DOCUMENT RESUME

ED 252 411 SE 045 333

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TITLE Aerobic Digestion. Biological Treatment Process Control. Instructor's Guide.
INSTITUTION Linn-Benton Community Coll., Albany, Oreg.
SPONS AGENCY Environmental Protection Agency, Washington, DC. Office of Drinking Water.
PUB DATE 84
GRANT EPA-T901238
NOTE 26p.; For related documents, see SE 045 334-354.
AVAILABLE FROM Linn-Benton Community College, 6500 S.W. Pacific Blvd., Albany, OR 97321 (Instructor's guide and accompanying slides).
PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052)

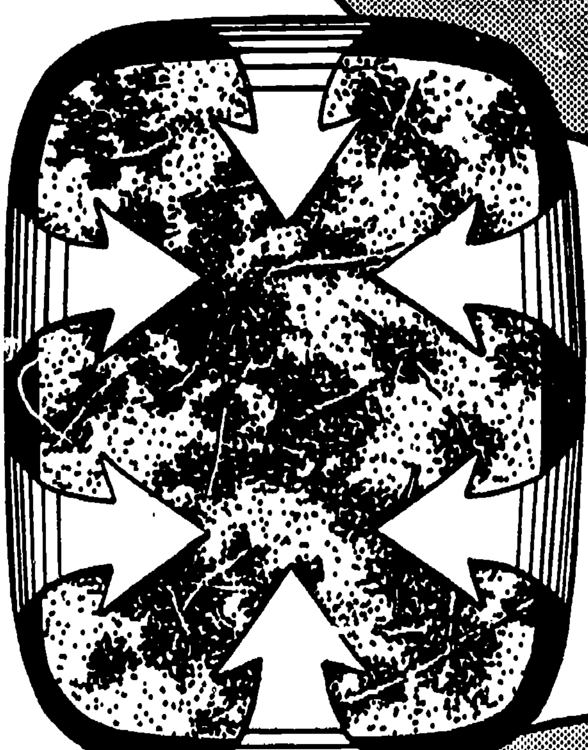
EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Biology; Laboratory Procedures; Microbiology; Post Secondary Education; *Sludge; *Training Methods; Waste Disposal; *Waste Water; *Water Treatment
IDENTIFIERS *Aerobic Digestion; Unit Processes

ABSTRACT

This unit on aerobic sludge digestion covers the theory of the process, system components, factors that affect the process performance, standard operational concerns, indicators of steady-state operations, and operational problems. The instructor's guide includes: (1) an overview of the unit; (2) lesson plan; (3) lecture outline (keyed to a set of slides designed for use with the unit); (4) narrative for the slide program; (5) overhead transparency masters; (6) student worksheet (with answers); and (7) two copies of a final quiz (with and without answers). (JN)

Biological Treatment Process Control

Aerobic Digestion



Instructor's Guide

Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL PROCESS TREATMENT CONTROL

AEROBIC DIGESTION

INSTRUCTOR'S GUIDE

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Developed Under:
EPA Grant #T901238
1984

AEROBIC DIGESTION

Instructor's Guide

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AEROBIC DIGESTION

Overview of Lesson

This unit on aerobic sludge digestion covers the theory of the process, the system components, factors that affect the process performance, standard operational concerns, indicators of steady-state operations and operational problems. Much of the material in this unit was developed as part of a project funded by EPA and created by LBCC on solids handling processes. An audio tape is available to accompany the slide program. A written text of the narrative is included in this instructor's guide. The audio tape can be obtained from EPA or from LBCC, Water/Wastewater Department, 6500 SW Pacific Blvd., Albany, Oregon 97321.

Lesson Plan

- Have student read text material ahead of time, if possible.
- Lecture from outline with slide support (about 45 min)
- Or use the audio tape (if obtained) with slides (about 25 min)
- Assign worksheet (15 min)
- Correct and discuss worksheet (15 - 20 min)
- Assign final quiz (15 min)

AEROBIC DIGESTION

Lecture Outline

Slide #	
#1 & #2	Title and Credit Slides
	The Aerobic Digestion Process
#3 & #4	Part of sludge management system
#5	A modification of the activated sludge process
#6	Biological stabilization of primary and secondary sludges
	Components
#7	Mechanical aerator
#8	Diffused Air
#9	(Floating mechanical aerator used in this lesson)
#10	Piping around the basin
	Sludge feed
	Sludge withdrawal
	Tank drain
	Supernatant draw off
#11	Decant mechanism
#12	Concern about Side Stream Flows
	High BOD and suspended solids
#13	Normal Sequence of Operations
	Normally a continuous cycle of aeration and feed, shut down, settling, decanting
#14	Performance Factors - Outline
#15	Performance Factors

#16 Sludge type

- Very little control
- Aeration in absence of feed
- Biomass breaks down to carbon dioxide and water

#17, #18, #19 Digestion Time

- Digester volume divided by sludge flow
- Low flow means long detention time
- High flow means short detention time

#20
- Thick sludge requires longer digestion time

#21 Digestion Temperature

- Two-fold increase in biological activity for each 10 degrees Celcius
- Optimum temperature is 18 degrees Celcius

#22
- Colder temperatures require longer detention times

#23 Volatile Solids Loading - Outline

#24
- Lbs per day per cubic ft
- 0.07 to 0.20 lb/day/cu ft

#25
- VSS loading influenced by concentration and volume of sludge flow

#26
- Loadings influenced by sludge type and temperature

#27 Air Requirements

#28
- 1 → 2 mg/l

#29
- Vary depending upon sludge type, temperature, concentration, and biological activity

Oxygen Uptake Rates

#30 Best measured with a portable probe at several locations

#31 Oxygen uptake is the dissolved oxygen consumed by the bacteria

#32 Typical oxygen uptake testing equipment

#33 Uptake rate decreases as sludge becomes more stabilized.

#34 Odor

Should be relatively odor free

#35 Foam

Several inches thick, dark tan greasy color

#36 Standard Operations - Outline

#37 Monitoring Regularly

Influent and effluent

SS

VSS

pH

Basin contents

D.O.

Temperature

#38 Monitoring Intermittently

Influent and effluent

Alkalinity

COD

Nitrogen

Typical Performance

#39 Digestion time

Pri Sludge 15-20 days
Sec Sludge 10-15 days

#40 VSS loading

Pri & Sec Sludges
0.08-0.20 VSS/Cu ft/day

#41 % VSS destruction

Pri - 25-50%
Sec - 25-40%

#42 Indicators of Steady State Operation

Constant oxygen uptake rate and residual D.O.

#43 A change from the normal balance may be caused by:

- equipment
- influent
- mode
- temperature

#44 If D.O. increases, excess air may be present.

#45 & #46 If uptake rate is normal, then biomass is OK and D.O. increase is probably due to too high aeration rate; reduce to 1-2 mg/l

#47 & #48 If uptake rate is low, something is inhibiting biomass; check temperature and ph

#49 Best pH operating range: 6 - 8

#50 If D.O. drops, increase air discharge

#51 & #52 If high uptake rates also noted, VSS loading may be high; monitor carefully, check temp., pH, and digestion time; increase air

#53 & #54 Excess flows may reduce digestion time and increase VSS loading

#55 Foaming Problems

#56 Check air; if D.O. high may be excessive turbulence

#57	Low D.O. is conducive to filamentous bacteria
#58	Check incoming sludge characteristics, excess air, filaments
#59	Keep good records
#60	Summary Slide

Narrative

Slide #

1. This module covers aerobic digestion. The module covers the equipment and theory of the process and reviews the factors affecting process operation.

2. The module was written by Mr. Paul H. Klopping. The instructional development was done by Priscilla Hardin. Mr. Klopping was also the Project Director.

3. The main purpose of aerobic digestion is the stabilization of sludge organics.

4. At the same time, the mass and volume of sludge is reduced and the sludge is conditioned for further solids handling.

5. Aerobic digestion is an application of the activated sludge process in which the digester is operated with an extended aeration time.

6. Primary sludge, secondary sludge and mixtures of the two can be aerobically digested. Most commonly, however, aerobic digesters are used to stabilize secondary sludge.

7. An aerobic digester is simply a tank equipped with an air supply much like an aeration basin. Air is typically introduced by mechanical means such as a floating surface aerator

8. or compressed air is introduced through a diffuser mechanism.

9. This module will feature a mechanical aerator; operational principles are the same, regardless of the type of aeration system.

10. Important components of the aerobic digester include piping for sludge feed, for supernatnat draw-off, for sludge withdrawal, and for tank drain.

11. Supernatant draw-off is called decanting. The supernatant that is decanted from the digesting sludge is returned to the headworks of the plant.

12. The digester supernatant is a sidestream containing BOD and suspended solids which influences operation of the entire treatment plant when it is returned to the headworks.

13. Most digesters operate on a continuous cycle. The digester may receive sludge continuously or for a portion of the day. When the digester is full, the air supply is shut off for several hours, during which time sludge settles leaving a clear supernatant. This is then decanted back to the headworks, making room in the digester for more sludge.

14. Aerobic Digestion is influenced by a number of performance factors. These include: sludge type, digestion time, digestion temperature, volatile solids loading, quantity of air supplied, and dissolved oxygen concentrations in the digester.

15. "Sludge type" refers to the influent characteristics of the solids sent to the digester for stabilization. Very little control can be exerted over the chemical and biological composition of this sludge.

16. Digesters typically handle secondary sludges which are composed primarily of biological cells produced in the activated sludge or trickling filter processes. This biological sludge is aerated, in the absence of a food supply, in the digester. The biological matter partially breaks down to carbon dioxide and water, with a net decrease in sludge mass.

17. Digestion time is determined by the rate of sludge flow into the digester, which has a known volume.

18. As the flow to the digester increases.

19. Digestion time is calculated according to the following formula:

$$\text{Digestion time, days} = \frac{\text{Digester volume, gal}}{\text{Sludge Flow, gal/day}}$$

20. The degree to which sludge is thickened prior to being fed into the digester has an effect on the digestion time.

21. Temperature also has a significant effect on sludge digestion. As a general rule, biological activity increases two-fold for every 10^{o} Celcius rise in temperature. Aerobic digesters work best at temperatures above 18^{o} Celcius.

22. Most digesters are unheated. Detention time must be increased during cold weather. As weather warms up, stabilization occurs more rapidly and less digestion time is required.

23. Volatile solids loading is a measure of the quantity of organic material applied to the digester.

24. Volitile Sludge Solids or VSS loadings typically range from 0.07 lb to 0.02 lb/day/cu ft.

25. Volatile sludge solids loading is influenced by the concentration and volume of sludge placed in the digester.

26. Loadings are unique for each facility, and are influenced by the type of sludge and digestion temperature.

27. The quantity of air required for digestion is expressed as cfm of air/1000 cu ft of digester volume, or as horsepower per 1,000 cu ft when mechanical aerators are used.

28. The air requirements are governed by the need to keep the contents of the tank completely mixed and maintain a dissolved oxygen concentration of 1-2 mg/l in all parts of the tank.

29. Air requirements vary from time to time, depending on the sludge type, temperature, concentration and activity of the digesting sludge.

30. Dissolved oxygen is best measured with a portable DO probe. Measurements should be made at several locations within the tank to insure that at least 1 mg/l of free oxygen is present in all locations.

31. DO measurements are also useful in determining the activity of the microorganisms within the digester. In this case, oxygen uptake measurements are made.

32. The oxygen uptake determination requires the use of a sealed container into which a DO probe and a mixer are inserted. Typically, a BOD bottle, magnetic stirrer and DO probe are used.

33. The oxygen uptake rate decreases as the sludge becomes more stabilized.

34. Like any well-operating aerobic biological system, the digester should be relatively free of obnoxious odors. Some foul odors may be present immediately after aeration is resumed following the time when aerators were off for decanting supernatant.

35. The surface typically accumulates a small amount of foam. This foam is usually several inches thick, and has a dark tan greasy appearance.

36. Standard operation includes feeding sludge to the digester on as continuous a basis as possible and monitoring the process. The test results are the basis for good process control.

37. Regular laboratory analysis on the influent and effluent streams should include: suspended solids, volatile suspended solids, and pH. Dissolved oxygen concentrations and temperature if the digesting sludge should be monitered daily.

38. On an intermittent basis, the influent and effluent streams should be sampled for alkalinity, total and soluble COD, ammonia-nitrogen, nitrite and nitrate nitrogen.

39. Typical performance is summarized in the next three slides. Both primary and secondary sludges can be aerobically digested. Primary sludge requires a longer digestion time than secondary sludge because the organic solids found in primary sludge are more difficult to break down under aerobic conditions.

40. Loading is based on the pounds of volatile solids being sent to the digester and the size of digester in cubic feet. Loading rate is similar for primary and secondary sludges.

41. Volatile solids destruction is slightly greater for primary sludge.

42. When an aerobic digester reaches steady state, the oxygen uptake rate and the residual DO should be relatively constant from day to day.

43. However, aerobic digesters are subject to the same upsets which affect all biological systems. These may be caused by equipment malfunctions, changes in influent characteristics, changes in operating modes and changes in temperature. Good indicators, especially in times of upset, are the dissolved oxygen measurements and the oxygen uptake determinations.

44. If the residual DO increases significantly, this may suggest that the air rate is excessive or the oxygen uptake rate has decreased indicating the microorganisms are less active.

45. If the uptake rate is in the normal range, then the microorganisms are working properly and the increase in DO is most likely due to high air rates to the digester.

46. Air discharge rates should be adjusted to maintain a DO of 1-2 mg/l.

47. If the oxygen uptake rate is significantly lower than normal, something may be inhibiting the microorganisms. Temperature and pH should be checked. Significant decreases in temperature and pH are inhibitory.

48. If temperature is normal and the pH drops, the cause may be nitrification or changes in the influent sludge characteristics.

49. When caused by nitrification, the decrease in pH will be gradual over about a week's time. pH should not be allowed to drop much below 6.0.

50. If the DO residual drops significantly, air discharge rate should be adjusted to increase the residual DO to 1-2 mg/l.

51. If higher than normal oxygen uptake rates are also noted, volatile sludge solids loading rate to the digester may be higher than normal.

52. As long as sufficient air capacity exists to meet air requirements at higher loading rates, the system can still operate, but critical operating parameters should be closely tracked. These include: temperature, pH and digestion time. If low DO exists and the aeration system is operating at full capacity, flow and loading to the digester should be decreased.

53. Excessive sludge flows reduce the time of digestion and may increase the volatile sludge loading to the point where the digester is operating out of the recommended range of operation.

54. Adjustments should be made to the flows and volatile sludge solids loading to bring the operation back within normal ranges.

55. Aerobic digesters are often plagued with foaming problems. If excessive foam develops, air discharge rate and residual DO should be checked.

56. If they are high, the problem may be related to excessive turbulence. The air discharge rate should be reduced to the lowest rate which maintains adequate DO and mixing.

57. Low DO is conducive to filamentous bacterial growth in the digester. This may aggrevate foam problems and reduce the settleability of the sludge, making it difficult to decant supernatant.

58. Foaming problems may also be realted to influent characteristics and defoaming agents may be needed to suppress the foam. In summary, foaming in biological systems can be caused by a variety of conditions and generally constitutes a complex problem.

59. Both the digestion time and volitile sludge solids loading should be maintained within ranges found to be suitable for each particular facility. A review of daily influent and effluent amounts of volatile sludge solids indicates whether or not the digester is efficiently converting organic matter to stabilized end products.

60. Aerobic digesters are a common means of handling excess secondary sludges prior to ultimate disposal. They provide moderate stabilization of biological solids providing that climatic conditions are favorable.

$$\text{DIGESTION TIME}_{\text{DAYS}} = \frac{\text{DIGESTER VOLUME}_{\text{GALS}}}{\text{SLUDGE FLOW}_{\text{GAL/DAY}}}$$

$$\text{V.S.S. LOADING}_{,\ LBS/DAY/FT^3} = \frac{\text{VSS}_{,\ LBS/DAY}}{\text{VOL}_{,\ FT^3}}$$

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

AEROBIC DIGESTION

Answers to Worksheet

1. Aerobic digestion closely resembles the activated sludge wastewater treatment process.

2. Aerobic digestion is used most commonly on secondary sludges.

3. Name four items that govern sludge digestion time in an aerobic digester.

   temperature

   volatile solids loading

   D.O. concentration

   detention time

4. Calculate the digestion time if the digester has a volume of 40,000 gal and the sludge flow to the digester is 3500 gal/day.

$$\text{Dig. Time, days} = \frac{\text{Digester Vol, gal}}{\text{Sludge Flow, gal/day}}$$

$$= \frac{40{,}000}{3{,}500}$$

$$= 11.4 \text{ days}$$

5. When the temperature of a digester increases 10 degrees Celcius, biological activity increases by a factor of 2.

6. If loading stays the same, an aerobic digester will work faster during the (winter or summer)?

7. Calculate the volatile solids loading in lbs per cubic foot of digester per day if the digester volume is 40,000 gal and the total volatile suspended solids added per day is 650 lbs.

$$\text{V.S.S. Loading, lbs/day/ft}^3 = \frac{\text{V.S.S., lbs/day}}{\text{Vol, ft}^3}$$

$$= \frac{650 \text{ lbs/day}}{40{,}000 \text{ gal} \times \text{ft}^3/7.48 \text{ gal}}$$

$$= 0.12 \text{ lbs/day/ft}^3$$

8. A dissolved oxygen residual of ___1.0 - 2.0___ mg/l should be maintained in an aerobic digester to enhance mixing and support aerobic metabolism.

9. Name three daily lab tests that should be performed on the influent and effluent streams.

   pH

   suspended solids

   volatile suspended solids

10. Dissolved oxygen and temperature measurements on the digester contents should be made ___daily___.

11. Name two corrective actions that could be taken in response to high oxygen uptake rates.

   increase air discharge rate

   decrease volatile solids loading

12. A decrease in volatile solids destruction indicates that volatile solids loadings are (increasing or decreasing).

13. Calculate the percent volatile solids reduction if sludge of 12,000 mg/l VSS is fed to the digester and the VSS after digestion is 8000 mg/l.

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

$$= \frac{12{,}000 - 8{,}000}{12{,}000} \times 100$$

$$= 33\%$$

AEROBIC DIGESTION

Final Quiz

Multiple Choice: Choose the best answer (or answers) and place a "X" in front of the corresponding letter(s).

1. Which treatment process does aerobic digestion most closely resemble?

_____ a. Trickling filtration
_____ b. Activated sludge
_____ c. Sedimentation
_____ d. Anaerobic Digestion
_____ e. Disinfection

2. Choose three factors which affect the operation of an aerobic digester.

_____ a. Clarifier overflow rate
_____ b. Volatile solids loading
_____ c. D.O. concentration
_____ d. Detention time
_____ e. Weir overflow rate

3. What governs the digestion time of an aerobic digester?

_____ a. Digester size
_____ b. Rate of sludge feed
_____ c. Rate of sludge withdrawal
_____ d. Rate of supernatant withdrawal
_____ e. None of the above

4. An aerobic digester has a volume of 34,000 cubic feet. Each day, 2,000 lbs of volatile matter is added. What is the volatile solids loading? (Answers are in lbs organic matter per cubic foot of digester capacity.)

_____ a. .01
_____ b. .02
_____ c. .04
_____ d. .06
_____ e. .08

5. What is a good Dissolved Oxygen residual that should be maintained in an aerobic digester to enhance mixing as well as aerobic conditions?

_____ a. 0.5 - 1.0 mg/l

_____ b. 1.0 - 2.0 mg/l

_____ c. 4.0 - 8.0 mg/l

_____ d. greater than 10 mg/l

_____ e. None of the above.

6. Choose three daily lab tests that should be performed on the influent and effluent streamer of a digester.

_____ a. Chlorine residual

_____ b. pH

_____ c. Suspended solids

_____ d. Fecal coliform

_____ e. Volatile suspended solids

7. How often should dissolved oxygen and temperature be measured in operating an aerobic digester?

_____ a. Daily

_____ b. Weekly

_____ c. Monthly

_____ d. Hourly

_____ e. They don't need to be monitored.

8. Choose three causes of biological upset.

_____ a. Maintaining D.O. at 2.0 mg/l

_____ b. Shutting off air for 1-2 hours to decant digester

_____ c. Change in influent characteristics

_____ d. Increase volatile solids loading

_____ e. Temperature drops from $18^{o}C$ to $9^{o}C$

9. If excessively high oxygen uptake rates occur in a digester, choose two corrective actions.

_____ a. Increase volatile solids loading

_____ b. Increase air discharge rates

_____ c. Decrease volatile solids loading

_____ d. Decrease air discharge rates

_____ e. Add raw sludge from the primary clarifier

10. What is the typical foam appearance on an aerobic digester?

_____ a. White, crisp, billowy

_____ b. Black

_____ c. There shouldn't be any foam

_____ d. Dark tan, leathery, greasy

_____ e. Frothy, tan, 2-3 feet deep

11. A decrease in volatile solids destruction indicates that

_____ a. performance is improving

_____ b. performance is approaching biological equilibrium

_____ c. volatile solids loadings are increasing

_____ d. volatile solids loadings are decreasing

_____ e. digestion times have gotten longer

AEROBIC DIGESTION

Answers to Final Quiz

Multiple Choice: Choose the best answer (or answers) and place a "X" in front of the corresponding letter(s).

1. Which treatment process does aerobic digestion most closely resemble?

____ a. Trickling filtration
__X__ b. Activated sludge
____ c. Sedimentation
____ d. Anaerobic Digestion
____ e. Disinfection

2. Choose three factors which affect the operation of an aerobic digester.

____ a. Clarifier overflow rate
__X__ b. Volatile solids loading
__X__ c. D.O. concentration
__X__ d. Detention time
____ e. Weir overflow rate

3. What governs the digestion time of an aerobic digester?

__X__ a. Digester size
__X__ b. Rate of sludge feed
__X__ c. Rate of sludge withdrawal
__X__ d. Rate of supernatant withdrawal
____ e. None of the above

4. An aerobic digester has a volume of 34,000 cubic feet. Each day, 2,000 lbs of volatile matter is added. What is the volatile solids loading? (Answers are in lbs organic matter per cubic foot of digester capacity.)

____ a. .01
____ b. .02
____ c. .04
__X__ d. .06
____ e. .08

5. What is a good Dissolved Oxygen residual that should be maintained in an aerobic digester to enhance mixing as well as aerobic conditions?

____ a. 0.5 - 1.0 mg/l
__X__ b. 1.0 - 2.0 mg/l
____ c. 4.0 - 8.0 mg/l
____ d. greater than 10 mg/l
____ e. None of the above.

6. Choose three daily lab tests that should be performed on the influent and effluent streamer of a digester.

____ a. Chlorine residual
__X__ b. pH
__X__ c. Suspended solids
____ d. Fecal coliform
__X__ e. Volatile suspended solids

7. How often should dissolved oxygen and temperature be measured in operating an aerobic digester?

__X__ a. Daily
____ b. Weekly
____ c. Monthly
____ d. Hourly
____ e. They don't need to be monitored.

8. Choose three causes of biological upset.

____ a. Maintaining D.O. at 2.0 mg/l
____ b. Shutting off air for 1-2 hours to decant digester
__X__ c. Change in influent characteristics
__X__ d. Increase volatile solids loading
__X__ e. Temperature drops from 18°C to 9°C

9. If excessively high oxygen uptake rates occur in a digester, choose two corrective actions.

_____ a. Increase volatile solids loading
__X__ b. Increase air discharge rates
__X__ c. Decrease volatile solids loading
_____ d. Decrease air discharge rates
_____ e. Add raw sludge from the primary clarifier

10. What is the typical foam appearance on an aerobic digester?

_____ a. White, crisp, billowy
_____ b. Black
_____ c. There shouldn't be any foam
__X__ d. Dark tan, leathery, greasy
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11. A decrease in volatile solids destruction indicates that

_____ a. performance is improving
_____ b. performance is approaching biological equilibrium
__X__ c. volatile solids loadings are increasing
_____ d. volatile solids loadings are decreasing
_____ e. digestion times have gotten longer