



Filter Evaluation and Optimization

Student Guide

Southeastern Regional Small Public Water
Systems Technical Assistance Center
and the
Tennessee Association of Utility Districts
June 30, 2004

Filtration Requirements

I. Filtration requirements depend on:

A. _____ source;

B. _____ served.

II. Groundwater sources not under the direct influence of surface water – monitoring _____.

III. Groundwater sources under the direct influence of surface water.

A. The turbidity in the combined filter effluent must:

1. be less than or equal to _____ NTU in at least _____ of measurements taken each month;
2. at no time exceed _____ NTU.

IV. Surface water sources

A. The turbidity in the combined filter effluent must:

1. be equal or less than _____ NTU in _____ of the measurements taken each month;
2. at no time exceed _____ NTU.

V. If certain, specified turbidity levels in an individual filter's effluent are exceeded, depending on the severity of the exceedance, the system must conduct a:

A. _____

B. _____ – _____

C. _____

VI. Filter profile

- A. Required where the turbidity for an individual filter's effluent is greater than _____ NTU in _____ consecutive measurements, taken _____ apart; or,
- B. The turbidity for an individual filter's effluent is greater than _____ NTU in _____ consecutive measurements taken _____ minutes apart at the end of the first _____ hours of continuous operations after being returned to service.

VII. Filter Self-Assessment

- A. Required when the turbidity in an individual filter's effluent is greater than _____ NTU in _____ consecutive measurements, taken _____ apart in each of _____ consecutive months.
- B. A filter self-assessment consists of:
 - 1. an _____ of filter performance;
 - 2. development of a _____;
 - 3. _____ and _____ of performance limiting factors; and,
 - 4. preparation of a _____ - _____.

VIII. Comprehensive Performance Evaluation

A. Requirements for an individual filter where the turbidity is greater than _____ NTU in _____ consecutive measurements taken _____ minutes apart in each of _____ consecutive months.

B. Must be conducted by:

1. _____; or.

2. _____.

NOTES

Performance Limiting Factors

I. Factors which influence the ability of a filter to perform at an optimum level include:

- A. the _____ of the filter bed;
- B. the _____ of the filter media;
- C. _____; and,
- D. _____.

II. Physical Condition of the Filter Bed - Observable defects

- 1. _____
- 2. _____
- 3. _____
- 4. _____
- 5. Sand _____ from walls
- 6. _____
- 7. _____ defects
- 8. _____ in _____
- 9. _____ of troughs
 - a. length and _____
 - b. _____ troughs
- 10. _____

III. Physical Condition of the Media

- A. Media _____
- B. _____ Coefficient
- C. _____ size
- D. _____
- E. _____
- F. _____ sludge

IV. Media Depth

- A. Single-media filters – depth equal to or greater than _____ inches of sand.
- B. Dual-media filters
 - 3. Sand - _____ to _____ inches in a 30-inch bed.
 - 4. Anthracite - _____ to _____ inches in a 30-inch bed
 - 5. Total media depth – equal to or greater than _____ inches.

V. Uniformity Coefficient

- A. Sand – less than or equal to _____.
- B. Anthracite – less than or equal to _____.

VI. Effective Size

- A. Sand - _____ mm to _____ mm
- B. Anthracite - _____ mm to _____ mm

VII. Cementing

- A. Build-up of _____
- B. _____ media weight (density)
- C. _____ bed expansion
- D. _____ filter _____

VIII. Mudballs

- A. _____ by use of polymers or filter aids
- B. _____ effective filter area
- C. _____ turbidity _____
- D. Filter run times _____
- E. May lead to _____ areas in the filter.

IX. Retained Sludge

- A. _____ sludge always remains
- B. Too little - _____ turbidity spikes
- C. Too much - _____
- D. Just right - _____ turbidity spikes

X. Allowable Filtration Rates

A. Turbidity Removal Filters

1. Rapid Sand Filters - _____ gal/min/ft²
2. High Rate Filters - _____ gal/min/ft²

B. Iron Removal Filters

1. Rapid Sand Filters - _____ gal/min/ft²
2. High Rate Filters - _____ gal/min/ft²

XI. Backwash Procedures

- A. _____ Operating Procedures (SOPs)
- B. _____
- C. _____
- D. _____
- E. _____

XII. Backwash Conditions

- A. _____
- B. _____
- C. _____

XIII. Backwash Intensity – measured by

A. Backwash Rate

1. Single-media filters - _____ gal/min/ft²
 2. Dual-media filters - _____ gal/min/ft²
- B. Bed Expansion - _____% to _____%

XIV. Backwash Duration

- A. Defined as “time required for backwash water turbidity to fall into the _____ NTU to _____ NTU range.
- B. Target - _____ to _____ minutes

XV. Backwash Effectiveness – measured by:

- A. _____ retention profile
- B. _____

Filtration Rate Analysis

Purpose

To determine the actual filtration rate in gallons per minute per square foot (gal/min/ft²)

Equipment Required

Stopwatch

Filtration Rate Analysis Form

Hook gauge

Calculator

Procedure

1. Secure the hook gauge to the filter, ensuring it is level, with the top hook far enough below the surface of the water that all valves are fully open before water level reaches top nail.
2. Close the filter influent valve.
3. Record the effluent valve setting and flow meter reading.
4. Start timing when the top hook breaks the water surface.
5. Stop timing when the bottom hook breaks the water surface.
6. Record the time required for the water to drop 6 inches.
7. Refill the filter basin.
8. Repeat steps 3 through 8 two more times.

Calculations

Step One: Determine how many gallons of water passed through the filter during the drop (hook gauge) test.

1. Calculate the volume of water in cubic feet which passed through the filter during the test.

$$\text{Volume, ft}^3 = \text{Filter Bay Length, ft} \times \text{Filter Bay Width, ft} \times \text{Water Drop, ft}$$

- 2 Calculate the volume of water in gallons which passed through the filter during the test.

$$\text{Volume, gal} = \text{Volume, ft}^3 \times 7.48 \text{ gal/ft}^3$$

Step Two: Determine the average time in minutes required for the water to drop 6 inches during the test.

1. Calculate the average time in seconds required for the water to drop 6 inches.

$$\text{Average Time, sec} = \frac{\text{Time}_1 + \text{Time}_2 + \text{Time}_3}{3}$$

2. Calculate the average time in minutes.

$$\text{Time, min} = \frac{\text{Average Time, sec}}{60 \text{ sec/min}}$$

Step Three: Calculate the area of the filter bed in square feet.

$$\text{Area, ft}^2 = \text{Filter Bed Length, ft} \times \text{Filter Bed Width, ft}$$

Step Four: Determine the filtration rate in gallons per minute.

$$\text{Filtration Rate, gal/min} = \frac{\text{Volume, gal}}{\text{Average Time, min}}$$

Step Five: Determine the filtration rate in gallons per minute per square foot (gal/min/ft²).

$$\text{Filtration Rate, gal/min/ft}^2 = \frac{\text{Filtration Rate, gal/min}}{\text{Area, ft}^2}$$

Step Six: Determine the accuracy of the filter flow meter reading.

$$\text{Flow Meter Accuracy, \%} = \frac{\text{Flow Meter Reading, gal/min}}{\text{Calculated Filtration Rate, gal/min}} \times 100\%$$

Interpretation

Allowable Rates

Rapid Sand Turbidity Removal Filters	2.0 gal/min/ft ²
Rapid Sand Iron Removal Filters	3.0 gal/min/ft ²
High Rate Turbidity Removal Filters	4.0 gal/min/ft ²
High Rate Iron Removal Filters	4.0 gal/min/ft ²

If the filtration rate is higher than the allowable rate, adjust the rate-of-flow controller to slow filter down.

If the flow meter accuracy is too far off, have it calibrated.

Filtration Rate Math

Sample Problem 1: A drop test (hook gauge) analysis was performed on filter #3 at Monterey's water treatment plant. Each filter bay is 25 feet long and 19 feet wide. Each filter bed is 22 feet long and 19 feet wide. The test was run three times. The times for the water to drop six inches were as follow.

Test 1= 96 sec.

Test 2= 98 sec.

Test 3= 94 sec.

What was the filtration rate in gallons per minute per square foot (gal/min/ft²) during this test?

Sample Problem 2: The filter bay dimensions for Eastside Utility District's filters are 30 feet by 25 feet. The filter bed's are 27 feet by 25 feet. The operators at Eastside Utility District's water treat plant performed a hook gauge test (drop test) on filter number six. During the hook gauge test the water was allowed to drop six inches three times. The times required for the water to drop six inches in each tests were:

Test 1= 112 sec.

Test 2= 114 sec.

Test 3= 114 sec.

Calculate the filtration rate in gallons per minute per square foot (gal/min/ft²).

Sample Problem 3: Savannah Valley Utility District has two gravity filters. The filter bay dimensions are 12 feet by 8 feet. The filter bed's are 12 feet by 8 feet. The operators performed a drop test (hook gauge) on filter number 1. The operators measured how long it took for the water to drop six inches a total of three times. These times were measured and recorded.

Test 1= 182 sec.

Test 2= 182 sec.

Test 3= 188 sec.

Determine the filtration rate in gallons per minute per square foot (gal/min/ft²) during the test.

Optimizing Filter Performance

Practice Problems

Round your answers to the nearest tenth of a gal/min/ft² (one decimal place).

1. The operators at West Knox Utility District performed a hook gauge (drop) test on filter number six. The filter bay dimensions are 25 feet by 20 feet. The filter bed is 23 feet by 20 feet. The test was run three times. The times, in seconds, for the water over the filter to drop 6 inches were as follows.

Time 1= 100 sec.

Time 2= 98 sec.

Time 3= 102 sec.

Determine the filtration rate in gallons per minute per square foot (gal/min/ft²).

2. During a drop (hook gauge) test the water over a filter was allowed to drop six inches a total of three times. The times required for the water to drop six inches for each test were as follows.

Time 1= 78 sec.

Time 2= 74 sec.

Time 3= 76 sec.

The filter bay dimensions are 18 feet by 12 feet. The filter bed is 15 feet by 12 feet. Calculate the filtration rate in gallons per minute per square foot.

3. At Morristown's water treatment plant, the operators performed a hook gauge (drop) test to determine the filtration rate in gal/min/ft² for filter 7. They ran the test three times. During the hook gauge test the water was allowed to drop 6 inches each test. The times required for the water to drop 6 inches during each test were 84 sec., 86 sec., and 85 sec. The filter bay dimensions 17 feet by 11 feet. The filter bed is 14 feet by 11 feet. What was the filtration rate in gallons per minute per square foot (gal/min/ft²)?
4. The filter bay dimensions for Waldens Ridge Utility District's filters are 10 feet by 7 feet. The filter bed is 7 feet by 7 feet. An operator performed a hook gauge (drop) test on a filter three times. The times required for the water to drop six inches in each test were 102 sec., 104 sec., and 100 sec. Calculate the filtration rate in gallons per minute per square foot.
5. The operators at Dyersburg's water treatment plant ran a hook gauge (drop) test on filter 2. During the test the water dropped six inches a total of three times. The times required for the water to drop six inches were 96 sec., 98 sec., and 94 sec. The filter bay dimensions are 28 feet by 20 feet. The filter bed is 25 feet by 20 feet. Determine the filtration rate in gallons per minute per square foot.

NOTES

Optimizing Filter Performance
Filtration Rate Evaluation Form

Filter Bay Dimensions

Filter Bay Length = _____ ft Filter Bay Width = _____ ft

Filter Bed Data

Filter Bed Length = _____ ft Filter Bed Width = _____ ft

Drop Times

Time₁ = _____ sec

Time₂ = _____ sec

Time₃ = _____ sec

Filtered Water Volume

Volume, ft³ = Filter Bay Length, ft x Filter Bay Width, ft x Water Drop, ft

Volume, gal = Volume, ft³ x 7.48 gal/ft³

Average Time

$$\text{Average Time, sec} = \frac{\text{Time}_1 + \text{Time}_2 + \text{Time}_3}{3}$$

$$\text{Time, min} = \frac{\text{Average Time, sec}}{60 \text{ sec/min}}$$

Area

Area, ft² = Filter Bed Length, ft x Filter Bed Width, ft

Filter Bed Area, ft² = _____ ft²

Filtration Rate

$$\text{Filtration Rate, gal/min} = \frac{\text{Volume, gal}}{\text{Average Time, min}}$$

$$\text{Filtration Rate, gal/min/ft}^2 = \frac{\text{Filtration Rate, gal/min}}{\text{Area, ft}^2}$$

Meter Accuracy

$$\text{Flow Meter Accuracy, \%} = \frac{\text{Flow Meter Reading, gal/min}}{\text{Calculated Filtration Rate, gal/min}} \times 100\%$$

Interpretation

Is the calculated filtration rate in gal/min/ft² within allowable limits?

Yes

No

Allowable Rates

Rapid Sand Turbidity Removal Filters	2.0 gal/min/ft ²
Rapid Sand Iron Removal Filters	3.0 gal/min/ft ²
High Rate Turbidity Removal Filters	4.0 gal/min/ft ²
High Rate Iron Removal Filters	4.0 gal/min/ft ²

Is the flow meter reading within acceptable limits?

Yes

No

Backwash Flow Rate Analysis

Purpose:

To determine the actual backwash flow rate in gallons per minute per square foot (gal/min/ft²) and gallons per minute (gal/min), and determine the accuracy of the backwash water flow meter.

Equipment Requirements

Stop Watch

Calculator

Hook Gauge

Backwash Flow Rate Analysis Form

Procedure

1. Drain the filter to within a couple of inches of the media
2. Measure and record the length and width of the filter bay.
3. Measure and record the length and width of the filter bed.
4. Secure the hook gauge to the filter bay railing, making certain that it is vertical, left to right, and front to back.
5. Begin the backwash.
6. When the backwash pump is operating at the desired rate, record the backwash flow meter reading.
7. When the rising water reaches the lower nail point, start timing the rise.
8. Record the time required to reach the top nail.
9. Lower the water to beneath the bottom nail.
10. Repeat steps 6 through 9 two more times.

Calculations

Step One: Calculate the area of the filter bed in square feet.

$$\text{Area, ft}^2 = \text{Filter Bed Length, ft} \times \text{Filter Bed Width, ft}$$

Step Two: Calculate the average time in seconds required for the water to rise 6 inches.

$$\text{Average Time, sec} = \frac{\text{Time}_1 + \text{Time}_2 + \text{Time}_3}{3}$$

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Step Three: Calculate the average time in minutes.

$$\text{Time, min} = \frac{\text{Average Time, sec}}{60\text{sec/min}}$$

Step Four: Determine the volume of backwash water, in cubic feet, used during the rise test.

$$\text{Backwash Water Volume, ft}^3 = \text{Filter Bay Length, ft} \times \text{Filter Bay Width, ft} \times \text{Drop, ft}$$

Step Five: Determine the volume of backwash water, in gallons, used during the rise test.

$$\text{Backwash Water Volume, gal} = \text{Backwash Water Volume, ft}^3 \times 7.48 \text{ gal/ft}^3$$

Step Six: Determine the backwash rate in gallons per minute.

$$\text{Backwash Rate, gal/min} = \frac{\text{Backwash Water Volume, gal}}{\text{Average Time, min}}$$

Step Seven: Determine the backwash rate in gallons per minute per square foot.

$$\text{Backwash Rate, gal/min/ft}^2 = \frac{\text{Backwash Rate, gal/min}}{\text{Area, ft}^2}$$

Step Eight: Determine the accuracy of the filter flow meter reading.

$$\text{Flow Meter Accuracy, \%} = \frac{\text{Flow Meter Reading, gal/min}}{\text{Calculated Filtration Rate, gal/min}} \times 100\%$$

Interpretation

1. Design criteria calls for 18.75 gal/min/ft² for single media filters. Recommendations for dual media filters are 20 gal/min/ft².

Rise Test Math

Sample Problem 1: An operator performed a rise test on a filter in order to determine the backwash rate in gallons per minute per square foot ($\text{gal}/\text{min}/\text{ft}^2$). The operator used a hook gauge and stopwatch to determine how long it would take the water to rise six inches during backwash. The filter bay was 15ft long and 10ft wide. The filter bed was 15ft long and 10ft wide. The test was conducted three times, and these results were obtained.

Test 1= 13 sec. Test 2= 14 sec. Test 3= 12 sec.

What was the backwash rate in gallons per minute per square foot?

Sample Problem 2: At Kingston's water treatment plant the operators performed a rise test on filter 4. The filter bay is 20ft long and 15ft wide. The filter bed is 17ft long and 15ft wide. They conducted the test three times. During each test, a hook gauge and stopwatch were used to determine how long it took for the water to rise six inches during each of the three tests. These results were obtained.

Test 1= 16 sec. Test 2= 18 sec. Test 3= 18 sec.

Calculate the backwash rate for this filter in gallons per minute per square foot ($\text{gal}/\text{min}/\text{ft}^2$).

Sample Problem 3: An operator performed a rise test on a filter three times. The filter bay is 25 feet long and 19 feet wide. The filter bay is 25 feet long and 19 feet wide. The filter bed is 22 feet long and 19 feet wide. The operator used a stopwatch and a hook gauge during each test to determine how long it took for the water to rise six inches while backwashing the filter. These times were recorded during the test.

Test 1= 18 sec. Test 2= 19 sec. Test 3= 17 sec.

Determine the backwash rate in gallons per minute per square foot ($\text{gal}/\text{min}/\text{ft}^2$).

Practice Problems:

Round your answers to the nearest tenth of a gallon per minute per square foot (one decimal place).

1. The operators at Northeast Knox Utility District conducted a rise test on filter 6 in order to determine the backwash rate for the filter. The filter bay is 27 feet long and 20 feet wide. The filter bed is 24 feet long and 20 feet wide. During the test, the time required for the water to rise six inches was recorded three times, using a hook gauge and stopwatch. These times were recorded.

Test 1= 22 sec.

Test 2= 24 sec.

Test 3= 26 sec.

Determine the backwash rate in gallons per minute per square foot for their filter.

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2. Using a hook gauge and stopwatch, an operator measured how long it took the water in a filter to rise six inches, three times. These times were recorded.

Test 1= 18 sec.

Test 2= 19 sec.

Test 3= 17 sec.

The filter bed is 20 feet long and 20 feet wide. The filter bay is 24 feet long and 20 feet wide. Calculate the backwash rate in gallons per minute per square foot during the test.

3. The operators at Tiptonville's water treatment plant conducted a rise test on filter 12. The filter bay and bed are 12 feet long and 8 feet wide. During the test the operators used a stopwatch and hook gauge to measure the time required for the water to rise six inches during backwash. The rise rate was measured three times. These results were obtained.

Test 1= 20 sec.

Test 2= 19 sec.

Test 3= 21 sec.

What was the backwash rate in gallons per minute per square foot?

4. A rise test was conducted three times on a filter in order to determine its backwash rate in gallons per minute per square foot ($\text{gal}/\text{min}/\text{ft}^2$). A hook gauge and stopwatch were used to measure how long it took for the water to rise six inches during each test. These times were recorded.

Test 1= 9 sec.

Test 2= 10 sec.

Test 3= 11 sec.

The filter bay is 30 feet long and 18 feet wide. The filter bed is 27 feet long and 18 feet wide. Determine the backwash rate in gallons per minute per square foot ($\text{gal}/\text{min}/\text{ft}^2$) for the filter.

5. While conducting a rise test on a filter, a hook gauge and stopwatch were used to determine how long it took for the water to rise six inches during backwash. The rise rate was measured and recorded three times. The results were recorded.

Test 1= 13 sec.

Test 2= 13 sec.

Test 3= 13 sec.

Calculate the backwash rate in gallons per minute per square foot ($\text{gal}/\text{min}/\text{ft}^2$). The filter bed is 20 feet long and 15 feet wide. The filter bay is 17.5 feet long and 15 feet wide.

Backwash Rate Evaluation Form

Filter Bay Dimensions

Filter Bay Length = _____ ft Filter Bay Width = _____ ft

Filter Bed Data

Filter Bed Length = _____ ft Filter Bed Width = _____ ft

Rise Times

Time₁ = _____ sec

Time₂ = _____ sec

Time₃ = _____ sec

Backwash Water Volume

Volume, ft³ = Filter Bay Length, ft × Filter Bay Width, ft × Water Drop, ft

Volume, gal = Volume, ft³ × 7.48 gal/ft³

Average Time

$$\text{Average Time, sec} = \frac{\text{Time}_1 + \text{Time}_2 + \text{Time}_3}{3}$$

$$\text{Time, min} = \frac{\text{Average Time, sec}}{60 \text{ sec/min}}$$

Area

$$\text{Area, ft}^2 = \text{Filter Bed Length, ft} \times \text{Filter Bed Width, ft}$$

$$\text{Filter Bed Area, ft}^2 = \underline{\hspace{2cm}} \text{ ft}^2$$

Backwash Rate

$$\text{Backwash Rate, gal/min} = \frac{\text{Volume, gal}}{\text{Average Time, min}}$$

$$\text{Backwash Rate, gal/min/ft}^2 = \frac{\text{Backwash Rate, gal/min}}{\text{Area, ft}^2}$$

Meter Accuracy

$$\text{Flow Meter Accuracy, \%} = \frac{\text{Flow Meter Reading, gal/min}}{\text{Calculated Filtration Rate, gal/min}} \times 100\%$$

Interpretation

Is the calculated backwash rate in gal/min/ft² within recommended limits?

Yes

No

Recommended Rates

Single Media Filters

18.75 gal/min/ft²

Dual Media Filters

20 gal/min/ft²

Is the flow meter reading within acceptable limits?

Yes

No

Backwash Bed Expansion Analysis

Purpose:

To determine that filter bed expansion during backwash is adequate to clean the filter media.

Equipment:

Secchi Disc

5-ft Ruler

Tape

Backwash Bed Expansion Analysis Form

Procedure:

Step One: Determine the average depth of the media.

1. Using the 5-ft ruler, select several random spots for measuring the media depth.
2. Gently push the ruler into the media until the torpedo sand layer is found.
3. Read and record the media depth in inches.
4. Repeat steps 2 and 3 at the other spots selected for measuring the media depth.

Using this formula, calculate the average media depth in inches. (N = number of measurements)

$$\text{Average Media Depth, in} = \frac{\text{Measurement}_1 + \text{Measurement}_2 + \dots + \text{Measurement}_N}{N}$$

Step Two: Determine the filter bed expansion in inches, during backwash.

1. Locate a place to take measurements where the Secchi disc will hang free.
2. Place a piece of tape on the handrail or walkway to establish a fixed reference point.
3. Lower the Secchi disc until it rests on the media surface.
4. Using a fixed point as a reference, mark the Secchi rope with tape.
5. Remove the Secchi disc and start the backwash procedure.
6. When the backwash water clears, lower the Secchi disc until filter media washes onto the white sections.
7. Using the same fixed reference point from step 2, mark the Secchi disc rope with tape.
8. Measure the distance between the tops of each piece of tape.
9. Record as bed expansion, inches.

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Step Three: Determine the percent bed expansion.

$$\text{Bed Expansion, \%} = \frac{\text{Bed Expansion, in} \times 100\%}{\text{Average Media Depth, in}}$$

Interpretation

Backwash Flow Rate	Bed Expansion, %	Interpretation
Low	<20	Increase backwash rate and reperform bed expansion analysis.
Low	20 – 30 %	Increase backwash rate and reperform bed expansion analysis.
Low	>30	Note 1
Correct	<20	Note 2
Correct	20 – 30 %	No action necessary
Correct	>30	Check media effective size and uniformity coefficient
High	<20	Note 2
High	20 – 30 %	Note 2
High	>30	Lower backwash rate and reperform bed expansion analysis.

Note 1 - Check water temperature; if necessary, increase backwash rate. If water temperature is not the problem, check the design parameters for the filter.

Note 2 – Evaluate media for calcium carbonate scaling or polymer build – up.

If bed expansion is too low, chance of mudballs developing is high. Check physical observations for mud on media surface. Consider mudball analysis.

If bed expansion is too high, check physical observations for presence of media in trough. Check media depth.

Bed Expansion, %

Sample Problem 1: While evaluating a filter, a bed expansion test was performed. During backwash, the filter bed rose 5.75 inches. The average media depth was 31 inches. Calculate the bed expansion in percent.

Sample Problem 2: The average media depth for a filter was 26 inches. The filter bed rose 4 inches during a bed expansion test. Determine the bed expansion in percent.

Sample Problem 3: Roger performed a filter bed expansion test on a filter. The average media depth in the filter was 30 inches. The filter bed expanded by 4.5 inches during the test. What was the filter bed expansion in percent?

Practice Problems

Round your answers to the nearest percent.

1. Filter 4 at Three Way Utility District's water treatment plant has an average depth of 30 inches. When a bed expansion test was performed on the filter, the bed expanded by 5.25 inches. Determine the bed expansion in percent.
2. At Beaver Creek Utility District filter 3 has an average media depth of 32 inches. When Larry performed a bed expansion test on the filter, the media rose 5 inches. Calculate the bed expansion in percent.
3. Given the following information, calculate the filterbed expansion in percent. The average media depth was 26 inches. The bed rose 5.5 inches during a bed expansion test.
4. At Jakestown's water treatment plant the operator performed a bed expansion test on filter 21. During the bed expansion test, the media expanded by 7.75 inches. The average media depth in filter twenty-one is 22 inches. What is the bed expansion in percent?
5. Filter 8 at Skullbone's water treatment plant was tested to determine its bed expansion during backwash. During the expansion test the bed rose by 7.5 inches. The average media depth is 30 inches. Calculate the bed expansion in percent.

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NOTES

Filter Bed Expansion

Step One: Take at least 10 media depth measurements at randomly selected sites. The more measurements taken, the more accurate the results.

Filter Media Depth Measurements			
Measurements	Media Depth, inches	Measurements	Media Depth, inches
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	
Sum of Measurements		Sum of Measurements	
Total Depth - Add the Sums of the Two Columns of Measurements			
Average Depth - Divide the Total by the Number of Measurements			

Step Two: Measure the bed expansion in inches. Bed Expansion, Inches = _____ inches

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Step Three: Calculate the bed expansion in percent.

$$\text{Bed Expansion, \%} = \frac{\text{Bed Expansion, in} \times 100\%}{\text{Average Media Depth, in}}$$

Actual Filter Bed Expansion, \% = _____ %

Step Four: Is the bed expansion within the desirable range (20 to 30 percent)?

- Yes No

If answer is “NO”, why not?

- Filter backwash rate too low (<18.75 gal/min/ft² for single media: <20 gal/min/ft² for dual media)?
- Backwash rate not adjusted for water temperature at different seasons?
- Other: _____

Interpretation

Backwash Flow Rate	Bed Expansion, %	Interpretation
Low	<20	Increase backwash rate and reperform bed expansion analysis.
Low	20 – 30 %	Increase backwash rate and reperform bed expansion analysis.
Low	>30	Note 1
Correct	<20	Note 2
Correct	20 – 30 %	No action necessary
Correct	>30	Check media effective size and uniformity coefficient
High	<20	Note 2
High	20 – 30 %	Note 2
High	>30	Lower backwash rate and reperform bed expansion analysis.

Backwash Water Turbidity Analysis

Purpose:

To determine the desirable backwash duration. The desirable backwash duration is defined as the time it takes for the backwash water turbidity to drop to the 10-15 NTU range. The target duration is six to eight minutes.

Equipment Needed:

Stopwatch

Bucket with rope attached to handle or other device for grabbing backwash water samples

Bench-top turbidimeter

Thirty 100-ml sample bottles marked in 1-minute intervals

Backwash Water Turbidity Evaluation Form

Pencil

Straight-edge

Single-cycle, semi-log paper, or two-cycle semi-log paper

Procedure

1. Ensure all 100-ml sample bottles are marked in one-minute intervals and in order.
2. Designate one person to keep time during the backwash, and another to sample the backwash water.
3. Start the backwash cycle and the stopwatch.
4. At one-minute intervals sample the backwash water with the bucket.
5. Fill the 100-ml sample bottle to the line with backwash water from the bucket.
6. Dump the remaining backwash water from the bucket into the filter.
7. Repeat this sequence every minute until the normal backwash procedure is completed. It is advisable to extend backwash and sampling for 3 to 5 minutes beyond the normal backwash time.
8. Take the samples to the lab for analysis.
9. Shake each sample thoroughly before analysis.
10. Read the turbidity for each sample and record the results on the form.

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NOTE: Dilution may be required on some samples in order to read them in the turbidimeter. When samples are diluted the correction factor can be determined using this formula.

$$\text{Correction Factor} = \frac{V_s + V_d}{V_s}$$

Where V_s = volume of sample in ml

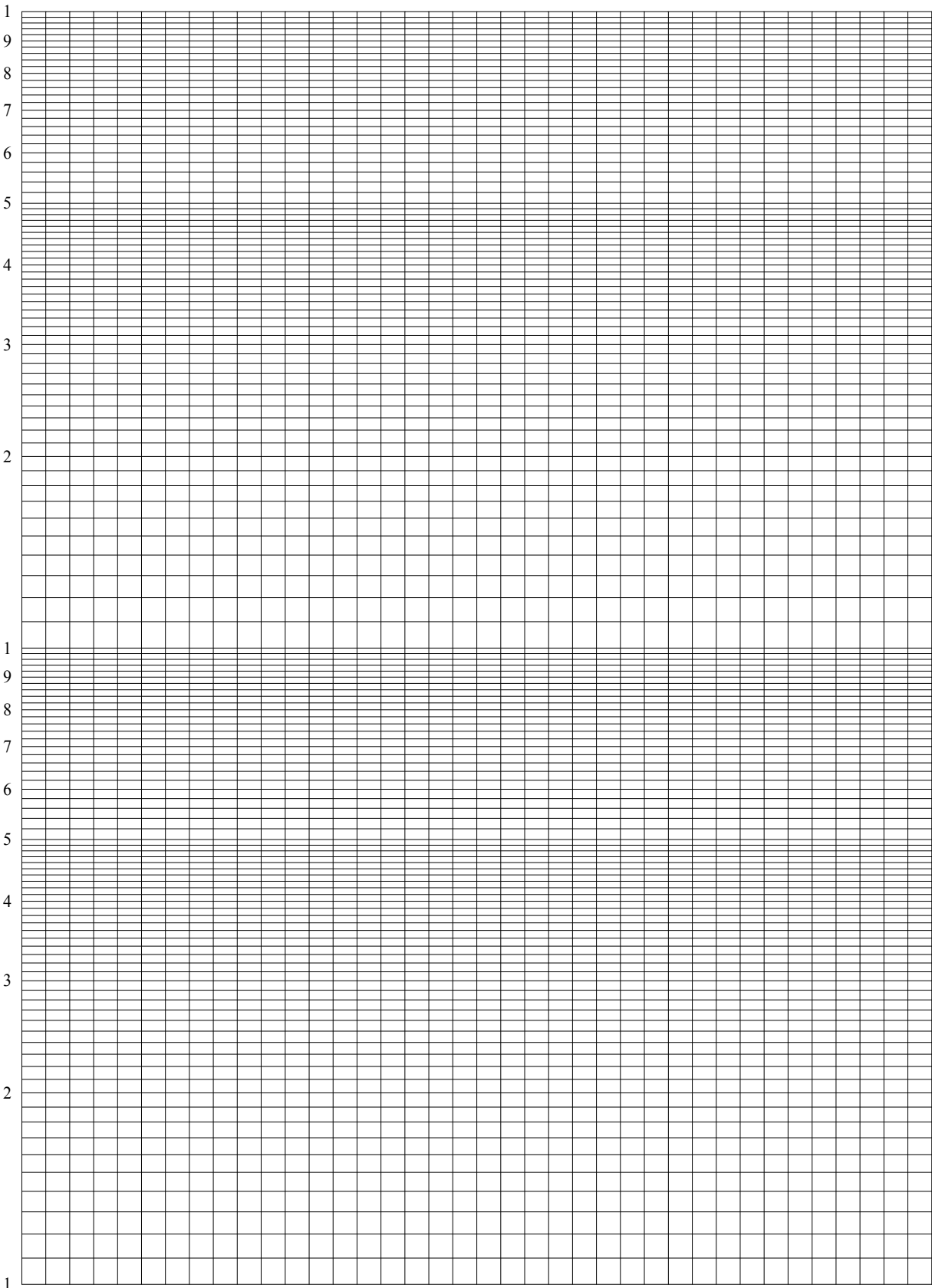
V_d = volume of dilution water in ml

11. Graph the results. Plot time in minutes on the x-axis (horizontal axis), and the turbidity in NTUs on the y-axis (vertical axis).

Interpretation

On the graph, draw a line from the 10-15 NTU range on the y-axis until the line intersects the curve on the graph. From this intersection, draw a line downward to the x-axis. Read the time in minutes. This is the desired backwash duration in minutes.

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Backwash Water Turbidity Analysis Form

Time, minutes	Backwash Water Turbidity	Time, minutes	Backwash Water Turbidity
1		16	
2		17	
3		18	
4		19	
5		20	
6		21	
7		22	
8		23	
9		24	
10		25	
11		26	
12		27	
13		28	
14		29	
15		30	

Interpretation

At what time did the backwash water turbidity fall between 10 NTU and 15 NTU?

_____ minutes

Target: 6 to 8 minutes

Sludge Retention Profile

In order to remove turbidity effectively and minimize turbidity spikes after backwashing, some sludge should remain in the filter. The Sludge Retention Profile is a way of determining how much sludge remains in the filter. Too much sludge or too little sludge will diminish filtration efficiency and cause other problems. The retained sludge in a properly backwashed and adequately ripened filter should be in the range of 30 – 60 NTU.

Equipment Needed:

24 to 36 one-gallon resealable plastic bags	50-ml beaker
Core sampler	Tap water
100-ml graduated cylinder	Bench-top turbidimeter
Pint Jar	1-liter Erlenmeyer Flask

Procedure

The following procedure is performed twice on a filter, once before backwashing, and once after.

Sample Collecting

1. Prepare two sets of six one-gallon resealable plastic bags, labeled “Before Backwash” and “After Backwash”, and with these media depths marked on the appropriate bag.

0-2 in	6-12 in	18-24 in	30-36 in
2-6 in	12-18 in	24-30 in	

2. Select three sampling sites on the filter.
3. Completely drain the water out of the filter media.

NOTE: Sampling should take place within one hour of draining to prevent the media from drying out.

4. Layout plywood boards to stand on. Do not stand or walk on the media.
5. Gently push the core sampler into the media to the 2-inch mark. Rotate the core sampler to widen the hole so that it won't cave in.
6. Form an airtight seal on the top of the core sampler by placing a hand over it, and slowly pull the core sampler from the media.
7. Deposit the media into the bag marked “Before Backwash – 0 to 2 in”.
8. Repeat steps 5 thru 7 for the other depths, making certain the sample is placed in the correct bag.

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9. Move to second sampling site and repeat procedure, placing sample in the appropriate bag used for the first sampling site.
10. After completing the second set of samples, move to the third sampling site and repeat sampling.
11. Backwash the filter.
12. Repeat steps 3 thru 10, using the bags marked “After Backwash”.
13. Remove all equipment and samples from the filter and take the samples to the lab for analysis.

Sample Preparation

1. Separate the before and after backwash sample bags and organize them in order of depth.
2. Thoroughly mix each sample by shaking the bag vigorously.
3. Measure out 50ml of sample from the “Before Backwash Bag” marked “0-2 in” , using the 100-ml graduated cylinder. Gently tap the graduated cylinder on the counter top to aid in settling the media.
4. Transfer the 50-ml sample to the 500-ml flask.
5. Add 100-ml of the tap water to the sample and shake vigorously for 60 seconds.
6. Pour the turbid water into the 1-liter Erlenmeyer flask.
7. Using the same media sample, repeat step 5 and 6 four more times until there is a total of 500-ml of turbid water in the beaker.
8. Stir the 500-ml sample of the turbid water.
9. Pour the required amount of turbid water into the cell and read the turbidity of the sample.
10. Multiply the turbidity reading by two and record that value on the Sludge Retention Profile Evaluation Form.
11. Repeat steps 2 thru 10 for the remaining samples.
12. Graph the results. Plot turbidity on the x-axis and media depth on the y-axis, for both the before and after backwash samples.

Interpretation of Results

Using the table, determine the condition of the filter.

<u>Turbidity</u>	<u>Filter Media Condition</u>
0 – 30 NTU	Clean-unripened filter (probable extended turbidity breakthroughs)
30 – 60 NTU	Cleaned-ripened filter (optimal filter performance)
60 – 120 NTU	Slightly dirty (adequate performance for short periods of time)
>120 NTU	Dirty (evaluate backwash procedure and/or system)
>300 NTU	Mudball problems

A turbidity range of 30-60 NTU is desirable.

NOTES

Sludge Retention Profile Analysis Form

Date: _____ Filter I.D.: _____
 Evaluator: _____ Evaluator: _____
 Evaluator: _____ Evaluator: _____
 Evaluator: _____ Evaluator: _____

Data

Before Backwash				After Backwash			
Core Sample Depth	Measured Wash Water Turbidity	X	Sludge Retention NTU	Level	Measured Wash Water Turbidity	X	Sludge Retention NTU
0-2 in		2		0-2 in		2	
2-6 in		2		2-6 in		2	
6-12 in		2		6-12 in		2	
12-18 in		2		12-18 in		2	
18-24 in		2		18-24 in		2	
24-30 in		2		24-30 in		2	
30-36 in		2		30-36 in		2	
Total Retained Sludge				Total Retained Sludge			
Average Retained Sludge				Average Retained Sludge			

Interpretation of Results

Turbidity

0 – 30 NTU

30 – 60 NTU

60 – 120 NTU

>120 NTU

>300 NTU

Filter Media Condition

Clean-unripened filter (probable extended turbidity breakthroughs)

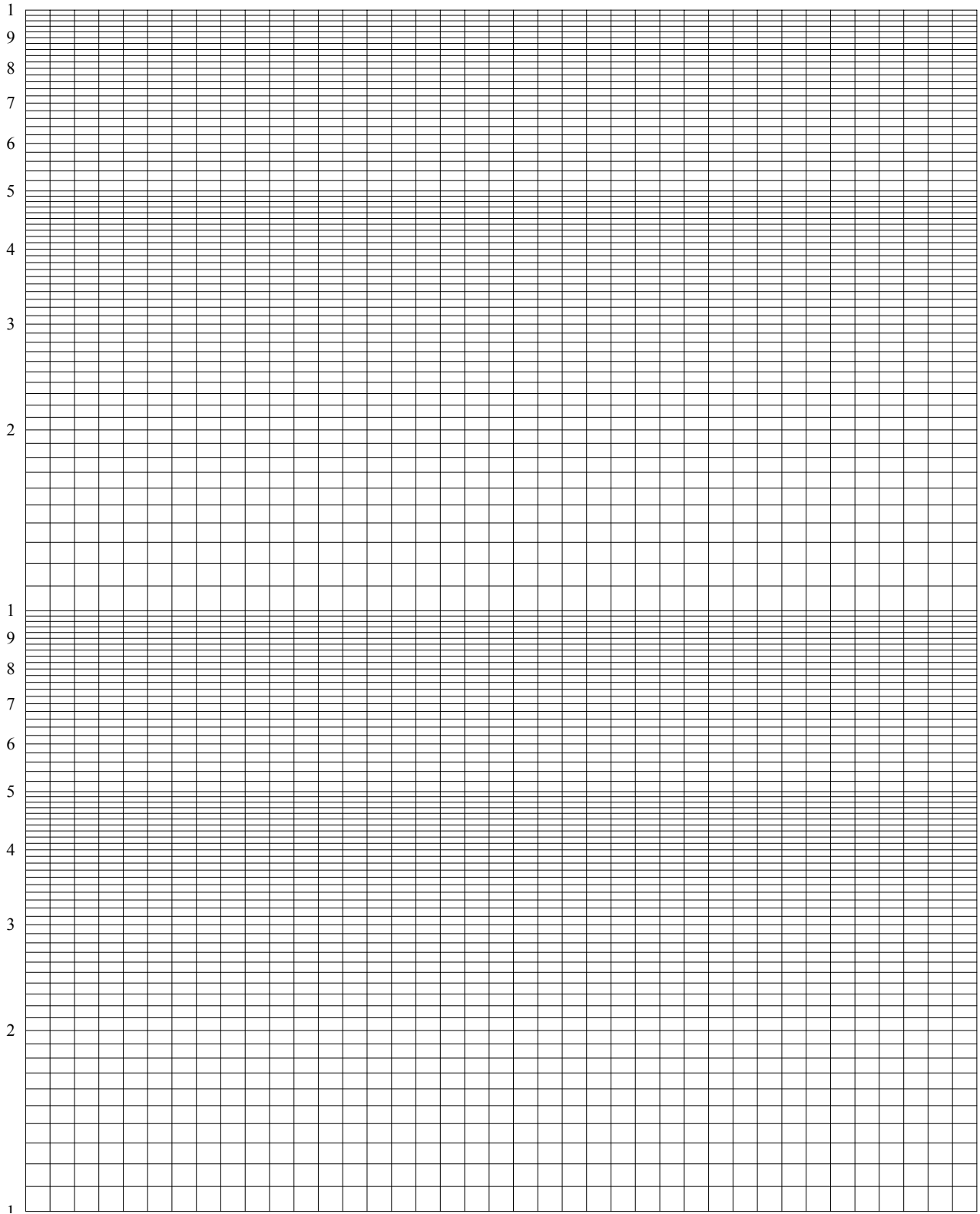
Cleaned-ripened filter (optimal filter performance)

Slightly dirty (adequate performance for short periods of time)

Dirty (evaluate backwash procedure and/or system)

Mudball problems

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Mudball Analysis

Purpose

To determine the condition of a filter as indicated by the presence or absence of mud balls.

Equipment Required

No. 12 (10 mesh) sieve	250-mL graduated cylinder
Mudball sampling device	If mudballs are large, a 500-mL or 1,000-mL graduated cylinder may be needed.
1-gal resealable plastic bags	
5-gal bucket	

Procedure

Sample Collection

1. Backwash the filter.
2. Drain the water from the filter to a point below the media surface.
3. Select five sampling points at random.
4. Beginning with the first sampling point, push the mudball sampling device into the media to a depth of six inches
5. Tilt the mudball sampler back until it is horizontal.
6. Lift the mudball sampler, keeping it horizontal.
7. Empty the contents of the mudball sampler into the 1-gal plastic bag.
8. Repeat steps 4-7 at the remaining sampling points, placing all samples in the same bag.
9. Mark the bag with the following information:
 - A. filter I.D.;
 - B. date;
 - C. name of person taking sampler.

Sample Preparation

1. Fill the 5-gal bucket half-full with water.
2. Lower the No. 12 sieve into the water until nearly submerged.
3. Put a handful of the media sample into the sieve.

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4. Raise and lower the sieve gently in the water until the media is washed through the sieve.
5. Repeat steps 3-4 until all of the media sample has been sieved.
6. Gently wash any mudballs to one side of the sieve.

Testing

1. Fill the 250 mL graduated cylinder to the to the 200-mL level with water.
2. Record this value on the Mudball Analysis form as the initial volume.
3. Gently transfer the mudballs from the sieve to the graduated cylinder.
4. Read the new volume in the graduated cylinder and record this value.

Calculations.

Step One: Calculate the volume of the mudball sampler in gallons (gal).

$$\text{Media Sample Volume, gal} = \frac{0.785 \times D^2 \times H \times N}{231 \text{ in}^3/\text{gal}}$$

Where

D = diameter in inches

H = height of sampler in inches

N= number of samples taken

Step Two: Convert the sample volume to milliliters (mL).

$$\text{Media Sample Volume, mL} = \text{Volume, gal} \times 3,785 \text{ mL/gal}$$

Step Three: Calculate the mudball volume, in milliliters (mL).

$$\text{Mudball Volume, mL} = \text{Final Cylinder Volume, mL} - \text{Initial Cylinder Volume, mL}$$

Step Four: Calculate the percent mudballs

$$\% \text{ Mudballs} = \frac{\text{Mudball Volume, mL} \times 100\%}{\text{Media Sample Volume, mL}}$$

Optimizing Filter Performance

Interpretation	
% Mudballs	Filter Condition
0.0 – 0.1	Excellent
0.1 – 0.2	Very Good
0.2 – 0.5	Good
0.5 – 1.0	Fair
1.0 – 2.5	Fairly Bad
2.5 – 5.0	Bad
>5.0	Very Bad

Mudball Volume, %

Sample Problem 1: An operator took five media samples in order to analyze the media for mudballs. After washing the media through a No. 12 (10 mesh) sieve, the mudballs were transferred to a 250-mL graduated cylinder. The initial cylinder reading was 200-mL. After the mudballs were placed into the graduated cylinder, the volume read 235-mL. The media sample volume was 3,482 mL. What is the mudball volume in percent?

Sample Problem 2: The mudballs found in media samples taken from a filter were transferred to a 250-mL graduated cylinder containing 200 milliliters of water. After the mudballs were transferred to the graduated cylinder, the cylinder reading was 242 mL. Determine the mudball volume in percent if the media sample volume was 3,482 mL.

Sample Problem 3: The volume of mudballs found during a mudball analysis was 31 mL. The media sample volume was 3,482 mL. Calculate the mudball volume in percent.

Practice Problems

Round your answers to the nearest hundredth of a percent (two decimal places).

1. During an analysis of filter media for mudballs, the mudball volume was found to be 12 mL. The volume of media sampled was 3,482 mL. What is the mudball volume in percent?
2. The operator at Big Creek Utility District took five media samples to be analyzed for mudballs. The mudballs which were found were placed into a 250-mL graduated cylinder containing 200 mL of water. After the mudballs were placed into the graduated cylinder, the volume reading was 227 mL. Determine the mudball volume in percent if the total media sample volume was 3,482 mL.
3. A total of five media samples were taken to analyze the media in a filter for mudballs. The total media sample volume was 3,482 mL. The mudballs found during the analysis were transferred to a 250-mL graduated cylinder containing 200 mL of water. When the mudballs were transferred to the graduated cylinder, the volume rose to 217 mL. Calculate the mudball volume in percent.
4. The operator of Consolidated Utility District's water treatment plant took five samples of filter media to analyze it for mudball volume. The total volume of media sampled was 3,482 mL. After placing the mudballs collected into a 250-mL graduated cylinder, the operators found the mudball volume to be 42 mL. What is the mudball volume in percent?
5. Calculate the mudball volume in percent if the mudballs collected from five media samples had a volume of 36 mL. The total sample volume was 3,482 mL.

Turbidity Analysis

Purpose

To evaluate startup spikes, filter profiles, and compare turbidity reduction to run time.

Equipment/ Reagents Needed

Computer with spread sheet software	85 to 150 100-ml bottles
Turbidimeter (inline or bench top)	Deionized water

Inline Turbidimeter Procedure

1. During the first hour of operation, read the turbidity from the inline turbidimeter every minute and record the reading on the Turbidity Analysis Form.
2. During the next three hours of operation, read and record the turbidity reading every 5 minutes.
3. During the remainder of the filter run, read and record the turbidity every 15 minutes.
4. Enter the data into the spread sheet program.
5. Generate a line graph plotting turbidity (NTU) on the vertical (y-axis) and time on the horizontal axis (x-axis).

Interpretation

1. Determine how long after startup it took for the turbidity to fall below 0.3 NTU. Cannot be more than 0.3 NTU in two consecutive samples, taken fifteen minutes apart, after the first four hours of continuous operation after being returned to service.
2. Determine how long it took after startup for the filter to show signs of turbidity break through.
3. Compare this profile to previous profiles to determine any changes in filter run time.
4. Determine if the filter could produce more water without exceeding the turbidity MCL.

NOTE: A bench top turbidimeter can be used if samples are collected in 100-mL sample bottles at the appropriate times, analyzed, and the results recorded.

NOTES

Optimizing Filter Performance

Student Guide



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Table of Contents

Preface.....	ii
Filtration Requirements	1
Performance Limiting Factors.....	5
Filtration Rate Analysis	9
Backwash Flow Rate Analysis.....	17
Backwash Bed Expansion Analysis.....	23
Backwash Water Turbidity Analysis.....	29
Sludge Retention Profile.....	33
Mudball Analysis	39
Turbidity Analysis	43

Developed by
John Shadwick, Training Director
Tennessee Association of Utility Districts
P.O. Box 2529
Murfreesboro, Tennessee 37133-2529
VOICE: 615.896.9022
FAX: 615.898.8283
Web: www.taud.org

Preface

This work was developed for the benefit of trainers and operators. It is intended to facilitate preparation of classes by trainers and help operators understand how to get optimum performance from their granular media filters.

It could not have been completed without the assistance of the following people.

Superintendents and Chief Operators

Donnie Chisholm, Waverly Water Department
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Ron Medley, West Knox Utility District
Benny Garner, West Knox Utility District
Ed Roberts, Kingston Water and Sewer
Eddie Partlow, Old Hickory Utility District
Greer Harris, Spring City Water System

TAUD Staff

Melanie Hammond
Administrative Assistant
TAUD Training Station

Doug Cherry, Training Program Specialist
Roger Booher, Circuit Rider
Greg Baker, Groundwater Specialist
Tony Wyatt, Circuit Rider



John Shadwick
Training Director, TAUD

