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ABSTRACT

This manual contains the textual material for a single-lesson unit on aerobic sludge digestion. Topic areas addressed include: (1) theory of aerobic digestion; (2) system components; (3) performance factors; (4) indicators of stable operation; and (5) operational problems and their solutions. A list of objectives, glossary of key terms, and student worksheet are included. (JN)

Biological Treatment Process Control

Aerobic Digestion

Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL PROCESS TREATMENT CONTROL

AEROBIC DIGESTION

STUDENT MANUAL

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AERObIC DIGESTION

Student Manual

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AEROBIC DIGESTION

Objectives

At the end of this lesson you should:

1. Be able to describe, in general terms, the aerobic digestion process.

2. Know that aerobic digestion is an application of the activated sludge process of extended aeration.

3. Know that aerobic digestion is used on primary and secondary sludges, but secondary is more typical.

4. Be able to list 4 of 6 criteria affecting the performance of the digester. Acceptable answers include:

   sludge type
   digestion time
   digestion temperature
   volatile solids loading
   quantity of air supplied
   dissolved oxygen concentrations

5. Know that digestion time is a function of digester capacity (volume) and rate of sludge feed.

6. Know the effect of temperature on digestion is that a two-fold increase in biological activity occurs for every 10°C rise in temperature.

7. Know that aerobic digesters typically operate at ambient temperatures.

8. Know that digestion is faster at warmer temperatures.

9. Be able to state that volatile solids loading is a measure of the quantity of organic matter applied to the digester per cubic foot of digester capacity.

10. Be able to state that the quantity of air required for digestion is used to insure mixing and a D.O. residual of 1-2 mg/l.

11. Know that there are two types of aeration mechanisms, diffused air and mechanical aerators.

12. Be able to list the three daily lab tests to be performed on the influent and effluent streams to be:

    suspended solids
    volatile suspended solids
    pH

13. Know that D.O. and temperature should be measured daily.

14. Be able to describe the use of the D.O. probe for measuring oxygen uptake rates.

15. List 3 of 4 influences which may cause biological upset. The acceptable answers include:

    equipment malfunctions
    changes in influent characteristics
    changes in operating modes
    changes in temperature

16. Be able to state the effect of excessive sludge flows on digestion time and solids loading.

17. Be able to describe the corrective action that should be taken when excessive oxygen uptake rates are experienced to be a reduction in the volatile solids loading and an increased sludge detention time.

18. Be able to describe typical foam characteristics.

19. Be able to describe the effect of low D.O. on filamentous organisms in the digester.

20. Be able to describe a solution to foaming when D.O. control is not effective.

21. Be able to recall that the measure of proper digester function is a decrease in volatile solids content of the sludge.

22. Be able to state that a decrease in volatile solids destruction indicates that either digestion times are too short or volatile solids loadings are too high.

Glossary

Aerator - A structure, round or rectangular, built for the purpose of aerating and mixing activated sludge liquor, (also called a reactor).

Air Diffusers - Devices for breaking up air into fine bubbles of water for the purpose of transferring a part of the oxygen in the air to the liquid surrounding bubble.

Decant - Removing liquid from the top.

Digested sludge - Sludge digested under either aerobic or anaerobic conditions until the volatile content has been reduced to the point at which the solids are relatively nonputrescible and inoffensive.

Dissolved oxygen - Usually designated as D.O. The oxygen dissolved in sewage, water, or other liquid, generally expressed MG/L or percent of saturation.

Headworks - The area of a treatment facility where wastewater is first processed.

Respiration - The physical and chemical processes by which an organism supplies its cells and tissues with oxygen needed for metabolism and relieves them of carbon dioxide formed in energy-producing reactions.

Sidestream - A flow originating within a treatment plant which is piped from one processing area to another. Supernate from a digester, when returned to the headworks, is a "sidestream." Sidestreams must be measured to account for their BOD, TSS and quantity.

AEROBIC DIGESTION

*Modification of activated sludge process

Aerobic digestion is the process of converting sludge organics to stable end products. In the digestion process, the mass and volume of sludge is reduced and the sludge is conditioned for further solids handling. Aerobic digestion is an application of the activated sludge process in which the digester is operated in an extended aeration mode. Primary sludge, secondary sludge and mixtures of the two can be aerobically digested. Most commonly, however, aerobic digesters are used to stabilize secondary sludge.

*Biological stabilization of secondary sludge

COMPONENTS

*Aeration mechanism
. . . Mechanical
. . . Diffused Air

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 or compressed air is introduced through a diffuser mechanism. This module will feature a mechanical aerator; operational principles are the same, regardless of aeration system.

*Decant mechanism

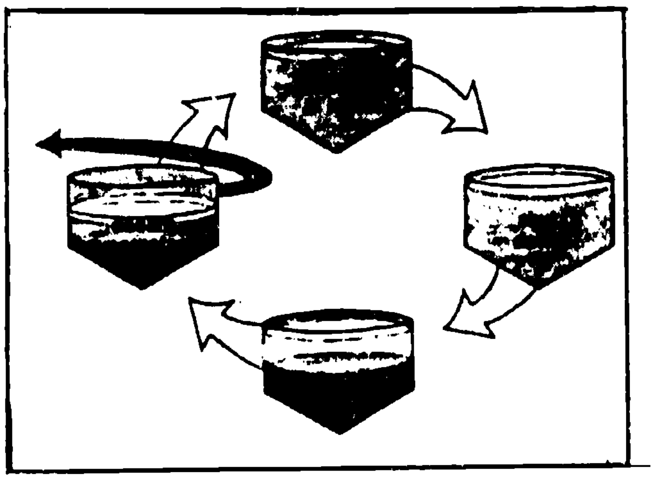
Other features of the aerobic digestor include piping for sludge feed, removal of supernatant and tank drain. A decant mechanism separates supernatant from the digesting sludge and returns it to the headworks of the plant.

*Sidestream
. . . BOD
. . . Suspended Solids

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.

Most digesters operate on a continuous cycle. The digester may receive sludge continuously or for a portion of the day. When the digester is

NORMAL SEQUENCE OF OPERATIONS



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.

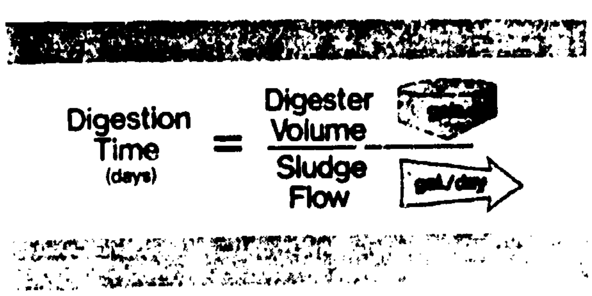
Aerobic Digestion is influenced by a number of factors. These include:

(1) Sludge Type
(2) Digestion Time
(3) Digestion Temperature
(4) Volatile Solids Loading
(5) Quantity of Air Supplied
(6) Dissolved Oxygen Concentrations in the Digester

PERFORMANCE FACTORS

*Sludge Type

"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. 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 biomass partially breaks down to carbon dioxide and water, with a net decrease in sludge mass.

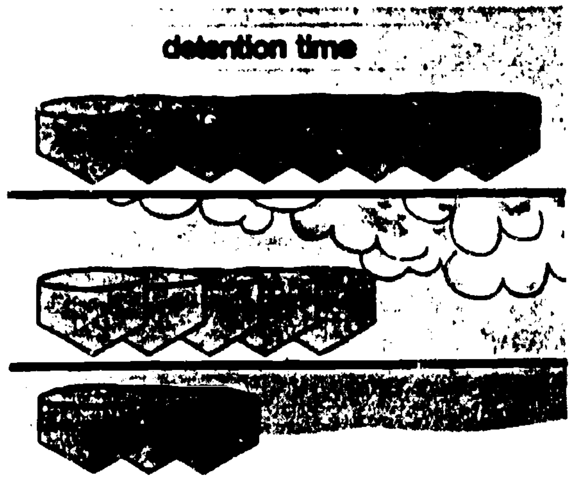


Digestion time is determined by the rate of sludge flow into the digester, which has a known volume. As the flow to the digester increases, the time allowed for digestion decreases. Digestion time is calculated according to the following formula:

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

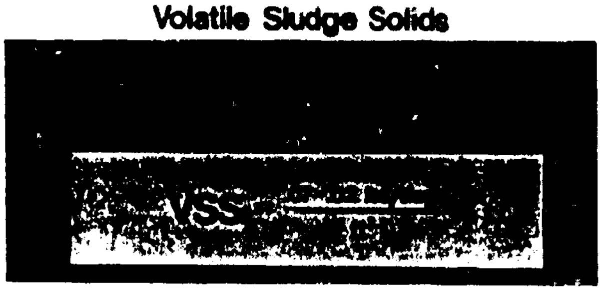
The degree to which sludge is thickened prior to being fed into the digester has an effect on the digestion time.

*Effect of Temperature



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

Volatile Sludge Solids



Volatile solids loading is a measure of the quantity of organic material applied to the digester. Volatile Sludge Solids (VSS) loadings typically range from 0.07 lb to 0.20 lb VSS/day/cu ft. Volatile sludge solids loading is influenced by the concentration and volume of sludge placed in the digester. Loadings are unique for each facility, and are influenced by the type of sludge and the temperature.

*Air Requirements
. . . D.O. 1-2 mg/l

The quantity of air required for digestion is expressed as cfm air/1000 cu ft of digester, or as horsepower per 1,000 cu ft when mechanical aerators are used. 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. Air requirements vary from time to time, depending on the sludge type, temperature, concentration and activity of the digesting sludge.

*Oxygen Uptake Rate

How fast are the bugs breathing?

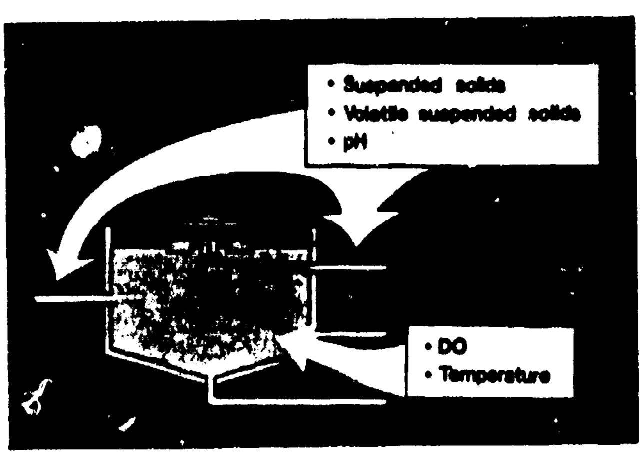
Dissolved oxygen is best measured with a portable DO probe. Measurements should be made at several locations within the tank to insure that at least 1 mg/l of free oxygen is present in all locations. DO measurements are also useful in determining the activity of the biomass within the digester. In this case, oxygen uptake measurements are made. 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.

The oxygen uptake rate decreases as sludge becomes more stabilized.

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.

*Foam

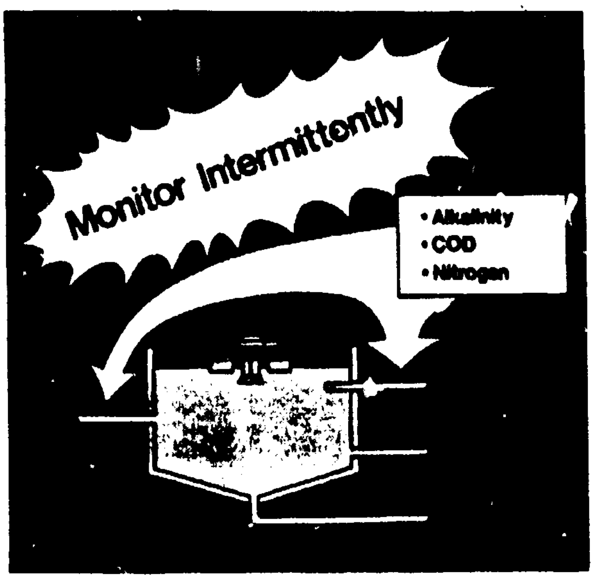
The surface typically accumulates a small amount of foam. This foam is usually several inches thick, and has a dark tan greasy appearance.



Sludge should be fed to the digester on as continuous a basis as possible and monitored. The test results are the basis for good process control. Regular laboratory analysis on the influent and effluent streams should include:

(1) Suspended solids
(2) Volatile suspended solids
(3) pH

Dissolved oxygen concentrations and temperature



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

Typical performance is summarized in the following table:

Typical Performance			
Sludge Type	Digestion Time(days)	Volatile Sus. Solids Loading lb VSS/cu ft/day	% V.S.S. Destruction
Primary	15 - 20	.08-.20	25-50
Secondary	10 - 15	.08-.20	25-40

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.

LOADING
*VSS/ft^3/day

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. Volatile solids destruction is slightly greater for primary sludge.

INDICATORS OF STABLE OPERATION

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

MONITOR D.O.

If the residual DO increases significantly, this may suggest that the air rate is excessive or the oxygen uptake rate has decreased indicating the biomass is less active. If the uptake rate is in the normal range, then the biomass is working properly and the increase in DO is most likely due to high air rates to the digester. Air discharge rates should be adjusted to maintain a DO of 1-2 mg/l. If the oxygen uptake rate is significantly lower than normal, something may be inhibiting the biomass.

WATCH OXYGEN UPTAKE RATE

Temperature and pH should be checked. Significant decreases in temperature and pH are inhibitory. A decline in the pH may be caused by nitrification or changes in the influent sludge characteristics. 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.

DROPPING D.O.?

If the DO residual drops significantly, air discharge rate should be adjusted to increase the residual DO to 1-2 mg/l. If higher than normal oxygen uptake rates are also noted,

EXCESSIVE LOADING?

volatile sludge solids loading rate to the digester may be higher than normal. 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 operating at full capacity, flow and loading to the digester should be decreased.

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

FOAMING PROBLEMS?

Aerobic digesters are often plagued with foaming problems. If excessive foam develops, air discharge rate and residual DO should be checked. If they are high, the problem may be related to excessive turbulence. The air discharge rate should be reduced to the lowest rate which still maintains adequate DO and mixing. Low DO is conducive to filamentous bacterial growth in the digesting sludge which may aggrevate foam problems and reduce the settleability of the sludge, making it difficult to supernate the digester. If reducing air discharge doesn't control foaming, check influent characteristics as a possible cause.

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

KEEP GOOD RECORDS!

Both the digestion time and volatile 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 volatile (organic) matter to stabilized end products.

Keep the bugs happy!

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.

References

Process Design Manual for Sludge Treatment and Disposal, U.S.E.P.A., September 1979, EPA 625/1-79-011.

Sludge Treatment and Disposal; Aerobic Digestion, U.S.E.P.A. Course #166, 1980.

Operation of Wastewater Treatment Plants, MOP 11, WPCF, Lancaster Press, 1976.

AEROBIC DIGESTION

Worksheet

1. Aerobic digestion closely resembles the ________________ wastewater treatment process.

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

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

   ____

   ____

   ____

   ____

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.

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

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.

8. A dissolved oxygen residual of ____________ 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.

____

____

____

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

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

____

____

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.