

Drinking Water Operator Certification Training



Module 17: Slow Sand Filtration

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Unit 1 – Introduction to Slow Sand Filtration

Unit 1 - Learning Objectives

As a result of this unit, the learner will:

- Receive a comparison of the 4 types of drinking water filtration; including the similarities and the differences of each type.

Historical Use

England

The first documented use of a slow sand filter was in London, England, in 1829.

Europe

Slow sand filters enjoyed wide spread use in England and to a lesser extent in continental Europe in the early and mid 19th Century.

New England

There was limited use of slow sand filters in New England in the 19th Century.

Regulatory Issues

Safe Drinking Water Act (SDWA)

SDWA was a comprehensive set of regulations intended to improve the reliability and safety of public drinking water. One of the most important provisions of the Act was to require the filtration of surface water.

Surface Water Treatment Rule (SWTR)

Of all of the SDWA requirements, the one that had the greatest impact was the SWTR. Although the SDWA affected all water systems, the filtration requirements in the SWTR especially impacted small communities served by surface water sources.

- Slow sand filtration is one of a number of filtration technologies that can permit a water system to comply with the filtration requirements of the SWTR.
- Due to a number of factors, slow sand filtration is usually a feasible alternative for SWTR compliance only for small water systems with relatively high quality source water.

Classifications

There are four general classifications of filtration. The classifications are based on the operating characteristics and the removal mechanism(s) used by the filter. The classifications are:

- Rapid Sand Filtration
- Pressure Filtration
- Mechanical Filtration
- Slow Sand Filtration

Rapid Sand Filtration

Rapid sand filtration is the most common type of filtration used in water treatment.

Mechanical Components

- **Filter Box:** The filter box contains the underdrain piping, a trough for collecting and removing the spent wash water from the filter, and usually a surface agitator.
- **Underdrain:** The underdrain of a rapid sand filter can be constructed of a variety of materials and in a variety of configurations. All of these configurations and materials serve the same purpose—to collect the filtrate and convey it to the clearwell and to distribute the backwash water evenly throughout the filter bed.
- **Surface Agitator:** The surface agitator is also a filter component that can be made in a variety of different styles. The purpose of the agitator is to breakup the material on the very top of the filter bed and enhance the efficiency of the backwash. Most of the material removed through the filter is actually deposited on the top inch or two of the filter bed. The surface agitator breaks up this material more readily than just the backwash water alone. Once this material is broken up the backwash water carries it from the filter bed to waste. Surface agitators can significantly reduce the amount of backwash water required to clean the filter.
- **Filter Media:** Filter media in a rapid sand filter refers to the granular material used to remove particles from the filter influent. Typical examples of filter media in a rapid sand filter include sand (of course), and sometimes a “cap” of coal or granular activated carbon (GAC) placed on top of the sand media layer. Filters with a sand and coal/carbon cap are referred to as dual media filters. Dual media filters can produce a filtrate with lower turbidity at higher flow rates and less head loss than mono media rapid sand filters (head loss will be defined shortly). Some rapid sand filters also contain a thin layer of garnet sand. This layer also tends to improve filter performance. Filters with a layer of garnet sand are referred to as mixed media filters.

Removal Mechanisms

- **Straining:** Straining occurs when particles that are too large to pass through the openings in between media grains are trapped in the filter. Removal by straining is enhanced through the coagulation/flocculation process since the coagulant chemicals used cause small particles to clump together forming larger particles that are more easily strained from the water.



Coagulation (in water treatment) is defined as the process of adding a coagulating chemical such as alum or ferric chloride to water to remove suspended or colloidal compounds. Naturally occurring particles in water tend to repel each other due to the negative charge on their surfaces. The coagulant neutralizes the surface charge of the particles eliminating the tendency for these particles to repel one another. These destabilized particles can then be brought together to form larger particles that will settle much more quickly than the non-destabilized particles.



Flocculation is the process of gently mixing the coagulated water to cause the destabilized particles to collide with one another to facilitate the formation of larger particles.

- **Settling/Sedimentation:** Settling/sedimentation occurs due to the slowing of a particle's velocity as it passes through the filter. If the particles are slowed sufficiently, they will not have enough velocity to travel through the filter.
- **Adsorption:** Adsorption is the primary mechanism of particulate removal in a rapid sand filter. In adsorption, particles attach themselves to the filter media. Although the exact mechanism of the attachment is unknown, it appears likely that there are electrical or chemical attractions between the filter media and the particulate material. Adsorption is enhanced by the coagulation process most likely due to the change in electrical charge or chemical characteristics of the particle's surface.

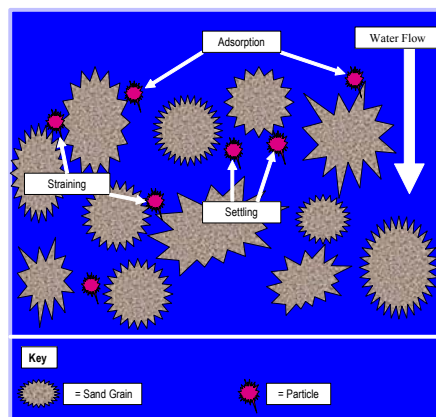


Figure 1.1 Sand Filtration Removal Mechanisms



Conventional filtration is a four step treatment process that consists of the treatment steps of coagulation, flocculation, sedimentation and rapid sand filtration.

Flow Rates

Historically speaking, rapid sand filters have been operated at two gallon per minute per square foot of surface area (gpm/sq. ft.). Over the last 20 or more years, research and real world use has shown that rapid sand filters can be operated at much higher flow rates, as high as 10 gpm/sq. ft. in some cases, without negatively impacting particulate removal. The performance of a rapid sand filter at rates in excess of two gpm/sq. ft. must be closely monitored and the importance of proper chemical pretreatment is magnified. Satisfactory filter performance at the elevated flow rates should be demonstrated in a pilot test prior to use in a treatment plant.

Cleaning

As previously described, the filtration process involves the removal of particles from the filter influent. At some point these particles must be removed from the filter media. This process of cleaning the filter media is referred to as backwashing the filter.



Backwashing consists of reversing the flow of water through the filter causing water to travel from the bottom of the filter to the top. The purpose is to remove or “flush out” particles that have been removed from the influent water during the filtration process. Backwash is done at specific rates in order to most effectively remove the particulate material. Wastewater used for the backwash is collected and removed from the filter.



Head Loss: It requires energy for water to pass through the filter. This energy in a rapid sand filter is usually in the form of head pressure—basically the weight of the water on top of the filter bed. As particles accumulate on the filter they begin to impede the flow of water through the filter. This loss of energy during the filtration process is known as head loss. At some point, the amount of energy being lost through the filter bed approaches the amount of energy available from the head pressure of the influent water. This condition is known as terminal head loss.

- **Backwash Flow Rates:** The backwash flow rate is very significant in a rapid sand filter. A rate is selected in order to expand the filter bed sufficiently to remove as much particulate material as possible without washing the media from the filter. Typical backwash flow rates are 15 to 20 gpm/sq. ft.
- **Surface Agitation/Air Scour:** As mentioned, backwashing efficiency is increased through the use of surface agitators which agitate the top few inches of the filter media during backwash. Some filter designs incorporate the addition of air to the filter bed during backwash. This is known as air scour. Air scour increases the efficiency of the backwash process by vigorously agitating the filter media during backwashing.



Filter-to-waste: At the completion of the backwash cycle, the filter bed may still contain significant amounts of particulate material and the filter will be less effective at removing particles for a short period of time when it is returned to service. For this reason, the water first filtered through a freshly backwashed filter will be of poorer quality than water filtered later in the filter run.

In order to avoid adding this poorer quality water to the clearwell, the filter should be run in filter-to-waste mode. Filter-to-waste involves diverting the filtrate from a freshly washed filter to waste rather than allowing it to enter the clearwell. The amount of time required to run a filter in filter-to-waste mode will vary from plant to plant and filter to filter, but generally should be long enough to allow the freshly washed filter to begin to produce water of similar quality to the other filters at the plant.

Pressure Filtration

Pressure filtration is quite similar to rapid sand filtration although there are a number of significant differences. Pressure filtration is typically used on ground water to accomplish iron and manganese removal or softening. Pressure filtration of surface water is permitted but its effectiveness must be demonstrated by a pilot test prior to its use. Examples of pressure filter applications include:

- Iron Removal
- Manganese Removal
- Ion Exchange Softening

Mechanical Components

- **Pressure Vessel:** In pressure filtration, the filter box of a rapid sand filter is replaced by the pressure vessel. Where the energy to push water through a rapid sand filter is provided by gravity, the energy in a pressure filter is usually provided by a pump or some other mechanism. The pressure vessel is required to conserve this energy so it's available to move water through the filter.
- **Underdrain:** Although it may be of a slightly different configuration, the underdrain of a pressure filter serves the same purpose as the underdrain of a rapid sand filter.
- **Surface Agitator:** While it may not be used in all pressure filters, some pressure filters utilize surface agitators for the same purpose they are used in rapid sand filters.

- **Filter Media:** Media in a pressure filter can be similar to the media in a rapid sand filter; that is, sand and coal or GAC. Diatomaceous earth media can also be used as filtration media. If the pressure filter is used for iron and manganese removal or softening, different filter media is used.



Diatomaceous earth is filter media made from the skeletal remains of diatoms. It is a silica based material that is mined from deposits found in various locations around the world.

Removal Mechanisms

- **Straining:** This mechanism is the same as what was discussed in the rapid sand filtration section of this module.
- **Settling/Sedimentation:** This mechanism is the same as what was discussed in the rapid sand filtration section of this module.
- **Adsorption:** This mechanism is the same as what was discussed in the rapid sand filtration section of this module, although the adsorption mechanism is less effective if chemical pretreatment is not provided.

Flow Rates

The flow rate through a pressure filter is limited to 3 gpm/sq. ft. by PA. DEP. Pressure filters must not be operated at a rate in excess of 3 gpm/sq. ft. unless PA. DEP approved testing has demonstrated acceptable performance at a higher rate.

Cleaning

- **Backwash/Cleaning:** Pressure filters must also undergo periodic backwashing to remove accumulated particles.
- **Head Loss:** Head loss in a pressure filter is the same as head loss in a rapid sand filter. The only difference is the source of the head pressure. As mentioned, a pressure filter obtains its head pressure from a pump or other device made to increase the pressure of the filter influent water.
- **Backwash Flow Rates:** Pressure filter backwash flow rates must **not** be less than 15 gpm/sq. ft.
- **Surface Agitation/Air Scour:** Pressure filters may use these techniques to enhance the efficiency of the backwashing process.
- **Filter-to-waste:** As with a rapid sand filter, a pressure filter must be run in filter-to-waste mode after backwashing.

Mechanical Filtration

Mechanical filtration is significantly different than rapid sand and pressure filtration. Mechanical filtration utilizes some type of manufactured media that strains particulate material from the influent water. These types of filters have some type of fabric or polymeric media that has pore sizes small enough to exclude all of the particles larger than the pore size from the filter effluent. Examples of mechanical type filters are:

- Membrane filtration systems
- Bag filters
- Cartridge filters

Mechanical Components

- **Pressure Vessel:** As with a pressure filter, the energy required to move water through a mechanical filter is usually created by a pump or some other means. A pressure vessel is required to conserve this pressure.
- **Influent, Effluent and Waste Collection Piping:** Mechanical filters come in a wide variety of configurations. All will include influent and effluent piping. In the case of bag or cartridge filters, there is no backwash or cleaning solution to remove from the filter housing. However, membrane filters will create these waste streams and piping must be provided to remove these streams from the filter system.
- **Filter Media:** The media used in a mechanical filter is quite different from the media in a rapid sand or pressure filter. The media is usually made from a fabric or polymeric substance. The media is manufactured to create a pore size that will remove particles larger than the pore size selected.

Removal Mechanisms

- **Straining:** Straining is the only removal mechanism used in a mechanical filter. The pore size of the filter prevents the passage of particles larger than the pore through the filter.

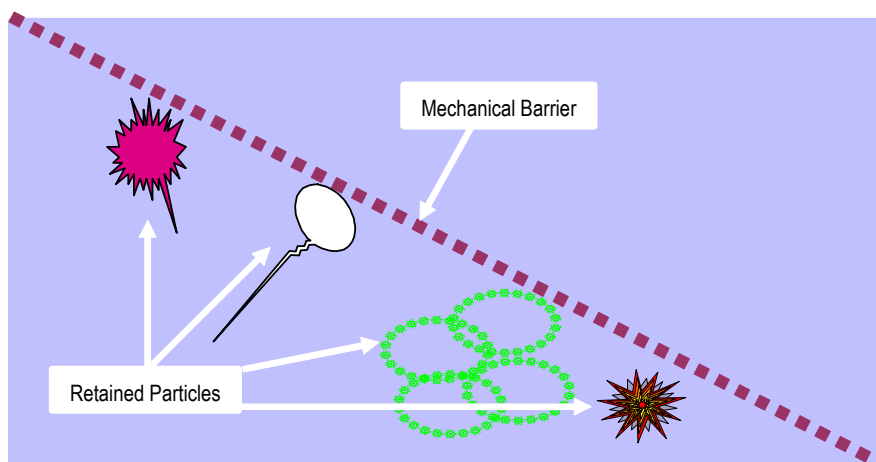


Figure 1.2 Mechanical Filtration—Removal by Straining

Flow Rates

Mechanical filters are operated at flow rates recommended by the manufacturer. The acceptable performance of the filters at the recommended flow rates must be demonstrated during pilot testing.

Cleaning

- **Backwash/Cleaning/Filter Changeout:** Mechanical filters do not undergo backwashing like rapid sand or pressure filters. Bag and cartridge filters are replaced when terminal head loss is reached. Membrane filters do utilize reverse flows to remove particles from the membrane's surface. This process tends to be less efficient than backwashing a rapid sand or pressure filter. In order to compensate for this lower efficiency, membrane systems periodically undergo chemical cleaning. Chemical cleaning typically utilizes chemicals to dissolve the particles not removed during backwashing.
- **Head Loss:** Bag and cartridge filters are replaced with new filters when terminal head loss is reached. Membrane filters undergo reverse flow and/or chemical cleaning to reduce the head loss through the system.
- **Reverse Flow Rates:** Reverse-flow flow rates for membrane systems are determined by the manufacturer based on previous experience and results of pilot testing. As mentioned, bag and cartridge filter systems do not utilize a backwash step.
- **Filter Changeout:** The procedure to determine when and how to change out a bag or cartridge filter is established by the manufacturer.

- **Filter-to-waste:** Since a mechanical filter only strains particulate material from the water and the level of filtration is determined by the pore size, there is no need to ripen the filter through a filter-to-waste step. However, recently permitted bag filter systems have been required to conduct filter-to-waste after filter changeout.

Slow Sand Filtration

Slow sand filtration is quite similar to rapid sand filtration. The chief differences in the two techniques are the vast difference in flow rates and the method used to clean the filter media (no backwashing required).

Mechanical Components

- **Filter Box:** A slow sand filter utilizes a filter box opened to atmospheric pressure just like a rapid sand filter.
- **Underdrain:** The underdrain of a slow sand filter is similar to the underdrain of a rapid sand filter except that the slow sand filter underdrain is not used to distribute backwash water.
- **Filter Media:** A slow sand filter utilizes only sand as its filtration media.

Removal Mechanisms

A slow sand filter utilizes all of the removal mechanisms that a rapid sand filter utilizes: straining, settling/sedimentation, and adsorption. These mechanisms are enhanced by the presence of the schmutzdecke.



Schmutzdecke is German for “dirty skin.” It is the layer that develops on the top of a slow sand filter and is made up of microorganisms that feed on and break down organic material that is trapped on the surface of the filter. As the organic material is broken down, it adds mass to the schmutzdecke which enhances the straining action of the filter.

- **Straining:** Straining in a slow sand filter is similar to straining in a rapid sand filter.
- **Settling/Sedimentation:** Settling/sedimentation is more effective in a slow sand filter than a rapid sand filter due to the presence of the schmutzdecke and the extremely low flow rates through the filter.
- **Adsorption:** The schmutzdecke enhances the adsorption mechanism in slow sand filters.



We know the Schmutzdecke is commonly referred to the biological growth area of the filter that provides most of the filtration process. Because of this biological system, a slow sand filter does not require coagulation for the filter to work and demands less chemical usages than a conventional filtration because of this biological filtration system.

Flow Rates



Flow Rates: Flow rates of 0.04 to 0.08 gpm/sq. ft. are common in slow sand filters. Pilot testing on the raw water to be filtered should be conducted to establish the suitability of slow sand filtration for the source water and to establish the maximum allowable flow rate.

Cleaning

- **Media Cleaning:** Unlike rapid sand or pressure filters, a slow sand filter is not backwashed. Cleaning is accomplished by scrapping off a thin layer of the schmutzdecke to remove the material clogging the filter bed.
- **Head Loss:** Although a slow sand filter develops head loss like any other type of filter, it is a loss in the rate of flow through the filter that dictates when media cleaning should be conducted.
- **Scraping:** Since a slow sand filter is not backwashed, it is necessary to manually remove the top layer of the schmutzdecke to restore the desired flow rate. This process is known as “scraping” the filter. The scraped material is removed from the filter and discarded or cleaned and recycled.
- **Media Replacement:** As more and more media is removed during the scraping process, it becomes necessary to add sand to the filter. There are a number of techniques to do this. They will be discussed in later units.
- **Filter-to-waste:** An adequate filter-to-waste cycle is important for the proper operation of a slow sand filter. The filter-to-waste cycle can be much longer than a filter-to-waste cycle in a rapid sand filter, lasting days or even weeks. This is necessary to allow the schmutzdecke to reestablish itself on the cleaned filter bed.

Summary Comparison of Filtration Techniques

The following table is presented as an aid in understanding the fundamental differences in the major classifications of filter types.

Table 1.1 Comparison of Filtration Techniques

Type of Filter	Removal Mechanisms	Rate of Flow	Cleaning
Rapid Sand	Straining, Adsorption, Settling	2 – 10 gpm/sq. ft.	Reverse flow, surface and/or air agitation
Pressure	Straining, Adsorption, Settling	3+ gpm/sq. ft.	Reverse flow, surface and/or air agitation
Mechanical	Straining	Determined by manufacturer/piloting	Reverse flow and chemical cleaning (membranes) or replacement of filter media (bag and cartridge filters)
Slow Sand	Straining, Adsorption, Settling	0.04 to 0.08 gpm/sq. ft.	Scraping of schmutzdecke

CRITERIA FOR DETERMINING THE SUITABILITY OF SLOW SAND FILTRATION

Given the many different types of filtration techniques, the question of which type to use for a particular application remains. The decision relies on two things.

- Which filtration techniques are capable of producing a finished water that complies with the pertinent requirements of the SDWA?
- Of those filtration techniques, which will do so in the most economic manner?

Four criteria can be examined to help answer the above questions. These criteria are:

- Source of the water supply.
- The quality of the source water.
- The population of the community to be served.
- The availability of relatively large tracks of flat land.

Source of Supply

The SWTR requires the filtration of:

- Surface water
- Ground water under the direct influence of surface water

Slow sand filtration is one option for satisfying this requirement.

CRITERIA FOR DETERMINING THE SUITABILITY OF SLOW SAND FILTRATION

Source Water Quality

Slow sand filtration is not a good choice for poorer quality surface waters. These waters tend to be less filterable and usually require some type of chemical pretreatment prior to filtration. Slow sand filtration facilities do not typically include the provision for chemical pretreatment. The general guidelines for determining if a source water is suitable for slow sand filtration is presented below.

Table 1.2 Source Water Quality Guidelines for Slow Sand Filters

Parameter	Turbidity	Colloids	Total Coliform	Color	Algae
Suggested Limit	< 10 Nephelometric Turbidity Units (NTU), (or lower if turbidity is caused by fine colloids)	Low levels	< 800 cfu/100 ml	< 5 Color Units (CU)	Low levels only

System Size

Given the extremely low flow rates in a slow sand filter, a significant amount of land area is required to produce fairly modest amounts of water. For this reason, slow sand filtration is most suitable for systems serving relatively small populations.

- **Population Served:** The required filter capacity can be calculated from the population to be served and the projected use per person. A figure of 100 gallons per person per day has been used to calculate the required system capacity. Allowances for industrial or commercial use in excess of the population to be served must be made.
- **Future Growth:** If the system capacity were based solely on the current population of the region to be served it may be inadequate in the future. It is vitally important to factor in any projected population growth for approximately 20 years in the design of a slow sand filter facility.

Available Space

If the source water is of acceptable quality and the population projections indicate that the use of a slow sand filtration system is feasible, the amount of area required by the filter can be calculated.

- **Flow Rates:** The acceptable filter flow rate is usually established by on-site piloting.
- **Area Required:** The required filtration area can be calculated from the allowable flow rate and population to be served. Keep in mind that the regulatory agency will most likely require system redundancy requiring that two filters of equal size be constructed so that system operation will not be affected if one of the filter units is out of service for cleaning or maintenance.

CRITERIA FOR DETERMINING THE SUITABILITY OF SLOW SAND FILTRATION

- **Characteristics of the Ground:** Once the area required has been calculated, a location close to the source and of sufficient area must be located. Major earth moving activities will greatly increase the cost of the system.



Calculate the area required for a slow sand filter if it is to serve a population of 1,500 and pilot testing has indicated that the filter should be operated at a flow rate of 0.04 gpm/sq. ft. Use a projected consumption of 100 gpd per person and assume that there will be no industrial or commercial users.



Exercise

Unit 1 – Exercise

Multiple choice:

1. Which of the following are filtration techniques? (*Choose all that apply*)
- a. rapid sand
 - b. pressure
 - c. mechanical
 - d. chlorination
 - e. slow sand

Fill in the blank:

2. Label the following as “R” for rapid sand filter and “S” for slow sand filter.

- _____ flow rates of 2 gpm/sq. ft. or higher
- _____ during cleaning, the top layer of the schmutzdecke is scraped from the top of the filter
- _____ uses backwashing to clean the media (water flow is reversed through the filter and the backwash waste water is removed from the filter)
- _____ mechanical components consist of filter box, underdrain, surface agitator, and filter media
- _____ mechanical components consist of filter box, underdrain, and filter media
- _____ flow rates of 0.04 to 0.08 gpm/ sq. ft. are common

True or False: Label the following statements as “T” for True or “F” for false:

- 3. _____ Pressure filtration is typically used on ground water to accomplish iron and manganese removal or softening.
- 4. _____ Slow sand filtration is a good choice for poorer quality surface waters
- 5. _____ The first documented use of a slow sand filter was in England in 1492.
- 6. _____ In pressure filtration, a pump or other mechanism pushes the water through the filter.
- 7. _____ The chemical use in slow sand filtration plants is much lower than in conventional filtration plants because biological filtration is used..
- 8. _____ Rapid sand filters may be preceded by the treatment processes of coagulation, flocculation, and sedimentation.
- 9. _____ Slow sand filters need to be backwashed on a periodic basis.

Fill in the blank:

10. Label the following as “M” for mechanical filtration, “R” for rapid sand filtration, and “S” for slow sand filtration.

- _____ straining, sedimentation, and adsorption are enhanced by the schmutzdecke
- _____ examples are bag and cartridge filters
- _____ typical example of filter media includes sand, sometimes a “cap” of granulated activated carbon, and sometimes a thin layer of garnet sand
- _____ media is usually made from a fabric or polymeric substance
- _____ the most common type of filtration used in water treatment
- _____ undergo periodic reverse flow chemical cleaning; whole filter is replaced when terminal head loss is reached
- _____ filter-to-waste cycle can last days or even weeks

Unit 1 - Summary



Key Points:

- Slow sand filtration differs from rapid sand filtration in the vast differences in flow rates and the method used to clean the filter media (no backwashing)
- Slow sand filtration is not a good choice for poorer quality surface waters, since these types of waters tend to be less filterable and usually require some type of chemical pretreatment prior to filtration (and slow sand filtration facilities do not typically include the provision for chemical pretreatment).
- Slow sand filtration does not require coagulation for the filter to work properly.
- The chemical use in slow sand filtration is much less than in a conventional filtration system because biological filtration is used.
- The “Schmutzdecke” is commonly referred to as the biological growth area of the filter that provides most of the filtration process.

Unit 2 – Plant Components and Design Considerations

Unit 2 - Learning Objectives

As a result of this unit, the learner will:

- Be introduced to the components of a slow sand filter.
- Receive information on the hydraulic controls and performance monitoring devices used to maintain the functioning of a slow sand filter.
- Be aware of the available process modifications that can be made to source water.

Although a slow sand filter is a relatively simple treatment process, there are certain components that are critical for effective operation. These items are discussed below.

Cover

Leaving the surface of a slow sand filter exposed to the atmosphere can result in negative consequences:

- Sunlight can encourage the growth of algae which can cause severe headloss problems.
- Sub-freezing air temperatures can cause ice to form on the surface of the filter.
- Wind can cause debris to accumulate on the filter surface.
- Wild life contamination.

For these reasons, as well as for security concerns, slow sand filters typically should be covered in some manner. While covering the surface of a slow sand filter may seem to be a relatively easy task, it can be expensive because:

- Slow sand filters can cover acres of ground.
- Access to the filter surface must be maintained.

Available Space

As mentioned previously, slow sand filters can require large amounts of space to construct. The area required for the filter, support structures, and equipment often requires acres of ground. In addition, it is not enough to have the adequate space available; the location must also be close to the source water and be reasonably accessible.

Access

Although slow sand filters have the advantage of not requiring much daily operational attention, there are certain maintenance/cleaning activities which require access to the filter. One of these activities is cleaning of the filter bed. This process is quite labor intensive, and depending on the size of the facility, can require placing a number of individuals or even mechanical equipment in the filter itself. Also, the removal of a portion of the schmutzdecke during cleaning creates a significant amount of material that must be removed.

In order to accommodate these activities, an easy method to enter and exit the filter must be provided. Manholes or other types of access ports may be sufficient when manual cleaning of the filter is possible. However, if mechanical equipment, such as garden tractors, all terrain vehicles, or lawn tractors are to be used, access must be provided so that the equipment can be driven in and out of the filter. To accomplish this, slow sand filters are often built with ramps or other accommodations to provide easy access to the filter bed.

Overflow

The height of the influent water on top of a slow sand filter is limited by a number of factors including the height of the filter tank itself and the maximum allowable filter flow rate. In order to prevent the height of the filter influent from exceeding this maximum allowable height, a filter overflow must be provided. This is significant from a facility requirement standpoint because, although the overflow is probably not intended for regular use, it will be active at times and when it is, the water must be carried away from the filter and disposed of or discharged to a receiving stream. Therefore, provisions must be made to convey overflow water from the filter and to obtain the necessary permits to discharge the overflow to the receiving stream.

The heart of a slow sand filter plant is the filter itself. The filter can be constructed of a variety of materials and configured as a:

- Circle,
- Square, or
- Rectangle.

The choice of configuration and materials is dictated, to a large extent, on the required size of the facility.

Sizing

As mentioned in the System Size section of the previous unit, the required area of the filter bed is influenced by a number of factors:

- ❶ The desired production capacity of the treatment facility.
- ❷ Flow rates and the quality of the source water to be filtered.
- ❸ The need for redundancy when one unit is out of service.

Materials of Construction

The filter tank can be constructed of a variety of different materials.

- Most facilities construct the filter tank on site from poured concrete which may or may not be reinforced with steel.
- It is also possible to construct the tank by forming earthen berms and lining them with a water tight membrane.

Smaller installations usually use the following materials:

- Prefabricated fiberglass
- Steel
- Reinforced concrete

Independent Chambers

As mentioned previously, the slow sand filter must have redundant components to assure that the rated plant capacity can be maintained with one unit out of service. This can be accomplished by constructing two or more completely independent slow sand filters or by constructing the filter with two or more independent chambers. Two or more independent chambers is the more economical method, however, it is important to remember that duplication of any components shared by the individual chambers must be provided if the failure of that component would prevent the proper operation of the filter. In other words, if a component failure would prevent the proper operation of the filter, then it must be provided in duplicate.

The underdrain of a slow sand filter serves much the same purpose as the underdrain in a rapid sand filter. There is, however, one notable exception; the underdrain of a slow sand filter only collects the filtrate, it does not distribute backwash water since a slow sand filter does not undergo backwashing.

Materials

The underdrain can be made from a variety of different materials.

- Slotted or perforated PVC pipe.
- Wire wound “well screen” pipe.
- Perforated plates.

Arrangement

If perforated pipe is used, the underdrain is usually laid out in a lateral/header arrangement. The laterals of perforated pipes are laid parallel to one another in the bottom of the tank. The laterals collect the filtrate and it then flows to the header and into the clearwell or reservoir.

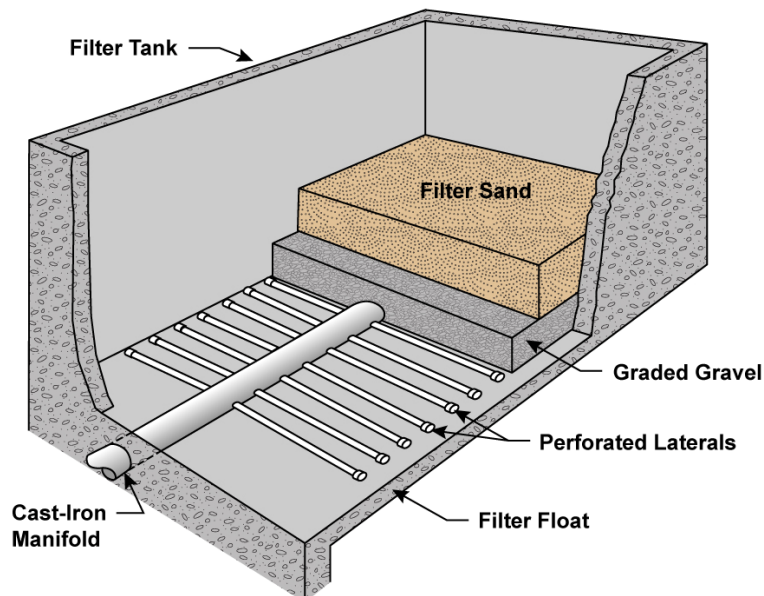


Figure 2.1 Underdrain

The media in a slow sand filter consists of:

- Support gravel
- Filter sand

These two components provide for the filtration of the influent water and represent the heart of the filtration process.

Gravel

As is the case in a rapid sand filter, the gravel in a slow sand filter serves two main purposes. It supports the sand media which is placed on top of it preventing the sand from traveling into the underdrain system and it helps to evenly distribute the water when the filter is being filled.

Gravel used as filter media usually consists of a number of different layers that are placed on top of the underdrain. The gravel is placed by laying down the largest gravel first then laying smaller gravel in layers on top of each other. When the gravel has been properly placed the smallest layer on top will prevent the sand from migrating into the underdrain system.

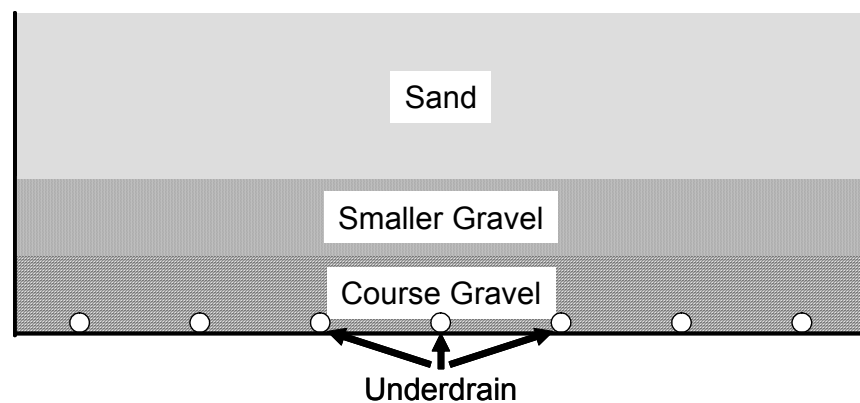


Figure 2.2 Media Placement

Sand

Sand is the “active ingredient” in a slow sand filter. That is, it is the media that actually accomplishes the removal of the suspended material.

The sand used in a slow sand filter is not just the sand that you would throw in a child’s sandbox. Filter sand is specifically sized and is composed almost exclusively of silica. Silica sand is used because it is:

- Durable and not prone to cracking or breaking down
- Readily available
- Inexpensive

Sand measurements include:



Effective Size (ES): The effective size of filter media is the diameter of the filter grain for which 10% percent of the total grains are smaller and 90% of the total grains are larger (calculated on a weight basis). In other words, the effective size is the size where only 10% of the sample is a smaller size. This is referred to as D10. Effective size is determined by passing a known amount of filter media through a series of progressively smaller sieve sizes and weighing the amount of media retained on each sieve.

For a slow sand filter an ES of 0.15 to 0.35 millimeters is generally recommended.



Uniformity Coefficient (UC): The uniformity coefficient is defined as the ratio of the sieve size where 60% of the filter media is smaller (referred to as D60) to the sieve size where 10% of the filter media is smaller (D10). So UC is D60 divided by D10.

For a slow sand filter an UC of 1.5 to 3 is generally recommended.



How would you calculate the ES and UC of filter sand given the following information:

Total weight of sample: 100 grams

Sieve Size (millimeter)	Weight of retained filter sand (grams)
0.55	0
0.50	0
0.45	2
0.40	3
0.35	5
0.30	30
0.25	20
0.20	20
0.15	10
0.10	5
0.05	5

To calculate the ES, you select the sieve size through which 10% (by weight) of the sample is smaller (D10).

Remember: To calculate the ES, you select the sieve size through which 10% (by weight) of the sample is smaller (D10). Starting with .55 millimeter, add up the weights retained until you reach 90 (since we used 100 grams as a starting weight). Now the students are going to be tempted to say 0.10 mm. But remember, it is the sieve size that retains 90% so it is 0.15 mm.

To calculate the UC, you divide the sieve size through which 60% (by weight) of the sample is smaller by the sieve size through which 10% (by weight) of the sample is smaller (D60/D10).

Remember: The UC is the ratio of the sieve through which 60% (by weight) of the sample is smaller to the sieve size through which 10% (by weight) of the sample is smaller (D60/D10). The latter number we already know, its actually the Effective Size—in our example it is 0.15 mm. The 60% is a little tricky. It is the sieve size that retains 40% of the media (remember if it passes 60% it must retain 40%). The sieve size that retains 40% is 0.30 mm. Divide 0.30 by 0.15 and you get 2. So the UC for this example is 2.

After the proper media has been selected, the amount of sand to be placed in the filter must be determined. Slow sand filters typically contain 30 – 36 inches of sand only. (Generally, a rapid sand filter will contain between 24 and 36 inches of sand, sand and anthracite, or sand and GAC.) Various sand ESs, UCs, and depths can be evaluated during pilot testing.

Prior to use of the sand and gravel, it is important to verify that the media is free of dirt, clay, or organic material. If this material is not removed from the media prior to placing it in the filter, it could migrate through the filter bed and contribute to excessively high filter effluent turbidity. Since a slow sand filter is not backwashed, it is not possible to clean the media after it has been placed in the filter bed.

Washing debris from sand and gravel can be an extremely laborious process. For this reason, it may be advisable to obtain sand and gravel filter media that has been already cleaned by the media supplier. Clean material may be more expensive, but the savings in labor costs may make up the difference in price.

Even though a slow sand filter is considered relatively “low tech,” there are certain filter operational control and monitoring devices to assure the proper operation of the filter. These include:

- Valves
- Drains
- Gauges
- Flow meters
- On-line analytical devices

Valves and Drains

A slow sand filter contains many different types of valves and drains used to control the operation of the filter. Not all slow sand filters contain the following components, but the function of the most common are described below.

- **Influent valve** is used to control the influent flow to the filter. It can be used to stop flow to the filter for maintenance.
- **Supernatant drain valve** is used to control the level of water in the filter tank. It can be used to rapidly dewater a filter for maintenance.
- **Filter bed drain** is used to drain the filter through the filter bed prior to maintenance. Using the filter bed drain will drain the filter slowly.
- **Filter-to-waste valve** is used to run the filter in its “normal” mode without adding the filtrate to the clearwell or finished water reservoir. Filter-to-waste is typically used in a slow sand filter during filter ripening after the filter bed has been scraped.
- **Backfilling valve** is used to re-water a filter after it has been drained for maintenance. If a drained filter is refilled from the top of the filter, air will be trapped in the bed resulting in air binding of the filter. An air-bound filter will not operate properly; it will experience short runs, high head losses, and poor quality filtrate.
- **Treated water waste valve** is used to waste filtered water when system demand is less than filter production. It is usually preferred to waste unneeded water rather stopping the filter during periods of low demand and restarting the filter as demand increases.

- **Valve to clearwell** is used to isolate the filter during maintenance. It could also be used to control the rate of flow through the filter but this is not a typical operating method.
- **Clearwell overflow** is used to recycle excess filtered water to the head of the filter in a continuously operated filter. Care must be taken in determining the placement of the overflow line so as not to permit a cross connection between raw and filtered water.
- **Rate of flow controller** is used to control the flow rate through the filter. There are two rate of flow control strategies, effluent flow control and influent flow control. The location of the rate of flow controller determines which mode of flow control is used. The mode of action of these two flow control strategies will be discussed in detail in Unit 3: Filter Operation.

Monitoring Devices

A slow sand filter must be monitored to verify that it is operating properly and producing a good quality filtrate. A variety of monitoring devices are used to verify proper filter operation.

- **Flow meters** are used to monitor the flow through the filtration process. Depending on the mode of flow control employed, the flow meter will be placed on either the influent or effluent line.
- **Head loss gauge** is used to monitor the head loss through the filter bed. Since the amount of head loss determines when a filter needs cleaned, a head loss gauge is used by the operator to determine when a filter must be taken out of service for cleaning.
- **Staff gauges** are used to allow the operator to monitor sand and water levels in the filter.
- **Sight tubes** are used to allow the operator to see the level of the supernatant in the filter or the water level in the clearwell.
- **Turbidimeters** can be used to measure the turbidity of the filter effluent and perhaps filter influent water. The filter effluent turbidimeter is the single most important piece of monitoring equipment to verify proper filter operation.
- **Chlorine analyzer** is not technically part of the slow sand filter itself. However, it is a very important monitoring device to verify the safety of the water exiting the treatment facility.

The outlet chamber serves a critical function in a slow sand filter. The outlet chamber prevents:

- Accidental dewatering
- Air binding

Filter Dewatering

Filter dewatering is prevented by the construction of the outlet chamber. The outlet chamber receives filter effluent and has a weir on the discharge side of the chamber. The top of the weir is placed slightly above the top of the filter bed. Since the water level behind the weir is slightly higher than the top of the filter bed, (even if the filter influent is shut off and the effluent valve is left open) the influent water can only drain to the level of the weir in the outlet chamber. This configuration eliminates the possibility of filter dewatering.

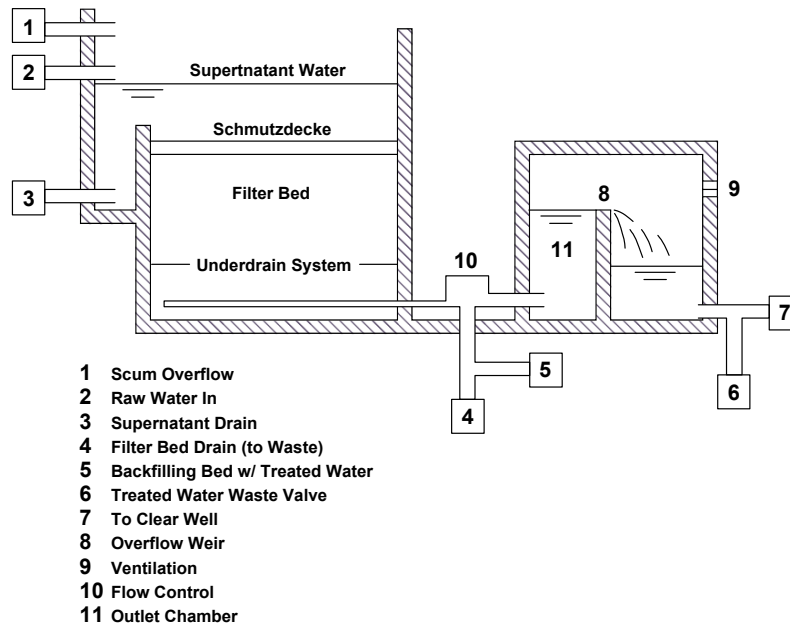


Figure 2.3 Cross Section of a Slow Sand Filter

Air Binding

If an outlet chamber were not used in a slow sand filter and the filter effluent were allowed to flow directly to a clearwell or reservoir, air binding of the filter could occur. This could happen if the level of the finished water storage facility dropped below the level of the filter effluent and the filter flow was stopped. Air could migrate through the filter effluent and move into the filter bed. If this occurs, the air could become trapped in the filter and the filter could become air bound.

After filtration, the filtered water is stored prior to delivery to the public. It is stored to:

- ① Provide time for disinfection.
- ② Provide a buffer between the filter's steady production rate and the varying system demands.

When sizing a storage facility, it is necessary to determine the capacity required according to system use and disinfection requirements.

Capacity Determination

The required capacity of the storage facility is determined by the need to:

- Provide detention time for disinfection
- Meet peak daily demands
- Satisfy fire protection requirements
- Provide a reserve capacity in case of a disruption in water production

Although we will not address all of the factors necessary to conduct this calculation, the storage facility should provide at least 12 hours reserve capacity.

Disinfection

The finished water holding tank must be large enough to provide adequate detention time to ensure that the finished water has been properly disinfected. Adequate disinfection is determined by conducting CT calculations.

Wasting water from the holding tank can be a problem. If the overflow is to be discharged to a receiving stream, it must be monitored and processed in a way that complies with pertinent regulations. If the overflow point is after the point where chlorine is added to the process, steps must be taken to dechlorinate the water prior to discharge.

Most of the previously described equipment (i.e. valves, drains, gauges, flow meters, on-line analytical devices, and storage facilities) are not necessarily unique to slow sand filters and can be found on rapid sand or pressure filters. However, the equipment used when cleaning the sand bed or reclaiming the removed sand media is unique to a slow sand filter.

The cleaning process will be described in detail in Unit 3, but the equipment used will be mentioned here. The cleaning process involves scrapping the top layer of sand from the filter bed. This can be accomplished with:

- Shovels
- Rakes
- Wheelbarrows

Large installations might utilize mechanized equipment like:

- Garden tractors with dump carts
- Quads
- “Bob-cats”
- Backhoes
- Dump trucks

Sand Ejectors

Removing sand from or placing sand in a filter is a labor intensive effort. In order to remove sand from a filter it is normally shoveled into some type of cart or dump truck and removed from the filter. An alternative to this is the use of a sand ejector. An ejector utilizes water flow to create an eductor effect. Sand is shoveled into a hopper and the water flow carries the sand out of the filter. This method can also be used to resand the filter. Rather than carry bags of sand into the filter, the ejector can be used to deliver the sand into the filter.

Sand Washing Unit

Sand is a major capital expense for a slow sand filtration plant—so much so that some larger facilities have sand washing equipment. This equipment is used to clean the sand that has been removed from the filter. This cleaned sand is suitable for reuse as filter media and saves the facility the cost of purchasing replacement sand.

Sieve Analysis

If sand is to be cleaned and recycled, it is important to verify that it is still of acceptable ES and UC. This is done by conducting a sieve analysis. In order to conduct a sieve analysis, the facility must have sieves and an accurate method to weigh the media.

As has been discussed, slow sand filtration is not suitable for all surface water sources. However, in some cases, utilization of pretreatment options can alter source water characteristics sufficiently to allow for the use of slow sand filtration.

Screening installed at the intakes structures will prevent debris or minimize large objects from entering with the raw water.

Presedimentation Basins/Raw Water Reservoir

If source water is of marginal quality, it may be possible to improve it by allowing it to settle in a presedimentation basin. A presedimentation basin would be especially useful in situations where the source water is of acceptable quality the bulk of the time, but sometimes deteriorates due to turbidity spikes associated with storms or runoff events. In these situations, a presedimentation basin would allow the excessive turbidity to settle prior to flowing to the filter.

Raw water reservoirs tend to be larger than presedimentation basins, but they serve a similar function. A presedimentation or raw water reservoir could be used if the source of supply was intermittent in nature. The raw water reservoir can be sized to provide water to the filter even during times of low stream flow.

A word of caution about the use of presedimentation basins or raw water reservoirs, these structures, by their nature, provide an ideal environment for the growth of algae. As previously mentioned, the presence of algae in source water can have a significant negative impact on the operation of a slow sand filter. It is important not to create an algae problem when trying to address source water quality or quantity issues.

Roughing Filters

As an option to the use of a presedimentation basin, it may be possible to utilize roughing filters prior to the slow sand filter. A roughing filter is a gravel packed compartment through which the source water flows prior to entering the slow sand filter. A roughing filter may be capable of reducing the loading of suspended solids or colloids before slow sand filtration. This is a viable option only if the suspended solids or colloids have characteristics which make them removable by a roughing filter. Finely divided colloids or suspended solids may be too small to be removed by a roughing filter.

Nutrient Addition

The schmutzdecke forms by bacteria consuming some of the organic material present in the filter influent. If there are insufficient nutrients present in the influent, the formation of the schmutzdecke can be negatively impacted.

There are source waters that naturally contain very low levels of nutrients. Also, low temperature source water may contain minimal amounts of the necessary nutrients. These limitations can be overcome, in some cases, by the addition of nutrients. These nutrients are primarily nitrate and phosphate.

Nutrient addition may also be used to shorten the time required to ripen a slow sand filter. As you may recall, the ripening period of a slow sand filter can be quite long, lasting days or even weeks. This ripening period is required to allow the schmutzdecke time to develop. In some instances, the addition of nutrients may decrease the amount of time for the filter to develop a satisfactory schmutzdecke.

**Exercise****Unit 2 – Exercise****Multiple Choice – Choose the best answer unless otherwise noted:**

1. Which of the following is **not** a requirement to consider when determining the feasibility of constructing a slow sand filter?
 - a. cover for the filter
 - b. location of the closest sand manufacturer
 - c. enough available space
 - d. site with good access
 - e. ability to discharge overflow water

2. Which of the following are pretreatment modifications that can be used to improve a source water quality to make it suitable for slow sand filtration? (*Choose all that apply*)
 - a. roughing filters
 - b. presedimentation basins
 - c. sand washing
 - d. nutrient addition for schmutzdecke formation

3. Which of the following is **not** a monitoring device on a slow sand filter?
 - a. sight tube
 - b. turbidimeter
 - c. air binding tube
 - d. flow meter
 - e. loss of head gauge
 - f. chlorine analyzer

4. The sand in a slow sand filter is composed almost exclusively of _____.
 - a. calcium
 - b. mica
 - c. silica

5. A slow sand treatment storage facility should provide at least _____ hours of reserve capacity?

- a. 12
- b. 10
- c. 8

6. A slow sand filter does not undergo _____ .

- a. backwashing
- b. draining for maintenance
- c. cleaning

Matching – Match the slow sand filter parts with the corresponding description:

- | | |
|---------------------------------------|--|
| _____ A. Underdrain | 1. Controls flow rate through the filter |
| _____ B. Rate of flow controller | 2. Consists of support gravel and filter sand |
| _____ C. Filter Effluent Turbidimeter | 3. Helps the operator determine when a filter needs cleaned – monitors head loss |
| _____ D. Head loss gauge | 4. Collects the filtrate |
| _____ E. Slow Sand Filter Media | 5. Single most important piece of monitoring equipment to verify proper filter operation |

Unit 2 - Summary



Key Points:

- Slow sand filters can require large amounts of space to construct.
- Leaving the surface of a slow sand filter exposed to the atmosphere can result in algal growth, surface ice formation, surface debris accumulation, and wildlife contamination.
- Screens at the intake structures will minimize entry of large objects.
- Sand is the media in a slow sand filter that actually accomplishes the removal of suspended materials; the gravel acts as support and provides even water distribution during filling.
- Not all surface source waters are suitable for slow sand filtration; in some cases, pretreatment options such as presedimentation basins, roughing filters, and nutrient addition can alter source water sufficiently to allow for the use of slow sand filtration..
- Silica sand of a specific size is used in slow sand filters because it is durable and not prone to cracking or breaking down, readily available, and inexpensive.

Unit 3 – Filter Operation

Unit 3 - Learning Objectives

As a result of this unit, the learner will:

- Review the two operational modes for a slow sand filter.
- Receive a description of the various methods for cleaning a slow sand filter.
- Be able to identify the cyclic influences that may impact the operation of a slow sand filter.
- Using given information, calculate the filter loading rate of a slow sand filter.
- Be able to state the maximum allowable turbidity that can be produced by a slow sand filter.

There are two methods which can be used to control the flow of water through a slow sand filter. They are:

- Influent flow control
- Effluent flow control

As the names suggest, the difference between the two methods is the location that flow is controlled in the filter system.

As previously mentioned, it is desirable to maintain a constant flow rate through the filter. Constant rate filtration tends to produce the best and most consistent quality effluent. As the filter operates, the head loss through the system increases and if no adjustments are made, the flow through the filter will become reduced. In order to compensate for the increase in head loss, flow can be maintained by either increasing the available head to the top of the filter or decreasing the head loss through the system. Increasing the available head is the method used in influent flow control and decreasing the head loss in the system is the method used in effluent flow control.

Influent Flow Control

As mentioned, influent flow control uses increasing head pressure to maintain a steady flow rate as the filter head loss increases. This is accomplished by allowing the level of water on top of the filter bed to increase as the filter head loss increases.

As the filter run time increases and the head loss through the filter increases, the operator compensates by opening the influent valve. By opening this valve, more water enters the filter and the level on top of the filter increases. Allowing this water level to increase increases the head pressure on top of the filter. This increase in head pressure offsets the increase in head loss through the filter and allows the filter to operate at a steady flow rate. With influent flow control, there are two possibilities that will lead to the cleaning of the filter bed:

- ❶ It is possible that, at some point, the influent valve will be opened fully and not be able to fully compensate for the head loss through the filter. At this point, cleaning of the filter bed is necessary.
- ❷ The more likely scenario is that the valve will continue to open and the head water level will continue to increase to the point where influent water will begin to flow out of the filter influent overflow. The filter can continue to operate if there are provisions in place to dispose of the water traveling through the overflow. However, it is likely that the head loss through the filter will soon exceed the amount of head available. At this point, cleaning of the filter bed will be necessary.

- By observing the water level on top of the filter the operator can get an idea as to the amount of head loss through the filter and form an estimate as to when cleaning will be necessary.
- However, a more accurate way to determine this is through the use of an influent head gauge. An influent head gauge is nothing more than a local or remote readout of the pressure of the head water on top of the filter bed. By watching this value increase day by day, the operator can estimate the amount of time left until cleaning will be required.
- Most filters utilize a head loss gauge which measures the head pressure at the top and the bottom of the filter bed. Criteria for filter bed cleaning are usually based on the head loss through the filter bed, not on the influent head pressure.

Effluent Flow Control

The alternative to increasing the head pressure on top of the filter bed is to reduce the head loss through the system.

Head loss is created primarily by the material removed as the water is filtered. However, piping, valves, and other items also create head loss. In an effluent flow control filter, an effluent valve is used to control the effluent rate of flow. This valve closes or opens to maintain the desired flow rate. As this valve opens or closes the head loss through the valve increases or decreases. As head loss through the filter bed increases, the effluent valve opens slightly and head loss through the valve decreases. The net result of this is that the overall head loss in the system remains relatively constant and therefore the flow remains at the desired rate.

In order to remain at a constant flow rate the head pressure on top of the filter should be held at a constant level. If the influent flow is significantly more or less than the effluent flow the level on top of the filter will fluctuate and the available head pressure will change. This problem is solved by the use of a float valve or level sensor to control the flow rate into the filter. The valve or sensor detects the elevation on top of the filter and modulates the influent valve to maintain a constant level of water on top of the filter bed.

Effluent flow control filters also utilize an influent overflow to prevent flooding of the filter if excess influent water is added to the filter. The elevation of the filter influent overflow determines the maximum amount of head available to the filter.

There are times when the filter must be taken off-line for cleaning, resanding, and/or maintenance. If the filter must be drained, as is the case for any of the above conditions, there is a certain procedure that must be followed in order to put the filter back on line properly. These procedures also apply when starting a filter for the first time.

Scraped or Resanded Filter

The process of cleaning the filter bed involves draining the filter in order to permit the necessary equipment and workers to enter the filter to remove the top layer of the schmutzdecke. After the cleaning has been completed, the depth of the remaining sand is measured and the need to add sand to the bed is determined. If the filter requires additional sand, the filter bed is left dry until the resanding is completed.

Backfilling

Once the filter maintenance activities have been completed, the filter is ready to be placed back into service. If the operator just opened the influent and effluent valves and tried to place the filter back into service, many significant problems would be created.

- 1 Most notably adding influent water to a drained filter will trap air in the sand layer of the filter bed. The trapped air will not permit water flow through portions of the filter effectively reducing the bed's available filter area. The reduced filter area will cause the remaining filter area to operate at a much higher rate than originally intended and filter head loss will increase rapidly.
- 2 Also, air in a filter bed can expel itself from the filter. If the air is expelled with sufficient force it can disturb the gravel above the filter underdrain. If the gravel is disturbed, sand can migrate into the effluent piping and create holes in the filter bed. Holes in the bed will cause the influent water to be inadequately filtered and of poor quality. A filter with a disturbed gravel layer is said to be "upset."



In order to prevent trapping air in the filter, the filter should be "backfilled" prior to placing it into service. Backfilling is a process of slowly introducing filtered water to the bottom of the filter bed (from the underdrain) and allowing it to flow up through the bed from the bottom to the top. Backfilling the filter pushes the air out of the bed and it is released into the atmosphere. The filter is backfilled until about two or three inches of water are on top of the sand bed and there is no more air being released from the bed. After this is accomplished the influent to the filter can be opened and influent water used to fill the filter up to its normal operating level.

Filter-to-Waste

After the filter has been backfilled, it is still not ready to be placed into service. After removal of a portion of the schmutzdecke or resanding, the filter must be operated in filter-to-waste mode for a period of time before it begins to produce an effluent of acceptable quality.

Filter Ripening

Filter-to-waste must be continued until the filter is producing an acceptable water quality. This process is referred to as filter ripening. The length of time for a filter to ripen is dependent on:

- Source water quality
 - Inorganic content
 - Organic content
 - Microbiological components
- Source water temperature

Below are some guidelines for determining when a filter has ripened and is ready to return to service.

- Analysis of the filter effluent turbidity and bacteriologic levels can be used to aid in this determination.



It is generally accepted that a slow sand filter that is producing an effluent with turbidity of less than 0.1 NTU and coliform levels of less than 1 colony forming unit (cfu) per 100 ml is adequately ripened and can be returned to service.

A ripened filter is said to be “mature.”

Monitoring and Recording

There are a number of operational checks that must be made on a slow sand filter. This data should be read and recorded on a daily or more frequent basis. Even if the plant is equipped with a SCADA system, the operator must verify that the filter is operating within established operating parameters. The following operating parameters should be read and recorded on at least a daily basis.

- **Rate of Flow:** The filter's rate of flow should be checked and recorded. If it is significantly changed from the previous reading, the cause should be identified and fixed if possible.
- **Head Loss:** The head loss through the filter bed should be read and recorded if the filter is equipped with a loss of head gauge. If a loss of head gauge is not present, the elevation of the water on top of the filter bed and in the filter tail water can be used as an indirect measurement of head loss.
- **Water Temperature:** As has been discussed previously, the water temperature can have a significant impact on filter operations. Also, rapidly changing water temperatures can be used as an indication of change in source water quality.
- **Turbidity:** Filter effluent turbidity is regulated by the PA. DEP. Currently, the combined filter effluent must be measured no less frequently than every 4 hours.
- **Chlorine Residual:** According to PA. DEP regulations, the chlorine residual of the finished water must be monitored continuously. Sudden changes in residual chlorine could indicate a problem with the chlorination equipment or a change in the chlorine demand of the filtered water.
- **Storage Facilities:** The elevation of water in storage facilities should be closely monitored. Sudden changes in elevation could indicate a main line leak or unauthorized use of a hydrant or other distribution system problem.

Mechanical Checks

Two areas that are critical for mechanical checks are pumps and chemical feed equipment. The goal of these checks is to detect and correct pump or chemical feeder problems before a complete failure results in problems with water quality or quantity.

- **Pumps:** The raw and/or high service pumps should be checked on a daily basis. (Raw pumps lift water from the river or lake and deliver it to the plant for treatment. High service pumps pump treated water into the distribution system.)

When conducting checks on pumps it is important for the operator to use all of his senses in order to detect any impending problems. As an operator gains experience he will develop a sense of what sounds, looks, feels, and even smells right. Of course suction and discharge pressure gauges and flow meters should also be used to verify proper pump operation. If something has changed, further investigation should be done to determine the cause and if any corrective action is required.

- **Chemical Feed Systems:** Chemical feed systems tend to offer fewer clues when something is not quite right. The best way to determine that a chemical feed system is operating properly is to keep a close eye on daily chemical usage. If usage is decreasing and plant flow rate and feed rate settings are the same as usual, the feed system may be heading for trouble. Similarly, if you must constantly increase the feed system setting to obtain the same dosage, there could very well be a problem that needs to be addressed. The old saying that an ounce of prevention is worth a pound of cure is never quite so true than at 2 A.M. while your trying to get a chemical feeder back on line.

Filter performance can be affected by:

- Raw water quality
- Loading rates
- Filter mode of operation
- Required performance standards
- Cleaning frequency and procedures

Cyclic Influences

Cyclic influences are those things that reoccur on a more or less regular basis. They can be caused by climatic changes such as rain or other meteorological events, diurnal changes, and/or seasonal variations.

- **Runoff:** Heavy downpours can seriously affect source water quality. Increases in turbidity from 2-3 NTU to 100-200 NTU can occur in minutes.
Options to combat these events are presedimentation basins, plant shut down, or other types of pretreatment.
- **Diurnal Fluctuations:** Diurnal refers to changes that occur between day and night. These changes can include changes in:
 - The quality of the raw water.
 - The amount of dissolved oxygen in the water.
 - The activity of microorganisms in the schmutzdecke.Solutions for diurnal fluctuations can be elusive since it is related to changes in atmospheric conditions. If algae activity is a problem, the water purveyor may alleviate the problem with source treatment algaecides.

- **Seasonal Changes:** There are two significant seasonal changes that can have an impact on slow sand filter operation.
 - ❶ Changes in water temperature:
 - Colder water is denser than warmer water which makes the water “harder” to filter.
 - As the water becomes colder, the amount of biological activity in the schmutzdecke is reduced, thus negatively impacting the schmutzdecke’s filtering capability.
 - ❷ Changes in the amount of solar radiation that the filter is exposed to:
 - The amount of solar radiation that the filter is exposed to is significant due to its impact on algae growth in the filter. In order to minimize the growth of algae on the filter bed, the filter’s exposure to solar radiation should be minimized. This can be accomplished by covering the filter bed with a roof or shade cloth.

Operational Mode

One of the challenges facing the operator of a slow sand filter is how to deal with the fluctuations in water demand seen in all water systems. In a conventional treatment system, the plant’s production can be increased or decreased to meet system demand. This is not always possible in a slow sand filtration facility. Therefore, an operator will need to decide if the filter should be run continuously or intermittently.

- **Continuous Operation:** Better quality effluent, better particle removal, better microbiological removal.
- **Intermittent Operation:** Poorer particulate and microbiological removal, algae and bacteria may create an anaerobic condition in an offline filter.

Loading Rates

Loading rates for slow sand filters were briefly discussed in Unit 1. As mentioned, slow sand filters typically operate in the range of 0.04 gpm/sq. ft. to 0.08 gpm/sq. ft., but flow rates can range from 0.016 gpm/sq. ft. to 0.16 gpm/sq. ft. PA. DEP regulations establish a maximum permissible flow rate of 0.1 gpm/sq. ft., but higher flow rates can be permitted if piloting demonstrates that acceptable treatment is achieved at the higher flow rate.

Increasing flow tends to reduce the filter's particulate and microorganism removal efficiencies but acceptable removals are obtained even at 0.16 gpm/sq. ft.

In order to calculate loading rates the operator must know two things:

- The flow rate of water being added to the filter, and
- The surface area of the filter.

The flow rate is divided by the filter area to determine the loading rate.



Exercise: Calculate the loading rate on a slow sand filter if its dimensions are 20 ft. long by 40 ft. wide and it treats 35 gpm.

Surface Water Treatment Rule and Performance Standards

Slow sand filters can be used to comply with the filtration requirements of the Surface Water Treatment Rule (SWTR). In order to comply with the SWTR, certain performance levels must be achieved and maintained.



Turbidity: The Pa. DEP has established allowable filter effluent turbidity levels for slow sand filtration facilities. In current regulation states, the combined filter effluent turbidity must be less than or equal to 1 NTU in at least 95% of the measurements taken each month. This is different from conventional and direct filtration which require combined filter effluent turbidity of less than or equal to 0.3 NTU in at least 95% of the measurements taken each month. The combined filter effluent must be measured no less frequently than every 4 hours.



Giardia: PA. DEP regulations require that a slow sand filtration facility remove or inactivate 99.9% of *Giardia lamblia* cysts. In a slow sand filter a high percentage of Giardia cysts are removed by the biological process.



Viruses: The SWTR requires that slow sand filtration remove or inactivate 99.99% of viruses.



Chlorine Residual: The performance levels for *Giardia* and viruses are based on removal and inactivation. The inactivation is accomplished by the post disinfectant being used. In order to assure that the inactivation of any viable cyst or virus is not compromised, the PA. DEP requires that the chlorine residual of the finished water must be monitored continuously and that the chlorine residual must never be less than 0.2 mg/l for more than 4 hours.

Cleaning Criteria

The determination of when a slow sand filter needs to be cleaned is quite straight forward. If the filter cannot maintain the required rate of flow because of head loss or if the effluent turbidity approaches the regulatory standard, the filter should be taken off line and cleaned.



If a slow sand filter is shut down for an extended period of time, anaerobic conditions may occur.

Introduction

The most striking difference between conventional and slow sand filters is the procedures used to clean the filter media. Nearly all other types of filters are cleaned using some type of backwash methodology, reversing the water flow through the filter and disposing of the resulting waste water. Given the large size of a slow sand filter and the characteristics of the schmutzdecke, a traditional backwash of the filter is not practical.

The following three cleaning methods will be discussed in this section:

- ❶ Scraping
- ❷ Raking
- ❸ Wet Harrowing

The method to add sand to a cleaned filter will also be described in this section.

Cleaning Methods

The three commonly used methods to clean a slow sand filter are:

- **Scraping:** Scraping is the most commonly used and perhaps the most effective method of cleaning a slow sand filter.

Process

- Drain the filter to just below the top of the filter bed.
- Rake a thin layer of the schmutzdecke into windrows. (Prior to scraping, some operators will raise the filter level to allow loose debris to float out of the influent overflow.)
- Shovel the raked material into wheelbarrows or a cart and remove.
- Smooth the bed back to level.
- Larger facilities may use mechanized equipment throughout the process of scraping.

- **Raking:** Raking is a procedure used to increase the filter's run time without removing a layer of the schmutzdecke.

Process

- Drain the filter bed and loosen the surface of the schmutzdecke with a rake.
 - Saves time and effort but may drive debris deeper into the filter bed causing poorer quality effluent.
 - Will cause more sand to be removed at the next cleaning.
- **Wet Harrowing:** Wet harrowing is a cleaning method that uses water to move the raked windrows to a drain or weir rather than by manually removing the windrows.

Returning to Service

Scraping, raking, and wet harrowing all affect the amount of time required for the filter to ripen. A brief description of this is given below.

- Since scraping removes a layer of the schmutzdecke, a significant amount of time may be required to allow the filter to mature.
 - When slow sand filters are initially put into service, filters that are scraped cleaned provided better water quality than filters that have been completely resanded. This is because scraped filters still contain a mature population of organisms.
- A raked filter may not require a period to allow for ripening since the schmutzdecke is not removed, just disturbed.
 - As mentioned, raking is generally not recommended due to the possibility of a poorer quality effluent being produced and the need to remove deeper layers of the schmutzdecke when scraping is performed.
- A filter cleaned using the wet harrow method will need to be ripened just as a scraped filter since wet harrowing also removes a portion of the schmutzdecke.

An operator may well ask: What constitutes a "mature" filter? The answer is that it is determined by the quality of the effluent being produced by the filter. Generally, a filter is considered mature when it produces:

- Effluent with a turbidity of less than 0.1 NTU.
- Coliform counts of less than 1 cfu per 100 ml.
- Another rule of thumb is to return the filter to service when it begins to produce an effluent of the same quality it was producing when it was removed from service.

Resanding

Scraping a filter removes a portion of the sand from the filter. If this process is continued indefinitely, eventually no sand will remain in the filter bed. At some point sand must be added back to the filter.

Criteria

- A filter usually needs to be resanded after one foot of sand has been removed.
- It is not recommended to resand after every cleaning.
- Deeper beds can go longer between resandings.

Replacement Sand

There are two options for obtaining replacement sand:

- ❶ Purchase new sand.
- ❷ Clean previously removed sand.

As mentioned in Unit 2, cleaning sand requires specialized equipment and is probably not economical for all but the largest systems. If cleaned sand is to be used, the effective size and uniformity coefficient of the sand should be determined prior to reuse.

If cleaning the removed sand is not an option, replacement sand can be purchased from a filter media supplier.



If dirt, clay and organic matter are not washed from the sand before it is placed in the slow sand filter, there will likely be a problem with an increase turbidity of the filter water.

Replacement Techniques

There are two ways to add replacement sand to a slow sand filter:

- ❶ Adding sand to the top of the sand bed, or
- ❷ A technique known as “throwing over.”

If the replacement sand is added to the top of the bed, the schmutzdecke remaining after scraping will no longer be where it belongs—at the top of the filter bed. Adding sand to the top of a slow sand filter is not recommended.

MEDIA CLEANING AND REPLACEMENT

The “throwing over” technique is fairly simple to describe but it can be quite labor intensive. The goal of “throwing over” is to add the new sand to the bottom of the filter. Here is the process for “throwing over:”

1. Dig a trench down to the gravel layer.
2. Place the sand from the trench on top of another section of the filter.
3. Place new sand in the trench.
4. Place the old sand on top of the new sand.
5. Repeat the process across the width of the filter until all of the new sand has been added and covered with old sand.

Operational Difficulties

There are a few operational conditions which may require the operator to diagnose and correct a problem. Some of these conditions include:

- **Filter level:** An overflowing or draining filter is usually caused by a difference in the rate of flow entering the filter compared to the rate of flow exiting the filter.
 - Suspect a malfunctioning influent, effluent, or float valve.
- **Head loss:** A filter with higher than acceptable head loss must be cleaned to reduce the head loss.
 - If the problem continually reoccurs, suspect a change in raw water quality, especially algae loading or a malfunctioning pretreatment system (if used).
- **Rate of flow:** If the filter can not maintain the desired flow rate and the head loss is less than the maximum allowable:
 - Suspect a malfunctioning rate of flow control valve.
- **Effluent quality:** If the filter is producing an unacceptable water quality:
 - Suspect that it may be caused by a change in raw water quality, a malfunctioning pretreatment unit, or a filter bed that does not have a mature schmutzdecke.

Air Binding

Air binding, another operational difficulty, can be caused by a number of conditions, but the two most common are:

- ❶ Dewatering of the outlet chamber.
- ❷ Air trapped in the bed after cleaning.

Regardless of the cause, the solution for any type of air binding is backfilling. We discuss backfilling in more detail in other sections.

Suspect air binding if the filter has a “bubbly” look on the top and/or the filter is not producing the desired amount of water and is rapidly building head loss.

**Unit 3 – Exercise****Multiple Choice – Choose the best answer unless otherwise noted:**

1. What are the two different operational modes for a slow sand filter? (*Choose two*)
 - a. influent flow control
 - b. performance flow control
 - c. effluent flow control
 - d. loading flow control

2. Which is the most commonly used and perhaps the most effective method of cleaning a slow sand filter?
 - a. scraping
 - b. raking
 - c. wet harrowing

3. Water systems that filter must report turbidity results to the state within how many days after the end of each month? (*Choose one*)
 - a. 3
 - b. 5
 - c. 7
 - d. 10

4. Which is the cleaning method that uses water to move the raked windrows to a drain or weir?
 - a. scraping
 - b. raking
 - c. wet harrowing

5. Which is the cleaning procedure used to increase the filter's run time without removing a layer of the schmuzdecke?
 - a. scraping
 - b. raking
 - c. wet harrowing

5. Which is the best flow pattern for slow sand filter performance?
- constant
 - variable
 - intermittant
6. After cleaning, the schmutzdecke of a slow sand filter needs to ripen and mature by running the filter in "filter-to-waste" mode. A filter is considered mature when coliform counts are less than 1 cfu per 100 ml and the effluent has a turbidity below which of the following?
- 0.01 NTU
 - 0.1 NTU
 - 1 NTU
7. Select the cyclic influences that may impact the operation of a slow sand filter? (*Choose all that apply*)
- heavy downpours
 - diurnal fluctuations
 - changes in source water temperature
 - changes in the amount of solar radiation the filter is exposed to
8. In a slow sand filter a high percentage of Giardia cysts are removed by:
- biological processes
 - chemical disinfection
 - changes in source water temperature
 - changes in the amount of solar radiation the filter is exposed to
9. Select the description of the unfiltered water which will result in shorter filter run times.
- disinfected before being filtered
 - contains more than 15 units of color
 - is clear and cold
 - is undergoing an algae bloom
10. According to the PA. DEP Surface Water Treatment Rule, the maximum allowable turbidity that can be produced by a slow sand filter is that the combined filter effluent turbidity must be less than or equal to _____ NTU in at least 95% of the measurements taken each month.
- 0.3 NTU
 - 0.5 NTU
 - 1.0 NTU
 - 0.1 NTU

Calculation – Follow the directions to perform the calculation and select the best answer to fill in the blank:

The Tinytown slow sand filter is 30 ft. long by 50 ft. wide and treats 35 gpm, we use the following calculation to calculate Tinytown's loading rate:

Flow rate \div (filter length x filter width) = filter loading rate

35 gpm \div (30 ft. x 50 ft.) = Tinytown's loading rate (gpm/ sq. ft.)

11. Using the above calculation, what is Tinytown's loading rate? (*Choose one*)
- a. 58 gpm/ sq. ft.
 - b. 0.023 gpm/ sq. ft.
 - c. 5.8 gpm/ sq. ft.
 - d. 42.9 gpm/ sq. ft.
 - e. 0.23 gpm/ sq. ft.
12. Since the DEP maximum loading rate for a slow sand filter is 0.1 gpm/sq. ft., using the answer to question #11, is Tinytown's loading rate exceeding the allowable rate?
- a. yes.
 - b. no

Unit 3 - Summary



Key Points:

- If a slow sand filter is shut down for an extended period of time, anaerobic conditions may occur.
- It is desirable to maintain a constant rate of flow overtime through the slow sand filter. This flow pattern will result in the most effective performance.
- If a slow sand filter has only influent flow control, the water level above the filter will determine the flow rate.
- When starting a slow sand filter, the filter should always be filled from the underdrain to prevent air binding.
- After a slow sand filter is cleaned, the schmutzdecke will need time to ripen or mature; this can be done by running the filter in filter-to-run mode until it produces an acceptable water quality.
- Filters that are scraped clean provided better water quality than filters that have been completely resanded because the scraped filter still contains a mature population of organisms.
- A slow sand filter should be taken off-line and cleaned when it cannot maintain the required rate of flow because of head loss or if the effluent turbidity approaches the regulatory standards.
- If a slow sand filter effluent flow is at terminal head loss, a filter can be returned to service quickly by raking the top layer.
- A head loss gauge is used to monitor pressure differential across the filter.
- Pa. DEP regulations establish a maximum permissible loading rate of 0.1 gpm/sq. ft.
- Slow sand filters must comply with the DEP surface water treatment requirements for turbidity, Giardia and removal/inactivation, viruses, and chlorine residual.
- Slow sand filters combined effluent turbidity in 95% of the measurements taken must be less than or equal to 1 NTU.
- Water systems that filter must report turbidity results to the state within 10 days after the end of each month.
- The problem that is most likely to occur if dirt, clay and organic matter are not washed from the sand before it is placed in a slow sand filter is that filtered water turbidity will increase.

Unit 4 – Preventative Maintenance, Operational, and Equipment Records

Unit 4 - Learning Objectives

As a result of this unit, the learner will:

- Be able to identify which operational checks should be performed daily, weekly, and monthly to ensure proper operation of a slow sand filter.
- Review information on why it is important to maintain analytical records, sampling records, filter operation/cleaning records, equipment records, and maintenance records.

If source water is relatively stable, a slow sand filter can operate without operator involvement. However, that does not eliminate the need for the operator to verify that the equipment is operating properly. Any type of mechanical equipment requires periodic inspection and maintenance. Maintenance can be either:

- Reactive, or
- Preventative.

Reactive maintenance basically means you fix it after it breaks.

Preventative maintenance is a process of regularly inspecting, adjusting, and maintaining equipment in order to prevent equipment breakdown. The best way to implement a preventative maintenance program is to create a schedule of activities designed to maintain the equipment in good condition.

Below is a suggested schedule that can be followed to conduct maintenance and inspection activities.

Daily Checks

Certain maintenance and inspection activities should be conducted on a daily basis in order to ensure that a safe drinking water is being produced. In addition to the operator using his senses to notice if equipment is operating properly, there are specific items that should be checked on a daily basis.

- **System Controls:** All control panels and equipment should be inspected to verify that they are functioning properly.
- **Pumps, Motors, and Valves:** These pieces should be visually checked for unusual conditions that may impact their ability to function properly.
- **On-line Analytical Equipment:** On-line chlorine analyzers and turbidimeters should be checked daily. The proper operation of these instruments can be verified by analyzing samples for chlorine and turbidity using laboratory instruments and comparing the laboratory instrument's result to the on-line result.
- **Chemical Feed Equipment:** Daily checks should be conducted on the chemical feed equipment to verify its proper operation. The operator should note the amount of chemical used on a daily basis. Significant changes in the amount of chemical used from day to day could indicate a problem in the chemical feed system.

Weekly Checks

There are certain maintenance activities that should be looked at on a weekly basis (at a minimum):

- **Clean Equipment:** Wipe down the equipment. You may notice problems while you are cleaning and certain problems are easier to spot on equipment that has been kept clean.
- **Chemical Inventory:** Track chemical usage. A change in chemical usage will help identify changes in water quality or equipment operation.
- **Lubricate Equipment:** This is one of the most important maintenance activities. Follow manufacturer's recommendations and maintain a regular lubrication schedule.
- **Operate Valves, Other Mechanicals, and Standby Equipment:** If valves and other equipment are not used or "exercised" frequently, they may not work when you need them.
- **Change Charts/Verify Archive:** Change the charts or verify that the SCADA system is archiving data. Records of past plant performance are one the most important tools an operator can use when attempting to solve a current treatment problem.

Monthly Checks

After completing daily and weekly checks the operator can have confidence that the day-to-day operations of the plant will be relatively trouble free. However, there are activities that can be conducted less frequently to assure long term reliable plant operation. Some of these activities are described below.

- **Inspect Pumps and Chemical Feed Equipment:** Although this equipment is checked on a daily basis, more intensive monthly inspections may reveal significant problems that are not obvious to a cursory visual inspection. More intensive inspection activities may include:
 - Verifying that pump flow and discharge pressures are within original specifications.
 - Verifying that the bearing or pump motor temperatures are not exceeding manufacturer's recommendations.

- **Verify Proper Functioning of Safety Equipment:** Safety equipment is not useful if it malfunctions at the time it is needed. A good monthly inspection of safety equipment will ensure that the equipment will function properly when needed. Items to check include:
 - Fire extinguishers
 - Self-contained breathing apparatus

- **Calibrate On-line Analytical Equipment:** On-line analytical equipment can be a valuable tool to an operator. An operator's duties do not permit time to continually analyze raw and tap water samples. That is one of the greatest benefits of on-line analytical equipment. It watches the water quality for the operator.

If this equipment is not reading accurately, it is at best useless and at worst misleading. In order to have complete confidence in the on-line analytical equipment, it should be calibrated at least monthly. If the operator is confident in the accuracy of the on-line analyzers, he can react quickly to changes in raw or finished water quality.

Biannual Checks

While it is important to keep an eye on all the components of a plant, inspection of some items can be less frequent. Biannual (twice per year) inspection is suggested for the following items.

- **Piping:** Although the vast majority of piping in a water system is buried and cannot be regularly inspected, there are usually a number of pipe segments in the plant that can be visually inspected. Things such as leaking joints or misalignment can be observed during inspections and repairs made prior to a catastrophic leak.
- **Other Equipment and Facilities:** A water treatment plant consists of the treatment equipment and the buildings that house it. Most of the treatment equipment is inspected at least on a monthly basis. The buildings and other facilities should be inspected regularly to verify that they are still in serviceable condition. For instance, building walls should not show signs of cracking and the perimeter fence should be intact.

Annual Checks

There are some preventative maintenance activities which can be conducted even less frequently than those described above. Annual checks should be conducted on the following items.

- **Internal Pump Inspection:** Although an operator should visually check pumps daily, some problems may not be apparent unless the pump is disassembled and inspected. Follow manufacturer's recommendations for pump inspection and maintenance.
- **Calibrate Flow Meters:** Nearly all of an operator's treatment activities are based on flow through the plant. Chemical dosages, production figures and other items rely on accurate flow readings. For this reason the plant's influent and effluent meters should be calibrated at least annually.

State regulations require that certain operational records be collected and maintained. Even if not required by the PA. DEP, operational records can be an invaluable tool for the operator when trying to diagnose operating problems. Operational records for a slow sand filtration facility fall into three main categories:

- Analytical records,
- Sampling records, and
- Filter operation/cleaning records.

Analytical Records

Records of raw and finished water quality can be very useful reference material for an operator experiencing treatment difficulties. Referring to past treatment practices may reveal the solution to a current treatment problem. State regulations require that some records be maintained at the treatment plant. At a minimum, the operator will want to save the results of:

- Raw and finished turbidity,
- Finished chlorine, and
- Dissolved oxygen levels at various locations in the process.

Sampling Records

A log of date, time, and location of samples taken for SDWA compliance should be maintained. This can be a useful guide for a new employee who may not know what the sampling requirements are. It can also serve as verification that the samples were collected and submitted. In addition, a record of samples taken to maintain operational control of the treatment can be useful.

Filter Operation/Cleaning Records

At times questions arise as to when an activity was last conducted. For instance, filter cleaning will most likely be a fairly regular activity. By consulting operational records the operator can predict when the next filter cleaning will be required. Likewise, if the operator suspects that the filter cleaning frequency is increasing, a quick check of the records can verify it.

Filter cleaning records should include:

- Amount removed,
- Comments as to the condition of the sand, and
- Resanding records.

During the course of plant operations, questions will always arise about the nature of a piece of equipment, the maintenance procedures to follow, or results of previous maintenance. No one's memory is infallible; there is no substitute for well kept and thorough equipment and maintenance records.

Equipment Records

Frequently, during maintenance or repair of equipment, a question of how to proceed will arise. In these cases, it is important to follow the manufacturer's recommendations for repair or maintenance of the equipment. This information is almost always supplied by the manufacturer when the equipment is delivered. Other sources of equipment information include:

- Shop drawings,
- As-built drawings, and
- Plant flow schematics.

Maintenance Records

As discussed previously, there is no substitute for a good and conscientiously implemented maintenance program. However, the program will be of limited value if complete maintenance records are not maintained. Maintenance records need not be long or fancy, but they should include at a minimum:

- The date maintenance was performed.
- The employee(s) that did the work.
- A description of the work that was done.
- A description of any unusual occurrences.



Exercise

Unit 4 – Exercise

Fill in the blank:

1. An operator of a slow sand filtration facility should note and record certain items daily, weekly, and monthly.

Put a “D” in front of items that should be checked daily, “W” for items to be checked weekly and “M” for items to be checked monthly.

- | | |
|---------------------------|---|
| _____ rate of flow | _____ calibrate on-line analytical equipment |
| _____ head loss | _____ effluent turbidity |
| _____ lubricate equipment | _____ chlorine residual |
| _____ water temperature | _____ storage facilities |
| _____ chemical inventory | _____ verify proper functioning functions of safety equipment |

Matching – Match the slow sand records with the corresponding description:

- | | |
|--|--|
| _____ A. Sampling Records | 1. Raw and finished turbidity, finished chlorine, and dissolved oxygen at various locations in the process |
| _____ B. Maintenance Records process | 2. Log of date, time, and locations taken for SWDA compliance |
| _____ C. Filter Operation/Cleaning Records | 3. Includes amount removed, comments on the condition of the sand, and resanding records |
| _____ D. Analytical Records | 4. Includes the date maintenance was performed and the employee(s) that did the work |
| _____ E. Equipment Records | 5. Shop drawings, as-built drawings, and plant flow schematics |

Unit 4 Summary



Key Points:

- Filter cleaning records can help the operator predict when the next filter cleaning will be required.
- Records of raw and finished water quality can be very useful reference material for an operator experiencing treatment difficulties.
- A good schedule of daily, weekly, monthly, biannual, and annual preventative maintenance checks can help maintain the equipment in good condition and prevent breakdown.

Definitions:

Backwashing consists of reversing the flow of water through the filter causing water to travel from the bottom of the filter to the top. The purpose is to remove or “flush out” particles that have been removed from the influent water during the filtration process. Backwash is done at specific rates in order to most effectively remove the particulate material. Wastewater used for the backwash is collected and removed from the filter.

Conventional filtration is a four step treatment process that consists of the treatment steps of coagulation, flocculation, sedimentation and rapid sand filtration.

Diatomaceous earth is filter media made from the skeletal remains of diatoms. It is a silica based material that is mined from deposits found in various locations around the world.

Effective Size (ES): The effective size of filter media is the diameter of the filter grain for which 10% percent of the total grains are smaller and 90% of the total grains are larger (calculated on a weight basis). In other words, the effective size is the size where only 10% of the sample is a smaller size. This is referred to as D10. Effective size is determined by passing a known amount of filter media through a series of progressively smaller sieve sizes and weighing the amount of media retained on each sieve.

Filter-to-waste: At the completion of the backwash cycle, the filter bed may still contain significant amounts of particulate material and the filter will be less effective at removing particles for a short period of time when it is returned to service. For this reason, the water first filtered through a freshly backwashed filter will be of poorer quality than water filtered later in the filter run.

In order to avoid adding this poorer quality water to the clearwell, the filter should be run in filter-to-waste mode. Filter-to-waste involves diverting the filtrate from a freshly washed filter to waste rather than allowing it to enter the clearwell. The amount of time required to run a filter in filter-to-waste mode will vary from plant to plant and filter to filter, but generally should be long enough to allow the freshly washed filter to begin to produce water of similar quality to the other filters at the plant.

Head Loss: It requires energy for water to pass through the filter. This energy in a rapid sand filter is usually in the form of head pressure—basically the weight of the water on top of the filter bed. As particles accumulate on the filter they begin to impede the flow of water through the filter. This loss of energy during the filtration process is known as head loss. At some point, the amount of energy being lost through the filter bed approaches the amount of energy available from the head pressure of the influent water. This condition is known as terminal head loss.

Schmutzdecke is German for “dirty skin.” It is the layer that develops on the top of a slow sand filter and is made up of microorganisms that feed on and break down organic material that is trapped on the surface of the filter. As the organic material is broken down, it adds mass to the schmutzdecke which enhances the straining action of the filter.

Uniformity Coefficient (UC): The uniformity coefficient is defined as the ratio of the sieve size where 60% of the filter media is smaller (referred to as D60) to the sieve size where 10% of the filter media is smaller (D10). So UC is D60 divided by D10.

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