Drinking Water Operator Certification Training

Module 14
Conventional Filtration

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Topical Outline

Unit 1 – Conventional Water Treatment Overview

I. Purpose of Conventional Water Treatment

A. Compliance with Regulations

B. Production of Safe Drinking Water

II. Terms and Definitions

A. Clarification

B. Coagulation

C. Colloids

D. Conventional Filtration

E. Disinfection

F. Floc

G. Flocculation

H. Sedimentation

I. Sludge

J. Turbidity

III. Conventional Water Filtration Process Flow

A. Source Water

B. Chemical Addition

C. Pretreatment

D. Filtration

E. Disinfection

F. Corrosion Control

G. Water Distribution

Unit 4 – Filtration

I. General Overview of Conventional Filtration
   A. Process Description
   B. Filtration Mechanisms

II. Types of Filters
   A. Gravity
   B. Pressure

III. Filter Control Systems
   A. Purposes
   B. Common Control Systems

IV. Performance Considerations
   A. Filter Media
   B. Filter Underdrains
   C. Operational Criteria
   D. Backwashing

V. Process Calculations
   A. Filtration Rate
   B. Backwash Rate

VI. Record Keeping

Unit 1 – Conventional Water Treatment Overview

Learning Objectives

- Understand the purpose for Conventional Water Treatment and relevant regulations
- Use vocabulary appropriate to conventional filtration of water in discussing the process.
- Follow the Typical Process Flow Diagram and identify the four major conventional filtration processes.

The purpose for Conventional Water Treatment is two-fold.

Compliance with Regulations

The primary purpose for Conventional Water Treatment is to comply with the Environmental Protection Agency (EPA) and Pennsylvania Department of Environmental Protection (Pa. DEP) regulations requiring filtration as a mandatory "treatment technique" for all surface water supplies. This "treatment technique" must be operated so as to produce filter effluent that has a turbidity less than 0.3 ntu in 95% of all monthly samples taken at four hour intervals.

Turbidity

Turbidity is a physical characteristic of water and is an expression of the optical property that causes light to be scattered and absorbed by particles and molecules rather than transmitted in straight lines through a water sample. It is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, plankton and other microscopic organisms. Typical sources of turbidity in raw water sources include:

- Waste discharges
- Runoff from watersheds
- Algae or aquatic weeds and products of their breakdown
- Humic acids and other organic compounds resulting from decay of plants, leaves
- High iron concentrations which give waters a rust-red coloration
- Heavy rains flushing into a water reservoir (can greatly increase raw water turbidity)

Excessive turbidity in drinking water is aesthetically unappealing and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote re-growth of pathogens in the distribution system, leading to waterborne disease outbreaks, which have caused significant cases of gastroenteritis. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa. As discussed in further detail, systems rely heavily on the coagulation and sedimentation process to remove turbidity from water.

Relevant Regulations

- Surface Water Treatment Rule – Major components include:
    - Requires disinfection of all surface supplies.
    - Establishes treatment techniques to achieve at least 99.9% removal or inactivation (referred to as “3-log removal”) of *Giardia lamblia* cysts and 99.99% (referred to as “4-log” removal) of viruses.
    - Systems must be operated by “qualified personnel.”
    - Establishes criteria for operating without filtration.
    - Establishes “CT” as the basis for disinfection.
    - Establishes suitable filtration technologies and performance criteria for removal of turbidity and *Giardia*.
    - Establishes sampling requirements and MCL’s for combined filter effluent turbidity to monitor performance of the filtration system.

- Interim Enhanced Surface Water Treatment Rule - This rule builds upon the Surface Water Treatment Rule to improve control of microbial pathogens and address risk trade-offs with disinfection byproducts. Major components include:
  - Systems that are required to filter under the Surface Water Treatment Rule must achieve at least 99% (2-log) removal of the protozoan *Cryptosporidium.* Systems are considered to be in compliance with this requirement if filter effluent turbidity requirements are met.
  - Strengthened filter effluent turbidity requirements.
    - Combined filter effluent turbidity must be below 0.3 NTU in at least 95% of the turbidity measurements taken, and measurements must be taken at least every four hours.
    - Combined filter effluent turbidity must be below 1.0 NTU at all times.
    - Effluent turbidity of all individual filters must be monitored continuously.

- Long Term I Enhanced Surface Water Treatment Rule - This rule was put in place to improve control of microbial pathogens, specifically the protozoan *Cryptosporidium,* and to address risk trade-offs with disinfection by-products. However, this rule applies to public water systems that serve fewer than 10,000 people. Major components include:
  - All systems covered by this rule must achieve at least 99% (2-log) removal or inactivation of *Cryptosporidium.*
  - Strengthened filter effluent turbidity monitoring requirements, as described in the Interim Enhanced Surface Water Treatment Rule.

- Stage I Disinfectants and Disinfection Byproduct Rule - This rule sets maximum contaminant levels (MCL's) for total trihalomethanes (TTHM's) and the total of five haloacetic acids (HAA5). It also sets maximum disinfectant residual concentrations for chlorine, chloramines, and chlorine dioxide. Major components include:
  - Applies to all public water systems that add a disinfectant during **any** part of the water treatment process.
  - Sets MCL for TTHM's at 0.08 mg/L (80 parts per billion or ppb) and MCL for HAA5 at 0.06 mg/L (60 ppb).
  - Sets MCL for chlorite (a by-product of chlorine dioxide) at 1.0 mg/L and MCL for bromate (a by-product of ozone) at 0.01 mg/L (10 ppb).
  - Sets maximum residual disinfectant levels (MRDL's) of 4.0 mg/L (as Cl_2) for chlorine, 4.0 mg/L (as Cl_2) for chloramines, and 0.8 mg/L for chlorine dioxide (as ClO_2).
  - Requires removal of total organic carbon (TOC) present in the raw water by enhanced coagulation (for systems using conventional treatment). Chemical disinfectants react with organic carbon in the raw water to form by-products.

- Long Term 2 Enhanced Surface Water Treatment Rule (LT2): This rule became effective in PA in December 2009. It builds upon the earlier surface water treatment rules to address higher risk public water systems for protection measures beyond those required for existing regulations. Higher risk systems include filtered water systems with high levels of *Cryptosporidium* in their sources and all unfiltered water systems. Some of the major provisions include:
  - All systems covered by this rule will monitor their sources with two years of monthly sampling for *Cryptosporidium* (or *E. coli* for small systems).
  - Systems are classified into treatment bins based on their monitoring results. Many systems will be classified in the lowest treatment bin which carries no additional treatment

requirements. Systems classified in higher treatment bins must provide 90 to 99.7 percent (1.0 to 2.5-log) additional treatment for *Cryptosporidium.*
- o Systems will select from a wide range of treatment and management strategies in the "microbial toolbox" to meet their additional treatment requirements.

Production of Safe Drinking Water

Conventional Filtration also assists with production of safe drinking water. It is critical to consistently and reliably produce safe and pleasant drinking water. To achieve this on a regular basis, water treatment facilities will normally operate facilities focused on treatment goals that are below the regulatory Primary Maximum Contaminant Levels for those contaminants that present health risks based on acute or chronic exposure. These include certain metals and organic compounds, as well as radionuclides and microbiological contaminants. To provide aesthetically pleasing water that is free of tastes, odors and staining or scaling properties, operators typically also establish treatment goals that are below the Secondary Maximum Contaminant Levels.

National Secondary Regulations

- National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply.
    - States with primacy, at their option, may adopt regulations that are more stringent than EPA regulations. Pa. DEP **does** require monitoring for secondary contaminants.
- A listing of contaminants regulated by the secondary standards and their MCL's can be found on table 1.1.

Table 1.1
Secondary Contaminants

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

- Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 MG/L, and for lead is 0.015 MG/L.

Clarification – The removal of floc and heavier suspended matter, typically by gravity settling.

Coagulation – The use of coagulant chemical to promote aggregation of small and colloidal particles into larger "floc" particles. The coagulant chemical neutralizes the electrical charge on the surface of the small particles, resulting in destabilization of the colloidal suspension.

Colloids – Very small, finely divided solids that remain dispersed in a liquid for a long period of time due to their very small size and common electrical charges. Due to the common electrical charges, the particles tend to repel each other, preventing the particles from merging and forming heavier particles. The colloidal particles with common charge actually repel each other similarly to magnets when similar poles are placed near each other. This phenomenon actually causes the particles to remain in suspension, unless destabilized by the coagulant.

Conventional Filtration – A method of treating water which consists of the addition of coagulant chemicals, flash mixing, coagulation and flocculation, sedimentation, filtration and disinfection.

Disinfection – The process designed and operated to inactivate or remove pathogenic microorganisms in the water, including bacteria, virus, and protozoan cysts. The conventional process will disinfect water by removing these microorganisms through the clarification and filtration process and inactivating them with chemical disinfectants such as chlorine or rendering them non-infective with ultraviolet light. The water treatment process must include this multi-barrier approach to disinfection.

Floc – Aggregations of particulate impurities that have formed in a cluster. The formation of appropriate size and density of floc particle is critical to the performance of the subsequent clarification process. Density and size is normally a function of the particles in the water but is also impacted by the chemical coagulant, mixing energy and detention time in the floc basin.

Flocculation – The process of forming floc particles from coagulated colloidal matter typically accomplished in a separate process basin with a residence time of 20 to 30 minutes and including gentle mixing to promote inter-particle contact.

Sedimentation –The process of clarifying water by gravity settling of the floc particles.

Sludge – The settleable solids separated from the water during processing.

Turbidity –The clarity of water is measured by passing a light beam through the water and measuring how much of the light is reflected by the particles in the water. The instrument used to measure clarity is called a turbidimeter and the cloudy appearance of water is referred to as turbidity. Nephelometric turbidity units (ntu) are typically used to quantify the performance of the clarification and filtration process. Raw source water may have a level of turbidity anywhere from 1 to more than 1000 ntu. The goal for clarification is typically less than 1 ntu. Filtration must result in turbidity less than 0.3 ntu, and is normally less than 0.10 in an optimized filter plant.

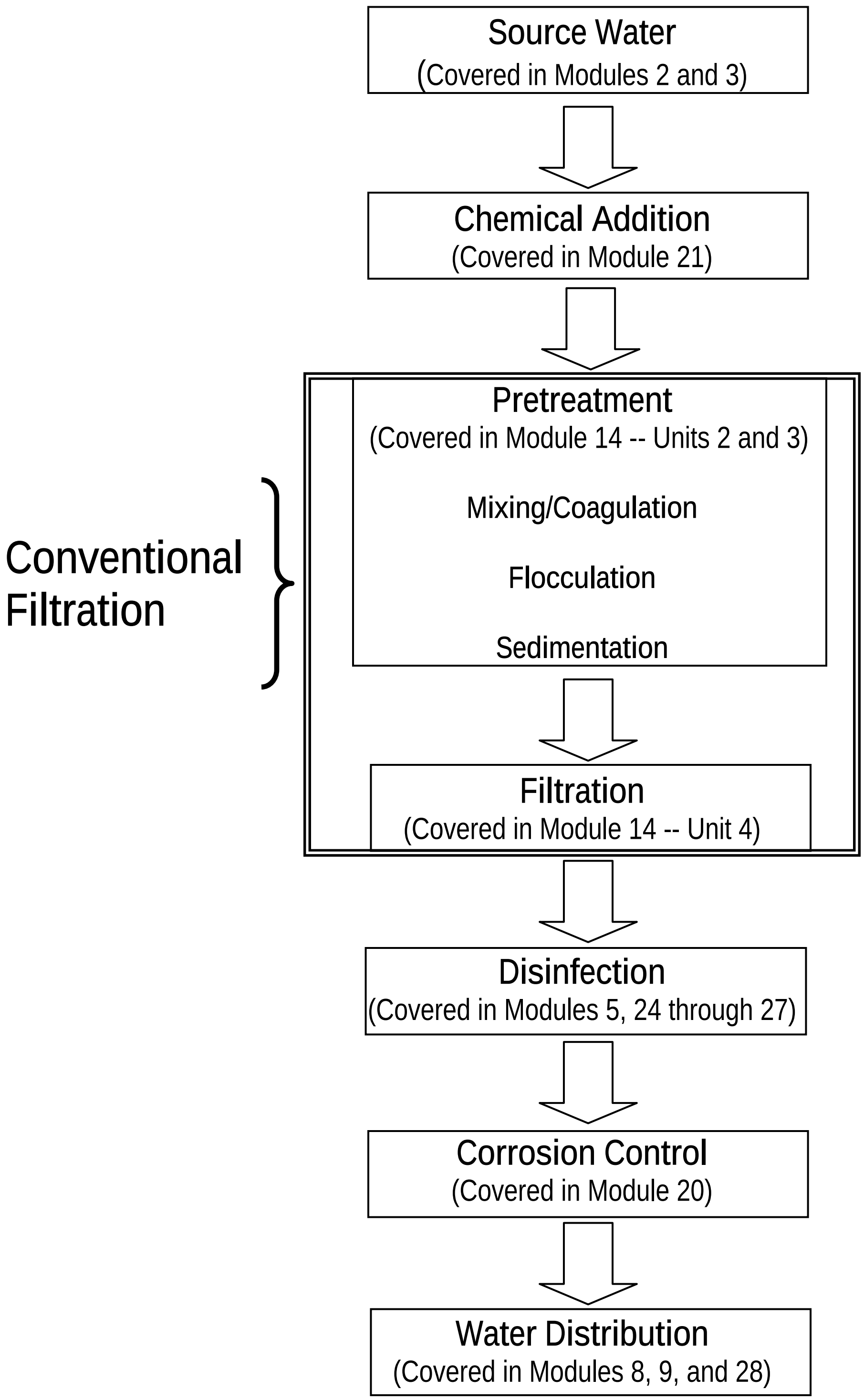


Figure 1.1 – Process Flow

Source Water

The treatment process begins with the raw, untreated water that flows into a Conventional Water Filtration facility. Surface water supplies can be divided into river, lake and reservoir supplies. The potential for contamination of surface water makes it necessary to regard such sources of supply as unsafe for domestic use unless properly treated including filtration and disinfection. Additionally, lakes and reservoirs are subject to seasonal changes in water quality such as:

- Stratification where separate layers of water are formed.
- The rapid growth of algal blooms.

It may be possible to eliminate or control water quality programs in domestic water supply lakes and reservoirs through a water quality management program. For example, copper sulfate pentahydrate ($CuSO_4 \cdot 5 H_2O$) can be used for controlling algal growths in domestic water supply lakes and reservoirs. Therefore, the system can:

- Prevent taste and odor problems resulting from algal blooms.
- Reduce the overall biological productivity and therefore reduce the rate of oxygen depletion in the raw water supply.
- Maintain acceptable aesthetic conditions in the lake or reservoir.

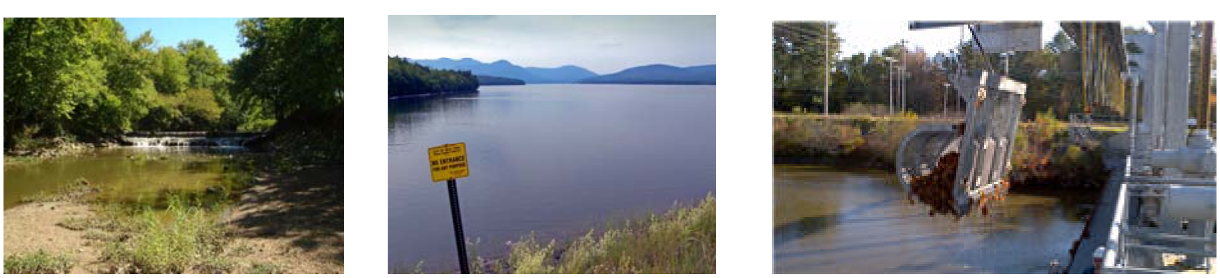
Intake Structures

The type and location of an intake structure will depend on the water source.

In a lake or reservoir where the water quality varies depending on level, a multi-leveled intake structure is best. In a river or stream, a single-level intake structure may be sufficient.

Some plants have screens that remove large debris like rocks, sticks, leaves and other debris as the water enters the intake structure.

Other pretreatment steps may include presedimentation, chemical addition, aeration and flow measurement.



Figures 1.1 Raw Water Sources and Collection

Flow Measurement

Flow measurement is an important part of the pretreatment process. By measuring the rate at which water flows into the water treatment plant, the operator is able to adjust chemical feed rates, calculate detention times and monitor the amount of water being treated.

Common flow meter technologies used to measure potable water flow in large pipes include Venturi and magnetic flow measurement systems.

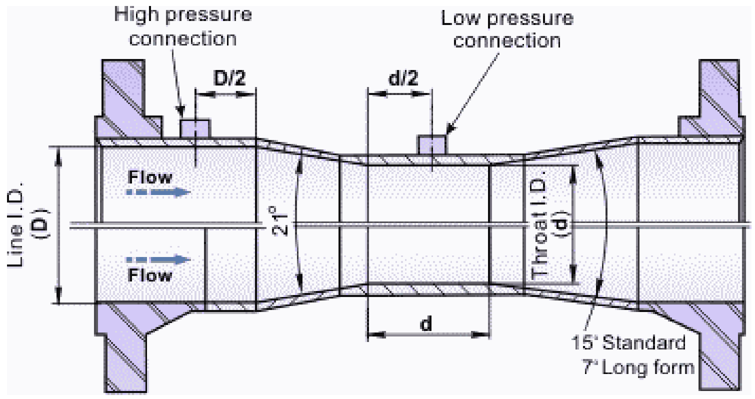


Figure 1.2 Venturi Meter[1]

As illustrated in figure 1.2, the Venturi meter consists of a tube whose diameter gradually decreases to a throat and then gradually expands to the diameter of the intake pipe. The flow is determined on the basis of the differences in pressure between the entrance and throat of the Venturi meter.

Raw Water Pumps

Pumps are the usual source of energy necessary to move surface water to the treatment facility (unless the system is gravity fed). Therefore, from the beginning, operators must be familiar with:

- Pumps
- Pump characteristics
- Pump operation
- Pump maintenance

Always read the manufactures installation, repair and maintenance information. Additionally, follow all lock-out/tag-out procedures before maintenance.

Unit 1 Exercise

Instructor Note: Give students 10 or so minutes to complete the following questions, then review.

Multiple Choice

1. Combined filter effluent turbidity must be below
   - A. 0.3 NTU in at least 95% of the turbidity measurements taken and 1.0 NTU at all times
   - B. 1.0 NTU in at least 95% of the turbidity measurements taken and 1.5 NTU at all times
   - C. 0.3 NTU in at least 95% of the turbidity measurements taken and 0.5 NTU at all times
   - D. 0.5 NTU in at least 95% of the turbidity measurements taken and 1.0 NTU at all times

2. Typical sources of turbidity in raw water sources include:
   - A. Humic acids and other organic compounds resulting from decay of plants, leaves
   - B. High iron concentrations which give waters a rust-red coloration
   - C. Heavy rains flushing into a water reservoir
   - D. All of the above

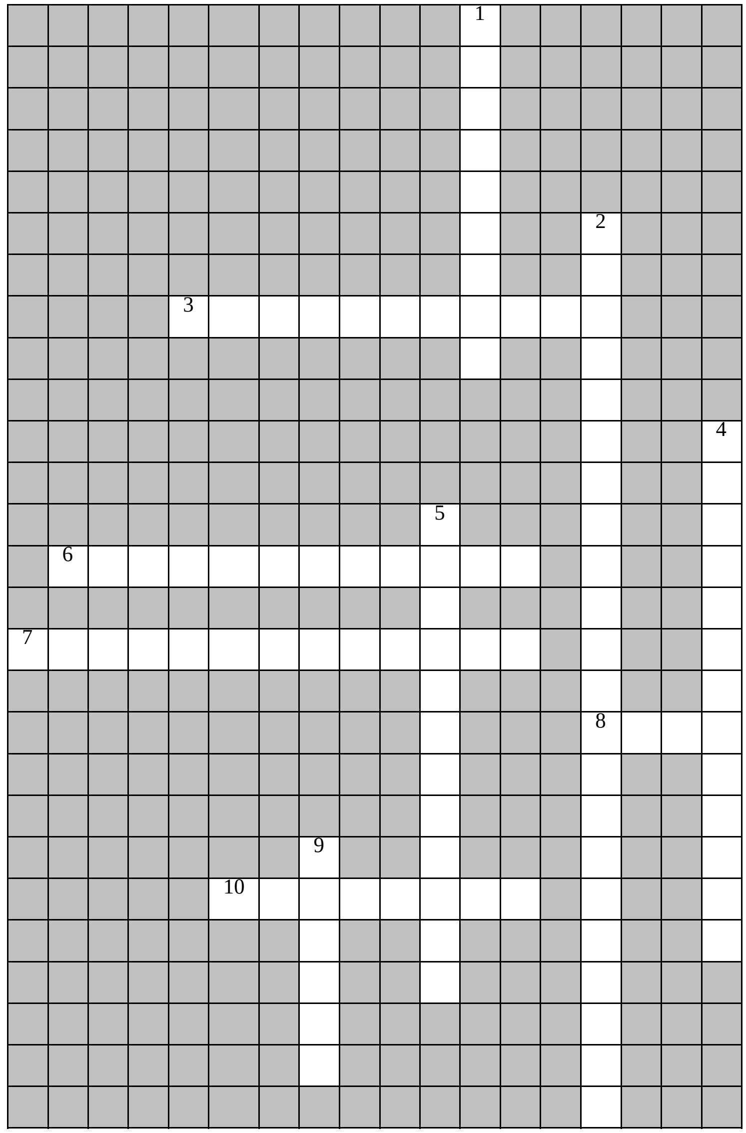
3. National Secondary Drinking Water Regulations:
   - A. Are focused on treatment goals that are below the regulatory Primary Maximum Contaminant Levels for those contaminants that present health risks based on acute or chronic exposure
   - B. Are guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water
   - C. Both A and B
   - D. None of the above

4. Venturi and magnetic flow measurement systems are used to:
   - A. Regulate the rate at which water flows into the water treatment plant
   - B. Measure the rate at which water flows into the water treatment plant
   - C. Monitor the chemical which flow into the water treatment plant
   - D. All of the above

Vocabulary Review

Across

3. The use of a coagulant chemical to promote aggregation of small and colloidal particles into larger "floc" particles. The coagulant chemical neutralizes the electrical charge on the surface of the small particles, resulting in destabilization of the colloidal suspension.
6. The process of forming floc particles from coagulated colloidal matter typically accomplished in a separate process basin with a residence time of 20 to 30 minutes and including gentle mixing to promote inter-particle contact.
7. The process of clarifying water by gravity settling of the floc particles.
8. Aggregations of particulate impurities that have formed in a cluster. Density and size is normally a function of the particles in the water, but is also impacted by the chemical coagulant, mixing energy and detention time in the floc basin.
10. Very small, finely divided solids that remain dispersed in a liquid for a long period of time due to their very small size and common electrical charges.



Down

1. The clarity of water is measured by passing a light beam through the water and measuring how much of the light is reflected by the particles in the water.
2. A method of treating water which consists of the addition of coagulant chemicals, flash mixing, coagulation and flocculation, sedimentation, filtration and disinfection.
4. The removal of floc and heavier suspended matter, typically by gravity settling.
5. The process designed and operated to inactivate or remove pathogenic microorganisms in the water.
9. The settleable solids separated from the water during process.

Unit 1 Key Points

- Conventional Filtration consists of coagulation, flocculation, sedimentation and filtration.
- Colloidal particles in water do not settle readily.
- The gentle agitation of coagulant treated water for an appreciable period of time is known as flocculation.
- Inlets or gates should be located in a raw water reservoir intake so that water can be taken from multiple depths.
- Bar screens (or racks) are used to remove large objects which may damage plant equipment.
- The *Interim Enhanced Surface Water Treatment Rule* strengthened filter effluent turbidity requirements.
- Stage I Disinfectants and Disinfection Byproduct Rule sets maximum residual disinfectant levels (MRDL's) of 4.0 mg/L (as Cl_2) for chlorine, 4.0 mg/L (as Cl_2) for chloramines, and 0.8 mg/L for chlorine dioxide (as ClO_2).
- Copper sulfate pentahydrate ($CuSO_4 \cdot 5 H_2O$) can be used for controlling algal growths in domestic water supply lakes and reservoirs.
- Common flow meter technologies used to measure potable water flow in large pipes include Venturi and magnetic flow measurement systems.

- [1] "Venturi Meter" http:// http://www.thermopedia.com (29 Oct. 2013).

Unit 2 – Mixing, Coagulation, and Flocculation

Learning Objectives

- List the major chemicals used in the coagulation process and explain their importance to the process.
- Explain the importance of flocculation to conventional filtration.
- List two types of mechanical flocculators in common use.

All waters, especially surface waters, contain both dissolved and suspended particles. Coagulation and flocculation processes are used to separate the suspended solids portion from the water. After souce water has been screened and passes through the optional steps of pre-chlorination and aeration, it is ready for coagulation and flocculation. This two step process may appear as three separate functions:

1. Mixing

2. Coagulation

3. Flocculation

Mixing

Mixing – The introduction and uniform dispersal of chemicals into the water in as short a time period (rapid) as possible.

- Besides distributing a coagulant evenly through the water, rapid mixing is to encourage collisions between suspended particles.

- Figure 2.1 is a schematic of the mixing/coagulation/flocculation process. Note:

    - The coagulant should be added just in front of the mixer (mechanical or static).

        - Floc that is too large may be caused by chemical addition at the wrong point.

    - The flash mixer is located before the coagulation basin.

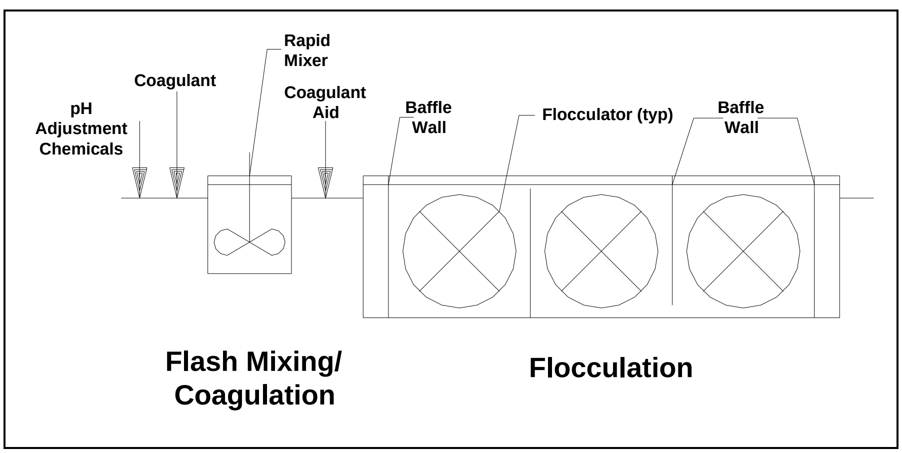


Figure 2.1 - Mixing, Coagulation & Flocculation Schematic

- This process is commonly referred to as flash mixing. Flash mixing occurs in a very short time and the results are the formation of very small particles.

Mixing Methods

There are two methods for mixing: Hydraulic and Mechanical.

Figure 2.2 - Static Mixer [1]

Hydraulic Mixing: installed in-line in a process stream. The associated pipe or conduit can be round, square or rectangular in shape.

- Uses the hydraulic energy of the flowing water.
- Is often called Static Mixing.

Mechanical Mixing: widely used for rapid mixing because of their good control features. They are usually placed in a small chamber or tank and include the propeller, impeller, or turbine types. Mechanical mixers can also be mounted directly into a pipeline; they are then referred to as in-line-mixers.

- Mechanical equipment is used to stir the water.
- This equipment has a propeller that usually has a vertical orientation.

Figure 2.3 - Mechanical Mixer [2]

Figure 2.4 - Mechanical Mixer

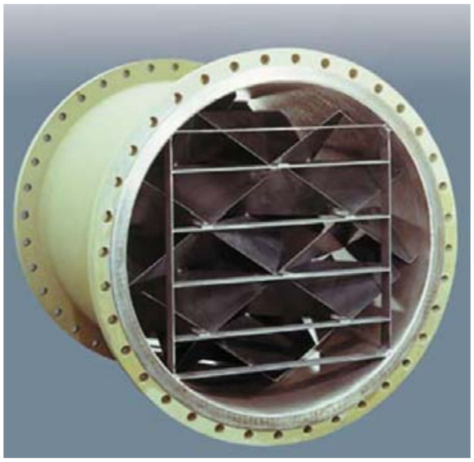


Figure 2.5 – Static Mixer

Coagulation

Coagulant Chemicals

Coagulation and flocculation occur in successive steps intended to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc. If step one is incomplete, the following step will be unsuccessful. Therefore, a coagulant chemical is mixed into the water. All chemicals used in the water treatment process must be approved by both the Environmental Protection Agency (EPA) and the Department of Environmental Protection (DEP) for potable water use.

Primary Coagulants: Purpose is to aid in the removal of nonsettleable solids from water. Used to cause particles to become destabilized and begin to clump together.

Suspended particles in water *normally* have a negative (-) charge. Since these particles all have the same charge, they repel each other, keeping each other from settling. Coagulation neutralizes the forces; once the repulsive forces have been neutralized these particles can stick together (agglomerate) when they collide. The force which holds the floc together is called the Van der Waals force.

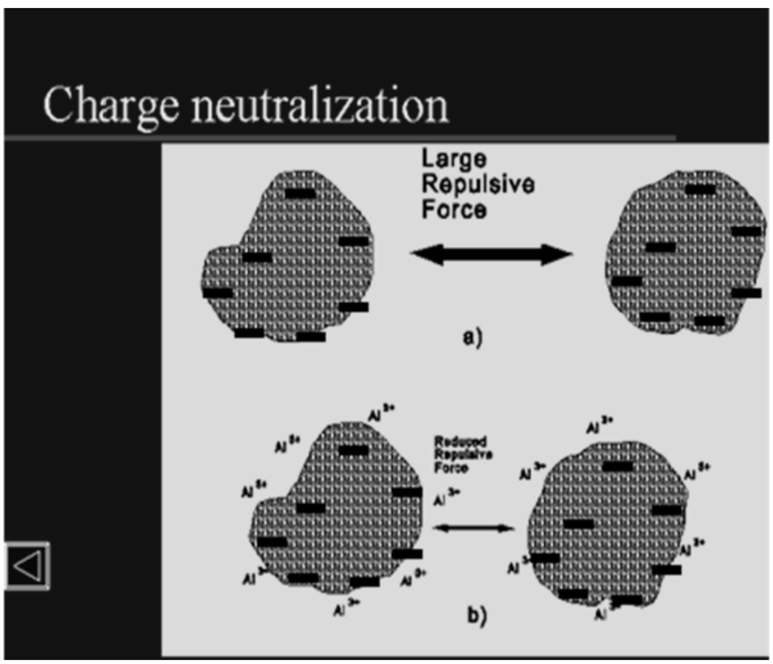


Figure 2.6 – Charge Neutralization

There are a variety of primary coagulants which can be used in a water treatment plant.

Types of Primary Coagulants

- Metallic salts
  - Aluminum Sulfate (Alum) – $Al_2(SO_4)_3 \bullet 14\ H_2O$
    - One of the earliest and still one of the most extensively used coagulants.
    - Can be bought in liquid form with a concentration of 8.3% or in a dry form with a concentration of 17%.
    - When alum is added to water, it reacts with the water and results in positively charged ions.
    - Tight/optimal effective pH range of 5.5 – 7.5. And a pH over 9.0 could result in increased dissolved aluminum.
  - Ferric Sulfate - $Fe_2(SO_4)_3 \bullet 9\ H_2O$
  - Ferric Chloride - $FeCl_3 \bullet 6\ H_2O$
    - Ferric chloride ($FeCl_3$) is the most common iron salt used to achieve coagulation.
    - Broader effective pH range of 5.0 – 8.5.
    - The greatest safety hazard involved with the use of ferric chloride is corrosiveness.
- Synthetic inorganic polymers
  - Polyaluminum Chloride - $Al_n(OH)_mCl_{(3n\text{-}m)} \bullet H_2O$
    - The polyaluminium coagulants in general consume considerably less alkalinity than alum.
    - Works satisfactorily over a pH range of 5.0 to 8.0.
    - PAC is noted for needing a lower dose, no required neutralizing agents like lime, shorter flocculation time, producing smaller amounts of sludge, ease in backwash, and increased treated water quality.

Coagulant Aids - Chemicals used to add density to slow-settling floc and to strengthen floc formation.

Coagulant aids are added to the water during the coagulation process to:

1. Improve coagulation
2. Build a stronger, more settleable floc
3. Overcome slow floc formation in cold water
4. Reduce the amount of coagulant required


Figure 2.7 - Bentonite Clay

Types of Coagulant Aids

- Activated Silica
  - Better settling, decrease sludge
  - Strengthen floc at low temperatures
  - Color removal
- Weighting Agents – Bentonite Clay
  - Used to treat water with high color
  - Used to treat water with low turbidity issues
  - Used to treat water with low mineral content
- Synthetic organic polymers
  - Commonly referred to as polyelectrolytes
  - Cationic – positively charged
  - Adsorb on negatively charged particles (turbidity) to neutralize the charge. Forming an interparticle bridge trapping particles which helps increase floc strength in the coagulation basin.

Basic Coagulant Chemistry

The choice of coagulant chemicals is a financial decision which depends upon the nature of the suspended solids to be removed, the facility design, and the raw water conditions including:

1. pH
2. Alkalinity
3. Water Temperature
4. Turbidity

- pH
  - Extremes can interfere with the coagulation/flocculation process.
  - The optimum pH depends on the specific coagulant.
- Alkalinity
  - Low alkalinity causes poor coagulation.
  - May be necessary to add lime, soda ash or caustic soda to add/replace alkalinity and pH during the coagulation process.
  - A waters alkalinity must be considered when using Alum since every 1 mg/L of alum added will consume 0.5 mg/L alkalinity (as $CaCO_3$) for coagulation. Therefore supplemental addition of alkalinity to the raw water is often required to achieve the optimum coagulation pH.
  - A waters alkalinity must be considered when using Ferric since every 1 mg/L of Ferric added will consume 0.92 mg/L alkalinity (as $CaCO_3$) for coagulation. Therefore supplemental addition of alkalinity to the raw water is often required to achieve the optimum coagulation pH.
- Temperature
  - Low water temperatures slow chemical reactions, causing decreased efficiency and slow floc formation.
  - Polymers, Bentonite Clay and coagulant aids can be added to assist floc formation in cold water.
  - Higher coagulant doses may be required to maintain acceptable results.
- Turbidity
  - Difficult to form floc with low turbidity water, may need to add weighting agents.
  - Dissolved organic matter is preferentially coagulated and exerts a higher demand than turbidity.

Process Control

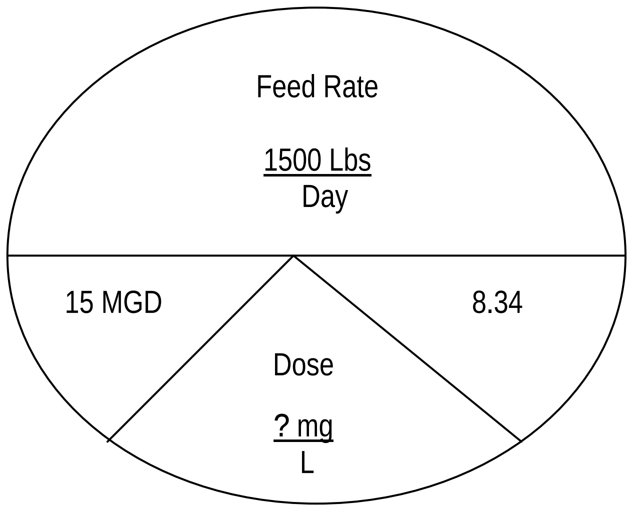
Plant operators must be able to measure and control plant performance on a day-to-day basis depending on variability of source water. The most important consideration is the selection of the proper type and dosage of coagulant chemical(s).

Jar Test

- Tests should be performed at least daily.
- Tests should be performed whenever the raw water quality changes.
- Tests should be performed whenever changes are made to the type of coagulant chemicals.

Example 2.1 – Dosage Calculation

Calculate the dosage (mg/L), if 1500 pounds of dry Alum are required to treat 15 - MGD of water.



Completed by using the Davidson Pie Chart or rearranging the "pounds formula".

$$\frac{\text{Lbs}}{\text{Day}} = \text{Flow} \times \text{Dose} \times 8.34$$

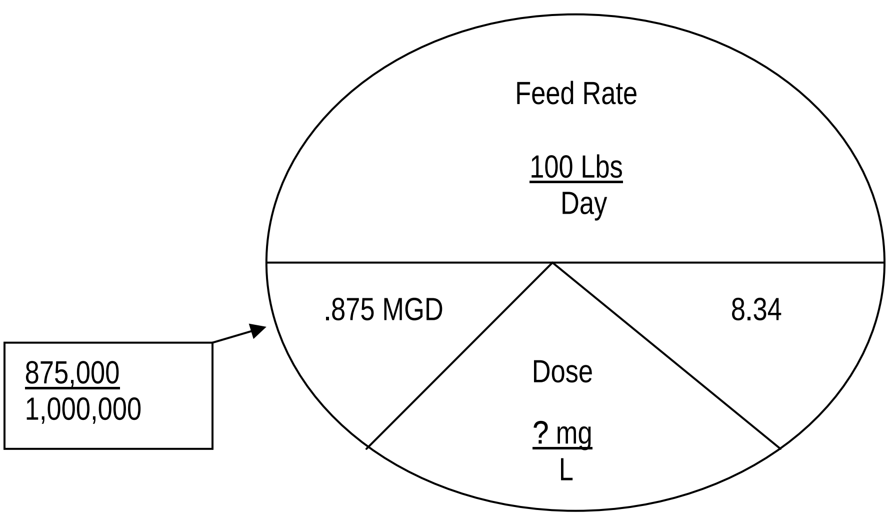
$$\text{Dose} = \frac{(\text{lbs/day})}{\text{Flow} \times 8.34}$$

$$\frac{\text{mg}}{\text{L}} = \frac{1500 \text{ lb/day}}{(15 \times 8.34)}$$

12 mg/l

Example 2.2 – Dosage Calculation

A system treated 875,000 gallons of water using 100 pounds of lime. Calculate the lime dosage in mg/L.



Completed by using the Davidson Pie Chart or rearranging the "pounds formula"

$$\frac{\text{Lbs}}{\text{Day}} = \text{Flow} \times \text{Dose} \times 8.34$$

Had to convert flow from gallons to million gallons

$$\text{Dose} = \frac{(\text{lbs/day})}{\text{Flow} \times 8.34}$$

$$\frac{\text{mg}}{\text{L}} = \frac{100 \text{ lb/day}}{(0.875 \times 8.34)}$$

13.7 mg/l

Chemical Safety

Knowledge with regard to the chemicals used and wearing appropriate personal protection equipment is critical. For example, caustic soda is widely used in water treatment. Upon reading the Safety Data Sheet (SDS), it is apparent that caustic soda is highly corrosive and reactive. The SDS convinces the reader to prevent any contact with caustic soda and leaves no doubt that if caustic soda comes in contact with skin, burns will result. Additionally, after reading the SDS for alum or ferric, it is apparent that appropriate forms of personal protection equipment include gloves, goggles and a respirator.

- Safety Data Sheets provide information on:
  - Chemical handling
  - Personal safety
  - First Aid
  - Chemical disposal
  - Spill and clean-up
  - Specific gravity
  - CAS#, Chemical name(s)
  - Chemical properties

Figure 2.8 Secondary Containment

- Refer to the manufactures SDS on chemical storage. Shelf-life should be noted. This is especially important when mixing a batch of chemical; the strength will degrade over a period of time.
- Refer to the SDS to determine the density of a liquid chemical for accurate determination of chemical dosages.
- Secondary containment is required for storage of hazardous materials. Secondary containment requirements are addressed by the Environmental Protection Agency (EPA) through the Resource Conservation and Recovery Act (RCRA) contained in title 40 of the Code of Federal Regulations (CFR) part 264, the 2006 Uniform Fire Code (UFC) in standard 60.3.2.8.3 and in the 2006 International Fire Code (IFC) in 2704.2. A concrete barrier around chemical storage or a portable container as demonstrated in figure 2.8 are examples of secondary containment.

Emergency Response Planning

A variety of chemicals used in water treatment have the potential for causing environmental degradation or endangerment of public health and safety through accidental release. Protective actions to mitigate against, prepare for, respond to and recover from the impact of the unwarranted release of toxic, hazardous, or other pollutants to the environment shall be developed and implemented in an Emergency Response Plan (ERP). A spill response procedure in an ERP can ensure employees are prepared and know what actions must be taken and what materials will be needed during a chemical spill.

Flocculation

Following rapid mixing/coagulation the flocculation process occurs; this is done through a continuous agitation of the coagulated water with less intensity but a longer duration.

This gentle mixing stage is where the microflocs formed during coagulation are brought into contact with each other. Collisions of the microfloc particles cause them to bond and produce larger, visible flocs called pinflocs.

The floc size continues to build through additional collisions and interaction with inorganic polymers formed by the coagulant or with the addition of coagulant aids. Macroflocs are then formed and once the floc has reached its optimum size and strength, the water is ready for the sedimentation process (Unit 3).

The goal of flocculation is to promote growth of flocs to a size that can be removed by sedimentation and filtration.

Floc Formation

Figure 2.9 Flocculation

Floc formation is controlled by three factors:

- The effectiveness of coagulation,
- The effectiveness of collisions in promoting attachment between particles. Stable colloidal suspensions will not floc well, and
- The rate at which collisions occur.

Detention Time

Flocculation is a time-dependent process that directly affects clarification efficiency. Therefore, detention time is important in the flocculation process. Efficient flocculation involves selecting the right stirring time.

- The detention time for floc formation is recommended to be 30 minutes.
  - It is required for the necessary chemical reactions to occur.
- The size and shape of the flocculation facility also influence the detention time needed for optimum floc development.

Calculating Theoretical Detention Time

- Theoretical Detention Time Formula:

  Detention Time (time) = Volume of Tank (gallons) / Influent Flow *

*Influent flow can be measured in MGD, gpm, gph, gpd

Actual Detention Time

- Actual time based on tracer studies. This is when a chemical is injected into the basin influent and time is measured until 10% of the chemical is noted in the effluent.

- Usually different than theoretical detention time due to:
  - Short-circuiting
  - Inlet and outlet conditions
  - Hydraulic currents

☑ Example 2.3 – Flocculation Detention Time Calculation

The flow to a flocculation basin that has a volume of 36,670 gallons is 1930 gpm. What is the detention time in the tank, in minutes?

Detention Time (time) = Volume of Tank (gallons) / Influent Flow *

= 36,670 gallons / 1930 gpm

= 19 minutes

☑ Example 2.4 – Flocculation Detention Time Calculation

A flocculation basin receives a flow of 2,830,000 gpd. System prints indicate the basin holds 60,915 gallons. Assuming the flow is steady and continuous, what is the flocculation basin detention time in minutes?

1. Need the units to match (flow given in gpd, question wants answer in minutes).

   So convert 2,830,000 gpd to gpm = 2,830,000 gpd ÷1440 = 1965 gpm

2. Determine the detention time:

   Detention Time (time) = Volume of Tank (gallons) / Influent Flow *

   = 60,915 gallons / 1965 gpm

   = 31 minutes

Stirring

To increase the size of floc particles, collision of floc particles is necessary. This is achieved through:

- Proper stirring time (detention time).
- Proper stirring intensity.
- Properly shaped basin for uniform mixing.
- Having a means of creating the stirring action.

Stirring is achieved through slow mixing and is a key aspect of the flocculation process. In slow mixing, the water is stirred to encourage floc particles to clump together. "Ten States Standards" guidelines specify a speed no greater than 3.0 fps should be followed to minimize floc shear while maintaining particle suspension. The goal is to produce well-formed/good size floc during the flocculation process that will quickly settle during the sedimentation process (Unit 3). Sounds simple, however, this crucial stage can be problematic:

- Insufficient stirring or stirring too slowly can prevent particles from clumping enough and will result in ineffective collisions and poor floc formation.
- Excessive stirring or stirring too fast, may tear apart flocculated particles after they have clumped together. Once flocs have been torn apart, it is difficult to reform to their optimum strength and size.
- Slow stirring can cause floc particles to settle out prematurely.

Types of Flocculators

A wide variety of flocculation stirring mechanisms have been used in water treatment. They include vertical shaft mechanical mixers, horizontal shaft mechanical mixers, and hydraulic mixing systems. There are two types of mechanical flocculators in common use: The Horizontal Paddle Wheel Flocculator and the Vertical Flocculator. Both types provide satisfactory performance. There is also the Walking Beam Flocculator.

Horizontal Paddle Wheel Flocculator

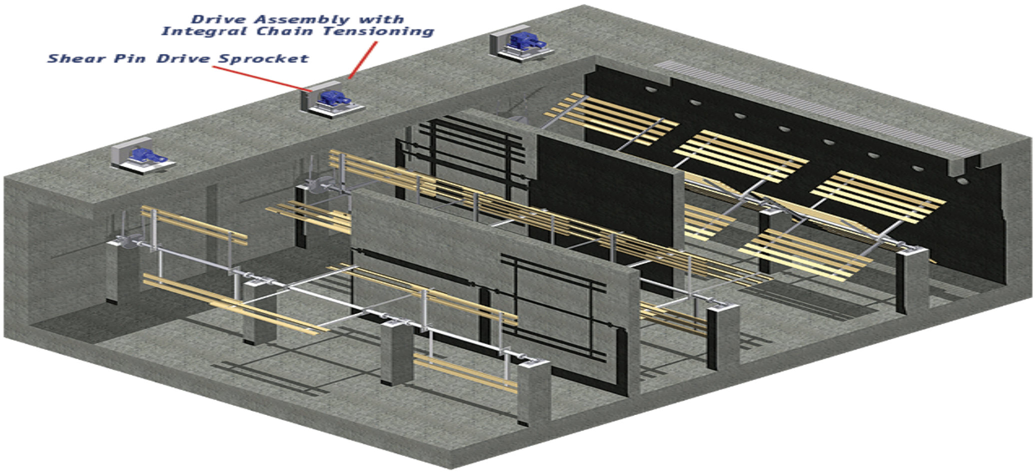


Figure 2.10 - Horizontal Paddle Wheel [3]

Vertical Flocculators – Two Types

- Propeller or Turbine
- Paddle

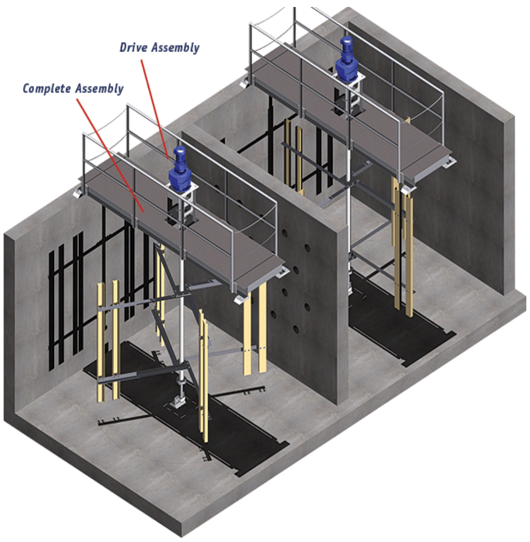


Figure 2.11 - Vertical Paddle Wheel [4]

Walking Beam Flocculator

- Not as common, but still in use today.
- Uses paddles moving in an up & down motion, like walking; rather than the circular motion common to both horizontal and vertical paddle type units.

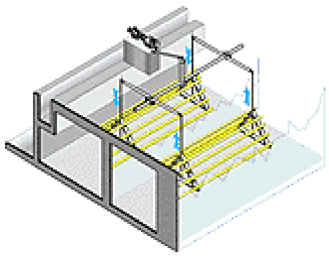


Figure 2.12 - Walking Beam[5]

Flocculation Basins

Size and Shape

The size and shape of a flocculation basin is usually established by the design engineer.

- Generally rectangular for horizontal type flocculators and square for vertical type flocculators.
- The depth is generally the same or deeper than the sedimentation basins.

Compartments

The best flocculation is usually achieved by using several smaller compartments (usually three or more) rather than one equivalent sized basin.

- Compartments are separated by baffles to prevent short-circuiting.
- The mixing intensity is generally reduced as flow passes through the compartments. This is called tapered-energy mixing. It helps prevent breaking larger floc particles after they have formed.

Multiple Stage Flocculation

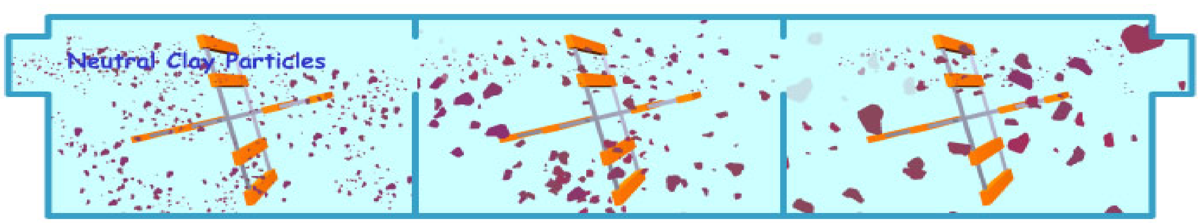


Figure 2.13 Flocculation

The flocculation basin can have a number of compartments with decreasing mixing speeds as the water advances through the basin. Compartmentalized chambers allow increasingly larger floc to form without being broken apart by the mixing blades.

- As depicted in Figure 2.13, in multiple stage flocculation, the floc particles are increasing in size. The paddle speeds could be adjusted; each step the particles get bigger and the paddles move slower (but not so slow that the floc particles settle out prematurely).

Performance Considerations

For a conventional treatment process, chemical coagulation/flocculation is critical for effective removal of microbial pathogens. A system cannot really rely on disinfection:

- Additional disinfectant would be required to oxidize material that is not removed. This can result in the formation of disinfection by-products following chlorine disinfection.

- Bacteria and other pathogens can be bound up in suspended particles and shielded from the disinfectant.

The removal of pathogens through filtration depends on the overall plant performance and successful coagulation/flocculation. Therefore, if a system can remove as much turbidity (which can provide food and shelter for pathogens) as possible, before moving on to filtration, the coagulation/flocculation process will help remove many bacteria which are suspended in the water.

Short Circuiting

An important factor that determines the functioning of a flocculator is short circuiting.

Short-circuiting occurs when water bypasses the normal flow path through the basin and reaches the outlet in less than the normal detention time. For example, the flocculation basin could have a predetermined 30 minutes of agitation however a large portion may get only 10 minutes while a sizable amount may get 60 minutes thus producing very inferior settled water.

Flocculation could be incomplete and currents could be introduced into the settling process. A compartmentalized basin can be used to prevent short circuiting of the water being treated. Additionally, the turbulence in the basins can be reduced (as discussed, paddle speeds could be adjusted; each step the particles get bigger and the paddles move slower). Therefore, the water is ready for the settling process.

Unit 2 Exercise

1. List the primary coagulants (3 metallic salts and 1 synthetic inorganic polymer) used in the coagulation process.

2. In the space provided, explain the importance of coagulant aids—synthetic organic polymers.

3. List three types of chemicals that can be used to add or replace alkalinity or pH.

True/False: Mark those that are true with a T, those that are false with an F.

4. _____ The effectiveness of sedimentation, filtration and overall plant performance depends on successful coagulation/flocculation.

5. _____ Poor coagulation/flocculation does not affect performance.

6. _____ Appropriate personal protective equipment needed when handling alum includes goggles, gloves and a respirator.

7. _____ When dissolved in water, alum generally produces negatively charged ions.

8. _____ Using iron salts instead of alum for coagulation is less effective over a broader pH range.

9. _____ Adding chemicals at the wrong location may cause floc to be too large.

10. _____ Coagulants added in the influent line before a flash mix basin will produce better results.

11. _____ Mixing is the rapid uniform distribution of a chemical in the water being treated.

12. _____ If caustic soda comes in contact with skin, burns will result.

13. _____ If an operator observes floc splitting and breaking up in the flocculation chamber, the rate of the flocculators should be slowed down.

14. _____ The main purpose of coagulation/sedimentation is to remove turbidity.

15. _____ A systems Emergency Response Plan contains information on how to clean up a chemical spill.

16. _____ Compartmentalized flocculation chambers allow increasingly large floc to form without being broken apart by the mixing blades.

17. ______ In multiple stage flocculation, floc particles should increase in size.

18. _______ A pH under 9.0 could result in increased dissolved aluminum.

19. ______ Polyphosphate is used to add density to floc particles.

20. ______ Collision of floc particles decreases the overall size of the floc.

21. _______ To overcome slow floc formation in cold water, coagulant aids can be added.

22. ______ Coagulant should be added just after a static mixer.

23. A system treats 845,000 gallons of water using 25 pounds of calcium hydroxide (slaked lime) every day. What is the dose?

a. 1.42 mg/L
b. 3.55 mg/L
c. 7.11 mg/L
d. 9.23 mg/L

24. A system uses 225 lbs of dry polymer as coagulant aid each day to treat a plant flow set at 3,260,000 gpd. What is the dose?

a. 576.33 mg/L
b. 103.27 mg/L
c. 8.28 mg/L
d. 4.21 mg/L

25. If the plant flow is set at 350,000 gallons and the system uses 12 pounds of anhydrous ferric chloride, what is the dose?

a. 4.11 mg/L
b. 411 mg/L
c. 2.86 mg/L
d. 286 mg/L

26. The flow to a flocculation basin is 399,000 gpd. The basin holds 11,550 gallons. What is the detention time in the tank, in minutes?

a. 42 minutes
b. 35 minutes
c. 37 minutes
d. 39 minutes

Unit 2 Key Points

- An indication the coagulation/floccualtion is working well is, in the flocculation/sedimentation proces, well-formed, good-sized floc is entering the flocculation baisns, and a very small amount of very small-sized floc is going to the filters.
- The main purpose of coagulation/sedimentation is to remove turbidity.
- The rapid uniform distribution of a coagulant or other chemicals in the water being treated is called mixing.
- The purpose of rapid mixing is to distribute coagulant evenly throughout the water and to encourage collisions between suspended particles when the water makes it to the coagulation basin.
- For best results in a plant equipped with a flash mix basin, coagulant should be added to the influent line just ahead of the flash mix basin.
- The purpose of adding a coagulant aid is to increase floc strength and density.
- Alum is added to raw water as a coagulant. The effect this will probably have on the pH of the water is to decrease it. Lime could be added to the flash mixer to replace alkalinity lost during the coagulation process.
- When dissolved in water, aluminum sulfate generally produces ions that are positively charged. If alum is used for coagulation at a pH above 9.0, increased dissolved aluminum will result in the filtered water.
- A major advantage of using iron salts instead of alum for coagulation is that iron salts are more effective over a broader pH range than alum. A problem with ferric chloride is its corrosivity.
- During the coagulation/flocculation process, floc that is too large may be caused by chemical addition at the wrong point.
- If an operator observed floc splitting and breaking up in the flocculation chamber, the flocculator rate should be slowed down.
- In a flocculation/sedimentation process, well-formed, good-sized flocculation is entering the flocculation basins, and a very small amount of very small-sized flocculation is going to the filters. This indicates that the coagulation/flocculation process is working well.
- During the coagulation/flocculation process, if the rapid mix is too slow, complete floc will not form.
- Change of composition and break down of the chemical is a concern in diluting a chemical prior to feeding.

- If heavy rains have occurred, causing source water turbidity to increase significantly, and additional alum is added, a chemical to increase alkalinity may also be added to optimize coagulation.

- The purpose of a Material Safety Data Sheet is to provide information on chemical handling, chemical properties and personal safety. For example, refer to the MSDS to determine the density of a liquid chemical for accurate determination of chemical dosages.

- Concrete barriers around chemical storage or a portable container set under a chemical drum are examples of secondary containment.

- Add lime, soda ash or caustic soda to increase or replace alkalinity or pH.

- Three forms of personal protection equipment when handling alum or ferric chloride include gloves, goggles and a respirator

[1] "Static Mixer." http://www.koch-glitsch.com (17 Jun. 2003).

[2] "Mechanical Mixer." http://www.lightnin-mixers.com (17 Jun. 2003).

[3] "Horizontal Paddle Wheel." http://www.myersequipment.com/products.html (18 October 2013).

[4] "Vertical Paddle Wheel." http://www.myersequipment.com/products.html (18 October 2013).

[5] "Walking Beam." http://www.myersequipment.com/products.html (26 May 2003).

Unit 3 – Sedimentation/Clarification

Learning Objectives

- List seven operating parameters important to sedimentation.
- Identify the four zones of a sedimentation basin.
- Given the formula and required data, calculate each of the following: detention time, surface loading rate, mean flow velocity, and weir loading rate.
- Explain why tube or plate settlers increase settling efficiency.
- Identify five characteristics upon which the sedimentation process is dependent.

Settling Characteristics

After coagulation and flocculation comes sedimentation. Sedimentation is dependent upon seven basic factors, or settling characteristics, which are presented in this section.

1. Particle Size

- Typical size of particles in surface waters:

Type of Particle	Diameter (microns [a])
Coarse Turbidity (sand, silt, etc.)	1 – 1000
Algae	3 – 1000
Silt	10
Bacteria	0.3 – 10
Fine Turbidity	0.1 – 1
Viruses	0.02 – 0.26
Colloids	0.001 – 1

Note: [a] 1 micron = 0.00004 inches.

2. Gravitational Settling

- Sand or silt larger than 10 micron diameter generally have a density greater than that of water and will readily settle.
- Finer particles do not readily settle. They require pretreatment to produce larger, denser, settleable floc. They will increase in size and density as floc continues to clump together.

3. Particle Shape

- Smooth, round particles settle quicker than irregular shaped particles with ragged edges.

4. Relationship of Downward Movement of Particle to Forward Flow Velocity

- Water must remain in the basin long enough for a particle at the surface to fall through the basin depth until captured in the sludge zone.
  - The time it takes for a particle at the surface to fall to the bottom must be shorter than the time it takes for it to be carried from the inlet to the outlet.
  - Sedimentation is improved by uniform low velocity flow across the basin.

5. Water Temperature

- Water reaches maximum density at 4^0 C.
  - Water expands as temperature increases (above 4º C) and contracts as temperature decreases to 4^0 C.
  - Once the water has reached its maximum density (4^0 C) and the temperature continues to drop, the opposite is true. That is, as the temperature continues to decrease, the water begins and continues to expand.

- Generally water temperature and settling rate are parallel. As water temperature increases settling rate increases. As water temperature decreases so does settling rate.
  - Water density increases as temperature decreases.
  - The density differential between water and floc is less, thus settling is slower.
  - Overcoming problems of cold water floc can be accompanied by adding weighing agents (refer to 2-6).

6. Electrical Charge on Particles

- Most colloidal particles have a slight negative electrical charge. The particles tend to repel each other, like magnets with like poles. However, proper coagulation neutralizes the charge.
  - The greatest removal of the colloidal material in raw water should occur during sedimentation.

7. Environmental Conditions

- Currents within sedimentation basins can affect settling. Currents can be:
  - Caused by wind – surface currents.
  - Caused by temperature – density currents.
  - Caused by water flow through basin – currents and eddies.

Short Circuiting

Short circuiting may occur in a sedimentation basin; the water is not evenly distributed across the width of the basin and floc does not have enough time to settle. The water in the sedimentation basin must be evenly distributed across the width of the basin to prevent short-circuiting to ensure that water does not reach the outlet in less than the normal detention time.

Detection

Basic methods of detecting short circuiting in a sedimentation basin can be done by looking for areas of water that do not appear to be circulating or by an uneven buildup of sludge on the bottom of the basin.

Sedimentation Basin Characteristics

Basin Zones

Sedimentation basins are divided into 4 zones, each with a specific purpose.

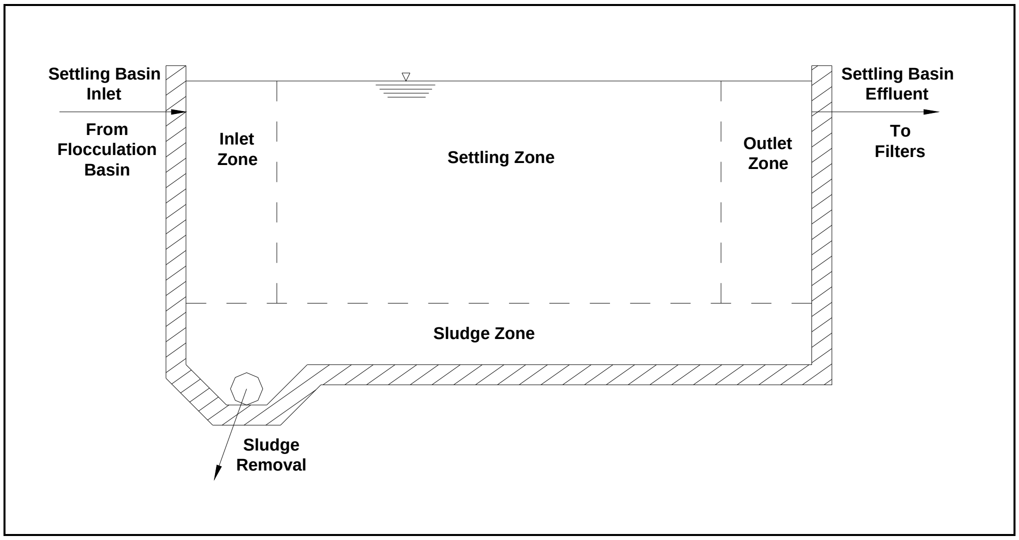


Figure 3.1 - Sedimentation Basin Zones

- Inlet Zone
  - The area where water from flocculators enters the sedimentation basins.
  - Baffle walls and overflow/underflow devices help to minimize flow, density, and wind currents.
- Settling Zone
  - Largest portion of the basin.
  - It provides a calm, undisturbed zone for a sufficient time period to permit effective settling of the flocculated particles.
- Sludge Zone
  - Located at the bottom of the basin.
  - Serves as a temporary storage place for settled particles.
  - Sludge is removed and transferred for further handling.
- Outlet Zone
  - Provides a smooth transition to settled water channel or pipe.
  - Usually located by channels or troughs called Launders.
  - Collection pipes with orifices are also used to collect settled water. The orifices control velocity.

Basin Types

- Rectangular Basin
    - Common in large plants.
    - High tolerance to changes in water quality.
    - Predictable performance.
    - Low maintenance.
    - Minimal short-circuiting.
    - Sludge collection usually with in-line scrappers.
        - Flat or slightly sloping bottom to sludge collection hopper.
        - Collection hopper usually at influent end of basin.
        - Sludge collection devices should move very slowly.

- Circular or Square Basins
    - Commonly called Clarifiers.
    - The usual flow path is center inlet with flow to the edges.
        - More likely to have short-circuiting problems.
    - Sludge collection is usually done with a rotating scraper.
        - Sloping bottom to central sludge collection hopper.
        - Scraper can cause currents resulting in solids settling problems.
        - Sludge can build up in corners of square units. This is a problem because it can turn septic.

            Note: If a sludge collector is not moving but the motor is running, check to see if the shear pin is broken.

Operating Parameters

Detention Time

Detention Time is the time required for a given molecule of water to move through the basin at a given rate of flow. The average detention time in a sedimentation basin should be 1 to 4 hours.

Theoretical Detention Time (from unit 2)

- Theoretical Detention Time Formula:

$$\text{Detention Time (time)} = \frac{\text{Volume of Tank (gallons)}}{\text{Influent Flow *}}$$

*Influent flow can be measured in MGD, gpm, gph, gpd

Example 3.1 – Sedimentation Detention Time Calculation

A water treatment plant treats a flow of 1.5 mgd. It has 2 sedimentation basins, each 20 feet wide by 60 feet long, with an effective water depth of 12 feet. Calculate the Theoretical Sedimentation Detention Time (in hours) with both basins in service.

1. Determine the volume of both basins:

Volume = Length x Width x Depth
60 feet x 20 feet x 12 feet
14,400 ft^3 for the first basin
x 2
28,800 ft^3 for both basins
x 7.48 gallons conversion factor
215,424 gallons

3. Determine the detention time:

$$\text{Detention Time (time)} = \frac{\text{Volume of Tank (gallons)}}{\text{Influent Flow *}}$$

$$= \frac{215{,}424 \text{ gallons}}{1{,}500{,}000 \text{ gpd}}$$

(note: 1.5 mgd = 1,500,000 gpd)

$$= 0.144 \text{ day}$$

4. Convert day to hours:

$$\text{hours} = 0.144\ \text{day} \times \frac{24\ \text{hour}}{\text{day}} = 3.45\ \text{hours}$$

Surface Overflow Rate

Surface Overflow Rate is one of most important factors influencing sedimentation. It is often called Overflow Loading Rate and translates into a velocity which equals the settling velocity of the smallest particle which will be removed. It is simple to remember that loading rates are in gallons per square foot of surface area per unit of time, gpd/sq.ft.

- Generally, particles settle downward (in a direction opposite water flow) while water rises in a sedimentation basin.
  - Particles with settling velocities greater than the Overflow Rate will be removed.
  - Particles with settling velocities less than the Overflow Rate will be carried through and out of the basin.

    Note: Particles carried through and out of the basin can be due to "floc carryover" which can be caused by too much coagulant, too little coagulant, or an improper pH.

- Surface Loading Rate Equation:

  $$\text{Surface Loading Rate (flow/ft}^2) - \frac{\text{Flow Rate}}{\text{Surface Area, ft}^2}$$ (note: flow may be given in gpm, gpd, gph)

- When flow increases through the basin, the surface overflow rate will decrease and the detention time increases.

Example 3.2 – Surface Overflow Rate Calculation

A water treatment plant treats a flow of 1.5 mgd. It has 2 sedimentation basins, each 20 feet wide by 60 feet long, with an effective water depth of 12 feet. Calculate the Surface Overflow Rate in gallons per minute per square foot of surface area (gpm/ft^2) for the treatment plant with both basins in service.

1. Convert the mgd to gpm:

$$\text{gpm} = \frac{1.5\text{ mgd} \times 1{,}000{,}000}{1440} = 1042\text{ gpm}$$

2. Determine the area of both basins:

Area = Length x Width
60 feet x 20 feet
1200 ft^2
x 2
2400 ft^2

3. Plug into Surface Loading Rate Equation:

$$\text{Surface Loading Rate (flow/ft}^2) - \frac{\text{Flow Rate}}{\text{Surface Area, ft}^2} = \frac{1042\text{ gpm}}{2400\text{ ft}^2}$$
$$= 0.43\text{ gpm/ft}^2$$

Mean Flow Velocity

Mean Flow Velocity is a function of the sedimentation basin cross-sectional area and the flow going through the basin.

- A high mean flow velocity will reduce sedimentation efficiency. A high flow velocity can cause "scour" where the flowing water will pick up some of the settled sludge from the bottom of the basin, cause re-suspension of the settled sludge and carry it on to the filters. Therefore, the calculated mean flow velocity should be very low which will prevent re-suspension of settled sludge. The rate should not exceed 1.0 foot per minute.

- Mean Flow Velocity Formula

$$\text{Mean Flow Velocity, ft/min} = \frac{\text{flow, gpm}}{\text{Area, sq ft} \times 7.48\ \text{gal/ft}^3}$$

Example 3.2 – Mean Flow Velocity Calculation

A water treatment plant treats a flow of 1.5 mgd. It has 2 sedimentation basins, each 20 feet wide by 60 feet long, with an effective water depth of 12 feet. Calculate the Mean Flow Velocity in feet per minute for one of the sedimentation basins, assuming both basins are in service and there is equal flow distribution to each basin.

1. Convert the mgd to gpm:

$$\text{gpm} = \frac{1.5\ \text{mgd} \times 1{,}000{,}000}{1440} = 1042\ \text{gpm}$$

That is the flow for both basins. We need to determine the flow for one basin:

$$\frac{1042\ \text{gpm}}{2} = 521\ \text{gpm}$$

2. Determine the cross sectional area of one basin:

Cross Sectional Area = Width x Depth

$$20\ \text{feet} \times 12\ \text{feet} = 240\ \text{ft}^2$$

3. Plug into Mean Flow Velocity Formula:

$$\text{Mean Flow Velocity} = \frac{\text{flow}}{\text{Cross Sectional Area, ft}^2 \times 7.48\ \text{gal/ft}^3} = \frac{521\ \text{gpm}}{240\ \text{ft}^2 \times 7.48\ \text{gal/ft}^3}$$

$$= 0.29\ \text{ft/min}$$

Tube or Plate Settlers

Tube or Plate Settlers are high rate sedimentation equipment developed to increase settling efficiency.

Physical Characteristics

- Small tubes, approximately 2” in diameter, or
- Stacked (incline or tilted) plates placed approximately 2” apart.
- Each tube or plate is inclined at either 55 to 60 degrees or 7.5 degrees to provide maximum surface area.
- Lamellar plates, also used in shallow depth sedimentation, are thin parallel plates installed at 45-degree angles

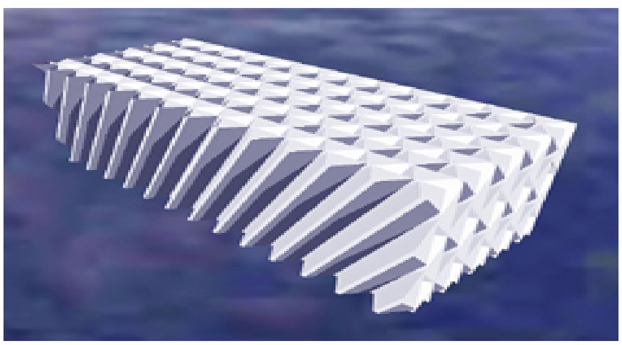


Figure 3.2-Tube Settler Module [1]

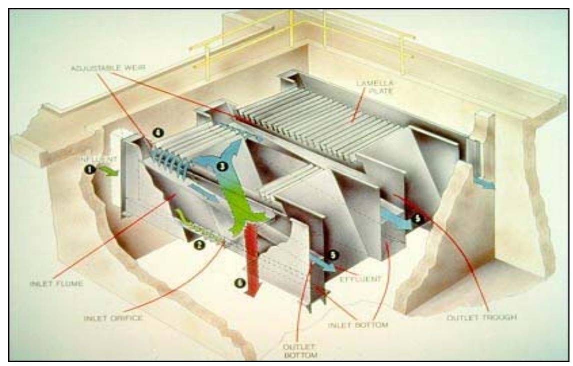


Figure 3.3 - Inclined Plate Settler [2]

Performance Characteristics

- Each tube or plate acts as a shallow settling basin.
- Tube or plate settlers provide a high ratio of effective settling area per surface area.

Uses

- To reduce initial capital cost.
- Where plant site area is restricted or of limited size.
- In packaged treatment plants.
- To increase capacity of existing units.

Specialized Processes

Specialized processes have been developed to improve overall solids removal under certain design conditions; they combine coagulation, flocculation, and sedimentation into one unit.

Solids Contact Clarifiers

- Often called “solids contact units,” “sludge blanket clarifiers,” or "up-flow solids clarifiers.”
- May be either square, round, or rectangular.
- Flow is generally upward through a sludge blanket or slurry of flocculated, suspended solids.
- Most often criticized for instability during rapid changes such as:
  - Flow rate
  - Turbidity
  - Temperature
- Provides better performance under ideal conditions.
- Coagulation and flocculation take place in what is referred to as the zone of mixing.

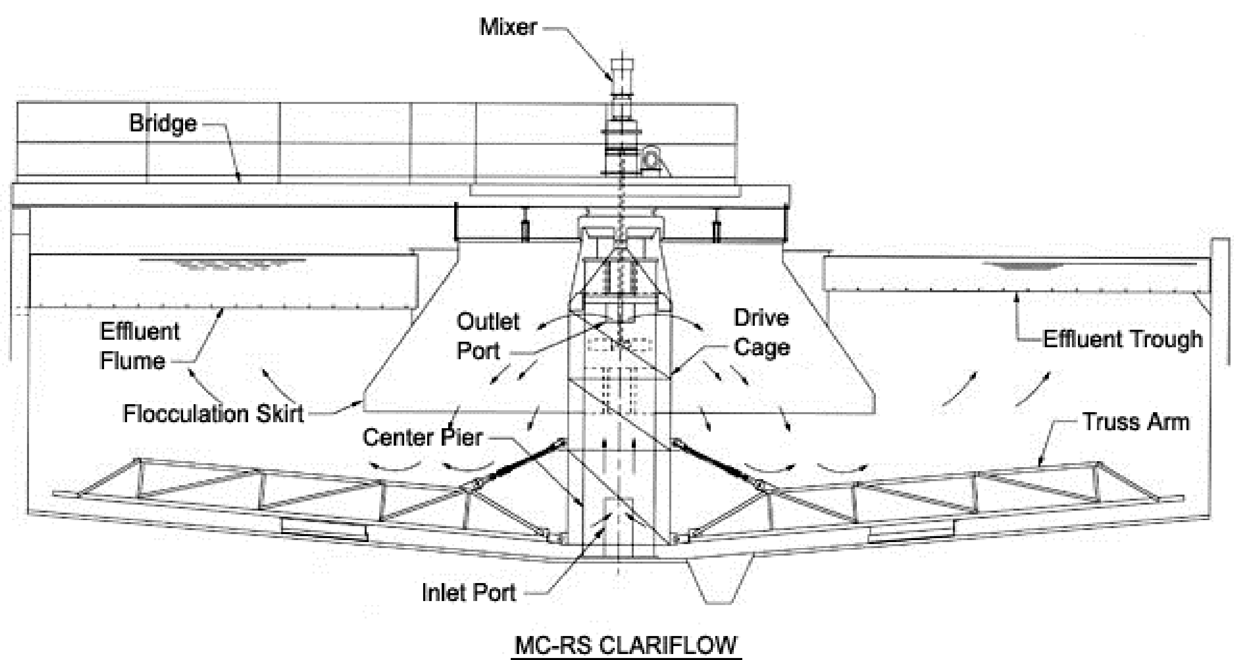


Figure 3.4 - Solids Contact Clarifier [3]

Ballasted Flocculation/Clarification

- Combination of several high-rate processes. Conventional layout – mixing, coagulation, flocculation, and clarification in a single process.
  - Sand and polymer added to provide dense particle on which floc can form.
  - Tube settlers to reduce required sedimentation area.
  - Sand returned to influent for reuse.

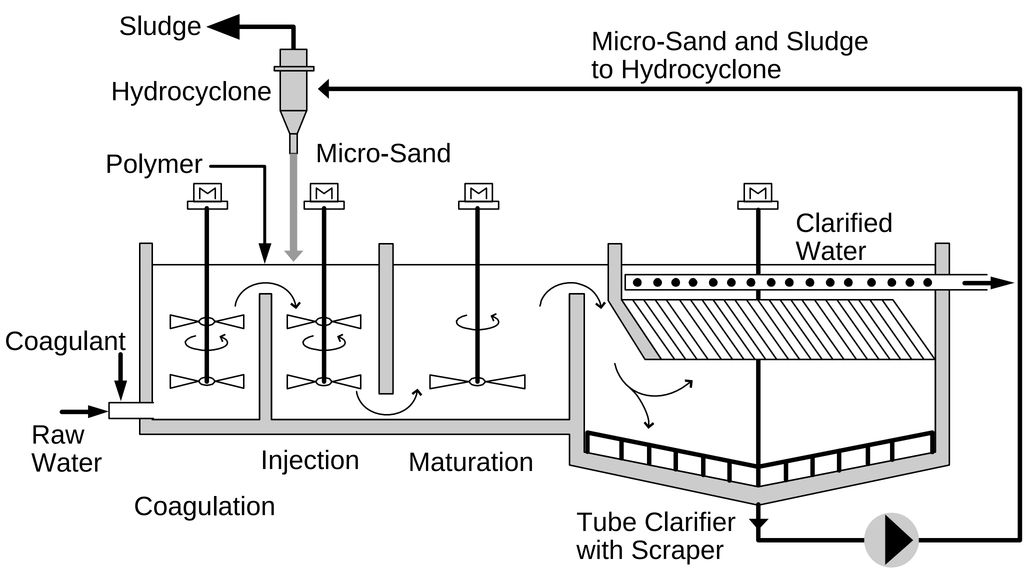


Figure 3.5 Actiflo® Ballasted Flocculation/Clarification System [4]

Upflow Contact Clarifier

- Flow is passed through a course media bed for removal of floc.
- Sludge is removed by backwashing the media bed:
  - Based on time or headloss.
  - Usually uses raw water for backwash.

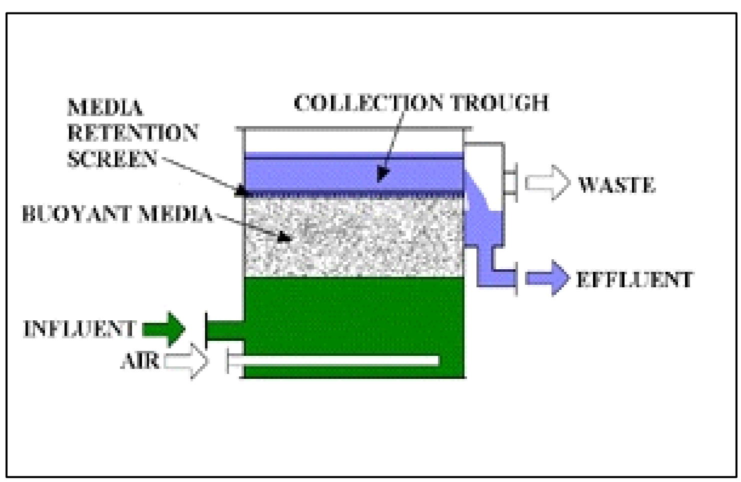


Figure 3.6- Upflow Clarifier [5]

Weir Loading Rate

Weir Loading Rate is the rate at which settled water passes over the basin effluent weirs or orifices.

- Rate should not exceed 20,000 gallons per day per foot of weir length.
  - When increasing the flow rate, the weir overflow rate for the clarifier will be increased. If the weir overflow rate is higher than design specifications, the operator may observe floc carryover from the sedimentation basin onto the filters.
- Weir Loading Rate Formula

$$\text{Weir Loading Rate} = \frac{\text{Flow, gpm}}{\text{Weir Length}}$$

Example 3.3 – Weir Loading Rate Calculation

A rectangular sedimentation basin has a total of 95 feet of weir. What is the weir loading rate in gpm/ft when the flow is 763 gpm?

$$\text{Weir Loading Rate} = \frac{\text{Flow, gpm}}{\text{Weir Length}}$$

$$= \frac{\text{763, gpm}}{\text{95 ft}}$$

$$= \text{8.0 gpm/ft}$$

Unit 3 Exercise

Word Box

a. Water temperature	k. Electrical charge of particle
b. Particle size	l. Environmental conditions
c. Inlet zone	m. Sludge
d. Detention time	n. Clarifiers
e. Gravitational settling	o. Surface loading rate
f. Particle shape	p. Sludge zone
g. Outlet zone	q. Settling zone
h. Relationship of downward movement of particle to forward flow velocity	r. Mean flow velocity
	s. Weir overflow rate
i. Rectangular basin	t. Tube or Plate settlers
j. Circular or Square basin	

Use the Word Box above to complete the following:

1. Identify the four zones of a sedimentation basin.

2. List four operating parameters important to sedimentation.

3. List the settling characteristics upon which the sedimentation process is dependent.

Fill in blanks:

4. The _______________ portion of the horizontal flow sedimentation basin is the settling zone.

5. If the motor is normally running and the sludge collector is not moving, the most likely cause of a clarifier sludge collector problem would be that a ________________________ is broken.

6. A sludge collector device should move very _____________.

7. Increased flow to the treatment plant will affect the settling tank in that the detention time will ____________ and the overflow rate will _____________.

8. A series of thin parallel plates installed at 45-degree angle for shallow depth sedimentation are known as ____________________.

9. Two methods of improving settling efficiency in a sedimentation basin are using tilted plates or _______________.

10. If the weir overflow rate for a clarifier is too _______________, floc carry over will be observed.

11. Improper coagulant dosage and/or improper pH, could cause _________________________.

12. When increasing the flow rate, the weir overflow rate for the clarifier will be _________________.

13. A sedimentation basin is 65 feet long, 20 feet wide and has water to a depth of 12 feet. If the flow to the basin is 1297 gpm, what is the detention time in hours?

1. Determine the volume of the basin (in gallons):

2. Determine the detention time:

$$\text{Detention Time (time, min)} = \frac{\text{Volume of Tank (gallons)}}{\text{Influent Flow (gpm)}}$$

3. Convert minutes to hours:

Unit 3 Key Points

- After coagulation and flocculation comes sedimentation.
- The largest portion of the horizontal flow sedimentation basin is the settling zone.
- Conventional sedimentation basins require detention times ranging from 1 to 4 hours.
- When checking the sedimentation basin immediately before filtration, an operator notices an extreme amount of floc carryover. The best corrective measure to take is to run a jar test to check chemical dosage and effectiveness.
- Sedimentation is improved by uniform low velocity flow across the basin.
- In a properly designed and operated water treatment plant, the greatest removal of the colloidal material in raw water should occur during sedimentation.
- Sedimentation basin loading rates in gallons per square foot of surface area per unit time are called surface overflow rates.
- Increased flow to the treatment plant will affect the settling tank in that the detention time will increase and the overflow rate will decrease.
- If the weir overflow rate for a clarifier is too high, floc carry over will be observed.
- A method of improving settling efficiency of shallow rectangular sedimentation basins is by the addition of a series of plates.
- Tilted plate settlers are a method used to improve sedimentation and function similar to tube settlers.
- A series of thin parallel plates installed at a 45-degree angle for shallow depth sedimentation are known as lamellar plates.
- Tube settlers are used to aid sedimentation.
- A solids-contact basin combines the treatment steps of coagulation, flocculation, and sedimentation.
- Coagulation and flocculation in a solids contact basin take place in the zone of mixing.
- If the motor is running normally and the sludge collector is not moving, the most likely cause of a clarifier sludge collector problem would be that a shear pin is broken.
- A sludge collection device should move very slowly.

[1] "Tube Settler Module." http://www.enviropax.com (17 Jun. 2003).

[2] "Inclined Plate Settler." http://www.waterlink.com (17 Jun. 2003).

[3] "Solids Contact Clarifier." http://www.walkerprocess.com (17 Jun. 2003).

[4] "Actiflo® Ballasted Flocculation/Clarification System." http://www.usfilter.com((17 Jun. 2003).

[5] "Upflow Clarifier." http://www.usfilter.com (17 Jun. 2003).

Unit 4 – Filtration

Learning Objectives

- Define filtration as it relates to water treatment.
- Identify the four performance considerations of Filtration.
- Given the formula and required data, calculate each of the following: filtration rate and backwash rate.
- Explain the importance of good record keeping.

Process Description

Filtration – The process of passing water through a bed of material to remove impurities—floc and particulate matter. Filtration is the final step in removing suspended matter.

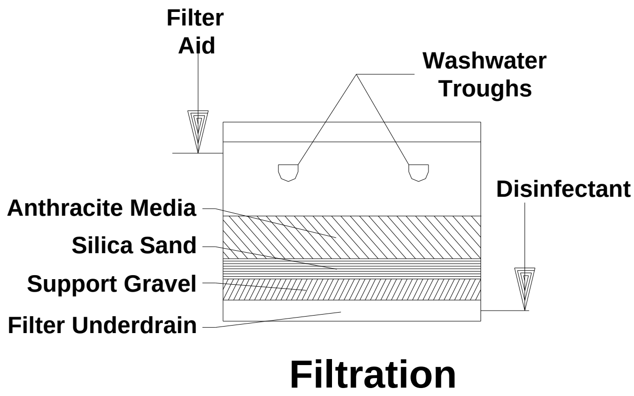


Figure 4.1 – Filtration Schematic

Filter Bed Materials

Generally, filter beds are made from granular materials.

- Silica sand
- Anthracite coal
- Other granular materials such as garnet sand and granular activated carbon

Impurities Removed

- Suspended particles – silts and clays
- Colloids – very small, finely divided solids that remain dispersed in a liquid due to their small size and electrical charge
- Biological forms – bacteria, plankton, algae, cysts, oocysts, and viruses
- Floc

Filtration Mechanisms

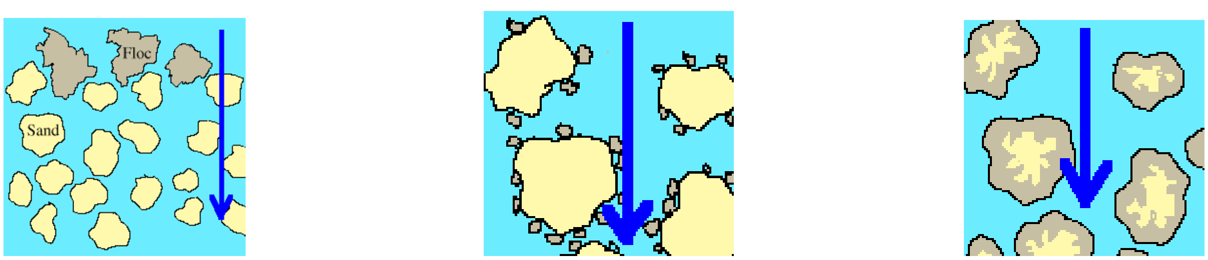
Physical and Chemical Process

Based upon:

- Chemical characteristics of the water
- Nature of suspended material
- Types and degree of pretreatment
- Filter type and operation

Removal Processes

- Sedimentation on media.
- Adsorption – The collection of a gas, liquid or dissolved substance on the surface and interface zone of another material.
- Biological action.
- Absorption – The taking in or soaking up of one substance into the body of another by molecular or chemical action (e.g., tree roots absorb dissolved nutrients in the soil).
- Straining – The removal of particulates by trapping in the open spaces between the grains of the media. The floc particles cannot fit between the gaps in the filter media.



Straining | Adsorption | Absorption

Figure 4.2 – Removal Processes[1]

Gravity Filters

Gravity Filters – Water moves downward through filter media by gravity.

Slow Rate Gravity Filtration (Covered in Module 17)

- Low filtration rates:
  - 45 to 150 gpd/sqft (0.03 to 0.10 gpm/sq ft).
- Majority of material removed in top several inches of media.
- Cleaned by removing and replacing top media layer.
- Limited application due to area requirements and manual cleaning.
- Filter media – 24” to 30” deep silica sand bed.

Rapid Rate Gravity Filtration

- Filtration rate is dependent on the media used.
  - Single media = 2 gpm/sqft
  - Dual or Multi media = 4 gpm/sqft
  - Higher rates permitted if justified based on raw water quality, degree of pretreatment, media type, and other factors.
- Filter media can be single, dual or multi.
  - Single media bed is 24” to 30” deep, and made up of:
    - Clean silica sand, or
    - Clean, crushed anthracite coal.
  - Dual media bed is 24” to 30” deep containing both sand and anthracite:
    - Silica sand, 9” to 12” deep, and
    - Crushed anthracite 15” to 18” deep.
  - Multi or mixed media bed is 24” to 30” deep containing silica sand, anthracite coal, and a layer of dense, small grained garnet sand:
    - Garnet Sand - 3” layer,
    - Silica Sand - 9” to 12” layer, and
    - Anthracite - 15” to 18” layer.

Pressure Filters

Pressure Filters – Water is forced through the media under pressure.

Pressure Filtration

This is simply the conventional filtration process under pressure.

Precoat Filtration (Diatomaceous Earth) (Covered in Module 16)

- Media is added to water being treated prior to the water entering the filter.
- Media collects on porous screening device.
- Media coating thickness increases during filter run as more media is added.
- Media is wasted during backwash process.
- Swimming pool filter is good example.

Cartridge or Bag Filtration (Covered in Module 18)

- Uses replaceable cartridge or bag filters.

We will discuss the rapid rate filter.

Rate of Flow Controller

First, most rapid rate filters contain a controller or filter control system. The ability to control the rate of flow through a filter is important. Plants with multiple filters may not distribute the total plant flow in a reasonably equal manner due to varying head losses among the filters. Filter control systems regulate flow rates by maintaining adequate head above the media surface. This prevents sudden flow increases, or surges, which could dislodge trapped solids.

Common Filter Control Systems

Flow is controlled in one of two ways: mechanically or non-mechanically and can be classified as:

Constant Rate

- Each filter is equipped with a rate-of-flow control valve.
- The valve maintains a constant rate of water flow through the filter.
- As filter clogs the valve slowly opens to maintain the flow rate.

Declining Rate

- The filter controller maintains a constant level of water above the media.
- Filtration rate declines as filter clogs.
- A loss of head gauge on a filter is used to measure the drop in pressure through a filter bed.

Filter Media

Filter Media Materials

The filter media is the part of the filter which actually removes the particles from the water being treated.

- The filter media consists of a bed of silica sand and anthracite coal. Garnet sand is sometimes included in a Mixed Media bed.
- The anthracite coal can be replaced with Granular Activated Carbon (GAC) for organic, taste, and odor control applications.
  - The largest particles are strained out by the anthracite or GAC. The sand and garnet then trap the rest of the particulate matter through a combination of adhesion and straining. (Applying the layer of anthracite provides a higher filtration rate and a longer filter run time than sand alone.)
- The filter bed depth depends on treatment application.
  - Periodic probe checks should be performed to determine depth to the gravel.
- Filter aids such as polymers can be added.

Filter Media Support

- Silica gravel is commonly used to support the media bed.
- An alternative media support uses an IMS® Cap.
  - This is a porous material which replaces the common silica gravel bed system.
  - Commonly used where overall filter depth is a concern, as a ½ inch thick Cap replaces 12 or more inches of silica gravel.

Media Characteristics

- Good hydraulic characteristics (permeable bed)
- Inert and easy to clean
- Hard and durable
- Free of impurities
- Insoluble in water
- Comply with AWWA B-100 Standard for Filtering Media

Media Classification

A filter media is defined by effective size and uniformity coefficient:

Effective Size (ES)

- Size of sieve opening which permits 10 percent of media particles (by weight) to pass.
- Some operational problems are improved by proper selection of media effective size:
  - Time required for turbidity breakthrough.
  - Time required for filter to reach limiting or terminal headloss.

Uniformity Coefficient (UC)

➢ Referred to as the measure of uniformity of filter media.

- UC is a ratio based on sieve size.
- UC is equal to the size of the sieve opening that will just pass 60 percent (by weight) of a representative sample of the media, divided by the size of the sieve opening that will just pass 10 percent (by weight) of the same sample.
- Formula: $UC = D_{60} \div D_{10}$
- Media with lower UC is more uniform in size than media with higher UC. Generally, the lower the UC, the slower the headloss buildup

Specific Gravity (SG)

- Ratio of the unit weight of the media to that of water

Hardness

- Resistance to erosion or wearing away of the particle

Typical Filter Media Characteristics

Table 4.1 – Typical Filter Media Characteristics

Material	Size Range (mm)	Uniformity Coefficient	Specific Gravity	Hardness (MOH scale)
Anthracite Coal	0.8 – 1.2	< 1.85	1.5 – 3.0	3.0
Silica Sand	0.3 – 0.6	< 1.5	> 2.5	7.0
Garnet Sand	0.2 – 0.4	< 1.5	3.8 – 4.3	7.5 – 8.0
Silica Gravel	1.0 - 50	N/A	> 2.5	7.0
GAC	0.8 – 1.2	< 2.0	1.5 – 3.0	N/A

Filter Underdrains

Filter Underdrains collect filtered water during normal operation and distribute backwash water during backwash process.

Underdrain Types

- Perforated Pipe System (Header/Lateral system)

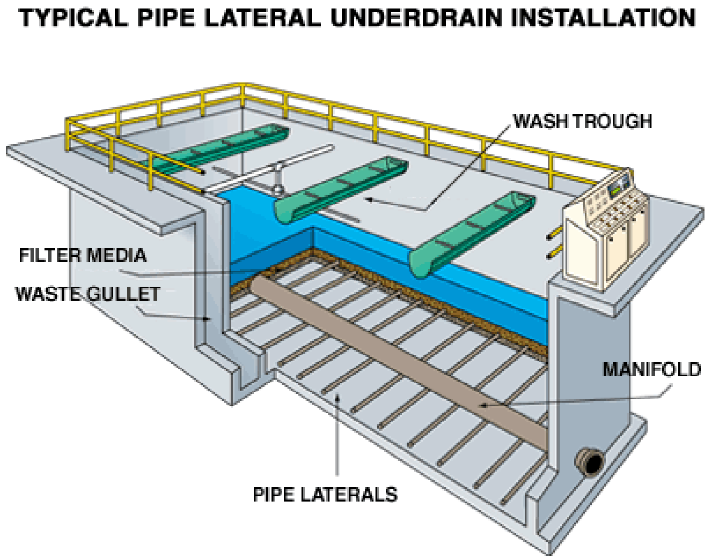


Figure 4.3 – Perforated Pipe Lateral Underdrain[2]

- Wheeler Bottom

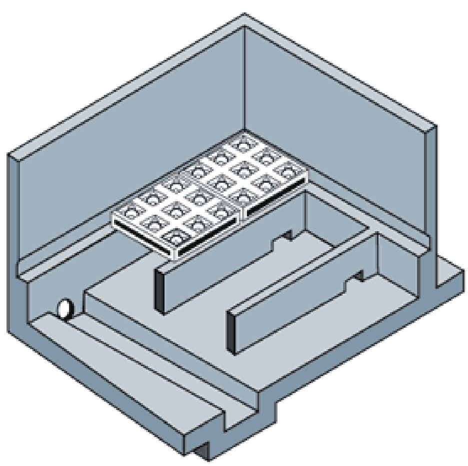


Figure 4.4 – Wheeler Filter Bottom [3]

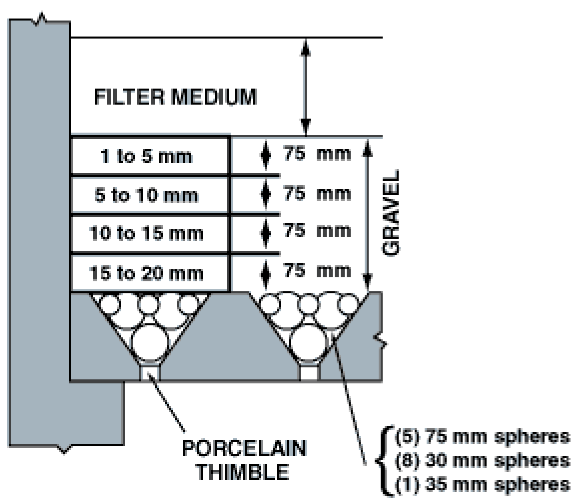


Figure 4.5 – Wheeler Bottom Section [4]

- Filter Block Systems
    - o Glazed tile filter blocks
    - o Plastic filter blocks

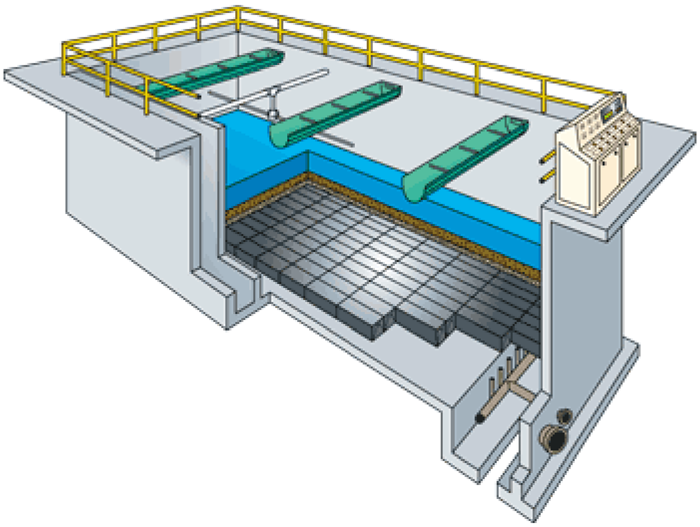


Figure 4.6 – Filter Block Underdrain [5]

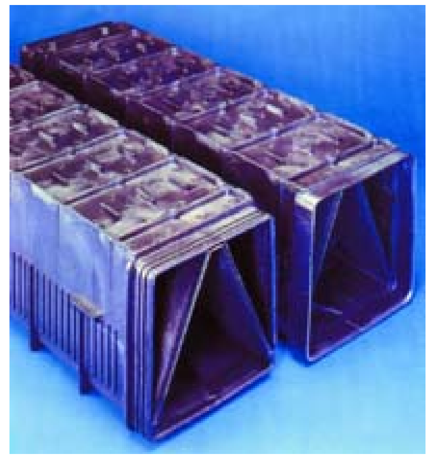


Figure 4.7 – Polyethylene Filter Blocs [6]

- Porous Plates

- Nozzle and Strainer

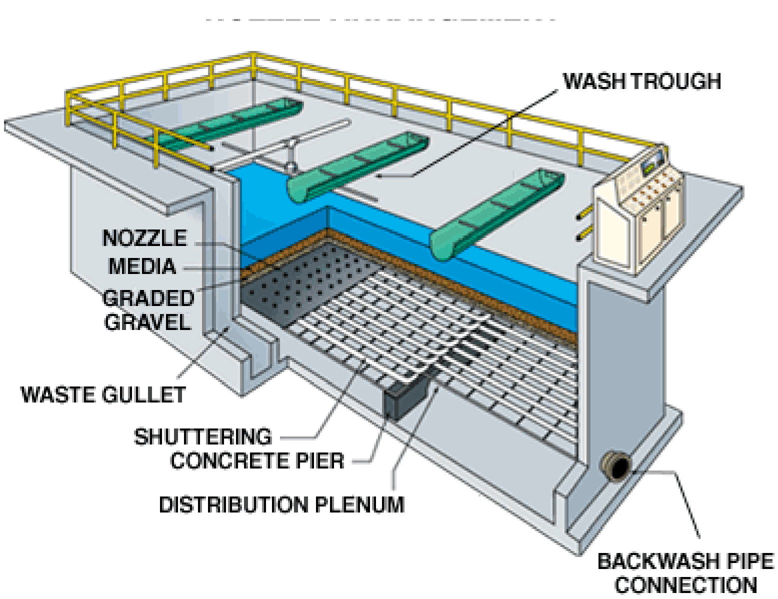


Figure 4.8 - Nozzle & Strainer Underdrain [7]

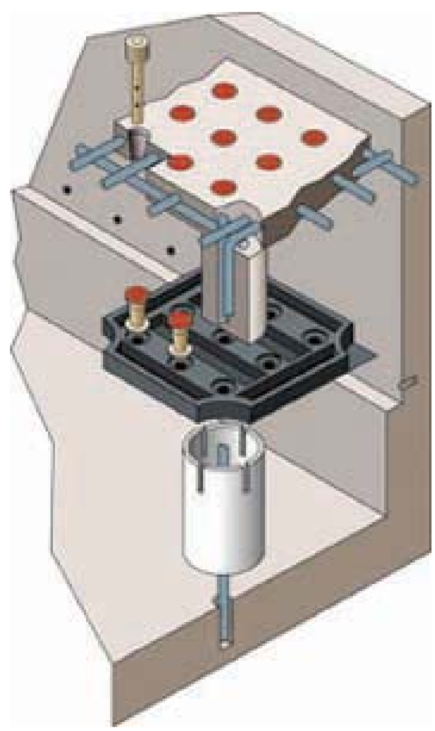


Figure 4.9 - Nozzle & Strainer Underdrain [8]

Filter Operation
Start-Up

The normal cycle for a filter begins with the placement of a clean filter in service and follows through with the steps of filter ripening, effluent production and subsequent head loss increase. It may then result in particle and turbidity breakthrough bringing the need for the backwash sequence.

Filter Ripening

When a filter is brought online, the filter produces water with a higher turbidity for several minutes during a process called filter ripening. Ripening can be thought of as a process in which floc particles that are passing through the clean bed are captured and released and recaptured by the filter media.

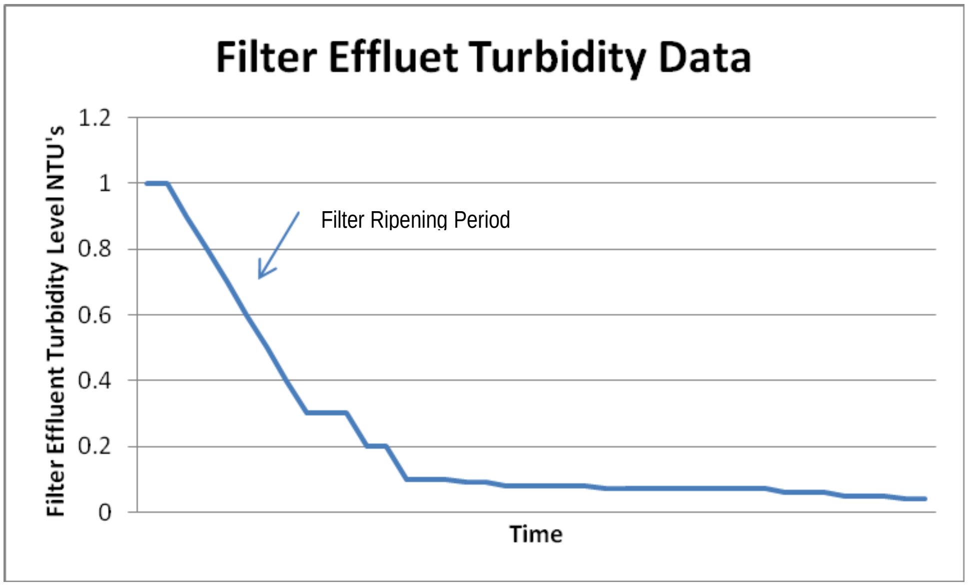


Figure 4.10 Filter Effluent Data

A clean filter is not efficient in the process; however as more and more floc particles are captured, the filter ripens. Filter ripening is important because the bulk of the particles that pass through a filter do so during the initial ripening period.

Options to Reduce Filter Ripening Time:

- Delayed start-up or filter resting (allow the filter to rest before start-up).
- Slow start-up where a freshly washed filter is started at a slower filter rate and eventually brought up to full rate.
- Filter aid addition where a chemical like an anionic polymer or a coagulant is added to the influent of the filter. (The addition of the anionic polymer can increase head loss on filters.)
- Filter to waste.
- Careful attention to backwash so that beds are not overly cleaned.

Filter Operation
Effluent Production

As a filter run proceeds, foreign material collects in the media, causing turbidities to drop and stabilize.

Filter Efficiency

Turbidity monitoring of filtered water is done to indicate that pathogenic organisms such as Giardia and Cryptosporidium are being removed during the filtration process. The turbidity at each filter must be monitored continuously and combined filter effluent turbidity must be measured and meet regulatory requirements. Lower system turbidity goals are recommended however such levels require optimized pretreatment, careful filter operation, and continuous monitoring of filtered water turbidity from each filter.

The use of particle counters can also be used in the operation of a water treatment plant. Particle counters sense, measure and count individual particles, providing the number and size of particles per unit volume. This information can be used to determine the efficiency of a filter and optimize its performance.

Factors Influencing Efficiency

The efficiency of a filter can be influenced by a variety of factors:

- The type of water being treated
- Size, shape and chemical characteristics of the particles
- The type of filter
- Filter operation

Filter Problems

➢ Mud balls
  - A small agglomerate of floc and filter media which form on the surface of filters which can grow in size during a filter cycle.
  - Mud balls can eventually sink down into the filter media preventing uniform filtration through the filter bed.
  - Mud balls result in shortened filter run times and loss in filter capacity since water will not pass through the mud balls and must flow around them.

➢ Air Binding
  - Caused by the release of dissolved gases from the water in the filter or under drain or if the water in the filter bed is drawn down below the filter surface.
  - Air binding can also be caused by allowing the filter to run too long.
  - The air prevents water from uniformly passing through the filter.
  - Preventing air binding is done by limiting head loss in filters during times when air binding might be a problem (limiting the filter run time).
  - During backwashing, the air in the filters can damage the filter media.

Filter Operating Parameters

Filter Production – The difference between the total water produced and the backwash water used. Filter capacity is recorded in million gallons per day.

Filtration Efficiency – The measure of overall plant reduction in turbidity.

Filter Capacity

Filter Capacity, gpm – The rated capacity of a filter given the surface area of the filter and the filtration rate.

$$\text{Filter Capacity, gpm} = \text{Filtration Rate, } \frac{\text{gpm}}{\text{sq ft}} \times \text{Surface Area, sq ft}$$

Example 4.1 – Filter Capacity Calculation

What is the filter capacity of a system if the sand bed has a surface area of 700 sq ft and the filters are rated to have a capacity of 3 gpm/sq ft (in gpm)?

$$\text{Filter Capacity} = \text{Filtration Rate} \times \text{Surface Area}$$

$$= \frac{3\text{ gpm}}{\cancel{\text{sq}}\text{ ft}} \times 700\ \cancel{\text{sq}}\text{ ft}$$

$$= 2{,}100\text{ gpm}$$

Example 4.2 – Filter Capacity Calculation

The surface of a filter is 15 feet long and 10 feet wide. What is the rated total capacity for a rate of 5 gpm/sq ft? (in gpm)

Step 1 – Determine the surface area. Area = Length x Width

$$= 15\text{ ft} \times 10\text{ ft}$$

$$= 150\text{ sq ft}$$

Step 2 – Determine the filter capacity. Filter Capacity = Filtration Rate x Surface Area

$$= \frac{5\text{ gpm}}{\cancel{\text{sq}}\text{ ft}} \times 150\ \cancel{\text{sq}}\text{ ft}$$

$$= 750\text{ gpm}$$

Filtration Rate

Filtration rate – The flow which is filtered by one (1) square foot of filter surface area.

It is determined by dividing the flow rate through the filter, in gallons per minute, by the filter surface area, in square feet.

$$\text{Filtration Rate, } \frac{\text{gpm}}{\text{sq ft}} = \frac{\text{Flow Rate, gpm}}{\text{Filter Area, sq ft}}$$

Example 4.3 – Filtration Rate Calculation

A rapid sand filter has a surface area of 150 sq ft. If the flow through the filter is 312 gpm, what is the filter loading rate in gpm/sq ft?

$$\text{Filtration Rate} = \frac{\text{Flow Rate, gpm}}{\text{Filter Area, sq ft}}$$

$$= \frac{312 \text{ gpm}}{150 \text{ sq ft}}$$

$$= 2.08 \frac{\text{gpm}}{\text{sq ft}}$$

Example 4.4 – Filtration Rate Calculation

Determine the filter loading rate (in gpm/sq ft) of a filter 35 feet in diameter treating a flow of 3000 gpm.

Step 1 – Determine the surface area. $\text{Area} = 0.785 \times D^2$

$$= 0.785 \times (35 \text{ ft})^2$$

$$= 961.63 \text{ sq ft}$$

Step 2 – Determine the filter loading rate.

$$\text{Filtration Rate} = \frac{\text{Flow Rate, gpm}}{\text{Filter Area, sq ft}}$$

$$= \frac{3000 \text{ gpm}}{961.63 \text{ sq ft}}$$

$$= 3.12 \text{ gpm/sq ft}$$

Filtration efficiency is dependent upon:

- Quality of water being treated.
- Effectiveness of pretreatment.
- Filter operation.

Effectiveness of pretreatment processes in conditioning water for filtration is the single most important aspect to good filtration efficiency.

Backwashing

Backwashing – The process of reversing the flow of water back through the filter media to remove the trapped material.

When to Backwash

- Three methods to determine when to backwash a filter:
  - Gallons filtered or when a specified time period has passed indicates the need to backwash.
  - Head loss on the filter may be used to indicate the need to backwash. As the filter gets clogged, more negative pressure is created. The more clogged the filter, the more resistant to the flow as it passes through the filter media. The more resistance, the greater the head loss which can be measured on a differential pressure gauge.
  - An increase in the cleanliness or cloudiness (turbidity) of the water coming out of the filter.

Purpose

- When the filters pores become clogged, they need cleaned.
  - Backwashing a filter is required to remove material trapped by media.

Processes

- Influent valve is closed to the filter.
- Waste line is opened to the filter.
- Backwash pump or elevated backwash storage tank forces treated (finished) water from the system back up through the filter bed.
- Media is expanded or fluidized by reversing water flow.
  - Backwashing should begin slowly. If begun too quickly, backwash water can damage the under drain system, gravel bed and media.
  - The backwash rate should them be accelerated to ensure enough velocity and volume to agitate the filter media and carry away the foreign material.
    - Normally uses 2 to 5 percent of the treated water produced.
  - Entrapped solids are collected by wash trough and taken away for further processing in the residual waste handling system.
- Backwashing times vary depending on the length of the filter run and the quantity of material to be removed.

Supplemental Filter Wash Systems

- Help to break deposited solids loose from media grains.
  - Surface Wash System
    - Mechanical or water powered wash system.
  - Air Scour System
    - Pressurized air introduced underneath the media with the backwash water.

Monitoring Backwash Cycle

- The cleanliness of a filter bed depends on the ability to achieve and sustain a proper filter bed expansion during the backwash cycle.
  - This expansion, commonly recorded as percent of bed depth, should remain constant year round.
    - Water supplies that are subject to wide temperature variations will need to use a different wash-water flow rate to keep this consistency.
  - Proper filter bed expansion should be confirmed periodically. Various approaches to accomplish this task include using a Secchi disk and a filter bed expansion tool.
    - When the rise rate is too high and bed expansion is excessive, media can be washed out.
    - A rise rate that is insufficient to fluidize a filter bed can result in a backwash that is not as effective as desired.

Backwash Rate

Backwash Rate is the flow rate at which the filter is backwashed.

The Backwash Rate is usually expressed in gallons per minute per square foot of filter surface area, or the backwash pumping rate in gallons per minute.

- Formulas involving backwash calculations are similar to formulas for computing filtration rates.

Backwash Pumping Rate, gpm = Filter Area, sq ft x Backwash rate, gpm/sq ft

- Since colder water has more lifting power than warmer water, it is usually necessary to adjust the wash water rate from summer to winter.

Typical Backwash Rates

Low Wash: 3 – 8 gpm/sq ft of filter area

High Wash: 15 – 20 gpm/sq ft of filter area

Air Scour: 3 – 5 scfm/sq ft of filter area

Surface Wash: 0.5 – 2.0 gpm/sq ft of filter area

☑ Example 4.5 – Backwash Rate Calculation

A filter 26 feet wide by 30 feet long needs a backwash rate of 18 gallons per minute per square foot. Determine the required backwash pumping rate in gpm.

Step 1 – Determine the surface area. Area = Length x Width

= 30 ft x 26 ft

= 780 sq ft

Step 2 – Determine the Backwash Pumping Rate, gpm = Filter Area, sq ft x Backwash rate, gpm/sq ft

= 780 sq ft x 18 gpm/sq ft

= 14,040 gpm

☑ Example 4.6 – Backwash Rate Calculation

A fitler is 40 ft long and 20 ft wide. If the desired backwash rate is 20 gpm/sq ft, what backwash pumping rate (gpm) will be required?

Step 1 – Determine the surface area. Area = Length x Width

= 40 ft x 20 ft

= 800 sq ft

Step 2 – Determine the Backwash Pumping Rate, gpm = Filter Area, sq ft x Backwash rate, gpm/sq ft

= 800 sq ft x 20 gpm/sq ft

= 16,000 gpm

Backwash Water

- Backwash water is very dirty and care must be taken to dispose properly.
  - With proper care, backwash water can be discharged into the sanitary sewer.
  - Can be sent to settling basins where backwash water can be treated, tested and possibly emptied into a nearby stream with the proper National Pollutant Discharge Elimination System (NPDES) permits.
  - Backwash water can be transported to either a sewer plant or landfill.

Filter to Waste

- One of the most common techniques of eliminating the turbidity spike directly after a filter backwash is to filter to waste during the filter ripening period.
  - The first slug of filter water after a backwash is directed to the sanitary sewer or backwash basin.
  - Filter to waste should continue until the turbidity spike subsides; the less turbidity in the clear well, the better.
    - Monitoring the turbidity level is done with a continuous in-line turbidity meter on each individual filter.

Daily Logs

Plant operators maintain a daily log of process performance data and water quality characteristics. Various performance records are required by regulatory agencies and these logs contain the necessary information. Good historical operational records can also serve as a guide to current plant performance and process changes necessary to improve finished water quality.

Logs are Accurate Records of:

- Process water quality
  - Turbidity
  - Color
- Process operation
  - Filters in service
  - Filtration rates
  - Loss of head
  - Length of filter runs
  - Frequency of backwash
  - Backwash rates
- Process water production
- Percent of water production used to backwash filters and other plant uses (laboratory samples, mixing chemicals, washdown, etc.)
- Process equipment performance
  - Types and number of equipment in operation
  - Equipment adjustments made
  - Maintenance performed
  - Equipment calibration

Log Entries Should:

- Be neat and legible
- Reflect time and date of an event
- Be initialed by operator making entry

Unit 4 Exercise

1 – 4. There are four performance considerations of Filtration listed below. Match each consideration with the correct explanation of that consideration.

Performance Consideration	Explanation
1. Filter Media	Filter production and efficiency
2. Filter Underdrains	The materials used to filter out impurities
3. Filter Operating Parameters	The process of reversing the flow of water back through the filter media to remove trapped material.
4. Backwashing	Where filtered water is collected during normal operation.

5. List two ways filters can become air bound.

____

____

____

____

6. How can a system achieve longer filter run times?

____

____

Choose the correct answer:

7. The removal of particulates by trapping in the open space between the grains of the media:
   a. Straining
   b. Adsorption
   c. Biological Action
   d. Absorption

8. The measurement used to define the uniformity of filter media:
    a. Specific Gravity
    b. Hardness
    c. Uniformity Coefficient
    d. All of the above

9. One of the most common techniques of eliminating the turbidity spike directly after a filter backwash is to filter to waste during the:
    a. End of a timed backwash
    b. Filter ripening period
    c. Middle of a timed backwash
    d. None of the above

10. Ways to reduce filter ripening time:
    a. Delayed start-up
    b. Filter aid addition like an anionic polymer or coagulant
    c. Filter to waste
    d. All of the above

11. A problem in a filter that can prevent water from uniformly passing through a filter:
    a. Well formed floc
    b. Mudballs
    c. Air binding
    d. Both b and c

12. A method used to indicate when a filter needs backwashed:
    a. Time
    b. Head loss
    c. Increase in effluent turbidity (breakthrough)
    d. All of the above

13. Backwash rates set too high:
    a. This is not a problem
    b. Can cause loss of filter media
    c. Will not adequately expand the filter bed
    d. All of the above

14. A backwash normally uses _____________ of treated water produced (finished water).
    a. 1-2%
    b. 2-5%
    c. 6-8%
    d. 8-10%

15. A filter 35 feet wide by 20 feet long needs a backwash rate of 20 gallons per minute per square foot. Determine the required backwash pumping rate in gpm.
    a. 12,000 gpm
    b. 13,000 gpm
    c. 14,000 gpm
    d. 15,000 gpm
16. What is the filter capacity (in gpm) of a system with a sand bed 40 feet in diameter when the filters are rated to have a capacity of 2.5 gpm/sq ft?
    a. 78.5 gpm
    b. 250 gpm
    c. 1,500 gpm
    d. 3,140 gpm

17. A system has filters that measure 25 feet long and 15 feet wide. What is the rated total capacity at a rate of 2 gpm/sq ft?
    a. 250 gpm
    b. 500 gpm
    c. 750 gpm
    d. 1,000 gpm

18. Determine the filter loading rate of a filter 20 feet in diameter treating a flow of 1500 gpm.
    a. 4.8 gpm/sq ft
    b. 9.8 gpm/sq ft
    c. 15.1 gpm/sq ft
    d. 95.2 gpm/sq ft

19. A filter 25 feet long and 35 feet wide treats a total of 1400 gpm. What is the filter loading rate?
    a. 1.6 gpm/sq ft
    b. 3.2 gpm/sq ft
    c. 3.4 gpm/sq ft
    d. 9.8 gpm/sq ft

20. A filter has a diameter of 35 feet. If the desired backwash rate is 25 gpm/sq ft, what backwash pumping rate (gpm) will be required?
    a. 687 gpm
    b. 1,508 gpm
    c. 12,761 gpm
    d. 24,041 gpm

Unit 4 Key Points

- In conventional water treatment, the final step in the removal of suspended matter is filtration.
- In a filter using anthracite and sand, the anthracite should be located as the top layer of media.
- The indicator used to monitor the mixed media filtration process is turbidity.
- The term “uniformity coefficient” refers to the measure of uniformity of filter media size.
- The maintenance of a filter bed involves a periodic probe check to determine depth to the gravel.
- The addition of the anionic polymer can increase head loss on filters.
- Polymers used as filter aids work to improve filter performance because they strengthen bonds between particles and coat filter media to improve adsorption.
- Loss of head in a filter represents the resistance to flow as it passes through the filter media.
- If the water in a filter bed is drawn below the filter surface and more water is applied, air binding of the filter bed may occur.
- Air binding a filter prevents uniform filtration through all parts of the filter bed.
- A loss of head gauge (differential pressure gauge) on a filter is used to measure the drop in pressure through the filter bed.
- The purpose of the rate-of-flow controller on the effluent piping of a filter is to control the rate of filtration.
- Larger particle size and lower density of anthracite filter media provides for longer filter run, higher filtration rates.
- Before placing a rapid sand filter into service, the filter should be backwashed.
- A filter needs backwashing when the operator observes excessive effluent turbidity.
- Filtered water is always used for backwashing to avoid contamination of the filter bed.
- After backwashing a filter, you should filter to waste and check turbidity.
- A Secchi disk is used to determine bed expansion during backwash which helps determine the proper backwash rate of flow

- Polymers used as backwash aids are injected into the backwash water in very low doses to reduce the ripening time of filters.

- A layer of anthracite provides a higher filtration rate and a longer filter run time than sand filter media.

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[3] "Wheeler Filter Bottom." http://www.fbleopold.com (17 Jun. 2003).

[4] "Wheeler Bottom Section." http://www.fbleopold.com (17 Jun. 2003).

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[7] "Nozzle & Strainer Underdrain." http://www.fbleopold.com (17 Jun. 2003).

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Unit 5 – Operation of Conventional Filtration Facilities

Learning Objectives

- Identify the five components of ***Normal*** Operations.
- Explain the importance of "jar testing" and describe how the test is performed.

Process Performance Monitoring

Overview

- Monitoring process performance is an ongoing, regular activity of plant operators.
- Early detection of a pre-treatment failure is extremely important to effective filtration performance.
- Keep accurate plant operation records. They:
  - Serve as a guide to help solve current or future process related operational problems.
  - Provide a running account of plant operations.
  - Are required by regulatory agencies.
  - Should be neat, legible, and easily found.
  - Should contain the date and time of an event and be initialed by the operator making the entry for future reference.
  - Should include plots of key process variables (i.e., raw water turbidity vs. coagulant dosage).
- Early detection of a potential problem may allow for process modifications to correct a problem, limit the severity, or maybe even prevent the problem altogether. Don't wait for customer complaints as an indication of problems in filtration and backwashing.

Monitoring Methods

- Continuous water quality analyzers for continually measuring various process variables:
  - Turbidity
  - Temperature
  - pH
  - Streaming current

Figure 5.1 Stream Current

- Visual observations of:
  - Mixing turbulence
    - Floc quantity and quality.
      - Water flow patterns indicating short circuiting.
      - Buildup of foreign material such as leaves, twigs, other debris.
  - Turbidity
    - Upon entering and leaving sedimentation basin.
      - Indication of floc or solids loading on sedimentation process.
      - Difference reveals effectiveness or efficiency of process.

                • Low sedimentation process effluent turbidity is desirable as it minimizes the filter load.

- o Temperature
    - ▪ Water temperature very important.
        - • Affects settling rate.
        - • Colder water = Slower settling.
    - ▪ Temperature changes usually gradual.
        - • Dependent on time of year and weather.
- o Floc settling characteristics such as:
    - ▪ Floc size and density.
    - ▪ Floc settling rate.
    - ▪ Floc carryover to filters.

Figure 5.2 Hand Held Turbidimeter

Monitor Filtration Process

- ➢ Filter influent turbidity or, settled water turbidity.
    - o Check on periodic basis
        - ▪ Continuous sample or grab sample.
        - ▪ Frequency dependent on raw water quality and pretreatment operations.
        - ▪ Minimum 1X per shift.
        - ▪ More frequently is better.

- ➢ Filter effluent turbidity or filtered water turbidity.
    - o Continuous monitoring with on-line turbidimeter
        - ▪ Provides continuous feedback on filter performance.

- ➢ Headloss - measures solids accumulation in the filter bed. It is the resistance to flow as it passes through a filter.
    - o Actual filter head loss
        - ▪ Good indication of how well the filter is performing.
        - ▪ Indication that backwash is required.
    - o Rate of increase
        - ▪ Should be constant increase.
        - ▪ Sudden increase indicates potential problem such as surface sealing.
    - o Anionic polymers are one chemical that could increase head loss on the filters.
    - o A malfunctioning differential pressure gauge will display an incorrect head loss.

Process Controls and Equipment

Check and Adjust Process Controls and Equipment

- Calibration of analytical instruments.
- Coagulation/flocculation process:
    - Check and adjust flash mixer and flocculator speed controls.
    - Chemical feeders:
        - Check chemical feed rate.
        - Check feeder accuracy.
    - Make pretreatment modifications as necessary.
- Sedimentation process:
    - Operate sludge removal equipment.
- Filtration process:
    - Add and remove filters from operation as required by water demands.
    - Change filtration rate.
    - Backwash filters.
        - Determine need for backwashing on the basis of filter headloss, time in service, or turbidity breakthrough.
            - Headloss is generally limited to a maximum of 7 feet.
            - Wash every 48 to 72 hours regardless of filter headloss.
            - Wash prior to filter effluent turbidity exceeding established Maximum Contaminant Level (MCL).
        - Record filter run length, effluent turbidity, and headloss since last backwash.
        - Close filter influent valve.
        - Open drain valve.
        - Close effluent valve.
        - Start surface wash or air scour system.
        - Start water backwash at low wash rate.
        - Stop surface wash or air scour system.
        - Increase backwash rate to high rate to fluidize media bed at proper time.
            - Observe backwash for:
                - Backwash water clarity near end of wash cycle.
                - “Boils” or uneven distribution of flow.
                - Media carry-over into backwash troughs.
                - Wash at high wash rate until filter is clean.

        - Decrease backwash rate to low rate to restratify filter bed.
        - Stop water backwash.
        - Close drain valve.
        - Open rinse valve.
        - Open influent valve and rinse filter until effluent turbidity levels return to normal.
        - Close rinse valve and open effluent valve.
        - Return filter to normal service.
            - Observe condition of media surface.
            - Record length of wash, rinse, and water usage.

- Evaluate filter media condition.
    - Examine filter media at least annually:
        - Measure media level to determine media loss during backwashing.
        - Monitor for mud ball accumulation in media to evaluate backwash effectiveness.
        - Observe for signs of surface cracking or cracks along the filter wall.
    - If the filter media is replaced, the best way to disinfect a filter is use enough chlorine so that a significant residual remains after 24-hours.

Process Support Equipment

Plant operators must operate and maintain support equipment in accordance with manufacturer's recommendations:

- Filter control valves
- Backwash and surface wash pumps
- Chemical feed pumps
    - Chemical feed pumps like positive displacement diaphragm pumps need calibrated and monitored on a regular basis.
    - Any leak throughout the system will cause a reduction in the amount of chemical solution pumped which could effect floc formation or settling.
    - For example, if the pump looks to be operating, but the chemical feed is less than expected, suspect a ruptured diaphragm.
- Air scour blowers
- Flow meters and level/pressure gauges
    - Isolate and depressurize the line before removing and cleaning a primary in-line raw water meter.
- Water quality monitoring equipment (turbidimeters)

- A 4-20mA control signal is typically used for an output signal from the turbidity meter to chart recorder, flow meter signal, and the output signal from chlorine analyzer.

- Process monitoring equipment (head loss and filter level)
- Mechanical and electrical filter control systems
- Sludge drying: Sludge drying beds and sludge filter presses
  - Reduce the volume of sludge that must be handled or disposed.

Housekeeping

Plant operators must perform routine housekeeping chores and keep the area clean and free of debris. Several items of routine maintenance and housekeeping that are common to all facilities include:

Painting

Routine repainting of equipment and other plant facilities both improves appearance and extends useful life.

Equipment Maintenance

Routine equipment maintenance includes:

- Check lubrication,
- Clean,
- Check for proper operation, and
- Adjust as necessary.

General Plant and Yard Work

- Cleaning and sweeping.
- Mowing lawn areas.
- Cleaning up chemical spills.

Laboratory Testing

Perform Required Laboratory Testing

- Perform on a routine basis.
  - Frequency of testing depends on source water.
    - Water quality from lake and reservoir supplies are generally less variable than stream or river supplies so these sources may require less frequent testing.
    - Direct diversions from streams and rivers are usually more variable, and, therefore, require source quality changes more rapidly.
  - Most commonly tested for turbidity, alkalinity, pH, color, temperature, and chlorine demand.
  - Other common tests include iron, manganese, nitrates depending on source type and normal raw water quality.

- Evaluate water quality - both raw and treated.
  - Compare raw water quality test results with historical records.
  - Compare treated water quality with historical records and MCL limits.

- Jar Testing

  While it is almost impossible to duplicate actual plant conditions, Jar Testing is used to verify process performance. It attempts to duplicate in the laboratory what is occurring in the plant in relation to detention times, mixing conditions, and settling conditions and should be used as a method to forecast plant process performance.

  - Plant operating conditions should closely approximate jar test results at the best coagulant dose.
  - Routine performance of Jar Tests provides additional information to help make required adjustments to actual plant chemical feed rates.

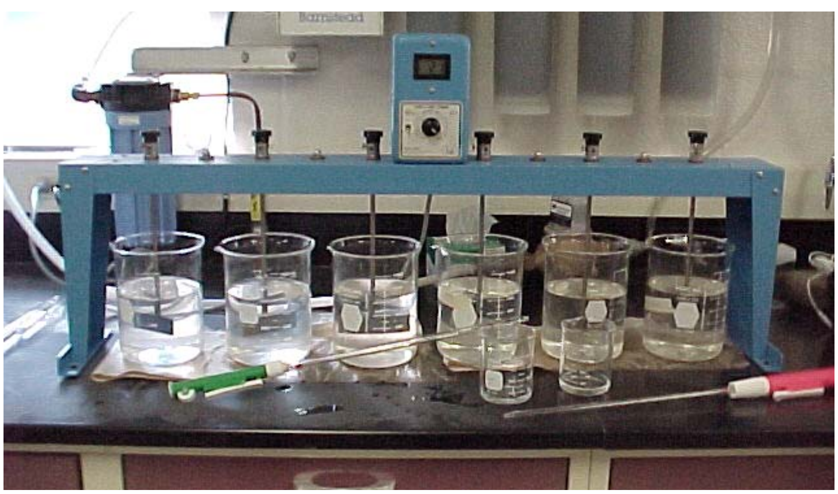

Figure 5.3 Jar Test Stirrer Equipment

- Jar Test Procedure
  - Preparation for test:
    - Jar test apparatus – “Gang Stirrer.”
    - Prepare fresh chemicals.
    - Use test data sheets.
  - Establish dosage range.
    - Compare raw water quality with past records and experience.
    - Bracket expected “best” dosage (i.e., if 15 mg/l of alum is expected to be best, test 5, 10, 15, 20, 25, and 30 mg/l).
  - Establish test sequence.
    - Determine testing required – What combinations of coagulants and coagulant aids will be tested?
    - Change only one variable (i.e., alum dosage only) during each test run.
      - Any noted changes in test results are then due to the change in that single variable.
      - Perform multiple runs if multiple variable changes are necessary.

- Perform Jar Test
  - Collect raw water samples.
    - Temperature of sample being tested should be approximately the same as the water being treated.
  - Add chemicals as quickly as possible.
  - Lower stirring paddles and operate at high speed for a minimum of 15 seconds to represent flash mixing.
  - Reduce speed to represent flocculation basin conditions and mix for a period equivalent to the flocculation basin detention time.
  - Record time required for visible floc formation and describe floc characteristics (i.e., pinhead size floc, flake size floc, etc.).
  - Stop stirrers and allow floc to settle for a period equivalent to the sedimentation basin surface loading rate (settling velocity).
    - Measure turbidity at regular intervals and plot turbidity vs. time curve.
    - Observe and note floc settling characteristics, floc appearance, and clarity of settled water above floc.
  - Measure turbidity of settled water.
  - Plot Turbidity vs. chemical dosage curve.
    - Note that over dosage usually results in a turbidity increase.

- Evaluate Jar Test Results
  - Rate of floc formation.
    - Floc formation should begin shortly after "flash mixing."
    - Floc should gradually clump together during flocculation mixing.
  - Type of floc.
    - Discrete, dense floc particles are usually better than light, fluffy floc and are less subject to shearing (breaking up of the floc).
    - Large, light floc does not settle as well as smaller, denser floc and is subject to shearing - breaking up the floc.
  - Amount of sludge is another consideration.
    - It is desirable to have smaller amounts of sludge. This reduces sludge handling and disposal requirements.
    - Most sludge volume is the precipitates of the added chemicals rather than suspended solids removed.
  - Clarity of settled water.
    - Quantity of floc is not as critical as quality or clarity of settled water.
      - Hazy water indicates poor coagulation.
      - Properly coagulated water contains floc particles that are well formed with clear water between the floc.
  - Floc settling rate.
    - The rate at which floc settles after mixer is stopped is important.
      - Floc should start to settle as soon as mixing stops and should be almost complete after 15 minutes.
      - Floc remaining suspended longer than 15 to 20 minutes is not likely to settle in the plant sedimentation basin and will increase load on the filter.

Startup and shutdown procedures are not a routine operating procedure. Generally it is required when facilities are shut down for maintenance.

Start-up Procedures

General Start-up Procedures

- Check the condition of all mechanical equipment for proper lubrication and operational status.
- Prepare chemicals.
- Collect raw water sample and run jar tests.
- Determine chemical feeder settings and adjust feed rates.
- Start raw water flow.
    - DO NOT allow any untreated water to go through the plant.
        - All raw water must be treated with coagulant.
        - Untreated water can pass through filters without proper removal of color and particulates.

Coagulation/Flocculation Equipment Start-up Procedures

- Start chemical feeders following manufacturer's recommendations.
- Start mechanical flash mixers following manufacturer's instructions.
    - May need to wait until tank or channel is full.
- Start sample pumps following manufacturer's recommendations.
    - Allow sufficient flushing time before collecting samples.
- Start flocculators following manufacturer's recommendations.
    - Observe floc formation and make any necessary changes to the coagulation/flocculation equipment, including chemical feeders, flash mixers, and flocculators.
        - Perform water quality analyses and make process adjustments and required.

Sedimentation Equipment Start-up Procedures

- Check equipment operational status and mode of operation (manual or automatic). Make sure that:
  - Basin drain valves are closed.
  - Basin isolation gates or stop logs have been removed.
  - Weir plates have been laundered, level has been set, and plates are at proper elevation.
  - All trash, debris and tools are removed from basin.
- Test sludge removal equipment operation. Make sure that:
  - Equipment is properly lubricated and ready for operation.
  - Sludge removal equipment is started following manufacturer's instructions.
  - Equipment operation is observed.
- Fill basin to:
  - Proper water depth, and
  - Remove floating debris from water surface.
- Start sample pumps following manufacturer's instructions.
- Perform water quality analyses and make process adjustments as required.
- Operate sludge removal equipment.

Filters Start-up Procedures

- Backwash filter.
- Start filter and filter initial flow to waste.
- Once turbidity is acceptable (less than 0.3 NTU or one-half of raw water turbidity value):
  - Close filter to waste valve, and
  - Open filter effluent valve.
- Monitor filter performance.

Shutdown Procedures

General Shutdown Procedures

- Shut off raw water flow.
- Turn off chemical feeders and clean or flush feed lines as necessary.
- Shut down flash mixer and flocculators as water leaves each process following manufacturer's instructions.
- Shut down sample pumps as water leaves sampling location.
- Waste all water that has not been properly treated.
- Lock out and tag appropriate electrical switches.

Coagulation/Flocculation/Sedimentation Shutdown Procedures

- Stop flow to basin.
  - Close valves.
  - Install gates or stop logs.
- Turn off sample pumps.
- Turn off sludge removal equipment.
  - Shut off and disconnect where appropriate.
  - Check valves for proper position (open or closed).
- Lockout and tag electrical switches and equipment.
- Drain basin if necessary.
  - Be sure water table is not high enough to float the empty basin.
  - Open drain valves.
- Immediately following dewatering, grease and lubricate all gears, sprockets, and mechanical moving parts which have been submerged.
  - Can freeze up (seize up) in a few hours.
  - Avoids repairs and equipment breakage.

Filter Shutdown Procedures

- Remove filter from service.
  - Close filter influent valve.
  - Close filter effluent valve.
- Backwash filter.
- If filter is to be out of service for an extended time, drain water to avoid algae growth.
- Note filter status in operations log.

Sudden changes in source or filtered water turbidity, pH, alkalinity, temperature, chlorine demand of source water, or color are signals that the plant operator should immediately review the performance of the coagulation/flocculation process and the sedimentation process.

Changes in Source Water Quality

Increases or decreases in source water turbidity, alkalinity, pH, or temperature can affect floc formation.

Plant Operators need to:

- Verify effectiveness of chemical addition through visual observations and jar testing.
    - Jar Test indicating higher dosages are required may mean:
        - Increased pH adjustment chemical (alkalinity) dosages may be required.
        - Increased operation of sludge removal equipment may be necessary.
    - Temperature changes may require an adjustment to mixing intensity in flash mix or flocculators.
        - Floc carry-over causes problems in the filtration as the water temperature drops.
- Check filter efficiency.
    - Compare filter influent turbidity with filter effluent turbidity to determine filter removal efficiency.
    - Compare data with recent records.
    - Remember, coagulation, flocculation, and sedimentation determine filtration performance.

Increased Filtered Water Turbidity

Sudden increases in filtered water turbidity could be caused by poor filter performance, indicating a need for backwash and or media replacement. Poor coagulation/flocculation performance is usually the cause.

Plant operators need to:

- Watch for rapid changes in headloss or filtered water turbidity during normal filter operation.
    - Both indicate an upset or failure in the filtration process or pretreatment processes.

- Watch for other indicators of abnormal conditions.
  - Mud balls, media cracking or shrinkage.
    - Possible causes are ineffective or improper backwashing.
  - Excessive media loss, visible disturbance, or media boils during backwash.
    - Possible causes include improper backwash rates and filter underdrain failure.
  - Short filter runs indicated by: mud ball formation, clogging of the underdrain system, and air binding of filter.
    - Possible causes include: increased solids loading, filter aid overdosing, and filtration rates too high.
    - Mud balls in a filter may cause a decrease filter area.
  - Algae on the media and filter box walls.
    - Growth of algae in natural bodies of water is most successfully control by adding copper sulfate.

Record Keeping

Good record keeping is necessary especially during periods of abnormal operation. They provide an historical account of actions taken and may be helpful from a legal or regulatory perspective. “Good records” require plant operators to:

- Document unique conditions for future reference.

- Document actions taken to correct the condition.

Conventional Filtration Process Troubleshooting Table
Source Water Quality

Table 5.1 Source Water Quality Trouble Shooting Table

Source Water Quality Changes		
Identified Problem	Operator Actions	Possible Process Changes
o Turbidity o Temperature o Alkalinity o pH o Color o Chlorine Demand	o Perform necessary analysis to determine extent of change o Evaluate overall process performance o Perform Jar Tests o Make appropriate process changes o Increase monitoring frequency o Verify response to process changes	o Adjust coagulant dose o Change coagulant(s) o Adjust flash mixer intensity (if possible) o Adjust Flocculator mixing intensity o Adjust alkalinity or pH o Add coagulant aid or filter aid polymer

Conventional Filtration Process Troubleshooting Table
Process Quality—Coagulation/Flocculation

Table 5.2 Coagulation/Flocculation Trouble Shooting Table

Coagulation/Flocculation Process Changes		
Identified Problem	Operator Actions	Possible Process Changes
o Turbidity o Alkalinity o PH o Color o Floc Formation	o Evaluate source water quality o Evaluate overall performance o Perform Jar tests o Observe floc • Dispersion • Size • Settling Rate o Verify process performance • Coagulation/Flocculation • Floc Settling o Make appropriate process changes o Verify response to changes	o Adjust coagulant dosage o Change coagulant(s) o Adjust flash mixer intensity (if possible) o Adjust flocculator mixing intensity o Adjust alkalinity or pH o Adjust improperly operating chemical feeders o Add coagulant aid polymer

Conventional Filtration Process Troubleshooting Table
Process Quality—Sedimentation

Table 5.3 Sedimentation Trouble Shooting Table

Sedimentation Process Changes		
Identified Problem	Operator Actions	Possible Process Changes
o Floc formation o Floc Settling o Rising or Floating Sludge o Turbidity or Floc Carryover	o Observe floc: • Dispersion • Size • Strength o Evaluate overall performance o Perform Jar Tests o Make appropriate process changes o Verify response to changes	o Adjust coagulant dosage o Change coagulant(s) o Adjust alkalinity or pH o Adjust flash mixer intensity (if possible) o Adjust flocculator mixing intensity o Add coagulant aid polymer o Change sludge removal frequency o Repair broken sludge removal equipment o Add filter aid polymer

Conventional Filtration Process Troubleshooting Table
Process Quality—Filtration

Table 5.4 Filtration Trouble Shooting Table

Filtration Process Changes		
Identified Problem	Operator Actions	Possible Process Changes
o Headloss increase o Short Filter runs o Media surface sealing o Media cracks, shrinkage o Media will not come clean o Mud balls o Media loss or boils	o Evaluate overall performance o Perform Jar Tests o Make appropriate process changes o Verify response to changes	o Adjust coagulant dosage o Change coagulant(s) o Adjust flash mixer and/or floccculator mixing intensity o Change sludge removal frequency o Decrease or stop filter aid feed o Decrease filtration rate (add more filters) o Adjust backwash rate o Manually remove mud balls (hoses or rakes) o Replace lost media

Unit 5 Exercise

A. Write the 5 components of *Normal* operations of conventional filtration on the lines below.

____

____

____

____

____

B. Circle all of the following which are indicators of abnormal operating conditions.

6. Filter backwash solids
7. Filter control valves
8. Floc
9. Increased filtered water turbidity
10. Increased raw water turbidity
11. Jar Test
12. Media cracks and shrinkage
13. Mud balls
14. Rapid filter headloss increase
15. Short filter runs
16. Turbidimeter

C. True/False Mark the following statements with at "T" for true or an "F" for false.

___ 17. Process performance monitoring is an ongoing activity for plant operators.

___ 18. New analytical equipment never needs calibration.

___ 19. Some plants use air scour during filter backwash.

___ 20. If a diaphragm pump looks to be operating, but the chemical feed is less than expect, suspect a ruptured diaphragm.

___ 21. Equipment maintenance is a routine operating procedure.

___ 22. Good floc formation is an indicator of properly operating coagulation/flocculation equipment.

___ 24. Sludge drying beds reduce the volume of sludge that must be handled or disposed.

___ 25. Media "boils" during filter backwash are an indication of proper cleaning.

___ 26. Raw water alkalinity does not affect the water treatment process.

Unit 5 Key Points

- In a conventional filtration system, a 4-20 mA control signal would be found in the following: an output signal from a turbidity meter to a chart recorder, flow meter signal, and the output signal from a chlorine analyzer.
- The first step taken to remove and clean a primary in-line plant raw water meter is to isolate and depressurize the line.
- Loss of head in a filter represents the resistance to flow as it passes through the filter media.
- A loss of head gauge on a filter is used to measure the drop in pressure through the filter bed.
- If a filter's differential pressure gauge is malfunctioning, the result would be incorrect head loss.
- When a customer complains should not be used as an indicator of when to backwash the filter.
- Once filter media has been replaced, the best way to disinfect a filter is use enough chlorine so that a significant residual remains after 24 hours.
- Mud balls in a filter will most likely cause a decreased filter area.
- Inadequate backwashing causes the filter media to crack.
- Floc carry-over causes problems at a filtration plant as the water temperature drops.
- A chemical that would likely increase head loss on a filter is anionic polymer.
- Growth of algae in natural bodies of water is most successfully controlled by adding copper sulfate.
- Drying beds are used by treatment facilities to reduce the volume of sludge that must be handled and disposed.