natural waters usually have a PH of between 6.5 and 8.5
- Most Hardness is caused by calcium carbonate and calcium sulfate
- The difference between tier one and tier two violations is Tier one violations potentially impose direct and adverse health effects: Tier two violations do not pose a direct threat to public health
- For public water systems using surface water and groundwater under the influence of surface water, turbidity must be recorded at least every four hours
- Final determination of vulnerability is made by the primacy agency
- 1 amp = 440 watts, 4 amps = 1760 watts
- Maximum contaminant levels relate to health effects, while Secondary maximum contaminate levels relate to aesthetic concerns
- 4 log removal means 99.99 percent removal/inactivation
- Chemicals that cause alkalinity in water are calcium carbonate and calcium oxide
- Clarification of water by sedimentation and filtration removes suspended solids
- A violation of the MCL for total trihalomethanes occurs when the running average of quarterly samples during the previous 12 months exceeds the MCL
- The butterfly valve is most suitable for throttling, gate valves are not
- Backwash, add brine, rinse, and return to service is the correct order for regeneration of a zeolite softening unit
- Two pumps of the same flow capacity and pressure rating that are piped in series would result in double the head.
- Point of entry (POE) devices can be used to achieve compliance with volatile organic chemical (VOC) maximum contaminant level (MCL)
- The basic unit of electrical power is the WATT

- Velocity of flow in mains is usually expressed in terms of feet per second fps
- Flow (Q) = Velocity (V) x Pipe Area (A)
- Cathodic protection means protection against Corrosion
- At the same barometric pressure, the amount of dissolved oxygen in cold water tends to be MORE THAN the amount of dissolved oxygen in warm water
- Oxidation and filtration can be used to remove high iron content
- Hardness may be expressed in milligrams per liter (mg/l) as $CaCO_3$
- The basic unit of electrical power is watts, flow is current (amps), pressure is (volts)
- The water table is defined as the upper surface of the groundwater and top of artesian sping
- 1 milligram per liter equals 1 parts per million; 10,000 ppm = 1% by weight
- Lead in drinking water can result in impaired mental functioning in children
- Copper poisoning will be abdominal pains
- An average percentage range for unaccounted-for water in a fully metered system is 11 to 15%
- The primary source of trihalomethanes (THM's) in drinking water is the reaction of chlorine compounds and organic matter
- High nitrate concentrations in water can affect infants, methemoglobinemia
- The metal strip in an electrical fuse will melt from the heat caused by high amperage demands
- A trench must be shored if it is 5 feet deep or deeper
- A PH of treated water below 6.5 indicates corrosive water
- One major factor that leads to reservoir turnover is the upper strata becoming more dense and sinking to the bottom
- Daily consumption of gaseous chlorine may be checked by a platform scale
- The permissible exposure limit (PEL) for chlorine is 0.5 parts per million
- Addition of lime, caustic soda or soda ash will increase PH
- Polyphosphate will keep iron in water in suspension
- Primacy means the primary authority for implementation and enforcement of drinking water regulations
- Granular filtration is designed to reduce turbidity
- Health risks associated with nitrates and nitrites is "blue baby" syndrome
- An operator uses DPD to test chlorine residuals
- Three most commonly used coagulants in water treatment are aluminum sulfate, ferric chloride, and ferrous sulfate
- A high heterotrophic plate count (HPC) in water samples can mask detection of coliforms
- Potassium permanganate is used for Taste control
- Greensand is often used as a filter medium for water with high manganese concentrations
- One of the most common causes of mud balls in the filter media is insufficient backwash rate
- Copper sulfate is the most effective compound for controlling algae growth *

- Activated carbons absorptive properties is widely used for taste and odor control
- In a filter using gravel, anthracite and sand, the anthracite should be the top layer of media
- The depth of sludge applied to the sludge drying bed each time should be 8 – 12 inches
- Microstraining is a treatment process designed to remove algae and aquatic organisms
- The precipitate formed in alum coagulation is aluminum hydroxide
- Sulfuric acid is used for titration of water for alkalinity
- Tube settlers are used to improve turbidity removal
- The proper range of fluoride in potable water is 0.8 – 1.2 mg/l
- High amperage demands will melt the metal strip in electrical fuses
- A trench must be shored if it is 5 ft deep or deeper
- An amperometric titrator is used to measure chlorine residual
- The PH of water may be reduced by adding carbon dioxide
- PVC is Piping polyvinyl chloride
- SCHMUTZDECKE – A biological slime or Mat formed on the surface of the (Slow sand filter) bed, which traps small particles and degrades organic materials present in the raw water.
- NTU nephelometric turbidity unit
- Nanograms = Parts per trillion parts
- Water Hammer – The rise and fall of pressure caused by rapid change of a valve position
- Cavitation – Usually caused when pump inlet pressure drops below the design inlet pressure

2. More Study Questions for Water Treatment Plant Operators:

- Ferric hydroxide is the most soluble form of iron in water
- For public water systems using surface water and groundwater under the influence of surface water (UDI) must meet surface water requirements
- Final determination of vulnerability is made by the primacy agency
- Vulnerability is the most important factor to consider in locating a well site from the health point of view
- The primary purpose of pressure reducing valves between water systems pressure zones is to reduce downstream pressure.
- A well is acidized in order to increase yield
- The drawdown in a well is measured from the static water level to the pumping water level
- If volatile organic chemicals (VOC's) are detected, sampling must then be conducted quarterly
- Maximum contaminant levels relate to health effects, while Secondary maximum contaminate levels relate to aesthetic concerns
- 4 log removal means 99.99 percent removal/inactivation

- A violation of the MCL for total trihalomethanes occurs when the running average of quarterly samples during the previous 12 months exceeds the MCL
- Backwash, add brine, rinse, and return to service is the correct order for regeneration of a zeolite softening unit
- Two pumps of the same flow capacity and pressure rating that are piped in series would result in double the head pumping ability.
- All lubrications must be NSF approved
- Disinfection is not sterilization; disinfection is inactivation of organisms
- Consumer confidence reports due July 1st
- There are 1440 minutes in a day (24 hours)