



Wisconsin Department of Natural Resources Wastewater Operator Certification

Advanced Tertiary Filtration Study Guide

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Subclass H

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Preface

This operator's study guide represents the results of an ambitious program. Operators of wastewater facilities, regulators, educators and local officials, jointly prepared the objectives and exam questions for this subclass.

Note: Key knowledge 2.1.1 was edited July 2013.

How to use this study guide with references

In preparation for the exams you should:

1. Read all of the key knowledges for each objective.
2. Use the resources listed at the end of the study guide for additional information.
3. Review all key knowledges until you fully understand them and know them by memory.

It is advisable that the operator take classroom or online training in this process before attempting the certification exam.

Choosing A Test Date

Before you choose a test date, consider the training opportunities available in your area. A listing of training opportunities and exam dates is available on the internet at <http://dnr.wi.gov>, keyword search "operator certification". It can also be found in the annual DNR "Certified Operator" or by contacting your DNR regional operator certification coordinator.

Acknowledgements

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Chapter 1 - Principle, Structure and Function

Section 1.1 - Principle of Tertiary Filtration

- 1.1.1 List the items that should be considered in selecting a tertiary filtration system.
1. The existing and possible future discharge permit requirements
 2. The hydraulic design loading to the filters
 3. The organic design loading to the filters
 4. Operability considerations (ease of operation and maintenance)
 5. The operational costs including chemical additions
 6. The maintenance costs including part availability
 7. The need for multiple units to ensure continuous operations when units are out-of-service for maintenance or backwashing
- 1.1.2 Describe the impact of upstream processes on the operation of a tertiary filter.
- The impact of upstream processes on the operation of a tertiary filter would be of suspended solids loading to the filter and possible oil/grease concerns. Good primary and secondary clarifier operations along with a pretreatment program should eliminate any oil/grease concerns. The suspended solids loading to the filter is dependent on good secondary system operations and most importantly the secondary clarifier. A well operated and properly sized secondary clarifier should minimize suspended solids loading to the filter and extend filter run times.

Section 1.2 - Structure and Function

- 1.2.1 Define the following terms as related to filter media:
- A. Specific gravity
 - B. Media effective size
 - C. Uniformity coefficient
- A. Specific gravity: is the ratio of the weight of a volume of material to an equal volume of water; the specific gravity of water is 1.0; a specific gravity greater than 1.0 is heavier than water and a specific gravity less than 1.0 is lighter than water; this is important in filter media because when a multi-media filter backwash cycle is completed the fluidized bed will settle in order of specific gravity value; the highest specific gravity on the bottom and the lowest specific gravity on the top
- B. Media effective size: is the diameter of media particles; spherical is the shape that would have the same transmission constant as the actual media material under consideration; in actual practice it is a procedure using mesh sieves of various sizes to determine grain size; for a given effective size the mesh openings will permit 10% of the sample to pass through and will retain the remaining 90%; different filter media and types of filters require different effective sizes
- C. Uniformity coefficient: the degree of variation in the size of the grains that constitute a granular material; it is sieve analysis calculating a ratio of grain size diameters; the coefficient is 1.0 for any material having grains all the same size and increases above 1.0 with variations in grain size; the uniformity 2.0 coefficient for the media in sand filters is

readily available at a value of 1.5 and the value of 1.3 is achievable but very costly; typically the uniformity coefficient for sand and anthracite media would be between 1.5 to 1.7; the "recommended standard for wastewater facilities" for the Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers requires that the uniformity coefficient not exceed 1.7

1.2.2 Discuss types of media, effective media size, specific gravity, and where solids should be caught in the following types of filters:

- A. Shallow bed filter
- B. Deep bed single-media filter
- C. Deep bed multi-media filter

A. Shallow bed filter: have lower (finer) effective size (0.5 to 0.6 mm) sand media with specific gravity of 2.65; the majority of the suspended solids are trapped at the very top of the media

B. Deep bed single media filter: have coarser (larger) effective size (1.2 to 2.5 mm) sand media with specific gravity of 2.65; suspended solids are captured within as well as on the surface of the media

C. Deep bed multi-media filter: have various combinations of anthracite (specific gravity 1.6 to 1.7 with an effective size of 1.0 to 1.2 mm), sand (specific gravity 2.65 with an effective size of 0.5 to 0.6 mm), garnet (specific gravity 4.0 to 4.6 with an effective size of 0.2 to 0.3 mm), and even a low density coal (specific gravity 1.3 to 1.4 with an effective size of 1.2 to 1.4 mm); when backwashing, the beds are fluidized and media separated by specific gravity with the lightest on top and the heaviest on the bottom; this causes the light/coarse material to be on top grading down to the heavier fine material on the bottom; this allows the entire filter bed to capture solids with the large suspended solids trapped in the upper media and the fine suspended solids trapped in the lower media

Chapter 2 - Operation and Maintenance

Section 2.1 - Operation

2.1.1 Compare deep bed filters to shallow bed filters for the following:

- A. Run time
- B. Media depth (range)
- C. Backwashing
- D. Expected percent suspended solids removal range with secondary effluents

A. Run time:
Deep bed = 1-3 days
Shallow bed = 6-12 hours

B. Media depth (range):
Deep bed = 24" - 36"
Shallow bed = 8" - 12"

C. Backwashing:

Deep bed -

1. Take whole filter out of service
2. The bed is fluidized
3. Possible-air scour
4. Possible-surface wash

Shallow bed -

1. Each cell is backwashed separately (filter is in service)
2. Has a traveling bridge
3. The bed is fluidized
4. No air scour or surface wash

D. Expected percent suspended solids removal range with secondary effluents:

Deep bed = 70 - 80%

Shallow bed = 70 - 80%

2.1.2 List the design and operational factors that affect the filtration rate of a tertiary filter.

A. Design factors affecting filtration rates:

1. Hydraulic head available over the media
2. Type of filter (deep bed multi-media versus shallow bed)
3. Type of media used
4. Media effective size
5. Media uniformity coefficient
6. Filter size compared to hydraulic loading

B. Operational factors affecting filtration rates:

1. Excessive solids build-up in the media
2. Poor backwashing practices (surface clogging and mudballs)
3. Excessive chemical additions
4. Air binding
5. Poor operations of upstream treatment units
6. Breakthrough or channeling

2.1.3 Describe where various sized solids would be captured in a multimedia filter composed of layers of anthracite, sand, and garnet.

Influent solids to a multi-media filter will be captured in the various layers depending on particle size. The larger particles will be captured in the anthracite layer because of its larger effective size while the medium and fine particles will pass through the anthracite. The medium sized particles will be captured by the sand layer and the fine particles will be captured by the garnet layer. Larger particles are captured in the media with the larger effective size and the finer particles captured in the media with smaller effective size.

- 2.1.4 Describe the operational problems that may occur when filtration is required following pond systems.

Filtration following pond systems can be a major problem in the summer when duckweed or algae blooms occur. These relatively large sized plant growths can rapidly cause surface clogging of the filters which will require more frequent backwashing. In many cases a larger effective size media must be used to reduce clogging but this also allows finer particles to pass through the filter. It usually means that suspended solids removal following lagoons is in the range of 20% to 50% as compared to other secondary processes where removal rates may be 70% to 80%.

- 2.1.5 Discuss the items an operator should consider when selecting replacement media for an existing filter.

The main considerations in selecting replacement media for an existing filter would be media effective size and media uniformity coefficient. The selection of the right effective size is dependent on the type of filter (shallow bed, deep bed, or multi-media deep bed), hydraulic and organic loading rate, and desired or required effluent suspended solids limits. The uniformity coefficient should not exceed 1.7. An operator must understand the importance of effective size and uniformity as these factors control the effectiveness of filtration. If the media effective size is too large particles will pass through the filter causing high effluent turbidity. If the effective size is too small surface clogging will occur requiring frequent backwashing.

- 2.1.6 Discuss the use of feed rates and types of filter aids (polymers) for improving filter performance.

To optimize filter run time filtration systems are equipped to feed polymers if they are needed. Polymers are water soluble organic chemicals that are used to coagulate finer particles, increase the strength of the chemical floc, and to control the depth of particle penetration into the filter. Polymers are supplied as anionic (negative charge), cationic (positive charge), or nonionic (carrying no charge). Generally application of polymer dosages are below 1 mg/L and in most cases less than 0.1 mg/L. Effectiveness of filter aids is usually measured by monitoring the turbidity of the filter effluent and adjusting feed rates accordingly. At an optimal polymer feed rate effluent turbidity should remain low until terminal headloss is reached. At an excessive polymer feed rate turbidity will remain low but terminal headloss will be reached too quickly requiring frequent backwashing. At an inadequate polymer feed rate filter breakthrough (openings or channels in the media that allows water to pass through with inadequate treatment) can occur increasing effluent turbidity which will require backwashing even though terminal headloss has not been reached.

- 2.1.7 Describe a problem that could be caused when excessively long filter runs occur.

Excessively long filter runs allow accumulated organic solids trapped in the media to become anaerobic (septic) which can cause odor problems and floating organic material.

2.1.8 Discuss the use of chlorine in tertiary filter operations for the following:

- A. Control of algae and slime growths
- B. Control of mudballs
- C. Control of colored influents
- D. Control of high influent BOD or coliform
- E. Control of odors

A. Algae and slime growths: occasionally chlorinate ahead of the filters to control algae and slime growths on walls and within the media; this may cause short periods of discolored effluent after application but will clear in a short while

B. Control of mudballs: Mudballs that have not been removed by thorough backwashing can be treated with chlorine; manually super chlorinate and draw the chlorinated water into the filter media; close the influent and effluent lines let stand for 24 to 48 hours and then thoroughly backwash

C. Colored influent: filtering will not remove colored influents unless the color is related to suspended solids; jar testing with chlorine may prove effective to remove some soluble colors

D. High BOD or coliform: the first step would be to correct the problems with upstream operations; after optimizing the upstream operations apply chlorine to reduce BOD and coliform organisms; BOD reduction from chlorination is minor (pound for pound applied)

E. Odors: high organic and solids loadings or long filter runs can cause odors; this can be controlled with the use of chlorine; in general, the use of chlorine fed to the filter influent can increase filter run times, reduce some operation and maintenance activities, and control several nuisance problems

2.1.9 Describe the process of starting-up a new filter or a filter that has been out-of-service.

The filter should be filled with water very slowly through the underdrain system. This will allow air to escape from the filter media. If filled from the top the trapped air can cause overturning of the media (loss of stratification), unevenness within the media, and loss of fine media during subsequent filter cycles. If the filter media is new or completely dry it is further recommended that the media be allowed to soak for 8 hours before attempting filter operations.

2.1.10 State the range of rates for the following:

- A. Air scour rates (standard cubic feet/minute/ft²) (SCFM/ft²)
- B. Surface jetting rates (GPM/ft²)
- A. Air scour rates: 2-6 SCFM/ft²
- B. Surface jetting rates: 0.75 to 1.0 GPM/ft² at 50 to 100 psi

2.1.11 Describe the use and benefit from using the air scour cycle in backwashing.

The air scour cycle injects air into the bottom of the media bed which agitates the entire filter bed. The air and backwash water should not be operated at the same time as media loss can occur. The normal backwash cycle with air scour would be:

- A. Shut-off the influent and effluent valves; draw water down to near the top of the media
- B. Turn-on the air scour and operate as recommended
- C. Shut-off the air and begin water backwash with a low flow to release air from the media; do not use air and water at the same time as media loss can occur especially in multimedia filters
- D. Complete the normal water backwash at the recommended flow rate for the filter

The benefit of using an air scour is that it improves cleaning and reduces the amount of backwash water required. This reduces backwash pumping costs and reduces the amount of backwash water requiring treatment.

2.1.12 Outline a procedure to take a filter out-of-service for an extended period of time.

The following steps should be taken:

- 1. Thoroughly backwash the filter
- 2. Chlorinate the filter (5-15 mg/L)
- 3. Let stand for 2-3 days to kill biological growths
- 4. Thoroughly backwash the filter
- 5. Open drain valve and allow to drain
- 6. Store the filter wet; if the filter is stored dry the operator should remember to use the proper start-up procedure for a new or dry filter

2.1.13 Discuss the impact on plant operations of excessive backwash volumes due to short filter runs.

High backwash volumes are generally considered to be when the backwash volume is greater than 5% of the throughput. Excessive backwash volumes due to short filter runs could have the following effects on plant operations:

- A. Hydraulic overloading of treatment units (reduction in clarifier detention times and reduced times in biological secondary units); this could be especially critical if waste washwater holding tanks are not available and backwash flows are directed back to the plant headworks
- B. Possible organic overloading from the organic suspended solids in the backwash water
- C. Insufficient capacity in the waste washwater holding tanks
- D. Increased costs for pumping of backwash water to the filters and the pumping of waste washwater back to the treatment process

2.1.14 Describe the reason for increasing backwash rates as washwater temperatures increase. The expansion of a filter during backwash is dependant on the backwash rate. This rate

can vary with washwater temperature because as the backwash water temperature rises its viscosity is lowered. For a given media type and the same bed expansion a temperature change from 50 degrees F. to 65 degrees F. will require a washwater rate increase of about 30%.

Section 2.2 - Maintenance

2.2.1 List the maintenance considerations unique to the following:

1. Shallow bed filters
2. Deep bed filters
1. Shallow bed filters: maintenance on the traveling bridge
2. Deep bed filters: maintain the air compressors for the air scour system; cleaning the air diffusers; surface jet maintenance (nozzles and pumping equipment)

2.2.2 List the maintenance items for tertiary filtration:

1. Backwash pumps and piping
2. Compressors and piping for air scour
3. Pumps, piping, and nozzles for surface jets
4. Traveling bridge and associated equipment
5. Chlorine handling equipment and piping
6. Operating controls and recorder chart gauges for filters
7. High and low water level alarms
8. Underdrain system cleaning/repair
9. Media cleaning/replacement
10. Surface coatings (as required)
11. Maintenance of wastewater storage tanks
12. Maintenance of waste washwater tanks

As with other maintenance activities this work should be scheduled in a daily, weekly, monthly, and yearly basis and have a tracking system (card system or computer program).

2.2.3 List the rules to use in determining if spare parts should be kept on hand or purchased as needed from local suppliers.

1. The availability of parts (locally or can be obtained fast)
2. How often the parts are needed
3. If the parts are critical to plant operation
4. What is the lifespan of the part
5. The amount of capital investment to keep the part on-hand

Chapter 3 - Monitoring and Troubleshooting

Section 3.1 - Monitoring

3.1.1 Discuss the two primary control measurements for filter operations.

The two primary control measurements for filter operations are effluent turbidity and filter

headloss. These two items should be measured and recorded continuously with automatic instruments. Filter effluent turbidity is an indirect measurement of suspended solids and can be measured quickly. Filter headloss is the determining factor for backwashing providing there are no other operational problems (channeling or breakthrough). Between effluent turbidity and filter headloss total operations of tertiary filters can be done without additional laboratory testing.

3.1.2 Describe the methods of measuring loss of media.

The most common method for measuring loss of media is to measure from a fixed point (washwater through or top of wall) to the surface of the filter media. Recording this measurement over a period of time will provide a continuous record of the elevation of the top of the media and the loss of media that has occurred. Another indirect method is to usually check the empty waste washwater tanks for filter media that has settled-out on the bottom of the tank.

3.1.3 Discuss the difficulty in getting a representative sample from filter backwash for suspended solids analysis.

It is almost impossible to get a representative sample for suspended solids analysis from filter backwash. This is because the majority of solids captured in deep bed filters will be removed in the first three to five minutes of backwash. The rest of the backwash cycle removes the minority of solids held deeply in the filter or attached to media particles. The only possibility would be to grab sample at frequent intervals and plot them on a graph showing time against suspended solids.

3.1.4 Discuss the use of a plug sample in deep bed filters.

A plug sample is done by inserting a 1 1/2 inch pipe into the media. The plug sample can be used to determine the media profile to assure proper grading after backwashing, it can be used to check media depth, and it can be used to check for proper media cleaning after backwashing.

Section 3.2 - Troubleshooting

3.2.1 Describe the consequences resulting from improper installation of the porous plate assembly in a shallow bed filter.

If the porous plates are improperly installed loss of media will occur. The media will accumulate in underdrains and effluent channel. In addition this can cause channeling which will reduce the effectiveness of filtration.

3.2.2 Discuss the possible causes and corrective actions for the loss of filter media.

1. Cause: excessive backwash rates causing media to be discharged with the backwash water

Correction: reduce backwash rates

2. Cause: damaged filter underdrain system allowing high flows through portions of the filter ("boiling" area or very "dead" areas)

Correction: take the filter out-of-service and repair the damaged underdrain system to provide even flows through-out the filter during backwash

3. Cause: using air scour and water backwash at the same time

Correction: operate air scour first, shut-off air, and begin backwash at a low rate until air is released; complete a normal backwash cycle

- 3.2.3 Define the term "negative head." Explain how it can cause air binding in a filter and what effect this can have on filter operations.

Negative head in a filter means that the actual pressure in the filter media is reduced to less than atmospheric pressure. This will usually occur below the fine sand media of the filter. It is not normally a problem unless the filter influent water contains dissolved gases (air) at or near the saturation level (in most wastewater applications gases present are not at or near saturation levels). This lowering of pressure can release gases (as bubbles) from solution causing a condition known as "air binding." The solubility of gases or air in water is directly proportional to atmospheric pressure. If sufficient bubbles of gas accumulate in the media there will be a large loss of filter capacity because of the resistance (blocking) of flow through the filter. To correct this situation it will be necessary to backwash the filter more frequently and at lower backwash rates to prevent loss of media as the bubbles may attach themselves to the lighter media and carry it out with the backwash water.

- 3.2.4 Describe the cause of large air bubbles in only certain areas of a deep bed filter during air scour.

Large air releases in only certain areas of a filter during air scour would indicate uneven air flows through the system. It would be necessary to check for broken air lines or damage to air diffusers.

Chapter 4 - Safety and Calculations

Section 4.1 - Safety

- 4.1.1 Discuss the personal safety considerations associated with chemicals used to assist filtration of smaller particles.

For chlorine follow chlorine handling safety procedures. For other chemicals (in general) gloves, goggles, and protective clothing should be worn when handling. Avoid spills which could cause slippery surfaces, especially with polymers.

- 4.1.2 Discuss what to do in the event of a major liquid chlorine spill during the process of shock chlorinating a filter.

Dilute the chlorine as much as possible. Aerate the solution as much as possible. Bleed the chlorine solution back through the plant as slowly as possible. Keep personnel from coming in contact with the chlorine solution as it is a strong oxidizing solution that can irritate skin, eyes, and nose.

- 4.1.3 Review the hazards associated with gas chlorination and sodium or calcium hypochlorination.

Calcium hypochlorite is a stable white crystalline solid and can be supplied in powder, granule, or pellet form. Safe storage requires keeping it in original containers and keeping it dry. If moisture comes in contact with calcium hypochlorite a chlorine solution would be formed creating a corrosive solution with all the attendant oxidizing problems of chlorine in solution.

Sodium hypochlorite is supplied in an aqueous solution with different percentages of available chlorine. Safe storage requires keeping it in original containers and protecting it to prevent physical damage that might rupture the container causing a leak. If a leak occurs the corrosive solution will cause oxidizing problems of chlorine in solution.

Chlorine gas is supplied as a compressed gas/liquid in 150 pound and one ton cylinders. Unlike the hypochlorites free chlorine gas can be released in case of a leak which can represent severe respiratory problems. If gas chlorination is used safety equipment needed include gas mask or self contained breathing apparatus, separate chlorine storage room with proper ventilation, and require chlorine repair kits to correct leaks.

Section 4.2 - Calculations

4.2.1 Given data, calculate the cubic yards of media in a filter.

Given:

Length = 10 feet

Width = 12 feet

Depth = 3 feet

Formula:

cubic feet = length x width x depth

one cubic yard = 27 cubic feet

cubic feet = $10 \times 12 \times 3$

= 360 cubic feet

cubic yards = $360 \text{ cubic feet} \div 27$

= 13.3 cubic yards

4.2.2 Given data, calculate the backwashing flow rate in GPM per square foot of surface area.

Given:

Length = 10 feet

Width = 12 feet

Backwash flow = 1,920 GPM

Formula:

flow rate GPM/ft² = backwash flow (GPM) ÷ surface area (ft²)

flow rate = 1,920 ÷ (10 x 12)

= 16 GPM/ft²

4.2.3 Given data, calculate total backwashing flow rate in GPD.

Given:

Length = 10 feet

Width = 12 feet

Flow rate = 20 GPM/ft²

Backwash time = 8 minutes/day

Number of filters = 3 (each backwashed once/day)

Formula:

backwash flow/daily = length x width x flow rate x backwash time x # of filters

backwash flow = 10 x 12 x 20 x 8 x 3

= 57,600 gallons per day

4.2.4 Given data, calculate the pounds of solids loaded to a filter, pounds of solids in the filter effluent, and the pounds of solids in the backwash.

Given:

Flow = 1 MGD

TSS influent = 30 mg/L

TSS effluent = 5 mg/L

Formula:

pounds/day = flow (MGD) x concentration (mg/L) x 8.34

solids loaded to filter = 1 MGD x 30 (mg/L) x 8.34 (lbs/gal)

= 250.2 lbs/day

solids in effluent = 1 MGD x 5 ppm x 8.34 (lbs/gal)

= 41.7 lbs/day

solids in backwash = 250.2 lbs/day - 41.7 lbs/day

= 208.5 lbs/day

4.2.5 Given data, calculate the average daily flow rate through a tertiary filter in GPM/ft².

Given:

Average daily flow = 0.4 MGD

Filter width = 10 feet

Filter depth = 12 feet

Formula:

Flow Rate = (Average Daily Flow (Gallons/day) ÷ Minutes/Day) ÷ Filter Area

= (400,000 GPD ÷ 1,440 min/day) ÷ (10 ft x 12 ft)

= 277.77 GPM ÷ 120 ft²

= 2.3 GPM/ft²

- 4.2.6 Given data, calculate the percent of average daily flow returned to the plant from backwashing.

Given:

Number of filters = 2

Width = 10 feet

Length = 12 feet

Backwash time = 8 minutes

Backwash rate = 15 GPM/ft²

Filter backwash = once per day

Average daily flow = 0.60 MGD

Formula:

backwash volume = backwash rate (GPM/ft²) x length x width x time x number of filters

backwash = 15 x 10 x 12 x 8 x 2

= 28,800 GPD

% return flow = (backwash volume ÷ average daily flow) x 100

% return flow = (28,800 ÷ 600,000) x 100

= 4.8 %

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