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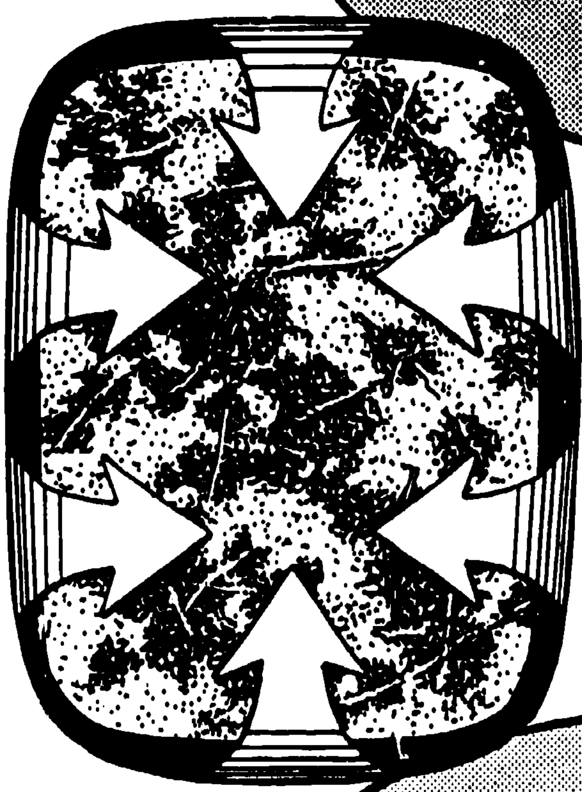
IDENTIFIERS	Unit Processes

ABSTRACT

This instructor's guide contains the materials needed to teach a seven-lesson unit on activated sludge. These materials include an overview of the unit, lesson plans, lecture outlines (keyed to slides designed for use with the lessons), student worksheets for each of the seven lessons (with answers), and two copies of a final quiz (with and without answers). Topic areas addressed in the lessons include: (1) review of activated sludge concepts and components (including aeration tanks, aeration systems, clarifiers, and sludge pumping systems); (2) activated sludge variations and modes; (3) biological nature of activated sludge; (4) sludge quality and respirometry for process control; (5) return sludge control; (6) waste sludge control; and (7) trend charts, testing, and data management. (JN)

Biological Treatment Process Control

Activated Sludge



Instructor's Guide

Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL TREATMENT PROCESS CONTROL

ACTIVATED SLUDGE

INSTRUCTOR'S GUIDE

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ACTIVATED SLUDGE

Instructor's Guide

Table of Contents | Page #

ACTIVATED SLUDGE

Overview

This module on Activated Sludge is the largest of the set and is made up of seven separate lessons. As with other modules the material is considered to be intermediate level. There is, however, a review of activated sludge concepts and system components in Lesson 1. The text material develops process control based on the sludge quality concept. Methods for controlling return sludge and waste sludge flows are discussed in detail. In Lesson 7 reference is made to activated sludge operational test procedures. Written instructional material and 35 mm slide/tape programs describing these tests are available from:

EPA-IRC
OSU
1200 Chambers Rd.
Columbus, OH 43212

or

Water/Wastewater Department
Linn-Benton Community College
6500 SW Pacific Blvd.
Albany, OR 97321
503-928-3620

Material available for the following tests:

Settleometer
Centrifuge
Depth of Blanket
Oxygen Profile
Oxygen Uptake
Turbidity
Mass Balance
Sampling

ACTIVATED SLUDGE

Lesson Plans

Lessons 1, 2 & 3

The first 3 lessons can follow the same format.

- Assign text reading ahead of time, if possible.
- Lecture using slide support (30-45 min)
- Assign Worksheet (15-20 min)
- Review and correct Worksheet (15-20 min)

Lesson 4

The text material for this lesson is divided into 2 sections.

The first part deals with sludge quality and the second more generally with the whole concept of process control and stresses the use of respirometry. Slide support is available for the second section.

- Assign reading of both sections of text, ahead of time if possible.
- Lecture on sludge quality and respirometry, use slides (60 min)
- Assign Worksheet (15 min)
- Review and correct Worksheet (15 min)

Lessons 5 & 6

Lessons 5 and 6 can follow the same format.

- Assign text reading ahead of time, if possible.
- Lecture from outline (no slide support available). Use overhead or blackboard to present math calculations (45 min).
- Assign Worksheet (20-30 min)
- Review and correct Worksheet (20-30 min)

Lesson 7

- Assign text reading ahead of time, if possible.
- Lecture and demonstrate use and construction of trend charts. Use overhead or blackboard (15 min)
- Assign Worksheet (15 min)
- Review and correct Worksheet (10 min)

Review and Conclusion

An eighth worksheet entitled "Camp Swampy Problem" is included as a final review to be used as a troubleshooting exercise to integrate all the sections of this module. The instructor may wish to lead into this worksheet with comments about how to approach troubleshooting.

- Assign "Camp Swampy Problem" (45-60 min)
- Review and correct "Camp Swampy Problem" (45 min)
- Assign Final Quiz (60 min)

ACTIVATED SLUDGE

Lecture Outline

Lesson 1 - Concepts and Components

Slide #	
#1 and #2	Title and Credits
	Concepts
#3	Development of the activated sludge process
	Ardern & Lockett - 1914
	At first concerned with settling and solids removal
#4	Odor was a problem
#5	Discovered that air solved odor problem and improved treatment
#6	Air caused increase in solids but also improved settleability
#7	Solids must be returned to aeration basin and removed from the system
#8	Control of return and wasting was operator's main involvement
#9	Today's activated sludge plant has two main features - aeration basin and clarifier
#10	Control Factors -
	Air Feed
	Return Sludge Flow
	Waste Sludge Flow
#11, #12	The typical Activated Sludge System
	Components
#13	Aeration Basins
#14	Basin shapes

#15 Inlets and Outlets

#16 Aeration Systems

#17 Mechanical Aerators

Up-draft

Down-draft

Plate

Combination

Brush

#18 Diffused Air

Porous

Non-porous

#19 Pure oxygen

#20 Clarifiers

#21 Rectangular

#22 Circular

Summary

#23 Components of the process

#24 Solids production and settling

#25 Control factors

Lesson 2 - Variations and Modes

Slide #	
#1 & #2	Title and Credits
#3	Process Modifications
	Variations - loading changes
	Modes - physical changes
	Variations
	Variables
#4	Detention Time
#5	MLSS
#6	F/M
#7	Variables interrelated
#8	Process Variations - Title
#9	High Rate
	DT 2 hr
	F/M 1.0
	MLSS 500 mg/L
#10	High Rate Plant Flow
#11	Conventional
#12	DT 4-8 hr
	F/M 0.2-0.5
	MLSS 2500 mg/L
#13	Conventional Plant Flow
#14	Extended Aeration
#15	DT 16-24 hr
	F/M 0.01-0.08
	MLSS 4000 mg/L
#16	Extended Aeration Plant Flow

#17 Contact Stabilization

#18 Contact

Stabilization plant

Flow

#19 Loading for both stages

Loading

#20 Relationship between food and microorganisms

#21 F/M ratio - food vs bugs

#22 F/M ratio vs process variations

#23 Sludge Yield

Sludge accmulation with no wasting

Wasting keeps solids concentration constant

#24 Sludge Yield vs Process Variations

Loading Factor

#25 Equation

#26 Loading factor vs process variations

#27 Loading factor vs sludge yield

#28 Activated Sludge Modes - Title

#29 Complete Mix
#30 Plug Flow
#31 Step Feed (Aeration)
#32 Tapered Aeration
#33 Kraus Process
#34 ABF

Summary

#35 Activated Sludge Modes

#36 Process Variations

#37 Process Modifications

Lesson 3 - Biological Principles

Slide #

Slide #	
#1 & #2	Title & Credits
#3	What is good sludge quality?
	A sludge that settles well producing an effluent low in BOD & SS
#4	What is happening in the sludge to influence Sludge Quality?
#5	Basically, it is the action of the microorganisms in the sludge that determines sludge quality
#6	Bacterial Metabolism
	Bacterial Cell Structure
	Protoplasm
	Cell Wall
	Cell Membrane
#7	Slime Layer (capsule)
	Enzymes
	exoenzymes
	endoenzymes
#8	Food must enter the cell in order to be used (respiration ⟶ conversion of food to usable energy)
#9	Food, oxygen converted by enzymes to energy (process of respiration)
	Results in energy for reproduction and cell maintenance
#10	How food (organics) enter the cell
#11	Dissolved food enters easily
	Particulate food adsorbs to slime layer and is broken down partially by exoenzyme

#12 The partially broken down particles are then absorbed into the cell

#13 After entering the cell respiration takes place releasing energy

#14 If food is abundant (F/M high) respiration occurs rapidly and cells reproduce at a high rate

If food is limited (F/M low) cell uses energy for cell maintenance

- Very little cell reproduction
- Called endogenous respiration

#15 Growth Pressures

The major pressures of food and oxygen therefore have a large influence on sludge quality

Sludge Quality

#16 Young Sludge

- High F/M
- Rapid cell reproduction

Old Sludge

- Low F/M
- Cell Maintenance
- Endogenous respiration

#17 Young Sludge

- High F/M
- White, billowy foam
- Turbid effluent
- Poor floc
- Slow settling
- Poor compacting
- High yield

#18 Old Sludge

Low F/M

Dark, leathery foam

Good floc

Fast settling

Good compaction

Low yield

#19 In Transition from Young to Old

Consider the relative portions of each as the transition occurs

#20 In Transition from Old to Young

Relative portions

#21 At Equilibrium

Some old, some young, mostly middle range

#22 Floc Structure

Some filaments a backbone of floc desirable

Too many filaments cause poor settling

#23 Characteristics of Good Sludge Quality

Strong, large floc

Balance between filaments and floc formers

Clear supernatant

Good compaction

Low SVI

Lesson 4 - Sludge Quality (Respirometry)

Slide #

#1 & #2 Title & Credits

Respiration Rate - Rate of Oxygen Uptake

#3 In a resting (low food - endogenous) state bacteria respire at a given rate

#4 If food is added more oxygen is used and respiration accelerates

#5 As food is used up less oxygen is used and respiration declines

#6 Eventually respiration returns to resting (endogenous) phase

Respiration

#7 #8 Occurs in aeration tank, clarifier and sludge return critical

Progressive Sequence of Respiration Rate Changes

#9 Organism in RAS

"Hunger" - Endogenous

#10 RAS mixed with Primary Eff. - Food

Food is adsorbed

#11 Oxygen requirement high at front end of aeration basin

#12 Absorption of food and use of oxygen

#13 Absorption and oxygen consumption continues throughout length of aeration basin

#14 At end of aeration basin food is used

Bacteria at slower to endogenous

#15 Oxygen consumption tapers from high at front end to lower at end of aeration basin

	Review of Cellular Metabolism
#16, #17	Cell structures
#18, #19, #20	Respiration, food, enzymes and oxygen
#21	Adsorption
#22	Absorption
#23	Energy used for reproduction and cell maintenance
	Oxygen Demand
#24	Compared to combustion of wood
	More fuel more oxygen demanded
#25	Same concept with "combustion" (respiration) of organic food (fuel). More fuel more oxygen demanded
#26	Bacteria can be under and over oxidized.
	With oxygen limiting (underoxidized) bugs cannot reproduce quickly, are slow, fat
	With oxygen in abundance (over-oxidized) reproduction occurs quickly, bugs are thin and active
#27	Relationship of oxygen demand vs food load and area of aeration basins
#28	Operators must consider the entire plant in optimizing operational control
#29 #30, #31	Operators must try to reduce cost and improve performance; must balance these two to find the optimum
#32	Optimum operations means optimizing Sludge Quality
	Factors influencing sludge quality
#33	Secondary Clarifier
	design considerations
	hydraulic loadings

#34 Aeration Basin

detention time

oxygen supply

Growth Pressures

#35 Aeration Time

#36 Mode of Operation

#37 Clarifier Sludge Detention Time

#38 Wasting Rate

#39 Sludge Age

#40 F/M Ratio

#41 D.O. Residual

#42 Summary Slide

#43 Two extremes of Poor Sludge

Bulking

Predominate filaments

Strong, large floc

Poor compaction

Pin Floc

No filaments

Weak, small floc

#44 Nitrification/Denitrification - Over-aeration

Nitrogen gas floats sludge in clarifier

#45 Sludge Production

Don't forget the impact of operational pressure (food) on sludge yield

#46 Operator must make financial decisions regarding labor, energy, chemicals, and maintenance

Use of Respirometry

#47 Can check for effect of toxic materials

#48 Predict impact of influent food (organics) on respiration rate

#49 Predict impact of toxics on respiration rate

#50 Outline of uses of respirometry

#51 Predict impact

#52 Develop treatment strategy

- Aeration time
- Chemical feed
- Sludge concentrations

#53 Evaluate design

#54 Apply sewer use ordinance

#55 Implement sewer use ordinance

#56 Use respirometry to optimize effluent quality and cost of treatment

#57 Modeling Operational Variables

#58 Use respirometry to optimize detention time

MLSS conc., F/M ratio, Nutrients, Temperature, pH

#59
#60 Balance good sludge quality with sludge handling; these two are major contributors to treatment cost

#61 Cost of Operation a result of method of process control which in turn is a result of respirometry, traditional lab tests and the crystal ball.

Lesson 5 - Return Sludge Control

Objectives of return sludge control

- Return biomass from the clarifier to the aeration basin
- Optimize clarifier operation
  - Effluent quality
  - Energy consumption

Clarifier Theory

- Solids have a greater density than water
- Clarifier sized on the basis of particle settling rate
- Solids loading must not exceed the ability to move sludge to the return pipe
- Flux - lbs loaded to each square foot of clarifier per day
- Return is theoretically determined on the basis clarifier area, plant flow, and solids flux

Classical Return Sludge Flow Determinations

- Desired MLSS
- Clarifier Sludge Flow Demand
- SVI Determination of RSF
- Fixed Rate of Flow
- Percent Return Rate

Sludge Quality Based Return Sludge Control

- Settleometer and centrifuge data
  - SSC - Settled Sludge
  - Concentration
  - SSV - Settled Sludge Volume

ATC - Aeration Tank Concentration

RSC - Return Sludge Concentration

Use of plotted data to determine whether sludge is old or young

Use of trend charts for settleometer data

Determination of clarifier efficiency by diluting settleometer samples

Lesson 6 - Waste Sludge Control

Objectives of Waste Sludge Control

- Regulate quantity of sludge in the system
- Regulate sludge quality

System Inventory Control

- Materials balance program must answer three questions
  - How many bugs in every unit process?
  - How many bugs are coming and going from the unit processes?
  - How long do the bugs stay in any one unit process?

Calculating flows and efficiencies for clarifiers

How to determine the amount of excess solids

- Yield and Growth concepts

Specific Control Parameters

- Assume the following conditions:
  - Accurate measure of system solids
  - Solids measured representative of active biomass
  - Measurement of WAS and Secondary Eff. representative of biomass lost
  - Inf. and Eff. Food representative of food available and food utilized
  - Must be no limitations to growth
  - Growth linear to the amount of food
  - System must be operating in a steady state

- MCRT
- F/M
- MLSS

WAS Adjustments

- Use control parameters to calculate sludge yield, then use yield to select target for wasting
- Compare wasting to selected control parameter(s) and monitor trends
- Change ,asting rate by 10% per day
- How to respond if parameters are high or low

Use of visual observations and settleometer to determine wasting program

Lesson 7 - Trend Charts, Testing, and Data Management

- Trend Charts
  - Definition
  - Usefulness
  - Moving Averages
    - 3,7,10 and 28 day moving averages
    - Calculation procedures
- Testing
  - Settleometer
  - Centrifuge
  - Depth of Blanket
  - Oxygen Uptake
  - Mass Balance Procedure
- Data Management
  - Characteristics of good data sheets
  - Examples of data sheets

ACTIVATED SLUDGE

Answers to Worksheet 1 - Review of Concepts and Components

1. Who were the two wastewater chemists who discovered the activated sludge process in 1914?

   Ardern and Lockett

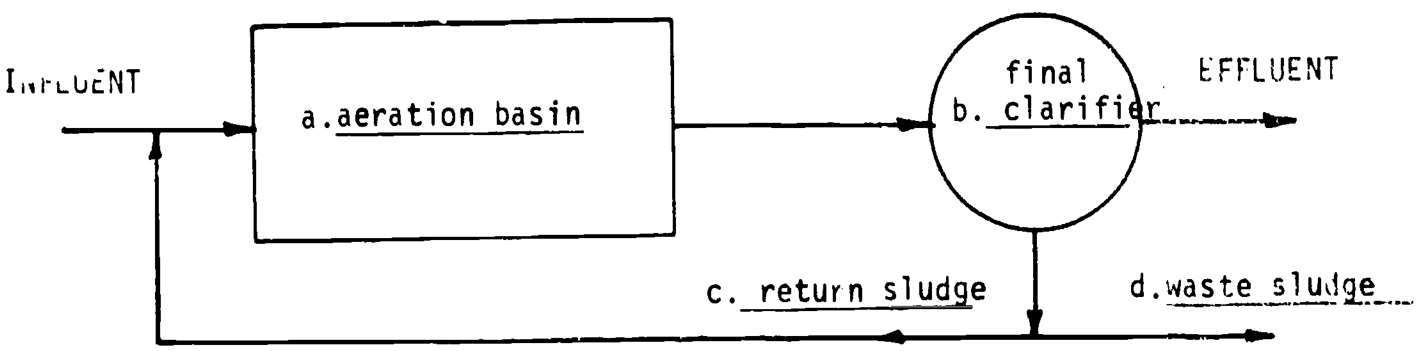
2. Define the activated sludge process.

   The treatment of sludge through the use of the suspended biological solids with the addition of oxygen and controlled by wasting excess solids and recycling of settled solids in the clarifier.

3. The three major control variables for the activated sludge process are:

   D.O. feed, wasting of excess solids, and returning settled sludge.

4. Identify the basin and the flows indicated on the diagram of an activated sludge process plant below:



5. The mechanical aerator with vertical blades attached at the periphery of a circular flat plate that rotates creating a hydraulic jump is the plate type aerator.

6. The mechanical aerator that has an impeller located near the surface that forces liquid from the top to the bottom and entrains air is the down draft aerator.

7. Combination type aerators combine the diffused air process and the mechanical aerator process.

8. Describe one advantage and one disadvantage of each of the following aeration systems:

   a. Diffused air:

      Adv. - better control
      - better oxygen transfer

      Disadv. - requires more maintenance
      - requires more energy

   b. Fine air diffuser:

      Adv. - better oxygen transfer than coarse air

      Disadv. - requires high air pressure
      - clogs easily

   c. Coarse air diffuser:

      Adv. - doesn't clog as easily
      - lower air pressure required

      Disadv. - poorer oxygen transfer

   d. Surface aerators:

      Adv. - lower maintenance
      - lower energy

      Disadv. - lower oxygen transfer
      - less control

9. Pure oxygen can be supplied to covered or sealed reactors or to open tanks.

10. Both circular and rectangular shaped clarifiers are often used in activated sludge systems.

11. Design surface loading rates for secondary clarifiers average are 600 gal/day/ft^2 and weir overflow rates are between 10,000 and 30,000 gal/day/ft.

12. List two methods of removing sludge from a secondary clarifier.

    a. Scrapers move sludge to hopper from which it is pumped.

    b. Draft tubes on scraper arms.

ACTIVATED SLUDGE

Answers to Worksheet 2 - Activated Sludge Variations and Modes

1. Process variations are usually defined by three major process variables. These are:

   aeration detention time (D.T.)

   mixed liquor suspended solids (MLSS)

   BOD to MLSS ratio (F/M)

2. The four classic variations are:

   High rate

   Conventional

   Contact stabilization

   Extended aeration

3. Give the expected F/M ratios for each of the following variations:

   High rate: 1.0

   Conventional: 0.2 - 0.5

   Extended aeration: 0.01 - 0.08

4. Arrange the following variations in order of lowest to highest sludge age by placing 1, 2, or 3 in front of the name.

   __2__ Conventional

   __3__ Extended aeration

   __1__ High rate

5. Draw and label a diagram of a contact stabilization plant:

6. Which of the four variations is expected to yield the most sludge? High rate

7. Calculate the loading factor if the following conditions exist:

Detention time	=	6 hrs
MLSS	=	2000 mg/L
F/M	=	0.25

$$L.F. = \frac{D.T. \times MLSS}{F/M \times 1000}$$

$$= \frac{6 \times 2000}{0.25 \times 1000}$$

$$= 48$$

8. The operational mode where the contents of the tank are theoretically uniformly mixed is complete mix.

9. The operational mode where waste flow is added at different points along the aeration basin is called step aeration.

10. The operational mode where air is discharged into the aeration basin in a reduced amount along the basin is called tapered aeration.

11. The operational mode where the wastewater flows through the system in a slug is called plug flow.

Answers to Worksheet 3 - Biological Nature of Activated Sludge

1. Define good sludge quality.

   Settles rapidly in the final clarifier and produces an effluent that is low in BOD and TSS.

2. List four types of microorganisms found in activated sludge floc.

   bacteria — worms

   protozoa — algae

   viruses

   fungi

3. Bacteria break down organic food materials for two main reasons. They are to produce energy for growth and cell maintenance.

4. Food particles stick to the outside of the bacteria cell in a process called adsorption. The enzymatically broken down food is then through absorption taken into the bacteria through the cell membrane.

5. Energy obtained from nutrients entering the cell is converted to new cells by a process called respiration.

6. Energy obtained from nutrients stored in the cell itself and used for cell maintenance is converted by a process called endogenous respiration.

7. Cellular respiration is also referred to as the oxidation (stabilization) of the nutrient chemical.

8. Observation of the types and numbers of protozoa can help determine the status of the bacterial population.

9. If the following list of microorganisms were to be used as indicators of sludge age, arrange the list in the correct order, from youngest to oldest.

   rotifers, free-swimming ciliates, worms, amoeba, stalked ciliates, flagellates

   a. amoeba (youngest)
   b. flagellates
   c. free-swimming ciliates
   d. stalked ciliates
   e. rotifers
   f. worms (oldest)

10. For each of the following characteristics indicate whether they represent young (Y) or older (O) cells:

    _Y_ short generation time

    _O_ low degree of motility

    _Y_ white, billowy foam

    _O_ fast settling

    _O_ low F/M ratio

    _O_ low Volatile SS production

11. Explain what a "two-sludge" system is.

    Where old and young sludge exist together. Can occur when a large percent (50%) of the sludge is wasted. This drastically changes the F/M ratio and light young floc forms in the presence of the older sludge already there.

12. Why does sludge flocculate better as it gets older?

    As sludge ages the "bugs" lose their flagella and motility and accumulate more slime. This makes it easier for the floc particles to stick together.

13. Is the presence of filamentous bacteria in floc beneficial or detrimental? Explain.

    A few filaments is good. Filaments in the center of floc particles serve as a backbone holding the floc together. Too many filaments, however, hinder settling.

14. Floc with low SVI, small, dense and over-oxidized is called _pin_ floc.

15. Floc which is large and feathery, has many external filaments, and an SVI greater than 200 is called _straggler floc_.

16. Normal floc is about _100-500_ microns in diameter and has an SVI of _100-500 mL/gram_.

ACTIVATED SLUDGE

Answers to Worksheet 4 - Sludge Quality

1. Good quality sludge can be defined as the right mixture of organisms that produce a good effluent.

2. Factors that affect growth and thus sludge quality are often referred to as oxidation pressures.

3. List three items that can be visually assessed at the aeration tank.

   sludge color

   foam color

   characteristics of foam

4. Describe the appearance of good sludge in the aeration basin.

   A modest accumulation of crisp white foam with tan to brown floc.

5. Describe a young sludge in terms of:

   a. foam appearance - light colored, fairly large, not dense

   b. settling characteristics - slow settling with straggler floc

6. Describe an old, over-oxidized sludge:

   a. foam appearance - dark colored, small, dense

   b. settling characteristics - rapid settling with pin floc

7. Describe the difference between solids lost due to hydraulic washout and that due to bulking sludge.

   True bulking is a sludge blanket that never settles so solids are lost. Hydraulic washout is the forcing up of settled sludge due to increase clarifier flow.

8. Distinguish between straggler and pin floc.

   Straggler floc - 1/8 - 1/16" diameter, fluffly, buoyant, almost transparent.

   Pin floc - less than 1/32" diameter, compact, dense

9. BOD loading for activated sludge systems range from 0.5 lb BOD per lb of MLVSS for high rate to 0.05 - 0.10 lb BOD per lb of MLVSS for extended aeration systems.

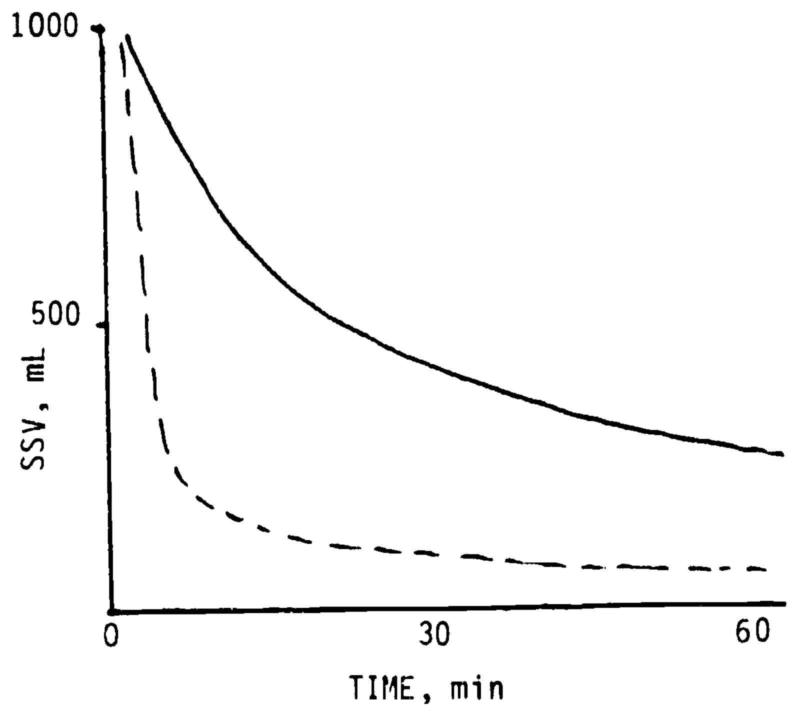
10. How is sludge yield defined?

Pounds of biomass produced per pound of BOD fed
or
pound of net biomass wasted per pound of BOD fed

11. Define respiration rate.

mg/L of oxygen used per hour per gram of MLSS

12. On the graph below draw a settling curve for an under-oxidized (young) sludge using a solid line and a curve for an over-oxidized (older) sludge using a dashed line.



13. Calculate SVI for the following system:

30 min. settleability = 300 mL/L
MLSS = 2700 mg/L

$$SVI = \frac{30 \text{ min settleability, mL/L} \times 1000 \text{ mg/g}}{\text{MLSS mg/L}}$$

$$= \frac{300 \times 1000}{2700}$$

$$= 111 \text{ mL/g}$$

14. Listed below are oxidation pressure forces and indicators. For each of the items listed indicate whether they represent over-oxidized (0) or under-oxidized (U) sludge.

0 high D.O.

U low MLSS

0 low F/M

0 high MCRT

0 pin floc

0 rapid settling

U high SVI

U white, fluffy foam

U high respiration rate

0 low turbidity in effluent

Answers to Worksheet 5 - Return Sludge Control

1. In the activated sludge process sludge is returned to the <u>aeration basin</u> from the <u>clarifier</u>.

2. The return sludge provides sufficient <u>biomass</u> to meet the incoming food.

3. Define the following terms:

   CSFD: Clarifier sludge flow demand

   RSF: Return sludge flow

   RSC: Return sludge concentration

4. Calculate return sludge flow in MGD by the desired MLSS method if:

   MLSS desired = 3000 mg/L
   Flow, Q = 1.2 MGD
   RSC = 10,400 mg/L

$$RSF = \frac{MLSS \times Q}{RSC - MLSS}$$

$$= \frac{3000 \times 1.2}{10{,}400 - 3000}$$

$$= \frac{3{,}600}{7{,}400}$$

$$= 0.49 \text{ MGD}$$

5. Calculate CSFD if:

   RSF = 0.6 MGD
   RSC = 10,400 mg/L
   MLSS = 3000 mg/L

$$CSFD = \frac{RSF \times (RSC - MLSS)}{RSC - MLSS}$$

$$= \frac{0.6 \times (10{,}400 - 3000)}{10{,}400 - 3000}$$

$$= \frac{0.6 \times 7400}{7400}$$

$$= 0.60 \text{ MGD}$$

6. Calculate return sludge flow (RSF) by the SVI method if:

Q	=	1.2 MGD
MLSS	=	3000 mg/L
SVI	=	100 mL/g

$$RSF = \frac{Q \times MLSS}{10^6/SVI - MLSS}$$

$$= \frac{1.2 \times 3000}{1,000,000/100 - 3000}$$

$$= \frac{3600}{7000}$$

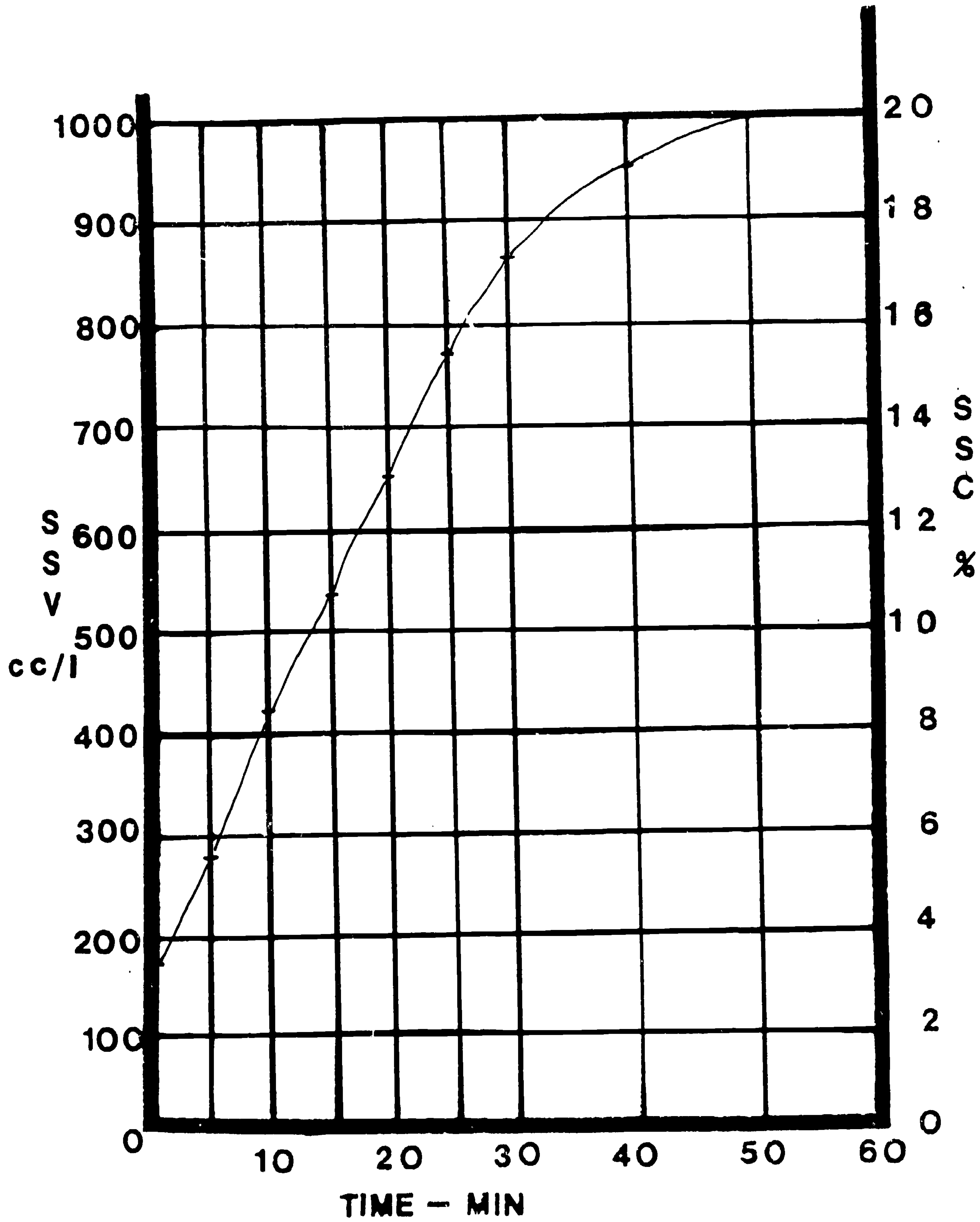
$$= 0.51 \text{ MGD}$$

7. From the following settleometer data calculate SSC and plot the data on the attached graph.

ATC = 3.8%

TIME, min	SSV, mL/L	SSC,%
0	1000	3.8
5	680	5.59
10	450	8.44
15	350	10.86
20	290	13.10
25	260	14.62
30	230	16.52
40	200	19.00
50	190	20.00
60	190	20.00

$$SSC = \frac{1000 \times ATC}{SSV}$$



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TIME — MIN

I-AS-31

Answers to Worksheet 6 - Waste Sludge Control

1. One of the two major goals of waste sludge control is to regulate the amount of sludge in the activated sludge system.

2. The second major goal of waste sludge control is to regulate the sludge quality.

3. Sludge inventory is the term used to describe the process of keeping track of where the sludge is in the system and how much is in each location.

4. A material balance program should be able to answer the three following questions:

   How many "bugs" are in every unit process?

   How many "bugs" are coming and going from unit processes?

   How long do the "bugs" stay in any one unit?

5. List five of the 9 methods used to evaluate the presence of excess sludge.

   Sludge Age

   F/M

   MCRT, CRT or SRT

   MLSS

   ASU

   CSU

   lbs SS in Pri. Eff.

   Sludge Quality

   Settleometer Data

6. Generally if F/M is higher than normal the response should be to (reduce or increase) wasting.

7. Generally if MLVSS is lower than normal the response should be to (reduce or increase) wasting.

8. Generally if the MCRT is lower than normal the response should be to (reduce or increase) wasting.

9. Increasing wasting tends to (increase or decrease) sludge age.

10. What is the value of using trend charts in determining waste sludge flows?

    Trend charts show visually how process variables are moving. If moving averages are used the trends (as opposed to incidental fluctuations) are easily seen.

11. If the trend charts indicate that the MCRT should be adjusted to 5.0 days and there are currently 120,000 lbs of VSS in the total system, what should the wasting be in lbs/day?

$$\text{MCRT, day} = \frac{\text{System VSS, lb}}{\text{Waste VSS, lb/day}}$$

$$\text{Waste VSS lbs/day} = \frac{\text{System VSS, lb}}{\text{MCRT, day}}$$

$$= \frac{120{,}000 \text{ lbs}}{5.0}$$

$$= 24{,}000 \text{ lbs/day}$$

12. If the trend charts indicate that wasting should be adjusted so that the F/M is 0.40 and the BOD loading per day is 50,000 lbs/day, what should the MLVSS be in a 5.5 Mgal aeration tank?

$$\text{F/M} = \frac{\text{Inf. BOD, lbs}}{\text{MLVSS, lbs}}$$

$$\text{MLVSS, lb} = \frac{\text{Inf. BOD, lbs}}{\text{F/M}}$$

$$= \frac{50{,}000 \text{ lbs}}{0.4}$$

$$= 125{,}000 \text{ lbs}$$

$$\text{lbs} = \text{Vol, MG X Conc, mg/L X } 8.34$$

$$\text{Conc, mg/L} = \frac{\text{lbs}}{\text{Vol, MG X } 8.34}$$

$$= \frac{125{,}000}{5.5 \text{ X } 8.34}$$

$$= 2725 \text{ mg/L}$$

Answers to Worksheet 7 - Trend Charts, Testing, and Data Management

1. Graphs of various plant and control data parameters plotted for each day are called trend charts.

2. The moving average is an average of a prescribed number of previous day's data plotted each day, using a newly generated average each day.

3. Calculate the seven day moving average for the following data:

Day/Date	24-hr Avg. Value
M 4/1	6
T 4/2	6
W 4/3	2
H 4/4	5
F 4/5	6
S 4/6	2
S 4/7	10
M 4/8	8
T 4/9	7
W 4/10	28
H 4/11	6
F 4/12	6
S 4/13	1
S 4/14	5
M 4/15	7
T 4/16	6
W 4/17	6
H 4/18	15
F 4/19	8
S 4/20	4
S 4/21	6

(Cont.)

$\sum_{7}^{0}$	Σ/n	Moving Avg.
6		
12		
14		
19		
25		
27		
37	37/7	5.3
39	39/7	5.6
40	40/7	5.7
66	66/7	9.4
67	67/7	9.6
67	67/7	9.6
66	66/7	9.4
61	61/7	8.7
60	60/7	8.6
59	59/7	8.4
37	37/7	5.3
46	46/7	6.6
48	48/7	6.9
51	51/7	7.8
52	52/7	7.4

Answers to Camp Swampy Problem

Camp Swampy is a plant that is plagued by inadequate solids handling. It also suffers from a lack of preliminary treatment as well as primary treatment as evidenced by fouling of the propeller flow meters. There does not appear to be any screening or grinding upstream of the aeration basin. There also does not appear to be grit removal.

Sludge quality data indicates sludge that is highly oxidized. The aeration tank has a dark brown greasy scum on the surface. This may be caused either by lack of primary treatment wh[illegible] grease and oil should be removed, but more probably is caused by the growth of the bacteria Nocardia. Nocardia is characteristically present in sludge qualities like the one found at Camp Swampy. It typically results from an over-oxidized condition where mean cell residence time (or sludge age) is too great. The clarifier appearance noted in the "Summary of Plant Status" indicates ashing and straggler floc with surface scum accumulations. Again this is a classic picture of over-oxidation and old sludge. In such a case, the surface scum accumulations are probably Nocardia coming out of suspension because of its hydrophobic nature. This can be easily confirmed by microbial observation.

It should be noted that the initial settling rate of the mixed liquor is reasonably good - that is, it settles to half its volume in the first five minutes. This is generally a goal to achieve a sludge settleability in that range. It is suspected that the apparent settling characteristics are resulting from the fact that mixed liquor concentrations (ATC) have gotten high, and we see a slow settling rate because of a high amount of solids in the system. We generally refer to this condition as "hindered settling". It is suggested that a dilution of the mixed liquor (25% and 50%) with final effluent be performed. It is expected that a marked increase in settling rate would occur upon dilution, confirming "hindered settling". The concentrations characteristic of the sludge are quite good - in fact, the settled sludge concentration after 40 minutes of approximately 24% (by spin) is very high. Ideally, we would like to see the 40-60 minute concentration under 20% which must be achieved through a reduction in overall sludge inventory. It should also be noted that the return sludge concentration of 10% represents a very short clarifier sludge detention time on the

theoretical sludge compaction characteristics that the settleometer data would indicate is possible. From a comparison between aeration tank and return sludge concentrations, it looks like a reduction in clarifier sludge flow is indicated. Prior to changing recycle flow it would be advisable to measure the depth of sludge blanket in the clarifier to assure that reduction of return flow would not adversely affect clarifier inventory. With the apparent settling characteristics for this sludge quality it would be appropriate to target a return sludge concentration to achieve an SSC of 30-40 minutes (23-24%). This will represent a significant reduction in return sludge flow and may cause draft tube plugging, so proceed with caution! At least once per shift, measure clarifier sludge blanket depths. At the same time, an increase in wasting should be initiated. The thicker return sludge flow will also allow more effective wasting to the aerobic digester (more pounds per gallon wasted). It is suggested also that a microbial observation of the mixed liquor be performed to confirm the suspicion of Nocardia as opposed to an influent grease and oil problem. In the event that Nocardia is confirmed, it further substantiates the need for an increase in wasting to reduce sludge age.

The design of the aerobic digester does not lend itself to an effective sludge wasting program. The digester imposes a restriction on the amount and/or frequency of sludge wasting because of the fixed mechanical aerator. It is suggested that in the short term, digested sludge be hauled more frequently by tank truck to land disposal to provide room in the digester for more waste activated sludge.

The operational mode indicated on the flow diagram is "plug flow". For the short term, a modification is suggested to place the plant into "contact stabilization" which will effectively reduce sludge production (sludge yield) and create a net shift of solids from the final clarifier to the aerator. In the short term, this will "store" solids under aeration while digester capacity is created by an increase in sludge hauling.

It is necessary to analyze the influent on a composite basis for BOD and TSS so that process control targets can be set rationally. Food to microorganisms ratio cannot be calculated from the data provided, and this must be accomplished before overall wasting goals are developed and target MLSS concentrations established.

In summary, short term solutions call for: Increase monitoring tests to include sludge blanket measurements in the clarifier, perform a microbial analysis to confirm the suspicion of Nocardia, change operational mode to contact stabilization configuration, increase sludge hauling by truck to land disposal so as to allow an increase in sludge wasting, monitor and calculate food:microorganism ratio and set a MLSS target that represents a reasonable F/M (0.2-0.5).

Long term solutions include the redesign of the headworks of the treatment plant to provide screening, grinding and grit removal. Primary treatment should also be added to remove heavy settleable solids and any floating material that is initially removable. There does not appear to be a problem with the aeration system nor the secondary clarifier. Propeller meters are inappropriate in return and waste sludge lines. They should be replaced with non-fouling meters, such as a magnetic flow meter that measures flow from the outside of the pipe. The aerobic digester should be modified to allow addition of waste activated sludge without necessarily supernating prior to wasting. A floating mechanical aerator will accomplish the task of providing some flexibility in aerobic digester operation. The inclusion of a primary clarifier will necessitate another look at the entire solids handling strategy for the plant. While primary sludge may be aerobically digested, it could be that the volatile solids loading placed on the existing aerobic digester from primary sludge will be excessive, in which case Camp Swampy's treatment plant may need to go to anaerobic digestion. Without tank sizes provided in the given data, inadequate information exists to conclude the feasibility of using aerobic digestion in this particular plant modification. Certainly redesign of the overall solids handling system is in order. It would also be wise to include a sludge thickening process following aerobic digestion to increase sludge concentration and reduce hauling costs.

ACTIVATED SLUDGE

Final Quiz

MATCHING: Choose the most correct response(s) from the list and place an "X" in the space to the left.

1. The two English wastewater chemists given credit for discovering the activated sludge process are

_____ a. Imhoff

_____ b. Arden

_____ c. Lockett

_____ d. Boe

_____ e. West

2. The three major control variables for the activated sludge process are

_____ a. D.O. feed

_____ b. detention time

_____ c. wasting of excess sludge

_____ d. influent BOD load

_____ e. return sludge flow from clarifier

3. Which of the following are mechanical type aerators?

_____ a. updraft aerators

_____ b. plate-type aerators

_____ c. fine air aerators

_____ d. coarse air aerators

_____ e. brush-type aerators

4. Advantages of mechanical aerators over diffused air aerators include

_____ a. requires high air pressure

_____ b. requires less maintenance

_____ c. better control of air delivered

_____ d. requires less energy

_____ e. higher oxygen transfer

5. Typical final clarifiers in the activated sludge process have average surface overflow rates of ______________ gal/day/sq ft of surface area.

_____ a. 100 gpdsf
_____ b. 300 gpdsf
_____ c. 600 gpdsf
_____ d. 1100 gpdsf
_____ e. 1300 gpdsf

6. The three variables that define the activated sludge process variations are

_____ a. MCRT
_____ b. F/M
_____ c. Detention time
_____ d. MLSS
_____ e. Sludge age

7. Of the four classic activated sludge process variations, which one would be expected to have an F/M in the 0.2-0.5 range?

_____ a. high rate
_____ b. conventional
_____ c. contact stabilization
_____ d. extended aeration

8. Which of the four classic process variations would be expected to produce the least sludge?

_____ a. high rate
_____ b. conventional
_____ c. contact stabilization
_____ d. extended aeration

9. The operational mode where the waste flow is added at different points along the aeration basin is called

_____ a. plug flow
_____ b. complete mix
_____ c. step aeration
_____ d. tappered aeration
_____ e. Kraus process

10. The operation mode where the wastewater flows through the system in a slug is called

____ a. plug flow
____ b. complete mix
____ c. step aeration
____ d. tappered aeration
____ e. Kraus process

11. Calculate the loading factor if the following conditions exist:

Detention time	=	5 hrs.
MLSS	=	1800 mg/l
F/M	=	0.3

____ a. 1.8
____ b. 3
____ c. 30
____ d. 270
____ e. none of the above

12. Which one of the following types of microorganisms is NOT typically found in activated sludge floc?

____ a. bacteria
____ b. protozoa
____ c. viruses
____ d. algae
____ e. rotifers

13. Microscopic observation of which group of microorganisms is often used to assess sludge quality?

____ a. bacteria
____ b. protozoa
____ c. fungi
____ d. larvae
____ e. all of the above

14. Which of the following are indications of "young" sludge?

_____ a. low F/M ratio
_____ b. fast settling sludge
_____ c. white, billowy foam
_____ d. low VSS production
_____ e. short generation time

15. Floc with a low SVI, small, dense and over-oxidized is called __________ __________ floc.

_____ a. bulking floc
_____ b. pin floc
_____ c. straggler floc
_____ d. floc rafts
_____ e. retarded floc

16. Three items that can be used to assess sludge by visual observations at the final clarifier are

_____ a. activated sludge color
_____ b. floc in supernatant
_____ c. clarity of supernatant
_____ d. activated sludge foam type
_____ e. ashing or clumping of floc

17. A BOD loading of 0.005 to 1.0 lbs BOD per day per lbs MLVSS would be considered loading for which process variation?

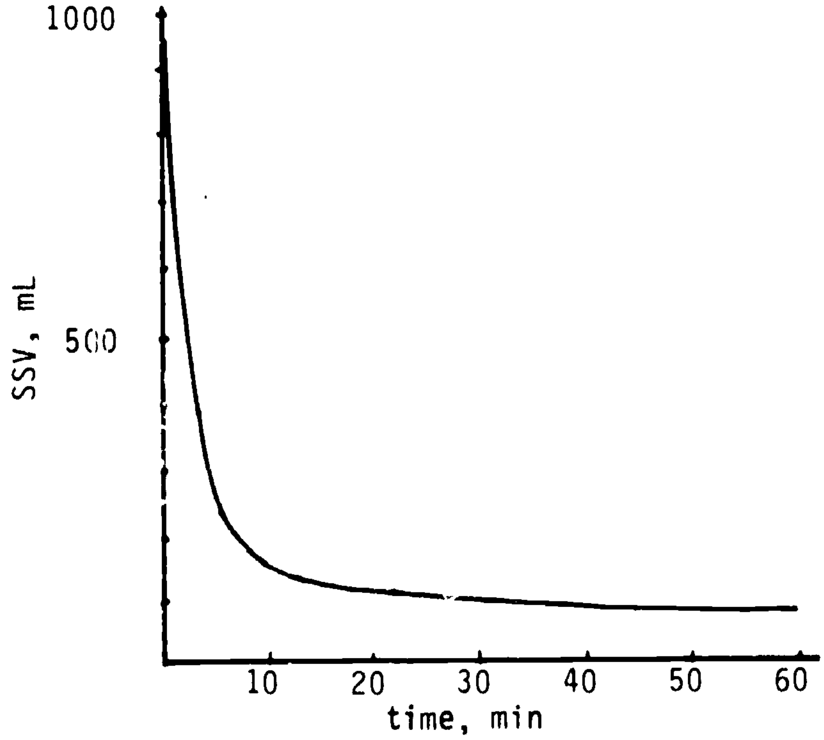
_____ a. high rate
_____ b. complete mix
_____ c. plug flow
_____ d. conventional
_____ e. extended aeration

18. The mg/l of oxygen used per hour per gram of MLSS is defined as

_____ a. sludge yield
_____ b. respiration rate
_____ c. mean cell residence time
_____ d. BOD conversion rate
_____ e. sludge metabolism

19. The following settling data was determined with a settleometer and plotted as shown below.

time	SSV
5	260
10	170
15	130
20	120
25	110
30	100
40	95
50	90
60	90



The curve represents ________ settling sludge.

_____ a. slow

_____ b. normal

_____ c. rapid

20. Calculate the SVI for the following system:

30 min settleability = 400 ml/l
MLSS = 2500 mg/l

_____ a. 6

_____ b. 60

_____ c. 100

_____ d. 160

_____ e. 600

21. Which of the following are used to control return sludge flow?

_____ a. MLSS
_____ b. CSFD
_____ c. SVI
_____ d. Fixed Rate Method
_____ e. Percent Return Rate Method

22. The goals of sludge wasting are

_____ a. remove excess sludge from the system.
_____ b. balance the amount of sludge between the aeration basin and the clarifier.
_____ c. to assure that the digester has adequate feed.
_____ d. to waste sludge from the aerobic digester to the aeration basin.
_____ e. to regulate sludge quality.

23. Generally if F/M is lower than normal the response should be

_____ a. reduce the wasting rate
_____ b. increase the wasting rate
_____ c. no change in sludge wasting is needed
_____ d. increase sludge return but leave wasting alone
_____ e. none of the above are appropriate responses.

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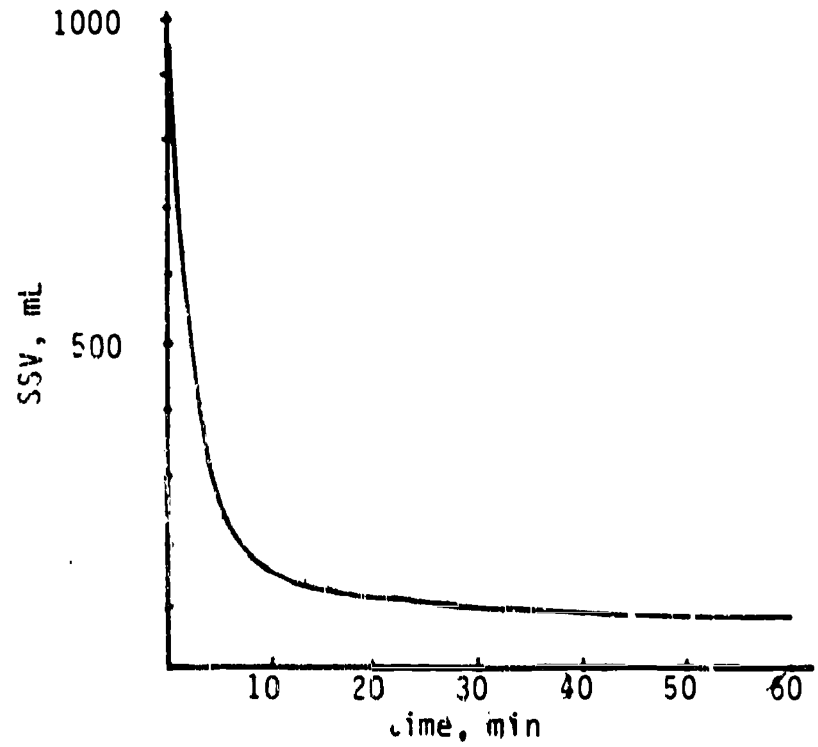

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