Drinking Water Operator Certification Training
Instructor Guide

Module 17:
Slow Sand Filtration

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group
Penn State Harrisburg Environmental Training Center

A Note to the Instructor

Dear Instructor:

The primary purpose of *Module 17: Slow Sand Filtration* is to introduce the students to the process of slow sand filtration. The capabilities and limitations of slow sand filtration will be discussed as well as performance requirements stipulated in the Safe Drinking Water Act. We will discuss the components of a slow sand filter and we will also discuss operational and maintenance activities. This module has been designed to be completed in 3 hours, but the actual course length will depend upon content and/or delivery modifications and results of course dry runs performed by the DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the topical outline. You may need to adjust these timeframes as necessary to match course content and delivery modifications made by the sponsor. Please make sure that all teaching points are covered and that the course is delivered as approved by DEP.

Web site URLs and other references are subject to change, and it is the training sponsor's responsibility to keep such references up to date.

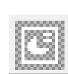
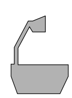
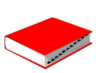
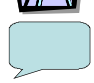
Delivery methods to be used for this course include:

- Lecture
- Exercises

To present this module, you will need the following materials:

- One workbook per participant
- Extra pencils
- Laptop (loaded with PowerPoint) and an LCD projector **or** overheads of presentation and an overhead projector
- Screen
- Flip Chart and Markers

Icons to become familiar with include:

Participant Workbook		Instructor Guide	
	Exercise/Activity	Same icons for Participant Workbook apply to the Instructor Guide.	
	Case Study	**Ans:**	Answer to exercise, case study, discussion, question, etc.
	Discussion Question		PowerPoint Slide
	Calculation(s)		Overhead
	Excerise		Flip Chart
	Key Definition(s)		Suggested "Script"
	Key Point(s)		

Instructor text that is meant to be general instructions for the instructor is designated by being written in script font and enclosed in brackets. For example:

[*Ask participants if they have any questions on how to read the table. Answer any questions participants may have about how to read the table.*]

If your module includes the use of a PowerPoint presentation, below are some helpful controls that you may use within the Slide Show.

PowerPoint Slide Show Controls

You can use the following shortcuts while running your slide show in full-screen mode.

To	**Press**
Advance to the next slide	N, ENTER, or the SPACEBAR (or click the mouse)
Return to the previous slide	P or BACKSPACE
Go to slide <number>	<number>+ENTER
Display a black screen, or return to the slide show from a black screen	B
Display a white screen, or return to the slide show from a white screen	W
Stop or restart an automatic slide show	S
End a slide show	ESC
Return to the first slide	Both mouse buttons for 2 seconds
Change the pointer to a pen	CTRL+P
Change the pen to a pointer	CTRL+A
Hide the pointer and button temporarily	CTRL+H
Hide the pointer and button always	CTRL+L
Display the shortcut menu	SHIFT+F10 (or right-click)
Erase on-screen annotations	E
Go to next hidden slide	H
Set new timings while rehearsing	T
Use original timings while rehearsing	O
Use mouse-click to advance while rehearsing	M

INTRODUCTION OF MODULE: 5 minutes

Display Slide 1—Module 17: Slow Sand Filtration.

[Welcome participants to "Module 17: Slow Sand Filtration." Indicate the primary purpose of this course is to introduce the students to the process of slow sand filtration. The capabilities and limitations of slow sand filtration will be discussed as well as performance requirements stipulated in the Safe Drinking Water Act. We will discuss the components of a slow sand filter and we will also discuss operational and maintenance activities.]

[Introduce yourself.]

[Ask the participants to introduce themselves.]

[Provide a brief overview of the module.]

This module contains 4 units. On page i, you will see the topical outline for the units.

[Briefly review the outline.]

[Continue to briefly review the outline.]

[Continue to briefly review the outline.]

[Continue to briefly review the outline.]

UNIT 1: INTRODUCTION TO SLOW SAND FILTRATION 35 MINUTES

Display Slide 2—Unit 1: Introduction to Slow Sand Filtration.

At the end of this unit, you should be able to:

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

DEVELOPMENT OF PROCESS: 5 MINUTES

Historical Use

The use of slow sand filtration can be traced back to 1829 when it was used to treat water in London, England. Slow sand filtration enjoyed widespread use throughout England and to a lesser extent in Europe in the 19th century but was not extensively used in the U.S. However, it was practiced to a limited extent in the New England states in the 19th century.

Regulatory Issues

*[Review the **Regulatory Issues** section. Include the following information.]*

In 1986, amendments to the Safe Drinking Water Act (SDWA), including the Surface Water Treatment Rule (SWTR), created a renewed interest in slow sand filtration.

The SWTR required all water systems utilizing surface water or ground water under the direct influence of surface water to provide filtration. This proved to be troublesome for many water systems, especially water systems serving small communities. The expense of constructing a conventional treatment plant was prohibitive for many small systems.

PROCESS COMPARISON: 15 minutes

Classifications

*[Review the **Classifications** section.]*

Rapid Sand Filtration

Article I. Mechanical Components

*[Review the **Mechanical Components** section.]*

Article II. Removal Mechanisms

A rapid sand filter removes suspended material from the influent in a number of ways.

Display Slide 3—Sand Filtration Removal Mechanisms.

Straining: *[Review the material in the workbook.]*

*[Review the definition of **coagulation**.]*

*[Review the definition of **floculation**.]*

Settling/Sedimentation: As particles pass through the media they collide with the grains of media and their velocity is slowed. If they are slowed sufficiently they will not have enough velocity remaining to pass completely through the filter. If this occurs, the particles settle out in the filter and remain in the media. This process is referred to as settling or sedimentation.

Adsorption: The final particulate removal mechanism in a rapid sand filter is adsorption. The exact mechanism of adsorption is not fully understood but appears to include electrical and/or chemical attractions between the filter media and the particles. The coagulation process is critical to permitting this adsorption process to function. The coagulant chemicals, most likely, cause the particle's surface to become charged electrically or chemically changed. This causes an attraction between the particle and the filter media and the particles adsorb or adhere to the media grains.

*[Review the definition of **conventional filtration**.]*

Article III. Flow Rates

Rapid sand filters can be operated at a wide range of flow rates.

*[Review the **Flow Rates** section.]*

Cleaning

As with any filter, there is only a finite amount of material that can be removed before it impedes the flow of water through the filter. In order for water to pass through the filter, energy, in the form of head pressure is required. As more and more particles are removed, it requires more energy for water to pass through the filter. This loss of energy is typically referred to as head loss.

When the head loss in a filter reaches a level where the flow is significantly impeded, it is necessary to clean the filter to remove the particles that are impeding the flow. Cleaning of a rapid sand filter is accomplished through a process known as backwashing. During backwash, water flow is reversed through the filter, traveling from the bottom of the filter to the top. It is also done at a much higher flow rate than the filtration process.

A typical backwash flow rate can be 15 to 20 gpm/sq. ft. This reverse flow forces the particles that were deposited in the filter to be removed.

*[Review **Surface Agitation/Air Scour**.]*

*[Review the definition for **Filter-to-waste**.]*

(i) Pressure Filtration

There are a number of similarities and differences between pressure filtration and rapid sand filtration. Both utilize filter media and underdrain piping to filter and clean the filter media. Also, the removal mechanisms used by both types of filters are the same. However, where a rapid sand filter is open to the atmosphere and uses gravity as the energy to push water through the filter, a pressure filter uses a pump or some other mechanism to provide the energy necessary to push the water through the filter.

*[Review the first paragraph in **Pressure Filtration** on iron removal, manganese removal, and ion exchange softening.]*

Article IV. Mechanical Components

*[Review the **Mechanical Components** section. Include the following information:]*

The mechanical components consist of a pressure vessel containing underdrain piping to collect the filtrate and distribute the wash water, collectors for removing the spent wash water from the filter, and, at times, a surface agitator to agitate the surface of the media during backwash.

The media in a pressure filter used to filter surface water typically consists of graded gravel covering the underdrain piping and sand media on top of the graded gravel.

*[Continue to review the **Mechanical Components** section.]*

Article V. Removal Mechanisms

A pressure filter removes suspended material from the influent in the same ways as a rapid sand filter. Particles are strained, settled, or adsorbed onto the filter media. However, the adsorption mechanism is less effective if chemical pretreatment is not provided.

Flow Rates

According to the PA DEP Public Water Supply Manual, the maximum flow rate at which a pressure filter can be operated is 3 gpm/ sq. ft., unless PA DEP approved testing has demonstrated acceptable performance at a higher rate.

Cleaning

As with a rapid sand filter, backwash of a pressure filter is accomplished by reversing the flow of water through the filter.

*[Review the **Cleaning** section.]*

Mechanical Filtration

For our purposes, the term mechanical filtration will be used to refer to those filtration processes which rely on some type of manufactured media that allow the removal of particulate material from the influent water using a straining mechanism. These types of filters have some type of fabric or a polymeric media that has pore sizes small enough to exclude all of the particles larger than the pore size from the filter effluent. That is, the holes in the filter media are so small that the particles can not pass through the filter and are retained on the media. Examples of mechanical type filters are:

- Membrane filtration systems
- Bag filters
- Cartridge filters

Article VI. Mechanical Components

*[Review the **Mechanical Components** section.]*

Article VII. Removal Mechanisms

[Review the ***Removal Mechanisms*** *section.]*

[Figure 1.2 visually shows how particles larger than the pore size can not fit through the filter media.]

Display Slide 4—Mechanical Filtration—Removal by Straining.

Flow Rates

Flow rates for mechanical filters are typically recommended by the manufacturer and are usually unique for each manufacturer's equipment. Pilot testing on the raw water to be filtered is usually required to establish the site specific maximum allowable flow rate.

Cleaning

Cleaning of a mechanical filter is very different from rapid sand and pressure filters.

[Review the ***Cleaning*** *section. Include the following information:]*

Bag and cartridge filtration systems do not undergo backwash or chemical cleaning. When the bag or cartridge filter becomes clogged with particulate material, the filtration process is stopped and the bag or cartridge filter is removed from the vessel and discarded. A new bag or cartridge filter is then placed into the pressure vessel.

*[Continue to review the **Cleaning** section.]*

(i) Slow Sand Filtration

A slow sand filter can be best described as a really slow rapid sand filter. The chief differences between a rapid sand and a slow sand filter involve the flow rate through the filter and the cleaning methods used.

Mechanical Components

The mechanical components consist of a filter box containing underdrain piping that collects the filtrate but does not distribute the wash water since a slow sand filter is not backwashed. The media in a slow sand filter typically consists of graded gravel covering the underdrain piping and sand media on top of the graded gravel.

Article VIII. Removal Mechanisms

A slow sand filter removes suspended material from the influent by straining, settling/sedimentation, and adsorption. This removal is enhanced by the presence of the "schmutzdecke" on the top of the filter bed.

*[Review the definition of **schmutzdecke**.]*

*[Review **Settling/Sedimentation** and **Adsorption**.]*

[Review the key point.]

Flow Rates

[Review the key point.]

Slow sand filters come by their name honestly. Flow rates for slow sand filters are typically 50 to 100 times less than the flow rate in a rapid sand filter. 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 is often required to establish:

- The suitability of slow sand filtration for the source water.
- The maximum allowable flow rate.

Cleaning

As more and more material is removed from the influent, the slow sand filter becomes clogged and the desired flow rate can not be maintained. At that point it is necessary to clean the filter.

[Review the ***Cleaning*** *section.]*

Summary Comparison of Filtration Techniques

Display Slide 5—Comparison of Filtration Techniques.

*[Review **Table 1.1 Comparison of Filtration Techniques**. Be sure to highlight the various differences between the Filtration Techniques.]*

CRITERIA FOR DETERMINING SUITABILITY OF SLOW SAND FILTRATION: 10minutes

As just discussed, slow sand filtration is just one filtration process that may be used to treat drinking water. The ultimate decision of whether to construct and operate a slow sand filter comes down to two things. Can a slow sand filter produce finished water that complies with the pertinent requirements of the SDWA and is it the most economically advantageous system?

[Review the four criteria.]

(i) Source of Supply

The first criterion to examine is the source of supply to be utilized. If a community's source of supply were a deep well not under the influence of surface water, it would not be necessary to provide filtration. Only if the community's source of supply is a surface water or ground water under the influence of surface water would it be necessary to provide filtration.

(ii) Source Water Quality

Display Slide 6—Source Water Quality Guidelines for Slow Sand Filters.

Once the need to provide filtration has been established, other aspects of the source water quality have to be examined. Generally, source waters with turbidities less than 10 NTU may be suitable for slow sand filtration. However, caution must be used if the source water turbidity is caused by fine colloidal clays. Also, total coliform counts should not exceed 800 colony forming units (cfu) per 100 ml and raw color should not exceed a maximum of 5 units. Particular attention should also be paid to the amount of algae in the source water. Algae can cause many problems with the operation of a slow sand filter.

Regardless of the source water quality, a slow sand filter pilot evaluation should be conducted prior to making the decision to utilize slow sand filtration.

(iii) System Size

Another aspect to consider when examining the feasibility of slow sand filtration is the size of the population to be served. There are no hard and fast rules for a maximum population capable of being supplied by a slow sand filtration facility, but economics tend to favor its use for only very small water systems. Those systems that serve in excess of 3,300 will probably find it economically advantageous to examine alternate filtration technologies.

It is important in any evaluation of a water system to take into account the projected population growth of the area served by the system. It is prudent to establish population projections for the service territory for at least the next 20 years in order to adequately size the treatment system.

(iv) Available Space

One of the factors limiting the use of slow sand filters is that they require relatively large amounts of land to provide adequate surface areas for the filters. For example, at a flow rate of 0.04 gpm/sq. ft., an acre of filter area would be required to produce 2.5 MGD.

*[Review the **Available Space** section.]*

[Continue to review the ***Available Space*** *section.]*

[Go over this problem as a group.]

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 use of 100 gpd per person and assume that there will be no industrial or commercial users.

Display Slide 7—Exercise.

Ans: Population: 1,500 * 100 gpd/person = 150,000 gpd requirement

150,000 gpd / 1,440 minutes/day = 104 gpm

104 gpm / 0.04 gpm/sq. ft. = 2,604 sq. ft.

Two filters of at least 2,604 sq. ft. will need to be constructed.

[Have the participants do the exercise by themselves or with a partner. Then discuss the answers as a large group.}

Exercise

Unit 1 – Exercise

1. Which of the following are filtration techniques? (*Choose all that apply*)

    a. rapid sand
    b. pressure
    c. mechanical
    d. chlorination
    e. slow sand

(Answer: a., b., c., and e.)

Fill in the blank:

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

R	flow rates of 2 gpm/sq. ft. or higher
S	during cleaning, the top layer of the schmutzdecke is scraped from the top of the filter
R	uses backwashing to clean the media (water flow is reversed through the filter and the backwash waste water is removed from the filter)
R	mechanical components consist of filter box, underdrain, surface agitator, and filter media
S	mechanical components consist of filter box, underdrain, and filter media
S	low 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. _***T***_____	Pressure filtration is typically used on ground water to accomplish iron and manganese r removal or softening.
4. _***F***______	Slow sand filtration is a good choice for poorer quality surface waters
5. _***F***______	The first documented use of a slow sand filter was in England in 1492.
6. _***T***_____	n pressure filtration, a pump or other mechanism pushes the water through the filter.
7. _***T***______	The chemical use in slow sand filtration plants is much lower than in conventional filtration plants because biological filtration is used..
8. _***T***_____	Rapid sand filters may be preceded by the treatment processes of coagulation, flocculation, and sedimentation.
9. _***F***______	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.

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

Now let us summarize Unit 1 with a few key points.

*[Review the **Key Points**.]*

UNIT 2: PLANT COMPONENTS AND DESIGN CONSIDERATIONS 45 MINUTES

Display Slide 8—Unit 2: Plant Components and Design Considerations.

At the end of this unit, you should be able to:

- 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.

FACILITY REQUIREMENTS: <u>2 MINUTES</u>

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

Cover

*[Review the **Cover** section.]*

[Stress the benefits of covering the filter:

- ***Minimize algae growth:*** *algae can cause premature increase in headloss and greatly increase cleaning frequency and can cause taste and odor problems*
- ***Minimize ice formation:*** *can cause operational difficulties*
- ***Minimize accumulation of wind blown debris:*** *leaves, litter*
- ***Exclude wildlife:*** *waterfowl in particular*
- ***Enhance security**.]*

[Stress that the inclusion of a cover will greatly increase the cost of the facility.]

Available Space

Choosing the location of the filter can be quite involved. Factors to consider include the amount of land that will be required as well as close proximity to the source water. The location must be accessible to equipment moving in and out of the site and the filter must be located on flat land. Therefore, if extensive site work is required for any of these reasons, construction costs will increase rapidly.

Access

Even though there are few day-to-day operational requirements, the ability to enter and exit the filter must be considered. Removal of a portion of the schmutzdecke during cleaning will most likely require that some type of motorized equipment be moved in and out of the filter.

*[Continue to review the **Access** section.]*

Overflow

*[Review the **Overflow** section.*

Stress that the overflow is a safeguard to prevent the uncontrolled overflow of the filter and is found frequently on gravity type filters. The concern is that the overflow can not be simply allowed to be discharged to a receiving stream. Even if the water is withdrawn from the stream and is not treated in any way, an overflow back into the stream will usually require a discharge permit.]

FILTER TANK: 2 MINUTES

*[Review the introduction to the **Filter Tank** section.]*

Sizing

[Review the following items:]

- Sizing is determined by the desired production capacity.
- Production capacity can be calculated from the population to be served and any significant industrial or commercial users. Stress that population projections should be taken into account.
- Piloting should be conducted to determine acceptable filter flow rate.
- Review the need for redundant independent filter cells. The plant must be able to meet the maximum daily demand with the largest unit out of service.

Materials of Construction

*[Review the **Materials of Construction** section.]*

Independent Chambers

*[Review the **Independent Chambers** section.]*

UNDERDRAIN: 2 MINUTES

The underdrain in a slow sand filter only collects the filtrate; it does not distribute the backwash water.

Materials

The underdrain of a slow sand filter can be made from a variety of different materials. As with a rapid sand filter, slotted or perforated PVC pipe is often used. In addition, the use of wire wound "well screen" pipe has become increasingly popular in recent years. It is also be possible to use the new perforated plates that are available.

Arrangement

Display Slide 9—Arrangement.

*[Review the **Arrangement** section.]*

MEDIA: 9 MINUTES

*[Review the introduction to the **Media** section.]*

Some consider gravel to be a part of the underdrain system and not the filter media. The distinction does not change any of the information in this section, just the location of where it would be presented in the module.

Gravel

Display Slide 10—Media Placement.

*[Review the **Gravel** section. Be sure to highlight the following two purposes of gravel:*

1. *Supports the sand and prevents it from entering the underdrain.*
2. *Evenly distributes the water being used to fill an empty or drained filter.]*

Sand

[Review that sand is the actual filter media in a slow sand filter.]

[Review why silica sand is used.]

When selecting filter sand, the vendor will ask two things: What effective size (ES) and what uniformity coefficient (UC) do you want? In order to answer these questions, the operator will need to know what is meant by effective size and uniformity coefficient and what effective size and uniformity coefficient are used for the application in question.

*[Review **Effective Size** and **Uniformity Coefficient**.]*

[Review the example.]

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

Display Slide 11—Example.

Ex: 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.

Display Slide 12—Example.

Ex: 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.

*[Continue to review the **Sand** section.]*

Sand depth for a slow sand filter is usually between 30 – 36 inches.

[Stress the importance of either obtaining clean media or cleaning it prior to placement in the filter.]

Dirty media will cause poor quality effluent and rapidly increasing head loss.

HYDRAULIC CONTROLS AND MONITORING DEVICES: 3 MINUTES

[Stress that although a slow sand filter is low tech it contains several valves and control devices. The operator must maintain these components and pay attention to what the monitoring devices are telling him.]

Valves and Drains

[Briefly touch on the valves and drains but don't dwell on them.]

[Continue to review the ***Valves and Drains*** *section.]*

[Stress the rate of flow controller and briefly mention that there are two modes of filter rate control: influent and effluent flow control. These two rate of flow control strategies will be detailed in Unit 3.]

Monitoring Devices

[Review the ***Monitoring Devices*** *section.]*

OUTLET CHAMBER: <u>3 MINUTES</u>

The outlet chamber serves a critical function in a slow sand filter. It prevents the accidental dewatering and air binding of the filter.

Filter Dewatering

Display Slide 13—Cross Section of a Slow Sand Filter.

*[Review the **Filter Dewatering** section.]*

Air Binding

*[Review the **Air Binding** section.]*

FINISHED WATER HOLDING TANK: 3 MINUTES

The finished water holding tank provides storage capacity to compensate for fluctuations in system demand and to allow time for adequate disinfection.

Capacity Determination

*[Review the **Capacity Determination** section.]*

Disinfection

Disinfection must be sufficient to provide adequate CT. CT is the product of the chlorine residual multiplied by the time in the finished water holding tank. A calculation must be done in order to determine the necessary size of the holding tank.

One issue to be aware of is the wasting of water from the storage facility. Slow sand filters operate best when allowed to run at a steady flow rate. At times this rate may exceed system demand and if this occurs at a time when the holding tank is full, it is necessary to waste water and discharge it to a lagoon or receiving stream. If the water has been chlorinated prior to discharge it could be damaging to the environment. For this reason, the point of chlorine application could be delayed until after the overflow point or it must be dechlorinated prior to discharge.

FILTER CLEANING EQUIPMENT: 11 MINUTES

Cleaning of the filter bed can be a very labor intensive effort. The bed can be cleaned manually using rakes, shovels, and wheelbarrows. Larger installations may use mechanized equipment like garden tractors, all terrain vehicles, or even backhoes and dump trucks.

Once the dirty sand is removed, the question of what to do with it remains. It can be discarded or used as fill in some cases, or, since the cost of sand is perhaps the single largest capital expense for a slow sand filtration plant, it can be cleaned and reused. Specialized equipment is required for the handling and cleaning of the spent sand.

Sand Ejectors

*[Review the **Sand Ejectors** section.]*

Sand Washing Unit

*[Review the **Sand Washing Unit** section.]*

Sieve Analysis

*[Review the **Sieve Analysis** section.]*

PROCESS MODIFICATIONS: 5 MINUTES

If the source water is not suitable for slow sand filtration, there are a few treatment steps that can be taken to improve the source water quality so it is acceptable.

Presedimentation Basins/Raw Water Reservoir

[Review the ***Presedimentation Basins/Raw Water Reservoir*** *section.]*

Roughing Filters

[Review the ***Roughing Filters*** *section.]*

Nutrient Addition

*[Review the **Nutrient Addition** section.]*

[*Have the participants do the exercise by themselves. Then discuss the answers as a large group.]*

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?

   f. cover for the filter
   g. location of the closest sand manufacturer
   h. enough available space
   i. site with good access
   j. ability to discharge overflow water

(Answer: b. location of the closest sand manufacturer)

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

(Answers: a., b., and d.)

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

(Answer: c. air binding tube)

4. The sand in a slow sand filter is composed almost exclusively of ________.

   a. calcium
   b. mica
   c. silica

(Answer: c. silica)

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

   a. 12
   b. 10
   c. 8

(Answer: a. – 12 hours)

6. A slow sand filter does not undergo _____ .

   a. backwashing
   b. draining for maintenance
   c. cleaning

(Answer: a. – backwashing)

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

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

Now let us summarize Unit 2 with a few key points.

[Review the ***Key Points****.]*

[References: *No need to discuss this page.]*

UNIT 3: FILTER OPERATION: 45 MINUTES

Display Slide 14—Unit 3: Filter Operation

At the end of this unit, you should be able to:

- 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.

Display Slide 15—Unit 3: Filter Operation

- Be able to state the maximum allowable turbidity that can be produced by a slow sand filter.
- Identify the two criteria used to determine when media cleaning is required.
- List the five most common operational problems exhibited by a slow sand filter.
- Name the method used to correct air binding of a slow sand filter.

MODE OF OPERATION: 4 MINUTES

[Review the introduction to the ***Mode of Operation*** *section.]*

Influent Flow Control

[Review the ***Influent Flow Control*** *section.*

- *Mention that some plants will use the influent overflow line to maximize the amount of available head.*
- *Discuss monitoring the influent level as a way to gauge filter head loss. Mention that a influent head gauge provides the same information but perhaps a bit more reliably.*
- *Point out that in influent flow control, a flow meter is placed on the influent line to measure the filter rate of flow.]*

*[Continue to review the **Influent Flow Control** section.]*

Effluent Flow Control

*[Review the **Effluent Flow Control** section.]*

FILTER STARTUP: 4 MINUTES

For a filter to operate properly, it should be started using a particular process. This process should be used if the filter is being started for the first time, or being started after being offline for maintenance and cleaning. The process for starting a filter is intended to assure that air is not trapped in the filter bed and that it is not placed into service before it begins to produce an acceptable water quality.

Scraped or Resanded Filter

[Review the ***Scraped or Resanded Filter*** *section. Include the following information:]*

After filter cleaning, the filter bed will be quite disturbed. It is important that the filter be returned to service properly in order to minimize impacts on operation and water quality.

Backfilling

[Review the ***Backfilling*** *section. Include the following information:]*

The only effective way to cure an upset filter is to remove the sand and gravel media and rebuild the filter. This is an extremely expensive and labor intensive process.

[Review the key point.]

Filter-To-Waste

After the completion of filter maintenance and backfilling, the filter should be run to waste until it begins to produce an acceptable water quality. This filter-to-waste cycle allows for the redevelopment of the schmutzdecke on a cleaned filter.

Filter Ripening

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

- Source water quality, and
- Water temperature.

As previously mentioned, the source water must contain adequate amounts of organic, inorganic and microbiological components in order for it to ripen within a short period of time. Source water temperature also plays a roll in the rate at which a filter ripens. Colder water tends to slow the ripening process. Warmer water increases the speed at which filter ripening occurs.

[Review the guidelines for determining when a filter has ripened and is ready to return to service.]

[Review the key point.]

DAILY OPERATION: 8 MINUTES

Daily operational responsibilities are fairly minor. They are limited to occasional adjustments of flow rate, monitoring and recording performance data, and the checking of mechanical equipment.

Monitoring and Recording

*[Review the **Monitoring and Recording** section. Include the following bullet statements:]*

- ***Rate of Flow:*** *Sudden changes in rate of flow may indicate problems with the filter bed or mechanical equipment.*
- ***Head Loss:*** *Sudden changes in head loss may indicate filter bed problems or significant changes in source water quality.*
- ***Water Temperature:*** *Can be used as an indirect indicator of impending changes in source water quality.*
- ***Turbidity:*** *Increasing effluent turbidity can indicate that filter cleaning is required.*
- ***Chlorine Residual:*** *Continuous monitoring is required by PA DEP. Sudden changes may indicate a significant change in source or filtered water quality.*
- ***Storage Facilities:*** *Sudden changes in elevation may indicate main line leaks or other distribution system problems.]*

Mechanical Checks

Operational checks can be used to indicate that the mechanical equipment is functioning properly. However, operational checks will indicate that there is a problem only after there is a mechanical failure. In order to avoid this, it is important to check various pieces of mechanical equipment on a daily basis. By checking the equipment on a daily basis, problems that might eventually be found by doing the operational checks may be discovered before they impact finished water quality. Two areas that should be checked are the raw and/or high service pumps and the chemical feed equipment.

*[Review **Pumps** and **Chemical Feed Systems**.]*

FILTER PERFORMANCE: 8 MINUTES

Performance of a slow sand filter can be impacted by a variety of factors. Obviously, things like raw water quality, loading rates, and the mode of filter operation can impact filter performance. But other factors like required performance standards and cleaning frequency/procedures can also impact filter performance.

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. The first cyclic influence is runoff.

- **Runoff:** Every fisherman knows heavy rains can have a dramatic impact on stream water quality. While this can be an annoyance for the fisherman, it can be considerably more troublesome for a water plant operator. A thunderstorm can change a peaceful babbling brook into a raging torrent and cause an increase in turbidity from 2-3 NTU to 100–200 NTU in minutes. Depending on the nature of the watershed, these storms may occur miles from the treatment plant and may catch the operator by surprise. Since a slow sand filtration facility generally has very limited pretreatment options, a drastic change in water quality can be disastrous.

  If these runoff events are not frequent or long in duration, it may be possible to accommodate these occurrences by more frequent filter cleanings after the fact or by implementing some type of intermittent pretreatment. If the events are frequent, continuous pretreatment or other type of filtration may be necessary. Some types of pretreatment were discussed in Unit 2—Process Modifications.

*[Review the **Diurnal Fluctuations** section. Include the following information:]*

Raw water with significant amounts of algae can exhibit diurnal pH fluctuations. The pH can increase during the afternoon and decrease after sunset. Changes in raw water pH can impact filtered water quality. Algae can also impact the amount of dissolved oxygen in the water. During daylight hours algae produces oxygen; after sunset the algae consumes oxygen. If too much oxygen is consumed during the night it can create an anaerobic condition in the filter and have a severe negative impact on the other microorganisms populating the schmutzdecke. This can negatively impact filtered water quality.

[Continue to review the ***Cyclic Influences*** *section. Include the following information:]*

As water becomes colder and more viscous, more energy is required to move the water through the filter and therefore, headloss is developed more quickly than with warmer water. This will require more frequent cleanings in order to maintain the desired production from the filter.

Algae growth in the filter is undesirable for a number of reasons. It can cause a rapid increase in headloss, consume nutrients that may be needed by the filter's beneficial microorganisms, and can impart unpleasant tastes and odors in the filtered water.

Operational Mode

[Review the ***Operational Mode*** *section. Include the following information:]*

Continuous Operation: It has been shown that a continuously operating filter will produce a better quality effective of effluent than a filter operated intermittently. Particle removal and bacteriological quality are enhanced in a continuously operated filter. Likewise, effluent quality is enhanced if the filter is operated at a steady rate of flow. Changes in rate of flow will have some impact on water quality but less so than if the filter is operated intermittently.

Intermittent Operation: The effluent of a slow sand filter is impacted by intermittent operation in two major ways.

1. Particulate and bacteriological removal efficiencies are reduced in an intermittently operated filter.
2. If a filter is taken off-line, the action of algae and bacteria may create an anaerobic condition in the filter bed. Anaerobic conditions will negatively impact filter performance.

Loading Rates

*[Review the **Loading Rates** section.]*

[Go over this exercise as a group. Use a flipchart to record the calculation.]

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.

Ans: First calculate the filter's surface area: 20 ft. X 40 ft. = 800 sq. ft.

Next divide the flow rate by the filter's surface area: 35 gpm / 880 sq. ft. = 0.044 gpm / sq. ft.

Surface Water Treatment Rule and Performance Standards

[Review the ***Surface Water Treatment Rule and Performance Standards*** *section. Include the following information and key points:]*

Turbidity removal is significant for a number of reasons. It is an indication of how well the filter is removing particulate material and this correlates directly to how well the filter is removing *Giardia* and *Cryptosporidium* from the influent. It is also necessary to produce water with as low a turbidity as possible in order to maximize the effectiveness of the disinfection process.

Slow sand filters have been shown to reliably achieve a 3-log (99.9%) removal of *Giardia lamblia* cysts when operated properly.

Virus removal by slow sand filtration has not been well documented but some reports suggest that virus removal by slow sand filtration is achievable.

[Review the key poinst.]

Cleaning Criteria

[Review the ***Cleaning Criteria*** *section.]*

[Review the key point.]

MEDIA CLEANING AND REPLACEMENT: 12 MINUTES

Introduction

*[Review the **Introduction** section.]*

Cleaning Methods

There are three methods for cleaning a slow sand filter.

- **Scraping:** Scraping is the most commonly used and perhaps the most effective method of cleaning a slow sand filter. There are a variety of techniques that can be used, but all consist of removing a thin layer, maybe an inch or so, of the schmutzdecke from the top of the filter bed. As has been discussed, most of the filtration activity in a slow sand filter occurs on the very top of the filter bed. So by removing the very top of the sand bed most of the material that has been deposited in the filter is also removed.

  Process

  – Scraping can be accomplished in a number of ways, but usually consists of draining the filter to just below the top of the filter bed and then using an asphalt rake or shovel to rake a thin layer of the schmutzdecke into parallel windrows throughout the filter bed. The windrows are then shoveled into buckets, wheelbarrows, or dump carts pulled by garden tractors. After the windrows are shoveled up they are removed from the filter for disposal or cleaning and reuse.

  – Larger slow sand filters can be cleaned mechanically using tractors with mechanized scrapers and dump trucks to remove a layer of the schmutzdecke.

  – After scraping, the filter bed should be smoothed using the back of the rake or a section of wire mesh or cyclone fence.

  – Prior to scraping, some operators will raise the filter level to allow loose debris to float out of the influent overflow. This can reduce the amount of material that must be shoveled from the filter.

The second method is raking.

- **Raking** is a procedure used to increase the filter's run time with out removing a layer of the schmutzdecke.

  Process

  – After the filter bed is drained to just below the top of the schmutzdecke, an ordinary garden rake is used loosen the surface of the schmutzdecke. This opens more surface area and allows flow to return to the desired level for a period of time.

  – Raking definitely saves labor effort and time, although there is some evidence that this practice allows the penetration of debris deeper into the filter bed and may negatively impact filter effluent quality. Also, by allowing the penetration of debris deeper into the filter bed, any subsequent scraping will need to remove more media to eliminate all of the material clogging the filter.

[Review the third method which is ***wet harrowing****.]*

Returning to Service

[Review the ***Returning to Service*** *section.*

Discuss the need to allow the filter to ripen. Stress that the action of the schmutzdecke is what provides for the removal of particles and other material. Note that an unripened filter will not produce a good quality effluent and the only effective way to ripen a filter is to run it in filter-to-waste mode.]

Resanding

Scraping a filter removes the top layer of sand. 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

What criteria should be used to determine when to add sand to a slow sand filter? Some installations add sand after every scraping, but there is some evidence that this can drive waste material deeper into the filter bed and degrade filter performance.

Typically, a filter should be resanded after approximately a foot of sand has been removed. Although, the deeper the filter bed, the lower the bed can be allowed to drop before resanding.

Replacement Sand

*[Review the **Replacement Sand** section.]*

[Review the key point.]

Replacement Techniques

*[Review the **Replacement Techniques** section.]*

[Continue to review the ***Resanding*** *section.]*

OPERATIONAL TROUBLESHOOTING: 4 MINUTES

Operational Difficulties

Slow sand filters are generally free of operational problems. However, there are a few common problems to be aware of.

*[Review the **Operational Difficulties** section.]*

Air Binding

*[Review the **Air Binding** section.]*

Have the participants do the exercise by themselves or with a partner. Then discuss the answers as a large group.

Exercise

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

(Answer: a. influent flow control + c. effluent 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

(Answer: a.-scraping)

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

(Answer: d. - 10)

3 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

(Answer: c. – wet harrowing)

4. 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

(Answer: b. - raking)

5. Which is the best flow pattern for slow sand filter performance?

   a. constant
   b. variable
   c. intermittant

(Answer: a. - constant)

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?

   a. 0.01 NTU
   b. 0.1 NTU
   c. 1 NTU

(Answer: b. 0.1 NTU)

7. Select the cyclic influences that may impact the operation of a slow sand filter? (*Choose all that apply*)

   a. heavy downpours
   b. diurnal fluctuations
   c. changes in source water temperature
   d. changes in the amount of solar radiation the filter is exposed to

(Answer: a., b., c., and d.)

8. In a slow sand filter a high percentage of Giardia cysts are removed by:

   a. biological processes
   b. chemical disinfection
   c. changes in source water temperature
   d. changes in the amount of solar radiation the filter is exposed to

(Answer: a., b., c., and d.)

9. Select the description of the unfiltered water which will result in shorter filter run times.

   a. disinfected before being filtered
   b. contains more than 15 units of color
   c. is clear and cold
   d. is undergoing an algae bloom

(Answer: d.- 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.

   a. 0.3 NTU
   b. 0.5 NTU
   c. 1.0 NTU
   d. 0.1 NTU

(Answer: c. 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 ÷ (filter length x filter width) = filter loading rate

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

11. Using the above calculation, what is Tinyown'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.

(Answer: b. – 0.023 gpm/ sq. ft.)

2. Since the DEP maximum loading rate for a slow sand filter is 0.1 gpm/sq. ft., using the answer to Calculation question #1, is Tinyown's loading rate exceeding the allowable rate?

    a. yes.
    b. no

(Answer: b. – they aren't exceeding the allowable rate since 0.023 gpm/ sq. ft. is less than 0.1 gpm/sq. ft.)

Now let us summarize Unit 3 with a few key points.

*[Review the **Key Points**.]*

UNIT 4: PREVENTATIVE MAINTENANCE, OPERATIONAL, AND EQUIPMENT RECORDS: 20 MINUTES

Display Slide 16—Unit 4: Preventative Maintenance, Operational, and Equipment Records

At the end of this unit, you should be able to:

- 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.

PREVENTATIVE MAINTENANCE: 5 MINUTES

*[Review the introduction to the **Preventative Maintenance** section.]*

Daily Checks

*[Review the **Daily Checks** section.]*

Weekly Checks

The following activities should be performed on a weekly basis:

- **Clean Equipment:** While it is not necessary to get the scrub brush out and scrub down all of the operating equipment every week, it is important to check the equipment once a week to make sure it is in a presentable condition. Remember, a water plant produces a product for human consumption. In addition, by keeping equipment clean, it may be easier to spot changes in the condition of the equipment. For instance, a gearbox leaking grease may not be noticed if you didn't wipe off the housing after the last time you greased it.
- **Chemical Inventory:** Running out of a critical treatment chemical is inexcusable. For this reason, a weekly chemical inventory check should be done. The weekly check can also reveal changes in chemical demand that may not be apparent on a day to day basis. Chemical feed pumps tend to loose capacity gradually, so succeeding days' usages may be just slightly less than the previous day and not readily noticeable. However, after a week a pump's loss of capacity will become apparent.
- **Lubricate Equipment:** Rotating equipment like pumps undergo a significant amount of stress even under normal operating conditions. In order to minimize the effects of this stress, it is important to provide all of the mechanical equipment with the necessary lubrication. Follow manufacturer's recommendations and maintain a regular lubrication schedule.
- **Operate Valves, Other Mechanicals, and Standby Equipment:** Many valves and other mechanical equipment do not operate on a regular basis. For instance, the suction and discharge valves on a high service pump may always be in the open position. These valves are provided primarily as a way to isolate the pump for maintenance. If the valves are not exercised on a regular basis they may seize in place and be inoperable when they are needed. For this reason, it is important to operate all of the mechanical equipment on a regular basis to ensure that it will function when needed.

  A similar situation may occur with emergency standby equipment such as a diesel generator or pump. If these pieces of equipment are not regularly used, they may not work properly when needed.
- **Change Charts/Verify Archive:** Most water facilities have a method to record certain types of operating data. It may be a circular or strip chart recording the filter effluent turbidity, or it could be tank elevation data being saved by a SCADA system. Regardless of how the data is collected and stored, the operator should verify that is being saved on a weekly basis. This may consist of saving files in the PC or querying the SCADA system to verify that the data exists. Or it may involve changing the weekly circular chart and putting last week's on the stack with the others.

Monthly Checks

*[Review the **Monthly Checks** section.]*

Biannual Checks

*[Review the **Biannual Checks** section.]*

Annual Checks

*[Review the **Annual Checks** section.]*

OPERATIONAL RECORDS: 5 MINUTES

*[Review the introduction to the **Operational Records** section.]*

Analytical Records

*[Review the **Analytical Records** section.]*

Sampling Records

*[Review the **Sampling Records** section.]*

Filter Operation/Cleaning Records

*[Review the **Filter Operation/Cleaning Records** section. Include the following information:]*

These records can be used to predict when the next cleaning will be required. They can be used as a guide for when to request vacation. They can be useful in predicting how much additional sand should be ordered.

*[Continue to review the **Filter Operation/Cleaning Records** section.]*

EQUIPMENT AND MAINTENANCE RECORDS: 5 MINUTES

In order to accurately keep track of equipment maintenance, it is very important to keep accurate records. In order to know what maintenance is required and at what intervals it should be performed, it is important to keep the original equipment information supplied by the manufacturer.

Equipment Records

*[Review the **Equipment Records** section.]*

Maintenance Records

*[Review the **Maintenance Records** section.]*

[Have the participants do the exercise by themselves or with a partner. Then discuss the answers as a large group.]

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.

__***D***__ rate of flow	__***M***__ calibrate on-line analytical equipment
__***D***__ head loss	__***D***__ effluent turbidity
__***W***__ lubricate equipment	__***D***__ chlorine residual
__***D***__ water temperature	__***D***__ storage facilities
__***W***__ chemical inventory	__***M***__ verify proper functioning functions of safety equipment)

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

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

Now let us summarize Unit 4 with a few key points.

*[Review the **Key Points**.]*

We are now finished with Unit 4 and Module 17. Are there any questions?