

# Drinking Water Operator Certification Training Instructor Guide



## Module 18: Bag Filtration and Cartridge 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 18: Bag Filtration and Cartridge Filtration is to introduce the students to the process of bag and cartridge filtration. This module has been designed to be completed in approximately 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
- Small group and full group discussion
- 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

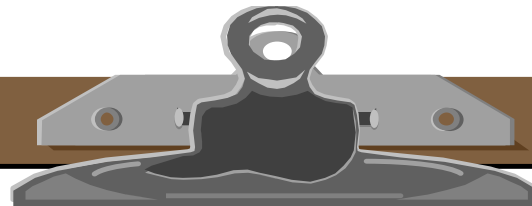
Icons to become familiar with include:

Participant Workbook	Instructor Guide
 Exercise/Activity	Same icons for Participant Workbook apply to the Instructor Guide.
 Case Study	<b>Ans:</b> Answer to exercise, case study, discussion, question, etc.
 Discussion Question	 PowerPoint Slide
 Calculation(s)	 Overhead
 Exercise	 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.

<b>To</b>	<b>Press</b>
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

## INSTRUCTOR GUIDE

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### INTRODUCTION OF MODULE: 5 minutes



Display Slide 1—Module 18: Bag Filtration and Cartridge Filtration.

*[Welcome participants to “Module 18: Bag Filtration and Cartridge Filtration.” Indicate the primary purpose of this course is to introduce the students to the process of bag filtration and cartridge filtration. The capabilities and limitations of bag and cartridge filtration will be discussed as well as performance requirements stipulated in the Safe Drinking Water Act. The module will discuss the components of bag filters and cartridge filters and also discuss operational and maintenance activities.]*

*[Introduce yourself.]*

*[Ask the participants to introduce themselves.]*

*[Provide a brief overview of the module.]*



This module contains 5 units. On page i, you will see the topical outline for this module.

*[Briefly review the outline.]*

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*[Continue to briefly review the outline.]*

## **INSTRUCTOR GUIDE**

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*[Continue to briefly review the outline.]*

## **INSTRUCTOR GUIDE**

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*[Continue to briefly review the outline.]*



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### UNIT 1: INTRODUCTION TO BAG FILTRATION AND CARTRIDGE FILTRATION: 20 MINUTES



Display Slide 2—Unit 1: Introduction to Bag Filtration and Cartridge Filtration.



As a result of this unit, the learner will:

- Be introduced to the principal similarities of and differences between bag filters and cartridge filters.
- Be able to identify the two major applications and two major limitations of both bag filtration and cartridge filtration.

### DEFINITIONS: 5 MINUTES



Bag filters and cartridge filters have been in use for many years. They are used for a variety of applications from industrial processes to water treatment. Most of you are probably familiar with cartridge filters from home filtration devices that are installed on a water line as it enters a residence. They are usually housed in a plastic vessel and filter particulate material out of the water.

An example of a bag filter, although not related to water treatment, is the dust bag in a vacuum cleaner.

### Bag Filters

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

*[Although discussed in other modules, briefly define and discuss Giardia cysts and Cryptosporidium oocysts since the primary application for bag and cartridge filters in water treatment is to remove these protozoans.]*



Chemical pretreatment is not required in bag filtration because the pore size of the filtration devices is small enough for effective particle removal without the need for pre-treatment.

**Cartridge Filters**

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

### APPLICATIONS AND LIMITATIONS FOR USE: 5 MINUTES

#### Applications



Bag filters and cartridge filters are used for a wide variety of applications in both industrial uses and in water treatment. Bag filters and cartridge filters are available in a wide range of pore sizes. The pore size selected for a location should be based on the size of the material that must be removed.

#### Industrial

*[Review the **Industrial** section.]*

#### Water Treatment

*[Review the three general applications for bag filtration or cartridge filtration in a water treatment plant.]*



For **Surface Water Treatment Rule (SWTR) Compliance**, bag filters and cartridge filters may be used to provide filtration of surface water or ground water under the influence of surface water. Due to the finite solids removal capacity of the filters, their application is likely specific to small systems with fairly high quality source water.

As solids are removed from the source water, they are deposited on the filter. Bag filters and cartridge filters are disposable, that is, not designed to be cleaned when they become clogged with particulate material. For this reason it is generally economically unfeasible to use bag filters or cartridge filters on low quality source waters.

When used for compliance with SWTR, it is necessary to select a filter with a pore size small enough to remove *Giardia* cysts and *Cryptosporidium* oocysts. However, this pore size may not be capable of producing water with turbidity low enough to comply with SWTR requirements. Verification of the ability of the filters to produce water of an acceptable turbidity must be done prior to purchasing and installing a bag filter or cartridge filter system.



**(Prefiltration)** Bag filters and cartridge filters can also be used as a prefilter prior to other treatment processes. For instance, membrane filter systems often use a bag filter with a relatively large pore size prior to introducing the feed water to the membrane itself. This prefiltration is intended to remove large debris that could become lodged on the surface of the membrane or in the pressure vessel. The removal of this large debris will allow the downstream process to operate more efficiently since it reduces the particulate loading on that process.



**(Solids Removal)** In some instances, bag filtration or cartridge filtration is used to remove solids from a waste stream. More information concerning solids removal can be found in the Appendix of your workbook.

### Limitations



As touched on above, bag filtration and cartridge filtration has limited use in water treatment. Two major items limit the use of bag filters or cartridge filters as a primary water treatment technique. The two major limiting factors are:

- Source water quality
- System size

### Source Water Quality

*[Review the **Source Water Quality** section.]*



Even if you are using low turbidity sources waters there is still the concern the water intake could contain large objects such as fish or other debris. Intake screening devices may be used to prevent or minimize the entry of large objects or fish into the treatment facility.

*[Continue to review the **Source Water Quality** section. Include the following information:]*



Algae is problematic in all water treatment applications. Unfortunately, all surface water contains some amounts of algae. Each bag filter and cartridge filter manufacturer will have slightly different criteria for allowable algae levels in source water. Only source waters with low algae levels are suitable for bag filtration or cartridge filtration.

### System Size

*[Review the **System Size** section. Include the following information:]*



**Capital Costs:** The capital costs of a bag or cartridge filter system can be relatively low compared to other treatment options. The capital equipment required is usually only the pressure vessels, pumps, chemical feed equipment, and analytical equipment. Of all of these items, only the pressure vessels are unique to a bag or cartridge filter system. Pressure vessels are relatively inexpensive when compared to the requirements of other types of treatments.

**Operation & Maintenance (O&M) Costs:** While capital costs are quite low for bag or cartridge filtration, the O&M costs can be quite significant. The most significant cost would likely be the expense of the replacement filters. The filters may not appear to be that expensive when looked at initially, but the number of filter elements required for a year's operation can create a very significant O&M expense for a water plant.

**Flow Rate:** Most bag or cartridge filter system manufacturers have established maximum flow rates for their equipment. There is a maximum amount of flow that can be accommodated through a single filter element or array. Additional filter elements are added to handle flows in excess of the rated capacity. Of course, the addition of elements will increase capital and O&M costs. Although there is no hard and fast rule, bag or cartridge filtration is most appropriate for lower flow systems.

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



### Exercise

## Unit 1 – Exercise

### Multiple Choice – Choose the best answer:

1. Which statement is true about bag and cartridge filters?

- a. Bag and cartridge filters tend to be non-rigid.
- b. Bag and cartridge filters are typically rigid.
- c. Bag filters tend to be non-rigid, cartridge filters are typically rigid.
- d. Bag filters tend to be rigid, cartridge filters are typically non-rigid.

(Answer: c.- Bag filters tend to be non-rigid, cartridge filters are typically rigid.)

2. Which type of systems are bag and cartridge filters usually limited to?

- a. Small sized systems
- b. Medium sized systems
- c. Large sized systems

(Answer: a. – Small sized systems)

3. Which of the following is **not** a water treatment application for bag or cartridge filters?

- a. For use with coagulants or a pre-coat.
- b. For use as a prefilter prior to another treatment process.
- c. To provide filtration of high quality surface water or ground water under the influence of surface water (GUDI) sources.

(Answer: a. - For use with coagulants or a pre-coat.)

4. Bag and cartridge filters typically remove which of the following? (Choose all that apply)

- a. Bacteria
- b. Giardia cysts
- c. Viruses
- d. Cryptosporidium oocysts
- e. Fine colloids

(Answer: b.- Giardia cysts and d. - Cryptosporidium oocysts)

5. What are the two main factors that limit the use of bag or cartridge filtration for water treatment (Select two)

- a. pH
- b. source water quality
- c. water temperature
- d. system size
- e. chemical pretreatment

(Answer: b. – source water quality and c. – water temperature)

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Now let us summarize Unit 1 with a few **Key Points**.

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



In this unit we have defined what is meant by bag and cartridge filtration and discussed some possible applications and limitations for the use of bag or cartridge filters. In the next unit we will discuss the design and configuration of bag or cartridge filter systems. We will also discuss materials and methods used to manufacture the filtration systems, and describe system components and configurations.



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### UNIT 2: SYSTEM DESIGN AND CONFIGURATION: 40 MINUTES



Display Slide 3—Unit 2: System Design and Configuration.



As a result of this unit, the learner will:

- Be able to identify the main components of both bag and cartridge filtration systems

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### MATERIALS AND METHODS OF CONSTRUCTION: 10 MINUTES



As was suggested by the learning objectives, the purpose of this unit is to:

- Introduce you to the materials and methods used to construct bag or cartridge filter systems.
- Discuss the different components that may be included in a bag or cartridge filter system.
- Describe possible configurations.

*[Stress that these systems are designed and manufactured by many different manufacturers and have many applications outside of the water industry; therefore, there are many different configurations and designs. Note that the filters can be constructed of many different materials.]*

*Indicate that since each system is manufacturer specific, there is little opportunity to interchange parts from different manufacturers' systems—in particular, filters tend to be NOT interchangeable.]*

### Filters

*[Review the **Filters** section. Note that there are few similarities between manufacturers.]*

### Materials

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

*[Stress that bags and cartridges can be made from many different types of materials. Filters made from certain materials may be better suited to certain applications. For instance, chlorine is somewhat aggressive to polypropylene. So, if the water fed to the filtration system is chlorinated, the operator may want to choose a bag or cartridge filter made from something other than polypropylene.]*

*Although the operator has to rely on the manufacturer's recommendations, the manufacturer may attempt to force his product to fit the application. For this reason, it is important to investigate different manufacturers' materials prior to making a decision on a filtration system.]*

### Manufacturing Techniques

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

*[Stress that the techniques are probably manufacturer specific and in some cases they are proprietary.]*

*(Bag filters) Indicate that a sewn seam may be more susceptible to short-circuiting through the sewn seam of the bag. Welding may be somewhat better at avoiding this.*

*(Cartridge Filters) Note that all cartridge filters have a central core around which the filter is placed.]*



Cartridge filters are rated by tensile strength.



The smaller the pore size in a cartridge filter, the higher the inlet pressure requirement.

### Filter Housings

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

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### Materials and Construction

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

*When discussing the importance of the O-ring in the second paragraph, stress that the seal separating influent from effluent is of critical importance. It is a mechanical seal—usually a rubber O-ring.]*



Display Slide 4—Examples of Bag Filter Housings and Example of the Internal Components of a Bag Filter Housing.

***[Figure 2.2 Examples of Bag Filter Housings: All four are bag filter housings of different sizes.]***

***[Figure 2.3 An Example of the Internal Components of a Bag Filter Housing: Note the holes in the top. Water enters through the holes. Then note the double O-rings. Finally, note the support screen that provides rigidity to the bag.]***

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*[Continue to review the **Materials and Construction** section.]*

### Orientation

*[Review the **Orientation** section. Include the following information about a cartridge filter:]*



Depending on the length of the filter itself, vertically orienting the filter may require quite a bit of head space (and a very tall ladder) to replace the cartridges. For this reason most long cartridge filter systems are horizontally oriented.



### SYSTEM COMPONENTS: 10 MINUTES



Thus far we have discussed the way bag and cartridge filters and their housings are manufactured and how the filters are placed into their housings. However, a bag or cartridge filter system consists of more components than just the filters and housings. In this section we will describe the components used to make the entire bag or cartridge filter system.

### Prefilter

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



The primary purpose of the prefilter is to save and extend the life of the final filter. Prefilters tend to be cheaper to manufacture and less exacting in pore size. They remove the larger particles so they don't clog the more expensive smaller pored final filter.

### Filter

*[Review the **Filter** section. Note that some systems may use multiple filtration steps, but some smaller applications would use only a prefilter and final filter.]*

### Other Components



As previously mentioned, the filters and housings are the heart of a bag or cartridge filter system. However a system will require other components in order to function properly. These components are common to any water treatment system and include valves, gauges, flow meters, chemical feed equipment, and on-line analyzers.

*[Review the **Other Components** section. Please reaffirm the following statements:]*



The housings for cartridge filters should be equipped with inlet and outlet pressure gauges.

The purpose of inlet and outlet pressure gauges on a cartridge filter is to monitor head loss.

*[When discussing Chemical Feeders, include the following information:]*



**Chemical Feeders:** Although the proper operation of a bag or cartridge filtration system does not rely on chemical treatment, some chemical addition will be required. For instance, PADEP requires chlorination of any surface water or ground water under the influence of surface water. Since most water treatment applications for bag and cartridge filters are to provide for filtration of surface water, some type of chlorination equipment will be required.

Depending on the quality of the source water, other treatment chemicals may be necessary. For instance, if the source water pH is lower than desired, caustic soda or soda ash may need to be fed to raise the pH. If distribution system corrosion inhibition is desired, chemical feed equipment will be required for this application as well.

*[When discussing on-line analytical equipment, please state the following:]*



The use of chart recorders at the filters to obtain a continuous record of head loss and flow rate is advantageous because it provides an easily monitored means of determining the best time to change the filter.

### SYSTEM CONFIGURATIONS: 10 MINUTES



The configuration of the filter system depends primarily on the source water quality and on the production capacity. The worse the source water and the higher the flow rate, the more filters and the more complex the system will be.

### Bag Filter Systems

*[Review the **Bag Filter Systems** section. Include the following information:]*



The phrase “Single Filter System” could be somewhat misleading. Even though only one filter is required for treatment and only one would be on-line at any given time, the PA DEP will require full redundancy of the treatment system. That means that even a single filter system will require two separate treatment trains each consisting of one filter.

The usefulness of a Prefilter – Post Filter System is determined by the characteristics of the feed water. If the source water does not contain significant quantities of large particles the usefulness of the prefilter will be somewhat limited.

A Multiple Filter System is an extension of the prefilter – post filter configuration. Rather than having a prefilter and a post filter, a multiple filtration system would consist of progressively finer filters plumbed in series.

**Cartridge Filter Systems**

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



### Exercise

## Unit 2 – Exercise

### Multiple Choice – Choose the best answer:

1. Which of the following are true statements about cartridge filter? (**Choose all that apply**)
- The larger the pore size in a cartridge filter, the higher the inlet pressure requirements.
  - Cartridge filter housings may be made of Teflon.
  - Cartridge filters are rated by tensile strength.

*(Answer: only c. is true;*

- is false because the **smaller** the pore size in a cartridge filter, the higher the inlet pressure requirements.*
- Is false – cartridge filters may be made of stainless steel or plastic; Teflon is neither of these materials.)*

2. Which of the following statements about pressure gauges are true? (**Choose all that apply**)
- The housings for cartridge filters should be equipped with pressure gauges
  - The purpose of inlet and outlet pressure gauges on a cartridge filter is to monitor flow at various locations.
  - When the pressure differential exceeds the manufacturer's limit, the effectiveness of the filter may be compromised.
  - The pressure differential across the bag or cartridge filter dictates when filter change-out must be conducted.

*(Answer: a., c., and d. are true;*

*b is the only false statement - The purpose of inlet and outlet pressure gauges on a cartridge filter is to monitor **pressure** at various points of the treatment process.)*

3. Which of the following, when located at the filters, would provide a continuous record of head loss and flow rate as well as an easily monitored means of determining the best time to change the filter?

**(Choose one)**

- valves
- pressure gauges
- chart recorders

*(Answer: c.)*

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**Matching: Match the letter of the corresponding bag or cartridge filter system component with the number of the correct statement.**

- A. on-line analytical equipment
- B. flow meters
- C. pressure gauges
- D. chemical feeders
- E. prefilter
- F. filter

1.     F     Has a smaller pore size and usually removes the target contaminant.
2.     A     Examples: Turbidimeters, particle counters, and chlorine analyzers
3.     E     Has a larger pore size to remove larger particles
4.     B     Measures finished water flow
5.     C     Monitors head loss
6.     D     Examples: chlorinator, caustic soda, or soda ash feeder

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Now let us summarize Unit 2 with a few Key Points.

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



In this unit we discussed the design and configuration of bag and cartridge filter systems. We also discussed materials and methods used to manufacture the filtration systems, and described system components and configurations. In the next unit we will discuss how to determine if bag or cartridge filtration is a viable treatment alternative for a water supplier. In addition, regulatory issues, economics, and advantages and disadvantage of the filtration systems will be discussed.

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### UNIT 3: DETERMINATION OF APPLICABILITY: 45 MINUTES



Display Slide 5—Unit 3: Determination of Applicability.



As a result of this unit, the learner will:

- Be able to identify the characteristics of source water that can impact the effective operation of either a bag or cartridge filter system.
- Be aware of the reasons why site specific piloting should be considered prior to installing either a bag or cartridge filter system.
- Receive an explanation of the advantages and disadvantages of both bag and cartridge filtration systems.



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### SOURCE WATER QUALITY: 5 MINUTES

[Review the introduction to **Source Water Quality**.]

#### Turbidity

[Review the **Turbidity** section. Include the following information:

*While reviewing the second paragraph, include that even though the filters may be able to handle relatively high turbidities, their use may prove to be uneconomical due to frequent filter change-outs. Realistically, bag and cartridge filters can be used economically on source waters of less than 1 NTU.*

*While covering the key point, include that turbidity caused by clays or fine colloids may not be removed by the filters. A pilot test would reveal if the source water is not suitable for a bag or cartridge filtration system.]*



Some types of turbidity, especially those caused by clays or fine colloidal compounds may not be well removed by bag or cartridge filters. If the filter can not produce water with a turbidity of less than 0.3 NTU in at least 95% of the samples taken on a monthly basis and never exceed 1 NTU, a different filtration system should be considered. For this reason alone, a pilot test of the proposed bag or cartridge filtration system should be conducted to confirm that the system can achieve these turbidity requirements.



Even if you are using low turbidity sources waters there is still the concern the water intake could contain large objects such as fish or other debris. Intake screening devices may be used to prevent or minimize the entry of large objects or fish into the treatment facility.

### Color/Colloids

*[Review the **Color/Colloids** section.]*

### Algae



Algae is present in the vast majority of all surface waters. The amount of algae present in the water is dependent on many things but it is determined primarily by the presence of nutrients. Things like fertilizer runoff and other agricultural and industrial practices can contribute to the growth of algae in surface water.

As with color, algae may impact the operation of the bag or cartridge filtration system in two ways. Source water algae levels would be higher than acceptable if they created an unsatisfactory filtered water quality or caused frequent filter change-outs.

Piloting, especially during summer months, can be used to gauge the input of algae.

### *Giardia/Cryptosporidium*

*[Review the **Giardia/Cryptosporidium** section.]*



Even 3-log means the removal of 99.9% of a target organism.

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**FLOW: 5 MINUTES**

*[Review the introduction to the **Flow** section. Note that the systems are modular in nature. If more flow is required, more filtration trains can be added. Economics will dictate whether adding filter trains is feasible.]*

### **Single Train Systems**

*[Review the **Single Train Systems** section.]*

### Multiple Train Systems



Display Slide 6—Example of a Multiple Train Filter System.

*[Review the **Multiple Train Systems** section.]*



In the photograph, note how the manifolds distribute the water evenly to each filter train.

We have looked at the water quality and flow issues that need to be examined during an evaluation of bag or cartridge filters. Next we will examine the treatment goals that must be considered when evaluating bag or cartridge filters.

### TREATMENT GOALS: 5 MINUTES



The evaluation of a treatment system should answer two questions. Can it produce an acceptable water quality and can it do it economically? Operational records provide the best source of information to answer these questions.

### Water Quality

[Review the **Water Quality** section.]



The PA DEP requirements are:

- The filter effluent turbidity must be less than 0.3 NTU in at least 95% of the samples analyzed each month.
- The filter effluent turbidity must never exceed 1 NTU.
- The filtration system must provide at least 2-log removal of *Giardia* and *Cryptosporidium* cysts.

### Costs of Operation

[Review the **Costs of Operation** section.]



As we have discussed, in order to determine if a bag or cartridge filtration system is a viable treatment alternative, certain issues like source water quality, system flow rate and treatment goals must be examined. Frequently, these evaluations are not sufficient to make a full determination of the viability of the proposed system. In these situations, site specific pilot scale evaluations may be necessary. Many regulatory agencies will require site specific piloting regardless of the results of any desk top or bench scale evaluations.

### SITE SPECIFIC PILOTING: 5 MINUTES

*[Review the introduction to the **Site Specific Piloting** section.]*

#### Regulatory Requirements



Most regulatory agencies will require a site specific pilot for any type of “innovative” treatment technology. It is assumed, with good reason, that conventional treatment processes will be able to produce a satisfactory finished water from any reasonable source of raw water. This is because conventional treatment practices have been used extensively for many years and have shown their ability to perform acceptably. Conventional treatment offers the flexibility to react to changing raw water quality and still produce a good quality of finished water.

Innovative treatment technologies, like bag and cartridge filtration, are not widely used for potable water treatment. Although the popularity of this type of filtration is growing, the confidence in it is not nearly as high as it is for conventional treatment. In order for regulatory agencies to develop confidence in these technologies, piloting is essential.

#### Water Quality

*[Review the **Water Quality** section.]*

### REGULATORY APPROVAL: 5 MINUTES



Even if every evaluation conducted on a proposed treatment system is favorable, gaining regulatory approval for the process is by no means guaranteed. Experience has demonstrated that the best way to get a proposed treatment system disapproved by the regulatory agency is to keep them “out of the loop” for as long as possible. Conversely, the best way to gain acceptance of an innovative technology is to involve regulators from the very beginning of the project. This will allow all of those involved in the project to become familiar and comfortable with the proposed treatment system.

There are, in fact, a number of PA DEP requirements regarding the manner in which pilot evaluations are conducted. If your pilot evaluation does not address these requirements, it will definitely not be approved. Some of the PA DEP piloting requirements are discussed in this section. There may be other requirements that are not included in this discussion.

### Pilot Protocol

*[Review the **Pilot Protocol** section.]*



After the protocol has been developed it should be submitted to the PA DEP for review and approval. Only after approval is received should testing commence.

### Seasonal Testing



One requirement for pilot evaluations of surface water sources is the necessity to conduct three seasons of testing. A season of testing typically consists of 30 days of operation. These 30 day tests are usually repeated during three different seasons of the year. The purpose of three season testing is to quantify, as accurately as possible, the impacts of seasonal changes on the quality of the source water. Significant seasonal changes can be seen in many source waters. If the testing is not conducted during different seasons, the treatment system's ability to function acceptably in those conditions will be unknown until it is, perhaps, too late.

### *Giardia and Cryptosporidium Challenge Testing*

*[Review the **Giardia and Cryptosporidium Challenge Testing** section.]*



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### ECONOMICS: 5 MINUTES



After all of the desktop, bench, and pilot scale evaluations, one question may remain: “How much will this cost?” Although as an operator your primary responsibility is to provide safe drinking water, someone in your organization will want to make sure that the water is being produced as inexpensively as possible. In this section, we will discuss the methods used to determine the economics of purchasing and operating a bag or cartridge filtration system.

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

### Capital Expense

*[Review the **Capital Expense** section.]*

### Operation and Maintenance Expense

*[Review the following operational and maintenance expense items.]*



**Labor:** Bag and cartridge filter systems are very straightforward and require very little operator involvement. With the appropriate on-line instrumentation, it is not necessary to “baby-sit” the system 24 hours a day, 7 days a week. From this standpoint, the labor expense to operate a bag or cartridge filter system is quite low.



**Expendables like Replacement Filters:** Another O&M expense, and perhaps the most significant one, is the cost of replacement filters. As mentioned, bag and cartridge filter systems are usually proprietary in nature. That means that once a system is selected, the replacement filters must be purchased from that manufacturer. In addition, switching to a different filter supplier would most likely require that the pilot evaluation be repeated with the new filters. The inability to “shop around” for replacement filters may force the operator to pay a premium for the replacement filters. If filter change-outs are frequent and the cost of the replacement filters is high, the O&M costs for a bag or cartridge filter system could be prohibitively expensive.



Switching to a different filter supplier would most likely require that the pilot evaluation be repeated with the new filters. The inability to “shop around” for replacement filters may force the operator to pay a premium for the replacement filters.



**Disposal of the Waste Created by the System:** Another expense with a bag or cartridge filter system may be the disposal of the used filters. Although this may not seem to be a significant item, it could be possible, depending on what is being removed from the source water, that the used bags would be considered hazardous waste. This may not be likely, but it should be investigated prior to committing to a bag or cartridge filter system.



**System Maintenance:** System maintenance is another area of O&M expense. Again, due to the simplicity of a bag or cartridge filter system, maintenance costs should be quite low. Simply put, there is not that much equipment to maintain in a bag or cartridge filter system.



**Instrumentation Maintenance:** The last major area of potential O&M expense is in instrumentation maintenance. As discussed above, the instrumentation required by a bag or cartridge filter system is quite modest and similar if not less than a conventional treatment system. So instrumentation maintenance expense is likely to be very modest.

### Life Cycle Costs

*[Don't dwell on this aspect of economics. It can get a little complicated—just introduce the concepts to the participants. Review the **Life Cycle Costs** section.]*



In deciding whether to purchase a treatment system, it is important to consider life cycle costs. That can be difficult for an operator to do and is best left to the accountants. However, it is important for an operator to understand the process.

### ADVANTAGES/DISADVANTAGES OF BAG FILTRATION AND CARTRIDGE FILTRATION: 5 MINUTES



As with any treatment system, there are advantages and disadvantages inherent in bag and cartridge filtration systems. These advantages and disadvantages have been discussed or hinted at in previous sections, but we will summarize them now.

*[Briefly review the advantages and disadvantages of the systems.]*

#### **Advantages**



Two principal advantages to the use of bag or cartridge filters are low capital costs and ease of operation. As mentioned, there is very little equipment required to construct a bag or cartridge filtration facility. The filter housings and support equipment is all that is really needed. The equipment is also relatively compact which means that the footprint of the building to house the treatment equipment is usually small. Since there is less equipment, installation costs tend to be low.

The other principal advantage to bag or cartridge filtration is that they require very little operator involvement. This means that the operator is available for other duties.

#### **Disadvantages**

*[Review the **Disadvantages** section.]*



### Exercise

## Unit 3 – Exercise

### Multiple Choice – Choose the best answer:

1. Which of the following source water qualities will not affect the operation of a bag or cartridge filter:

- a. turbidity
- b. color
- c. colloids
- d. algae
- e. Giardia
- f. pH

(Answer: f.)

2. Select the items that are true for bag and cartridge filters:

- a. low “up front” cost
- b. ease of operation
- c. suitable mainly for high flow systems
- g. little operator involvement
- h. suitable for waters with high algae content

(Answer: a., b., and g.)

3. Choose the statements that are true about why site-specific piloting should be considered prior to installing a bag or cartridge filter system.

- a. To verify that the filter is capable of producing water that meets regulatory requirements.
- b. To quantify the system’s ability to produce a water quality that will be acceptable to the consumer.
- c. The confidence in bag and cartridge filtration is much higher than in the conventional treatment process.
- d. To aid in the determination of the cost of operation of the proposed system.

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

4. Is this statement True or False?

The purpose of intake screening devices on the front end of a treatment plant is to allow of large objects to pass through into the treatment plant.

- a. True
- b. False

(Answer: False, the purpose is **not** to allow large objects or fish to pass through the screens to the treatment plant.)

5. The Interim Surface Water Treatment Rule was enacted to primarily control? (Choose one)

- a. chlorine residual
- b. turbidity
- c. lead and copper

(Answer: b.)

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6. 3-log means the removal of \_\_\_\_\_% removal of a target organism. **(Choose one)**

- a. 90
- b. 75 (three quarters of 100%)
- c. 99.9
- d. 33.3 (1/3 of 100%)

*(Answer: c.)*

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Now let us summarize Unit 3 with a few Key Points.

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



In this unit we discussed the factors that need to be examined to determine if bag or cartridge filtration is a viable treatment alternative for a water supplier. In the next unit we will discuss the operation and maintenance requirements of a bag or cartridge filtration system. System startup, performance, records, and troubleshooting will also be discussed.

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### UNIT 4: SYSTEM OPERATION AND MAINTENANCE: 40 MINUTES



Display Slides 7 & 8—Unit 4: System Operation and Maintenance.



As a result of this unit, the learner will:

- Be able to identify the factors that determine when a filter should be removed and/or replaced.
- Be aware of the four water quality parameters that should be examined to verify the proper operation of a bag or cartridge filter.
- Review the three steps that must be completed in order to start a bag or cartridge filtration system.

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### SYSTEM STARTUP: 5 MINUTES



In this unit we will discuss the O&M requirements of a bag or cartridge filtration system and present procedures for system startup and filter change-out. Filter performance requirements will also be detailed.

*[Review the introduction to the **System Startup** section.]*

### Flow Rate

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



**Air Bleed**

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

**Filter-To-Waste**

*[Review the **Filter-to-Waste** section.]*

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### **FILTER PERFORMANCE: 5 MINUTES**



After system startup, the operator's job is to verify that the system is functioning properly. In order to know if it is functioning properly, there needs to be some objective measures established.

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

### **Allowable Flow Rates**

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

### **Surface Water Treatment Rule and Performance Standards**

*[Review the **Surface Water Treatment Rule and Performance Standards** section.]*

[Continue to review the **Surface Water Treatment Rule and Performance Standards** section.]

### Turbidity



The surrogate is filter effluent turbidity. Filter effluent turbidity has been shown to be a reliable predictor of water quality in terms of *Giardia* and *Cryptosporidium* content.

- The PA DEP performance standards for combined filter effluent turbidity are that the filter effluent turbidity must be less than or equal to 0.3 NTU in 95% of the samples taken each month and never exceed 1 NTU. Samples of the combined filter effluent must be analyzed at least every four hours. In addition, the regulations require that individual filter effluents (or the filter effluent from individual filter trains in the case of bag or cartridge filters that use a series of filters in the train) be monitored on a continuous basis.
- Exceeding 1.0 NTU in an individual filter train effluent in consecutive samples taken 15 minutes apart at any time in three consecutive months requires the system to perform a filter self-assessment.
- Exceeding 2.0 NTU in an individual filter train effluent in consecutive samples taken 15 minutes apart at any time in two consecutive months requires the system to arrange for PA DEP to conduct a comprehensive performance evaluation no later than 30 days following the exceedence.

### Chlorine Residual



For surface water systems, a residual disinfectant concentration may not be less than of 0.2 mg/L for more than four hours before the first customer.

### SYSTEM CHECKS: 10 MINUTES



After the system has been started and is operating according to design parameters, the operator must check the system periodically to verify that it is operating properly. The frequency of these checks is determined by the importance of the item being checked.

*[Review the introduction to the **System Checks** section.]*

### Daily Checks



Certain maintenance and inspection activities should be conducted on a daily basis to ensure that 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.

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



Cartridge filter vessel drains should be flushed daily.

*[Continue to review the **Daily Checks** section.]*

**Weekly Checks**

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

*[Continue to review the **Weekly Checks** system.]*

**Monthly Checks**

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

*[Continue to review the **Monthly Checks** section.]*

### **Biannual Checks**

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

### **Annual Checks**

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

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SYSTEM MAINTENANCE: 5 MINUTES

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

### Filter Replacement

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



Cartridge filters should be changed when the pressure drop reaches 15 psi.



*[Continue to review the **Filter Replacement** section.]*



The vast majority of bag and cartridge filters are not reusable. Do not attempt to clean and reuse your spent filter unless the manufacturer allows for filter cleaning and the cleaning and rinsing procedure is followed to the letter.



A bag or cartridge filter approved for Giardia removal should be replaced if it becomes clogged.

*[Continue to review the **Filter Replacement** section.]*



When performing a routine inspection or maintenance on a bag or cartridge filter approved for Giardia removal, divert the flow through a back up filter unit.

### SYSTEM TROUBLESHOOTING: 5 MINUTES



This is not intended as a guide to use at a particular location but as a way to reinforce the operator's understanding of how a bag or cartridge filter system operates.

*[Review the introduction to the **System Troubleshooting** section.]*

### High Differential Pressure

*[Review the **High Differential Pressure** section.]*

### Short Run Times

*[Review the **Short Run Times** section.]*

**Water Quality**

*[Review the **Water Quality** section.]*

*Stress the importance of becoming familiar with the filter's normal operation so that abnormal operation can be identified. In addition, stress the importance of turbidity and particle counts.]*



### Exercise

## Unit 4 – Exercise

### Multiple Choice – Choose the best answer:

1. Cartridge filters should be changed when the pressure reaches \_\_\_\_\_ psi.
- 5 psi
  - 10 psi
  - 15 psi
  - 20 psi

(Answer: c. 15 psi)

2. Cartridge filters drains should be flushed \_\_\_\_\_.
- daily
  - bi-weekly
  - weekly
  - monthly

(Answer: a. daily)

3. Which one of the following statements is true? **(Choose all that are correct)**

- A bag or cartridge filter approved for Giardia removal should always be repaired if it becomes clogged.
- A bag or cartridge filter approved for Giardia removal should always be removed and replaced with a new filter if it becomes clogged.
- When doing a routine inspection or performing maintenance on a bag or cartridge filter approved for Giardia removal, divert the flow through a backup filter unit.
- When doing a routine inspection or performing maintenance on a bag or cartridge filter approved for Giardia removal, divert the flow through a chlorinator or UV light.

(Answer: b. and c.)

### Fill in the blank:

4. Four water quality parameters that should be examined to verify the proper operation of a bag or cartridge filter are: filtrate turbidity, Giardia and Cryptosporidium removal, **virus removal**, and chlorine residual.
5. The three steps that must be completed to start a bag or cartridge filter system are: establish/verify the proper flow rate, then bleed any air from the system, and finally operate in **filter to waste** mode.
6. The use of **chart recorders** at the filters to obtain a continuous record of head loss and flow rate is advantageous because it provides an easily monitored means for determining the best time to change the filter.
7. For a surface water system, the required residual disinfectant concentration may not be less than **0.2** mg/L for more the **4** hours before the first customer.

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Now let us summarize Unit 4 with a few Key Points.

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



In this unit we discussed the operation and maintenance requirements of a bag or cartridge filtration system. System startup, performance, maintenance, and troubleshooting were also discussed. In the next unit we will discuss record keeping requirements.

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### UNIT 5: RECORD KEEPING: 25 MINUTES



Display Slide 9—Unit 5: Record Keeping.



As a result of this unit, the learner will:

- Review the three types of operation records that should be maintained for bag and cartridge filtration systems.
- Receive a description of the three types of plant records that should be maintained.
- Be aware of reasons to maintain good maintenance records.

### OPERATIONAL RECORDS: 5 MINUTES

#### **Analytical Records**

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

*Stress that the analytical records are very useful reference material.*

*Note that State regulations require that records be maintained.]*

#### **Sampling Records**

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

*Point out that a log of date, time, and location of samples taken for SDWA compliance should be maintained.]*

#### **Filter Replacement Records**

*[Review the **Filter Replacement Records** section.]*



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### **PLANT RECORDS: 5 MINUTES**

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

#### **Shop Drawings**

*[Review the **Shop Drawing** section.]*

*Stress that shop drawings are a good source of spare parts lists.]*

#### **As-Builts**

*[Review the **As-Builts** section.]*

*Differentiate as-built plans from the design plans for the facility.]*

#### **Plant Flow Schematics**

*[Review the **Plant Flow Schematics** section.]*

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### EQUIPMENT MAINTENANCE RECORDS: 5 MINUTES

*[Review the introduction to the **Equipment Maintenance Records** section.]*

#### Maintenance Procedures

*[Review the **Maintenance Procedures** section. Mention that a file listing maintenance procedures and frequencies is a valuable tool for any treatment plant.]*

#### Documentation of Maintenance Conducted



Relying on memory to recall the last time a maintenance procedure was conducted is a sure way to miss a scheduled maintenance activity. For that reason, it is very important to maintain a record of the maintenance conducted.

*[Review the **Documentation of Maintenance Conducted** section.]*



These records should be reviewed periodically to help predict when future maintenance will be required and exactly what types of procedures may be needed. For instance, if an operator notices that a pump bearing was beginning to show signs of wear but did not yet require replacement, he should enter that into the maintenance log. Then, by reviewing that log prior to the next scheduled maintenance he may decide that the bearing will most likely need to be replaced during the next scheduled maintenance event. Then a quick check of the spare parts will reveal whether he needs to order the new bearing. This assures that all of the required items will be on hand and available when needed.

#### Uses of Maintenance Records

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



### Exercise

## Unit 5 – Exercise

### Fill in the blank.

1. A log of date, time, and \_\_\_\_\_ of samples taken for SDWA compliance should be maintained (check with your local PA DEP office in the Appendix for sample record keeping requirements).

*(Answer: location)*

2. Filter replacement records may assist the operator in determining if \_\_\_\_\_ replacement frequency is increasing.

*(Answer: filter)*

3. Good maintenance records can aid in conducting maintenance procedures on the proper schedule and will help in using the proper \_\_\_\_\_ when conducting maintenance.

*(Answer: procedures)*

4. At a minimum, \_\_\_\_\_ and \_\_\_\_\_ water turbidity and finished chlorine records should be kept. (Check with your local PA DEP office in the Appendix for analytical record keeping requirements).

*(Answers: raw and finished)*

5. It is recommended the following three plant records be maintained: shop drawings, as-built and \_\_\_\_\_ schematics.

*(Answer: plant flow)*

*[After reviewing the Exercise, thank the participants for attending the class and encourage them to use their workbook as a reference when needed. Provide any additional reference information that will help participants with the effective operation of a bag or cartridge filtration system.]*

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Now let us summarize Unit 5 with a few Key Points.

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