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AUTHOR	Klopping, Paul H.
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ABSTRACT

The basic operation of the gravity thickener is described in this lesson, focusing on the theory of operation, components found in a typical thickener, and the parameters which must be understood in optimizing the opeation of the thickener. Attention is given to mathematics concepts which are used in controlling hydraulic loading, detention time, and material balance. The lesson includes an instructor's guide and student workbook. The instructor's guide contains a description of the lesson, estimated presentation time, instructional materials list, suggested sequence of presentation, reading lists, objectives, lecture outline, narrative of the slide/tape program used with the lesson, and student worksheet (with answers). The student workbook contains plant flow diagrams, objectives, glossary, text material on gravity thickening, references, and worksheet. (JN)

GRAVITY THICKENING

Written By:
Paul H. Klopping
Linn-Benton Community College
Albany, Oregon

Instructional Design:
Priscilla Hardin
Corvallis, Oregon

Technical Consultant:
Envirotech Operating Services
San Mateo, California

Project Director:
Paul H. Klopping
Linn-Benton Community College
Albany, Oregon

Project Officer:
Lynn S. Marshall
United States Environmental Protection Agency
National Training and Operational Technology Center
Cincinnati, Ohio

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GRAVITY THICKENING

CONTENTS

GRAVITY THICKENING

Lesson Description

This lesson deals with the basic operation of the gravity thickener. It covers the theory of operation and describes the components found in a typical thickener. Consideration is then given to the parameters which must be understood in optimizing the operation of the thickener. Attention is given to math concepts which are used in controlling hydraulic loading, detention time and material balance.

Before using this module, review the concepts covered in "Sludge Characteristics" and "Sludge Conditioning". It may also be helpful to review the module on "Planning Considerations" as a means of seeing this process unit in relation to other types of solids handling.

Estimated Time

Student Preview	5 - 10 minutes
Presentation	30 - 40 minutes
Discussion	5 - 10 minutes
Worksheet and Review	20 - 30 minutes

Instructional Materials List

1. Student text, "Gravity Thickening".
2. Slide set, "Gravity Thickening".
3. Slide projector and screen.
4. Chalk and blackboard or marking pens and flip chart.

Suggested Sequence of Presentation

1. Assign reading.
2. Lecture and discussion using slide format and outline. This material may also be presented in a slide/tape sequence using a Wollensak cassette player coupled to a 35mm carousel projector. The tape is equipped with a non-audible cue to automatically advance and synchronize the slides.
3. Open discussion.
4. Assign worksheet.
5. Review worksheet.

GRAVITY THICKENING

Required Reading

EPA Course #166, Gravity Thickening.

Reference Reading

EPA Course #166, Sludge Characteristics, Sludge Conditioning, Planning Considerations, Lab Procedures.

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GRAVITY THICKENING

Objectives

Upon completion of this lesson the student should be able to do the following:

1. Recall two ways that gravity influences thickening:
   a. Gravitational force - sludge is heavier than water.
   b. Sludge is compacted by the weight of the solids in the blanket pressing down from above.
2. Identify on a diagram the following components:
   a. Inlet and Distribution Assembly
   b. Rake or Collector Mechanism
   c. Pickets
   d. Scum Removal
3. List four of the six criteria which influence the operation of a gravity thickener. The list includes:
   a. Type of sludge
   b. Age of sludge
   c. Sludge blanket depth
   d. Solids and hydraulic detention time
   e. Solids and hydraulic loading
   f. Temperature of sludge
4. Define Gasification
5. List the gases produced by the biological decomposition of sludge.
6. Recall that secondary sludges are difficult to thicken by gravity due to a large amount of bound water.
7. Define nitrification.
8. Define denitrification.
9. Explain why nitrification - denitrification is an important consideration in thickening secondary sludge.
10. Explain why filamentous bacteria in secondary sludge causes thickening problems.
11. Recall that an increase in temperature causes an increase in biological activity.
12. Recall that gravity thickener operation varies between summer and winter due to the effect of temperature on gasification.
13. Recall two of three types of control for operating a thickener. The list includes:
    a. Control solids retention time
    b. Control speed of collector
    c. Control sludge blanket depth
14. Define and calculate hydraulic loading.
15. Recall typical hydraulic loading on a gravity thickener is 400 - 800 gpd/sq. ft.

16. Define and calculate solids loading as lbs. solids/day/[illegible].

17. List three of the four factors which affect sludge detention time. These include:

    a. Solids applied
    b. Depth of blanket
    c. Solids concentration in blanket
    d. Solids removed

18. Define sludge volume ratio as:

$$\frac{\text{Vol. of sludge blanket}}{\text{Vol. of sludge pumped/day}}$$

19. Recall typical SVR's for gravity thickeners is 0.5 - [illegible] days.

20. Recall that SVR should decrease during warm weather.

21. Recall points where flow should be monitored in the operation of a thickener. These include:

    a. Influent
    b. Effluent
    c. Concentrated sludge stream

22. Describe the surface of a properly functioning thickener to be:

    a. Relatively clear
    b. Free of gas bubbles
    c. Free of solids
    d. Free of excessive scum accumulation

23. Recall that the sludge blanket depth should be below three feet.

24. State the criteria for setting the speed of the sludge collector. It should be:

    a. Fast enough to move settled solids to collection point.
    b. Slow enough to avoid disruptive turbulence which causes solids to float.

25. Recall that the proper rate of sludge withdrawal is:

    a. One which maintains proper blanket level.

26. Define and calculate "concentration factor" as:

$$\frac{\text{Thickened Sludge Concentration}}{\text{Influent Sludge Concentration}}$$

27. Recall that primary sludge should have a concentration factor greater than 2.0, secondary sludge greater than 3.0.

28. The student will be able to recall expected performance of a gravitational thickener in concentrating sludges as follows:

a. Primary sludge	8 - [illegible]
b. Trickling Filter sludge	7 - [illegible]
c. Waste activated sludge	2 - 3%
d. Digested primary	12%
e. Primary and waste activated	4%
f. Primary and $FeCL_3$	4%
g. Primary and lime	7 - 12%

GRAVITY THICKENING - LESSON OUTLINE

I. GRAVITATIONAL THICKENING

A. Gravitational Force To Separate Solids from liquids.

1. Solids heavier than water settle to bottom.
2. Compacted by weight of solids above.

B. Thickeners - Construction

1. Circular

a. Inlet and Distribution Assembly - steel skirt - baffle - 2 - 3 feet deep from surface.

b. Sludge rake - moves sludge to sump for removal.

c. Pickets - on rake, gently stir sludge, release gas.

d. Scum removal

C. Operation

1. Good operation depends on:

a. Type of sludge

b. Age of feed sludge

c. Temperature of sludge

d. Sludge blanket depth

e. Solids and hydraulic detention time

f. Solids and hydraulic loading

2. Gasification - due to septic sludge

a. H_2S

b. CH_4

c. CO_2

3. Secondary sludges

a. Large amounts of bound water.
85 - 90% intracellular water in biological solids.

b. Difficult to thicken by gravity.

c. Nitrification

d. Filamentous bulking

4. Temperature

a. Increase in temperature = increase in biological activities.

(1) Gasification

(2) Pump sludge at faster rate in summer versus winter.

5. Operating Guidelines

a. Control solids retention time.

b. Control speed of collector.

c. Control sludge blanket depth.

6. Hydraulic loading

a. Definition: gallons/sq. ft./day = hydraulic surface loading or overflow rate.

gallons = sludge flow + 2^0 clarifier effluent blend.

b. Typical rates = 400 - 800 gpd/ft.^{2}

7. Solids loading

a. Definition: lbs. solids/day/ft.^{2}

8. Sludge Detention Time

a. Definition: Time solids remain in blanket.

b. Based on:

(1) Solids applied

(2) Depth of blanket

(3) Solids concentration of blanket

(4) Solids removed

9. SVR = Sludge Volume Ratio

   a. $SVR = \frac{\text{Volume of Sludge Blanket}}{\text{Daily Volume of Sludge Pumped}}$

   b. Typical = SVR of 0.5 - 2 days

      Increase SVR = maximum sludge concentration, but gasification may occur.

      Decrease SVR during warm weather.

D. Normal Operating Procedures

1. Monitoring

   a. Once per shift

      (1) Influent

      (2) Effluent

      (3) Concentrated sludge stream

2. Water Surface

   a. Relatively clear

      (1) Free of gas bubbles, solids and scum

3. Sludge blanket depth

   a. Kept below 3 feet

4. Speed of Collector

   a. Fast enough to remove settled solids to sludge collection pump.

   b. Slow enough not to disrupt settled solids and cause them to float.

5. Withdrawal of sludge

   a. Fast enough to maintain blanket level.

E. Typical Performance

1. Actual plant may vary - all sludges are unique. Below is a general guideline:

Sludge Type	Solids Loading lbs./day/ft.^{2}	Influent Feed Sludge %	Thickened Sludge %
Separate			
Primary	20-30	3.0-5.0	8-10
A/S	5-8	0.5-1.5	2-4
T/F	8-10	1.0-2.0	7-9
Combined			
1^0 + A/S	6-12	1.5-2.5	4-9
1^0 + T/F	10-20	2.0-3.0	7-9

2. Efficiency

   a. $$\text{Efficiency \%} = \frac{(\text{Influent} - \text{Effluent})}{\text{Influent}} \times 100\%$$

3. Concentration Factor (CF)

   a. $$CF = \frac{\text{Thickened Sludge Concentration \%}}{\text{Influent Sludge, Concentration \%}}$$

   b. Primary sludge = 3%

      Thickened sludge = 7%

      $$CF = \frac{7.0\%}{3.0\%} = 2.33$$

   c. Guidelines:

      Primary sludge = CF 2.0

      Secondary sludge = CF 3.0

Narrative

Slide #

1. This module discusses Gravity Thickening. It will present a description of the process, the components typically found on a thickener, information on process control, safety and other basic items necessary for a sound understanding of the process.

2. This module was written by Mr. Paul Klopping. Instructional Development was done by Priscilla Hardin and Envirotech Operating Services provided technical review.

3. Gravity thickening of wastewater sludges uses the force of gravity to separate solids from water. Those solids that are heavier than water settle by gravity

4. and are then compacted by the weight of overlying solids.

5. Gravity thickeners are usually circular, resembling clarifiers.

6. The main components of gravity thickeners include: (a) an inlet and distribution baffle assembly,

7. (b) a sludge rake to move settled solids to a sump for removal, (c) vertical pickets attached to the rake mechanism,

8. (d) a scum removal mechanism, (e) overflow weir and outlet piping.

9. The inlet and distribution assembly is a circular baffle, extending from slightly above the water surface downward 2-3 feet. Sludge enters the center baffled area of the thickener, flows downward under the baffle and accumulates in the bottom of the thickener, forming a sludge blanket.

10. A sludge blanket is the accumulated mass of solids that forms when individual particles settle and appear as a discernible layer separate from the water in which they are contained.

11. The sludge rake gently stirs the sludge blanket. This moves concentrated sludge to the center of the tank where it is dropped into a sump.. The sloping bottom of the thickener also helps move heavy solids to the center of the tank for removal.

12. In addition to moving the sludge to the center sump, the gentle stirring of the blanket releases trapped gas bubbles and water, further enhancing concentration of the solids. If trapped gas is not released from the blanket, solids become bouyed up and float to the surface.

13. While the sludge collection mechanism rotates at the bottom of the thickener, a scum removal mechanism moves across the surface, collecting and depositing floating debris in a scum pit.

14. The scum pit must be emptied on a regular basis.

15. Effluent from the thickener overflows a weir on the outside of the tank. Scum is prevented from overflowing the effluent weir by a baffle.

16. There are several criteria influencing the performance of a gravity thickener. Thickeners are influenced by sludge characteristics and operational controls.

17. Important sludge characteristics are: (a) type of sludge, (b) age of the feed sludge, (c) sludge temperature.

18. Both the type and age of sludge to be thickened can have a pronounced effect on a thickener's overall performance.

19. Fresh primary sludge has the potential of compacting to the highest concentrations of any sludge.

20. If the primary sludge is septic or allowed to go anaerobic, gasification may occur, releasing hydrogen sulfide, methane and carbon dioxide gases.

21. These gases attach to the solids in the blanket and carry them to the surface. Gasification significantly reduces the efficiency of the thickener.

22. Secondary sludges are biological solids and are not well-suited for gravity thickening because of large quantities of bound water.

23. These solids are composed of 85-90% water within the cell mass. This water may either be bound as a thin layer to the cells or actually contained within the cells as intracellular water.

24. Besides having large quantities of bound water, biological solids tend to be smaller or finer in size than primary sludge solids. This differnce in size makes them more difficult to settle than primary solids.

25. The age of feed sludge is also important when gravity thickening secondary, or biological sludge because of nitrification.

26. In the activated sludge and trickling filter processes, ammonia may be converted to nitrite and nitrate in the presence of oxygen. This oxidation of ammonia to nitrite and then to nitrate is called nitrification.

27. It requires the presence of oxygen and a relatively long aeration time or sludge age which encourages the buildup of nitrifying bacteria, the organisms responsible for making the conversion of ammonia.

28. Secondary sludges which have been nitrified under aerobic conditions may undergo further biological activity when fresh oxygen is no longer present, as would be the case in a sludge blanket. In this case, under anaerobic conditions, nitrite and nitrate are converted to nitrogen gas.

29. This process of denitrification produces gas which attaches to the sludge particles, causing them to float to the surface. Any floating sludge problem adversely affects the efficiency of a gravity thickener.

30. When nitrified secondary sludges are to be gravity thickened, a close watch must be kept on the sludge detention time in the thickener so that sludge is thickened and pumped out before it has a chance to dentrify and float to the surface.

31. Secondary sludge may also have poor settling properties due to the presence of filamentous bacteria. Filaments extending from the floc prevent sludge from compacting well.

32. Temperature of the feed sludge will also affect the operation of a gravity thickener.

33. As the temperature increases, the rate of biological activity increases, and the sludge tends to gasify and rise at a faster rate.

34. To shorten detention time during warm weather, sludge should be pumped from the thickener at a faster rate than during winter months.

35. In response to the variations in sludge characteristics, operation of the gravity thickener calls for specific operational controls:

36. (a) sludge blanket depth, which is influenced by the speed of the collection mechanism and the sludge withdrawal rate, (b) solids and hydraulic detention time, (c) hydraulic and solids loading.

37. The sludge blanket depth is maintained by removing solids from the blanket in the bottom of the thickener at the same rate as they are added at the top.

38. In order to maintain a blanket, it is first necessary to measure the volume of the sludge blanket. This figure will be a fraction of the total thickener volume.

39. Second, approximate the average concentration of solids in the blanket. This is done by measuring both the feed sludge and thickened sludge concentrations and taking an average of the two. This concentration is the average of all solids in the blanket. Knowing the volume and concentration of the blanket, total pounds in the blanket can be calculated.

40. Knowing the volume and concentration of the feed sludge, and volume and concentration of thickened sludge allows the operator to know what's coming in and what's going out. When these two amounts are equal, a solids balance will be maintained, resulting in a stable blanket level.

41. Sludge detention time is the time the solids remain in the gravity thickener and is based on the solids applied, the depth and concentration of the sludge blanket and the solids removed from the bottom of the thickener. The operator has the ability to control the solids detention time and degree of thickening to some extent by controlling the depth of the sludge blanket.

42. Sludge Volume Ratio (SVR) provides a means of regulating the detention time of sludge within the blanket of the thickener.

43. SVR is defined as the volume of the sludge blanket divided by the daily volume of sludge pumped from the thickener. This term is a relative measure of the average detention time of solids in the thickener and is calculated in days.

44. Typical SVR values are between ½ and 2 days.

45. During operation of a gravity thickener, several points should be monitored at least once per shift. These points are: (a) influent, (b) thickener overflow, (c) thickened sludge stream.

46. Normally, the surface should be relatively clear and free of solids and gas bubbles. The sludge blanket should be kept below 3 feet. The speed of the collection mechanism should be such that sludge is continuously moved to the center sump without creating turbulence which impedes settling. Sludge should be pumped from the thickener at a rate that will maintain a relatively constant blanket level.

47. If the blanket is maintained at too high a level and the solids detention time is too long, gasification may cause floating sludge and poor effluent quality.

48. If the blanket is too low, too much water will be pumped out of the thickener with the thickened sludge. Most probably, if a thin blanket exists, sludge has not been held in the thickener long enough to reach ultimate compaction, and a higher volume of dilute sludge will have to be handled than if more thickening had occurred before removal. Trial and error is often the best means of finding optimum conditions for a particular facility.

49. The hydraulic surface loading or overflow rate is expressed as: Gallons applied per square foot of thickener surface area per day, (GPD/sq ft/day)

50. In figuring out the hydraulic surface loading, one must find the gallons applied per day to the thickener and then divide that amount by the water surface area in square feet.

51. Thickeners usually operate best if a relatively high flow of fresh liquid is applied. To accomplish this, secondary effluent may be blended with the sludge feed.

52. The solids loading is defined as the total number of pounds of solids applied per square foot of thickener surface area per day.

53. The amount of loading that a thickener will handle is dependent on the type of sludge to be thickened. For instance, a thickener can handle more primary sludge per square foot than secondary sludge, because primary sludge settles and compacts at a faster rate.

54. The operation of a thickener may be expressed in terms of efficiency of removal. Efficiency is calculated as:

$$\frac{\text{IN} - \text{OUT}}{\text{IN}} \times 100\% = \%\ \text{Efficiency}$$

In the case of gravity thickeners, the efficiency of removal of sludge solids is the key indicator of proper performance.

55. Since the overflow from a thickener is returned to the headworks of the plant, any solids which are not captured by the thickener are recirculated where they exert an additional load beyond that applied by fresh wastewater entering the plant. Efficiency of removal should be calculated on a regular basis so that close track can be kept on the thickener and its impact on the rest of the plant.

56. The primary goal of operation is concentrating sludge thereby reducing the volume of solids to be handled. A concentration factor can be used to determine the effectiveness of the thickener in concentrating the sludge.

57. The concentration factor is calculated as follows:

$$\text{CF} = \frac{\text{Thickened Sludge Conc \%}}{\text{Feed Sludge Conc \%}}$$

58. For primary sludge, concentration factors (CF) of 2.0 or higher should be achieved. In handling secondary sludges, concentration factors of 3.0 or greater should be achieved.

59. In summary, a gravity thickener is a common means of increasing the concentration of sludge prior to other sludge handling. As sludge is concentrated, less volume needs to be handled for an equivalent weight of dry solids. This improves the efficiency of most sludge treatment and disposal processes.

60. The process relies on the fact that most wastewater solids are slightly heavier than water, and will settle by the force of gravity under the right conditions.

61. Careful adjustment of operational controls enables the force of gravity to produce efficient, economical thickening.

GRAVITY THICKENING - WORKSHEET

1. Which components are found on a gravity thickener?
   - _X_ a. Inlet and distribution assembly
   - ___ b. Spark arrestor
   - _X_ c. Rake or collector mechanism
   - ___ d. Aerator
   - _X_ e. Pickets
   - ___ f. Bar screen
   - _X_ g. Scum removal

2. Circle three criteria which influence the operation of a gravity thickener.
   - _X_ a. Hydraulic loading
   - _X_ b. Solids loading
   - _X_ c. Rate of removal of sludge
   - _X_ d. Temperature
   - _X_ e. Type of sludge

3. Which of the following gases are produced when sludge decomposes in a gravity thickener?
   - ___ a. Sulfur dioxide (SO_2)
   - _X_ b. Carbon dioxide (CO_2)
   - _X_ c. Hydrogen sulfide (H_2S)
   - ___ d. Nitrous oxide (N_2O)
   - _X_ e. Methane (CH_4)

4. The conversion of ammonia nitrogen to nitrate nitrogen is called:
   - ___ a. Aeration
   - ___ b. Nitrogen fixing
   - _X_ c. Nitrification
   - ___ d. Denitrification
   - ___ e. Fermentation

5. The conversion of nitrate nitrogen to nitrogen gas is called:
   - ___ a. Respiration
   - ___ b. Clarification
   - ___ c. Sedimentation
   - _X_ d. Denitrification
   - ___ e. Nitrification

6. Which of the following conditions have a biological cause?

X a. Floating sludge on the surface due to denitrification.

X b. Floating sludge on the surface due to septic decomposition and the production of H_2S and CO_2.

X c. Poor settling due to excessively filamentous secondary sludge.

X d. Gasification

___ e. Loss of solids due to short circuiting and turbulence.

7. Which of the following would not be used in controlling a gravity thickener?

X a. Estimation of rainfall

___ b. Aeration detention time

___ c. Solids retention time

___ d. Collector speed

___ e. Sludge blanket depth

8. A gravity thickener is 30 feet in diameter and operates at 300 gallons per minute. Calculate the overflow rate (hydraulic loading) in gallons per day per square foot.

Area = πr^2 gallons per day = gallons per minute x 1440 min/day

Choose the closest answer:

___ a. 200 gpd/sq ft.

___ b. 400 gpd/sq ft.

X c. 600 gpd/sq ft.

___ d. 800 gpd/sq ft.

___ e. 1000 gpd/sq ft.

9. 100 gpm of sludge at a concentration of 10,000 mg/l is fed to a 30 foot diameter gravity thickener. Calculate the solids loading in lbs/day/sq ft.

lbs = flow (MGD) x conc. (mg/l) x (8.34 lb/gal)

$$MGD = \frac{GPM \times 1440}{1,000,000}$$

Choose the closest answer:

___ a. 10 lb/day/sq ft.

___ b. 13

X c. 17

___ d. 20

___ e. 23

10. Circle three factors which affect sludge detention time.

- X a. Amount of solids applied
- X b. Amount of solids removed
- ___ c. Temperature of sludge
- X d. Amount of solids in sludge blanket
- ___ e. Weir overflow rate

11. The sludge blanket in a 55,000 gallon gravity thickener occupies a volume of 16,000 gallons. Sludge is pumped from the blanket at a rate of 420 gallons per hour. What is the sludge volume ratio?

$$SVR = \frac{\text{blanket volume}}{\text{volume pumped/day}}$$

- ___ a. 1.0 days
- X b. 1.6 days
- ___ c. 2.8 days
- ___ d. 5.5 days
- ___ e. 3.2 days

12. A typical sludge volume ratio for gravity thickeners is:

- X a. 0.5 - 2.0 days
- ___ b. 2.5 - 4.0 days
- ___ c. 4.0 - 6.0 days
- ___ d. 6.0 - 8.0 days
- ___ e. greater than 8 days

13. When the weather gets warmer, how should the SVR be controlled?

- ___ a. Increase,
- X b. Decrease.
- ___ c. keep it the same.

14. Choose three places where samples should be collected in monitoring the operation of a gravity thickener.

- X a. Influent to thickener
- ___ b. Influent to grit chamber
- ___ c. Influent to plant headworks
- X d. Effluent from thickener.
- X e. Concentrated sludge stream from bottom of thickener.

15. In a gravity thickener, the sludge blanket should be kept below the surface by at least:

_____ a. 1 inch

_____ b. 1 foot

__X__ c. 3 feet

_____ d. 6 feet

_____ e. It doesn't matter.

16. A thickener is fed with raw sludge at 2% concentration. Thickened sludge is removed at 5% concentration. What is the concentration factor?

$$CF = \frac{\text{Thickened Conc.}}{\text{Feed Conc.}}$$

_____ a. 1.0

_____ b. 2.0

__X__ c. 2.5

_____ d. 0.4

_____ e. 3.0

17. Primary sludge should have a concentration factor greater than _______.

_____ a. 1.0

__X__ b. 2.0

_____ c. 3.0

_____ d. 4.0

_____ e. 5.0

18. Secondary sludge should have a concentration factor greater than _____.

_____ a. 1.0

_____ b. 2.0

__X__ c. 3.0

_____ d. 4.0

_____ e. 5.0

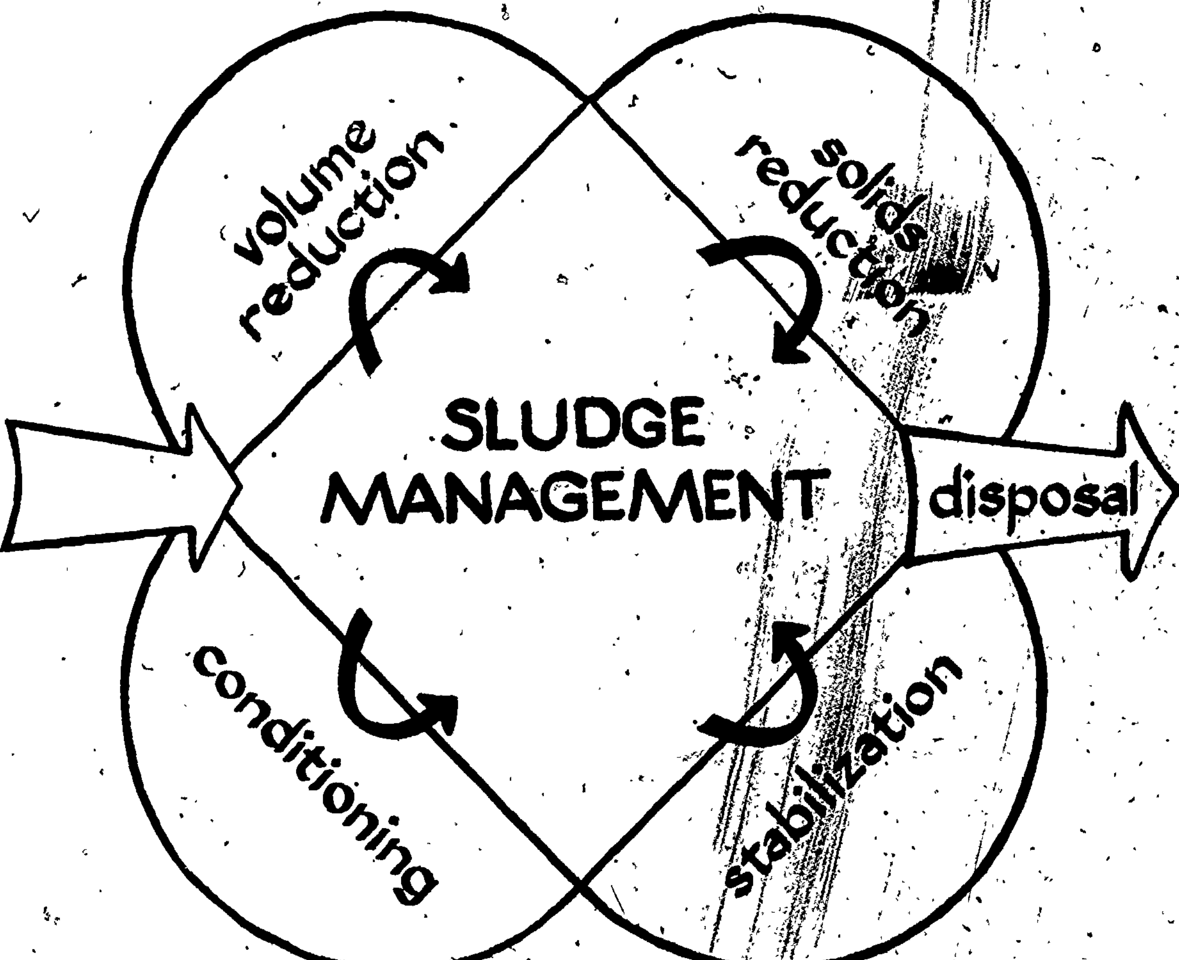
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

GRAVITY THICKENING



STUDENT WORKBOOK

Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

GRAVITY THICKENING

Written By:
Paul H. Klopping
Linn-Benton Community College
Albany, Oregon

Instructional Design:
Priscilla Hardin
Corvallis, Oregon

Technical Consultant:
Envirotech Operating Services
San Mateo, California

Project Director:
Paul H. Klopping
Linn-Benton Community College
Albany, Oregon

Project Officer:
Lynn S. Marshall
United States Environmental Protection Agency
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GRAVITY THICKENING

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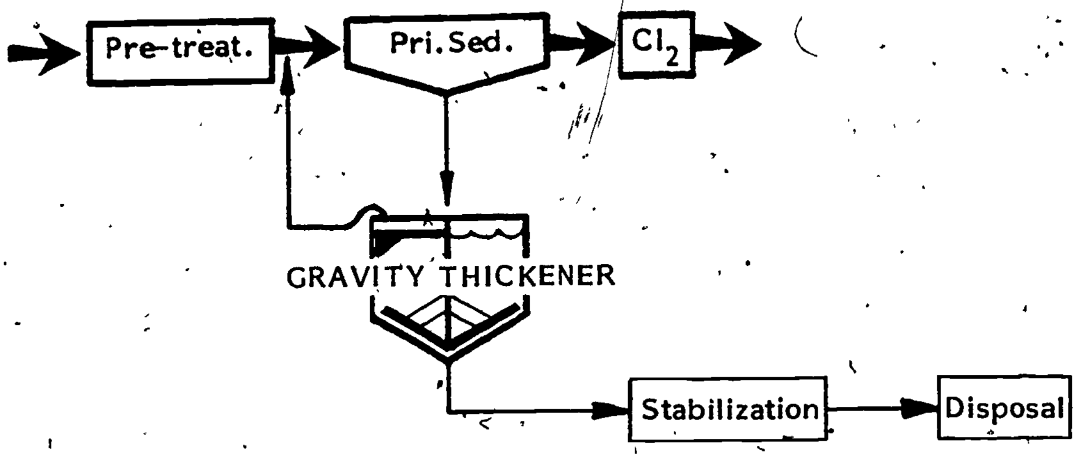
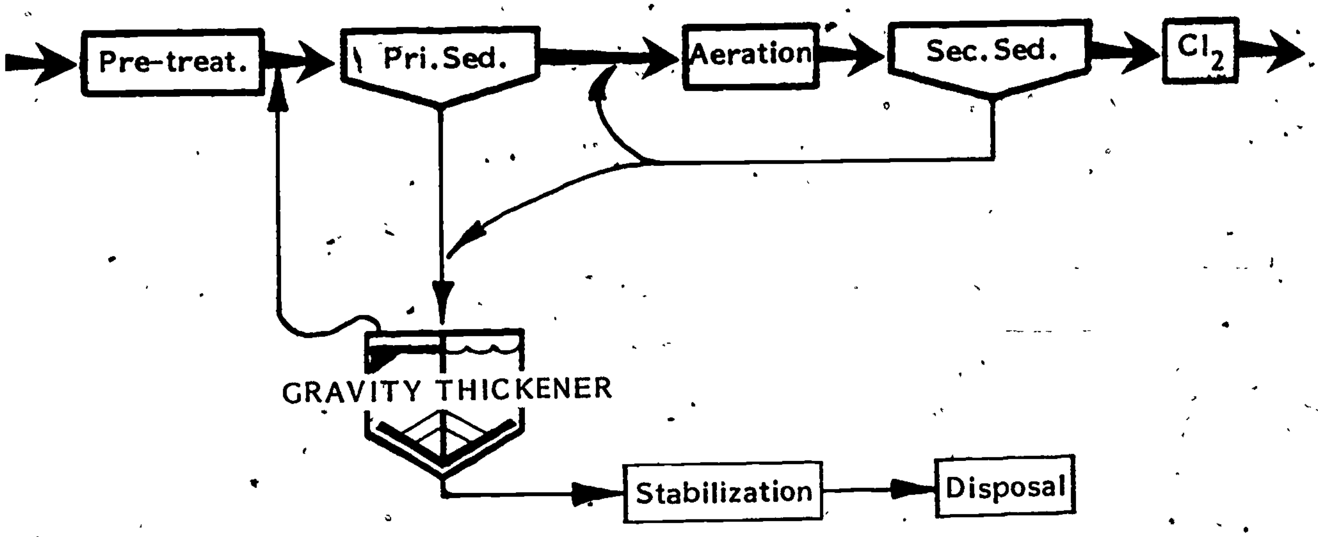
PLANT FLOW DIAGRAMS

PRIMARY PLANT



SECONDARY PLANT



GRAVITY THICKENING

Objectives

Upon completion of this lesson the student should be able to do the following:

1. Recall two ways that gravity influences thickening:
   a. Gravitational force - sludge is heavier than water.
   b. Sludge is compacted by the weight of the solids in the blanket pressing down from above.
2. Identify on a diagram the following components:
   a. Inlet and Distribution Assembly
   b. Rake or Collector Mechanism
   c. Pickets
   d. Scum Removal
3. List four of the six criteria which influence the operation of a gravity thickener. The list includes:
   a. Type of sludge
   b. Age of sludge
   c. Sludge blanket depth
   d. Solids and hydraulic detention time
   e. Solids and hydraulic loading
   f. Temperature of sludge
4. Define Gasification
5. List the gases produced by the biological decomposition of sludge.
6. Recall that secondary sludges are difficult to thicken by gravity due to a large amount of bound water.
7. Define nitrification.
8. Define denitrification.
9. Explain why nitrification - denitrification is an important consideration in thickening secondary sludge.
10. Explain why filamentous bacteria in secondary sludge causes thickening problems.
11. Recall that an increase in temperature causes an increase in biological activity.
12. Recall that gravity thickener operation varies between summer and winter due to the effect of temperature on gasification.
13. Recall two of three types of control for operating a thickener. The list includes:
    a. Control solids retention time
    b. Control speed of collector
    c. Control sludge blanket depth
14. Define and calculate hydraulic loading.
15. Recall typical hydraulic loading on a gravity thickener is 400 - 800 gpd/sq. ft.

16. Define and calculate solids loading as lbs. solids/day/ft^2.

17. List three of the four factors which affect sludge detention time. These include:

    a. Solids applied
    b. Depth of blanket
    c. Solids concentration in blanket
    d. Solids removed

18. Define sludge volume ratio as:

    $$\frac{\text{Vol. of sludge blanket}}{\text{Vol. of sludge pumped/day}}$$

19. Recall typical SVR's for gravity thickeners is 0.5 - 2.0 days.

20. Recall that SVR should decrease during warm weather

21. Recall points where flow should be monitored in the operation of a thickener. These include:

    a. Influent
    b. Effluent
    c. Concentrated sludge stream

22. Describe the surface of a properly functioning thickener to be:

    a. Relatively clear
    b. Free of gas bubbles
    c. Free of solids
    d. Free of excessive scum accumulation

23. Recall that the sludge blanket depth should be below three feet.

24 State the criteria for setting the speed of the sludge collector. It should be:

    a. Fast enough to move settled solids to collection point.
    b. Slow enough to avoid disruptive turbulence which causes solids to float.

25. Recall that the proper rate of sludge withdrawal is

    a. One which maintains proper blanket level.

26. Define and calculate "concentration factor" as:

    $$\frac{\text{Thickened Sludge Concentration}}{\text{Influent Sludge Concentration}}$$

27. Recall that primary sludge should have a concentration factor greater than 2.0, secondary sludge greater than 3.0.

28. The student will be able to recall expected performance of a gravitational thickener in concentrating sludges as follows:

a.	Primary sludge	8 - 10%
b.	Trickling Filter sludge	7 - 9%
c.	Waste activated sludge	2 - 3%
d.	Digested primary	12%
e.	Primary and waste activated	4%
f.	Primary and $FeCL_3$	4%
g.	Primary and lime	7 - 12%

GRAVITY THICKENING

GLOSSARY

Aerobic - A condition in which "free" or dissolved oxygen is present in the aquatic environment.

Anaerobic - A condition in which "free" or dissolved oxygen is not present in the aquatic environment.

Clarifier - Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time, during which the heavier solids settle to the bottom and the lighter material will float to the water surface.

Denitrification - The reduction of nitrates to nitrites and nitogen gas.

Gasification - The transformation of wastewater solids into gas during decomposition.

Gravity - The gravitational attraction of the earth's mass for bodies at or near its surface.

Nitrification - The biochemical conversion of unoxidized nitrogenous matter (ammonia and organic nitrogen) to oxidized nitrogen (usually nitrate). The second-stage BOD is sometimes referred to as the nitrification stage (first-stage BOD is called the carbonaceous stage - carbon compounds oxidized to CO_2).

Supernatant Liquor - (1) The liquor overlying deposited solids. (2) The liquid in a sludge-digestion tank which lies between the sludge at the bottom and the floating scum at the top.

Weir - A vertical obstruction, such as a wall, or plate, placed in in open channel and calibrated in order that a depth of flow over the weir can easily be converted to a flow rate.

GRAVITY THICKENING

This module discusses Gravity Thickening. It will present a description of the process, the components typically found on a thickener, information on process control, safety and other basic items necessary for a sound understanding of the process.

This module was written by Mr. Paul Klopping. Instructional Development was done by Priscilla Hardin and Envirotech Operating Services provided technical review.

FUNCTION

*Separate solids from water

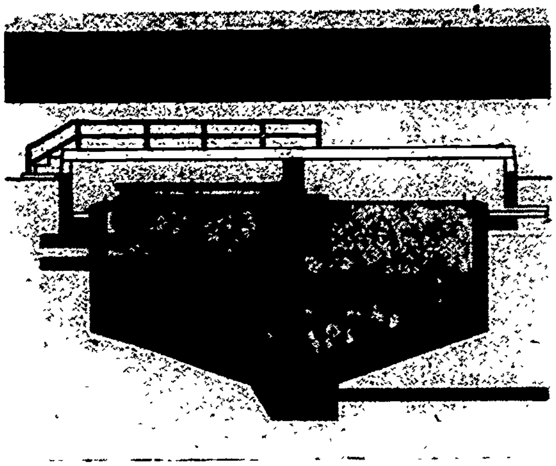
Gravity thickening of wastewater sludges uses the force of gravity to separate solids from water. Those solids that are heavier than water settle by gravity and are then compacted by the weight of overlying solids. Gravity thickeners are usually circular, resembling clarifiers.

COMPONENTS

The main components of gravity thickeners include:

(a) an inlet and distribution baffle assembly
(b) a sludge rake to move settled solids to a sump for removal
(c) vertical pickets attached to the rake mechanism
(d) a scum removal mechanism
(e) overflow weir and outlet piping

The inlet and distribution assembly is a circular baffle, extending from slightly above the water surface downward 2-3 feet. Sludge enters the center baffled area of the



thickener, flows downward under the baffle and accumulates in the bottom of the thickener, forming a sludge blanket. A sludge blanket is the accumulated mass of solids that forms when individual particles settle and appear as a discernible layer separate from the water in which they are contained.

The sludge rake gently stirs the sludge blanket. This moves concentrated sludge to the center of the tank where it is dropped into a sump. The sloping bottom of the thickener also helps move heavy solids to the center of the tank for removal. In addition to moving the sludge to the center sump, the gentle stirring of the blanket releases trapped gas bubbles and water, further enhancing concentration of the solids. If trapped gas is not released from the blanket, solids become bouyed up and float to the surface.

While the sludge collection mechanism rotates at the bottom of the thickener, a scum removal mechanism moves across the surface, collecting and depositing floating debris in a scum pit. The scum pit must be emptied on a regular basis.

Effluent from the thickener overflows a weir on the outside of the tank. Scum is prevented from overflowing the effluent weir by a baffle.

PERFORMANCE

FACTORS AFFECTING
*Sludge Characteristics
*Operational Controls

There are several criteria influencing the performance of a gravity thickener. Thickeners are influenced by sludge characteristics and operational controls. Important sludge characteristics are:

SLUDGE CHARACTERISTICS

(a) type of sludge
(b) age of the feed sludge
(c) sludge temperature

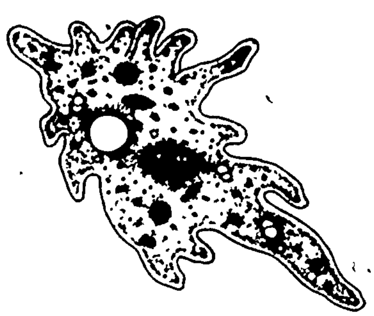
PRIMARY SLUDGE
*Good compaction

Both the type and age of sludge to be thickened can have a pronounced effect on a thickener's overall performance. Fresh primary sludge has the potential of compacting to the highest concentrations of any sludge. If the primary sludge is septic or allowed to go anaerobic, gasification may occur, releasing hydrogen sulfide, methane and carbon dioxide gases. These gases attach to the solids in the blanket and carry them to the surface. Gasification significantly reduces the efficiency of the thickener.

GASIFICATION
*Floating sludge

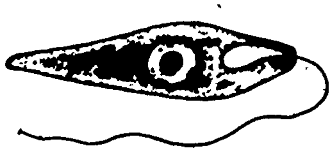
SECONDARY SLUDGE
*Biological

Secondary sludges are biological solids and are not well-suited for gravity thickening because of large quantities of bound water.



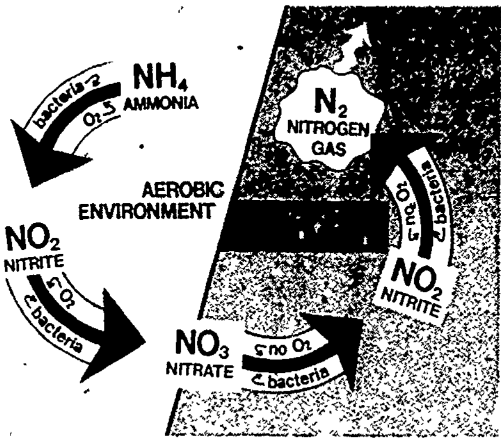
These solids are composed of 85-90% water within the cell mass. This water may either be bound as a thin layer to the cells or actually contained within the cells as intracellular water.

Besides having large quantities of bound water, biological solids are also oftentimes smaller or finer in size than primary sludge solids. This difference in size makes them more difficult to settle than primary solids.



The age of feed sludge is also important when gravity thickening secondary, or biological sludge because of nitrification. In the activated sludge and trickling filter processes, ammonia may be converted to nitrite and nitrate in the presence of oxygen. This oxidation of ammonia to nitrite and

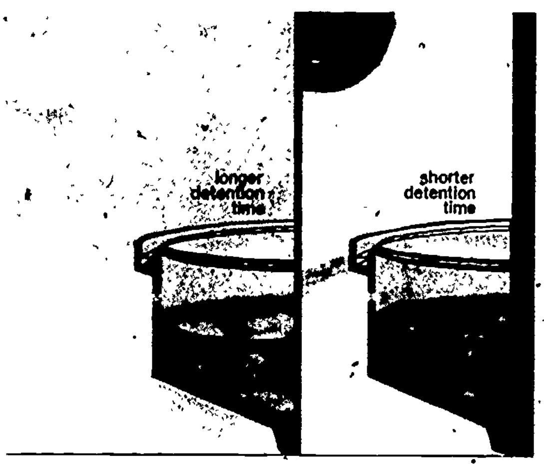
then to nitrate is called nitrification. It requires the presence of oxygen, a relatively long aeration time or sludge age which encourages the buildup of nitrifying bacteria, the organisms responsible for making the conversion of ammonia.



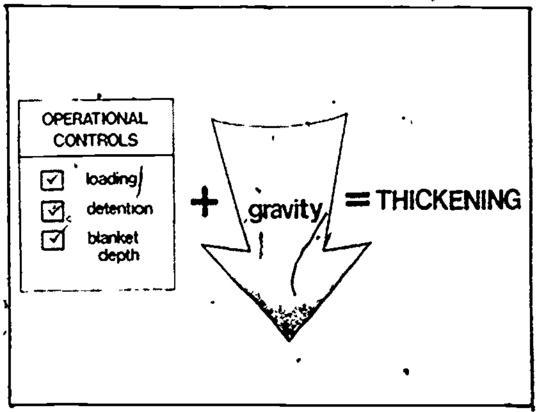
Secondary sludges which have been nitrified under aerobic conditions may undergo further biological activity when fresh oxygen is no longer present, as would be the case in a sludge blanket. In this case, under anaerobic conditions, nitrite and nitrate are converted to nitrogen gas. This process of denitrification produces gas which attaches to the sludge particles, causing them to float to the surface. Any floating sludge problem adversely affects the efficiency of a gravity thickener. When nitrified secondary sludges are to be gravity thickened, a close watch must be kept on the sludge detention time in the thickener so that sludge is thickened and pumped out before it has a chance to denitrify and float to the surface.

BULKING
*Filamentous bacteria
*Inhibits thickening

Secondary sludge may also have poor settling properties due to the presence of filamentous bacteria. Filaments extending from the floc prevent sludge from compacting well.



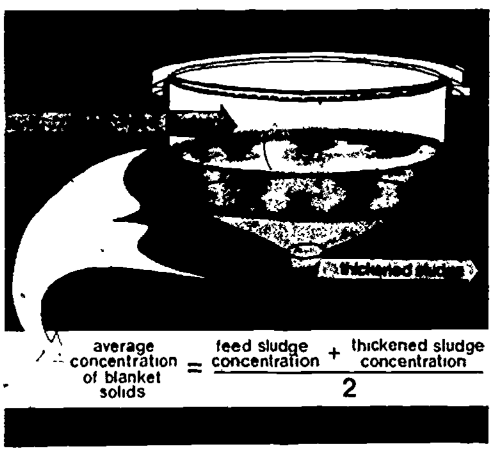
Temperature of the feed sludge will also affect the operation of a gravity thickener. As the temperature increases, the rate of biological activity increases, and the sludge tends to gasify and rise at a faster rate. To shorten detention time during warm weather, sludge should be pumped from the thickener at a faster rate than during winter months.



In response to the variations in sludge characteristics, operation of the gravity thickener calls for specific operational controls:

(a) sludge blanket depth, which is influenced by the speed of the collection mechanism and the sludge withdrawal rate
(b) solids and hydraulic detention time
(c) hydraulic and solids loading

SLUDGE BLANKET DEPTH



The sludge blanket depth is maintained by removing solids from the blanket in the bottom of the thickener at the same rate as they are added at the top. In order to maintain a blanket, it is first necessary to measure the volume of the sludge blanket. This figure will be a fraction of the total thickener volume. Second, approximate the average concentration of solids in the blanket. This is done by measuring both the feed sludge and thickened sludge concentrations, and taking an average of the two. This concentration is the average of all solids in the blanket. Knowing the volume and concentration of the blanket, total pounds in the blanket can be calculated. Knowing the volume and concentration of the feed sludge, and volume and concentration of thickened sludge allows the operator to know what's coming in and what's going out. When these two amounts are equal, a solids balance will be maintained, resulting in a stable blanket level.

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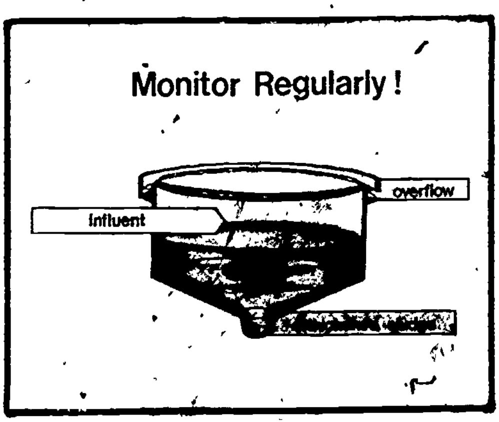
SLUDGE DETENTION TIME

Sludge detention time is the time the solids remain in the gravity thickener and is based on the solids applied, the depth and concentration of the sludge blanket and the solids removed from the bottom of the thickener. The operator has the ability to control the solids detention time and degree of thickening to some extent by controlling the depth of the sludge blanket.

SLUDGE VOLUME RATIO

Sludge Volume Ratio (SVR) provides a means of regulating the detention time of sludge within the blanket of the thickener. SVR is defined as the volume of the sludge blanket divided by the daily volume of sludge pumped from the thickener. This term is a relative measure of the average detention time of solids in the thickener and is calculated in days. Typical SVR values are between ½ and 2 days.



During operation of a gravity thickener, several points should be monitored at least once per shift. These points are:

(a) Influent

(b) Thickener Overflow

(c) Thickened Sludge Stream

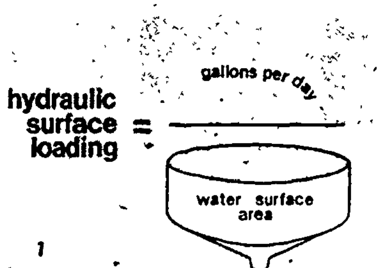
Normally, the surface should be relatively clear and free of solids and gas bubbles. The sludge blanket should be kept below 3 feet. The speed of the collection mechanism should be such that sludge is continuously moved to the center sump without creating turbulence which impedes settling. Sludge should be pumped from the thickener at a rate that will maintain a relatively constant blanket level.

BLANKET LEVEL

*Too high

*Too low

If the blanket is maintained at too high a level and the solids detention time is too long, gasification may cause floating sludge and poor effluent quality. If the blanket is too low, too much water will be pumped out of the thickener with the thickened sludge. Most probably, if a thin blanket exists, sludge has not been held in the thickener long enough to reach ultimate compaction, and a higher volume of dilute sludge will have to be handled than if more thickening had occurred before removal. Trial and error is often the best means of finding optimum conditions for a particular facility.



The hydraulic surface loading or overflow rate is expressed as:

Gallons applied per square foot of thickener surface area per day

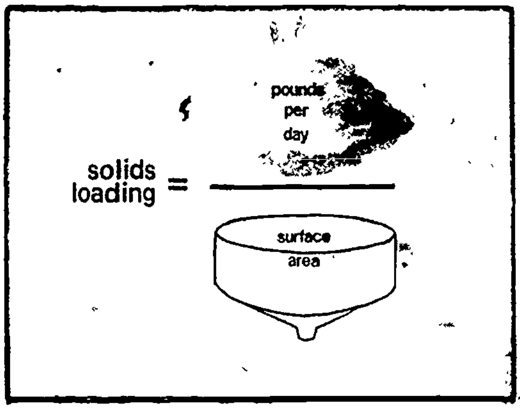
(GPD/sq ft/day)

In figuring out the hydraulic surface loading, one must find the gallons applied per day to the thickener and then divide that mount by the water surface area in square feet.

The thickener usually operates best if a relatively high flow of fresh liquid is applied. To accomplish this, secondary effluent may be blended with the sludge feed.

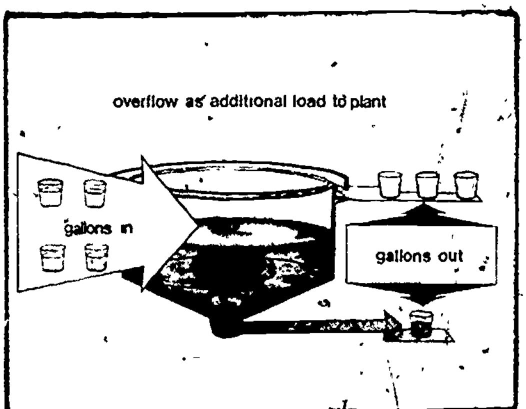
The solids loading is defined as the total number of pounds of solids applied per square foot of thickener surface area per day.

(lbs/sq ft/day)



The amount of loading that a thickener will handle is dependent on the type of sludge to be thickened. For instance, a thickener can handle more primary sludge per square foot than secondary sludge, because primary sludge settles and compacts at a faster rate.

REMOVAL EFFICIENCY

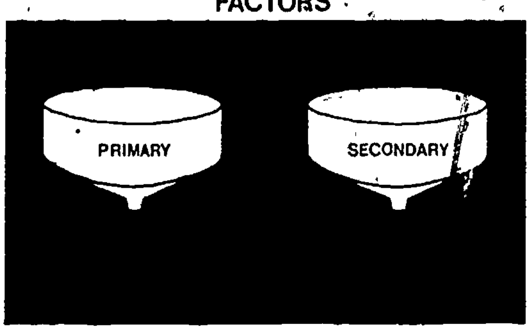


The operation of a thickener may be expressed in terms of efficiency of removal. Efficiency is calculated as:

$$\frac{\text{IN} - \text{OUT}}{\text{IN}} \times 100\% = \%\ \text{Efficiency}$$

In the case of gravity thickeners, the efficiency of removal of sludge solids is the key indicator of proper performance. Since the overflow from a thickener is returned to the headworks of the plant, any solids which are not captured by the thickener are recirculated where they exert an additional load beyond that applied by fresh wastewater entering the plant. Efficiency of removal should be calculated on a regular basis so that close track can be kept on the thickener and its impact on the rest of the plant.

EXPECTED CONCENTRATION FACTORS



The primary goal of operation is concentrating sludge thereby reducing the volume of solids to be handled. A concentration factor can be used to determine the effectiveness of the thickener in concentrating the sludge.

The concentration factor is calculated as follows:

$$\text{CF} = \frac{\text{Thickened Sludge Conc }\%}{\text{Feed Sludge Conc }\%}$$

For primary sludge, concentration factors (CF) of 2.0 or higher should be achieved. In handling secondary sludges, concentration factors of 3.0 or greater should be achieved.

A gravity thickener is a common means of increasing the concentration of sludge prior to other sludge handling. As sludge is concentrated, less volume needs to be handled for an equivalent weight of dry solids. This improves the efficiency of most sludge treatment and disposal processes.

The process relies on the fact that most wastewater solids are slightly heavier than water, and will settle by the force of gravity under the right conditions.

GRAVITY THICKENING
*volume reduction
*efficient
*economical

Careful adjustment of operational controls enables the force of gravity to produce efficient, economical thickening.

References

EPA Course #166, Sludge Characteristics, Sludge Conditioning, Planning Considerations, Lab Procedures.

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GRAVITY THICKENING - WORKSHEET

1. Which components are found on a gravity thickener?

____ a. Inlet and distribution assembly

____ b. Spark arrestor

____ c. Rake or collector mechanism

____ d. Aerator

____ e. Pickets

____ f. Bar screen

____ g. Scum removal

2. Circle three criteria which influence the operation of a gravity thickener.

____ a. Hydraulic loading

____ b. Solids loading

____ c. Rate of removal of sludge

____ d. Temperature

____ e. Type of sludge

3. Which of the following gases are produced when sludge decomposes in a gravity thickener?

____ a. Sulfur dioxide (SO_2)

____ b. Carbon dioxide (CO_2)

____ c. Hydrogen sulfide (H_2S)

____ d. Nitrous oxide (N_2O)

____ e. Methane (CH_4)

4. The conversion of ammonia nitrogen to nitrate nitrogen is called:

____ a. Aeration

____ b. Nitrogen fixing

____ c. Nitrification

____ d. Denitrification

____ e. Fermentation

5. The conversion of nitrate nitrogen to nitrogen gas is called:

____ a. Respiration

____ b. Clarification

____ c. Sedimentation

____ d. Denitrification

____ e. Nitrification

6. Which of the following conditions have a biological cause?

_____ a. Floating sludge on the surface due to denitrification.

_____ b. Floating sludge on the surface due to septic decomposition and the production of H_2S and CO_2.

_____ c. Poor settling due to excessively filamentous secondary sludge.

_____ d. Gasification

_____ e. Loss of solids due to short circuiting and turbulence.

7. Which of the following would not be used in controlling a gravity thickener?

_____ a. Estimation of rainfall

_____ b. Aeration detention time

_____ c. Solids retention time

_____ d. Collector speed

_____ e. Sludge blanket depth

8. A gravity thickener is 30 feet in diameter and operates at 300 gallons per minute. Calculate the overflow rate (hydraulic loading) in gallons per day per square foot.

Area = πr^2 gallons per day = gallons per minute x 1440 min/day

Choose the closest answer:

_____ a. 200 gpd/sq ft.

_____ b. 400 gpd/sq ft.

_____ c. 600 gpd/sq ft.

_____ d. 800 gpd/sq ft.

_____ e. 1000 gpd/sq ft.

9. 100 gpm of sludge at a concentration of 10,000 mg/l is fed to a 30 foot diameter gravity thickener. Calculate the solids loading in lbs/day/sq ft.

lbs = flow (MGD) x conc. (mg/l) x (8.34 lb/gal)

$$MGD = \frac{GPM \times 1440}{1,000,000}$$

Choose the closest answer:

_____ a. 10 lb/day/sq ft.

_____ b. 13

_____ c. 17

_____ d. 20

_____ e. 23

10. Circle three factors which affect sludge detention time.

_____ a. Amount of solids applied

_____ b. Amount of solids removed

_____ c. Temperature of sludge

_____ d. Amount of solids in sludge blanket

_____ e. Weir overflow rate

11. The sludge blanket in a 55,000 gallon gravity thickener occupies a volume of 16,000 gallons. Sludge is pumped from the blanket at a rate of 420 gallons per hour. What is the sludge volume ratio?

$$SVR = \frac{\text{blanket volume}}{\text{volume pumped/day}}$$

_____ a. 1.0 days

_____ b. 1.6 days

_____ c. 2.8 days

_____ d. 5.5 days

_____ e. 3.2 days

12. A typical sludge volume ratio for gravity thickeners is:

_____ a. 0.5 - 2.0 days

_____ b. 2.5 - 4.0 days

_____ c. 4.0 - 6.0 days

_____ d. 6.0 - 8.0 days

_____ e. greater than 8 days

13. When the weather gets warmer, how should the SVR be controlled?

_____ a. Increase.

_____ b. Decrease.

_____ c. keep it the same.

14. Choose three places where samples should be collected in monitoring the operation of a gravity thickener.

_____ a. Influent to thickener

_____ b. Influent to grit chamber

_____ c. Influent to plant headworks

_____ d. Effluent from thickener.

_____ e. Concentrated sludge stream from bottom of thickener.

15. In a gravity thickener, the sludge blanket should be kept below the surface by at least:

_____ a. 1 inch

_____ b. 1 foot

_____ c. 3 feet

_____ d. 6 feet

_____ e. It doesn't matter.

16. A thickener is fed with raw sludge at 2% concentration. Thickened sludge is removed at 5% concentration. What is the concentration factor?

$$CF = \frac{\text{Thickened Conc.}}{\text{Feed Conc.}}$$

_____ a. 1.0

_____ b. 2.0

_____ c. 2.5

_____ d. 0.4

_____ e. 3.0

17. Primary sludge should have a concentration factor greater than _______.

_____ a. 1.0

_____ b. 2.0

_____ c. 3.0

_____ d. 4.0

_____ e. 5.0

18. Secondary sludge should have a concentration factor greater than _____.

_____ a. 1.0

_____ b. 2.0

_____ c. 3.0

_____ d. 4.0

_____ e. 5.0