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ABSTRACT

This lesson is the first of a two-part series on anaerobic digestion. Topics discussed include the five basic functions of an anaerobic digester, basic theory of the biological processes involved, basic equipment necessary for digestion, and the products of digestion. The lesson includes an instructor's guide and student workbook. The instructor's guide contains a description of the lesson, estimated presentation time, instructional materials list, suggested sequence of presentation, reading lists, objectives, lecture outline, narrative of the slide/tape program used with the lesson, and student worksheet (with answers). The student workbook contains plant flow diagrams, objectives, glossary, discussion material, references, and worksheet. Discussion material is presented in four sections titled: digester function, basic equipment, theory--"the basics," and by-products of digestion. (JN)

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SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

ANAEROBIC DIGESTION I

ED230396

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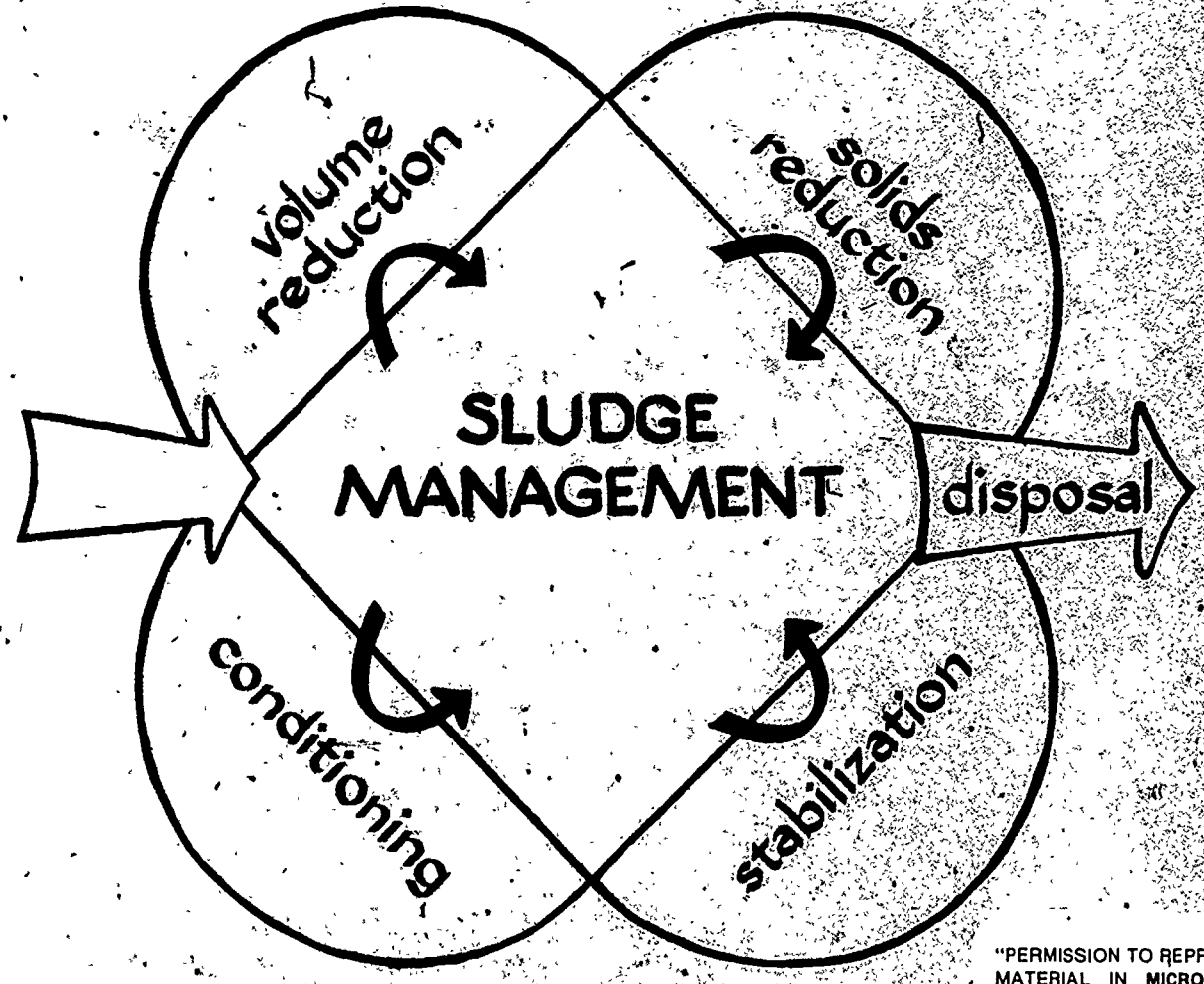

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INSTRUCTOR'S GUIDE

Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

ERIC

ANAEROBIC DIGESTION I

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Developed Under:
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ANAEROBIC DIGESTION I

CONTENTS

ANAEROBIC DIGESTION I

Lesson Description

This lesson is Part I of a two-part series on anaerobic dibestion. Part I must be shown before Part II. This lesson discusses the five basic functions of a anaerobic digester, the basic theory of the biological process, the basic equipment necessary for digestion and the products of digestion.

Estimated Time

Student preview of objectives	10-15 minutes
Presentation of material	30-60 minutes
Worksheet	10 minutes
Correct worksheet and discussion	10-15 minutes

Instructional Materials List

1. Student text "Anaerobic Digestion, Part I."
2. Slide set "Anaerobic Digestion, Part I."
3. Slide projector.
4. Auto-sync. cassette tape player.
5. Screen.
6. Samples of digested sludge, raw sludge, supernatant and scum.

Suggested Sequence of Presentation

1. Assign reading - emphasis on flow diagrams, glossary and objectives.
2. Show slide tape program or lecture using the slides presentation.
3. Open discussion; concentrate on the appearance of sludge, supernatant, etc.
4. Assign work sheet.
5. Correct work sheet.

Required Reading

Lesson - "Anaerobic Digestion, Part I."

Reference Reading

Operations Manual, Anaerobic Sludge Digestion, pages 4-4 through 4-8.

Objectives

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

1. Describe the five major functions of anaerobic digestion.
2. Identify the following basic equipment: tank, heat exchanger, boiler, mixing system, gas collection, and removeal system.
3. Define in nontechnical terms the meaning of volatility of sludge.
4. Recall the number of steps involved in anaerobic digestion.
5. Recall the major products of the first stage of digestion.
6. Recall the major products of the second stage of digestion.
7. Recall the most acceptable pH range for anaerobic digestion.
8. Recall the name of the top layer of material in a digester.
9. Recall the approximate concentration of by-products of digestion on S.S. in anaerobic digestion supernatant.
10. Describe the color and odor of digested sludge.
11. Recall the percent volatile reduction that could be expected in an anaerobic digester.
12. Recall the optimum percent methane in digester gas.
13. Recall the approximate quanity of digester sludge produced for each one lb. of volatile solids reduced.
14. Compare the BTU value of digester gas to commercial gas.
15. Describe three uses of digester gas.
16. Recall that digester gas is explosive, corrosive and can cause physiolocal damage.
17. Recall the basic purposes of the anaerobic digestion process withing the confines of an overall solids management system.

ANAEROBIC DIGESTION I
LECTURE OUTLINE

I. Types of Sludges Produced in Sewage Treatment:

- A. Primary Clarification.
  - 1. Raw sludge.
  - 2. Organic and inorganic.
- B. Biological.
  - 1. Trickling filters.
  - 2. Activated sludge.
  - 3. Organic sludge.
- C. Chemical Precipitation.
  - 1. Lime precipitation.
  - 2. Inorganic.

II. Nature of Sludge - Reasons for Treatment.

- A. Offensive Odors.
  - 1. P.R.
- B. Degrade Water Sources.
  - 1. High BOD and S.S.
- C. High Moisture Content.
  - 1. Difficult to handle

III. Basics of Digestion.

- A. Place Sludges in Sealed Container.
  - 1. Promotes anaerobic digestion.

B. Accomplishments.

1. Solids reduction.

2. Conditioning.

C. Five Basic Functions

1. Stabilizes volatile content.

2. Reduces the mass.

3. Results - reduces offensive odors.

4. Results - reduces pathogenic organisms.

5. Conditions.

D. Results

1. Useful gas.

2. Easily handlable sludge.

3. Supernatant.

a. impair system.

b. improve system.

IV. Mechanical Equipment.

A. Basic Equipment.

1. Tank

2. Inlet and outlet valves and piping.

3. Heat exchanger.

a. boiler.

4. Mixing system.

5. Gas collection and removal.

V. Biological Process.

A. Food.

1. Volatility.

a. food value.
b. quality.

2. Volatility varies.

a. industry type.
b. industry number.
c. sludge use.

B. Two-Step Process.

1. Acid formers - stage 1.

a. convert V.S. to V.A.

2. Methane formers - stage 2.

a. convert V.A. to methane, CO_2 and water.
b. by-product buffer = alkalinity.
c. need controlled environment.

1) pH 6.8-7.2

VI. By-Products of Digestion.

A. Scum.

1. Grease

2. Petroleum products, rubber goods, plastic, hair, grit, ect.

3. Two to 15 feet deep.

a) Thickness relative to mixing efficiency.

4. Reduces efficiency.

B. Supernatant.

1. Fluid from sludge and organisms.
2. By-products of digestion (B.O.D.) 1000 to 10,000 mg./l.
3. S.S. 5000 to 15,000 mg./l.
4. Prevent supernatant overflow to plant.

C. Digested Sludge.

1. Physical appearance.
   a. black.
   b. no green or gray streaks.
2. 40 to 60% less volatile material.
3. Dewater easily.
4. No noxious odor.
5. Disposal.
   a. land application.
   b. land fill.
   c. incineration.

D. Gas

1. 65-70% methane.
2. 12-18 $ft.^3$/ 1 lb. of volatile solids reduced.
3. BTU 600-800/$ft.^3$.
4. BTU commercial 1000-1100/$ft.^3$.
5. Explosive.
6. Corrosive.
7. Physiological damage.

8. Uses - energy producer

   a. fire boiler.
   b. heat building.
   c. internal combustion engines.
   d. mix sludge.

VII. Summary

A. Sources of Sludge.

   1. Raw.

   2. Biological.

   3. Chemical.

B. Reasons for Treatment.

   1. Odors.

   2. Prevent degradation of water sources.

   3. Reduce moisture content.

C. Basic Functions.

   1. Stabilization.

   2. Reduction of mass.

   3. Reduction of odor.

   4. Reduction of pathogenic organisms.

   5. Conditioning.

D. Biological Process.

   1. Two groups of organisms.

      a. acid formers.
      b. methane formers.

E. Basic Components.

1. Tank and piping.
2. Boiler, heat exchange.
3. Mixers.
4. Gas system.

Narrative

Slide #

1. Anaerobic digestion - Part I of a two-part series on the basic theory and operation of anaerobic digesters. The two parts should be viewed consecutively.

2. This program was written by Mr. E. E. "Skeet" Arasmith. The instructional development was done by Priscilla Hardin. Mr. Paul Klopping was the project manager.

3. Wastewater treatment facilities may produce one or more of the following sludges: raw, biological, or chemical.

4. Primary clarification yields a product referred to as raw sludge. This raw sludge contains both organic and inorganic material.

5. Biological processes such as activated sludge and trickling filters produce biological, organic sludges.

6. Chemical precipitation, such as phosphorous removal by lime precipitation, produces an inorganic chemical sludge.

7. Both organic and inorganic sludges contain material which if not treated could cause offensive odors and degrade any water source they enter. They also have a high moisture content which makes them difficult to handle.

8. By placing these sludges in a sealed container and controlling the environment, anaerobic digestion can be promoted.

9. In the overall sludge management program, anaerobic digestion accomplishes volume reduction, solids reduction, stabilization, and some conditioning. More specifically, digestion serves five purposes:

10. It further stabilizes the volatile content or biological food value of the sludge, thereby reducing the mass.

11. As a result, digestion reduces odors, reduces the total number of pathogens, and conditions the sludge so that it can be more easily dewatered.

12. This digestion process produces useful gas and an easily handled and useful sludge. It also generates a recycle sidestream called a supernatant, which can impair or improve the biological action of some secondary waste treatment systems.

13. Naturally, the process of sludge treatment requires certain mechanical equipment. The anaerobic digester equipment can be divided into four categories. First, a covered tank and related inlet and outlet valves and piping.

14. Second, a heat exchanger and boiler to heat the sludge and optimize the digestion process by maintaining a constant temperature.

15. In this view the boiler is shown behind the heat exchanger which is painted blue.

16. The third category is a mixing system to speed the digestion process and

17. from it a gas collection and removal system.

18. All of this equipment is used to reduce the volatility of the sludge. It could be said that the volatility of the sludge is an indication of the food value and indirectly a measure of the quality of the sludge.

19. This volatility, which is directly related to the organic content of the sludge, will vary with sludge age and the nature and number of industries on line.

20. The process of anaerobic digestion is carried oh by two interdependent groups of organisms. The acid formers produce by-products needed for the survival of the methane formers. The methane formers complete the process of anaerobic digestion and contribute to the environment required for the survival of the acid formers.

21. During the first stage of this process, volatile solids are converted to various by-products. The most important of these are volatile acids.

22. In the second stage of digestion, a group of methane forming bacteria use the volatile acids as food to produce methane, CO_2, and other by-products.

23. One of the results of these by-products is the production of acid buffering and neutralizing materials, commonly referred to as alkalinity.

24. The methane producers are extremely fragile. To keep them alive, a balance must be maintained between the methane formers and the amount of acid present.

25. A balance between the volatile acids and the alkalinity must be achieved in order to maintain an acceptable pH range of between 6.8 and 7.2.

26. As the volatile solids within the digester are stabilized, several zones develop. They include gas, scum, supernatant and sludge.

27. The scum is caused by rising gas lifting floatable materials to the top of the liquid level. The majority of the scum is grease but the scum also contains rubber goods, plastic, hair, grit and filter tips.

28. This scum which may vary from 2 to 15 ft, depending upon the degree of mixing, reduces mixing, and concentrates the food supply, thus, reducing the efficiency of the digestion process.

29. The supernatant consists of fluid that was pumped into the digester as part of the sludge and water from organisms that have died.

30. Typically, supernatant BOD strength may range from 1,000 to 10,000 mg/l with a S.S. concentration of 5,000 to 15,000 mg/l. Returning this material to the head works or primary influent of a conventional activated sludge facility may cause plant upset.

31. From an operational standpoint, it would be desirable to prevent this supernatant overflow to the system. This can be accomplished with proper sludge drawoff rates.

32. As the sludge is digested, it must be removed from the digester. This digested sludge should, upon withdrawal, be checked for physical appearance. The color should be black and contain no green or gray streaks. The presence of green or gray streaks is indicative of undigested sludge.

33. Digested sludge should contain 40 to 60% less volatile matter than the incoming sludge and. . .

34. should dewater easily and not have a noxious odor.

35. The anaerobically digested sludge must ultimately be disposed of. Common methods of disposal of this sludge are dependent upon local conditions and may include land application, land fill, and incineration.

36. One of the beneficial by-products of the anaerobic digester is a usable gas.

37. This gas is a combination of methane, carbon dioxide, and water vapor. Normally, the gas is 65 to 70% methane. Methane is a combustible gas that can be used as a fuel source.

38. Let's take a closer look at this gas. For each pound of volatile material that is digested by the microorganisms, 12 to 18 cubic feet of gas are produced.

39. This gas has a BTU value of 600 to 800 BTU's per cubic foot. By comparison, commercial gas ranges from 1,000 to 1,100 BTU's/ft.^{3}

40. Digester gas is very explosive, can cause physiological damage if inhaled, and is extremely corrosive due to the presence of sulfides within the gas.

41. The methane portion of the digester gas can be used to fire a boiler for heating the digester,

42. heat the treatment plant buildings,

43. operate internal combustion engines to power blowers and electrical generators,

44. and used to mix the digesting sludge.

45. In summary, let's take a look at what we have discussed in this lesson. We discussed the three sources of sludge; raw, biological, and chemical.

46. We discussed the three reasons for treatment. They are to reduce offensive odors, to prevent degradation of water sources and to reduce high moisture content in the sludge.

47. Then we looked at the five functions of the digestion system; further stabilization, reduction of mass, reduction of odor and pathogenic organisms, and the conditioning of the sludge to help make it dewaterable.

48. We discussed the biological process and the interrelationship between the acid formers and the methane formers and finally. . .

49. We took a quick look at the basic digester components and four of the products of the digestion process.

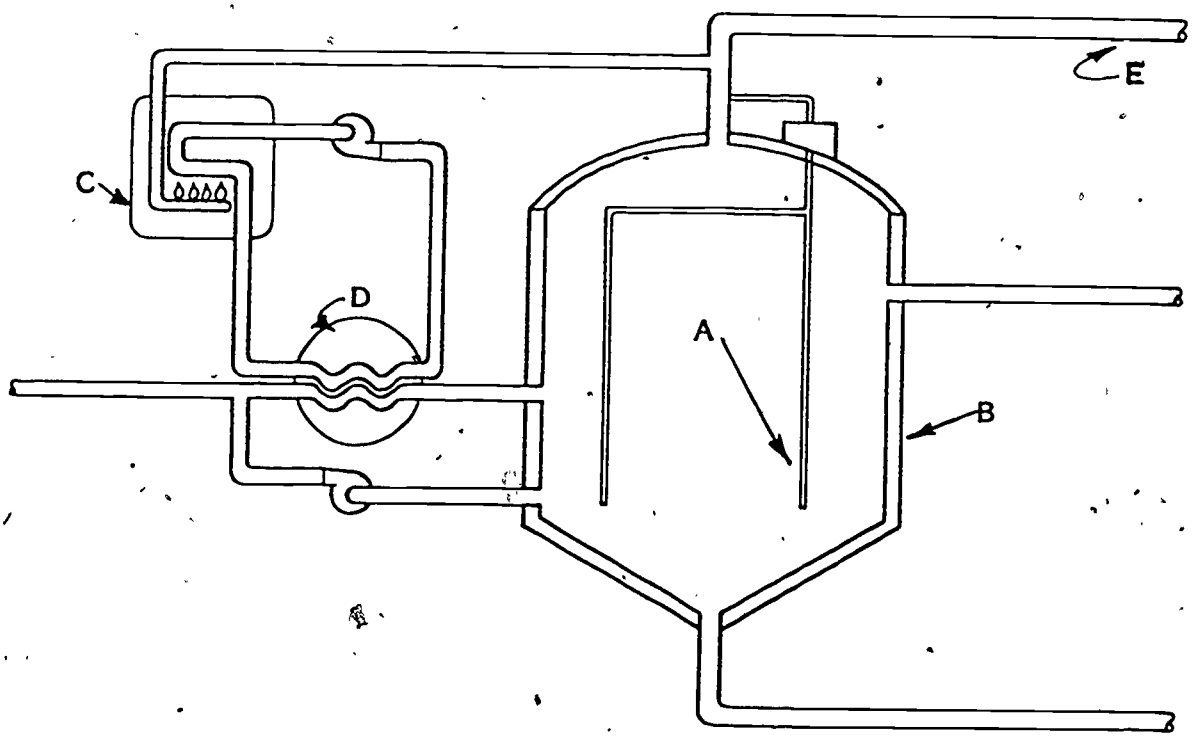
50. In the next lesson, "Anaerobic Digestion II", we will discuss the classification of digestions, the results of temperature control, mixers, the gas system, and basic operational techniques.

SLUDGE TREATMENT AND DISPOSAL

ANAEROBIC DIGESTION

1. Match the letters on the diagram with their descriptions:

E gas collection and removal system
C boiler
A mixing
B tank
D heat exchanger



2. Which of the following are considered valid purposes of anaerobic digestion? (select five)

_____ a. reduce water consumption
_____ b. increase volatile content
__X__ c. reduce volatile content
__X__ d. reduce odor
_____ e. prevent reliquification
_____ f. produce usable gas
__X__ g. reduce mass of sludge
__X__ h. condition sludge
_____ i. improve plant efficiency
__X__ j. reduce numbers of pathogenic organisms

3. The volatility of sludge is an indication of:

_____ a. heat production cababilities.
__X__ b. sludge food value.
_____ c. weight of the sludge.
_____ d. the difference between the weight of the sludge and the weight of an equal volume of water.
_____ e. all of the above..

4. Anaerobic digestion is basically a _____ step process.

_____ a. 4
_____ b. 3
__X__ c. 2
_____ d. 6
_____ e. none of the above.

5. The first stage of digestion converts _____ to _____.

_____ a. volatile solids to methane
_____ b. methane to acid formers
_____ c. volatile acid to methane and CO_2
__X__ d. volatile solids to volatile acids
_____ e. none of the above.

6. During the second stage of digestion there is a conversion of:

_____ a. volatile acids to pH.
__X__ b. volatile acids to methane.
_____ c. volatile solids to volatile acids.
_____ d. microogranisms to food.
_____ e. all of the above.

7. During the second stage of digestion a buffering material is produced. This buffering material is usually called:

__X__ a. alkalinity.
_____ b. CO_2.
_____ c. pH.
_____ d. acid.
_____ e. none of the above.

8. The most acceptable pH range for anaerobic digestion is between:

_____ a. 6.5 and 7.5.
_____ b. 6.4 and 8.4.
__X__ c. 6.8 and 7.2.
_____ d. 5 and 8.
_____ e. none of the above.

9. When a digester contains such items as petroleum products, plastic, rubber goods and etc., these materials may form a layer on the top of a digester. This layer is usually called:

_____ a. upper layer.
_____ b. supernatant.
_____ c. scrapings.
__X__ d. scum blanket.
_____ e. none of the above.

10. The BOD range for digester supernatant would probably run between:

_____ a. 2,500 and 1,000,000 lbs/day.
_____ b. 1,000 and 100,000 mg/kg.
_____ c. 10,000 and 100,000 mg/l.
__X__ d. 1,000 and 10,000 mg/l.
_____ e. all of the above.

11. Supernatant from an anaerobic digester could have a S.S. level between:

X a. 5,000 and 15,000 mg/l.

____ b. 500 and 1,500 mg/l

____ c. 500 and 1,500 kg/g.

____ d. 500 and 15,000 kg/l.

____ e. none of the above.

12. A description of properly digested sludge might be:

____ a. green and contain black and gray streaks.

____ b. gray and contain streaks of black and dark green.

X c. black and contain no green or gray streaks.

____ d. black and contain a few green or gray streaks.

____ e. none of the above.

13. The volatility of properly digested sludge should be reduced by:

____ a. 20 - 40%.

X b. 40 - 60%.

____ c. 60 - 80%.

____ d. 50 - 70%.

____ e. none of these.

14. If the digester is operated properly, the gas production will usually contain methane at:

X a. 65 - 70%.

____ b. 40 - 65%.

____ c. 30 - 40%.

____ d. 70 - 80%.

____ e. none of these.

15. For each 1 pound of volatile material that is reduced by digestion gas is produced. The approximate volume produced for each pound would be:

____ a. 12 - 18 mg/l.

____ b. 12 - 18 kg.

____ c. 12 - 18 cubic yards.

X d. 12 - 18 cubic feet.

____ e. none of the above.

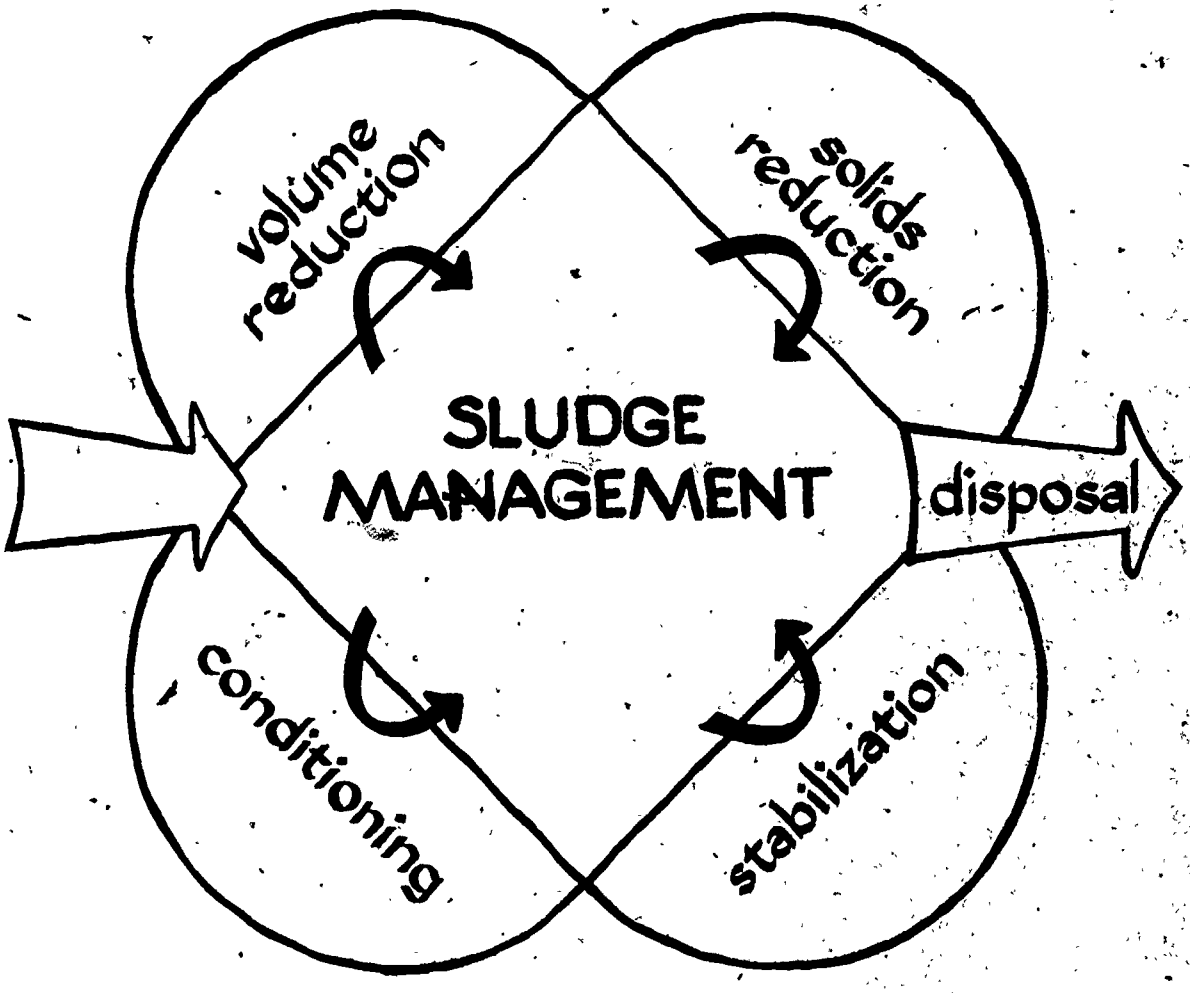
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

ANAEROBIC DIGESTION I



STUDENT WORKBOOK

Prepared by
Linn-Benton Community College
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ANAEROBIC DIGESTION I

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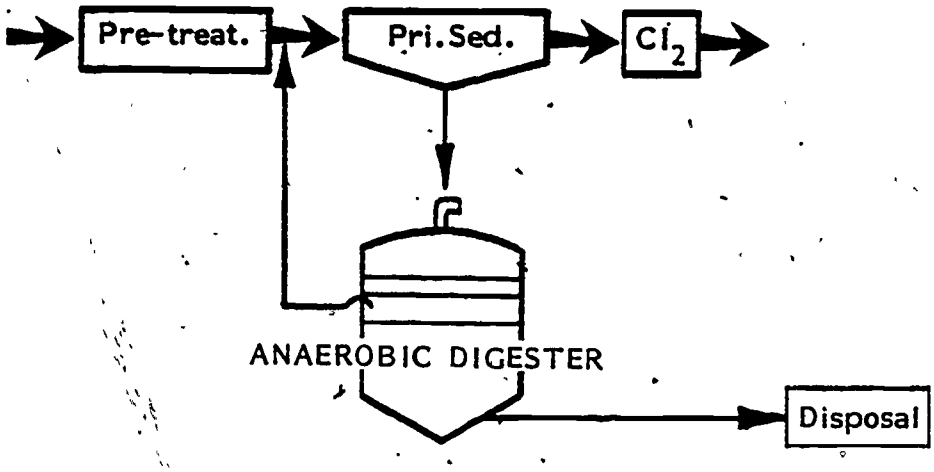
ANAEROBIC DIGESTION I

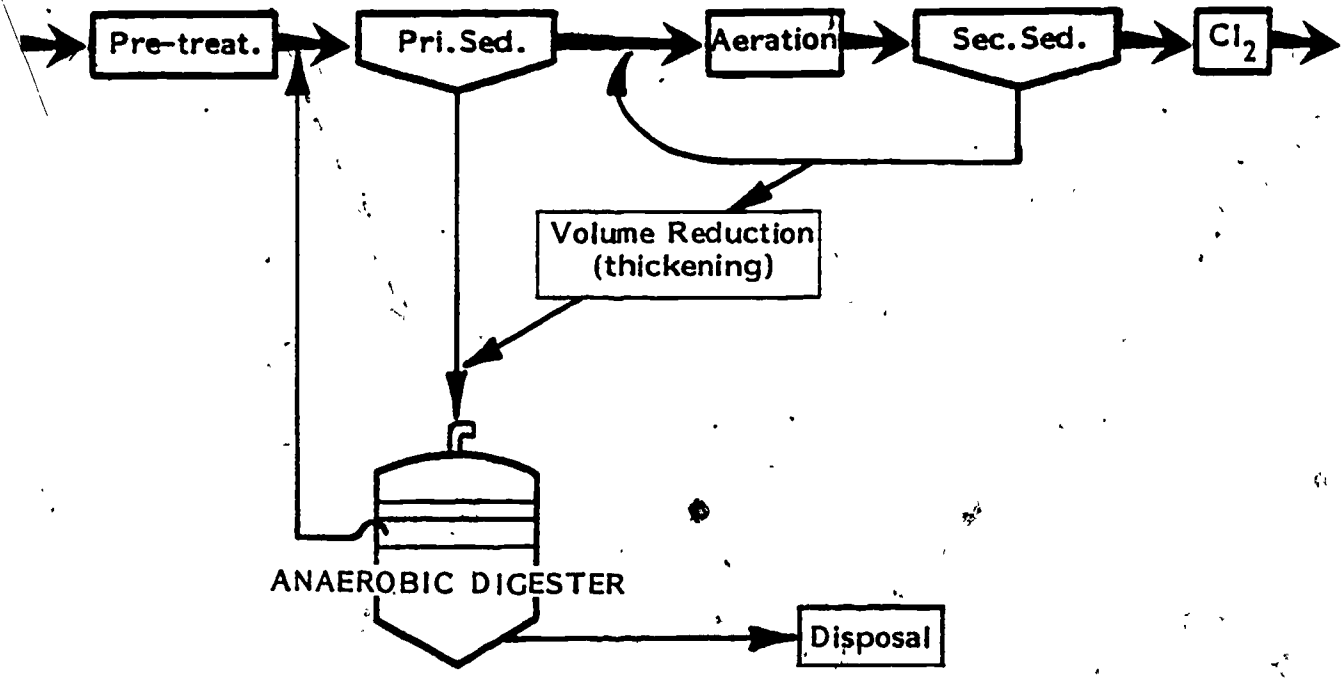
CONTENTS

PLANT FLOW DIAGRAMS

PRIMARY PLANT



SECONDARY PLANT



ANAEROBIC DIGESTION I

Objectives

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

1. Describe the five major functions of anaerobic digestion.
2. Identify the following basic equipment: tank, heat exchanger, boiler, mixing system, gas collection, and removal system.
3. Define in nontechnical terms the meaning of volatility of sludge.
4. Recall the number of steps involved in anaerobic digestion.
5. Recall the major products of the first stage of digestion.
6. Recall the major products of the second stage of digestion.
7. Recall the most acceptable pH range for anaerobic digestion.
8. Recall the name of the top layer of material in a digester.
9. Recall the approximate concentration of by-products of digestion on S.S. in anaerobic digestion supernatant.
10. Describe the color and odor of digested sludge.
11. Recall the % volatile reduction that could be expected in an anaerobic digester.
12. Recall the optimum % methane in digester gas.
13. Recall the approximate quantity of digester sludge produced for each one lb. of volatile solids reduced.
14. Compare the BTU value of digester gas to commercial gas.
15. Describe three uses of digester gas.
16. Recall that digester gas is explosive, corrosive and can cause physiological damage.
17. Recall the basic purposes of the anaerobic digestion process within the confines of an overall solids management system.

ANAEROBIC DIGESTION I

GLOSSARY

Acid forming bacteria: The group of bacteria in a digester that produce volatile acids as one of the by-products of their metabolism. The acids are used as a food source by the methane forming bacteria.

Alkalinity: The capacity of water to neutralize acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. It is expressed in milligrams per liter of equivalent calcium carbonate.

Anaerobic digestion - Wastewater solids and water (about 5% solids, 95% water) are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen. At least two general groups of bacteria act in balance: (1) Saprophytic (acid forming) bacteria break down complex solids to volatile acids; and (2) Methane Fermenters break down the acids to methane, carbon dioxide, and water.

Methane: An odorless, colorless, flammable gas, CH_4 that is the major constituent of natural gas. It is used as a fuel and is an important source of hydrogen and a wide variety of organic compounds.

Methane forming bacteria: The group of bacteria in a digester that use volatile acids as a food source and produce methane as a by-product.

Stabilize: To convert to a form that resists change. Organic material is stabilized by bacteria which convert the material to gases and other relatively inert substances. Stabilized organic material generally will not give off obnoxious odors.

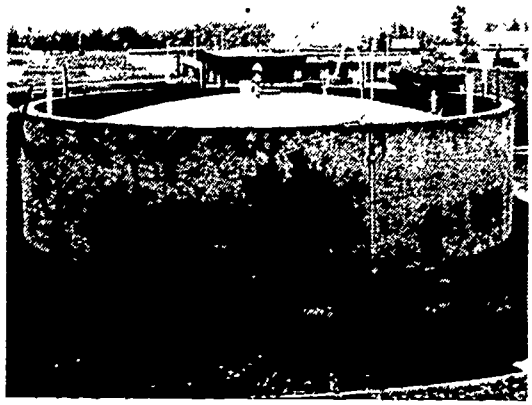
Stabilized Waste: A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.

Supernatant: Floating on surface, like oil on water. Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface on a anaerobic digester.

Volatile Acids: Fatty acids which are produced by acid forming bacteria and which are soluble in water. They can be steam-distilled at atmospheric pressure. Volatile acids are commonly reported as equivalent to acetic acid.

Volatile Solids: The quantity of solids in water, sewage, or other liquid, lost on ignition of the dry solids at 600^{0} C.

ANAEROBIC DIGESTION THEORY



Anaerobic digestion - Part I of a two-part series on the basic theory and operation of anaerobic digesters. The two parts should be viewed consecutively.

This program was written by Mr. E. E. "Skeet" Arasmith. The instructional development was done by Priscilla Hardin. Mr. Paul Klopping was the project manager.

Wastewater treatment facilities may produce one or more of the following sludges: raw, biological, or chemical.

Primary Clarification
↓
raw sludge

Primary clarification yields a product referred to as raw sludge. This raw sludge contains both organic and inorganic material.

Biological Processes
(Activated Sludge, Trickling Filter)
↓
biological sludge

Biological processes such as activated sludge and trickling filters produce biological, organic sludges.

Chemical Treatment
↓
inorganic sludge

Chemical precipitation, such as phosphorous removal by lime precipitation, produces an inorganic chemical sludge.

Both organic and inorganic sludges contain material which if not treated could cause offensive odors and degrade any water source they enter. They also have a high moisture content which makes them difficult to handle.

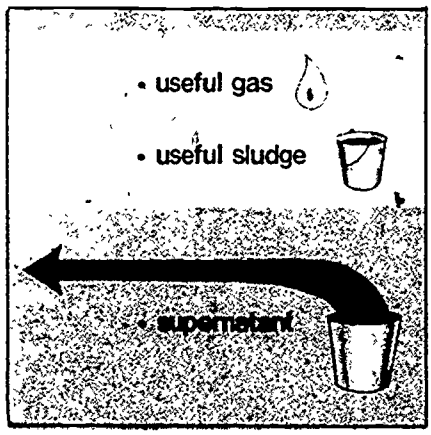
By placing these sludges in a sealed container and controlling the environment, anaerobic digestion can be promoted.

In the overall sludge management program, anaerobic digestion accomplishes volume reduction

solids reduction, stabilization, and some conditioning. More specifically, digestion serves five purposes:

It further stabilizes the volatile content or biological food value of the sludge, thereby reducing the mass.

As a result, digestion reduces odors, reduces the total number of pathogens, and conditions the sludge so that it can be more easily dewatered.

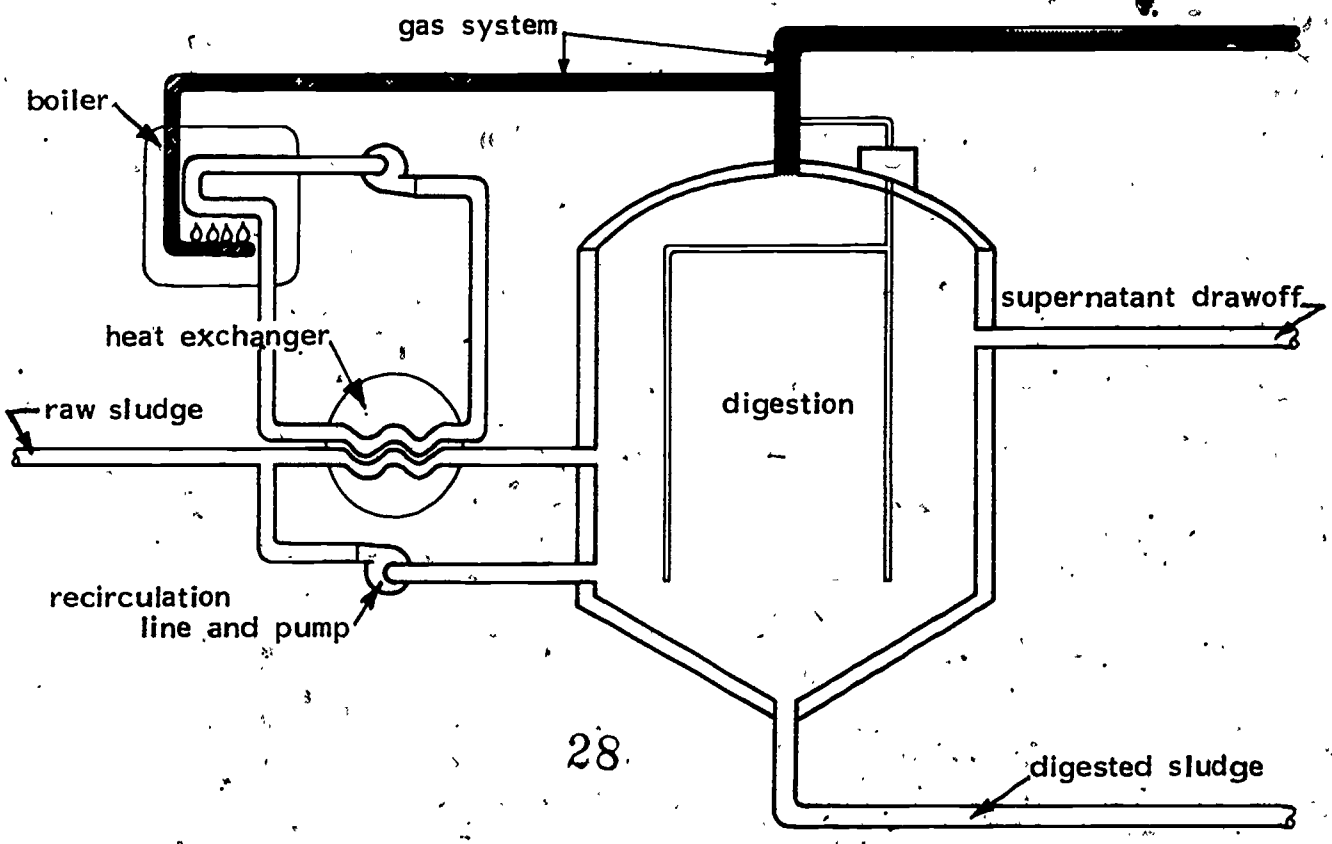


This digestion process produces useful gas - an easily handled and useful sludge.

And a recycle sidestream called a supernatant, which can impair or improve the biological action of some secondary waste treatment systems.

BASIC EQUIPMENT

Naturally, the process of sludge treatment requires certain mechanical equipment. The

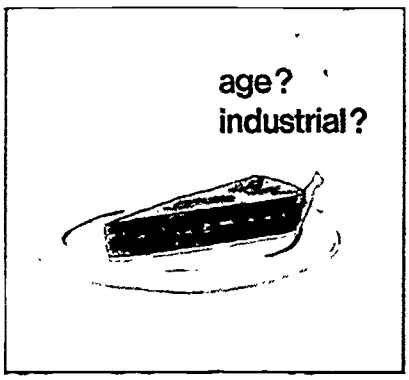


anaerobic digester equipment can be divided into four categories; a covered tank and related inlet and outlet valves and piping. . .

A heat exchanger and boiler to heat the sludge and optimize the digestion process by maintaining a constant temperature, . . .

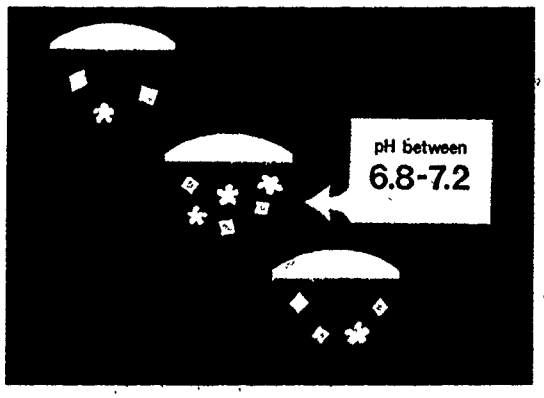
a mixing system to speed the digestion process and . . .

a gas collection and removal system.



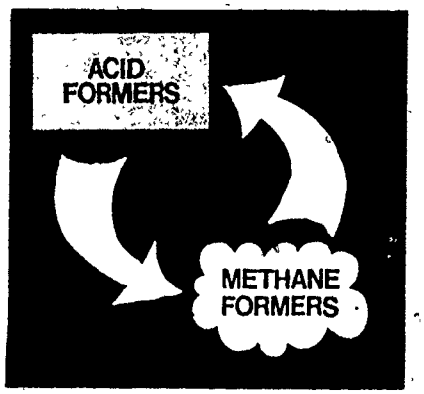
THEORY - "THE BASICS"

All of this equipment is used to reduce the volatility of the sludge. It could be said that the volatility of the sludge is an indication of the food value and indirectly a measure of the quality of the sludge.



This volatility, which is directly related to the organic content of the sludge, will vary with sludge age and the nature and number of industries on line.

The methane producers are extremely fragile. To keep them alive, a balance must be maintained between the methane formers and the amount of acid present.

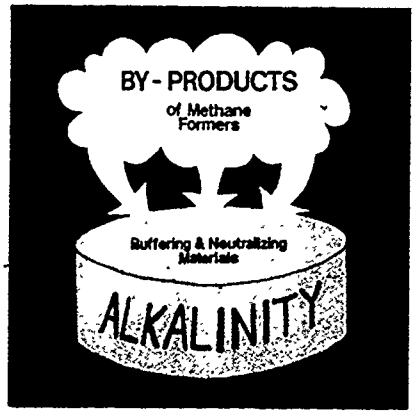


A balance between the volatile acids and the alkalinity must be achieved in order to maintain an acceptable pH range of between 6.8 and 7.2.

The process of anaerobic digestion is carried on by two interdependent groups of organisms. The acid formers produce by-products needed for the survival of the methane formers. The methane formers complete the process of anaerobic

digestion and contribute to the environment required for the survival of the acid formers.

During the first stage of this process, volatile solids are converted to various by-products. The most important of these are volatile acids.

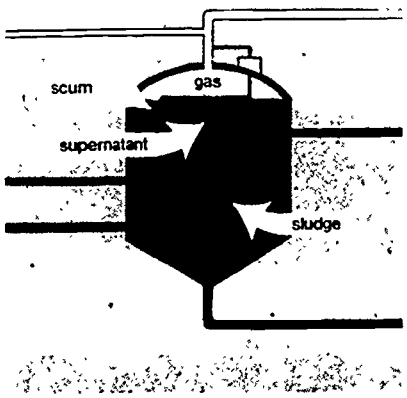


In the second stage of digestion, a group of methane forming bacteria use the volatile acids as food to produce methane, CO_2, and other by-products.

One of the results of these by-products is the production of acid buffering and neutralizing materials, commonly referred to as alkalinity.

BY-PRODUCTS OF DIGESTION

As the volatile solids within the digester are stabilized, several zones develop. They include gas, scum, supernatant and sludge.



The scum is caused by rising gas lifting floatable materials such as petroleum products, rubber goods, plastic, hair, grit and filter tips to the top of the liquid level.

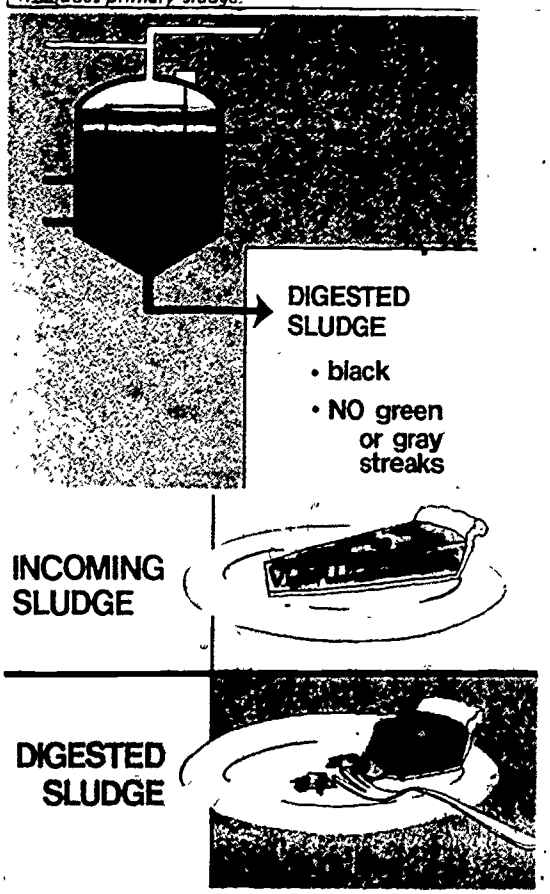
The scum is caused by rising gas lifting floatable materials to the top of the liquid level. The majority of the scum is grease but the scum also contains rubber goods, plastic, hair, grit and filter tips.

This scum which may vary from 2 to 15 ft, depending upon the degree of mixing, reduces mixing, and concentrates the food supply, thus, reducing the efficiency of the digestion process.

TABLE OF EXPECTED RANGES OF SUPERNATANT QUALITY FOR DIFFERENT TYPE PLANTS

	Primary Plants (mg/l)	Trickling Filters* (mg/l)	Activated Sludge Plants (mg/l)
Suspended solids	200-1,000	500- 5,000	5,000-15,000
BOD_5	500-3,000	500- 5,000	1,000-10,000
COD	1,000-5,000	2,000-10,000	3,000-30,000
Ammonia as NH_3	300- 400	400- 600	500- 1,000
Total phosphorus as P	50 200	100- 300	- 300- 1,000

*Includes primary sludge.



The supernatant consists of fluid that was pumped into the digester as part of the sludge and water from organisms that have died.

Typically supernatant BOD strength may range from 1,000 to 10,000 mg/l with a S.S. concentration of 5,000 to 15,000 mg/l. Returning this material to the head works or primary influent of a conventional activated sludge facility may cause plant upset.

From an operational standpoint, it would be desirable to prevent this supernatant overflow to the system. This can be accomplished with proper sludge drawoff rates.

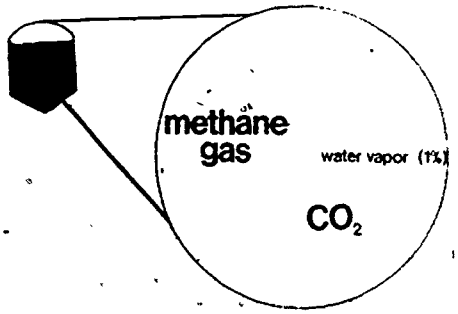
As the sludge is digested, it must be removed from the digester. This digested sludge should, upon withdrawal, be checked for physical appearance. The color should be black and contain no green or gray streaks. The presence of green or gray streaks is indicative of undigested sludge.

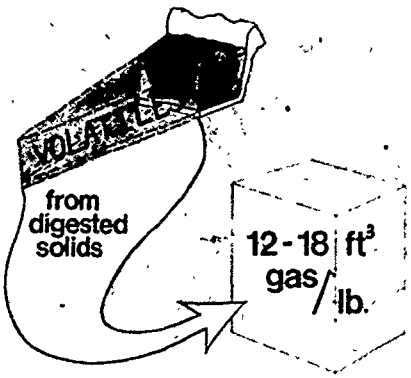
Digested sludge should contain 40 to 60% less volatile matter than the incoming sludge and. . .

should dewater easily and not have a noxious odor.

The anaerobically digested sludge must ultimately be disposed of. Common methods of disposal of this sludge are dependent upon local conditions and may include land application, land fill, and incineration.

One of the beneficial by-products of the anaerobic digester is a useable gas.





This gas is a combination of Methane, Carbon Dioxide, and water vapor. Normally, the gas is 65 to 70% methane. Methane is a combustible gas that can be used as a fuel source.

Let's take a closer look at this gas. For each pound of volatile material that is digested by the micro-organisms, 12 to 18 cubic feet of gas are produced.

This gas has a BTU value of 600 to 800 BTU's per cubic foot. By comparison, commercial gas ranges from 1,000 to 1,100 BTU's/ft.

Digester gas is very explosive, can cause physiological damage if inhaled, and is extremely corrosive due to the presence of sulfides within the gas.

The methane portion of the digester gas can be used:

1. To fire a boiler for heating the digester.
2. To heat the treatment plant buildings.
3. To operate internal combustion engines to power blowers and electrical generators.
4. To mix the digesting sludge.

In summary, let's take a look at what we have discussed in this lesson. We discussed the three sources of sludge; raw, biological, and chemical.

They are to reduce offensive odors, to prevent degradation of water sources and to reduce high moisture content in the sludge.

Then we looked at the five functions of the

digestion system; further stabilization, reduction of mass, reduction of odor and pathogenic organisms, and the conditioning of the sludge to help make it dewaterable.

We discussed the biological process and the interrelationship between the acid formers and the methane formers and finally . . .

We took a quick look at the basic digester components and four of the products of the digestion process.

In the next lesson "Anaerobic Digestion II" we will discuss the classification of digestions, the results of temperature control, mixers, the gas system, and basic operational techniques.

References

"Operations Manual; Anaerobic Sludge Digestion;" EPA, 430/9-76-001, Cincinnati, OH, 1976.

"Manual of Practice #11 Operation of Wastewater Treatment Plants," WPCF, Lancaster Press, Lancaster, PA, 1976.

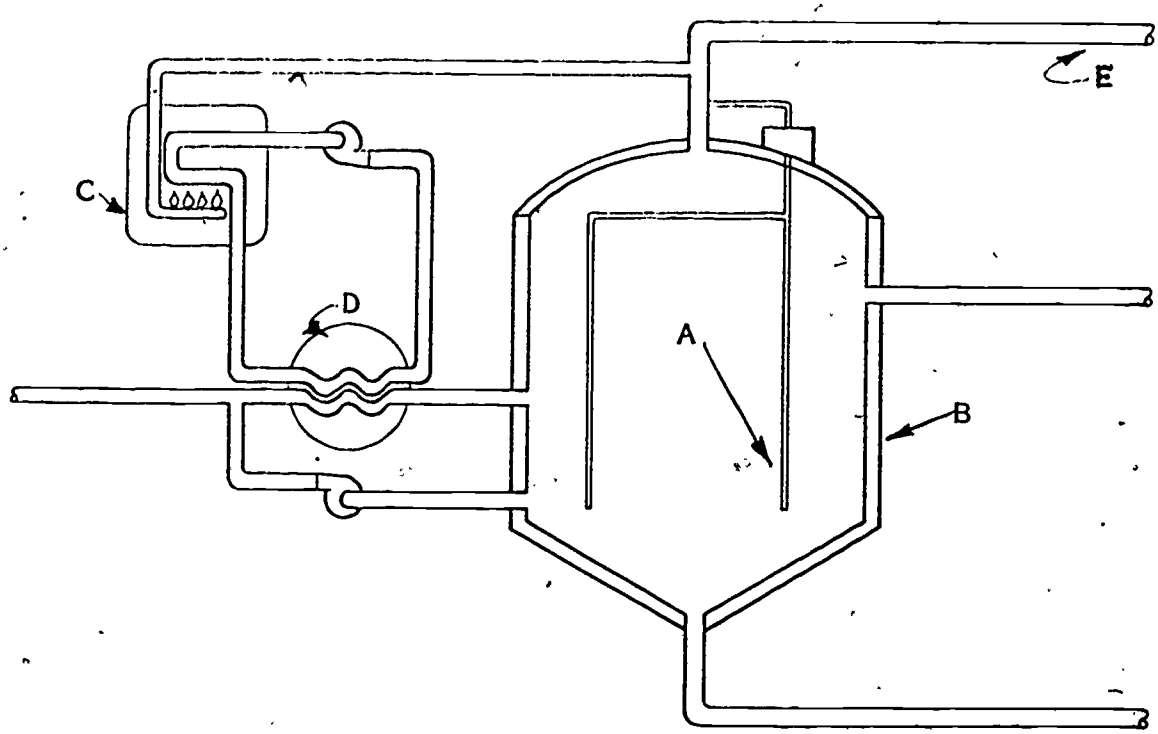
"Operation of Wastewater Treatment Plants", Kenneth D. Kerri, Sacramento State College, Sacramento, CA, 1980.

SLUDGE TREATMENT AND DISPOSAL

ANAEROBIC DIGESTION

1. Match the letters on the diagram with their descriptions:

_____ gas collection and removal system
_____ boiler
_____ mixing
_____ tank
_____ heat exchanger



2. Which of the following are considered valid purposes of anaerobic digestion? (select five)

_____ a. reduce water consumption
_____ b. increase volatile content
_____ c. reduce volatile content
_____ d. reduce odor
_____ e. prevent reliquification
_____ f. produce usable gas
_____ g. reduce mass of sludge
_____ h. condition sludge
_____ i. improve plant efficiency
_____ j. reduce numbers of pathogenic organisms

3. The volatility of sludge is an indication of:

_____ a. heat production cabapilities.
_____ b. sludge food value.
_____ c. weight of the sludge.
_____ d. the difference between the weight of the sludge and the weight of an equal volume of water.
_____ e. all of the above.

4. Anaerobic digestion is basically a _____ step process.

_____ a. 4
_____ b. 3
_____ c. 2
_____ d. 6
_____ e. none of the above

5. The first stage of digestion converts _____ to _____.

_____ a. volatile solids to methane
_____ b. methane to acid formers
_____ c. volatile acid to methane and CO_2
_____ d. volatile solids to volatile acids
_____ e. none of the above.

6. During the second stage of digestion there is a conversion of:

_____ a. volatile acids to pH.

_____ b. volatile acids to methane.

_____ c. volatile solids to volatile acids,

_____ d. microogranisms to food.

_____ e. all of the above.

7. During the second stage of digestion a buffering material is produced. This buffering material is usually called:

_____ a. alkalinity.

_____ b. CO_2.

_____ c. pH.

_____ d. acid.

_____ e. none of the above.

8. The most acceptable pH range for anaerobic digestion is between:

_____ a. 6.5 and 7.5.

_____ b. 6.4 and 8.4.

_____ c. 6.8 and 7.2.

_____ d. 5 and 8.

_____ e. none of the above.

9. When a digester contains such items as petroleum products, plastic, rubber goods and etc., these materials may form a layer on the top of a digester. This layer is usually called:

_____ a. upper layer.

_____ b. supernatant.

_____ c. scrapings.

_____ d. scum blanket.

_____ e. none of the above.

10. The BOD range for digester supernatant would probably run between:

_____ a. 2,500 and 1,000,000 lbs/day.

_____ b. 1,000 and 100,000 mg/kg.

_____ c. 10,000 and 100,000 mg/l.

_____ d. 1,000 and 10,000 mg/l.

_____ e. all of the above.

11. Supernatant from an anaerobic digester could have a S.S. level between:

_____ a. 5,000 and 15,000 mg/l.
_____ b. 500 and 1,500 mg/l
_____ c. 500 and 1,500 kg/g.
_____ d. 500 and 15,000 kg/l.
_____ e. none of the above.

12. A description of properly digested sludge might be:

_____ a. green and contain black and gray streaks.
_____ b. gray and contain streaks of black and dark green.
_____ c. black and contain no green or gray streaks.
_____ d. black and contain a few green or gray streaks.
_____ e. none of the above.

13. The volatility of properly digested sludge should be reduced by:

_____ a. 20 - 40%.
_____ b. 40 - 60%.
_____ c. 60 - 80%.
_____ d. 50 - 70%.
_____ e. none of these.

14. If the digester is operated properly, the gas production will usually contain methane at:

_____ a. 65 - 70%.
_____ b. 40 - 65%.
_____ c. 30 - 40%.
_____ d. 70 - 80%.
_____ e. none of these.

15. For each 1 pound of volatile material that is reduced by digestion gas is produced. The approximate volume produced for each pound would be:

_____ a. 12 - 18 mg/l.
_____ b. 12 - 18 kg.
_____ c. 12 - 18 cubic yards.
_____ d. 12 - 18 cubic feet.
_____ e. none of the above.

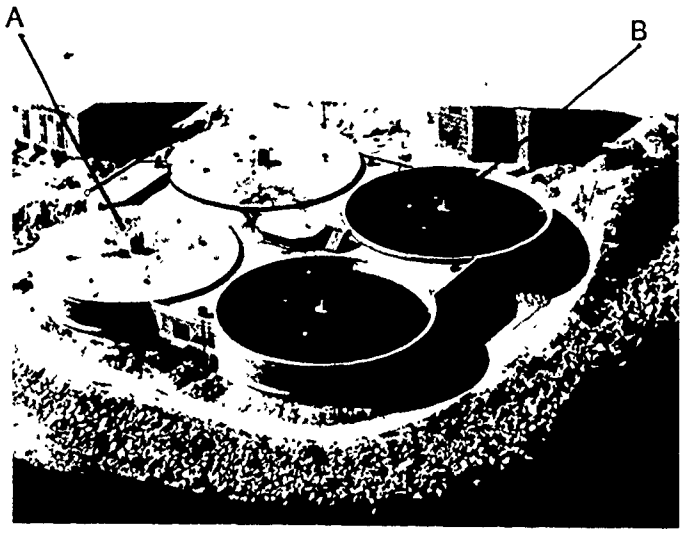
5. Using the drawing below, identify each of the digesters by roof design.

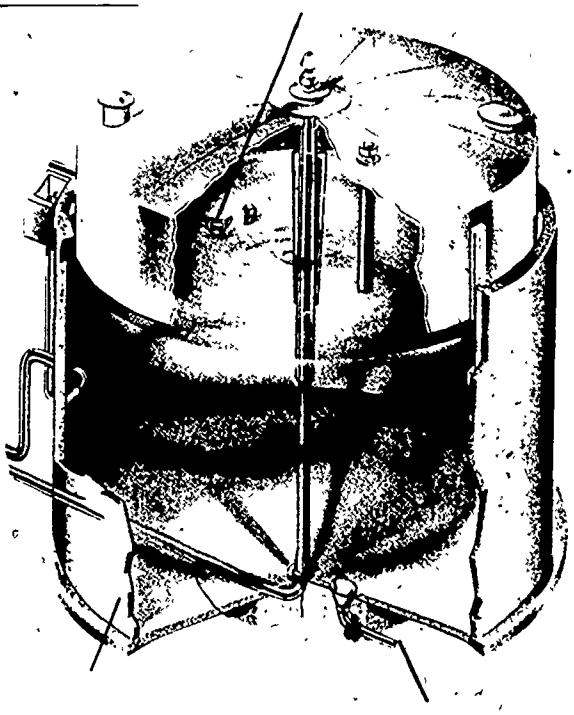
a. _____

b. _____

c. _____

d. _____





C: _____