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ABSTRACT

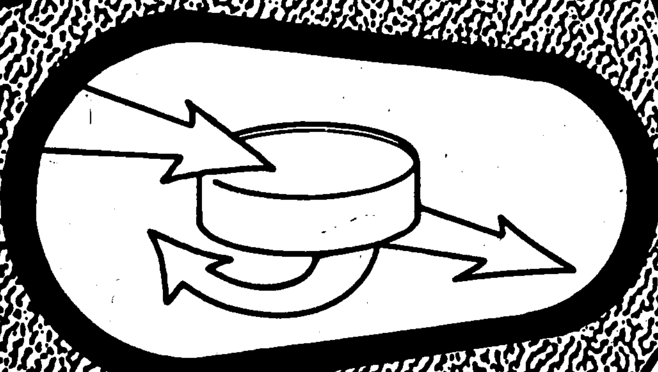
This module describes the process used to determine solids mass and location throughout a waste water treatment plant, explains how these values are used to determine the solids mass balance around single treatment units and the entire system, and presents calculations of solids in pounds and sludge units. The instructor's manual contains a statement of instructional goals, lists of instructor/student activities and instructional materials, narrative of the slide/tape program used with the module, overhead transparency masters, and student worksheet (with answers). The student workbook contains objectives, prerequisite skills needed before the module is started, laboratory procedures and worksheet. (Author/JN)

Operational Control Tests

for Wastewater Treatment Facilities

Mass Balance

Instructor's Manual



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MASS BALANCE

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MASS BALANCE

CONTENTS

INSTRUCTIONAL GOALS

Upon completion of this lesson the student should be able to calculate the amount of solids in a basin or a flow in pounds and sludge units. The student should be able to identify sources and locations of solids throughout a plant and begin to develop an understanding of balancing the flow of solids around treatment systems as well as individual units.

INSTRUCTOR'S ACTIVITIES

For best results follow this sequence:

	Activity	Time
1.	Review objectives with students.	5 minutes
2.	Have students read Mass Balance procedure.	10 minutes
3.	View slide/tape program.	18 minutes
4.	Work through example problems on chalk board with students.	15 minutes
5.	Assign practice problem.	20 minutes
6.	Review practice problem.	15 minutes
7.	Assign worksheet.	10 minutes
8.	Correct worksheet.	5 minutes

OTHER ACTIVITIES

Time may not allow assignment of practice problem. If more time is available discuss use of mass balance calculation to analyze sludge distribution around single units and complete system. Also discuss the use of sludge units (SU) as an alternative method. Use chalk board or overhead projector to explain calculations.

Appendix A contains an overhead which displays the plant data used as the example in the slide/tape presentation.

Appendix B contains an overhead with plant data to be used as an assigned problem if time permits.

Appendix C contains overheads which can be used to explain the basic formulas used in mass balance calculations.

STUDENT ACTIVITIES

1. Read objectives.
2. Read procedure.
3. View slide/tape program
4. Read through example problem
5. Do practice problem.
6. Complete worksheet

INSTRUCTIONAL MATERIALS LIST

1. Instructor's Guide for Mass Balance
2. Student Workbook for Mass Balance
3. 35 mm projector
4. Cassette recorder with automatic synchronization
5. Overhead projector
6. Blank, clear acetate and felt pens
7. Projector screen
8. Chalkboard and chalk

MASS BALANCE

NARRATIVE

Slide #

1. This lesson deals with the concept of solids mass balance in a wastewater treatment plant, how the calculations are done, and how mass balance is applied to plant operations.

2. The lesson was written by Dr. John W. Carnegie who was also the project director. The instructional design and art work was done by Priscilla Hardin.

3. Control of a wastewater treatment plant can be viewed, basically, as the control of solids. The distribution, quantity, and quality of solids in the various treatment plant units must all be considered.

4. Solids are found throughout the plant. Solids enter the treatment plant in the raw influent.

5. Some solids are removed in pretreatment and primary clarification.

6. Some, hopefully only a small amount, may leave the plant in the final effluent.

7. Solids are removed from the plant as secondary sludge. Sludge is treated and disposed of in a solids handling program.

8. And during normal operation solids are continually being recycled and moved from one place to another within the plant.

9. Keeping track of solids (that is, how much and where) is an important operational concern. The accounting of solids is referred to as solids mass balance.

10. The concept of mass balance is used to describe the amount and location of solids around an individual treatment unit or throughout an entire system.

11. The movement of solids through a treatment unit is like the movement of money through a bank. The cash flow shows money entering the bank, leaving the bank, and money in the bank. Similarily, solids enter the treatment unit, solids leave the unit, and solids are in the unit.

12. And as with a business, a knowledge of the amount and location of inventory is critical to successful operation.

13. The basic concern then, is, "Do the solids entering the system balance with solids leaving the system?"

14. To keep track of the solids inventory and to establish the mass balance in a plant you need the following data: flows, concentrations, volumes, and depth of the sludge blanket in the clarifiers.

15. Let's look at each of these data separately. You must have flow data for every place where solids are being moved. For example, if you are determining mass balance around a clarifier you need influent, effluent and sludge withdrawal flows.

16. You will need solids concentration for every place where solids are being moved and for every unit containing a quanity of solids. For example, in the clarifier you would need to know solids concentration in the influent, in the effluent, and the concentration of sludge being withdrawn, as well as the average concentration of sludge in the clarifier sludge blanket.

17. You must also know the volume of the various process units such as the clarifier or aeration basin.

18. And finally, you must know the average depth of the sludge blanket in the clarifier.

19. Now we can look at how each of these items would be determined. The easiest way to observe flow is with a flow meter of some type. In line devices such as Venturis or turbins connected to recorders or digital read out devices that indicate instantaneous flow are acceptable.

20. Flow can also be measured using weirs and flumes. This is frequently done on final effluent in small plants. If no other means is available, determining the amount of time required to fill a bucket can be used to estimate flow.

21. Flow may be recorded in a number of ways. Regardless of how flow is recorded, for most calculations, the units of flow must be converted to million gallons per day or MGD.

22. Solids concentration can be determined by gravimetric means using an analytical balance or by centrifugation.

23. Although it takes more time, the gravimetric procedure gives the most accurate results. The lab procedure used is called the suspended solids test. The results are given as mg/l.

24. The centrifuge test can also be used to determine solids concentration. Results from this test are expressed as percent solids.

25. The centrifuge test is much quicker and easier to run. However, it is not as accurate as the suspended solids test since sludges of different quality compact differently in the centrifuge. In most cases,

the use of the centrifuge is quite acceptable for solids concentration determinations. Solids concentration in percent is converted to sludge units for use in mass balance calculations. These procedures are described in the student materials.

26. This lesson will describe the mass balance calculations using the suspended solids method of determining concentration.

27. The volume of process units can be determined by referring to construction plans and specifications or by measurement. Volumes must be expressed as millions of gallons for most calculations.

28. The sludge blanket is determined by electric blanket finders or sight glasses.

29. The depth of blanket, or DOB, is the distance from the clarifier surface to the top of the sludge blanket. The average blanket thickness is the average depth of the clarifier minus the depth of the blanket.

30. The sludge blanket occupies a fraction of the clarifier volume proportional to the blanket thickness. So, calculate the blanket volume by multiplying the total clarifier volume by the fractional portion occupied by the blanket.

31. These basic pieces of data are then used to calculate the pounds of solids moving into or out of the clarifier as well as the pounds of solids in the clarifier blanket.

32. The same data is used to calculate pounds of solids moving into and out of an aeration basin and the pounds of solids in the aeration basin.

33. In any case, the formula for pounds of solids per day moving into or out of a unit is flow in MGD X concentration in mg/l X 8.34. The factor 8.34 is used to convert gallons to pounds.

34. The formula for pounds of solids in the unit is the same except substitute volume for flow. So the formula is volume in MG X concentration in mg/l X 8.34.

35. Now let's use the formulas to determine the mass balance around a typical clarifier. First, determine and record the basic data. We need flows. Here we have an influent flow of 6.1 MGD, effluent flow of 4.6 MGD, and a sludge withdrawal flow of 1.52 MGD.

36. We also need solids concentration at these points. We have 3000 mg/l in the influent, 13 mg/l in the effluent, and a withdrawal concentration of 12,000 mg/l.

37. There are three pieces of data needed for the clarifier basin itself. The total clarifier volume (which is 0.71 MG in our example), the average clarifier depth (14 feet, in our case), and the depth of blanket (which is 12 feet).

38. So, put all together, this is the raw data needed to calculate mass balance around a clarifier.

39. First, calculate the concentration of solids in the clarifier. As we have seen, solids settle into a layer at the bottom. For secondary clarifiers we assume that the solids at the top of the blanket are the same as those in the influent, and the solids at the bottom of the blanket are the same as the solids in the withdrawal line.

40. The average solids concentration in the blanket is the average of these two values or 7,500 mg/l. For primary clarifiers we assume the solids concentration is equal to the primary sludge draw-off concentration.

41. Next, calculate the blanket thickness by subtracting the depth of blanket from the average clarifier depth. This gives a blanket thickness of 2 feet, in our case.

42. Blanket volume is determined by multiplying the clarifier volume by the fraction of the depth occupied by the blanket. The fraction occupied by the blanket thickness is 2 feet. The clarifier depth is 14 feet. The clarifier volume is 0.71 MG. So, the blanket volume is 2 feet over 14 feet multiplied by the 0.71 MG volume. This calculates out as 0.1 MG for blanket volume.

43. Put altogether, this is the basic data we need for mass balance calculations around the clarifier.

44. Now use the pounds per day formula to calculate the pounds per day of solids in the influent, effluent, and solids withdrawal. In our example, influent solids is 152,621 pounds per day. In the effluent it is 499 pounds per day. And in the withdrawal it is 152,122 pounds per day.

45. Similarly, calculate the pounds of solids in the clarifier. For our example we have 6,344 pounds of solids in the clarifier. Details of all of these calculation are in the student materials.

46. In summary, the solids around our clarifier look like this. To be in balance, the solids "in" should equal the solids "out".

47. In our case, 152,621 lbs/day is coming in, 152,122 lbs/day is being withdrawn, and 499 lbs/day is getting out in the effluent. The "in" just equals the "out". It's balanced! We are not losing or accumulating solids in our clarifier.

48. Solids mass balance is an important operational tool for activated sludge systems. Mass balance can be determined around any process unit or the entire system. As a second example we'll calculate mass balance around a small activated sludge plant.

49. In our small plant we will have an aeration basin, a secondary clarifier, and sludge return and waste lines. For simplicity we will assume there are no sidestreams entering the system.

50. As with the first example of the clarifier we need some basic data. We need to know the flows at all points. This diagram shows the flow entering and leaving each of the units.

51. Next, we need to know the volumes of the aeration basin and the clarifier.

52. And we need the solids concentration in each flow as well as the concentration in the aeration basin and the concentration of the sludge blanket in the clarifier.

53. Use these basic data and the standard pounds per day formula to calculate the amount in each area.

54. These pound values constitute the solids inventory in pounds from which a mass balance can be determined. The inventory list includes solids in the aeration basin.

55. The inventory also includes solids in the clarifier influent, clarifier effluent and in the clarifier basin itself.

56. And finally, solids in the sludge waste line and the sludge return line complete the inventory.

57. Analysis of the mass balance around and in this system is completed using the solids inventory list. By determining and studying mass balance an operator can maintain close control over the location and the quantity of solids in his system.

58. Used around a primary clarifier, mass balance can be used to express loadings and raw sludge quantities. It can express clarifier solids removal efficiency. If the mass balance changes considerably it may indicate mechanical problems such as plugged pumps or lines, or raker arm failures before they are visably evident.

59. Solids distribution problems around a secondary clarifier in an activated sludge system can be assessed. Such solids distribution problems may adversely affect sludge quality if they become severe.

60. Probably the most useful application is to monitor solids location and movement through secondary treatment and through the solids handling areas of the plant.

61. The determination of solids in motion is also important. Calculation of sludge detention time and cycles per day through an aeration tank is possible using mass balance calculations.

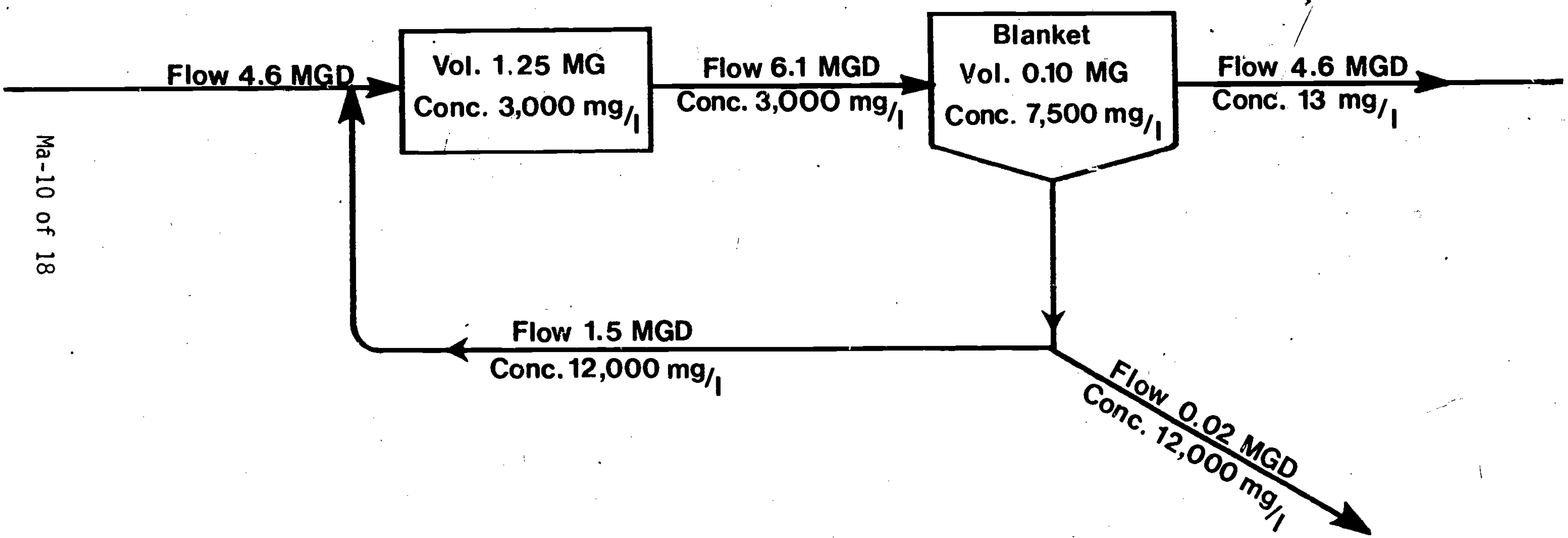
62. If chemicals are being fed into the system it is necessary to know the amount of solids that flow past a feed point, and how many times the solids pass that point in a day.

63. The smooth and successful operation of a treatment plant is dependent upon knowing where the solids are and how much there is. Using the concepts of mass balance the operator can account for solids and adjust operations to maintain proper solids inventory and distribution.

APPENDIX A

Plant Data for slide/tape example.

Overhead #1 is the same plant data used as the final example in the slide/tape program. This overhead can be used to review the calculations illustrated in the slide/tape program.


Flow 4.6 MGD
Vol. 1.25 MG
Conc. 3,000 mg/l
Flow 6.1 MGD
Conc. 3,000 mg/l
Blanket
Vol. 0.10 MG
Conc. 7,500 mg/l
Flow 4.6 MGD
Conc. 13 mg/l
Flow 1.5 MGD
Conc. 12,000 mg/l
Flow 0.02 MGD
Conc. 12,000 mg/l

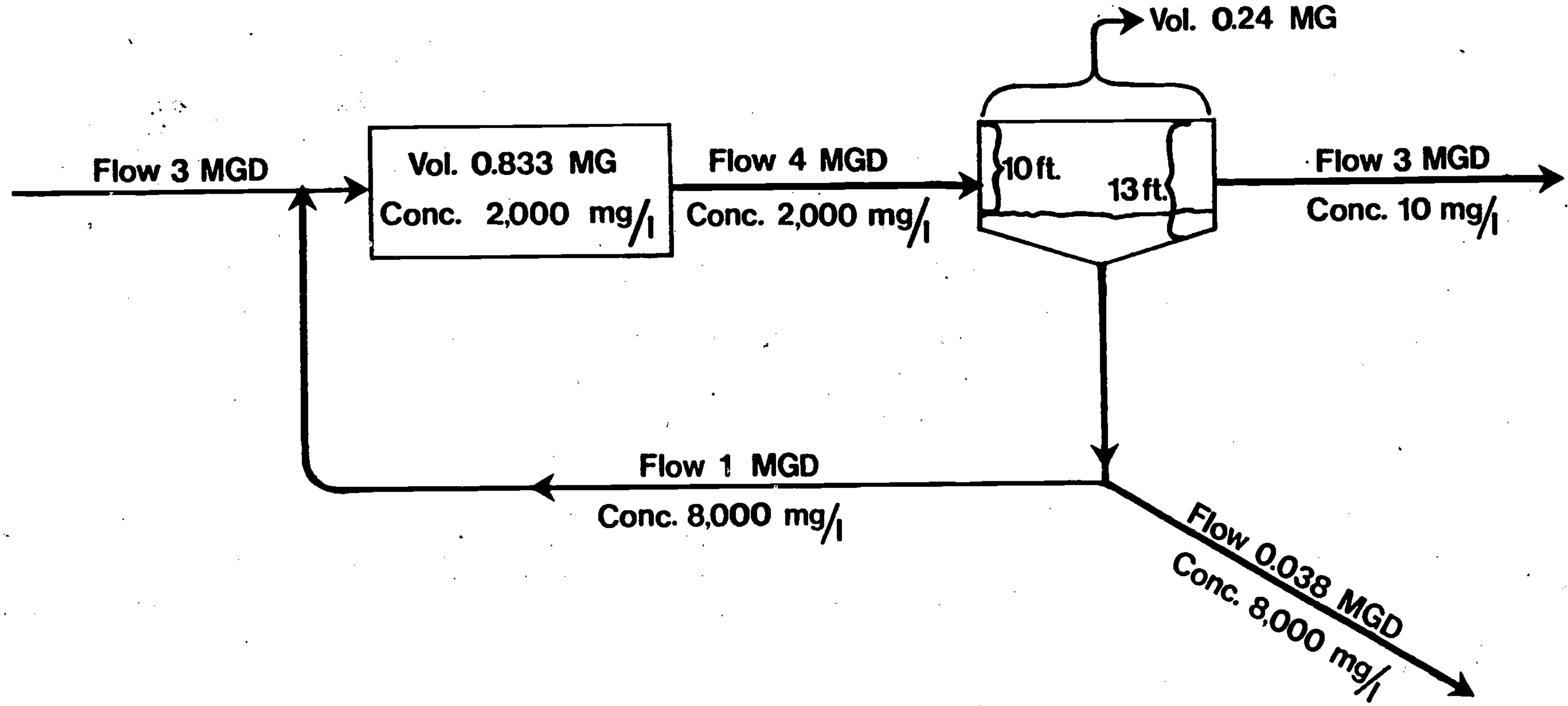
APPENDIX B

Additional Mass Balance Problem

Overhead #2 is a simple activated sludge plant with flow and suspended solids data given. Project this problem on the screen and ask the students to calculate solids around the system. Students should calculate the following items. The answers are given in parenthesis.

Pounds per day:

1.	in return sludge flow.	(66,720 lbs/day)
2.	in waste sludge flow.	(2,535 lbs/day)
3.	entering clarifier.	(66,720 lbs/day)
4.	in clarifier effluent.	(250 lbs/day)
5.	in clarifier withdrawal flow.	(69,255 lbs/day)
6.	under aeration.	(13,894 lbs/day)
7.	in clarifier blanket.	(2,310 lbs/day)


Flow 3 MGD
Vol. 0.833 MG
Conc. 2,000 mg/l
Flow 4 MGD
Conc. 2,000 mg/l
Vol. 0.24 MG
10 ft.
13 ft.
Flow 3 MGD
Conc. 10 mg/l
Flow 1 MGD
Conc. 8,000 mg/l
Flow 0.038 MGD
Conc. 8,000 mg/l

APPENDIX C

FORMULAS

Overhead 3

Use to explain calculation of clarifier blanket thickness.

Overhead 4

Use to explain calculation of clarifier blanket volume.

Overhead 5

Use to explain calculation of average sludge concentration in a clarifier.

Overhead 6

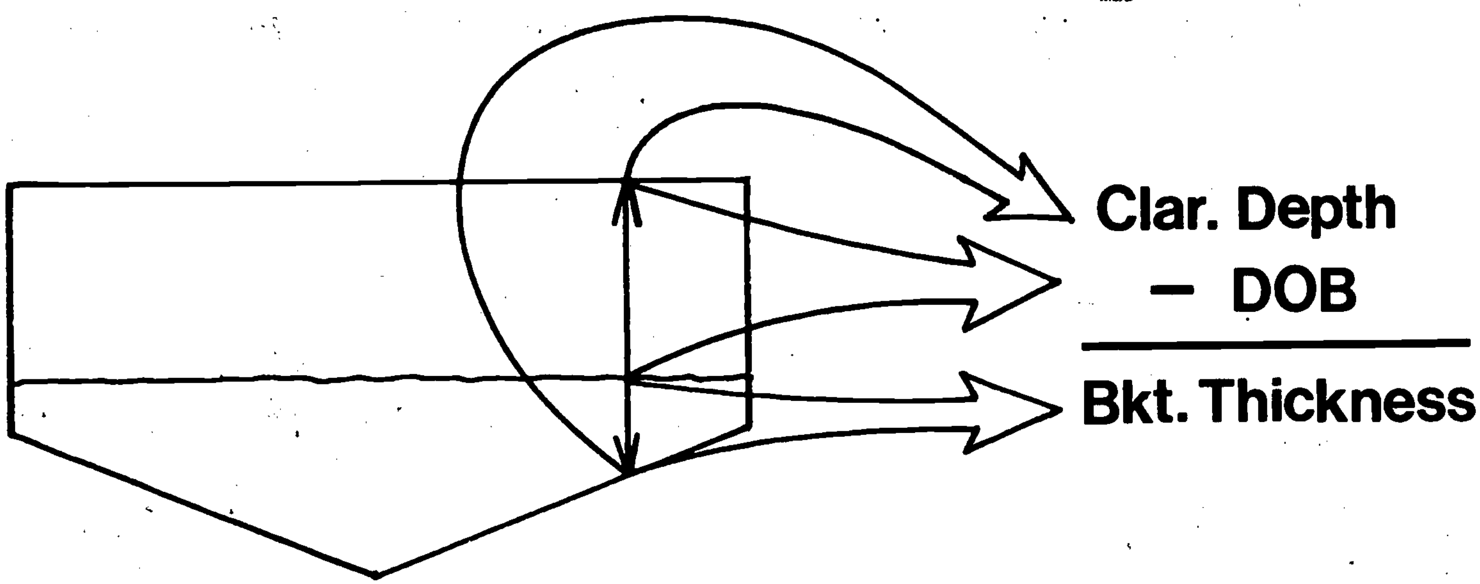
Use to explain calculation of lbs/day and SU/day.

Overhead 7

Use to explain calculation of lbs and SU.

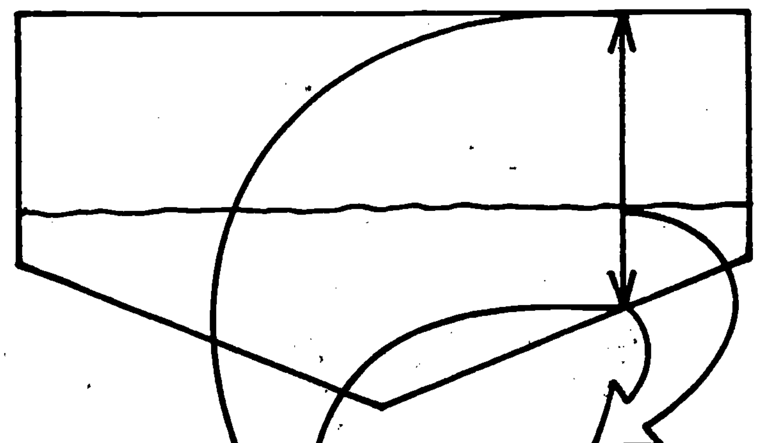
Clarifier Blanket Thickness

Bkt. Thick. = Clar. Depth − DOB



Clarifier Blanket Volume

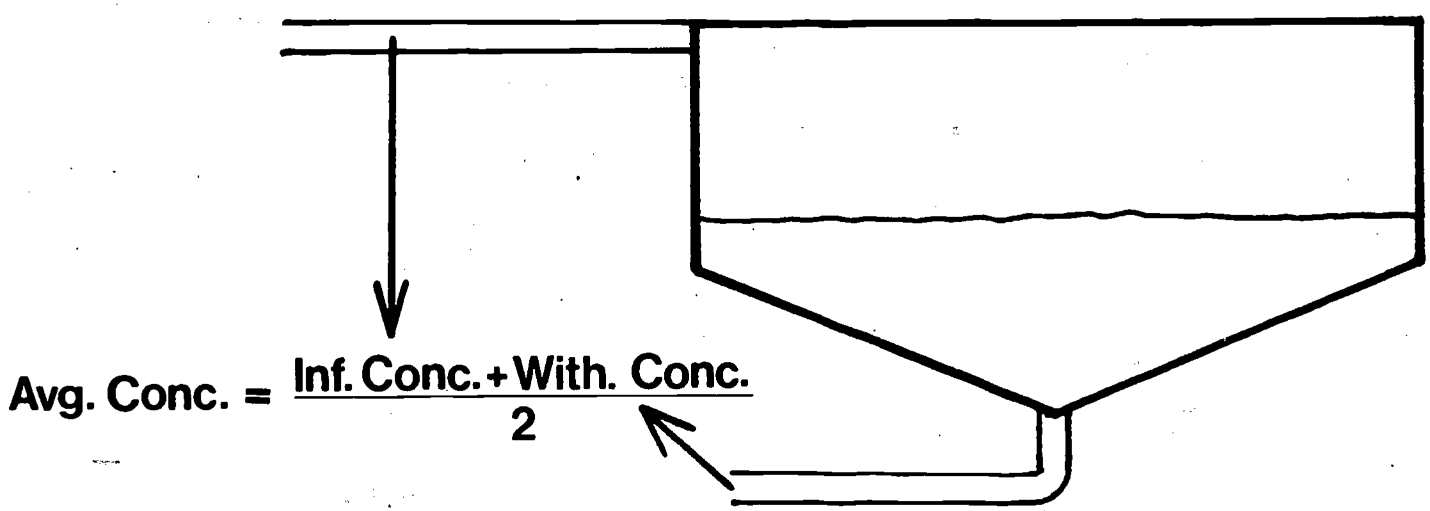
$$\text{Bkt. Vol.} = \frac{\text{Bkt. Thick.}}{\text{Clar. Depth}} \times \text{Clar. Vol.}$$



$$\text{Bkt. Volume} = \frac{\text{Bkt. Thick.}}{\text{Clar. Depth}} \times \text{Clar. Volume}$$

Average Concentration in Clarifier

$$\text{Avg. Conc.} = \frac{\text{Inf. Conc.} + \text{Withdrawal Conc.}}{2}$$



lbs/day = Conc, mg/l x Flow, MGD x 8.34

SU/day = Conc, % x Flow, MGD

$$lbs = Conc,\ mg/l \times Vol,\ MG \times 8.34$$

$$SU = Conc,\ \% \times Vol,\ MG$$

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MASS BALANCE

WORKSHEET

Directions: Place an "X" by the best answer. There is only one best answer for each question.

1. In a typical wastewater treatment plant solids will be found:

   a)______ in the aeration basin and clarifier.
   b)______ in the solids handling processes.
   c)______ in the sludge return line.
   d)______ in the plant effluent.
   e)__X___ All of the above.

2. The basic data needed to calculate solids concentration is:

   a)______ BOD and SS.
   b)______ flow and BOD.
   c)__X___ flow, volumes, SS, and DOB.
   d)______ DOB, flow, and total coliform.
   e)______ flow and SS.

3. Which formula is used to calculate lbs/day?

   a)__X___ lbs/day = conc., mg/l X flow, MGD X 8.34
   b)______ lbs/day = conc., % X flow, MG
   c)______ lbs/day = conc., % X flow, gpm X 8.34
   d)______ lbs/day = SS, mg/l X SVI
   e)______ lbs/day = conc., mg/l X flow, MGD X 1,000

4. Which formula is used to calculate pounds of solids in a basin or clarifier?

   a)______ lbs = % X Vol. gal
   b)__X___ lbs = conc., mg/l X Volume, MG X 8.34
   c)______ lbs = conc., % X Volume, MG
   d)______ lbs = SVI X Volume, MG
   e)______ lbs = conc., mg/l X Volume, MG X 7.48

5. Which statement best describes a sludge unit?

a)_______ 100 gallons of waste activated sludge.

b)_______ Enough activated sludge to occupy 1 cubic foot after drying.

c)___X___ 1 MG of 1% sludge.

d)_______ 1 MG of 10% sludge.

e)_______ 100 lbs of sludge.

6. Mark below the two analytical methods used to determine solids concentrations for use in mass balance calculations.

a)_______ Turbidimeter

b)_______ 30 minute sludge settleability

c)___X___ Suspended solids gravimetric procedure

d)_______ Volatile acids procedure

e)___X___ Centrifuge test

7. Calculate the lbs/day of solids in a flow of 2.5 MGD with a concentration of 3,500 mg/l.

a)_______ 8,750 lbs/day

b)_______ 87,500 lbs/day

c)_______ 7,297 lbs/day

d)___X___ 72,975 lbs/day

e)_______ 65,625 lbs/day

8. Determine the SU's in a 1/25 MG basin and a solids concentration by centrifuge test of 2.5%.

a)___X___ 3.125 SU

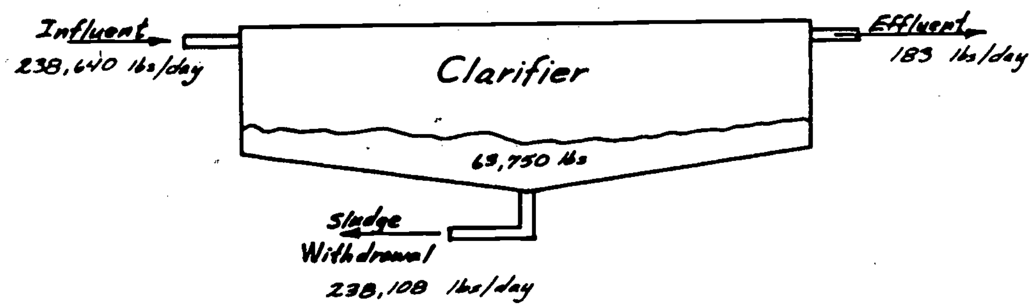
b)_______ 0.3 SU

c)_______ 26.06 SU

d)_______ 23.375 SU

e)_______ 1/25 SU

9. Consider the following clarifier with solids flows as indicated. Which statement best describes the situation?



a)______ All the solids entering the clarifier are leaving in the effluent.

b)___X___ Sludge is slowly accumulating in the clarifier.

c)______ The sludge blanket is slowly being depleted.

d)______ The system is balanced.

e)______ None of the above.

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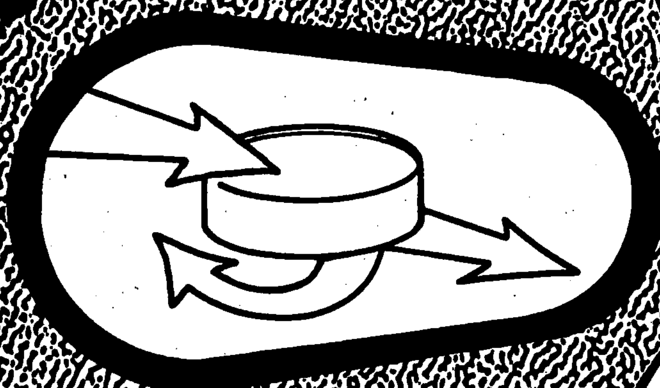
Operational Control Tests

for Wastewater Treatment Facilities



Mass Balance

Student Workbook

Linn-Benton Community College
Albany, Oregon

MASS BALANCE

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MASS BALANCE

CONTENTS

INTRODUCTION

This module describes the process used to determine solids mass and location throughout a treatment plant and explains how these values can be used to determine the solids mass balance around single treatment units and the entire system. Calculation of solids in pounds and sludge units will be presented.

OBJECTIVES

Upon completion of this module you should be able to:

1. List the places (flows and basins) where solids would be found in a typical treatment plant.
2. List the basic information needed to calculate solids concentration.
3. Recall the formulas used to calculate lbs/day of solids in a flow and lbs/day of solids in a basin.
4. Recall the formula used to calculate sludge units.
5. Calculate solids mass in pounds and sludge units.
6. Give two methods of determining solids concentration.
7. Perform mass balance calculations around a unit process such as an aeration basin or clarifier.

PREREQUISITE SKILLS

The following skills are required before attempting this procedure:

1. Calculate volumes of basins and clarifiers.
2. Convert any flow measurement to MGD.
3. Perform basic algebra calculations (multiply, divide, and cancel units in simple linear equations.)

REFERENCE LIST

1. Activated Sludge Operational Control Workshop Manual, Paul H. Klopping, Linn-Benton Community College, Albany, Oregon, 1980.

2. Procedures Used in Conducting Selected Activated Sludge Control Tests, Owen K. Boe, Linn-Benton Community College, Albany, Oregon, 1978.

3. Operational Control Procedures for the Activated Sludge Process, Part II, 758-495/1241 (1974), Control Tests, Part IIIa, Calculation Procedures, 758-495/1233 (1974), Alfred W. West, U. S. Government Printing Office.

MASS BALANCE

INTRODUCTION

Solids are present in basins and lines throughout a treatment plant. A knowledge of the amount and location of solids is very important to the successful operation of the plant (particularily, activated sludge systems). The pounds of solids in a basin or a line can be calculated if you know the solids concentration and the volume or flow rate. Alternatively, solids can be expressed as sludge units. Once the amount of solids has been determined analysis can indicate such things as sludge accumulating in the clarifier and improper flow splitting for sludge return lines.

This lesson discusses the calculation used in solids mass balance. Explanation of analytical methods can be found by referring to the listed references.

EQUIPMENT

All laboratory equipment needed to run Suspended Solids or Centrifuge test.

PROCEDURE

1. <u>COLLECT OR DETERMINE BASIC DATA</u>.

   You will need solids concentration for each basin or line, the volume of each basin or the flow in each line, and the depth of sludge blanket in the clarifier.

   Solids concentration is expressed as mg/l suspended solids. Sludge units will be discussed later.

2. <u>CONVERT ALL VOLUMES TO MG (MILLION GALLONS)</u>.

3. <u>CONVERT ALL FLOWS TO MGD (MILLION GALLONS PER DAY)</u>.

4. <u>CALCULATE POUNDS IN BASINS</u>.

   Use the following formula:

   POUNDS = Concentration, mg/l X Volume, MG X 8.34

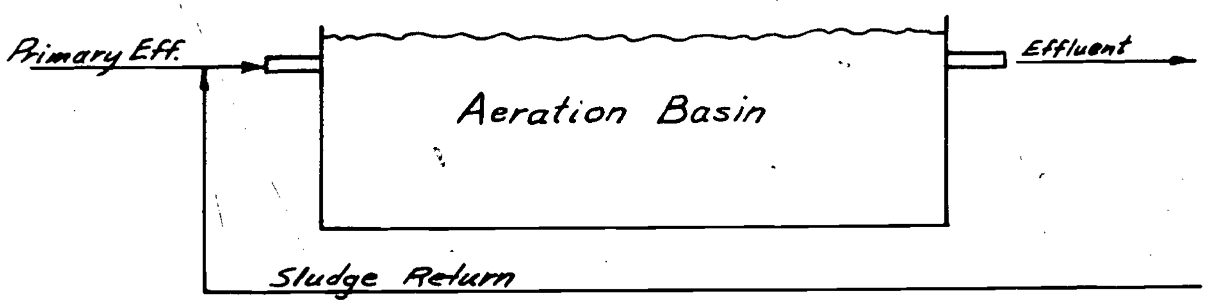
5. <u>CALCULATE POUNDS/DAY IN LINES</u>.

   Use the following formula:

   Pounds/Day = Concentration, mg/l X Flow, MGD X 8.34

6. TABULATE AND ANALYZE RESULTS.

For an aeration basin:

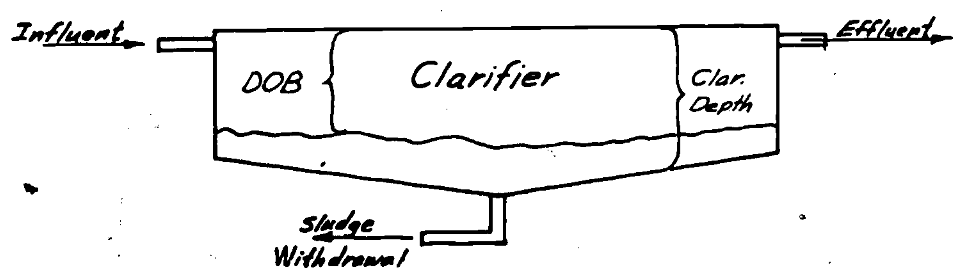


a. You should have data for influent line, effluent line, sludge return line, and the aeration basin itself.

b. How many pounds of solids are in the basin?

c. Does the pounds/day of solids entering equal the total of the pounds/day solids leaving the basin?

For a clarifier:



a. First, determine the average sludge concentration. Sludge occupies only the bottom of the clarifier. Assume the average concentration to be the average of the influent solids and the withdrawal solids.

$$\text{Average Concentration} = \frac{\text{Influent solids, mg/l} + \text{Withdrawal solids, mg/l}}{2}$$

b. Second, determine thickness of sludge blanket.

Blanket thickness = Average Clarifier Depth - Depth of Blanket

(Refer to lesson on Depth of Blanket for details.)

c. Third, determine volume of sludge in clarifier.

$$\text{Blanket Vol.} = \frac{\text{Blanket Thickness, ft}}{\text{Ave. Clar. Depth, ft}} \times \text{Clar. Vol., MG}$$

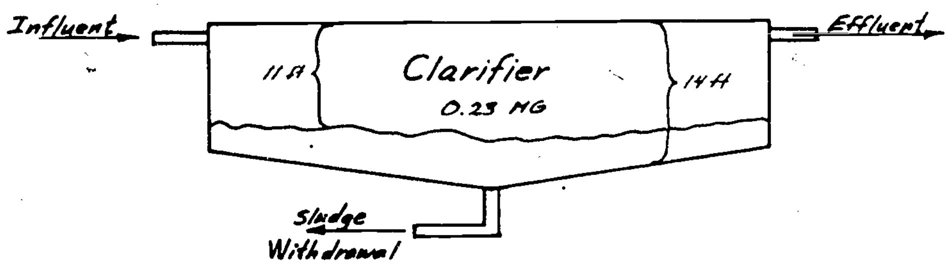
d. Calculate pounds. You should have data for influent line, effluent line, sludge withdrawal line, and the clarifier sludge blanket.

e. How many pounds are in the clarifier?

f. Does the pounds/day of solids entering equal the total pounds/day of solids leaving the clarifier?

EXAMPLE CALCULATIONS

To find volume of sludge in a clarifier:



Given: Average clarifier depth: 14 feet
Depth of blanket: 11 feet
Clarifier volume: 0.23 MG

Blanket thickness, feet = Average clarifier depth, ft - Depth of blanket, ft

= 14 ft - 11 ft

= 3 ft

$$\text{Blanket Volume, MG} = \frac{\text{Blanket thickness, ft}}{\text{Ave. Clar. Depth, ft}} \times \text{Clar. volume, MG}$$

$$= \frac{3 \text{ ft}}{14 \text{ ft}} \times 0.23 \text{ MG}$$

$$= 0.049 \text{ MG}$$

To find lbs of sludge in clarifier:

Given: Concentration in Clarifier Influent: 2,000 mg/l
Concentration in Sludge Withdrawal Line = 10,000 mg/l

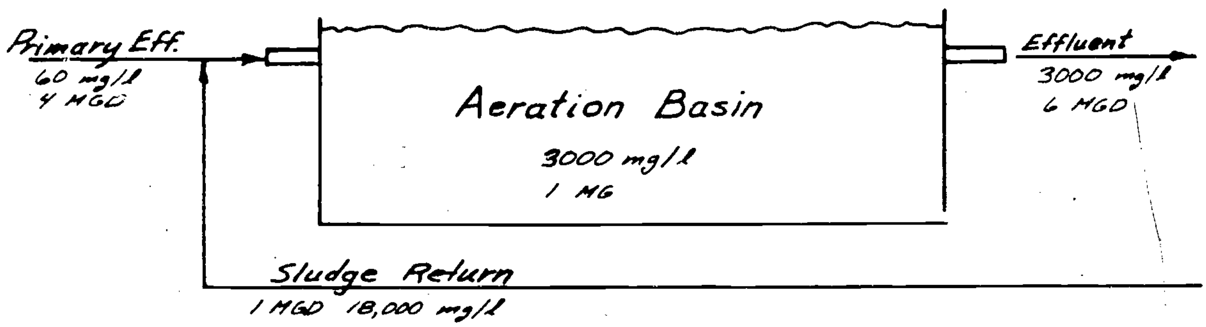
$$\text{Average Concentration, mg/l} = \frac{\text{Inf. Solids, mg/l} + \text{Withdrawal Solids, mg/l}}{2}$$

$$= \frac{2{,}000 \text{ mg/l} + 10{,}000 \text{ mg/l}}{2}$$

$$= 6{,}000 \text{ mg/l}$$

lbs = Concentration, mg/l X Volume, MG X 8.34
= 6,000 mg/l X 0.049 MG X 8.34
= 2,452 lbs

To find solids around aeration basin:



lbs under aeration = Concentration, mg/l X Vol., MG X 8.34
= 3,000 mg/l X 1 MG X 8.34
= 25,020 lbs

lbs/day, primary effluent = Concentration, mg/l X Flow, MGD X 8.34
= 60 mg/l X 4 MGD X 8.34
= 2,000 lbs/day

lbs/day, sludge return = 18,000 X 1 X 8.34
= 150,120 lbs/day

lbs/day, entering basin = lbs/day, primary effluent + lbs/day sludge return
= 2,000 lbs/day + 150,120 lbs/day
= 152,120 lbs/day

lbs/day, leaving basin = 3,000 mg/l X 6 MGD X 8.34
= 150,120 lbs/day

ANALYSIS OF MASS BALANCE IN ACTIVATED SLUDGE SYSTEMS

Solids mass balance for an entire system can provide useful information about what is happening where in the plant. The operator can determine the significance of various flow streams, the production and build-up of sludge, and quantitive change in particular flow streams. Furthermore, mass balance will help track the impact of changes in operational control parameters.

Appendix 1 shows a schematic diagram of a simple activated sludge system and list the pertinent data. This data can be entered or a worksheet or data sheet similar to the sample data sheet shown. After the various calculations have been made and the solids determined for various basins and lines, enter the values on the data sheet. Various comparisons and totals can then be made to analyze the state of the system. As a minimum, you should consider:

lbs to clarifier

lbs from clarifier in sludge withdrawal lines

lbs from clarifier in effluent overflow

lbs from clarifier

lbs in clarifier sludge blanket

lbs under aeration

lbs wasted

total lbs in system

Other operational items to consider are:

Are solids accumulating or deminishing in any basin?
Are flows split evenly?
What is your sludge detention time in aerator and clarifier?
How many cycles/day does sludge make?

USE OF THE SLUDGE UNIT (SU) SYSTEM

Mass balance calculations using suspended solids determination requires fairly extensive lab equipment and several hours of laboratory time. A less expensive and quicker way to estimate the amount of solids is to use the Centrifuge Test. Solids concentration determined by the Centrifuge Test are expressed as percent. (The details of this procedure are explained in the lesson on Centrifuge Test.)

Instead of pounds we use the sludge unit to express the amount of total solids. The sludge unit (SU) is an arbitrary unit defined as the amount of 1% sludge by centrifuge test in a 1 MG volume.

1.0 Sludge Unit = 1.0% X 1.0 MG

The sludge unit, therefore, provides a small number representative of total amount of solids present. To find sludge units use the following formula:

SU = % X volume, MG

Some examples:

Suppose we have the same 1 MG tank volume but with solids concentration of 2.0%. How many sludge units?

SU = 2.0% X 1 MG

= 2 SU

How many sludge units are present in a flow of 4.1 MGD and concentration 10.5%.

SU = 10.5% X 4.1 MGD

= 43.05 SU/day

Sludge units can easily be used to analyze soldis mass balance. Referring back to the examples above, sludge units would be calculated as follows:

For the clarifier: Influent Concentration = 2%
Influent Flow = 4 MGD
Withdrawal Concentration = 10%
Withdrawal Flow = 1.2 MGD
Solids Concentration in Clarifier = 6%
Blanket Volume = 0.049 MG

SU around clarifier

SU in influent = 2% X 4 MGD = 8 SU/day

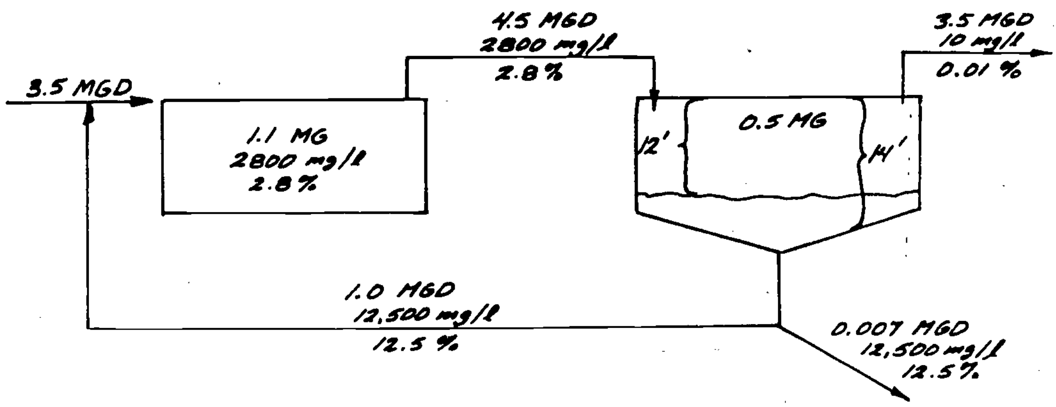
SU in withdrawal = 10% X 1.2 MGD = 12 SU/day

SU in blanket = 6% X 0.049 MG = 0.28 SU

PRACTICE MASS BALANCE PROBLEM

Analyze the mass balance status of the following system. Use either mg/l or % solids. Calculate the following in either pounds or SU's.

1. Solids to clarifier
2. Solids from clarifier in withdrawal line
3. Solids from clarifier in effluent overflow
4. Total solids from clarifier
5. Solids wasted from system
6. Solids in clarifier
7. Solids in aerator
8. Total solids in the system



ANSWERS TO PRACTICE PROBLEM

Formulas:

lbs = Concentration, mg/l X Volume, MG X 8.34

lbs/day = Concentration, mg/l X flow, MGD X 8.34

SU = % X Volume, MG

SU/day = % X Flow, MGD

1. Solids to Clarifier

lbs/day = 2,800 mg/l X 4.5 MGD X 8.34
= 105,084 lbs/day

SU/day = 2.8% X 4.5 MGD
= 12.6 SU

2. Solids from Clarifier in Effluent Overflow

lbs/day = 12,500 mg/l X 1.007 MGD X 8.34
= 104,980 lbs/day

SU/day = 12.5% X 1.007 MGD
= 12.59 SU

3. Solids from Clarifier in Effluent Overflow

lbs/day = 10 mg/l X 3.5 MGD X 8.34
= 292 lbs/day

SU/day = 0.01% X 3.5 MGD
= 0.0035 SU

4. Total Solids from Clarifier

lbs/day = 104,980 + 292
= 105,272 lbs/day

SU/day = 12.59 + 0.0035
= 12.5935 SU

5. Solids Wasted from System

lbs/day = 12,500 mg/l X 0.007 MGD X 8.34
= 729.75

SU/day = 12.5% X 0.007 MGD
= 0.0875 SU

6. Solids in Clarifier

Blanket thickness = 14 ft - 12 ft
= 2 ft

Blanket volume $= \frac{2 \text{ ft}}{14 \text{ ft}} \times 0.5$ MG
= 0.071 MG

Average concentration $= \frac{2800 \text{ mg/l} + 12{,}500 \text{ mg/l}}{2}$
= 7650 mg/l = 7.65%

lbs = 7650 mg/l X 0.071 X 8.34
= 4,530 lbs

SU = 7.65% X 0.071
= 0.54 SU

7. Solids in Aerator

lbs = 2,800 mg/l X 1.1 MG X 8.34
= 25,687 lbs

SU = 2.8% X 1.1 MG
= 3.08 SU

8. Total Solids in System

Total Solids = Solids in Aerator + Solids in Clarifier

= 25,687 lbs + 4,530 lbs

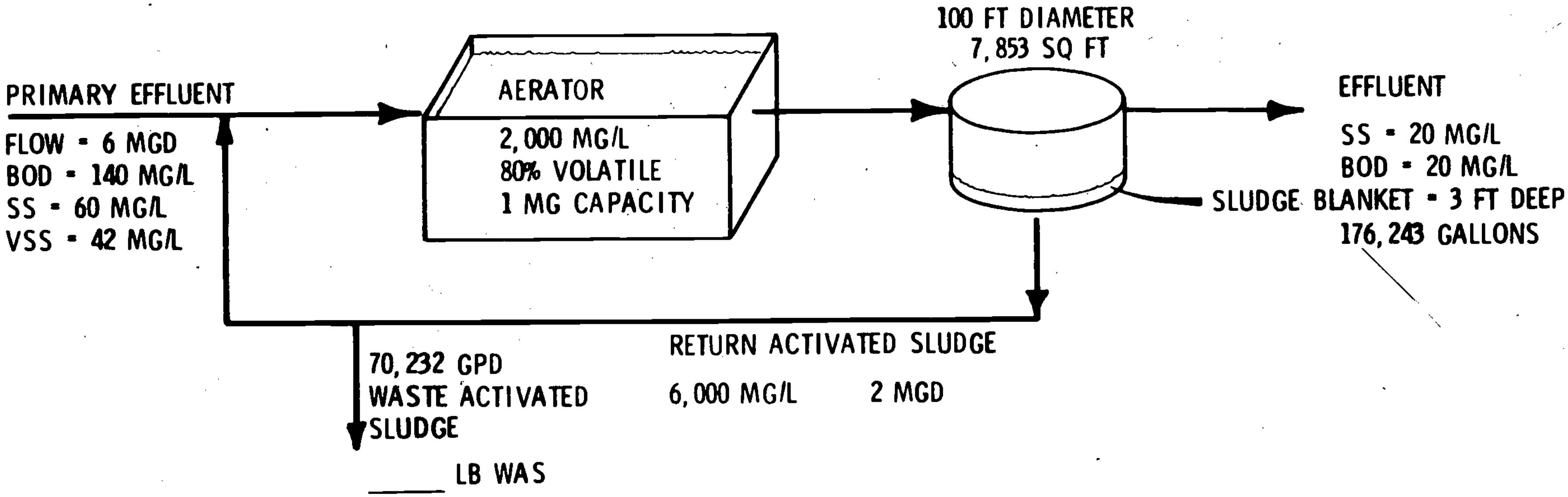
= 30,217 lbs

= 3.8 SU + 0.54 SU

= 57.08 SU

ACTIVATED SLUDGE SYSTEM SOLIDS ANALYSIS

(Brown & Caldwell, 100 W. Harrison St., Seattle, WA 98119)



_____ LB BOD IN
_____ LB SS
_____ LB VSS
_____ LB NON-VOLATILE SOLIDS

_____ LB MLSS

_____ LB IN CLARIFIER

_____ LB SS IN EFFLUENT
_____ LB BOD IN EFFLUENT

F/M = _____
MCRT = _____

VOLATILE SOLIDS IN SYSTEM = _____ LB
TOTAL SOLIDS IN SYSTEM = _____ LB

EXPECTED RESPIRATION RATE = _____ MG O_2/GM/HR

EXPECTED SETTLING CURVE =

EXPECTED SETTLED SLUDGE CONCENTRATION = _____

PROCEDURE SUMMARY

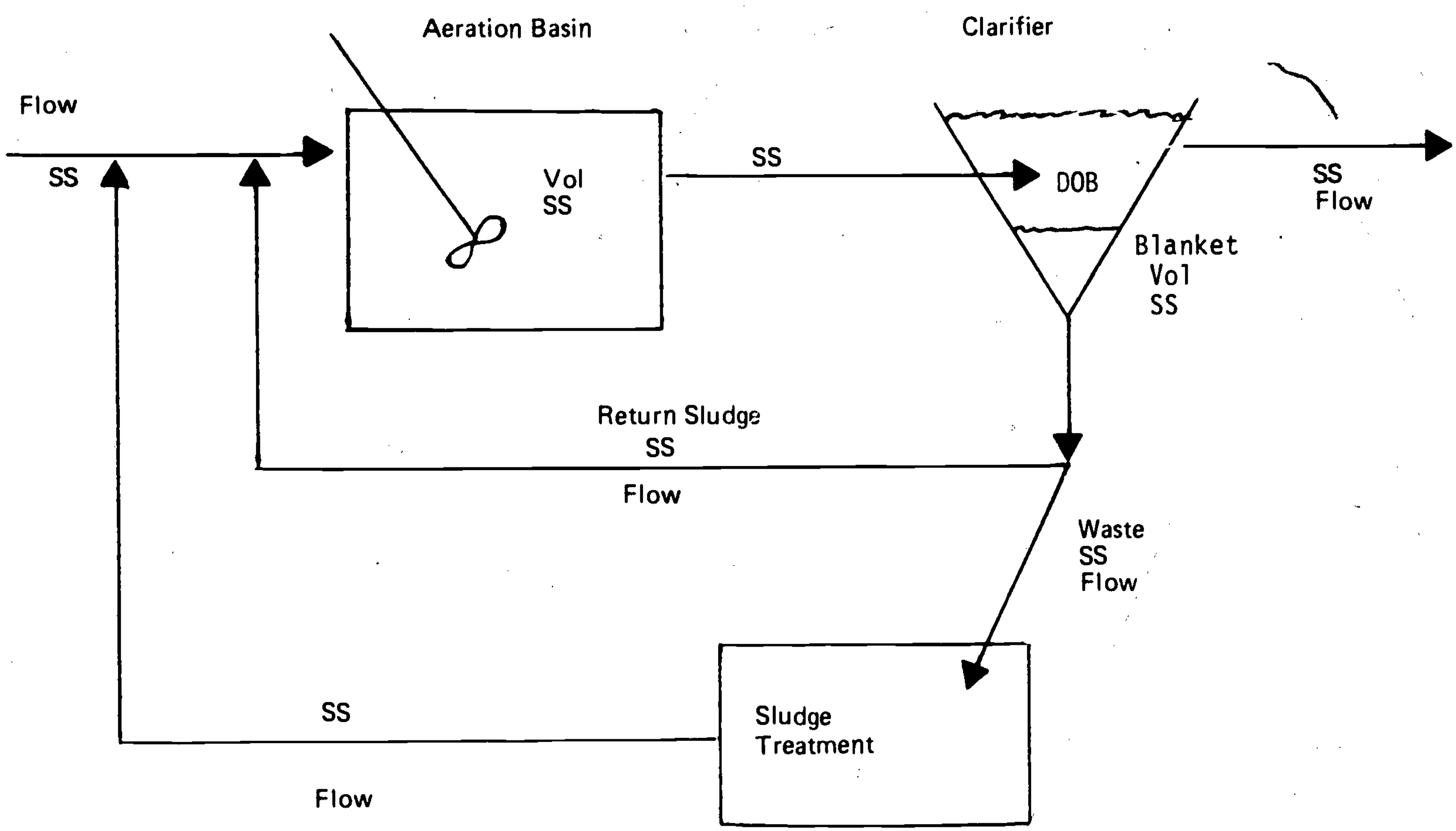
PROCEDURE	CALCULATIONS
1. Collect data: Flows, Volumes, DOB	
2. Convert to MG and MGD	
3. Calculate Blanket Thickness	Bkt. Thick. = Clar. Depth - DOB
4. Calculate Blanket Volume	$\text{Bkt. Vol.} = \frac{\text{Bkt. Thick.}}{\text{Clar. Depth}} \times \text{Clar. Vol.}$
5. Calculate Average Concentration in clarifier	$\text{Ave. Con.} = \frac{\text{Inf. Conc.} + \text{Withdrl conc}}{2}$
6. Calculate lbs/day	lbs/day = Conc. mg/l X Flow, MGD X 8.34
7. Calculate SU/day	SU/day = Conc. % X Flow, MGD
8. Calculate lbs	lbs = Conc, mg/l X Vol. MG X 8.34
9. Calculate SU	SU = Conc. % X Vol. MG
10. Tabulate and Analyze	

MASS BALANCE CALCULATIONS

The above procedure summary is designed as a laboratory aid. It may be cut out and attached to a 5" X 7" index card for convient reference at the laboratory bench. To protect the card you may wish to cover it, front and back, with clear, self-adhesive shelf paper or similar clear material.

Figure I

MATERIAL BALANCE INFORMATION*



* From: Procedures Used in Conducting Selected Activated Sludge Control Tests, Owen K. Boe, Linn-Benton Community College, Albany, Oregon 97321.

MASS BALANCE

WORKSHEET

Directions: Place an "X" by the best answer. There may be more than one best answer for each question.

1. In a typical wastewater treatment plant solids will be found:

   a)_______ in the aeration basin and clarifier.
   b)_______ in the solids handling processes.
   c)_______ in the sludge return line.
   d)_______ in the plant effluent.
   e)_______ All of the above.

2. The basic data needed to calculate solids concentration is:

   a)_______ BOD and SS.
   b)_______ flow and BOD.
   c)_______ flow, volumes, SS, and DOB.
   d)_______ DOB, flow, and total coliform.
   e)_______ flow and SS.

3. Which formula is used to calculate lbs/day?

   a)_______ lbs/day = conc., mg/l X flow, MGD X 8.34
   b)_______ lbs/day = conc., % X flow, MG
   c)_______ lbs/day = conc., % X flow, gpm X 8.34
   d)_______ lbs/day = SS, mg/l X SVI
   e)_______ lbs/day = conc., mg/l X flow, MGD X 1,000

4. Which formula is used to calculate pounds of solids in a basin or clarifier?

   a)_______ lbs = % X Vol. gal
   b)_______ lbs = conc., mg/l X Volume, MG X 8.34
   c)_______ lbs = conc., % X Volume, MG
   d)_______ lbs = SVI X Volume, MG
   e)_______ lbs = conc., mg/l X Volume, MG X 7.48

5. Which statement best describes a sludge unit?

a)_______ 100 gallons of waste activated sludge.

b)_______ Enough activated sludge to occupy 1 cubic foot after drying.

c)_______ 1 MG of 1% sludge.

d)_______ 1 MG of 10% sludge.

e)_______ 100 lbs of sludge.

6. Mark below the two analytical methods used to determine solids concentrations for use in mass balance calculations.

a)_______ Turbidimeter

b)_______ 30 minute sludge settleability

c)_______ Suspended solids gravimetric procedure

d)_______ Volatile acids procedure

e)_______ Centrifuge test

7. Calculate the lbs/day of solids in a flow of 2.5 MGD with a concentration of 3,500 mg/l.

a)_______ 8,750 lbs/day

b)_______ 87,500 lbs/day

c)_______ 7,297 lbs/day

d)_______ 72,975 lbs/day

e)_______ 65,625 lbs/day

8. Determine the SU's in a 1/25 MG basin and a solids concentration by centrifuge test of 2.5%.

a)_______ 3.125 SU

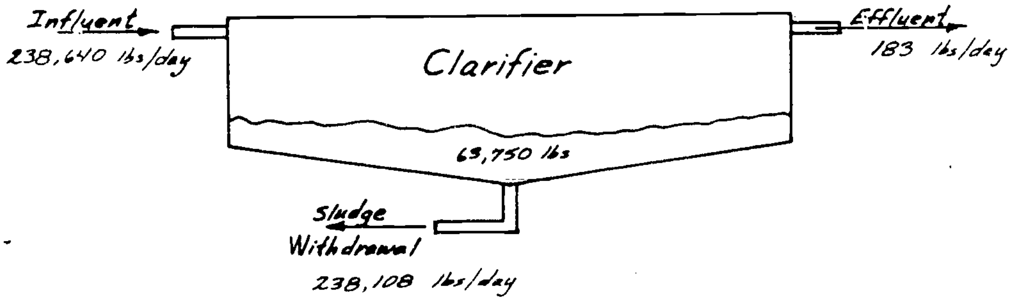
b)_______ 0.3 SU

c)_______ 26.06 SU

d)_______ 23.375 SU

e)_______ 1/25 SU

9. Consider the following clarifier with solids flows as indicated. Which statement best describes the situation?



a)_______ All the solids entering the clarifier are leaving in the effluent.

b)_______ Sludge is slowly accumulating in the clarifier.

c)_______ The sludge blanket is slowly being depleted.

d)_______ The system is balanced.

e)_______ None of the above.