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ABSTRACT

Focusing specifically on the wastewater treatment process of anaerobic digestion, this document identifies instructional and reference materials for use by professionals in the field in the development and implementation of new programs or in the updating of existing programs. It is designed to help trainers, plant operators, educators, engineers, consultants, and students efficiently identify and locate specific instructional materials. Part I presents a brief description of the anaerobic digestion process in wastewater treatment operations. Part II provides eleven selected chapters or sections from resource publications and other instructional materials which are representative of materials currently available. Part III contains abstracts of other pertinent instructional materials which may supplement those in Part II. The final section alphabetically lists bibliographic citations, mostly from technical and scientific journals, of additional resources which tend to be highly specific and more technical in nature. (Author/DC)

United States Environmental Protection Agency

National Training and Operational Technology Center Cincinnati, OH 45268

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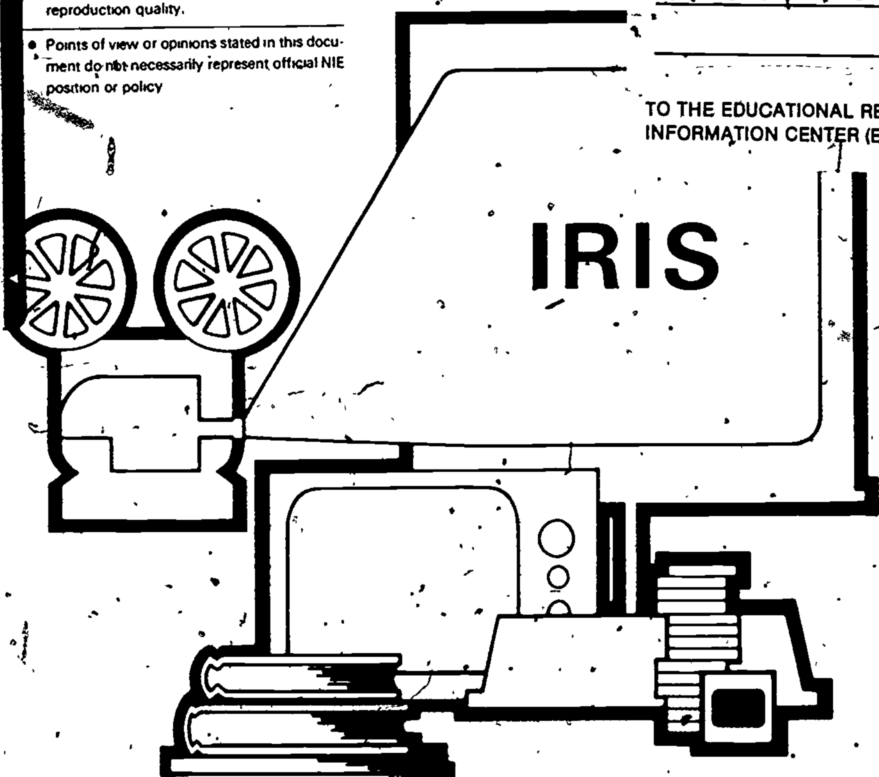
August 1981

Water

EPA

Instructional Resources Monograph Series:

Anaerobic Digestion



Monograph Series:
ANAEROBIC DIGESTION

Selected Instructional Activities and References

prepared by

EPA Information Dissemination Project
SMEAC Information Reference Center
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Compiled by - Robert D. Townsend

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Office of Water Program Operations
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Cincinnati, Ohio 45268

August 1981

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CREDITS

Mr. Lynn Marshall, Engineering Technician, Operational Technology Branch, National Training and Operational Technology Center, United States Environmental Protection Agency, Cincinnati, Ohio was particularly helpful in identifying instructional materials and providing a technical review of the introduction.

Ms. Thea Teich Townsend, Writer-Editor, Program Operations Branch, National Training and Operational Technology Center, United States Environmental Protection Agency, Cincinnati, Ohio was helpful in providing editorial review of the manuscript.

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FOREWORD

The National Training and Operational Technology Center in cooperation with The Ohio ~~State~~ University is developing an Instructional Resources Monograph Series. The monograph series is an extension of the information provided in the Instructional Resources Information System (IRIS) for water quality.

This document is one in the Instructional Resources Monograph Series. These documents will assist the professional in identifying and locating instructional and reference materials related to various technical aspects of water quality control. Emphasis is given to items useful in the development and presentation of wastewater treatment training programs.

Each monograph reviews an aspect of wastewater treatment, provides representative examples of available instructional materials, and includes an annotated bibliography plus additional references.

Your comments and suggestions regarding these publications are invited.

Walter G. Gilbert
Director
NTOTC, USEPA
Cincinnati, OH 45268

INTRODUCTION

The purpose of this monograph is to identify instructional and reference materials for use by professionals in the field in the development and implementation of new programs or in the updating of existing programs. The materials identified in this document are specific to the wastewater treatment process of anaerobic digestion. The monograph will be useful to trainers, plant operations, educators, engineers, consultants, and students with the need to efficiently identify and locate specific instructional materials.

To help meet this need, the monograph is organized into four parts:

Part I — Anaerobic Digestion - The Process. This section presents a brief discussion of the anaerobic digestion process in wastewater treatment operations.

Part II — Learning Resources. This section presents selected portions of illustrative resource materials taken from a chapter or section of a publication or other instructional material. These resources were identified by professionals as being representative of the materials currently available. A reference to the source where the material may be found in more detail is included. Bibliographic data regarding these resources are found in Part III, Abstracted Reference Materials.

Part III — Abstracted Reference Materials. This section presents document resumes of pertinent instructional materials that may be used to supplement those identified in Part II - Learning Resources. Instructions for interpreting a document resume are found in Part V.

Part IV — Reference Materials - Bibliographic Citations. This section provides additional resources, mostly from technical and scientific journals. Resources identified in this section tend to be highly specific and more technical in nature. Information provided includes title, author, corporate author (if applicable) and availability.

PREFACE

The need for training in the water pollution control field continues to grow. Gilbert (1981) states that, based on continuing changes in current programs and activities, the training programs provided by an institution or organization must be responsive to the information, knowledge, or skill gap that exists between what an individual already knows or can do and what the individual needs to know or be able to do to accomplish a given task. Examples of changing areas with training implications include wastewater treatment technology and water quality assessment.

Recent USEPA reports Gray, et al., (1979) and Hegg, et al., (1979) suggest that training needs do exist in the areas of wastewater treatment system management and process control. Major reasons given for the fact that many wastewater treatment plants currently in operation are not in compliance with their NPDES permits include lack of understanding by operators of the wastewater treatment process and the inability of operators to apply process control knowledge to inplant conditions. The General Accounting Office report (1980) showed 97 percent of the 242 treatment facilities surveyed to be in violation of their effluent discharge permits.

As technology alone cannot solve the problems, it is important to realize that a well-trained workforce is essential to clean up and control our water pollution problems. Most practitioners agree that training is critical to the improvement of performance of personnel. With training comes the need for training materials and it is the intent of this monograph to assist in identifying and locating instructional and reference materials specific to the wastewater treatment process of anaerobic digestion.

Learning resources and reference materials are assembled here to assist trainers and instructors in the development of training programs. The learning resources are often segments of illustrative materials on anaerobic digestion taken from a chapter or section of a publication or other learning resource that provides additional information. These resources are to serve only as a guide in selecting appropriate training materials and should not be considered a fixed structure or total program.

For further information about these materials contact:

EPA Information Dissemination Project
1200 Chambers Road, 3rd Floor
Columbus, Ohio 43212

614-422-6717

REFERENCES

American Academy of Environmental Engineers. An Analysis of the Role of the U. S. Environmental Protection Agency in the Development of Manpower for Water Pollution Control. P. O. Box 1278, Rockville, Maryland, July 1980.

Gilbert, W. G., Perspective on Training Needs. Paper presented at National Conference on Meeting Environmental Workforce Needs, Washington, D.C., February 1981.

Gray, A. C., Jr., et al. Evaluation of Operation and Maintenance Factors Limiting Biological Wastewater Treatment Plant Performance, Municipal Environmental Research Laboratory, U. S. Environmental Protection Agency, Cincinnati, Ohio, EPA-600/2-79-078 (July 1979).

Hegg, B. A., et al. Evaluation of Operation and Maintenance Factors Limiting Municipal Wastewater Treatment Plant Performance, Municipal Environmental Research Laboratory, U. S. Environmental Protection Agency, Cincinnati, Ohio, EPA-600/2-79-034 (June 1979).

U. S. General Accounting Office, Costly Wastewater Treatment Plants Fail to Perform as Expected, CED-81-9, November 14, 1980.

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Anaerobic Digestion

PART I

Anaerobic Digestion - The Process

ANAEROBIC DIGESTION

Introduction

One of the major problems resulting from the primary (settling) and secondary (biological) treatment of wastewater concerns the fate of the solids fraction. Watery and noxious, this "sludge" must undergo further treatment to minimize a variety of disposal problems. One of the most common treatments utilized is anaerobic digestion.

Anaerobic digestion stabilizes the organic solids in sludge. Total solids can be subdivided into a "volatile solids" (organic) fraction and an "ash" (inorganic) fraction. The sludge fed to the digester should contain as high a volatile solids fraction as possible because this portion can be treated by the digestion process. The inorganic material simply takes up space in the digester. Indeed, a high percentage of inert or inorganic matter in the sludge might indicate that the screening and grit removal machinery of the plant was not operating efficiently.

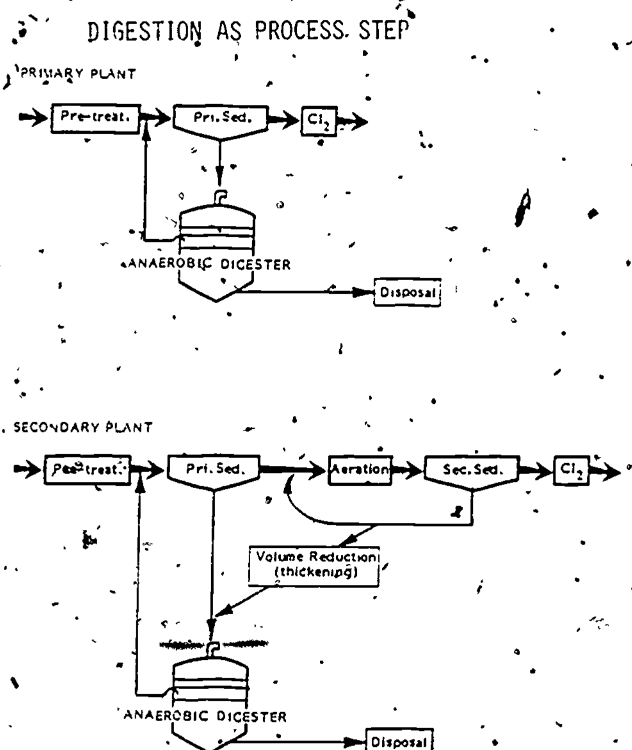


Figure I

Sludge contains not only the solids fraction of the wastewater flow, but also a great quantity of water. Very often, sludges must be "thickened" to assure the 4 to 8 percent solids concentration needed for efficient digestion. More diluted sludges can cause pH changes in the alkaline buffer in the digester, decreased bacterial contact with the organics, and increased digester heat and space requirements. After the digestion process, even more water is separated from the sludge so that other processes can further the dewatering.

Digestion can take place under aerobic (with oxygen) or anaerobic (without oxygen) conditions. Anaerobic digestion effectively handles primary sludge and results in the production of methane gas as a by-product, which can be used as a fuel source. However, the anaerobic process is more sensitive to environmental changes and can be upset by loading problems.

Anaerobic digestion proceeds through the action of certain forms of bacteria upon organic material. As a result, the unpleasant smelling sludge is broken down to several components; i.e.,

(1) methane gas with a lower Btu content than natural gas, but still high enough for use as a fuel;
(2) scum, consisting of lightweight sludge particles;
(3) supernatant, consisting mainly of water, which must be withdrawn from the digestion tank and subjected to secondary treatment before being released in the effluent; and
(4) digested stabilized sludge, relatively free of odor and pathogens, which can be landfilled, incinerated or recycled through land treatment.

These products will be discussed in further detail later.

DIGESTION PRODUCTS

RAW SLUDGE COMPLEX SUBSTRATE CARBOHYDRATES FATS PROTEINS	+	MICROORGANISMS "A" PRINCIPALLY ACID FORMERS SAPROPHYTIC FACULTATIVE	→	CO_2, H_2O, INTERMEDIATE DEGRADATION PRODUCTS	+	ORGANIC ACIDS CELLULAR & OTHER INTERMEDIATE DEGRADATION PRODUCTS
ORGANIC ACIDS CELLULAR & OTHER INTERMEDIATE DEGRADATION PRODUCTS	+	MICROORGANISMS "B" PRINCIPALLY METHANE FORMERS OBLIGATE(?) ANAEROBES	→	CH_4 METHANE + CO_2 CARBON DIOXIDE	+	OTHER END PRODUCTS H_2O, H_2S, AND DEGRADATION PRODUCTS

Figure II

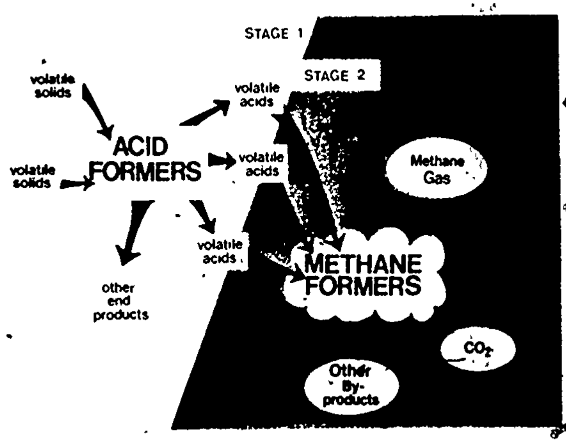
Process Components

Bacteria

Since the job of anaerobically digesting sludge is done by certain forms of bacteria already present in wastewater, a major objective of the process is to provide and maintain an environment conducive to the growth of those organisms.

Anaerobic digestion occurs in two phases which proceed concurrently. The first is the utilization of the sludge as food by a group of saprophytic bacteria which convert the volatile (organic) solids to organic acids. These bacteria are termed "acid formers." The organic acids, in turn, become the food for the second phase - which actually is the sludge stabilization step - where extremely sensitive bacteria convert the organic acids to methane gas and carbon dioxide. The bacteria involved in this conversion are called "methane fermenters."

As mentioned previously, these two phases occur at the same time except when the digester is just starting up or when the digestive process is upset or "going sour." One of the major reasons a digester goes sour is the high sensitivity of the methane fermenters to environmental change.



Environmental Conditions

The optimum conditions for anaerobic digestion call for

- a temperature of 80° to 100°F (29° - 37°C),
- absolutely no oxygen present,
- a pH of 6.8 to 7.2 (neutral), and
- no toxic materials present.

If these conditions are not met, the activity of the methane fermenters can decrease drastically. Unable to keep up with the acids produced by the acid formers, the methane fermenters continue to slow down because of the decreasing pH (or increasing acidity or "sourness") of the digester. Only part of the digestion process then occurs.

As noted earlier, an insufficiently thick sludge can also upset the process by diluting the alkaline buffer added to the digester to maintain a near-neutral pH. This dilution can lead to decreases in pH which result in poor methane fermenter activity and a "sour" digester. Such a digester may take 30 to 60 days to recover and require additions of alkaline compounds or "seed sludge" before returning to "normal." This will be discussed later.

The acid former and methane fermenter groups of bacteria can be further classified according to the temperatures at which they thrive. Psychrophilic bacteria thrive in temperatures below 68°F (20°C), although their activity becomes almost negligible below 50°F (10°C). Because sludge digestion in this temperature range takes 50 to 180 days, few digesters are designed today to operate in this range. However, many unheated digesters are still in use, including Imhoff tanks.

Mesophilic bacteria require higher temperatures, preferably 85° - 100°F (30° - 38°C). Thus, the digester must be heated. The advantage here is the reduced time required for digestion--5 to 50 days, with the normal time being 25 to 30 days, depending upon the adequacy of mixing.

Thermophilic bacteria prefer even higher temperatures; i.e., greater than 113°F (45°C). Digestion in this range is hastened, and takes from 5 to 12 days. However, difficulties in maintaining high temperature and the sensitivity of the bacteria to temperature changes have prevented most plants from operating at this level.

Contact (Mixing)

To utilize the volatile solids in the sludge as food, the bacteria must come into physical contact with them. In many anaerobic digestion tanks, the only mixing which occurs is that caused naturally by the rising methane gas. If the sludge loading to the digester can be maintained at 0.4 pounds of sludge/cu. ft. of digester capacity/day, natural mixing may be all that is needed. Periods of decreased loading can interrupt mixing and cause the formation of scum blankets at the top of the digester, fouling machinery and clogging valves. Increased loading can slow gas production. Thus, natural mixing works to a certain extent but only when carefully controlled. More recently designed digesters do not rely on natural mixing alone, however.

Mechanical mixing devices such as diffusers, propellers, impellers, and turbine wheels can keep sludge in motion. However, here again, the efficiency of the screening and grit removal stages of wastewater treatment must be high, otherwise, rotors, impellers, and other mixing equipment can be heavily damaged or worn by grit and debris. External pumped circulation of food to designated peripheral ports, has also become popular in design, mostly as an aid to gas mixing.

Food

The composition of the sludge itself obviously has a large effect upon the ease and speed of the digestive process. The volatile solids that are readily soluble in water will be easily broken down by the acid formers. Insoluble organics, such as vegetable fats and oils must first be converted to soluble forms by bacterial enzymes. Enzymes are proteins which occur in all living organisms and are necessary for biological functions. Mineral oils, such as fuel oils, automotive oils and paraffins, can cause toxicity problems in the digester. Large amounts are best handled by pretreatment.

As important as the composition of the sludge fed to the digester is its consistency. These factors have been noted in previous sections but are worth reviewing here:

> Sludge must be sufficiently concentrated or "thick" enough to prevent dilution of the digester alkaline buffer and other problems, yet "thin" enough to pump.
>
> Sludge must have a large enough concentration of volatile solids (organics to meet the food needs of the bacteria and prevent the digester capacity from filling with inert material (grit, debris).

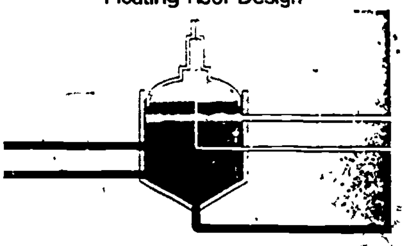
Tanks

The digestion process has been improved over the years through the addition of new equipment to increase efficiency and prevent problems. The earliest digesters were simply open-top, unheated tanks mixed only by the movement of gases. As the sludge was digested, it's various components would arrange themselves in the tank according to density. Grit and other inert material would fill in the bottom of the tank. Decomposed sludge solids would form the next layer. A zone of bacterial activity on newly-fed sludge would form next. Then would come the supernatant or water layer. On top of that a scum layer of lighter sludge particles would form. Gases produced during digestion would escape to the atmosphere. After a few years, digester capacity would be severely reduced because of growth in bottom deposits and the scum layer.

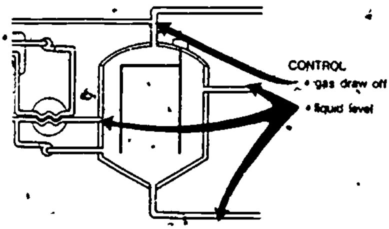
Placing a cover on the digester enables the operator to collect the methane gas produced by the digester process. Fixed covers are concrete or metal, and are bolted to the digester wall. They must be equipped with pressure relief devices. If these fail, serious damage can result since pressure changes inside the digester can cause an explosion or implosion (in case of vacuum relief failure).

ROOF DESIGNS

Floating Roof Design



Fixed Roof Design



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Floating covers move up and down along cover guides in the digester walls. The cover floats on the sludge at a level dependent upon the amount of sludge added to or withdrawn from the digester. The guides must be maintained in operating order for this cover to work properly. The amount of sludge pumped into the digester must also be carefully controlled in this variable capacity situation. Floating covers have been lifted over the digester walls because of high sludge levels.

An extension of the floating cover concept is the Gas Holder Cover. With this mechanism, the cover can lift as much as six feet above the minimum height because of gas pressure under its dome. Metal guides and rollers attached to the digester wall superstructure permit this movement. Problems arise when scum is allowed to accumulate between the walls and the cover.

The addition of a heating mechanism and a pump to recirculate deposited sludge back up into the active zone increases the contact between the volatile solids and the bacteria and decreases the amount of time required for digestion. Because the mixing activity prevents the layering present in unmixed tanks, all mixing mechanisms must be shut down and time allowed for the solids to settle before the supernatant liquid can be withdrawn from the tank.

This last problem can be eliminated by connecting a second tank to the process. Now, in one tank, active digestion takes place; in the other, settling occurs. This eliminates the need to shut down mixers before withdrawing supernatant or digested sludge. Futhermore, the second tank also contains digested sludge and active bacteria which can be added to the first tank to correct souring. The two-tank system is often referred to as "two-stage" digestion, just as one-tank systems are called "one-stage."

Anaerobic Digestion Products

Digestion products are gases (methane and carbon dioxide), supernatant liquid, and digested sludge. A problem by-product can be a blanket of scum which forms at the surface of the digester. Composed of lightweight sludge particles carried upward by rising gases, the scum, if not broken apart, can become 5 to 15 ft. thick. Volatile solids can become concentrated in the scum layer, and unless mixing occurs, digestion will be minimal.

The other nuisance by-product is excess alkalinity in the form of ammonium ions (NH_4^{+1}). Unless removed by a denitrification step before digestion, this ammonium must be eliminated by elutriation (washing) or some other method prior to the chemical conditioning step for sludge dewatering. Otherwise, the ammonium would react with the conditioning chemicals to form ammonia gas which would escape into

the atmosphere of the dewatering area, causing a health hazard to plant personnel.

The supernatant primarily consists of water removed from the sludge. This liquid is removed regulary and is commonly recycled to the headworks of the plant. Often high in solids and BOD_5, the supernatant may cause a decrease in the quality of the treatment plant's final effluent. Many operators increase the number of supernatant discharges to secondary treatment but decrease the amount released at each discharge. This can help prevent shocking the system. The problem of solids in the supernatant is also alleviated by ensuring good settling conditions.

The solids portion of the digestion products consists of inorganics and volatile solids that were not easily digested. Digested sludge:

(1) can drain or dewater easily;
(2) does not have a noxious odor;
(3) has a smaller volume than did the original sludge entering the digester;
(4) is "lumpy" and black in color--grey streaks indicate undigested sludge:
(5) should contain 40 to 60 percent less volatile solids than the feed sludge.

This stabilized sludge can then be disposed of through landfilling, land application, incineration, or other approved process.

PART II

Learning Resources

Presented are selected portions of existing training resources which may be useful in developing a training program on anaerobic digestion. Each resource has been selected for its representativeness to training level, topic area or instructional approach. These resources are to serve only as a guide in selecting appropriate training resources and should not be considered a total training program.

Learning Resource 1
Primary Treatment and Sludge Digestion Workshop.
Ontario Ministry of the Environment
Training and Certification Branch
Pollution Control Branch
Ministry of the Environment
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5

Presented are selected parts of a training manual prepared as a home study and reference manual for plant operators and as the text for the related workshop. Lesson objectives are indicated at the beginning of each topic. Hands-on participation is encouraged. This lesson discusses digester theory and operation, mixing, heating systems, and single- and two-stage digestion.

Other manuals relating to the water and wastewater treatment processes published by the Training and Certification Section, Ministry of the Environment, include:

Basic Sewage Treatment Operation.

Basic Water Treatment Operation

Surface Water Treatment Workshop

Activated Sludge Process Workshop

Prevention Maintenance Workshop

Pump Operation Workshop

Basic Gas Chlorination Workshop

Copies may be purchased at:

Ontario Government Book Store
880 Bay Street,
Toronto, Ontario M5S 1Z8

or may be ordered by mail by writing to:

Ministry of Government Services
Publications Centre
880 Bay Street
Toronto, Ontario M5S 1Z8

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SUBJECT:

Digester Operations

TOPIC: 4

Anaerobic Digestion

OBJECTIVES:

The trainee will be able to:

1. Recall the objectives of Sludge Digestion.
2. Discuss the principles of the Anaerobic Digestion Process.
3. List the parameters which must be controlled for good digester operation.
4. Show by a simple diagram the Anaerobic Digestion Process.
5. Name five objectives which mixing can attain in the Anaerobic Digestion Process.
6. Name the three temperature ranges at which a digester may be operated.
7. Name and discuss four means used to heat a digester.
8. Understand and discuss single stage and two-stage digester operation.

ANAEROBIC DIGESTION OF SLUDGE

OBJECTIVES OF SLUDGE DIGESTION

Settled solids and floating scum removed from the sedimentation tanks and clarifiers consist of a watery, malodorous mixture called raw sludge. In the majority of the plants this raw sludge is pumped to a digester for treatment before disposal. The primary purpose of sludge digestion is to reduce the complex organic matter present in the raw sludge to a material that is relatively odor free, can be readily dewatered, capable of being disposed of without causing environmental problems, and which will undergo little or no further decomposition. Digestion of sludge can be carried out either by anaerobic or aerobic processes. Topic 8 deals with the aerobic process.

ANAEROBIC DIGESTION PROCESS PRINCIPLES AND THEORY

In the anaerobic process the organic solids are liquified and brought into solution by a catalyst called enzymes present in the sludge. The organic material is then broken down by the action of two different groups of bacteria living together in the same environment. One group consists of microorganisms commonly referred to as acid formers. The second group, which utilize the acid formed by the acid formers are methane fermenters, commonly referred to as methane formers.

The digestion process is normally described in three stages:

1. Acid fermentation stage
2. Acid regression stage
3. Alkaline fermentation stage

Acid Fermentation Stage

During the acid fermentation stage, the organic compounds, principally carbohydrates, are broken down to volatile fatty acids, primarily acetic, butyric and propionic acids. This production of volatile acids results in a drop in pH and causes putrefactive odors. The organisms primarily responsible for this stage of digestion are the acid formers. This group encompasses a large number of bacteria which are anaerobic or facultatively anaerobic. As a rule, the acid formers are very vigorous reproducers and are less sensitive to environmental factors than the methane formers.

Acid Regression Stage

During the acid regression stage, decomposition of organic acids (volatile acids) and soluble nitrogenous compounds occurs which result in the formation of the following principal compounds:

1. ammonia
2. amines
3. acid carbonates

During this stage the pH will tend to increase.

Alkaline Fermentation Stage

During the alkaline fermentation stage, destruction of nitrogenous compounds and cellulose occurs. The volatile organic acids, produced during stage 1 of the process are broken down to produce carbon-dioxide (CO_2), methane (CH_4) and water. The principal organisms responsible for this process are the methane formers.

These organisms are strictly anaerobic, are a slower reproducing bacteria, and are much more sensitive to their environment than the acid formers. These organisms reproduce most effectively in the pH range of 6.8 - 7.2 although experience has shown that satisfactory digestion will continue at the pH range of 6.5 - 7.5.

These three stages occur continously and, for all practical purposes, simultaneously.

DIGESTER OPERATION CRITERIA

The basic criterion for good digester operation is the maintenance of a suitably balanced environment in the digester for the growing or reproducing of both acid formers and methane formers. To maintain this balance in the process the operator must exercise control over the following parameters:

1. food supply (raw sludge loading rate)
2. volatile acids/alkalinity relationship
3. mixing of the digester contents
4. temperature

Generally, in an efficient digester operation the volatile solids content of the sludge is reduced by 40 to 60 percent. The time required to digest the sludge, may be from two weeks to four months

duration and is dependent upon the above parameters. Figure 4-1 illustrates in simple equations what happens in the digester.

It is important to note that the methane forming organisms are more sensitive to upset and reproduce at a slower rate than the volatile acid formers. Every effort should be made to operate the anaerobic digester in a manner whereby the rate of acid formation is kept in balance with the production of methane. The most common cause of digester upset that occurs in the process is that of the methane gas formers failing to keep pace with the acid forming organisms with the result that the digester becomes overly acidic. When a buildup of this acid condition develops, the rate of the digestion process will begin to slow, and if left unchecked will result in serious inhibition or even complete failure of the digestion process. As acid concentrations increase, pH levels drop. The optimum range for a good digestion process is a pH value of 6.8 to 7.2. pH values lower than 6.8 might indicate a process failure. However, experience has shown that the digester process upset will be far advanced before the reduction in pH will indicate a problem. The volatile acids test and the alkalinity test have proven more useful and effective in predicting and avoiding process failures. In general, there is a relationship between acids and alkalinity which will remain fairly constant during satisfactory digestion. The alkalinity is always greater than the volatile acids concentration to some degree. A fairly rapid increase in volatile acids with an associated decrease in alkalinity indicates an impending process upset. Should the alkalinity concentration be allowed to drop to a level lower than that of the acids, all digester buffering capacity will be lost, the pH will very rapidly drop to a level well below 7.0, and the process could be considered as having failed. Such an upset is usually accompanied by poor gas production and quality and perhaps by foaming. Careful monitoring, therefore, of the alkalinity and acids concentrations, will provide warning of an impending process upset, as opposed to pH showing process upset after the fact, and various measures can be taken to avert complete digestion failure. Such measures are described in detail later in the text.

REACTIONS IN DIGESTION PROCESS

Raw Sludge Complex Substrate Carbohydrates Fats Proteins	+	Microorganisms "A" Principally Acid Formers (Saprophytic) (Faculative)	→	CO_2, H_2O Intermediate Degradation Products	+	Organic Acids Cellular & Other Intermediate Degradation Products.

Organic Acids Cellular & Other Intermediate Degradation Products	+	Microorganisms "B" Principally Methane Formers (Anaerobes)	→	CH_4 + CO_2 Methane Carbon Dioxide	+	Other End Products H_2O, H_2S

MIXING

Mixing is an important factor in the process and should accomplish the following:

1. Utilize as much of the total volume of the digester as possible.
2. Quickly distribute the raw sludge throughout the digester and put the microorganisms in rapid contact with fresh food sources.
3. Achieve good pH control by distributing buffering alkalinity throughout the digestion tank.
4. Obtain the best possible distribution of heat throughout the tank.
5. Minimize the deposition of grit and inert solids on the bottom, or floating scum material to the top.

Mixing the tank contents completely, speeds the digestion process greatly.

Mixing can be accomplished by various means:

1. By mechanical mixers.
2. By digester gas recirculation.

Some mixing action is also contributed by recirculating sludge through the heat exchanger.

Mechanical Mixing

The propeller-type mixers are found mainly on fixed-cover digesters. Normally, two or three of these units are supported on the roof of the tank. Electric motors drive the mixers. A typical propeller-type mixer is shown in Figure 4-2. It is usual for mixing action and control to be enhanced by the installation of draft tubes to serve the mixers. The draft tubes are steel and range from 18 to 24 inches in diameter. The top of the draft tube has a rolled lip and is located approximately 18 inches below the normal water level in the tank. The bottom of the draft tube may be straight or equipped with a 90-degree elbow. The 90-degree elbow type is placed so that the discharge is along the outside wall of the tank to create a vortex (whirlpool) action.

The mixer propeller is located about two feet below the top of the draft tube. This type of unit usually has a reversible motor so that the prop may be rotated in either direction. In one direction the contents are pulled from the top of the digester and forced down the draft tube to be discharged at the bottom. By operating the motor in the opposite direction, the digested sludge is pulled from the bottom of the tank and is then discharged over the top of the draft tube near the surface. If the digester is equipped with two units, an effective method in breaking up a scum blanket is by operating one unit in one direction and the other unit in the opposite direction, thereby creating a push-pull effect. Mechanical mixers are sometimes subject to shaft-bearing failure due to the abrasiveness of the sludge, and corrosion by hydrogen sulphide present in the digester gas. Maintenance consists of lubrication and, if belt-driven, adjustment of belt tension.

The drawback of a draft-tube-type mixer is related to the digester sludge level. If the sludge level is maintained at a constant elevation, a scum blanket may form on the surface. When the scum blanket becomes thick the mixer will only pull the liquid sludge from under the blanket and not disturb the scum itself. Lowering the level of the digester to just 3 or 4 inches over the top of the draft tube may help to force the scum to move over and down the draft tube. This particularly applies to single direction mixers.

Pumps are sometimes used to mix digesters. This method is common in smaller tanks. When external heat exchangers are utilized, a larger centrifugal pump is used to recirculate the sludge and discharge it back into the digester through one or two directional nozzles at the rate of about 200 to 1000 gpm.

The tank may or may not be equipped with a draft tube such that the pump suction can be from the top or the bottom of the digester. Control of scum blankets with this method of mixing is dependant upon how the operator maintains the sludge level and where the pump is pulling from and discharging to the digester.

Maintenance of the recirculating sludge pump requires normal lubrication and a good pump-shaft water sealing system. The digested sludge is abrasive and pump packing, shaft, wearing rings, and impellers are rapidly worn. Another problem associated with pump mixing is clogging of the pump impeller with rags, plastic materials, rubber goods and other pieces of material which can wind around the impeller causing it to plug.

It is very important to check pump operation several times a day.

Pressure gauges should be installed on the pump suction and discharge pipes. If a rapid increase in pressure differential is seen, the operator has an indication that pump clogging has occurred.

Mixing by Digester Gas Recirculation

In these systems, the digester gas is collected and fed by blowers to the bottom of the digester where it is exhausted through diffusers or "bubble-guns." Mixing of the sludge is accomplished as the gas rises to the surface. See Figure 4-2.

HEATING AND TEMPERATURE CONTROL

RANGES OF DIGESTION TEMPERATURES

A digester may be operated in one of three temperature zones or ranges, each of which has its own particular type of bacteria. The lowest range (in an unheated digester) utilized psychrophilic (cold temperature loving) bacteria. Temperature of the sludge inside tends to adjust to the outside temperature. However, below 10°C (50°F) little or no bacterial activity occurs and the required reduction in sludge volatile solids (organic matter) will not likely occur. When the temperature rises above 50°F the bacterial activity increases and the digestion process improves. The bacteria appear capable of surviving temperatures well below freezing with little or no harm. The psychrophilic digestion upper limit is around 20°C (68°F). Digestion in this range requires from 50 to 180 days, depending upon the degree of treatment required. Generally, these digesters are not very effective in digesting sludge.

The middle range of organisms are called the mesophilic (medium temperature loving) bacteria; they thrive between a temperature of 20°C and 45°C (68° and 113°F). This is the most common operational range, with temperatures usually being maintained at about 35°C to 37°C (95° to 98°F). Digestion at that temperature may take from about 25 to 30 days, depending upon the required degree of volatile solids reduction and the adequacy of mixing. The high rate processes

are usually operated in the mesophilic temperature range. The high rate process is a procedure providing mixing so that the organisms and the food source can be brought together to allow the digestion process to proceed more rapidly.

The third range of organisms are called the thermophilic (high temperature loving) bacteria and they thrive between 49°C and 60°C (120°F and 140°F). The time required for digestion in this range may be between five and twelve days, depending upon the operation and the degree of volatile solids reduction required. However, few plants have actually been operated in the thermophilic range of temperatures and there is little documentation of results.

When operating a digestion system in any of these temperature ranges, care must be taken to maintain a more or less constant temperature.

HEATING SYSTEMS

Digester heating can be accomplished by the following means:

1. Hot-water coils within the digester.

2. Recirculating sludge through an external heat exchanger.

3. Direct contact of hot gas with sludge.

4. Steam injection.

External Heat Exchanger

The most common of the four is the recirculation of sludge through an external heat exchanger. Hot water is pumped from the boiler to the heat exchanger where it passes through a jacket while the recirculating sludge passes through an adjacent jacket, and receives heat from the water. In some heating installations the boiler and exchanger are combined in a single unit. There are some advantages in using external heat exchangers. These are: they help to control scum buildup and there is no hotwater piping within the digester which can be corroded or caked up. The only disadvantage is that in a single stage digester system it is essential to stop sludge recirculation to allow the tank contents to stratify prior to the discharge of supernatant. This can result in an increased tendency to form a "cake" on the exchanger coils, or jackets due to localized overheating of the sludge.

Hot-Water Coil

Hot-water coils within the digester consisting of pipes either horizontally or vertically attached to the inside wall of the digester is another method of heating digesters, although not too common in newer plants. This method tends to create a problem of sludge caking on the pipes and thereby effectively insulating them, thus reducing the amount of heat transferred. Where coils are used water temperatures entering the coils are limited to a temperature of 49° to 54°C with boiler temperatures held to no higher than 82°C to prevent excessive corrosion or caking of the sludge on the coils.

Direct Contact and Steam Injection

Direct contact of hot gas with sludge and steam injection methods have been used in the past with varying degrees of success. However, these systems are rarely installed in current practice.

SINGLE-STAGE DIGESTION

For simplicity, single-stage digester operation will be covered under four headings:

1. Loading
2. Process
3. Supernatant Selection
4. Digested Sludge Removal

LOADING

Ideal conditions would be met if the raw sludge could be pumped continuously to the digester. In practice, however, for various reasons, continuous loading is not possible. Some small plants, receiving eight hours per day of operator's supervision, may load the digester three times a day, say at about 8 o'clock in the morning, 12 noon, and 4 in the afternoon. When automatic pumping facilities are provided, the other extreme may be reached with loading being effected once each hour. Where supervision is provided on a 24-hour basis, manual controls may dictate 6 to 8 pumping cycles per day. Excess amounts of primary effluent may be directed to the digester if too many pumping cycles are provided due to exhaustion of raw sludge supply. In installations where raw sludge must be pumped long distances to the digester, the sludge line must be filled with diluted sludge before the pump is shut off, to prevent plugging. The next pumping cycle will direct the diluted sludge to the digester.

In a single stage operation, the raw sludge is directed to the top half of the digester. As indicated in the Flow Diagram appended as Figure 4-3, the raw sludge may be mixed with seed sludge leaving the heat exchanger.

PROCESS CRITERIA

The same process parameters apply to single-stage digestion as multi-stage digestion with the following operational techniques being peculiar to the single-stage process:

1. Mixing
   In a single stage unit, mixing facilities, if any, are designed only to mix the material in the top half of the tank. In practice, this type of a design makes it almost impossible to operate an efficient digestion system. Thus it is difficult to obtain a concentrated sludge from a single-stage digester operation.

   In a single-stage digester an improper mixing program could lead to the process failure. The active volume for the digester process can be greatly reduced by:

   a) The formation of scum or sludge blankets.
   b) Foaming occurring when the scum blanket begins to digest.

2. Temperature
   The importance of temperature has been discussed in Section (Digester Systems). The major objective here is to maintain the sludge temperature to within, say, +1°C (±33°F).

SUPERNATANT SELECTION

In a single stage digester it is difficult to obtain a good supernatant. Nevertheless, an attempt should be made to remove any excess liquid. Mixing devices should be shut off for a period of time before the supernatant is withdrawn. Through experience, the operator will learn the duration of the quiescent settling period required to obtain an optimum supernatant.

In digesters where a variable level of supernatant selection is provided, the supernatant is removed via the line proving to be the most satisfactory. An example of a supernatant selector system is appended in Figure 4-4. In simpler installations the withdrawal control is maintained by a sleeve-height adjustment. Other installations

use valves to control these withdrawal processes. It should be noted that in all installations the safety overflow should be kept open at all times. To check the efficiency of the supernatant withdrawal process the operator should carry out a series of suspended solids tests. For quick results, the test can be carried out by using a centrifuge with the standard suspended solids test being used where complete laboratory equipment is available. In a good supernatant a suspended solids concentration of 3,000 to 10,000 mg/l might be seen, although many supernatants have solids levels far exceeding these concentrations.

DIGESTED SLUDGE REMOVAL

In a single stage digestion system the accumulated sludge should be removed as frequently as possible. It may be difficult to obtain a good concentrated sludge from this type of system. A 3 to 4 percent sludge may be considered good for the digested sludge obtained from an activated sludge plant using a single-stage digestion process. In a digester equipped with a fixed cover and from which digester gas is used to operate other components of the treatment system, the digested sludge is best removed when the raw sludge is being pumped to the digester. This practice will assist in maintaining the gas pressure in the tank, and will tend to avoid a vacuum being formed.

WARNING

The withdrawal rate of sludge from the digester with a fixed roof should be no faster than the rate of input of raw sludge. If the draw-off rate is too fast, the gas pressure drops due to volume expansion. This practice may create an explosive hazard by drawing air into the digester, through the pressure-vacuum relief valve.

TWO STAGE DIGESTION

GENERAL

Two stage digestion is covered under five headings:

1. Sludge Loading
2. Operating Criteria
3. Sludge Transfer
4. Supernatant Selection
5. Digested Sludge Removal

SLUDGE LOADING

Where mixing is practiced the raw sludge may be directed to any point in the first-stage tank. Ideally, as with most biological systems, a constant sludge feed rate would be preferred. However, in practice, sludge is fed on a cyclical basis, usually by timers, although manual operation may be featured from place to place. The feeding cycles should be frequent and preferably made over a 24-hour period although in smaller plants, the feeding might be accomplished over an 8-hour period. A good two-stage design will allow the use of either tank for the first stage. An example of a Two-Stage Digester is appended in Figure 4-5.

OPERATING CRITERIA

Where mixing devices are available they are operated to control the scum blankets and minimize inactive or dead spaces, and to bring bacteria and fresh food sources rapidly together. Mixing is carried out, in the first-stage digester, the mixing devices may be operated either full-or part-time. When part-time operation is desired the cycle is set up in relation to test and observation of scum blanket formation and not on power saving. In some operations the mixers may be operated only a few hours a day. It should be emphasized that full-time mixing is, however, the preferred practice.

An improper mixing program could result in process failure. The active volume available for the digestion process can be greatly reduced by the formation of a scum blanket or formation of foam when the scum blanket begins to digest. In two-stage digesters which are not equipped with positive mixing devices, the scum blankets may be partly controlled by the use of compressed air to mix the tank contents. This control measure may be carried out two or three times a year, depending on the need. Caution: when using air for mixing, great care must be taken to ensure that the explosive air/gas mixture is not ignited. Obtain the services of a qualified Safety Officer. Forbid smoking in plant area, use rubber footwear, use no-sparking tools and do not bang pipes so as to cause a spark at digester opening. Also, open as many manholes as possible for ventilation.

Temperature in the secondary digester normally is from 3° to 5° Centigrade below that of the primary unit. Under normal conditions, this makes heating of the secondary digester unnecessary except during the coldest part of the year. But if satisfactory digestion is not obtained, it may be necessary to increase the temperature. It should be remembered that the optimum mesophilic digestion is carried out at between 33 and 35 degrees C. However, lower temperatures may be used where excess digester capacity is available allowing long sludge retention times.

In digesters where heating is provided by external heat exchangers, the operator should recirculate warm supernatant to the top of the scum layer at the center of the tank and preferably at one or more additional points. This procedure will not only increase the temperature of the scum blanket, but will increase the moisture content of the blanket thus aiding digestion and increasing its specific gravity causing it to settle and mix with the rest of the materials in the digester.

Examples of Operating Criteria for Mesophilic Digestion

Loading	- 0.05 - 0.15 lbs. vS/ft^3/day
Temperature	- 35° - 37°C (95 - 98°F)
Retention Time	- 20 - 30 days
Volatile Acids	- 50 - 250 mg/l
Alkalinity	- 2000 - 3000 mg/l
pH	- 6.5 - 7.5

SLUDGE TRANSFER

Sludge can be transferred from the first-stage digester to the second-stage digester by a number of methods; three of which are as follows:

1. Automatic transfer may be effected by using an equalizing line, as shown on Diagram Figure 4-5.

2. Sludge may be transferred using the heat exchange unit recirculating line.

3. Bottom sludge may be pumped to the second stage unit directly.

Most of the sludge digestion is accomplished in the primary digester and 90% of the gas production occurs there. The secondary digester is used basically as a holding tank for separation of the solids from the liquor and to allow some further digestion of the volatile matter in the sludge. To accomplish this the secondary digester must be quiescent or with as little mixing as experience deems necessary. Therefore, on a normal operation process, when raw sludge is pumped to the primary digester, an equal volume is transferred to the secondary digester and settled supernatant from the secondary digester is returned to the plant. Nevertheless, at least once a

week, transfer of sludge must be made from the bottom of the first-stage tank. If this is not done the bottom withdrawal line will plug up with grit or heavy compacted solids.

SUPERNATANT SELECTION

In a two-stage digestion system the supernatant is obtained from the second digester. The supernatant can be selected automatically when a sludge transfer takes place or as a manual operating procedure when the plant can best receive the extra BOD loading. In either the fixed-cover or the floating-cover installations, the operater should select the best quality supernatant for withdrawal. By observing and sampling material from the various supernatant sampling lines, the operator can determine the depth of the best material. Automatic quality selectors are sometimes installed for this purpose. They should be checked for effectiveness quite frequently and backflushed when they become clogged.

DIGESTED SLUDGE REMOVAL

Digested sludge should be withdrawn as soon as it has reached a reasonably good stage of digestion as determined from its volatile content or at a rate commensurate with minimal supernatant discharges. In a fixed-cover installation the sludge must be removed in small batches. If this is not done the gas pressure will not be maintained. On the other hand, in a digester equipped with a floating cover, the sludge settled in a second-stage unit may be removed more or less as convenience requires; moderately large withdrawals will not cause process failure or loss of gas pressure.

SAFETY CONSIDERATIONS

When withdrawing sludge from a fixed-cover unit, air may be drawn into the digester creating possible explosive gas mixtures unless the rate of sludge replacement is equal to the rate of withdrawl. Equal care must be exercised to keep the liquid level above the stops of a floating cover if creation of a vacuum is to be prevented in the tank. For most efficient operation of the digestion system the withdrawal rate of the sludge from either digester should be no faster than the rate at which the gas production from the system is able to maintain a positive pressure in the digester (at least two inches of water). If the draw operation is too fast the gas pressure drops due to volume expansion. Some operators prefer to pump raw sludge to the digester during digested sludge drawoff to maintain the required positive pressure.

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Learning Resource 2
Sludge Treatment and Disposal
Course Number 166
Anaerobic Digestion II.
prepared by Linn-Benton Community College
6500 SW Pacific Boulevard
Albany, OR 97321
prepared for United States Environmental Protection Agency
National Training and Operational Technology Center
26 West St. Clair
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Presented is the second part of a two-part series on Anaerobic digestion. This lesson emphasizes the classification of digesters by function, roof design and temperature range. Also discussed are mixing systems, gas system components, operational control basics, and safety. The lesson utilizes the audio-visual (slide-tape) format with accompany printed student materials. The program is designed for use with any standard 35mm slide projector and a cassettee tape player. Trainee objectives lesson outline, slide narrative, references, and student worksheet are included.

ANAEROBIC DIGESTION II

CONTENTS

ANAEROBIC DIGESTION II

Lesson Description

This lesson is Part II of a two-part series on Anaerobic Digestion. Part I should be viewed before Part II. This lesson discusses the classification of digester by function, roof design and temperature range. The lesson also discusses mixing systems, gas system components, operational control basics, and general safety.

Estimated Time

Student preview of objectives	5-10 minutes
Presentation of material	40-80 minutes
Worksheet	10-15 minutes
Correct worksheet and discussion	10 minutes

Instructional Materials List

1. Student text "Anaerobic Digestion Part II"
2. Slide Set "Anaerobic Digestion Part II"
3. Slide Projector
4. Screen
5. Examples of gas safety equipment

Suggested Sequence of Presentation

1. Assign Reading - emphasis on flow diagrams, glossary and objectives.
2. Show slide tape programs, or lecture using the slides.
3. Open discussion - review plant flow diagrams, safety equipment, sampling and use of moving averages on trend charts.
4. Assign worksheets.
5. Correct worksheets.

Required Reading

Lesson "Anaerobic Digestion, Part II"

Reference Reading

Operations Manual Anaerobic Sludge Digestion, pages 4-25 through 4-31, 4-16 through 4-18.

Objectives

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

1. Recall the three digester classifications by function.
2. State which digester performs the majority of digestion.
3. Identify digesters by roof design.
4. Recall the name of the most common digestive operating range.
5. State the temperature range for the mesophilic temperature range.
6. State the normal digestion time for the mesophilic range.
7. Recall the maximum temperature variation allowed for a properly operated anaerobic digester.
8. State the three types of heat exchanges.
9. Recall which type of heat exchanger is the easiest to maintain.
10. Describe the purpose of mixing.
11. Identify basic gas components.
12. Describe the function of the gas components.
13. Recall the typical volatile slid/ft.^{3} loading.
14. Recall a typical volatile acid/alkalinity ratio.
15. Identify the five sample points on an anaerobic digester.

ANAEROBIC DIGESTION II

LESSON OUTLINE

I. Preview

A. Classification by function
B. Classification by roof design
C. Effects of temperature
D. Mixer types
E. Gas system
F. Sample points
G. Testing
H. Safety

II. Classification

A. Function
  1. Primary
    a) Receive sludge first
    b) Majority of digestion
  2. Secondary
    a) Follows primary
    b) Sludge gas storage
    c) Multiple digesters - operational flexibility
B. Roof design
  1. Fixed
    a) Primary
  2. Floating roof
    a) floats on sludge
    b) level controlled by sludge draw off
    c) secondary
    d) corbels prevent roof from falling
  3. Gas Holding
    a) floats on gas
    b) height controlled by gas and liquid draw off rates
C. Temperature Classification
    a) temperature controls digestion time
    b) normal mesophilic
    c) 95-98°F
    d) 20-30 days
    e) not vary more than 1°F/day

III. Boilers and Heat Exchangers

A. Boiler
  1. low pressure
  2. uses methane
  3. alternate source
B. Heat exchanger
  1. internal - coils
    a) difficult to maintain temperature

2. Steam injection
   a) internal
   b) both heating and mixing
   c) boiler water treatment
   d) adds extra water.
   e) maintenance
3. Direct gas
   a) heats and mixes
   b) danger
4. External
   a) ease of maintenance
   b) hot water
   c) pre-heat sludge
   d) circulate sludge next to hot water coils
   e) mixing
   f) regular cleaning
5. Temperature Control and Efficiency
   a) rate of recirculation
   b) efficiency of boiler
   c) BTU value of gas
   d) rate of flow
   e) temperature of raw sludge
   f) efficiency of heat exchanger
   g) $1^{o}F$/day

IV. Mixing System
   A. Contact of sludge and micro-organisms
   B. Mixer
      1. compressed gas
      2. mechanical
      3. pumps

V. Gas System
   A. Equipment
      1. heat sensitive valve
      2. flame arresters
      3. pressure reducing valve
      4. moisture - sedimentation traps
      5. orifices - manometers
      6. gas meters
   B. Designed for safety and control.
      1. corrosive
      2. explosive

VI. Operation Control
   A. Major areas
      1. bacteria
         a) anaerobic
         b) slow
         c) ratio 20:1
      2. Food
         a) 5-8% solids
         b) no toxic material
         c) stable pH
         d) constant feed rate

3. Loading
   a) F/M ratio
   b) hydraulic loading
   c) 0.03 to 0.1 lbs VS/ft^3
   d) 20 days retentive time
4. Mixing
   a) artificial best
   b) loading 0.4 lbs VS/ft gives natural loading
5. Environmental conditions
   a) anaerobic
   b) pH 6.8 - 7.2
   c) VA 50-300
   d) alk 3,000-600 mg/l
   e) VA/Alk 0.25 or below
6. Time
   a) controlled by loading and temperature
   b) 95-98°F, 20-30 days

VII. Sampling and Texting
A. Sampling points
   1. digested sludge
   2. digesting sludge
      a) thief hole
   3. raw sludge
   4. supernatant
   5. gas
B. Typical test pH, %, moisture, temperature, alk, V.A.
C. pH and temperature
   1. raw, digested, digesting, supernatant
D. Flow
   1. all points
E. Efficiency
   1. T.S., % moisture, VS compared between raw and digested
F. Gas
   1. CO_2, Flow
G. Supernatant
   1. BOD, S.S. and VSS
H. Control test
   1. VA/Alk ratio
   2. better than pH
I. Plot on 30-day moving averages

VIII. Safety
A. General
   1) rubber-soled shoes
   2) relight burner with caution
   3) fix leaks ASAP
   4) check for combustible gas and O_2 in tanks,

IX. A. Summary

Narrative

Slide #

1. Anaerobic Digestion - This is Part II 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. During this lesson, we will deal with the classification of digesters by function, roof design and temperature, the effects of sludge temperature and ways to control that temperature.

4. We will discuss mixer types, the gas system components, specifically the safety devices and the overall system operation. We will also discuss six factors that affect operational control, some common test points and typical tests and finally there will be an overview of safety considerations.

5. Digesters may be classified by function as to primary, secondary, or gas-holding.

6. Primary digesters are the units that first receive the sludge - it is here that the majority of the digestion takes place.

7. Secondary digesters receive digested sludge from the primary digester. They serve essentially as sludge and gas storage areas. The third function which a digester may provide is that of gas holding. Gas holding digesters usually would follow secondary digesters and collect gas from both primary and secondary digesters. Having multiple digesters provides an operational flexibility, especially during start up and digester upset.

8. Primary and secondary digesters may be further classified by roof design as to fixed or floating roof. The gas holder is a type of floating roof.

9. With the fixed roof design, gas is stored in the upper portion of the tank. Gas pressure in the tank is controlled by gas draw off rate and liquid level.

10. On the other hand, with the floating roof design, the roof floats on the sludge. With this design, the gas must be drawn off as it is produced. There is very little gas storage area.

11. Fixed roof digesters can be identified by the fact that the solid concrete roof usually is flush with the top of the walls.

12. On the floating roof digesters the roof may be below or above the walls, and roof guides are visible around the top edge of the digester.

13. Primary digesters are usually the fixed roof type, and secondary digesters are usually the floating roof design.

14. The floating roof allows for unsteady sludge draw off rates so that disposal maybe periodic rather than constant. To prevent the roof from falling to the bottom of the digester, steel or concrete corbels project from the wall of the digester.

15. Digesters that serve the third function, gas holding, require a special roof design. The roof of this type of digester floats high above the sludge and is totally supported by the gas pressure in the digester. Since gas pressure holds up the roof, its position is controlled by rates of gas produced and gas and/or sludge draw off.

16. The dome shaped roof makes the gas-holding digester easy to identify.

17. Besides classifying digesters as to function and roof design, they may be classified by the operating temperature of the digesting sludge. There are three typical temperature ranges: psychrophilic, mesophilic, and thermophilic, the most common of which is the mesophilic.

18. The length of time required for digestion to come to completion is a function of the temperature range. Operating within the mesophilic range at 95-98° F. will normally complete digestion in 20-30 days.

Boilers and Heat Exchangers

19. This temperature should not vary more than 1° F. per day. To maintain this temperature, a boiler and heat exchanger of some type are necessary.

20. The boiler is usually of the low pressure type (less than 300 psi) and fired by the methane in the digester gas. Using the digester gas to fire the boiler reduces overall energy requirements and makes the anaerobic digestion process an energy producer rather than a consumer.

21. Besides having the digester gas available, an alternative energy source such as natural gas is usually required for start up and as back up at times of digester upset. During these incidents, the quality of the gas will deteriorate to the point that proper temperature can no longer be maintained.

22. Along with the boiler, there must be a heat exchanger. There are three basic types: internal, direct gas and external.

23. Internal heat exchangers are usually the hot water type and consist of a set of internal coils through which the hot water passes.

24. Internal heat exchangers are difficult to maintain and require efficient mixing to prevent stratification of the sludge.

25. Another type of internal heat exchanger is the steam injection type - with this style of heat exchange, live steam is bubbled through the digesting sludge both heating and mixing.

26. This type of heating adds extra water to the sludge. Furthermore, it requires special chemical treatment of the boiler make up water and continuous maintenance of check valves to prevent back flow of sludge into the boiler.

27. Direct gas systems consist of an open flame contained in a hollow tube below the sludge surface. This type of heat exchanger both heats and mixes.

28. This type of system offers an obvious safety problem; that is, if the methane within the digester is ignited by the open flame, a violent explosion will occur.

29. External heat exchangers are much easier to maintain than either internal or direct flame and are, therefore, more common. So, let's look at the process when one of the many external heat exchangers is used.

30. Hot water from the boiler is passed through a set of tubes within the heat exchanger. Partially digested sludge is mixed with raw sludge by the sludge recirculation pump and then circulated through the spaces between the hot water tubes and then to the digester.

31. The mixing of partially digested sludge with raw sludge improves heat transfer efficiency. The recirculation pump helps with mixing.

32. To maintain the heat exchanger efficiently, the tubes must be cleaned on a regular basis.

33. Controlling the temperature of the sludge and the overall energy efficiency of the system is primarily dependent upon the BTU value of the gas and the efficiency of the boiler and heat exchanger. The efficiency is also effected by the temperature and feed rate of the raw sludge as well as the recirculation rate of the digested sludge.

34. Remember, the temperature must not vary more than $1^{o}F$. per day. Fluctuations of greater than one degree per day, even though within acceptable temperature ranges, will cause digester upset.

Mixing Systems

35. As has been mentioned before, the digestion of raw sludge cannot take place unless the microorganisms within the digester can come in contact with the volatile solids within the sludge.

36. This contact is enhanced by continual mixing of the digesting sludge. Several methods of mixing are used. They include:

37. Compressing the gas that is produced and forcing it back through the digesting sludge, or one of several types of mechanical mixers, or a combination of mechanical mixers and pumps, such as the heat exchanger recirculation pumps.

Gas System

38. As has been mentioned previously, one of the major by-products of the anaerobic digestion process is the production of digester gas, which is mostly methane.

39. Because of the explosive nature of the gas, special equipment is required for safe handling. This is true regardless of the major use of the gas.

40. To prevent flash fires in the digester, flame arresters are installed on the top of the digester as well as all other gas exit points.

41. Heat sensitive valves are installed at various points in the gas system to help prevent explosion as a result of a fire within the gas system,

42. Pressure within the gas system is maintained by a compressor and various pressure regulation valves.

43. The functional quality of the gas is improved by the reduction of moisture and sediment by moisture and sediment traps.

44. The rate of gas flow is measured by sharp edged orifices and indicated on manometers.

45. Gas consumption is measured by the typical gas meter.

46. When digester gas systems are properly designed they operate safely while controlling a steady pressure and removing sedimentation and moisture, plus monitoring both gas flow and consumption.

47. Digester gas is not easily stored in a typical gas container due to its corrosive and explosive nature. Therefore, any excess that is produced is consumed via a waste gas burner.

48. To obtain optimum digestion from the digester, six factors must be controlled.

49. They are bacteria, food, loading, mixing, environmental conditions and time.

50. The bacteria of major concern are the methane producers which are strict anaerobes. To protect their environment, all air must be prevented from entering the digester.

51. These organisms are rather slow in their digestion process; therefore, a ratio of 20 times more seed organisms than food is required. That is, each day, only one lb. of food should be fed for each 20 lbs. of organisms in the digester. That is why it normally takes 20 days or more to complete digestion.

52. The food should be of high quality.

53. To be high quality, the raw sludge should contain a low volume of water. It should contain no toxic materials, and have a stable pH. The rate and frequency of feed must be constant.

54. Loading refers to both the food to organisms ratio and the hydraulic loading.

55. The food to organisms ratio for conventional operations will range from 0.03 to 0.1 lbs. of volatile solids per cubic foot of digester sludge. Hydraulic loading affects detention time. The detention time must be long enough to allow for complete digestion, which may be 20 days or more.

56. The food must mix with the organisms. Mixing may be natural or artifical. However, artifical mixing gives the best results and reduces dead spots.

57. As mentioned before, the environmental conditions must be strictly anaerobic, and a volatile acids to alkaline ratio of 0.25 or below will maintain a steady pH.

58. Digestion time is relative to temperature and controlled by loading. That is, at 95-98°F. a detention time of 20-30 days should be maintained.

59. To control the digester, it is necessary to monitor regularly at various points. Samples should be collected from raw sludge, digester sludge, digested sludge, supernatant and gas. Digested sludge is usually collected through special sampling holes called thief holes.

60. One or more of these thief holes are located on the roof of the digester.

61. Samples collected from these points should be evaluated by laboratory tests. Tests such as pH, percent of moisture, temperature, alkalinity, and volatile acids are among the many required monitoring tests.

62. Raw sludge, digesting sludge, digested sludge, and supernatant are all checked for pH and temperature. These tests should be run and compared at least daily.

63. Sludge and gas flow are measured at all entrance and exit points on the digester.

64. To determine the efficiency of the digester, total solids, percent moisture, and volatile solids tests are run on the raw sludge and compared with digesting and digested sludge. These same tests are conducted on the supernatant to determine its quality and ultimate effect on the other treatment processes.

65. The percent of CO_2 in the digester gas as well as flame color indicates gas quality and digester performance. To determine the effect of supernatant on the other treatment processes, both BOD and S.S. are monitored.

66. The ultimate control tests for digester operations are volatile acids and alkalinity. This ratio indicates impending changes in the pH of the digester and, thus, the health of the methane formers. A change in VA/Alk ratios will indicate possible digester problems long before a change in pH can be measured.

67. For best control, trend charts of all parameters should be established with 30 day moving averages.

68. To prevent accidents with digesters, the following precautions should be considered. Wear rubber soled shoes when walking on the roof. Never smoke around the digester vents. Relight the waste gas burner with caution.

69. Fix gas leaks ASAP. Never enter a partially full or empty digester without checking for oxygen depletion and explosive gases.

70. During this lesson, we have seen that digesters are classified three ways: by function, by roof design, and by operating temperature. The mesophilic temperature classification is the most common.

71. We learned that digester temperature is controlled by a heat exchanger and that the sludge temperature must be controlled within 1^{o} F/day.

72. We looked at several types of mixers and learned that mixing improves digestion.

73. We previewed the basic components of the gas system and learned that the system is designed to control the pressure of the gas, remove sediment and moisture, measure flow and consumption and protect the digester from fire and explosion.

74. We saw that for proper operational control, the digester must be monitored and special control tests run on the samples collected.

75. And, finally, we discussed some general safety precautions that should be considered when working in and around digesters.

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.

ANAEROBIC DIGESTION II

WORKSHEET

1. Digestion may be classified by function. On the list below, place an "X" beside the three terms used to describe these three functions:

_____ a. digestion

__X__ b. primary

_____ c. solids reduction

_____ d. conditioning

__X__ e. secondary

_____ f. gas production

_____ g. energy cost savings

_____ h. gas producers

__X__ i. gas holding

2. Find the correct name for this digester in the above list and write the corresponding letter in the following blank: __B__.

3. Select the proper name for the most common digester operating range.

__X__ a. mesophilic

_____ b. psychrophilic

_____ c. esophilic

_____ d. thermophilic

_____ e. none of the above

4. Select the temperature range for the most common digester operating range.

_____ a. 65-78° F

_____ b. 79-95° F

__X__ c. 95-98° F

_____ d. 98-108° F

_____ e. none of the above

5. For a normally operated anaerobic digester operating within the typical temperature range, complete sludge digestion should take place in:

_____ a. 10-20 days

__X__ b. 20-30 days

_____ c. 30-35 days

_____ d. 40-50 days

_____ e. none of the above

6. Using the pictures below, identify each of the digesters by roof design.

A. gas holding

B. fixed

C. floating

D. floating

7. In order to maintain an anaerobic digester in optimum condition, the digester sludge temperature should not change more than ______ degrees F. per day.

____ a. 4

____ b. 3

____ c. 2

__X__ d. 1

____ e. none of the above

8. From the list below, select the three most common types of heat exchangers.

____ a. internal combustion engine

__X__ b. direct gas flame

____ c. low pressure

____ d. coil type

__X__ e. internal

____ f. draft tube

__X__ g. external

____ h. boiler

9. From the previous list, indicate the type of heat exchanger that offers the easiest maintenance.

G

10. The major purpose for mixing is to : (select one)

__X__ a. bring food and microorganisms into contact.

____ b. break up the scum blanket.

____ c. reduce energy requirements by circulation heated sludge.

____ d. release gas from the sludge particles.

11. Match the list of gas handling equipment on the left with the list of functions on the right. (An answer may be used more than once.)

D	flame arresters	a.	improve gas quality
E	waste gas burner	b.	measure gas consumption
B	gas meter	c.	measure gas flow
D	heat sensitive valve	d.	safety
C	sharp edged orifice	e.	disposal of excess gas
A	moisture traps		
A	sediment traps		

12. Typical volatile solids/ft.^{3} loadings for an anerobic digester might be:

_____ a. 0.004 to 0.04 lbs./ft.^{3}

_____ b. 0.04 to 0.4 lbs./ft.^{3}

X c. 0.03 to 0.1 lbs./ft.^{3}

_____ d. 0.03 to 1.0 lbs./ft.^{3}

_____ e. all of the above

7

13. Using the drawing above, match the items indicated with the description.

__A__ flame arrester

__F__ waste gas burner

__E__ gas meter

__D__ heat sensitive valve

__B__ moisture and sediment traps

__C__ manometers

14. The most common volatile acids to alkalinity ratio for an anaerobic digester would be:

____ a. 0.25

____ b. 150

____ c. 0.4

__X__ d. 0.25

____ e. 0.4

15. Using the diagram below, indicate what material is being sampled at each point.

__D__ supernatant

__A__ raw sludge

__C__ digesting sludge

__B__ gas

__E__ digested sludge

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Learning Resource 3
"Anaerobic Digestion"
Wastewater Treatment Plant Operator Training Program
Intermediate Course - Volume B
Water Pollution Control Federation
2626 Pennsylvania Avenue, N.W.
Washington, DC 20037

Presented are selected parts of a training program designed for those already employed as wastewater treatment plant operators. The general objective of the program is to prepare students for further hands-on and skills training in unit process operation.

This part of the unit describes the purpose and the methods of anaerobic digestion. Also examined is the activity that occurs in the anaerobic digester. Performance objectives, unit objectives, instructional resources, instructor activities, and discussion questions are included.

The unit uses the audio-visual (slide-tape) formate with an accompanying printed student workbook. The audio-visual portion of the program is designed for use with any standard 35mm slide projector and a cassette tape player. Pre- and post-tests are provided within the student workbooks.

UNIT 8B - PRE-TEST

NAME: ______________________________ DATE: ________________

The following questions are designed to help you find out how much you already know about what we are going to be talking about in the next Unit. This will give you a better idea about how much you have learned by going through the Unit. Answer each question carefully, and where necessary in your own words. Don't worry if you can't answer some of the questions -- you're not expected to be able to.

1. Put an "X" beside each of the following statements that is a reason for and result of anaerobic digestion:

   a. _____ production of a sludge easier to dewater.
   b. _____ elimination of all odors.
   c. _____ lowering in the number of pathogens.
   d. _____ reduction in the volume of solids.

2. What are the two different kinds of bacteria involved in the anaerobic digestion process?

   a. ______________________________
   b. ______________________________

3. Briefly explain how these two different kinds of bacteria work together.

   ____
   ____
   ____

4. Which of these two different kinds of bacteria is more sensitive?

   ____

5. a. If organic loadings are too high, what will happen to the balance between the bacteria?

   ____
   ____

   b. If organic loadings are too low, what will happen to the balance between the bacteria?

   ____
   ____

6. About what percentage of the gases produced in the digester is methane?

_______%

7. Why is it important to provide mixing in the digester?

____

____

8. Sludge that is easily dewaterable, does not smell too bad, has a lumpy black appearance, and does not have grey streaks in it is (well/incompletely) digested sludge.

9. Give a brief description of a:

a. two-stage digestion set-up

____

____

____

b. one-stage digestion set-up

____

____

____

10. It is expected that the liquid level will vary greatly in a digester with a fixed cover.

TRUE ________ FALSE ________

11. The bottoms of digesters are cone-shaped. Why?

____

____

12. It is important that the temperature of the digester be kept at a constant temperature, someplace in the range of 90 to 98°F. How is this done?

____

____

13. What important control do we have over gas pressure or vacuum build-ups in the fixed-cover digester?

____

14. There is water vapor in the gas removed from the digester. As the gas cools in the pipes, this water vapor condenses and forms water, Where is this water collected?

____

15. What are the two ways used to provided mixing in the digester?

a. ____________________

b. ____________________

16. In terms of good digester results, what are the two main things that we are looking for?

a. ____________________

b. ____________________

17. What are the two main indicators that we can use to warn us about possible digester problems?

a. ____________________

b. ____________________

18. If we are getting indications of digester problems, can you list at least two things that should be checked?

a. ____________________

b. ____________________

When you have completed your answers and are ready to check them, go on to the next page.

ANSWERS TO
UNIT 8B - PRE-TEST

Check over your answers, remembering that we are more concerned with you having the right idea than the same words as given here. Points allotted for each question are indicated in parentheses.

1. (four points)

   a. X
   b.
   c. X
   d. X

2. (two points)

   a. acid-forming bacteria
   b. methane-producing bacteria

3. (four points) The acid-forming bacteria digest the organics in the sludge producing acid as they do so. Too much would upset the process. The methane-producing bacteria eat the acid, and thus keep the process going.

4. (one point) methane-producing bacteria

5. (four points)

   a. Acid forming bacteria will multiply rapidly and produce too much acid. The methane-producing bacteria will not be able to handle it all, and the process will fail.

   b. There will not be enough acids produced to keep enough methane producers alive. This means that even a small increase in loading will be too much for the methane producers to handle and the process will fail.

6. (one point) 65%

7. (two points) Mixing helps prevent a scum blanket from forming at the top of the digester. It also helps distribute heat, prevent dead areas, and helps to mix microorganisms and sludge.

8. (one point) well

9. (four points)

a. Two stage digestion involves two tanks. In the primary digester, the sludge is heated, mixed and broken down. The secondary digester is used as a holding tank (a secondary clarifier), where the supernatant is separated from the sludge.

b. The digestion process happens in one tank. Mixing has to be stopped before supernatant is withdrawn.

10. (one point) FALSE

11. (one point) This helps the sludge settle, and allows the thickest sludge to be removed from the digester.

12. (one point) A sludge recirculation system is used to pass sludge through a heat exchanger to keep the temperature in the proper range.

13. (one point) pressure vacuum relief valve

14. (one point) drip traps

15. (two points)

a. mechanical mixing
b. gas mixing

16. (two points)

a. reduction in the volume of organic solids
b. a good supernatant

17. (two points)

a. volatile acids level
b. gas production

18. (two points) Any two of the following:

a. temperature
b. mixing system
c. hydraulic overloading

How well did you make out? Mark your score here.

__________ out of 36

Now let your program administrator know that you are ready to begin studying Unit 8B. Do not go on to the next page until after you have completed the Unit 8B Tape 1 audio-visual program.

UNIT 8B - SUMMARY
TAPE 1

The following summarizes what has been talked about so far in Unit 8B, Tape 1. Read this summary over carefully, making sure that you understand each of the points mentioned.

Reasons for and results of sludge digestion:

- production of a sludge easier to dewater;
- reduction of odors;
- lowering in the number of pathogens; and
- reduction in the volume of solids.

Anaerobic digestion is a biological process that makes use of two different kinds of bacteria.

- Acid forming bacteria: These bacteria form acids as they digest organics in the sludge. They keep on growing and reproducing as long as food is available. They also keep on producing acid as they work.

- Methane producing bacteria: The methane producing bacteria provide the balance to the acid forming bacteria. The methane producing bacteria eat the acid produced by the acid-producing bacteria, and keep the process working. If there were too much acid, the digestion process would stop.

The acid formers will survive as long as there is food available. But the methane producers are sensitive and can only operate under anaerobic conditions. Even changes in loading, pH, or temperature will affect methane producers. Methane producers work best at a constant temperature someplace between 90 and 98°F. They don't like changes of more than 1°F per day.

If the methane producers cannot work, there will soon be too much acid in the digester. The color of the sludge will become dirty grey, and there will be a strong sour smell. Once it starts, the situation will get worse.

Acid-forming bacteria form volatile acids. These volatile acids are eaten by the methane producing bacteria, which change the acid into methane, carbon dioxide, and water.

There has to be a proper balance between the acid forming and methane producing bacteria.

- If the organic loading is too high, then the acid forming bacteria will multiply rapidly and produce a large amount of acid. The methane producing bacteria will not be able

to handle it all, and the extra acid will lower the pH in the digester. The process will fail.

- If the organic loading is too low, there will not be enough acids formed to keep a reasonable number of methane producers alive. Even a small increase in loading will be too much for the methane producers to handle. The process will fail.

There are gases produced in the digester. About 65% is methane, 30% carbon dioxide, and 5% other gases like nitrogen and hydrogen. (In the Basic Course, we had lumped this 5% in with the methane.)

Mixing in the digester is important because it helps prevent a scum blanket from forming at the top of the digester liquid. Mixing also helps distribute heat, prevent dead areas, and helps to mix the microorganisms and the sludge.

When mixing is stopped, a supernatant forms. It includes the water that was formed during the digestion process. This supernatant is put back through the plant because it is high in suspended solids and B.O.D.

Well digested sludge is easily dewaterable and does not smell too bad. It has a lumpy black appearance.

Incompletely digested has an extremely strong sour smell, and has grey streaks in it.

Properly digested sludge is dewatered, and then disposed of on approved land or land fills.

We can talk about two different anaerobic digestion set-ups.

<u>Two-stage digestion</u>: Two tanks are involved. The first is called the primary digester. It is used to heat, mix, and break down raw sludge. The second tank is called the secondary digester. It is used as a holding tank and essentially is a secondary clarifier. In the secondary digester, the supernatant is separated from the sludge.

Most of the decomposition and gas production takes place in the primary digester.

When raw sludge is pumped to the primary digester, about the same amount of digested sludge is transferred to the secondary digester.

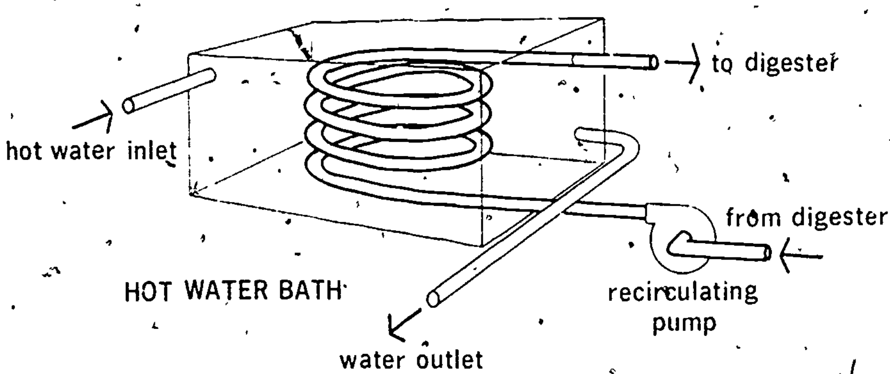
The <u>one-stage digestion</u> set-up is more difficult to operate because everything has to happen in the same tank. Also, all mixing has to stop for several hours before any supernatant can be drawn off.

If a digester has a fixed cover, then every time raw sludge is added, about the same amount of supernatant has to be displaced because the liquid in the digester is kept at about the same level.

If the digester has a floating cover, the roof can move up and down. This means that the liquid level in the digester can vary.

The bottoms of all digesters are cone-shaped so that the thickest sludge can be removed from the digester.

The sludge recirculation system keeps the contents of the digester at the proper temperature. This diagram shows how digester sludge passes through the heat exchanger:



Supernatant drawoff lines are set up so that the operator can choose where he will withdraw from.

Gas from the digester is drawn off and carried to the boiler if the methane is being used as fuel, or to the waste gas burner.

It is important that a close watch be kept on the gas produced in the digester. If there is too much gas in a fixed cover digester, there will be a build-up of pressure. On the other hand, if there is a rapid drop in the level of the liquid, a vacuum could develop. Either way, the digester cover could be damaged.

One of the safeguards against pressure or vacuum build-ups is the pressure-vacuum relief valve. If the pressure is too great, gas is released. If there is a vacuum, air will be sucked in. Often, water seals can be used as well.

Even if there are water seals or pressure-vacuum relief valves, this does not allow you to disregard what is happening to gas pressure in the digester. If the methane and air are allowed to mix, an explosive combination could result.

Manometers outside the digester tell you what the pressure is inside the digester. The actual control of the gas pressure takes place on the waste gas burner line by the pressure regulating valve.

Pipes carrying digester gas have drip traps, where condensed water vapor from the digester gas will collect. These drip traps have to be drained regularly.

Mixing in the digester can be done either mechanically, or by gas.

- Mechanical mixing: A propeller is attached to a shaft which goes through the cover. A motor turns the shaft and creates mixing action in the digester.

- Gas mixing: Basically, some digester gas is taken from the digester, passed through a compressor, then forced back into the digester a few feet from the bottom of the digester. The gas bubbling back to the surface causes mixing of the sludge.

When you have completed this review and are sure of all the points, tell your program administrator that you are ready to go on to Unit 8B Tape 2 audio-visual program.

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In this part of the summary we will review the main points about anaerobic digester control. Be sure that you understand each of the points mentioned.

In terms of digester control, what we are looking for is:

- a reduction in the volume of organic solids; and
- the production of a good quality supernatant.

Inorganic solids are not affected in the digestion process, but there are changes in organic or volatile solids.

Some of the organic or volatile solids are changed to water and gas in the digester. In a properly operated digester, there should be an organic solids reduction of about 40 to 60%. That is, the digestion process reduces the amount of organic solids by about one-half.

If the supernatant is not as good as it should be, you probably need a longer settling time before any supernatant is withdrawn.

There are two indicators that warn us if we are running into digester problems:

- Volatile acids level: If there is a drastic change from your digester's usual volatile acids level, or if the volatile acids level reaches 2000 mg/l, you can expect digester problems.

- Gas production and quality: Normally the gas produced in the digester is about 65% methane, 30% carbon dioxide, and 5% other gases. Your warning sign is a drop in the methane concentration, or an increase in the carbon dioxide concentration. Normally the methane burn-off flame will be blue with only a trace of yellow. It will be almost invisible in sunlight. As the methane concentration drops, the flame will become yellower. With less methane, red tongues and a little black smoke may appear, or the flame may go out.

If your indicators are showing that you might be running into problems, here are the things you should check:

- temperature: The temperature of the digester should be kept constant, someplace between 90 and 98°F. A temperature change of more than a couple of degrees in the past week, or more than one degree in any one day, could be the cause of the problem.

- mixing system: Is the mixing system working properly? If the plant has an intermittent mixing system, increase how often and how long mixing takes place.

- hydraulic loading: Hydraulic loading is the number of days that the liquid stays in the digester. In a heated mixed digester, the detention time is 10 to 15 days. If the detention time is too short, the digestion process will probably not be complete. If you cannot increase the detention time, try to feed a more concentrated sludge to the digester. You always have to be careful that you are not pumping too much water - or grit - to the digester. Try shorter and more frequent pumping of sludge to the digester.

MORE POINTS ABOUT DIGESTER OPERATION

If you are already operating an anaerobic digester, these extra points may help you out a bit, until you are able to take the skill training program on the anaerobic digester.

Digester Loading

It would be ideal if raw sludge could be pumped to the digester continuously. But this is not possible. Smaller plants that are supervised for only eight hours a day may only load the digester three times a day (eight in the morning, noon, and three in the afternoon). In larger plants where automatic pumping is possible, pumping mav be so frequent that it is almost continuous. If there is 24-hour supervision of the plant, and pumping is manually controlled. there may be six to eight pumping cycles every day.

If sludge is being pumped to the digester for too long a period it mav become too thin and there will be too much extra water being pumped to the digester.

Sludge Transfer

Moving sludge from the primary to the secondary digester can be done from the top or the bottom of the primary digester. It is a good idea, though, to use the bottom lines at least one a week, so that they will not plug up with grit and/solids.

Supernatant Selection

It is hard to get a good supernatant from a single stage digester. Still, you should try to remove excess liquid. Mixing devises should be shut off for a while before supernatant is withdrawn. Experience will tell you how long a settling time is needed to get a good supernatant. If you have a number of supernatant draw-off lines, you should use the one that gives the best supernatant.

In two-stage digesters, the supernatant is drawn off from the secondary digester. The supernatant might be selected automatically when a sludge transfer takes place, or the supernatant might be withdrawn when the plant can best take the extra B.O.D. loading. The equipment you have available will determine how and when supernatnat is withdrawn.

You should carry out a suspended solids test on the supernatant. If the suspended solids levels are more than 5000 to 7500 mg/l, you can probably expect problems to develop in other parts of the plant.

Digested Sludge Removal

When you are taking out sludge from a fixed cover digester. This would draw in air and create an explosive condition. Your best bet is to pump only small amounts, and if possible, raw sludge should be added at the same time so that the liquid level in the digester stays the same.

In single-stage digesters, sludge should be removed as often as possible. It will be hard to get a concentrated sludge from the single-stage digester. In fact, a 3 to 4% sludge is considered good for an activated sludge plant using a single-stage digester. To judge the stability of the sludge and its concentration, you should be using the total, and the volatile solids tests.

A two-stage digester will produce a more concentrated sludge. If at least one of the digesters has a floating cover, then you can remove the sludge from the secondary digester whenever it is convenient. Because the tanks are connected and at least one of the digesters has a floating cover, taking out a lot of sludge at one time will not disturb the process or cause a loss of gas pressure. Again, you should be using the total, and the volatile solids tests to evaluate the stability of the sludge and its concentration.

This is the end of the review for this Unit. Before going on to the review exercise, however, you should check over the complete summary, just to be sure that you have not missed any of the points.

When you are ready, go on to the review exercise on the next page.

UNIT 8B - REVIEW EXERCISE

Answer the following questions as best you can, in your own words where necessary.

1. We mentioned four results of the sludge process. Do you recall what they are?

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

2. There are two different kinds of bacteria involved in the anaerobic digestion process. What are they? Briefly describe what each kind does.

   a. ____________________

   b. ____________________

3. These bacteria will survive as long as there is food available.

   ____

4. These bacteria are sensitive and can only operate under anaerobic conditions.

   ____

5. There has to be a proper balance between these two different kinds of bacteria.

   a. What will happen if the organic loading is too high?

   ____

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b. What will happen if the organic loading is too low?

____

____

____

6. Normally about what percentage of the gases produced in the digester is methane?

______ %

7. What are some of the reasons why it is important to have mixing in the digester?

____

____

____

8. How would you describe:

a. a well-digested sludge? ______________________________

____

b. an incompletely digested sludge? ______________________________

____

9. Briefly describe the difference between two-stage and one-stage operation:

____

____

____

10. Changes in gas pressure and liquid level are not as critical in the ______ cover digester.

11. Why are the bottoms of digesters cone-shaped?

____

____

12. What is the purpose of the sludge recirculation system?

____

____

____

13. What is done with the gas that has been removed from the digester?

____

14. Briefly describe the double purpose of the pressure vacuum relief valve.

____

____

____

15. What is the purpose of the drip traps?

____

____

16. What are the two ways in which mixing can be accomplished in the digester?

a. ____________________

b. ____________________

17. In terms of digester control, what are the two things that we are looking for?

a. ____________________

b. ____________________

18. What are the two indicators that we use to get warnings of digester problems? Briefly describe each.

a. ____________________: ____________________

____

____

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b. ______________________ : ______________________________

____

____

19. If you are getting warnings that there are digester problems, what three things should you check?

a. ______________________

b. ______________________

c. ______________________

When you have completed your answers and are ready to check them over, go on to the next page.

ANSWERS TO
UNIT 8B - REVIEW EXERCISE

In checking your answers, remember that we are more concerned that you had the right idea rather than the exact words as given here.

Points are given for each question so that you can grade yourself.

1. (four points)

   a. production of a sludge easier to dewater
   b. reduction of odors
   c. lowering in the number of pathogens
   c. reduction in the volume of sludge

2. (four points)

   a. Acid forming bacteria: These bacteria form acids as they digest organics in the sludge. They keep on growing and reproducing as long as there is food available.

   b. Methane producing bacteria: These bacteria provide the balance to the acid forming bacteria. They eat the acid produced by the acid forming bacteria, and thus keep the process working. (If there were too much acid, the digestion process would stop.)

3. (one point) acid forming bacteria

4. (one point) methane producing bacteria

5. (four points).

   a. Acid forming bacteria will multiply rapidly and produce a large amount of acid. The methane producing bacteria will not be able to handle it all. The extra acid will lower the pH in the digester, and the process will fail.

   b. There will not be enough acid formed to keep a reasonable number of methane producing bacteria alive. Even a small increase in loading will be too much for the methane producers to handle, and the process will fail.

6. (one point) 65%

7. (two points) Mixing helps prevent a scum blanket from forming at the top of the digester liquid. It helps distribute heat, prevent dead areas, and helps to mix the microorganisms and the sludge.

75

8. (two points)

   a. Well-digested sludge is easily dewaterable, and does not smell too badly. It has a lumpy black appearance.

   b. Incompletely digested sludge has a strong sour smell, and grey streaks in it.

9. (three points) Two tanks are involved in two-stage digestion. The primary digester is used to heat, mix and break down raw sludge. The secondary digester acts as a holding tank, and essentially is a secondary clarifier. Supernatant is separated from the sludge in the secondary digester. In one-stage digestion, everything has to happen in one tank.

10. (one point) floating cover

11. (one point) This allows the thickest sludge to be removed from the digester.

12. (one point) The sludge recirculation system keeps the contents of the digester at the proper temperature.

13. (two points) The gas is carried to the boiler if it is being used as fuel, or to the waste gas burner.

14. (two points) The pressure-vacuum relief valve helps prevent gas pressure or vacuum build-ups in the digester. Too much pressure lifts the weights and allows the extra gas to escape. A vacuum forces a valve open to let air into the digester.

15. (one point) The drip traps collect the water that is condensed inside the pipes carrying the digester gas.

16. (two points)

   a. mechanical mixing
   b. gas mixing

17. (two points)

   a. a reduction in the volume of organic solids
   b. the production of a good quality supernatant

18. (four points)

   a. Volatile acids level: The volatile acids level should be about 50 to 300 mg/l. At 1000 mg/l there will be too much acid produced and the process is likely to fail. At 2000 mg/l, there is not much you can do to stop the digestion process from failing.

b. Gas production: Normally the methane burn-off flame is blue with only a trace of yellow. As the methane production drops, the flame will become yellower. Red flames and black smoke may appear, or the flame may go out.

19. (three points)

a. temperature
b. mixing system
c. hydraulic loading

How well did you do? Mark your score here:

__________ out of 41

If you score 33 or more points, you are doing fine. That is at least 80%.

On the other hand, if you scored less than 33 points, you should review the points you had trouble with. If you want to go over this Unit again, now is the time to do so.

When you are ready to try the final exercise for Unit 8B, see your program administrator.

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UNIT 8B - POST-TEST

NAME: ______________________ DATE: ____________

The following questions relate to the things you have studied in this Unit. Answer each of the questions as best you can in your words.

1. Put an "X" beside each of the following statements that is a reason for and result of anaerobic digestion:

   a. _____ production of a sludge easier to dewater.
   b. _____ elimination of all odors.
   c. _____ lowering in the number of pathogens.
   d. _____ reduction in the volume of solids.

2. What are the two different kinds of bacteria involved in the anaerobic digestion process:

   a. ______________________
   b. ______________________

3. Briefly explain how these two different kinds of bacteria work together.

   ____

   ____

   ____

4. Which of these two different kinds of bacteria is more sensitive?

   ____

5. a. If organic loadings are too high, what will happen to the balance between the bacteria?

   ____

   ____

   b. If organic loadings are too low, what will happen to the balance between the bacteria?

   ____

   ____

6. About what percentage of the gases produced in the digester is methane? ______________ %

7. Why is it important to provide mixing in the digester?

____

____

8. Sludge that is easily dewaterable, does not smell too bad, has a lumpy black appearance, and does not have grey streaks in it is (well/incompletely) digested sludge.

9. Give a brief description of a.:

   a. two-stage digestion set-up

   ____

   ____

   ____

   b. one-stage digestion set-up

   ____

   ____

   ____

10. It is expected that the liquid level will vary greatly in a digester with a fixed cover.

    TRUE __________ FALSE __________

11. The bottoms of digesters are cone-shaped. Why?

____

____

12. It is important that the temperature of the digester be kept at a constant temperature, someplace in the range of 90 to 98°F. How is this done?

____

____

13. What important control do we have over gas pressure or vacuum build-ups the fixed-cover digester?

____

14. There is water vapor in the gas removed from the digester. As the gas cools in the pipes, this water vapor condenses and forms water. Where is this water collected?

____

15. What are the two ways used to provided mixing in the digester?

a. ____________________

b. ____________________

16. In terms of good digester results, what are the two main things we are looking for?

a. ____________________

b. ____________________

17. What are the two main indicators that we can use to warn us about possible digester problems?

a. ____________________

b. ____________________

18. If we are getting indications of digester problems, can you list at least two things that should be checked?

a. ____________________

b. ____________________

When you have completed your answers to this Post-Test, see your program administrator.

Learning Resource 4
Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Facilities
prepared by Culp/Wesner/Culp
Clean Water Consultants
prepared for U.S. Environmental Protection Agency
Office of Water Program Operations
Washington, DC 20460

Presented is part of a manual designed to provide technical guidance for persons conducting evaluations of wastewater treatment plants and serve as a model which can be used by state regulatory agencies. Common operating problems with anaerobic digesters are identified by defining the indicators. Once the problem has been identified, certain monitoring, analyses, and/or inspections that must be performed prior to making a decision are discussed. Corrective measures to be utilized are detailed.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
1. A rise in the volatile acid/alkalinity (VA/Alk.) ratio.	1a. Hydraulic overload caused by storm infiltration, accidental overpumping, withdrawing too much sludge.	1a. Monitor the following twice daily until problem is corrected: - volatile acids - alkalinity - temperature	1a. If ratio increases to 0.3: (1) add seed sludge from secondary digester (or) (2) decrease sludge withdrawal rate to keep seed sludge in digester (and/or) (3) extend mixing time. (4) check sludge temperatures closely and control heating if needed.
	1b. Organic overload.	1b. Monitor sludge pumping volume, amount of volatile solids in feed sludge; check for increase in septic tank sludge discharged to plant or industrial wastes.	1b. See 1a.
	1c. Discharge of toxic materials to digesters such as heavy metals, sulfides, ammonia.	1c. Volatile acids, pH, gas production; check industrial wastes at source; check for inadequate sludge pumping generating sulfides.	1c. Use any or combination of the following: (1) solids recycle. (2) liquid dilution. (3) decrease feed concentration. (4) precipitate heavy metals with sulfur compound. Be sure pH in digester is greater than 7.0. (5) Use iron salts to precipitate sulfides. (6) institute source control program for industrial wastes.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
2. CO_2 in gas starts to increase.	2. VA/Alk. ratio has increased to 0.5.	2a. Waste gas burner. 2b. Gas analyzer.	2. See Item 1 and start adding alkalinity using the volatile acids to calculate the amount.
3. pH starts to drop and CO_2 increases to the point (42-45%) that no burnable gas is obtained.	3a. VA/Alk. ratio has increased to 0.8.	3a. Monitor as indicated above. 3b. Hydrogen sulfide (rotten egg) odor. 3c. Rancid butter odor.	3a. Add alkalinity. 3b. Decrease loading to less than 0.01 lb vol. solids/cu ft/day until ratio drops to 0.5 or below.
4. The supernatant quality returning to process is poor, causing plant upsets.	4a. Excessive mixing and not enough settling time.	4a. Withdraw sample and observe separation pattern.	4a. Allow longer periods for settling before withdrawing supernatant.
	4b. Supernatant draw-off point not at same level as supernatant layer.	4b. Locate depth of supernatant by sampling at different depths.	4b. Adjust tank operating level or draw-off pipe.
	4c. Raw sludge feed point too close to supernatant draw-off line.	4c. Determine volatile solids content. Should be close to value found in well mixed sludge and much lower than raw sludge.	4c. Schedule pipe revision for soonest possible time when digester can be dewatered.
	4d. Not withdrawing enough digested sludge.	4d. Compare feed and withdrawal rates - check volatile solids to see if sludge is well-digested.	4d. Increase digested sludge withdrawal rates. Withdrawal should not exceed 5% of digester volume per day.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
			4e. Review feasibility of adding powdered carbon to digesters with consultant or regulatory agency.
5. Supernatant has a sour odor from either primary or secondary digester.	5a. The pH of digester is too low.	5a. See Item 3.	5a. See Item 3.
	5b. Overloaded digester ("rotten egg odor").	5b. See Item 3.	5b. See Item 3.
	5c. Toxic load (rancid butter odor).	5c. See Item 1c.	5c. See Item 1c.
6. Foam observed in supernatant from single stage or primary tank.	6a. Scum blanket breaking up.	6a. Check condition of scum blanket.	6a. Normal condition but should stop withdrawing supernatant if possible.
	6b. Excessive gas recirculation.	6b. 20 CFM/1,000 cu ft is adequate.	6b. Throttle compressor output.
	6c. Organic overload.	6c. Volatile solids loading ratio.	6c. Reduce feeding rate.
7. Bottom sludge too watery or disposal point too thin.	7a. Short-circuiting.	7a. Draw-off line open to Supernatant Zone.	7a. Change to bottom draw-off line.
	7b. Excessive mixing.	7b. Take sample and check how it concentrates in settling vessel.	7b. Shut off mixing for 24-48 hours before drawing sludge.
	7c. Sludge coning, allowing lighter solids to be pulled into pump suction.	7c. Total solids test or visual observation.	7c. (1) "Bump" the pump 2 or 3 times by starting and stopping. (2) Use whatever means available to pump digester contents back through the withdrawal line.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
			7c. (continued) (3) If available, attach a water hose to the pump suction line and force water through it. (Water source must be nonpotable.) Run for no more than 2 or 3 min to avoid diluting the digester
8. Sludge temperature is falling and can not be maintained at normal level.	8a. Sludge is plugging external heat exchanger.	8a. Check inlet and outlet pressure on exchanger.	8a. Open heat exchanger and clean.
	8b. Sludge recirculation line is partially or completely plugged.	8b. Check pump inlet and outlet pressure.	8b. (1) Backflush the line with heated digester sludge. (2) Use mechanical cleaner. (3) Apply water pressure. Do not exceed working line pressure. (4) Add approx. 3 lb/100 gal. water of trisodium phosphate (TSP) or commerical degreasers. (Most convenient method is to fill scum pit to a volume equal to the line, add TSP or other chemical, then admit to the line and let stand for an hour.)
	8c. Inadequate mixing.	8c. Check temperature profile in digester.	8c. Increase mixing.
	8d. Hydraulic overload.	8d. Incoming sludge concentration.	8d. See Item 1a.

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INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
	8e. Low water feed rate in internal coils used for heat exchange.	8e. (1) Air lock in line. (2) Valve partially closed.	8e. (1) Bleed air relief valve. (2) Upstream valve may be partially closed.
	8f. Boiler burner not firing on digester gas.	8f. (1) Low gas pressure. (2) Unburnable gas due to process upset.	8f. (1) Locate and repair leak. (2) See Item 3.
	8g. Heating coils inside digester have coating.	8g. Temperature of inlet and outlet water is about the same.	8g. (1) Remove coating, may require draining tank. (2) Control water temperature to 130°F maximum.
9. Sludge temperature is rising.	9. Temperature controller is not working properly.	9. Check water temperature and controller setting.	9. If over 120°F, reduce temperature. Repair or replace controller.
10. Recirculation pump not running; power circuits O.K.	10. Temperature override in circuit to prevent pumping too hot water through tubes.	10. Visual check; no pressure on sludge line.	10a. Allow system to cool off. 10b. Check temperature control circuits.
11. Gas-mixer feed lines plugging.	11a. Lack of flow through gas line. 11b. Debris in gas lines.	11. Identify low temperature of gas feed pipes or low pressure in the manometer.	11a. Flush out with water. 11b. Clean feed lines and/or valves. 11c. Give thorough service when tank is drained for inspection.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
12. Gear reducer wear on mechanical mixers.	12a. Lack of proper lubrication. 12b. Poor alignment of equipment.	12a. Excessive motor amperage, excessive noise and vibration, evidence of shaft wear. 12b. See Item 15	12a. Verify correct type and amount of lubrication from manufacturer's literature. 12b. Correct imbalances caused by accumulation of material on the internal moving parts.
13. Shaft seal leaking on mechanical mixer.	13. Packing dried out, or worn.	13. Evidence of gas leakage (evident odor of gas).	13a. Follow manufacturer's instructions for repacking. 13b. Replace packing any time the tank is empty if it is not possible when unit is operating.
14. Wear on internal parts of mechanical mixer.	14. Grit or misalignment.	14. Visual observation when tank is empty, compare with manufacturer's drawings for original size. Motor amperage will also go down as moving parts are worn away and get smaller.	14. Replace or rebuild - experience will determine the frequency of this operation.
15. Imbalance of internal parts because of accumulation of debris on the moving parts of mechanical mixers (large-diameter impellers or turbines would be affected most).	15. Poor comminution and/or screening.	15. Vibration, heating of motor, excessive amperage, noise.	15a. Reverse direction of mixer if it has this feature. 15b. Stop and start alternately. 15c. Open inspection hole and visually inspect. 15d. Draw down tank and clean moving parts.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
16. Rolling movement of scum blanket is slight or absent.	16a. Mixer is off.	16a. Mixer switch or timer.	16a. May be normal if mixers are set on a timer. If not and mixers should be operating, check for malfunction.
	16b. Inadequate mixing.		16b. Increase mixing.
	16c. Scum blanket is too thick.	16c. Measure blanket thickness.	16c. See Items 18 and 19.
17. Scum blanket is too high.	17. Supernatant overflow is plugged.	17. Check gas pressure, it may be above normal or relief valve may be venting to atmosphere.	17. Lower contents through bottom drawoff then rod supernatant line to clear plugging.
18. Scum blanket is too thick.	18. Lack of mixing, high grease content.	18. Probe blanket for thickness through thief hole or in gap beside floating cover.	18a. Break up blanket by using mixers.
			18b. Use sludge recirculation pumps and discharge above the blanket.
			18c. Use chemicals to soften blanket.
			18d. Break up blanket physically with pole.
			18e. Tank modification.
19. Draft tube mixers not moving surface adequately.	19. Scum blanket too high and allowing thin sludge to travel under it.	19. Rolling movement on sludge surface.	19a. Lower sludge level to [illegible] above top of tube allowing thick material to be pulled into tube - continue for 24-48 hours.
			19b. Reverse direction (if possible)

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INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
20. Gas is leaking through pressure relief valve (PRV) on roof.	20. Valve not seating properly or is stuck open.	20. Check the manometer to see if digester gas pressure is normal.	20. Remove PRV cover and move weight holder until it seats properly. Install new ring, if needed. Rotate a few times for good seating.
21. Manometer shows digester gas pressure is above normal.	21a. Obstruction or water in main burner gas line.	21a. If all use points are operating and normal, then check for a waste gas line restriction or a plugged or stuck safety device.	21a. Purge with air, drain condensate traps, check for low spots. Care must be taken not to force air into digester.
	21b. Digester PRV is stuck shut.	21b. Gas is not escaping as it should.	21b. Remove PRV cover and manually open valve, clean valve seat.
	21c. Waste gas burner line pressure control valve is closed.	21c. Gas meters show excess gas is being produced, but not going to waste gas burner.	21c. Relevel floating cover if gas escapes around dome due to tilting.
22. Manometer shows digester gas pressure below normal.	22a. Too fast withdrawal causing a vacuum inside digester.	22a. Check vacuum breaker to be sure it is operating properly.	22a. Stop supernatant discharge and close off all gas outlets from digester until pressure returns to normal.
	22b. Adding too much lime.	22b. Sudden increase in CO_2 in digester gas.	22b. Stop addition of lime and increase mixing.
23. Pressure regulating valve not opening as pressure increases.	23a. Inflexible diaphragm.	23a. Isolate valve and open cover.	23a. If no leaks are found (using soap solution) diaphragm may be lubricated and softened using neats-foot oil.
	23b. Ruptured diaphragm.	23b. Visual inspection.	23b. Ruptured diaphragm would require replacement.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
24. Yellow gas flame from waste gas burner.	24. Poor quality gas with a high CO_2 content.	24. Check CO_2 content will be higher than normal.	24. Check concentration of sludge feed - may be too dilute. If so, increase sludge concentration. See Items 2 and 3.
25. Gas meter failure (propeller or lobe type).	25a. Debris in line.	25a. Condition of gas line.	25a. Flush with water, isolating digester and working from digester toward points of usage.
	25b. Mechanical failure.	25b. Fouled or worn parts.	25b. Wash with kerosene or replace worn parts.
26. Gas meter failure (bellows type).	26a. Inflexible diaphragm.	26a. Isolate valve and open cover.	26a. If no leaks are found (using soap solution) diaphragm may be lubricated and softened using neats-foot oil.
	26b. Ruptured diaphragm.	26b. Visual inspection.	26b. Replace diaphragm.
			26c. Metal guides may need to be replaced if corroded.
27. Gas pressure higher than normal during freezing weather.	27a. Supernatant line plugged.	27a. Supernatant overflow lines.	27a. Check every two hours during freezing conditions, inject steam, protect line from weather by covering and insulating overflow box.
	27b. Pressure relief stuck or closed.	27b. Weights on pressure relief valves.	27b. If freezing is a problem, apply light grease layer impregnated with rock salt.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
28. Gas pressure lower than normal.	28a. Pressure relief valve or other pressure control devices stuck open. 28b. Gas line or hose leaking.	28a. Pressure relief valve and devices. 28b. Gas line and/or hose.	28a. Manually operate vacuum relief and remove corrosion if present and interferring with operation. 28b. Repair as needed.
29. Leaks around metal covers.	29. Anchor bolts pulled loose and/or sealing material moved or cracking.	29. Concrete broken around anchors, tie-downs bent, sealing materials displaced.	29. Repair concrete with fast sealing concrete repair material. New tie-downs may have to be welded onto old ones and redrilled. Tanks should be drained and well ventilated for this procedure. New sealant material should be applied to leaking area.
30. Suspected gas leaking through concrete cover.	30. Freezing and thawing causing widening of construction cracks.	30. Apply soap solutions to suspected area and check for bubbles.	30. If this is a serious problem, drain tank, clean cracks and repair with concrete sealers. Tanks should be drained and well ventilated for this procedure.
31. Floating cover tilting; little or no scum around the edges.	31a. Weight distributed unevenly.	31a. Location of weights.	31a. If moveable ballast or weights are provided, move them around until the cover is level. If no weights are provided, use a minimal number of sand bags to cause cover to level up. (Note: pressure relief valves may need to be reset if significant amounts of weight are added.)

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INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
	31b. Water from condensation or rain water collecting on top of metal cover in one location.	31b. Check around the edges of the metal cover. (Some covers with insulating wooden roofs have inspection holes for this purpose.)	31b. Use siphon or other means to remove the water. Repair roof if leaks in the roof are contributing to the water problem.
32. Floating cover tilting, heavy thick scum accumulating around edges.	32a. Excess scum in one area, causing excess drag.	32a. Probe with a stick or some other method to determine the condition of the scum.	32a. Use chemicals or degreasing agents such as Digest-aide or Sanfax to soften the scum, then hose down with water. Continue on regular basis every two to three months or more frequently if needed.
	32b. Guides or rollers out of adjustment.	32b. Distance between guides or rollers and the wall.	32b. Soften up the scum (as in 32a) and readjust rollers for guides so that skirt doesn't rub on the walls.
	32c. Rollers or guides broken.	32c. Determine the normal position if the suspected broken part is covered by sludge. Verify correct location using manufacturer's information and/or prints if necessary.	32c. Drain tank if necessary taking care as cover lowers to corbels not to allow it to bind or come down ~~unevenly. It~~ may be necessary to use a crane or jacks in order to prevent structural damage with this case.
33. Cover binding even through rollers and guides are free.	33. Internal guide or guy wires are binding or damaged (some covers are built like umbrellas with guides attached to the center column).	33. Lower down to corbels. Open hatch and using breathing apparatus & explosionproof light, if possible, inspect from the top. If cover will not go all	33. Drain and repair, holding the cover in a fixed position if necessary.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK OR MONITOR	SOLUTIONS
		33. (continued) the way down, it may be necessary to secure in one position with a crane or by other means to prevent skirt damage to sidewalls.	

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Learning Resource 5
"Second Stage Digestion"
Criteria for the Establishment of Two-Year Post High School Wastewater Technology Programs (CEWT), Plant Operations for Wastewater Facilities, Part C - September 1975
Charles County Community College
Greenville Technical College
Linn-Benton Community College
Clemson University
Clemson, SC

Presented is an excerpt from the instructor's guide for a learning module on a floating-cover, second-stage digester unit with gas storage. The module is organized around sixteen objectives common to all processes. Each module is designed to help the instructor plan a course of study for the operation of a treatment process using the composite model plant process unit. Material in the module can be adapted for courses which upgrade the training of operators in normal operations procedures, abnormal operations procedures, preventive maintenance procedures, or corrective maintenance procedures.

Each module begins with a statement of purpose that explains what the student will be studying. Next, all the objectives of the module and code numbers keyed to a computerized list of instructional resources are listed. Also included are conditions of learning, acceptable performance levels, instructor activity, and student activity. Evaluation techniques are suggested. Examples for the first five objectives are presented.

MODULE 12

SECOND STAGE DIGESTION

A floating-cover unit with gas storage

Composite Model Plant Unit L

PURPOSE: In this module the student will learn to perform all the activities in the objectives as they apply to a floating-cover unit with gas storage. READ PAGES 1 TO 11 BEFORE USING THIS MODULE.

OBJECTIVES:

12.1 Identify the second stage digestion unit.

12.2 Describe the second stage digestion process in technical and nontechnical terms.

12.3 Describe the safety procedures for the second stage digestion unit and explain how the procedures protect employees and visitors.

12.4 Identify the components of a second stage digestion unit. Explain the purpose of each component, how the component works and why it is important.

12.5 Describe the normal operation procedures for the second stage digestion unit components.

12.6 Perform the normal operation procedures for the second stage digestion unit.

12.7 Describe and perform the start-up and shut-down procedures for the second stage digestion unit.

12.8 Describe the abnormal operation procedures for the second stage digestion process.

12.9 Describe the preventive maintenance procedures for the second stage digestion unit.

12.10 Perform the preventive maintenance procedures for the second stage digestion unit.

12.11 Describe the corrective maintenance procedures for the second stage digestion unit components.

12.12 Perform the corrective maintenance procedures for the second stage digestion unit components.

12.13 Perform the safety procedures for the second stage digestion unit and demonstrate how they protect employees and visitors.

12.14 Compare other second stage digestion units to the floating-cover unit with gas storage (composite model plant unit L).

12.15 Name and locate the components of the second stage digestion unit. Name and select reference materials which explain the normal operation procedures, the purpose of each component, how the component works and why it is important.

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12.16 Perform the abnormal operation procedures for the second stage digestion unit.

RESOURCES: 3 116 120 125 126 141 143 144 185 307 308 309 314 315 316 317 320 321 324 421 459 511 551 552 553 554 937 990 1033 1034 1399

***** *****

OBJECTIVE 12.1 Identify the second stage digestion unit.

CONDITIONS: Given a unit, a model of a unit or a photograph of a unit.

ACCEPTABLE PERFORMANCE: The student will:

Indicate whether the process unit is used for second stage digestion.

INSTRUCTOR ACTIVITY: 1. Point out characteristics which distinguish the second stage digestion unit from other process units.

STUDENT ACTIVITY: 1. Develop a picture file of second stage digestion units. Mark distinguishing characteristics.

OBJECTIVE 12.2: Describe the second stage process in technical and nontechnical terms.

CONDITIONS: Given photographs of the second stage digestion unit.

ACCEPTABLE PERFORMANCE: The student will:

Describe the second stage digestion unit, explaining the meaning of:

anaerobic digester
digester
digestion tank
sludge digester

Describe the purpose of second stage digestion.

Describe how second stage digestion affects.

sludge conditioning
sludge dewatering
solids disposal
flow measurement
pumping and piping

INSTRUCTOR ACTIVITY:

1. Use diagrams, photographs and slides to describe second stage digestion.
2. Describe the second stage digestion process during a plant tour. React to the student's description of the process.

STUDENT ACTIVITY:

1. Describe the second stage digestion process while viewing photographs, diagrams and slides.
2. Observe and describe the second digestion process during a plant tour.

***** *****

OBJECTIVE 12.3

Describe the safety procedures for the second stage digestion unit and explain how the procedures protect employees and visitors.

CONDITIONS:

Given a list of operation and maintenance procedures.

ACCEPTABLE PERFORMANCE: The student will:

Describe the safety procedures for the second stage digestion unit, commenting on:

High-risk activities

opening digester cover access hatches
removing debris from channels
working near sources of gas leakage
working with switches in automatic position

Sources of danger
acid wastes
caustic wastes
deep wells
electrical equipment
explosive gases

fire
moving parts
open doors and covers
slippery walks
toxic gases
welding torch

Safety equipment
explosion proof electrical fixtures
fire-fighting equipment
first aid kit
flame arrester
flame trap
gas masks
handrails
no smoking signs
nonsparking hand tools
pressure relief valve
protective clothing
safety treads on ladders and stairs
vacuum relief valve
vents

Explain how the procedures protect employees and visitors.

INSTRUCTOR ACTIVITY:

1. Discuss treatment plant case histories.
2. Describe the conditions in a plant and ask for evaluation.
3. Describe the safety procedures for each operation and maintenance procedure
4. Prepare slides of sources of danger and high-risk activities.

STUDENT ACTIVITY:

1. Read case histories and comment on employee safety procedures.
2. Evaluate conditions which the instructor has described. Suggest remedies.
3. Role play operation or maintenance procedures. Select proper safety equipment and name the sources of danger and high-risk activities. Develop a manual of safety procedures for the second stage digestion unit.
4. Identify sources of danger and high-risk activities pictured in slides.

***** *****

OBJECTIVE 12.4: Identify the components of a second stage digestion unit. Explain the purpose of each component, how the component works and why it is important.

CONDITIONS: Given a second stage digestion unit, unit components or a diagram, model or photographs of a unit and a list of components.

ACCEPTABLE PERFORMANCE: The student will:

Identify components of the second stage digestion unit and associated equipment.

- boiler
- fire-fighting equipment
- first-aid kit
- floating cover
- gas recirculation unit
  - compressor
  - oiler
  - pressure gage
  - valve
  - valve timer
- manometer
- meter
- motor
- piping
- pressure relief valve
- recirculation pump
- sludge pump
- switchgear
- vacuum relief valve
- water trap

Explain the purpose of each component, how the component works and why it is important.

INSTRUCTOR ACTIVITY:

1. Point out and name components in diagrams, photographs or models.
2. Arrange photographs or models of components in the workshop for student identification.
3. Point out and name components during a plant tour.
4. Question the students about the purpose of each component, how the component works and why it is important.

STUDENT ACTIVITY:

1. Identify the components which the instructor names on diagrams, photographs or models.
2. Identify the components at stations in the workshop in writing.
3. Identify components during a plant tour.
4. Explain the purpose of each component, how the component works and why it is important.

***** *****

OBJECTIVE 12.5: Describe the normal operation procedures for the second stage digestion unit components listed in Objective 12.4.

CONDITIONS: Given a second stage digestion unit or slides or photographs of a second stage digestion unit, a list of components of the unit, a checklist of characterists and a normal operation procedures manual.

ACCEPTABLE PERFORMANCE: The student will:

Describe the characteristics of each component which the operator checks to determine whether the component is functioning normally, commenting on:

color
corrosion
motion
odor
position
pressure
sound
temperature
vacuum
vibration

Name the sense or indicator which monitor each characteristic.

Explain how often the characteristics of each component must be checked and why the component indicate that it is not functioning normally, including:

making adjustments
deciding about corrective maintenance
reporting to supervisors
reporting in written records

Explain why a component's characteristics must be returned to normal.

Describe routine sampling for the second stage digestion process.

List routine calculations for the second stage digestion process.

Describe routine procedures for recording data.

INSTRUCTOR ACTIVITY:

1. Describe the characteristics of the components of the second stage digestion unit.
2. Describe the normal operation procedures for the second stage digestion unit. Use color pictures.
3. Describe the normal operation procedures during a slide show of components of the second stage digestion unit.
4. Describe and explain the normal operation procedures during a plant tour. Listen to the student's description of the procedures.

STUDENT ACTIVITY:

1. Develop a checklist, listing the components of the second stage digestion unit and their normal characteristics.
2. Develop a manual of normal operation procedures.
3. Describe the normal operation procedures during a slide show of components of the second stage digestion unit.
4. Observe and describe the normal operation procedures during a plant tour.

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Learning Resource 6
"Anaerobic Digestion and Analytical Control"
Slide Cassette XT-34 - 13 minutes
Available on loan from:
National Training and Operational Technology Center
26 West St. Clair
Cincinnati, OH 45268

Discussed are the anaerobic decomposition processes utilized to treat organic materials in wastewater, the environmental conditions required for the involved bacteria, and a description of the related process control analyses. The program is designed for experienced wastewater treatment plant operators who wish to upgrade plant performance and to increase their own knowledge and skills. References and instructions for the unit are provided.

Slide number	Material presented in slide
1.	Caption - Anaerobic Digestion and Analytical Control.
2	Three steps in treatment of organic wastes
3	Basic technology
4	Energy sources - organic materials
5	Bacteria
6	Anaerobic decompositions
7	Volatile organic matter
8	Digestion processes
9	Liquefaction
10	End products of liquefaction
11	End products of gasification
12	Balanced digestion processes
13	Stages of digestion
14	Graph
15	Acid fermentation stage
16	High acidity - low pH
17	Facultative organisms
18	Acid regression stage
19	Bicarbonate alkalinity
20	Alkaline fermentation state
21	Types of bacteria
22	Biological oxidation of organic wastes
23	Environmental characteristics of bacteria
24	Grow fast
25	pH independent
26	Temperature independent
27	Stimulated by oxygen
28	Characteristics of methane forming bacteria
29	Grow slow
30	Temperature dependent
31	Sudden temperature changes
32	pH dependent
33	Subject to oxygen toxicity

Slide number	Material presented in slide
34	Operation of an anaerobic digester
35	Analytical control
36	Analysis of sludge supernatant
37	Criteria for performance evaluation
38	Volatile acid to alkalinity ratio
39	Volatile acids determination in the laboratory
40	Adding indicator
41	Adding sample to fritted glass crucible
42	Applying suction
43	Adding chloroform-butanol reagent
44	Titration
45	Column partition chromatography
46	Routine process control
47	Importance of volatile acid determination
48	Alkalinity
49	Test for alkalinity
50	Analyses of ammonia
51	Total organic nitrogen
52	Kjedahl nitrogen determinations
53	Nitrogen content in sludge
54	COD test
55	COD criteria for a good supernatant
56	pH
57	Monitoring gas production
58	Environmental conditions
59	Need for analytical controls
60	Credits
61	Clean water

Learning Resource 7
Standard Operating Job Procedures for Wastewater Treatment Plant Unit Operations. SOJP 10-Digestion
Prepared by Charles Country Community College
Prepared for U.S. Environmental Protection Agency
Office of Water Program Operations
Manpower and Training Staff

Presented is a guide for the development of standard operating job procedures for the digestion process. Following a brief description of the process and equipment use, operating procedures and step sequence are provided for safety inspection, tank and structure inspection, equipment and electrical inspection, primary digester start-up, continuous shift operation, shut-down procedures, and equipment maintenance.

STANDARD OPERATING JOB PROCEDURES

SOJP NO 10 | Prepared by C.M. Schwing, T.T. Schwing | Date 4-73

PROCESS Digestion | Approved by

OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
A. PRESTART UP INSPECTION PROCEDURES			
1. Safety Inspection	1. Make certain all valves are closed.	1. If valves' operation is not proper-stop	V.1
	2. Lock out all switch gear.		XII.1
2. Tank and Structure Inspection	1. Physically inspect the interior of all tanks for obstruction.	1. Remove all foreign objects such as containers, woodscraps, welding rods, ladders, etc.	XII.2
	2. Replace and seal all inspection parts.		V.8
	3. Check all lines for leaks.		
	4. Fill all digesters with water or raw sewage to operating level in primary digesters and just enough to float covers of secondary digesters.		XII.3
	5. Close valves listed in previous step.		

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
3. Equipment Inspection	1. Check all manometers for proper fluid.	1. Refer to Manufacturers bulletin	V.3
	2. Check all gas meters for proper operation.	1. Refer to Manufacturers bulletin	V.4, XI.1
	3. Check sludge recirculation pumps for proper operation.	1. Refer to Manufacturers bulletin	V.5
	4. Check sludge drawoff pump for proper operation.	1. Refer to Manufacturers bulletin	V.5
	5. Check heat exchangers for proper operation.	1. Refer to Manufacturers bulletin	V.6
	6. Check pressure and vacuum relief valves for proper operation.	1. Refer to Manufacturers bulletin	V.7 XII.4
	7. Check gas recirculation unit for proper operation.	1. Refer to Manufacturers bulletin	V.8 XII.4
4. Electrical Inspection	1. Check electrical switch gear for proper nomenclature and make certain explosion-proof fixtures are intact.	1. Refer to equipment maintenance records for overload heater proper size.	V.9 XII.5
	2. Unlock and activate switch gear.	1. Measure voltage at all points up to motor disconnect.	

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Date 4-73

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
	3. Activate explosive gas detector and alarm system.	1. Refer to Manufacturers instructions.	V.10, XI.1 XII.6

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
B. STARTUP PROCEDURES			I.2
1. Primary Digester Startup	1. Heat #1 and #3 digesters to operating temperature.	1. To achieve goal, start up heat exchangers as outlined in O & M manual for this unit. Open valves 4, 6, 7, 8, 9, and 10; start recirculation pumps 1 and 2. Auxiliary fuel will have to be used for this step.	V.5
	2. Maintain digester at operating temperature.	1. To achieve this goal, by-pass heat exchanger by opening valves 18, 19, 20, and 21 and closing valves 7 and 8 until temperature drops 1°F and then go back to normal valve arrangement. Continue to recirculate the contents by the use of the recirculation pumps.	I.2
	3. Add seed sludge from a well operated digester.	1. Seed sludge should be about 20% of the volume of the digester being started up.	I.2
	4. Add sludge at the rate of 5 pounds of volatile solids per day/per 1000 cu.ft. of capacity.	1. Determine pH, total solids, volatile total solids, alkalinity and volatile acids on all sludge added to digesters.	III.1 VII.3 X.1

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
	5. If gas production, pH, and alkalinity increase increase the sludge feed rate to 10 pounds of volatile solids per day/per 1000 cu.ft. of capacity. This may take 60 days. If good digestion operation continues, increase sludge feed at increments of 5 pounds of volatile solids/per day/per 1000 cu.ft. of capacity until a loading of 50 pounds of volatile solids per day/per 1000 cu.ft. is achieved.	1. The pH should rise to approximately 6.8-7.2; alkalinity should increase to about 1800 ppm. SPECIAL NOTE: In general do not expect the volatile acids to drop until organic feed rate is stabilized.	III.1 VI.1 VII.1 & 3 VIII.1 X.1
	6. When sufficient gas is available, start up gas recirculation unit.	1. See manufacturers operations bulletin. WARNING: Do not permit digester gas pressure to fall below 0.5" W.C.	V.8, VII. 1 & 3 VIII.1 XII.7
	7. After initial digester is in operation, make all transfers to other primary unit and proceed through steps B.1 through B.6 above.		

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
	8. After both primary digesters are successfully operating make transfers to secondary digesters.		

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
C. CONTINUOUS OPERATING PROCEDURES			
1. Continuous Shift Operation	1. Pump raw sludge for thickener or other units on a continuous basis if at all possible.		I.2
	2. Grab sample and composite.		III.1 VIII.1 X.1
	1. Raw sludge pumped	1. Sample should be analyzed for pH, total solids, volatile total solids.	
	2. Transfer sludge	2. Sample should be analyzed for pH, total solids, volatile total solids.	
	3. Digested sludge	3. Sample should be analyzed for pH, total solids, volatile total solids.	
	4. Supernatant	4. Sample should be analyzed for pH, total solids, volatile total solids.	
	5. Gas	5. Sample should be analyzed for methane concentration.	VII.2
	3. Observe operation of heat-exchangers for proper temperature.		

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
	4. Observe operation of all pumps for proper operation.		
	5. Observe operation of gas recirculation units for proper operation.		
2. Every 4 Hours	1. Record the following meter readings: 1. Volume of gas from each digester. 2. Volume of gas to waste. 3. Volume of gas to other process units. 4. Volume of raw sludge to digester. 5. Volume of digested sludge from digester. 6. Volume of supernatant.		IV.1, XI.1 XIII.1

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
	2. Record the following manometer readings: 1. Each digester 2. Service line 3. Waste line		IV.1 XIII.1
	3. Record the elevation of the floating covers.		
3. Every Shift	1. Place composite samples in central sample storage.		IV.1, X.1
	2. Complete shift report.		IV.1 XIII.1
4. Daily	1. Replace recorder charts. 1. Carefully calculate 24 hour flows. 2. Check recorder pen for proper inking.		IV.1, XI.4 XII.1
	2. Complete daily and monthly log sheets.		IV.1 XIII.1

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTES
D. SHUT DOWN PROCEDURES			
1. The Shut Down Procedure is for taking the digester out of service for cleaning.	1. Stop feeding raw sludge or transferring sludge to the unit at least one week prior to expected shut down date. 2. When gas production has fallen off to a minimum, close gas valve. 3. Open hatches to atmosphere. 4. If primary digester, pump sludge to other primary and/or secondary digesters. 1. If secondary digester, withdraw as much supernatant as possible back to plant.		

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
	5. Pump digested sludge to disposal as long as possible.		
	6. When sludge can no longer be withdrawn by normal pumping, ventilate digester space above liquid by discharging fresh air into digester.	WARNING: Do Not enter digester unless equipped with breathing apparatus.	
	7. Use Stang deluge nozzle or fire hoses to break up sludge, scum, and grit deposit.		
	8. Recirculate contents with trash pump.		
	9. Pump homogenized sludge to disposal.		
	10. When digester is empty, continue ventilation and then do inspection for determining maintenance required.		
	11. After required maintenance, go back to startup procedures.		

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
E. PREVENTIVE MAINTENANCE (MAY BE DONE BY OTHERS)			
1. Equipment Maintenance	1. Inspect pumps	1. See Manufacturers O & M Manual	IV.1, V, IX.1 XIII.1
	2. Lubricate motors	1. See lubrication schedule for proper lubricant and interval.	IV.1, V, IX.1 XIII.1
	3. Check motor electrically	1. Record: 1. Voltage 2. Amperage 3. Insulation resistance	IV.1, V, IX.1 XIII.1
	4. Inspect switch gear annually.		IV.1, V IX.1 XIII.1
	5. Inspect pressure relief valves annually.	1. See Manufacturers O & M Manual	IV.1, V IX.1 XIII.1
	6. Inspect all flame arresters annually.	1. See Manufacturers O & M Manual	IV.1, V, IX.1 XIII.1
	7. Calibrate flow meters.	1. See Manufacturers O & M Manual	IV.1, V IX.1, XI.1 XIII.1

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OPERATING PROCEDURES	STEP SEQUENCE	INFORMATION/OPERATING GOALS/SPECIFICATIONS	TRAINING GUIDE NOTE
	8. Inspect heat exchangers annually.	1. See Manufacturers O & M Manual 2. Notify fire underwriters inspector in sufficient time for inspection of dewatered unit.	IV.1, V IX.1 XIII.1
	9. Paint floating covers as necessary.		IV.1, V IX.1 XIII.1

SOJP NO 10

Learning Resource 8

Operation of Wastewater Treatment Plants: A Field Study Training Program

Second Edition

Prepared by California State University, Sacramento

Kenneth D. Kerri, Project Director

Prepared for U.S. Environmental Protection Agency

Office of Water Program Operations

Municipal Permits and Operations Division

This lesson stresses the importance of sound and thorough daily operational checks in combination with adequate sampling and neat, well-organized records of the resulting data to the successful operation of a digestion system. Presented is a checklist intended to help the operator remain "on-top" of the system. The list is general in nature and serves as a model for the preparation of a similiar anaerobic sludge digestion checklist. Plotting certain operational data in graphic form is stressed.

CHAPTER 12. SLUDGE DIGESTION AND SOLIDS HANDLING

(Lesson 5 of 6 Lessons)

12.4 OPERATIONAL STRATEGY

All previous discussions and problem assignments were intended to provide you with the basic working principles of anaerobic sludge digestion. Their successful application in the operation of a digestion system requires sound and thorough daily operational checks in combination with adequate sampling and neat well-organized records of the resulting data. Many operators find that plotting certain operational data in a graphical form is very helpful to recognize changes or trends in digester performance. Informative operational data that could be plotted against time include:

1. Digester loading
   a. Volatile solids added, lbs/day per cubic foot of digester capacity
   or b. Volatile solids added, lbs/day per volatile solids under digestion, lbs
2. Volatile acids/alkalinity relationship
   Volatile acids, mg/L per alkalinity, mg/L
3. Gas production
   1000 cubic feet of gas produced per day
4. Carbon dioxide content of digester gas
   Percent carbon dioxide
5. Temperature
   Degrees Fahrenheit or Degrees Celsius

Successful plant operators use basic knowledge together with the daily checks and data to remain alert to changes in the system and to anticipate problems, rather than finding it necessary to react to fully developed upsets.

12.40 Operation and Maintenance Checklist

The following checklist is intended to help the operator remain on-top of the system. This list is general in nature, and does not cover all situations, but serves as an example of the checklist that should be made for each plant. You should prepare a similar checklist for the anaerobic sludge digesters at your treatment plant. As you make your rounds inspecting each item, be alert. Investigate and record anything that looks different or unusual, smells different, feels different (hotter or vibrating more) and sounds different. If problems appear to be developing, correct them now or alert your supervisor of the changes.

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ITEM	SCHEDULE: DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	AS REQUIRED
A. Raw Sludge Pumping					
1. Total sludge volume pumped in 24 hours or individual feed periods. Record pump counter or meter reading.	X				
2. Proper operation of pump(s). Check oil level. While operating check motor, pump, packing (leaks), suction and discharge pressure.	X				
3. If density meter is used, check for proper operation during pump run.	X				
4. Instrumentation, especially pump time clock operation.	X				
5. Sludge line valve positions.	X				
6. Visual observation of raw sludge being pumped. Note consistency (thick or thin), color and odor (septic).	X				
7. Automatic sampler operation.	X				
8. Exercise all sludge valves by opening and closing.		X			
9. Lubricate all valve stems. Inspect and grease pump motor bearings according to manufacturer's recommendations.				X	
B. Boiler and Heat Exchanger					
1. Temperature of the recirculated sludge	X				
2. Temperature of the recirculated hot water	X				
3. Boiler and heat exchanger temperature and pressure.	X				
4. Water level in sight glass of day-water tank	X				
5. Boiler and heat exchanger operation	X				
a. Gas pressure	X				
b. Make-up water valve	X				
c. Pressure relief (pop-off) valve	X				
d. Power failure or low gas pressure shutdown	X				
e. Safety devices			X		
6. Boiler firing (flame-air mixture).			X		
7. Recirculated sludge pump operation. Check oil level. While pump is operating check motor, pump, packing (leaks), suction and discharge pressures	X				
8. Inspect and grease pump motor bearings according to manufacturer's recommendations.				X	
C. Digesters					
1. Record gas meter reading.	X				
2. Check gas manometers. (digester gas pressure)	X				
3. Record digester gas pressure and/or floating cover position and indicator level reading.	X				
4. Drain gas line condensate traps and sedimentation traps (from one to four times per day depending on location of trap in gas system, temperature changes and digester mixing systems).					X
5. Check liquid level in the digester.	X				
6. Check supernatant tubes for operation and wash down supernatant box.	X				
7. Check digester gas safety analyzer (L.E.L.) and recorder.	X				

	SCHEDULE				
	DAILY	WEEKLY	MONTHLY	SEMI-ANNUALLY	AS REQUIRED
8 Check and record level of water seal (located on center dome of fixed cover digesters and between tank wall and cover of floating cover digesters)	X				
9 Check operation of mixing equipment					
GAS					
a. Flow rate, cfm	X				
b Pressure, psi	X				
c Compressor operation	X				
MECHANICAL					
a Motor operation	X				
b Drive belts or gear reducers	X				
c. Vibrations	X				
d Direction of mixing (down-up)	X				
10 Examine waste gas burner for proper operation		X			
a. Pilot on	X				
b Number of burners on		X			
c. Digester gas pressure (wasting or excess)		X			
11 Exercise all sludge and gas system valves by opening and closing.	X				
12. Check all supernatant tubes for operation and sample each for clearest liquor for supernatant removal from digester.		X			
13. Check digester for scum blanket buildup		X			
14 Examine the digester structure and piping system for possible gas leaks. Examine the digester structure for cracks.			X		
15. Clean, inspect and calibrate the digester gas safety analyzer and recorder			X		
16 Lubricate all valve stems and rotating equipment as required by the manufacturer.				X	
17 Clean and refill gas manometers with proper fluids to levels specified by manufacturers				X	
18 Flush and refill water seals (from 2 to 6 months) Check weekly on fixed cover digester seals					X
19. For floating cover digesters, inspect flotation compartment for leakage or excessive condensation buildup (pump out) and look for corrosion of cover interior				X	
20. Dewater digester and clean out, repair and paint. Normal cleanout schedules are three (3) to eight (8) years.					X

12.41 Sampling and Data Checklist

Results and interpretation of lab tests tell you what you are feeding a digester and how the digester is treating the sludge. Graphically recording lab results helps to interpret what's happening in a digester. If undesirable trends start to develop, refer to the appropriate section in this manual for the proper corrective action.

ITEM	SCHEDULE			
	DAILY	BI-WEEKLY	WEEKLY	MONTHLY
A. Raw Sludge				
1. Composite raw sludge sample. If grab is taken instead, then prepare a composite twice a week	X	(X)*		
2. Total and volatile solids	X	(X)		
3. pH		X		
B. Supernatant				
1. Solids (total and volatile) and COD. Graphically record the data and be alert to long-term decreasing quality (increased levels of solids and COD) of supernatant quality.				X
C. Digested Sludge				
1. Grab sample	X			
2. Temperature	X			
3. pH	X			
4. Cubic feet of total gas and CO_2 content	X			
5. Calculate and graphically record gas production and CO_2 content	X			
6. Calculate and graphically record loading rate (solids and hydraulic)	X			
7. Volatile acids	X			
8. Alkalinity		X		
9. Calculate and graphically record volatile acid/alkalinity relationship		X		
10. Digested sludge total solids and volatile solids		X		
11. Solids (total and volatile) and temperature profile at five-foot (1.5 m) intervals from the digester bottom up to the surface. If scum blanket present, try to break it up.				X
D. Solids Balance				
1. Calculate the solids balance on the digesters (see Section 12.3M, Solids Balance). This calculation helps indicate to you how well you are controlling the digester operation.				X

In Item 12.41, C-11, as regards the profile sampling of the digester, the solids and temperature data should be carefully examined for indications of poor mixing in the digester or grit accumulation at the bottom of the digester. The operator should use the data to calculate the useful volume of the digester (total volume minus the grit volume). Such data can be graphically plotted against time to show the rate of grit buildup and the date for digester cleaning. An example of such a plot is illustrated in Figure 12.21, although actual data may not plot a straight line.

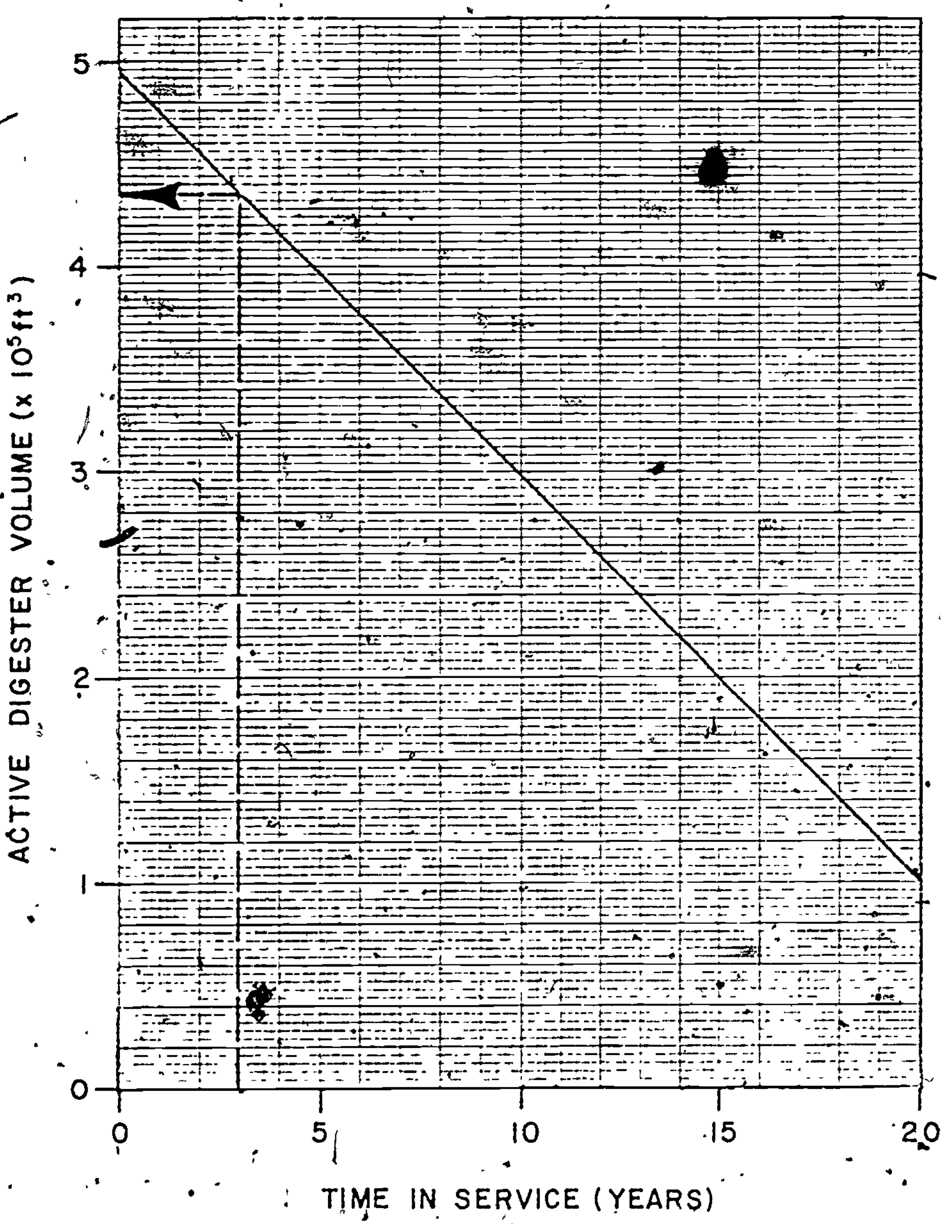


Fig 12.21 Active volume of a digester tank
(Permission of Los Angeles County Sanitation District)

12.42 Normal Operation

In this chapter we have discussed the following important topics regarding digester operation

1. Section 12 1, Components in the Anaerobic Sludge Digestion Process;
2. Section 12 2, Operation of Digesters; and
3. Section 12 3, Digester Controls and Test Interpretation

This section combines the highlights of those portions of the previous sections that are critical to the actual day-to-day operation of an anaerobic sludge digester For details, refer to the actual section The normal operation of a digester involves the following activities.

1. Feeding Sludge to the Digester (Section 12 22, Feeding).
2. Maintaining the Proper Temperature (Section 12 14, Digester Heating);
3. Keeping the Contents of the Digester Mixed (Section 12 15, Digester Mixing),
4. Removing Supernatant (Section 12 27, Supernatant and Solids), and
5. Withdrawing Sludge (Section 12 28, Rate of Sludge Withdrawal).

Let's study each one of these activities.

1. Feeding Sludge to the Digester (See Section 12 41, A. Raw Sludge)

   a. Pump as thick a sludge as possible to the digester Watch sludge being pumped, listen to sound of sludge pump, and observe any instruments that indicate thickness of sludge

   b. Pump small amounts of sludge at regular intervals to prevent adding too much raw sludge too fast for the organisms or for the temperature controls to maintain a constant temperature

   c Calculations

   (1) Try not to add more than one pound of volatile matter per day for every ten pounds of digested sludge in storage (1 kg V M./day per 10 kg digested sludge) This ratio may vary from digester to digester and from season to season.

   (2) Calculate the volatile acid/alkalinity relationship and plot the results If the relationship starts to increase, try to pump a thicker sludge or reduce the amount of volatile matter added per day Also reduce the pumping rate of digested sludge.

   See Section 12.3, Digester Controls and Test Interpretation, B. Volatile Acid/Alkalinity Relationship and K. Computing Digester Loadings for details.

2. Maintaining the Proper Temperature (See Section 12 40, B, Boiler and Heat Exchanger)

   Record the temperature of the recirculated sludge every day. If the temperature changes from the desired level, adjust the temperature controls. Do not allow the temperature to change more than 1°F (0 5°C) per day Determine the temperature (usually between 95 and 98°F or 35 and 37°C) that best suits your digester

3. Keeping the Contents of the Digester Mixed

   How a digester is mixed depends on the mixing equipment and whether you have a single-stage or two-stage digestion process Digester contents must be well mixed to provide an even distribution of food (raw sludge), organisms, alkalinity, heat and waste bacterial products Good mixing should prevent the buildup of a scum blanket and the deposition of grit on the bottom of the digester If mixing is inadequate, try increasing the time of mixing and/or looking for equipment problems

4. Removing Supernatant

   Supernatant should be removed from the digesters on a daily basis Whether you have a single-stage or two-stage digestion process, mixing should be stopped for 6 to 12 hours before supernatant removal to allow the supernatant to separate from the digested sludge. Adjust or select the supernatant tube that produces the least solids to remove supernatant from the digester Carefully observe your other treatment processes to be sure the supernatant does not cause a solids or BOD overload on other treatment processes Remove supernatant and digested sludge until sufficient space is obtained in the digesters for the incoming raw sludge

5. Withdrawing Sludge

   Before withdrawing sludge, stop mixing for 6 to preferably 12 hours to allow the digested sludge to separate from the supernatant. The digester contents must be well mixed before stopping mixing so a lot of raw sludge will not be removed with the digested sludge Good mixing also prevents the buildup of a scum blanket and the development of coning during the removal of digested sludge The withdrawal rate of sludge from either digester should be no faster than a rate at which the gas production from the system is able to maintain a positive pressure in the digester (at least two inches (5 cm) of water column)

12.43 Troubleshooting

Using the information obtained from the analysis of the samples and the daily rounds, the knowledgeable and alert operator can note changes from normal operation The first step is to realize that there is a problem, and the second step is to take the appropriate corrective action Table 12 2 is intended to be an example of a logical sequence that can be followed to identify and correct an impending or actual digester upset The four indicators of a problem tell you to look for one or more of the problem areas listed that need correcting

Toxicity can be a very difficult problem to identify and solve Heavy metals can gradually creep up in concentrations until toxic levels are reached Also as the pH decreases the concentrations of dissolved metals tend to increase and become toxic to bacteria in the digester

Possible methods of controlling toxic materials include

1. Remove toxic material from waste.
2. Dilute toxic material below its toxic level.
3. Add a chemical that will neutralize the toxic material, and
4. Add a chemical that will cause the toxic material to precipitate out of solution or form an insoluble compound

If soluble toxic heavy metals are present, sodium-sulfide (Na_2S) can be added which will cause the formation of non-toxic insoluble heavy metal sulfide compounds Digesters are similar to people in many ways A small amount of something may be very good for a digester, but too much may be toxic as shown in Table 12 3

TABLE 12.2 DIGESTER OPERATION TROUBLESHOOTING

INDICATION FROM DATA	PROBLEM AREA	POSSIBLE CAUSE
• Rise in V.A./Alk Ratio • Gas Production Decrease or Increase in CO_2 • Decrease in V.S. Reduction • High Solids in Supernatant	Toxicity	1. Slug of toxic material 2. Constant feed that has reached toxic limit
	Digester Loading	1. Change in raw sludge pumping 2. Raw sludge density or V.S. changed 3. Raw sludge pH change 4. Decrease in effective volume of the digester
	Digester Heating	1. Heat exchangers plugged. 2. Recirculated sludge pump not working 3. Boiler malfunction 4. Unsteady sludge temperatures — more than 1°F/day or 0.5°C/day
	Digester Mixing	1. Fouled draft tube 2. Mechanical or electrical failure. 3. In case of gas mixing, inadequate recirculation
	Gas System	1. Gas meter failure. 2. Leaking gas 3. Abnormal pressure 4. Plugged gas line

TABLE 12.3 BENEFICIAL AND TOXIC CONCENTRATIONS OF MATERIALS ON DIGESTION PROCESS

Material	Beneficial	Moderately Inhibitory	Toxic
Ammonia Nitrogen mg/L	50-200	1500-3000[a]	3 000
Calcium mg/L	100-200	2500-4500	8 000
Magnesium mg/L	75-150	1000-1500	3 000
Potassium mg/L	200-400	2500-4500	12 000
Sodium mg/L	100-200	3500-5500	8 000

[a]Toxic at higher pH values

12.44 Actual Digester Operation

By using the procedures outlined in this Section, digesters can be operated successfully without any problems. The information plotted in Figure 12 22 shows some of the information used by an operator to operate four digesters with a total capacity of 6 9 million gallons (26,000 cu m) This activated sludge plant treats an average daily flow of approximately 18 MGD (68 130 cu m/day) with flows averaging over 24 MGD (90,840 cu m/day) during the canning season Under adverse conditions, the digesters have provided only 8 days of detention time, yet the digesters have never become upset

Raw sludge from the primary clarifiers and gravity thickened waste activated sludge are fed on a regular basis throughout the day to each digester Every 2 hours the operators read and record the gages pump meters and temperature readings Temperatures are controlled by adjusting the heat exchanger

Digester contents are continuously mixed through draft tubes Every day the flows through the draft tubes are reversed for two hours to knock off rags accumulated on the draft tubes Additional mixing is available using digested sludge recirculation pumps, if necessary The operator reviews the lab data and if problems appear to be developing, additional mixing is applied if appropriate If everything is satisfactory and mixing is greater than usual, mixing is reduced

The following information is recorded with regard to the digesters.

1 Raw Sludge and Thickened Waste Activated Sludge to Digesters
   a Volume, gallons per day
   b pH
   c Total solids, %
   d Volatile solids, %
2 Digester Gas
   a Total production, cubic feet per day
   b Carbon dioxide, %
3 Digested Sludge (mixed digester contents)
   a Volatile acids, mg/L
   b Alkalinity, mg/L
   c Total solids, %
   d Volatile acids, %
   e pH
4 Sludge removed (mixed digester contents)
   a Volume, gallons per day
   b. Total solids, %
   c Volatile solids, %

Volatile acid/alkalinity relationship has been the key to successful digester operation over the last nine years without any of the five digesters becoming upset Volatile acids and alkalinity are normally run three times per week on each digester If one high volatile acid reading is observed, the volatile acid test is repeated the next day Usually the volatile acid value is back down to the normal range the next day If the volatile acid value is high, the raw sludge pumped to the digester is cut in half or stopped until the volatile acid reading is normal again Usually this requires only one or two days

These digesters are not used for liquid-solids separation Therefore, no information is collected on the supernatant

Learning Resource 9
Troubleshooting O&M Problems in Wastewater Treatment Facilities
Course 179.2 - 1979
Environmental Protection Agency
National Training and Operational Technology Center
26 West St. Clair
Cincinnati, OH 45268

Presented is a learning activity that requires trainees to practice applying the process of troubleshooting to anaerobic digestion problems using a role-playing simulations exercise. The exercise is conducted using the "fish bowl" technique in which second four-person group observes the role-playing exercise and then critiques the performance of the troubleshooters. This lesson includes: trainee entry level behavior and learning objectives, trainee and instructor materials used, classroom set-up lesson outline, and trainee notebook contents.

TROUBLESHOOTING O & M PROBLEMS IN
WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 2: Problem Solving in Anaerobic Digestion

Lesson 2 of 5 lessons | Recommended Time: 110 minutes

Purpose: This lesson requires the trainees to practice applying the process of troubleshooting to anaerobic digestion problems using a role playing simulation exercise. Three trainees from each four person work group role play troubleshooters while the fourth member of the work group role plays the operator. The exercise is conducted using a "fish bowl" technique in which a second four person work group observes the role playing exercise and then critiques the performance of the troubleshooters. Two problems are solved so that each work group participates in both observer and troubleshooter roles. The thrust of the exercise is to emphasize the importance of oral communication and attitude in troubleshooting. In this exercise proper application of the process of troubleshooting and interpersonal communication skills are more important than is solution of the technical problems provided.

Trainee Entry Level Behavior: Trainees should have achieved the learning objectives specified for Unit 12, Lesson 1 before beginning this lesson.

Trainee Learning Objectives: At the conclusion of this lesson the trainee will be able to:

1. Demonstrate proper troubleshooter behavior and apply the process of troubleshooting in an oral interview role playing exercise.

2. Explain the importance of proper troubleshooter behavior by observing and constructively critiquing other trainees' performances during a role playing troubleshooting exercise.

3. Demonstrate his/her ability to organize and conduct an oral interview to obtain essential technical data for troubleshooting an anaerobic digester problem and recognize how the interview technique must be adapted to respond to the personality and attitude of the plant operator.

4. Demonstrate his/her understanding of anaerobic digester operations and troubleshooting by successfully solving the problems presented.

Instructional Approach: Trainee problem solving in a role playing exercise using the "fishbowl" technique.

Fishbowl Technique. The approach to this lesson subdivision employs two educational techniques that allow the trainees to participate in and experience the process of troubleshooting.

1. One technique is "role playing." For each problem, a four-person group is assigned, with one person playing the role of the operator - with specific instructions, and the other three persons playing the role of troubleshooters.

The second technique is the "fishbowl" technique, where one group observes the other group carrying out the role playing exercise in attempting to solve the assigned problem. The observing group should take notes on what they see and report back at the appropriate time.

The group involved in "role playing" to solve the assigned problem is known as the "inner group" (inside the fishbowl) and is seated accordingly. The group of observers is known as the "outer group."

Groups for this lesson subdivision must be pre-designated by the instructor and should be as balanced as possible in composition so that all groups are roughly comparable.

2. The individual selected to play the role of "plant operator" from each group should be a person who is relatively experienced in the inspection of treatment plants compared to his/her fellow trainees. The selected individuals should also be chosen from among those who have personalities which would make them not reticent to participate. The individuals who are to be "plant operators" should be pre-selected and given their instructions in advance of this lesson subdivision.

3. It is very important that the observers be encouraged to give honest feedback to the troubleshooters - after the 20 minute troubleshooting experience is completed. It is this feedback that provides much of the learning experience for this lesson.

4. After one problem has been analyzed and feedback provided, the groups must switch so that the "inner" and "outer" groups change places. A new "operator" and new troubleshooters then address the second problem with the new observers taking notes.

5. After both problems have been analyzed and feedback is reported by the observers, it is important for the instructor to bring the entire class together to discuss the results and for the trainees to discuss their role playing experiences. This overall comparison of what occurred in each group is an essential conclusion to this exercise that allows the trainees to compare notes and obtain an overall impression of the troubleshooter-operator relationship.

6. Some trainees may be very timid in their role playing involvement. In trial presentations, a very small percentage (1%) were very negative and even belligerent. The instructor must "cruise" from group to group to see that people participate and to encourage them to do so. However, if a trainee's attitude is so negative as to disrupt the others, he/she should be excused from this portion of the lesson.

Details on administering the lesson are provided ~~in the~~ lesson plan outline.

Lesson Schedule: The 110 minutes allocated to this lesson should be scheduled as follows:

TIME	SUBJECT
0 - 10 minutes	Instructor Introduces the Lesson, Sets up Groups, Provides Instructions
10 - 30 minutes	Groups Plan their Approach to the Problem
30 - 50 minutes	Designated Groups Analyze and Troubleshoot Problem 1
50 - 60 minutes	Observers for Problem 1 Report Findings
60 - 80 minutes	Designated Groups Analyze and Troubleshoot Problem 2
80 - 90 minutes	Observers for Problem 2 Report Findings
90 - 110 minutes	Entire Class Convenes to Discuss Findings and Experiences with the Instructor

Trainee Materials Used in Lesson:

1. *Trainee Notebook*, pages T12.2.1, "Instructions to Troubleshooters: Problem 1.
2. *Trainee Notebook*, pages T12.2.2, "Instructions to Troubleshooters: Problem 2.
3. *Field Manual for Performance Evaluation and Troubleshooting at Municipal Wastewater Treatment Plants*, pages 295-315.

Instructor Materials Used in Lesson:

1. *Instructor Notebook*, pages 12.2.1 - 12.2.11, Unit 12, Lesson 2.
2. *Instructor Notebook*, pages H12.2.1 - H12.2.2, "Instructions to Operators: Problem 1."
3. *Instructor Notebook*, pages H12.2.3 - H12.2.5, "Instructions to Operators: Problem 2."

Instructor Materials Recommended for Development: None

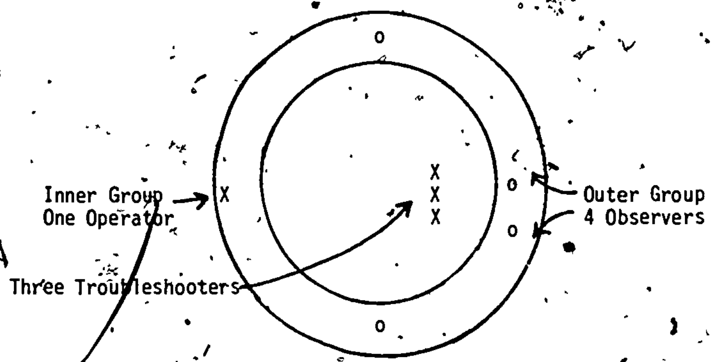
Additional Instructor References: None

Classroom Set-Up: The classroom should be set up to accommodate groups of eight (8) trainees. If possible, to avoid distraction from one group to another, separate rooms should be used for each group of 8.

Each group of 8 consists of two (2) four-person groups, an "inner" group who are actually participating in the role playing-problem solving and an "outer" group who are observing.

Each "inner" group consists of three (3) troubleshooters and one (1) trainee who is playing the operator's role.

Each group of 8 should be arranged as in this diagram.



LESSON OUTLINE

KEY POINTS & INSTRUCTOR GUIDE

I. Prior to Start of Lesson

A. Trainee groups should be designated by Course Director or instructor.

B. Instructor should choose one member of each group to play the role of "operator."

Guide: Instructions for operator are available as part of *Instructors Notebook*, pages H12.2.1 - H12.2.5 They must be reproduced prior to the lesson.

1. Distribute "Instructions to Operating Personnel" to persons selected as operators.

Instructions for troubleshooters are included in the *Trainee Notebook*, pages T12.2.1 - T12.2.2

II. Introduction (10 minutes)

A. Introduce lesson

Refer to the "Instruction Approach" section of the lesson plan for detailed discussion of the approach.

B. Announce group composition

C. Select groups to be "inner" or "outer" groups.

Pairing Group 1 with Group 2, Group 3 with Group 4, etc., is probably the easiest approach. Odd numbered groups solve problem 1 and even numbered groups solve problem 2.

D. Emphasize to trainees playing the role of troubleshooters that they should:

1. Work as a team in questioning the "operator."

2. Use the "Process of Troubleshooting." i.e.: be analytical.

3. Find the answer and solve the operator's problem in 20 minutes.

E. Emphasize to the "outer" group of observers to take notes and be prepared to comment on how well the troubleshooters perform.

F. Privately emphasize to the trainees acting as operators for Problem 1 that they are to be *cooperative but inexperienced*. In response to any question that is not covered in the operator's instruction sheet they are to indicate that they don't

Use the 20 minutes allocated for preparation below to brief the "operators" while the troubleshooters plan their approach.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
know the answer. If the troubleshooters give detailed instructions on how to obtain the answer, the operator will agree to get the answer and call the troubleshooter back tomorrow.	
Privately emphasize to the students acting as operators for Problem 2 that they are to be *reluctant and defensive to the point of thinly veiled hostility.* In response to any question that is not covered in the operator's instruction sheet, they are to indicate that they don't know the answer. If the troubleshooters ask for additional information or data, the operator cannot, will not or does not have time to furnish it.	
G. Have student groups go to their assigned places.	
III. Preparation (20 minutes)	
A. Allow troubleshooting groups and operators 20 minutes to prepare their approaches to Problem 1.	Use this time to brief "operators"
IV. Problem 1 (20 minutes)	
A. Instructor should make sure "inner" and "outer" groups go to their respective seats.	
B. Instructor should "cruise" from group to group to oversee the exercise.	
C. Call time after 20 minutes.	
V. Feedback for Problem 1 (10 minutes)	
A. Observers should report their findings on how the troubleshooters performed.	
B. After 10 minutes, have groups switch places for Problem 2.	

LESSON OUTLINE

VI. Problem 2 (20 minutes)

A. Instructor should make sure "inner" and "outer" groups go to their respective seats.

B. Instructor should "cruise" from group to group to oversee the exercise.

C. Call time after 20 minutes.

VII. Feedback for Problem 2 (10 minutes)

A. Observers should report their findings on how the troubleshooters performed.

B. After 10 minutes, bring the entire class back together to review the problems, the observations and the results of the exercise.

VIII. Discussion of Findings and Results (20 minutes)

A. Brief review of results of the troubleshooting problems.

1. Problem 1

If the troubleshooters follow proper troubleshooting techniques, the most obvious cause should become apparent.

The digester is organically and hydraulically overloaded because the weekend operator pumped down the out of service primary clarifier as quickly as possible. The operator should reduce or cease pumping raw sludge to the digester.

KEY POINTS & INSTRUCTOR GUIDE

Key Point: The instructor should cover the technical solutions as quickly as possible. Focus discussion on the observed behavior of the troubleshooters and operators.

Emphasize:
1. The importance of a systematic approach
2. That the technique can be used by people other than operations consultants
   a. Senior operators
   b. Department heads
   c. Regulatory personnel

Clues:
1. Rapid temperature drop indicates increased hydraulic load to digester.
2. Foaming and froathing characteristic of organic overload.
3. "Rotten egg" odor is typical of organic overload problems.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
He should add lime to raise the pH and continuously recirculate the digester contents via the heat exchanger to gradually raise the temperature to 95°F.	Feeding Lime: 1. Must slurry lime before feeding. 2. Can estimate lime dose by drawing a five gallon sample of digester contents and adding lime to sample while monitoring the pH. Can then estimate the total pounds of lime needed to increase the digester pH. 3. Feed about half the total lime dose the first day. Wait a day and monitor pH. Add more lime as needed on following days to avoid overdosing the digester.
The troubleshooter should have the operator start the corrective program immediately and then assure the operator that a continual follow-up will be implemented to confirm and assist.	
2. Problem 2 If the troubleshooters follow proper troubleshooting procedures, the problem and its cause can be determined.	
The digesters have received a slug of toxic material, maybe heavy metals. The operator should isolate and hold the waste if possible. (He tried to do this.) If not, the operator should reduce mixing to minimize contact of the toxic sludge with the entire digester contents.	Clues: 1. Sudden loss of gas production and rapid drop in pH indicates possible toxicity. 2. "Rancid butter" odor of digested sludge indicates presence of butyric acid. The methane formers have been killed. This is characteristic of toxic effects. "Rotten egg" odor is characteristic of organic overload. 3. Operator was treating the dairy waste problem which he had before but the treatment is not working this time.

LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
	4. The "rotten egg" odor came from the raw sludge pumped to the drying beds. Lime the sludge on the beds to reduce odors and decomposition. 5. "Bulking" in the activated sludge units may be deflocculation caused by toxic load to the plant.
The final solution will depend on the type and amount of waste present. It may be possible to dilute the waste below toxic level using either seed sludge from another digester or water for the dilution. Or you might: 1. Form an insoluble product. Remove soluble sulfides by adding iron salts causing iron sulfide to form. Remove heavy metals by adding sulfuric acid or a sulfide to cause formation of metal sulfides. 2. Use another compound that will react with the toxic compound to form less harmful compounds. To discover just what type of <u>antagonistic</u> element is needed, some careful work will be needed.	Note: This is especially true with cyanide and chromium wastes.
3. Empty the digesters and start all over again.	Have class discuss how one might implement a total digester dump if this is needed.
4. The best long-term solution is to implement a good industrial pretreatment system to make sure that this doesn't happen again.	

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LESSON OUTLINE	KEY POINTS & INSTRUCTOR GUIDE
B. Discuss with class whether or not the troubleshooters approached the problem by using the Process of Troubleshooting.	Key Points: Discuss these key points with the class and maximize class input.
C. What aspects of troubleshooter-operator behavior were observed in the exercise?	

Note on Distribution of Instructions

The following sets of instructions must be reproduced prior to this lesson and distributed to trainees for the lesson.

Distribution

"Instructions to Troubleshooters" go to each troubleshooter and each observer and are included in the *Trainee Notebook* as pages T12.2.1 and T12.2.2.

"Instructions to Operators" go only to trainees playing the role of "Operator" and to each observer. These are included in the *Instructor Notebook* as pages H12.2.1-H12.2.5. Troubleshooters are not given the "Instructions to Operators" for the problem which they must troubleshoot.

Troubleshooters may be given copies of the "Instructions to Operators" after the problem has been completed.

The easiest way to handle distribution of the "Instructions to Operators" is to give the trainee who role plays the operator eight copies of the instructions. The operator can distribute copies to the "observers" as the problem solving exercise begins and copies to the "troubleshooters" when the exercise is completed.

TROUBLESHOOTING O & M PROBLEMS IN
WASTEWATER TREATMENT FACILITIES

Unit of Instruction 12: Solids Handling

Lesson 2: Problem Solving in Anaerobic Digestion

Trainee Notebook Contents

Solids Handling

Problem Solving in Anaerobic Digestion

Instructions to Troubleshooters

Problem Number 1

You are an operations consultant with Acme Environmental Associates. It is early Monday morning and you receive a telephone call from an operator that is a client of your firm.

He reports that foam is being discharged from the upper level supernatent line and foam is visible through the sight glasses in the digester roof.

The plant is a 1 MGD trickling filter unit with a fixed cover anaerobic digester. The last time that you visited the plant was 6 months ago.

The operator is uncertified and has been on the job for about a year. He is cooperative but relatively inexperienced. He is concerned and asking for help.

You inform the operator that you expect to be in his vicinity later in the morning and will be traveling with some of the other field staff persons from your office, so you'll bring them along.

As you enter the plant you notice that the flame at the waste gas burner has an orange color. You detect a septic sewage "rotten egg" odor. You also notice that one of the two primary clarifiers is out of service.

When you arrive at the plant (after having reviewed all available records), you begin your troubleshooting procedures.

Solids Handling

Problem Solving in Anaerobic Digestion

Instructions to Troubleshooters

Problem Number 2

You are an operations consultant for Anderson Environmental Associates (AEA). You have just received a telephone call from an irate municipal official. He lives 600 yards downwind from a municipal wastewater treatment plant that your firm designed. He states that the plant smells terrible and that the odor is making him ill and the condition has existed for three days.

The official reminds you that AEA is on retainer to his city and demands that you remedy the situation immediately.

He has already complained twice to the treatment plant operator. The operator told the official that the odor wasn't his fault - he was doing all that he could, but he had a "damn poor" engineering design to work with. He suggested that the official talk with your firm since AEA designed and started up the plant about seven years ago.

Before calling the plant, you pull the file and study the situation. The plant is a 2 MGD activated sludge plant with two-stage anaerobic digesters. The plant serves a community of 12,000 people and several small industries. The industries consist of a poultry processing plant, a cheese and dairy products plant, a clothing manufacturer and a large metal office furniture manufacturing and finishing operation.

All monthly operating records that you could obtain show good operating results. You could find no operating records for the past 3 months however. The operator is certified under the grandfather clause and has over 25 years experience. The last AEA visit of the treatment plant site was about 7 months ago. The operator has never called AEA to ask for assistance, so you assumed that the operation was running smoothly.

You telephone the plant and offer to visit with the operator to assist in solving the odor problem. The operator says that he is too busy to be visiting with people because he's having digester problems and has had to dump sludge to the drying beds. He agrees to spend a few minutes with you but lets you know that he should be working on the digester problem and not wasting time with a bunch of "f---ing engineers."

It sounds like an interesting problem, so you decide to take along several work associates. As you enter the plant, you notice that there is no flame at the waste gas burner. As you near the plant, you detect a strong septic sewage "rotten egg" odor. The primary tanks which you pass look bad. They're black and black sludge is floating on the surface.

Unit of Instruction 12: Solids Handling

Lesson 2: Problem Solving in Anaerobic Digestion

Instructor Handout Contents

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Solids Handling

Problem Solving in Anaerobic Digestion

Instructions to Operating Personnel

Problem Number 1

1. You are the operator of a 1 MGD trickling filter plant with a single fixed cover, heated anaerobic digester.

2. You are an uncertified operator and, in addition to the wastewater treatment plant, you also operate the water plant, collection system and water distribution system. You're still on probation with your employer and are willing to do almost anything to solve the problem quickly and demonstrate your competence as an operator.

3. On Monday morning when you arrive at the plant, you discover foam being discharged from the upper level supernatant line and, when you investigate the cover, you see foam through the sight glass.

4. Your anaerobic digester is a fixed cover unit with no mechanical or gas mixing equipment. Total recirculation is possible and the unit is heated by an external heat exchanger. Recirculation through the heat exchanger provides the only mixing in the unit.

5. You immediately telephone your community's engineering firm and talk with their operations consultant who promised to stop by later today. The consultant has not been to your plant in 6 months.

6. In response to specific questions, you supply the following data. (If you knew what data were important and how to properly interpret the data, you would not have called for assistance.)

   a. Operating Data on the Digester

Parameter	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	Mon. (today)
pH	?	7.0	7.0	7.0	7.0	-	-	6.6
Temperature, °F	?	95	95	95	95	-	-	92
Volatile Acids, mg/l	800	-	-	-	-	-	-	?
Alkalinity, mg/l	2700	-	-	-	-	-	-	?
Sludge Pumped to Digester	------No Records------							

b. You cannot perform solids analyses or gas analyses in your laboratory because you don't have the equipment for these tests.

c. Digester gas has a "rotten egg" odor but is still burnable. The waste gas burner flame is orange colored.

d. No sludge has been withdrawn from digester for over a month.

e. Nothing unusual occurred last week when you were on duty. The only thing that you can remember is that a flight chain broke on number one primary settling tank Friday.

f. You instructed the weekend operator to dewater number one primary settling tank on Saturday and Sunday so you could repair the chain Monday. The tank was empty when you came to work this morning.

g. There are no significant industries connected to the system.

h. Lime is available at the water plant.

7. Additional Data:

a. If the troubleshooters ask you to do so, you will run additional tests. You will run these tests only if asked to do so.

Additional Data for Monday

Volatile Acids, mg/l	1600
Alkalinity, mg/l	1600

b. If the troubleshooters suggest that you "lime" the digester, make sure that they tell you how to do it because you've never limed a digester before. How do you add the lime? How much do you add?

Instructions on Operator Behavior

You are a cooperative but inexperienced operator. If you receive any questions for which the answers are not provided in these instructions, indicate that you do not know the answer. If the troubleshooter gives instructions on how to obtain the answer, agree to try to get it and indicate that you will call him back tomorrow with the answer.

Solids Handling

Problem Solving in Anaerobic Digestion

Instructions to Operating Personnel.

Problem Number 2

1. You are the operator of a 2 MGD activated sludge plant with two-stage anaerobic digesters.

2. You are certified under the grandfather clause because you have twenty-five years of experience and did not have to take a test designed by some young engineer.

3. The anaerobic digesters are floating cover units of equal size with gas mixing equipment and external heat exchangers. Digested sludge is dewatered on sludge drying beds.

4. For the past week you have been working twelve hours a day with two sick digesters and for the past three days people have been complaining and demanding that you do something. To top off your day, some engineer from AEA has decided to come over because of complaints by a city official.

5. The digesters were both full when you noticed the gas production and pH drop. The last time that happened the cheese plant had slugged the treatment plant. To cure the problem, you raised the pH with lime and rested the digesters. This is what you are doing now, except you had to fill two drying beds with sludge in order to have room to mix the lime. The beds and what little gas is being produced have a "rancid butter" odor.

6. You will answer questions from the troubleshooter but you will not offer any additional information.

   a. You have modified the digesters so that they operate as two single-stage complete mixing digesters. Both digesters are sick.

   b. pH: Today--6.1 on both digesters.
      Prior to failure: pH varied between 7.1 and 7.2 on both digesters.

   c. Volatile Acids: Today--4,000 mg/l
      Prior to failure: 400 mg/l on both digesters

   d. Alkalinity: Today--1,200 mg/l
      Prior to failure: 2,400 mg/l on both digesters.

e. To date you have added 1,500 lbs of lime to each of the digesters and have succeeded in stopping the pH drop. The pH has not yet begun to increase.

f. The temperature in each unit is 95°F and it has remained constant.

g. Prior to the failure the gas mixing system was operated on a daily basis and scum is not a problem.

h. Total raw sludge solids content is between 6 and 8 percent.

i. Volatile solids content of sludge is approximately 60 percent.

j. The rate of feed to the digester has remained constant.

k. The digested sludge and what little gas is being produced does not have a "rotten egg" odor. The odor is similar to the smell of "rancid butter."

l. Since you have not been pumping raw sludge to the digesters at a normal rate, there is a sludge build-up in the primary settling tank. The sludge is becoming septic and floating to the top. You've had to pump some raw sludge to the drying beds and its beginning to smell.

m. The pH drop occurred overnight and the usable gas production ceased overnight.

n. Your grit collector works well and there is no large accumulation of grit in the digesters.

o. You have no laboratory capability to run exotic texts. The only tests you can run are those required to operate the plant and comply with NPDES reporting requirements.

p. To top things off, the activated sludge units started bulking about the same time the digesters failed. You're having trouble getting the activated sludge plant back in operation.

Instructions on Operator Behavior

You're getting near retirement and you don't really like other people meddling around your plant. You are reluctant to provide information and are defensive. You will answer specific questions reluctantly but you won't volunteer any information.

You think you can solve your problem without any help if people will leave you alone and let you do the job. You're upset because you're about to receive a 25 year award from the State Water Pollution Control Federation Chapter and you don't want this incident to spoil it.

You're upset with the city officials because they've asked the engineers to come help you solve this problem. Your attitude about engineers is negative because in your opinion you've never met one that knew anything about operations and very few that knew anything about designing wastewater treatment plants. You had some good ideas when the plant was being designed but AEA chose to ignore them all.

You want to get rid of these AEA people as quickly as possible and get back to work.

Learning Resource 10

Operations Manual: Anaerobic Sludge Digestion - Part III, Potpourri,

U.S. Environmental Protection Agency
Office of Water Program Operations
Washington, DC 20460

Presented are selected parts of a manual designed to satisfy a need for a guide to digester operation and maintenance for plant operators. Topics include troubleshooting, general operation, safety, start-up of units, basic theory, sampling and laboratory testing. The selections presented: discuss safety, present case history examples of problem solving and operational experiences, and list examples of gadgets devised by operators to assist in solving problems around their plants.

BASIC CAUTIONS

Sludge handling areas and equipment are potentially among the most dangerous in a wastewater treatment plant.

Plant operators should be thoroughly familiar with the problem areas, the safety devices that should be used, the precautions to take and some general rules for working safely.

Pump rooms can accumulate combustible gases, deplete oxygen in the air and be the site of mechanical problems. Pump rooms should be adequately ventilated and provided with low-level oxygen alarms. Pumps should have isolation valves on the suction and discharge side for isolating the unit. Piping, connections and equipment should be checked on a frequent basis for leaks

Dried sludge and powdered chemicals present dust problems. Operators should wear goggles and face-type breathing filters when working with these compounds.

Methane gas is explosive when in contact with air. Avoid mixing air with methane in the range of from 20.1 to 5 1. Maintain a positive pressure in all gas lines to prevent leakage of air into the pipeline. Methane gas is also produced from digested or partially digested sludge, found in holding tanks. Therefore, wherever gas may be present, there should be no smoking, sparks or any open flame. Gas detectors must always be used before entering any empty digester

Electrical installations, including light switches, temporary devices or fixtures must be of the explosionproof type

Mechanical equipment should always have machine guards in place Operators must be trained in their proper use and follow all applicable safety rules.

MAINTENANCE SAFETY

The following rules apply at all times whenever working on equipment

1 Lock out and tag main switch to prevent accidental starting.

2 When working on pumps, be sure suction and discharge valves are fully closed and tagged Be sure pump is vented and drained.

3 Isolate fuel lines as applicable

DANGER AREAS

Digester

When you must enter the digester, observe the following basic rules for your protection

1 Provide adequate ventilation to remove gases and to supply oxygen. Be sure exhaust fan is on

2. Never enter the digester alone Always have someone to help in the event of trouble.

3 Use safety harness equipped with safety line.

4 Check for gases with explosimeter

5 Be extremely careful about footing

6 Use bucket and rope to lower tools and equipment

Laboratory Safety

The handling of wastewater and numerous chemicals creates a potential hazard to the health and safety of individuals in the lab Danger originates when lab workers fail to use caution in handling these materials, fail to read labels or fail to follow directions as to use and procedure There always exists the possibility of inadvertent or accidental spills which will require immediate, specific and correct action to minimize a potential hazard Inhalation of vapors must be avoided since many chemicals or compounds are dangerous in this respect Most hazards caused in the lab result from inattention, carelessness and poor housekeeping Some specific rules are listed below

1 Use chemicals with due respect Know their properties and how to use them

2 Be sure each bottle or container is labeled for contents, date, warnings, etc.

3 Read and follow directions carefully

4 Arrange and store chemicals according to poison, flammability, explosiveness, etc, and in proper areas

5. Use existing ventilation

6. Wear proper clothing, i e, rubber gloves, aprons, safety glasses, etc

7 Know the antidote for poisonous chemicals and keep these posted in lab

8 When collecting samples, use appropriate sample collecting devices

9 Use the eye wash in the lab to flush harmful chemicals accidently splashed on the face and the emergency shower to flush chemicals off other parts of the body

General Plant Safety

All personnel are to assume the responsibility of keeping walking areas safe and free of tools, debris, spills, grease, etc, checking to see that guards are in place on operating equipment, chain rails are in place and all areas properly lighted

Electrical Safety

1 Lock out and tag main switch of electrical equipment before working on it

2 Do not remove tag without first checking with person who initialed the tag.

3 Notify plant superintendent in the event a motor circuit breaker trips out

4 Only trained plant personnel are to open motor control center panels to perform authorized work

5 Report and log any unusual motor temperature, noise, vibration, etc

The safety material presented in this manual is an incomplete summary of general safety procedures. All plant operators should review their practices from time to time One of the best manuals on plant safety for operators is *Safety In Wastewater Works MOP No. 1, 1975* Edition published by the Water Pollution Control Federation

The following charts summarize details associated with devices and their function in digester safety

DIGESTER SAFETY DEVICES			
ITEMS	**SAFETY DEVICES**	**FUNCTION**	**MAINTENANCE**
GAS			
1. Methane—is explosive in contact with air	Flame Arrestors	Protect against flashback	Inspect monthly and clean every 6 months or as experience dictates
	Thermal Valves	Shut off gas.	
	Water Seal	Vents excessive gas to atmosphere and allows air into digester under vacuum	
	Pressure Relief Valve	Vents excessive gas pressure	Inspect every 6 months or more often for proper operation
	Vacuum Breaker Valve	Brings air into digester to break vacuum	Inspect every 6 months or more often for proper operation
	Pressure Regulator	Controls gas pressure on system.	Check diaphragm every 6 months
	Automatic Gas Pilot Valves	Controls gas burners.	
2. H_2S (hydrogen sulfide)—can be an odorless gas in lethal concentrations.	Gas Detector	To detect presence of H_2S	Check monthly
	Self Contained Air Pack	To protect personnel	Check monthly
3. General	Good Ventilation	To remove gases from area	Service according to manufacturer's instructions.
	No smoking, sparks or open flame.	To prevent explosion or fire	
	Good inspection and maintenance program on gas system and safety devices.	To be sure they work when needed	
DISEASE TRANSMISSION Such as Skin diseases Typhoid Dysentery	Personal Hygiene Wash basin Showers Rubber clothing Boots, gloves & aprons	To prevent spread of diseases into body	Check for corrosion and proper water pressure. Operate showers weekly. Check water flow rate annually.

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DIGESTER SAFETY DEVICES (Cont.)			
ITEMS	**SAFETY DEVICES**	**FUNCTION**	**MAINTENANCE**
CHEMICALS Danger from dust, inflammation and burns.	Self contained air pack Rubber gloves and aprons Face dust masks Eye wash Showers	To provide a noncontaminated source of air for a limited period of time in locations with deficient oxygen and/or lethal gases.	Check air pack monthly. Check clothing each time it is worn.
PHYSICAL INJURY Danger from falls and misuse of equipment	Machine guards Railings and safety chains Safety ladders Safety harness Housekeeping Lighting First aid kit	To prevent physical injury	Check machine guards, safety chains and lighting daily. Perform housekeeping continually. Check ladders and harness each time used. Check first aid kit weekly.
ELECTRICAL Danger from shock and fire.	Electrical lock out tags Rubber mats Maintenance program	To prevent accidental turning on of equipment. To prevent electrical shock by grounding through body. To keep equipment clean.	Provide a sound maintenance program
FIRE	Portable fire extinguishers	To put out fires	Check monthly. Invite representatives from fire department to set up routine for testing and checking fire protection equipment.

SAFETY RULES AND REGULATIONS FOR THE PREVENTION OF ACCIDENTS

1 **Protect your head! Wear a hard hat at all times.** Except in the office, lab or break areas

2. **Prevent falling! Keep all areas clear and clean.**
   - o Pick up all loose objects, tools, trash, ladders, hose, etc
   - o Clean up all oil or grease spills immediately

3 **Prevent body infections and disease!**
   - o Do wash hands.
   - o Do wear gloves when working on or with sewage equipment or collecting samples
   - o Do shower and change clothing before going home

4 **Do use common sense when moving or lifting heavy objects.**
   - o Use proper equipment
   - o Lift with your legs—not your back

5 **Do not RUN to answer the telephone!**

6 **Use handrails on stairways.**

7 **NEVER work on equipment without:**
   - o Locking it out at push-button or circuit breaker
   - o Tagging main circuit breaker

8. **Know where safety equipment is and how to USE it!**

9 **Know locations of all fire extinguishers and how to use them!**

10 **All injuries, even scratches or skin abrasions, MUST be reported and first aid given!**

11 **BE ALERT to safety conditions around the plant!**
If something is out of place or not working, fix it! Examples light bulbs burned out, safety chains not in place, padlocked equipment not locked

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LOADING

Controlling Waste Activated Sludge Load to a Digester

A low solids concentration in the digester feed caused detention time problems at a 5 mgd activated sludge plant treating wastes from an industry producing corn chips This was a result of mixing waste activated with the raw sludge The problem was solved by converting one of the two primary clarifiers to a thickener All of the waste activated sludge was then diverted to the new thickener The thickened waste activated sludge is then separately digested in one primary and one secondary digester while raw sludge is treated in another pair of digesters. By prethickening, the waste activated sludge was concentrated to approximately 3 3 percent solids and with separate digestion the digestion time was increased allowing both systems to function efficiently

Use of Soda Ash to Control Organic Overloading

Vegetable processing plants seasonally cause over 100 percent increase in the amount of sludge handled at one plant The operators daily monitor the volatile acids and alkalinity ratio for digester control during the processing season. When the ratio climbs above 0.25, soda ash is added to bring it back into control. As one example, when the ratio reached 0.25, 500 pounds of soda ash were added and then, seven days later when the ratio again approached 0 25, 1,500 pounds were added Following these two additions, the ratio dropped back down to less than .1 and gas production increased to its previous level.

Hydraulic Overload Control by Using Polymer

A 10 mgd primary plant was hydraulically overloaded and detention times were less than design.

A program was implemented to decrease the volume of sludge being fed to the digester This was accomplished by adding polymer to the thickener at about 0 2 milligrams per liter dosage to reduce the volume of sludge being pumped The polymer used was Zimmite No. 651.

Grit Removal in a Single Stage Digester

In a plant that was handling twice its design load, a single stage digester finally failed to operate due to a thick scum blanket and accumulation of grit This plant operator corrected the problem by opening all possible openings, such as manhole covers and sample vents, and allowing the digester to sit idle with no recirculation The scum blanket formed a cover thick enough to prevent odors in the area.

In order to move excess grit from the bottom, an air compressor with a long pipe was obtained and air was fed into the bottom of the digester while sludge was being drawn off to the beds. If tried in other locations, this procedure might be safer using steam

Breaking up a Scum Blanket with a Pump

How can a scum blanket be broken up without emptying the digester? A plant in the Northwest which had an eight-to-ten-foot scum blanket in an existing digester, solved the problem by inserting a large-capacity

chopper type pump (Vaughan Scum Gun) through a digester manhole Several precautions were necessary in this operation

1. Safety precautions were exercised to prevent explosive situations during the installation.

2. Very rapid breakup of the scum caused a load on the digester because food, which had been tied up in the scum, was released into solution very rapidly. It was necessary to monitor volatile acids and alkalinity frequently, similar to any heavy organic loading

3. Floating covers must be balanced to counter loads caused by placement of the pump. This is particularly important if the pump is placed off center

MIXING

Use Motor Amperage Readings to Indicate Impeller Wear

A plant in Washington noted progressively worse mixing results in a digester with a draft tube. This unit had a reversible propeller mounted on it. When the unit was pulled for inspection, the propeller which was originally 20 inches in diameter, had been worn to a 10-inch diameter. Amperage readings were compared and it was noted that the amperage had been getting progressively lower because a smaller volume of sludge was being moved. Regular monitoring of the motor's amperage would have warned the operator about this problem

LINE PLUGGING

How to Unplug a Supernatant Line

Continuous plugging of supernatant lines by scum can be a serious problem, particularly in a fixed cover digester. In one plant, a one-inch pipe was passed through a rubber plug. The plug was fit tightly into the supernatant line and high-pressure water discharged through the pipeline into the digester, dislodging scum

Freezing a Sludge Line to Install a Valve

During the remodeling construction at one plant, it was necessary to break into a live drain line that had no valve in it. This was done by constructing a two-piece collar to fit around the pipe. The collar was approximately four feet long and four inches larger in diameter than the sludge line. A space was left around the entire diameter of the pipe and the length of the device. Liquid nitrogen was fed into the space in the collar. This method froze the sludge in the pipeline in about two hours, blocking the line. The valve was inserted in the line below the frozen section. About eight hours later the frozen sludge had thawed and began to flow through the newly installed valve

TOXICITY

For over a year a plant had had chronic problems in starting the digester. The cause of the problem was found to be outside the plant. The digester would show signs of a good startup with increasing acid production, but every weekend the digester would quit working and on Mondays the operator would find no digestion taking place. This was repeated week after week

Because of the regular cycle of the problem, it was thought that some industry might be involved. The operator found that a furniture factory was consistently dumping about 1,500 gallons of paint waste into the sewer every Friday

The problem was handled when the operator reduced mixing to three hours a day. This allowed the toxic sludge to stay on one side of the tank and not become thoroughly and immediately mixed with the digester contents. The long-term solution for this problem is to enforce the industrial waste ordinance and prevent the paint dumps at the source

COLD WEATHER PROBLEMS

How to Prevent Freezing of Digester Pressure Relief Valves

Cold weather problems with gas pressure relief valves are common and one operator found the solution by placing a barrel over the relief valve with a light bulb inside it The bulb produced enough heat to keep the valves from freezing This type of device should contain an explosionproof cover over the bulb.

Another method of solving freezing problems in digester pressure relief valves is to put a light grease mixed with salt on the mating surfaces This will prevent freezing However, it should be cleaned off in the summertime to prevent corrosion

DIGESTER DRAINING

Solving a Sludge Removal Problem

Plant operators in one plant needed to empty a digester for routine cleaning An area suitable for sludge storage was found in a lagoon not connected to the digester Some method was needed to transfer the sludge other than the existing sludge drawoff line

It was determined that the city personnel could do the job less expensively than a contractor if they had their own pump and used their own personnel A pump normally used for emptying barnyard manure pits was fitted with an explosionproof motor and hoisted to the top of the digester

A tripod was arranged over a large manhole opening and the pump lowered into the digester A discharge hose was attached to an irrigation pipe to carry the sludge to the lagoon

The pump had a cutter bar underneath the impeller which chopped up thick scum, rags, sticks, etc When the thick scum was broken up with high pressure water, it flowed quite easily through the pump

As the sludge level dropped, the pump was lowered to keep it approximately 1½ to 2 feet below the surface of the sludge

About two digester volumes of water were needed to liquify the sludge enough to pump A scum layer about three feet thick and a grit layer about four feet deep were removed from a 50-foot diameter digester in ten days

How to Control Odors Using Hydrogen Peroxide

When it was necessary to drain a digester containing partially digested sludge, odors were a problem A line was tapped into the sludge draw-off pipeline and hydrogen peroxide solution at 30 percent concentration was added to the sludge The concentration was about one gallon for every 12,000 gallons of sludge drawn to the beds

PLANT STARTUP

A plant with two digesters, primary and secondary, found it necessary to empty the primary for repairs The following startup procedure was used

Day	Temp. Deg.	pH	Comments
1			Tank being filled with raw sewage
3	69	6 7	Tank full
4	75	6 1	Added 10,000 gallons secondary sludge from another plant
7	82	5 4	Added 250 lbs of lime
8	92	5 5	
9	93	5 6	
10	97	5 9	

11	97	5.7	Added 400 lbs. of lime
12	97	5 7	Added 200 lbs of lime
13	98	5 7	Added 200 lbs of lime
19	97	5 7	Added 300 lbs of lime
20	98	5 8	Added 150 lbs of lime
25	98	5 9	Added 1,000 lbs of lime in last five days
35	98	6 0	Added 1,000 lbs. of lime in last ten days
79	98	7 1	Added 2,000 lbs of lime in last 44 days in 100-lb or less increments Also added 2½ gal de-foaming agent about dav 60 to prevent foaming

Sludge was being added at about 4,000 gpd at 3 3 percent solids and 77 percent volatile At the end of about 80 days, the volatile reduction averaged about 51 percent.

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Operators have devised several gadgets that assist in solving problems around their plants. A few examples are listed on the following pages showing what can be done with little expense and some ingenuity.

DIGESTED SLUDGE SAMPLER—This "home-made" sampler is made from materials found around the plant (some, such as the rubber balls, might even be retrieved off bar screens)

The lead can be poured around the inner can using a metal container approximately one inch larger in diameter. The spring support and trip mechanism can be readily fashioned from scrap materials. The spring is weak enough so that it trips without lifting the device.

A tripod with a reel for raising and lowering can be used to allow selecting samples at the desired depths

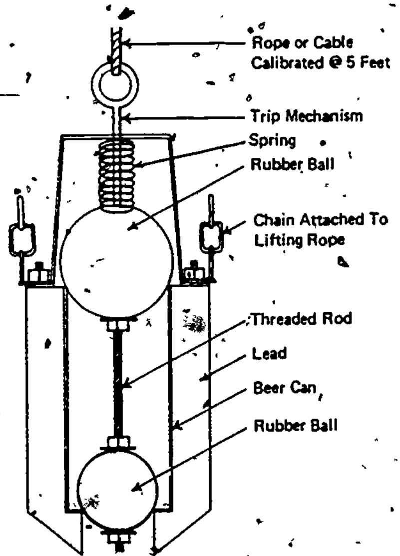

FIGURE 3-1
DIGESTED SLUDGE SAMPLER

GAS PRODUCTION ESTIMATOR—When the gas meter is not operating, the following system may be used as a rough estimate of gas production

1. Fill the carboy with sludge from the active zone.
2. Turn on heating pad and hold contents at same temperature as digester
3. Fill a 500 ml graduated cylinder with water and invert it in a 2 liter beaker over the end of the gas hose, being careful to keep the cylinder filled with water and not admit any air
4. Allow gas to purge from the carboy for one hour, then set gas tube under lip of cylinder
5. Note length of time to displace 400-500 ml
6. Repeat for several consecutive days to get trend of production.

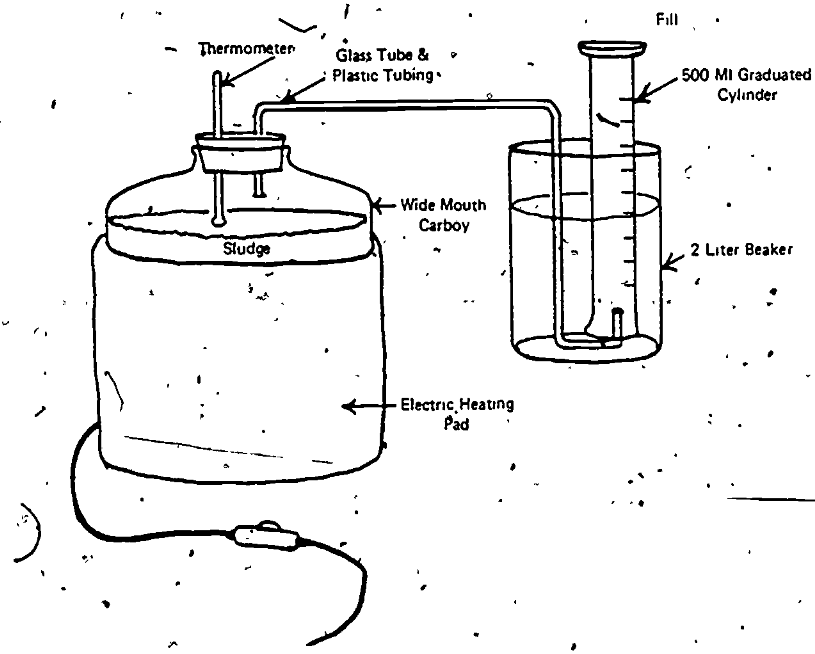

FIGURE 3-2
GAS PRODUCTION ESTIMATOR

SCUM BLANKET FINDER—One method for finding the depth of the scum blanket in a digester is illustrated here

A one inch pipe marked every foot is attached to a wooden paddle by a hinge This can be pushed between the digester wall and cover in the first position

As the finder is raised after passing the bottom of the blanket, the paddle will straighten out and lock under the scum blanket The appropriate depth mark is noted, the paddle pulled back parallel with the pole and lifted out of the digester

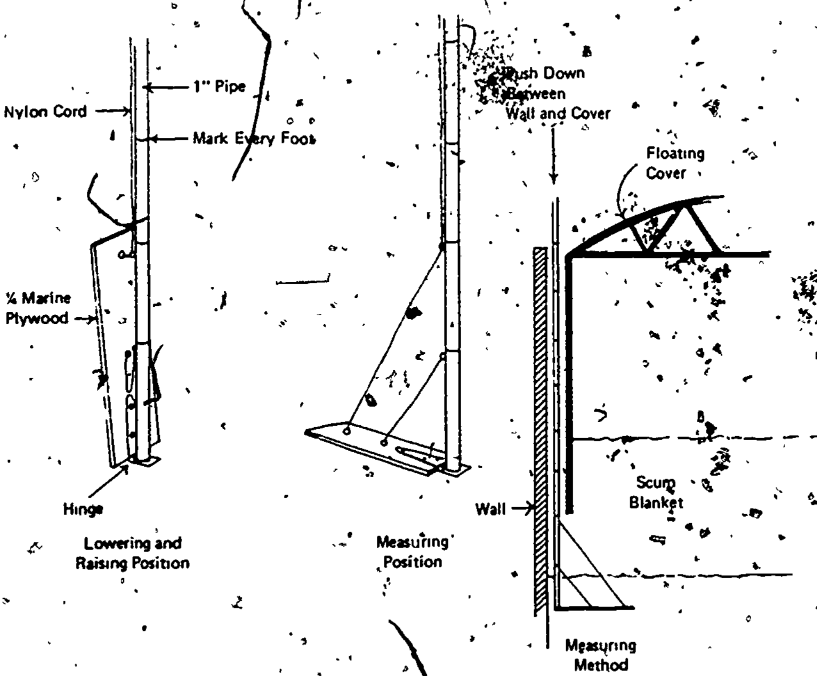

FIGURE 3-3
SCUM BLANKET FINDER

SUPERNATANT LINE PURGE DEVICE—Plugged lines due to scum can cause severe problems in fixed cover digesters, particularly in cold weather when pressure relief valves may freeze

A two inch piece of rubber approximately the same size as the I D. of the line can be fitted with a piece of pipe through the center and secured for moving up and down in the line

Either water or steam can be used to loosen the scum

This may be used also in a chronically plugged sludge line if a tee or wye and valve are provided for access

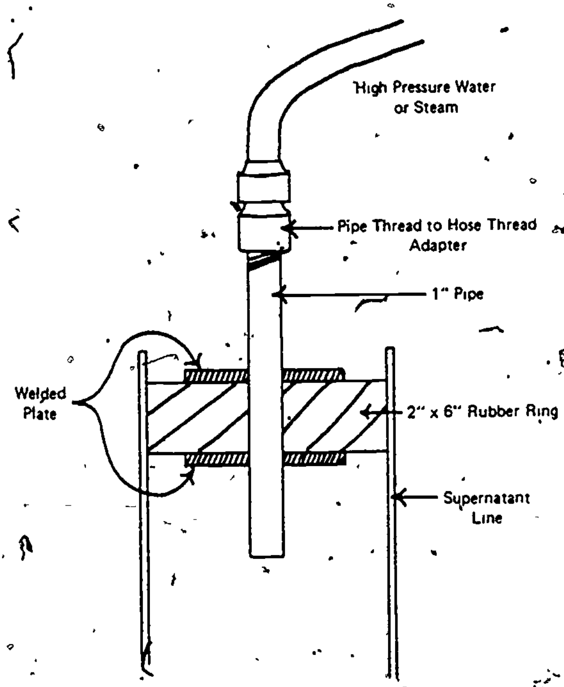

FIGURE 3-4
SUPERNATANT LINE PURGE DEVICE

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AUTOMATIC PUMP SHUT-OFF CONTROL—To prevent damage to the piston pump, sludge piping or valves, a pressure shut off control can be added to existing systems with a minimum of expense as described below.

An adjustable pressure switch to be used as a permissive interlock in the pump control circuit can be installed When pressures downstream from the pump exceed the switch setting, the pump shuts off This effectively prevents damage in the event a downstream valve is unintentionally closed or if plugging develops in the discharge line

The switch is available off the shelf at electrical or control supply firms

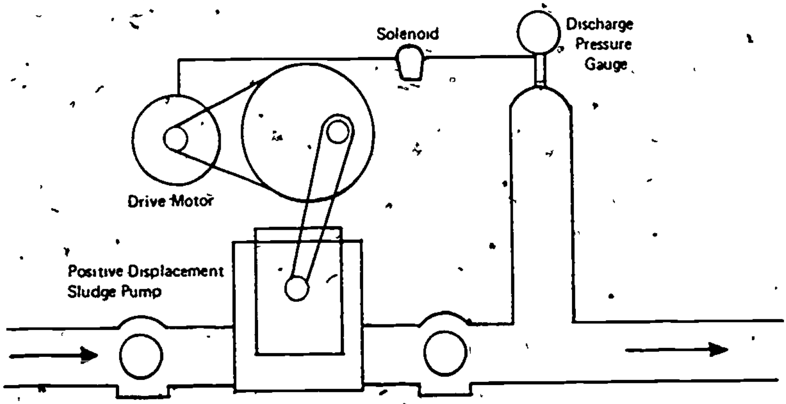

FIGURE 3-5
PRESSURE SHUT-OFF SYSTEM TO PREVENT DAMAGE TO PUMP

RAW SLUDGE THICKNESS CONTROL—A rather simple control system was installed at one plant to prevent pumping excess water to the digester by using the amperage from the piston pump motor to sense changing sludge thickness.

Amperage readings were recorded at the same time that total solids samples were collected. It was found that as the total solids decreased, amperage decreased and when the values for the two were plotted on a graph, the minimum desirable solids content could be matched with an amperage reading (see Appendix G for information on graphing).

A load meter that sensed amperage of the motor was installed in conjunction with a one minute time delay switch. When the pump came on automatically, sludge was cleared out of the line, then the load switch sensed the sludge thickness and the pump shut off if the sludge thinned out before the time clock timed out.

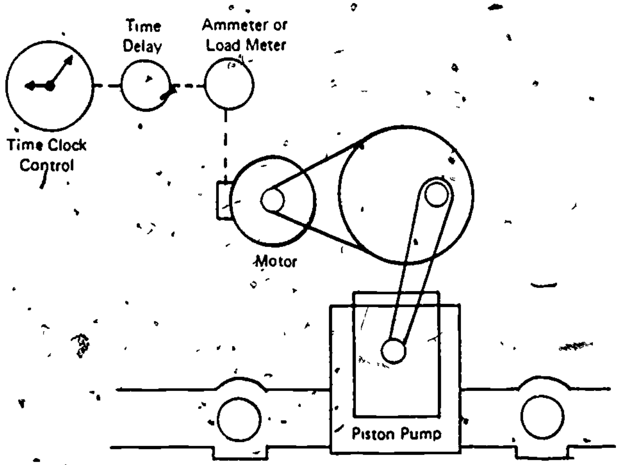

FIGURE 3-6
RAW SLUDGE THICKNESS CONTROL

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SUPERNATANT SELECTOR—An "operator made" device was installed in an existing digester while it was down for repairs that helped draw the best possible supernatant even though liquid level varied.

A hoist was mounted on the tank wall and ¼" plastic coated boat control cable was attached to a section of movable supernatant pipe. A swivel joint composed of an ell and street ell allowed the draw-off point to be changed by operation of the hoist.

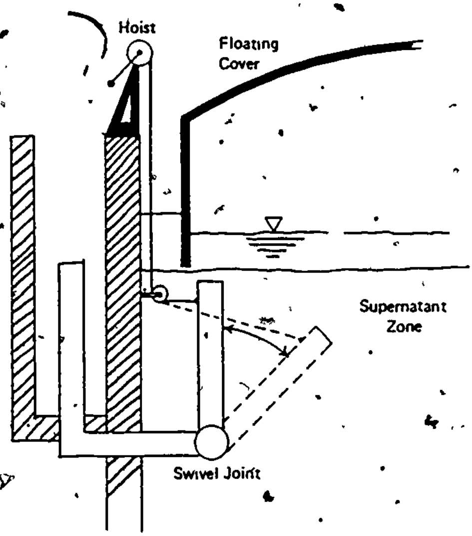

FIGURE 3-7
SUPERNATANT SELECTOR BUILT BY OPERATORS

Learning Resource 11
"Anaerobic Digestion Analysis Training Module" - 5.120.2.77
Kirkwood Community College
6301 Kirkwood Boulevard, S.W.
P.O. Box 2068
Cedar Rapids, IA 52406
Prepared for the:
Iowa Department of Environmental Quality
Wallace State Office Building
Des Moines, IA 50319

Presented are excerpts from an instructional module package for use by an instructor familiar with alkalinity, volatile acids, and carbon dioxide determinations for an anaerobic sludge digester. Included in the package are handouts, instructor guides, student handouts, and transparency masters. The learning activity detailed here describes the determination of volatile acids by the silicic acid method.

3.

ANAEROBIC DIGESTER TEST PROCEDURES

Topics:

Alkalinity
- Alkalinity Testing
- Determination of Alkalinity

Digester Gas Analysis.

Volatile Acids
- Volatile Acids Testing
- Volatile Acids/Alkalinity Ratio
- Determination of Volatile Acids by Silicic Acid Method
- Determination of Volatile Acids by Rapid Distillation
- Determination of Volatile Acids by Hach Method
- Selection of Method for Volatile Acids Analysis

Objective:

When the participants complete this module they should be able to analyze anerobic digester contents for alkalinity and volatile acids and report the results as a volatile acids/alkalinity ratio. The participant should also be able to determine the amount of CO_2 in digester gas upon completion of this module.

References:

Anaerobic Sludge Digestion Manual (EPA)
Operation of Wastewater Treatment Plants (Kerri)
Standard Methods, 13th and 14th Eds.

Instructional Aids:

EPA slide-tape is available from:

National Training and Operational Technology Center
Audio-Visual Lending Library
26 West St. Clair
Cincinnati, Ohio 45268

Overheads
- Typed overheads are example of overhead layout and content. For classroom use, the overhead should be constructed using colored, ½ inch dry transfer letters.

Other overheads may be copied directly

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Handouts
Handouts may be copied directly.

Laboratory supplies and apparatus

Supplies and apparatus should be supplied per handouts so that participants may work in groups of 2 or 3

Submodule Title: Volatile Acids

Topic: Determination of Volatile Acids by Silicic Acid Method

1. Identify proper apparatus and reagents needed for the volatile acids test by silicic acid method.
2. Obtain and prepare a proper sample for the volatile acids test.
3. Conduct a volatile acids test using the silicic acid method given proper test equipment, reagents, procedures sheet and sample.
4. Translate the raw data from the volatile acids test into proper units of expression given appropriate conversion factors and equations.

Instructional Aids: Handout Silicic Acid Method
Laboratory apparatus and reagents per handout
Overhead sample calculation

Instructional Approach: Laboratory

References: Standard Methods, 14th Ed.
Kerri

Class Assignments: Perform analysis

Instructor Notes:	Instructor Outline:
Handout	1. List the apparatus and reagents needed for silicic acid method.
Volatile Acids Silicic Acid Method	Demonstrate the makeup of reagents and setup of apparatus.
	2. Discuss sample collection and if possible demonstrate sample collection.

3. Demonstrate the silicic acid method for volatile acids.

Have participant perform the test.

Overhead — 4. Work a sample calculation

Sample Calculations — Have participant work calcualtions

Example

<u>Apparatus:</u>

1. Centrifuge or filtering apparatus
2. Two 50 ml graduated cylinders
3. Two medicine droppers
4. Crucibles, Gooch or fritted glass
5. Filter flask
6. Vacuum source
7. One 50 ml beaker
8. Two 5 ml pipettes
9. Buret

<u>Reagents:</u>

1. Silicic Acid, solids, 100-mesh. Remove fines from solid portion of acid by slurrying the acid in distilled water and removing the supernatant after allowing settling for 15 minutes. Repeat the process several times. Dry the washed acid solids in an oven at 103°C. and then store in a desiccator.
2. Chloroform - butanol reagent. Mix 300 ml chloroform, 100 ml N-butanol, and 80 ml 0.5 H_2SO_4 in separatory funnel and allow the water and organic layers to separate. Drain off the lower organic layer through filter paper into a dry bottle.
3. Thymol blue indicator solution. Dissolve 80 mg thymol blue in 100 ml absolute methanol.
4. Phenolphthalein indicator solution. Dissolve 80 mg phenolphtahlein in 100 ml absolute methanol.
5. Sulfuric acid, 10 N.
6. Standard sodium hydroxide reagent, 0.02 N Prepare in absolute methanol from conc. NaOH stock solution in water.

Procedure:

1. Centrifuge or filter enough sludge to obtain a sample of 10 to 15 ml. This same sample and filtrate should be used for both the volatile acids test and the total alkalinity test.
2. Measure volume (10 to 15 ml) of sample and place in a beaker.
3. Add a few drops of thymol blue indicator solution.
4. Add 10 N H_2SO_4, dropwise, until thymol blue color just turns to red.
5. Place 10 grams of silicic acid (solid acid) in crucible and apply suction.
6. With a pipette, distribute 5.0 ml acidified sample (from step 4) as uniformly as possible over the column. Apply suction briefly to draw the acidified sample into the silicic acid column. Release the vacuum as soon as the sample enters the column.
7. Quickly add 50 ml chloroform-butanol reagent to the column.
8. Apply suction and stop just before the last of the reagent enters the column.
9. Remove the filter flask from the crucible.
10. Add a few drops of phenolphthalein indicator solution to the liquid in the filter flask.
11. Titrate with 0.02 N NaOH titrant in absolute methanol, taking care to avoid aerating the sample. Nitrogen gas of CO_2 - free air delivered through a small glass tube may be used both to mix the sample and to prevent contact with atmospheric CO_2 during titration (CO_2 - free air may be obtained by passing air through ascarite or equivalent). Volume of NaOH used in sample titration, a = ____ml.
12. Repeat the above procedure using a blank of distilled water. Volume of NaOH used in blank titration, b = ____ml.

Precautions:

1. The sludge sample must be representative of digester. The sample line should be allowed to run for a few minutes before the sample is taken. The sample temperature should be as warm as the digester itself.

2. The sample for the volatile acids test should not be taken immediately after charging the digester with raw sludge. Should this be done, the raw sludge may short-circuit to the withdrawal point and result in the withdrawal of raw sludge rather than digester sludge. Therefore, after the raw sludge has been fed into the tank, the tank should be well mixed by recirculation or other means before a sample is taken.

3. If a digester is performing well with low volatile acids and then if one sample should unexpectedly and suddenly give a high value, say over 1000 mg/l of volatile acids, do not become alarmed. The high result may be caused by a poor, nonrepresentative sample of raw sludge instead of digested sludge. Resample and retest. The second test may give a more typical value. When increasing volatile acids and decreasing alkalinity are observed, this is a definite warning of approaching control problems. Corrective action should be taken immediately, such as reducing the feed rate, reseeding from another digester, maintaining optimum temperatures, improving digester mixing, decreasing sludge withdrawal rate, or cleaning the tank of grit and scum.

Example:

Equivalent Weight of Acetic Acid, $A = 60$ mg/ml

Volume of Sample, $B = 10$ ml

Normality of NaOH titrant, $N = 0.02$ N

Volume of NaOH used in sample titration, $a = 2.3$ ml

Volume of NaOH used in blank titration, $b = 0.5$ ml

Calculation:

$$\text{Volatile Acids, mg/l} = \frac{A \times 1000\ \text{ml/l} \times N(a-b)}{B}$$

$$= \frac{60\ \text{mg/ml} \times 1000\ \text{ml/l} \times 0.02\ (2.3\ \text{ml} - 0.5\ \text{ml})}{10\ \text{ml}}$$

$$= 216\ \text{mg/l}$$

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PART III

Abstracted Reference Materials

TITLE ACCELERATED DIGESTION OF CONCENTRATED SLUDGE.
AUTHOR SHINDALA, A.; DUST, J. V.; CHAMPION, A. L.
CORP AUTH MISSISSIPPI STATE UNIV., STATE COLLEGE. DEPT. OF SANITARY ENGINEERING.
AVAIL WATER AND SEWAGE WORKS, VOL. 117 NO. 9, SEPTEMBER, 1970, P 329-332, 2 FIG, 4 TAB, 16 REF.
DESC *ANAEROBIC DIGESTION; *SLUDGE TREATMENT; *DOMESTIC WASTES; ALKALINITY; HYDROGEN ION CONCENTRATION; PERFORMANCE; *WASTEWATER TREATMENT; SOLIDS CONCENTRATION; VOLATILE ACIDS; GAS PRODUCTION; LOADING RATE; VOLATILE MATTER REDUCTION.
ABSTRACT A LABORATORY STUDY WAS CONDUCTED TO DETERMINE THE EFFECT OF CONCENTRATION OF SLUDGE ON THE ANAEROBIC DIGESTION OF A DOMESTIC SLUDGE. SLUDGE CONCENTRATIONS OF 5, 15, 25, AND 35 PERCENT WERE USED AND A DIGESTION TEMPERATURE OF 92 TO 95F WAS MAINTAINED. LOADING PERIODS OF 10, 15, 20, AND 30 DAYS WERE USED. GAS PRODUCTION OF ALL DIGESTERS WAS RECORDED AND CHANGES IN PH, ALKALINITY, VOLATILE ACIDS, AND REDUCTION IN VOLATILE MATTER ADDED TO THE DIGESTERS WERE OBSERVED EVERY FOUR DAYS. RESULTS SHOWED THAT SOLIDS CONCENTRATION HAD A DEFINITE EFFECT UPON DIGESTION AS THE PERCENT REDUCTION IN VOLATILE MATTER DECREASED WITH INCREASED SOLIDS CONCENTRATION FOR ALL LOADINGS. ALSO, THE VOLATILE ACIDS AND ALKALINITY IN GENERAL INCREASED WITH THE INCREASE IN SOLIDS CONCENTRATION, HOWEVER, THE PH REMAINED NEARLY CONSTANT. THE MAXIMUM AMOUNT OF GAS PER LITER OF SLUDGE WAS PRODUCED AT THE 15 PERCENT SOLIDS LEVEL WHILE THE 5 PERCENT SOLIDS LEVEL PRODUCED THE MOST GAS PER UNIT OF DRY SOLIDS. LOADINGS OF CONCENTRATED SLUDGES UP TO 10 MG/L PER DAY PRODUCED AN ACCEPTABLE VOLATILE SOLIDS REDUCTION. (GALWARDI-TEXAS)

TITLE ALBUQUERQUE PLANT DESIGNED WITH COMPUTER IN MIND.
AUTHOR RICOY, J. L.; MOTOTAN, W. I.
CORP AUTH WILLIAM MATOTAN AND ASSOCIATES, ALBUQUERQUE, NEW MEXICO.
AVAIL WATER AND WASTES ENGINEERING, VOL. 13, NO. 1, P 32-35, 37, JANUARY, 1976.
DESC *TREATMENT FACILITIES; *WASTEWATER TREATMENT; NEW MEXICO; ACTIVATED SLUDGE; TRICKLING FILTERS; *AERATION; COMPUTERS; EQUIPMENT; SETTLEMENT BASINS; ANAEROBIC DIGESTION; *SEWAGE TREATMENT; WASTE DISPOSAL; PROCESS CONTROL; ALBUQUERQUE (NM); SCREW PUMPS.
ABSTRACT A NEW SECONDARY TREATMENT PLANT IN ALBUQUERQUE IS DESCRIBED. THE NEW ACTIVATED SLUDGE WASTE WATER TREATMENT PLANT INCLUDES A PROCESS CONTROL COMPUTER SYSTEM, NEW LABORATORY TESTING EQUIPMENT, AND MONITOR SENSORS. THE TWO EXISTING PLANTS

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INCORPORATE TRICKLING FILTERS. IN THE NEW SCHEME, EFFLUENTS FROM THE TWO OLD PLANTS COMBINE AND PASS THROUGH A SERIES OF SCREW PUMPS TO THE AERATION TANKS, THE FINAL SETTLING TANKS, AND THEN TO THE RIO GRANDE RIVER FOR DISPOSAL. AERATION FACILITIES WERE DESIGNED SO THAT THE PLANT CAN OPERATE AS EITHER CONVENTIONAL TAPED AERATION, STEP AERATION, OR CONTACT STABILIZATION. DIFFUSED AIR IS USED FOR MIXING AND OXYGEN NEEDS. FINAL SETTLING TANKS ARE OF RAPID SLUDGE REMOVAL TYPE. ANAEROBIC DIGESTION HANDLES SLUDGE SOLIDS, AND THE RESULTING GAS IS USED TO GENERATE ELECTRICITY THROUGH THE SYSTEM. PUMPS AND BLOWERS ARE CONTROLLED BY THE COMPUTER ON THE BASIS OF A RUNNING TIME INVENTORY. THIS IS ALSO USED AS AN AID IN DETERMINING MAINTENANCE AND OVERHAUL SCHEDULES. DISSOLVED OXYGEN LEVELS IN THE AERATION TANKS ARE CONTINUOUSLY MONITORED BY THE COMPUTER. ALGORITHMS ARE PROVIDED IN THE SYSTEM FOR A WIDE VARIETY OF CONTROLS AND SAMPLINGS. THE COMPUTER HAS A FIXED HEAD MASS MEMORY OF 246K AND A CORE MEMORY OF 24K, BOTH EXPANDABLE. (PINTO-FIRL)

TITLE	ANAEROBIC DIGESTION AND ANALYTICAL CONTROL (XT-34).
AVAIL	NATIONAL TRAINING AND OPERATIONAL TECHNOLOGY CENTER, 26 W. ST. CLAIR, CINCINNATI, OH 45268.
DESC	AUDIOVISUAL AIDS; INSTRUCTIONAL MATERIALS; LABORATORY PROCEDURES; MICROBIOLOGY; POST-SECONDARY EDUCATION; ANAEROBIC DECOMPOSITION; SLUDGE STABILIZATION; WASTEWATER TREATMENT; POLLUTION; WATER POLLUTION CONTROL.
DESC NOTE	13 MINUTE TAPE, 62 SLIDES, AND A SCRIPT.
ABSTRACT	THIS MODULE IS DESIGNED FOR EXPERIENCED WASTEWATER TREATMENT PLANT OPERATORS WHO WISH TO UPGRADE PLANT PERFORMANCE AND TO INCREASE THEIR OWN KNOWLEDGE AND SKILLS. IT PRESENTS A DISCUSSION OF THE ANAEROBIC DECOMPOSITION PROCESS UTILIZED TO TREAT ORGANIC MATERIALS IN WASTES, AND THE ENVIRONMENTAL CONDITIONS REQUIRED FOR THE INVOLVED BACTERIA. IT ALSO CONTAINS A DESCRIPTION OF THE RELATED PROCESS CONTROL ANALYSIS, VOLATILE ACIDS (STEPWISE PROCEDURE GIVEN), ALKALINITY, TOTAL ORGANIC NITROGEN CONTENT, TOTAL ORGANIC LOAD, PH, AND GAS PRODUCTION.

TITLE	ANAEROBIC DIGESTION ANALYSIS. TRAINING MODULE 5.120.2.77.
PUB DATE	77
AVAIL	ERIC DOCUMENT REPRODUCTION SERVICE, P.O. BOX 190, ARLINGTON, VA 22210.
DESC	CHEMISTRY; INSTRUCTIONAL MATERIALS; LABORATORY PROCEDURES; POST-SECONDARY EDUCATION; CARBON DIOXIDE; WASTEWATER TREATMENT SECONDARY EDUCATION; UNITS OF STUDY; WATER POLLUTION CONTROL; SLUDGE DIGESTION.

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DESC NOTE 44P.
ABSTRACT THIS DOCUMENT IS AN INSTRUCTIONAL MODULE PACKAGE PREPARED IN OBJECTIVE FORM FOR USE BY AN INSTRUCTOR FAMILIAR WITH ALKALINITY, VOLATILE ACIDS AND CARBON DIOXIDE DETERMINATIONS FOR AN ANAEROBIC SLUDGE DIGESTER. INCLUDED ARE OBJECTIVES, INSTRUCTOR GUIDES, STUDENT HANDOUTS AND TRANSPARENCY MASTERS. THIS MODULE CONSIDERS TOTAL AND BICARBONATE ALKALINITY TITRATION, PERCENT CARBON DIOXIDE AND DIGESTER GAS BY THE CARBON DIOXIDE ABSORPTION METHODS AND VOLATILE ACIDS CONCENTRATION IN DIGESTER SLUDGE. THE RAPID DISTILLATION, THE SILICIC ACID, AND THE "HACH" ESTERIFICATION METHODS ARE ALSO DETAILED.

TITLE ANAEROBIC SLUDGE DIGESTION.
PUB DATE 68
AVAIL WATER POLLUTION CONTROL FEDERATION PUBLICATIONS DEPT., 3900 WISCONSIN AVE. N.W., WASHINGTON, DC 20016.
DESC ANAEROBIC DIGESTION; INSTRUCTIONAL MATERIALS; OPERATIONS WASTEWATER; SLUDGE DIGESTION; SLUDGE; WASTEWATER TREATMENT; POST SECONDARY EDUCATION; WASTEWATER SLUDGE.
DESC NOTE PRICE: $3.50-MEMBERS, $7.00-NONMEMBERS.
ABSTRACT DESIGNED TO PROVIDE TREATMENT PLANT OPERATORS WITH THE FUNDAMENTAL THEORY OF ANAEROBIC SLUDGE DIGESTION AS IT CAN BE APPLIED TO SOLVING PLANT OPERATION PROCEDURES AND PROBLEMS.

TITLE ANAEROBIC SLUDGE DIGESTION: OPERATIONS MANUAL.
AUTHOR ZICKEFOSSE, C.; HAYES, R. B.
AVAIL SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402, PRICE: $9.95
DESC *ANAEROBIC DIGESTION; *INSTRUCTIONAL MATERIALS; *MANUALS; LABORATORY PROCEDURES; MAINTENANCE; *OPERATIONS (WASTEWATER); SAFETY; SAMPLING; *SLUDGE; *SLUDGE TREATMENT; *WASTEWATER TREATMENT.
DESC NOTE 189P
ABSTRACT COVERS TROUBLESHOOTING, GENERAL OPERATION, SAFETY, START-UP OF UNITS, BASIC THEORY, SAMPLING, AND LABORATORY TESTING. MANUAL DESIGNED FOR OPERATORS. FORMAT ALLOWS PORTION OF MANUAL OF MOST INTEREST TO BE USED DIRECTLY.

TITLE ANAEROBIC WASTE TREATMENT FACILITY.
AUTHOR GARROTT, W. A., JR.
AVAIL UNITED STATES PATENT 4,040,963. ISSUED AUGUST 9, 1977. OFFICIAL GAZETTE OF THE UNITED STATES PATENT OFFICE, VOL. 961. NO. 2, P 759, AUGUST, 1977.
DESC *ANAEROBIC DIGESTION; *SLUDGE DIGESTION; *PATENTS; *DIGESTION TANKS; *MIXING; DESIGN DATA; SLUDGE TREATMENT; WASTEWATER TREATMENT.

ABSTRACT AN ANAEROBIC DIGESTER WHICH CONTAINS A MIXING ZONE, A QUIESCENT ZONE, A CLEAR ZONE, AND AN INLET AND OUTLET FOR THE MOVEMENT OF WASTE WATER HAS BEEN PATENTED. THE SYSTEM CAN PREVENT THE ENTRY OF LARGE PARTICLES FROM THE QUIESCENT ZONE INTO THE CLEAR ZONE, AND SELECTIVELY CIRCULATE MATERIAL BETWEEN THE MIXING AND CLEAR ZONES WITH A ROTOR BELOW THE LIQUID LEVEL IN THE DIGESTER. ROTARY CIRCULATION IS ACCOMPLISHED BY A STATIONARY CONDUIT ROTOR AND A SECOND CONDUIT MEMBER WHICH IS VERTICALLY MOVEABLE WITH RESPECT TO THE FIRST ROTOR. VERTICAL MOTION OF THE SECOND ROTOR IS LIMITED SO THAT IT IS ALSO CONFINED BELOW THE LIQUID LEVEL IN THE SLUDGE DIGESTER. THE DIGESTER ITSELF IS A FLAT-BOTTOMED TANK WITH OUTWARDLY SLOPING SIDE WALLS AND A COVER. (SCHULZ-FIRL)

TITLE ANALYSIS AND OPTIMIZATION OF TWO-STATE DIGESTION.
AUTHOR FAN, L. T.; ERICKSON, L. E.; BALTES, J. C.; SHAH, P. S.
CORP AUTH KANSAS STATE UNIV., MANHATTAN. DEPT OF CHEMICAL ENGINEERING.
AVAIL JOURNAL WATER POLLUTION CONTROL FEDERATION, VOL. 45 NO. 4, P 591-610, APRIL, 1973. 11 FIG. 77 EQU, 28 REF.
DESC *ANAEROBIC CONTACT PROCESS; TWO-STAGE DIGESTION; STEADY STATE ANALYSIS; WASHOUT ANALYSIS; RECYCLE RATIO; ECONOMIC ANALYSIS; ANAEROBIC PROCESSES.
ABSTRACT A MATHEMATICAL FORMULATION EMPLOYING THE KINETIC MODEL OF WILLIMON AND ANDREWS IS USED TO SIMULATE CONVENTIONAL AND CONTACT ANAEROBIC DIGESTION PROCESSES CONSISTING OF TWO STAGES. PRESENTED IS A SYSTEM OF TWO COMPLETELY MIXED DIGESTERS IN WHICH THE PROCESS IS CARRIED OUT WITHOUT RECYCLE (CONVENTIONAL) AND WITH RECYCLE (CONTACT). PERFORMANCE EQUATIONS OF THE SYSTEM ARE DEVELOPED BY MEANS OF MASS BALANCE. A UNIFIED ANALYSIS OF THE STEADY STATES OF THE SYSTEM IS MADE BECAUSE OF THE POSSIBLE EXISTENCE OF MULTIPLE STEADY STATES. TWO SPECIFIC STEADY-STATE OPERATIONS--NORMAL STEADY-STATE AND WASHOUT STEADY-STATE--ARE CONSIDERED IN DETAIL. THE CRITICAL FLOW RATES THAT CAUSE WASHOUT OF SOME OR ALL SPECIES ARE INVESTIGATED. TO FURTHER CLARIFY THE RESULTS OF THE STEADY-STATE AND WASHOUT ANALYSES, NUMERICAL SIMULATIONS ARE CARRIED OUT. FINALLY, THE OPTIMAL DESIGN POLICY FOR A TWO-STAGE CONTINUOUS ANAEROBIC DIGESTER SYSTEM IS DETERMINED BY JOINING AN ECONOMIC MODEL TO THE PROCESS MODEL. THE OPTIMIZATION PROBLEM IS NONLINEAR AND IS PERFORMED USING THE SIMPLEX SEARCH TECHNIQUE.

TITLE ANNUAL DIGESTER UPSET CORRECTED.
AUTHOR LEE, JOHN P.
CORP AUTH SAN MATEO WASTE WATER TREATMENT PLANT, CALIF.

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*VOLATILE ACIDS; CARBON DIOXIDE; GAS PRODUCTION; SAN MATEO (CAL); *ANAEROBIC DIGESTION; *OPERATION AND MAINTENANCE; *WASTE WATER TREATMENT; HYDROGEN ION CONCENTRATION; LIME; CALIFORNIA; ACTIVATED SLUDGE; SLUDGE DIGESTION.

ABSTRACT SAN MATEO, CALIFORNIA HAS EXPERIENCED THREE IDENTICAL PRIMARY SEWAGE DIGESTER UPSETS IN THE PAST THREE YEARS AT ITS MUNICIPAL WASTE WATER TREATMENT PLANT. THE PRIMARY DIGESTER HANDLES APPROXIMATELY 20,000 GALLONS OF THICKENED SLUDGE PER DAY. THE UPSETS WERE CHARACTERIZED BY (1) AN INCREASE IN THE VOLATILE ACID CONTENT OF THE DIGESTER, (2) AN INCREASE IN THE CARBON DIOXIDE FRACTION OF THE GAS PRODUCED, AND (3) A DRAMATIC DECREASE IN GAS PRODUCTION-OPERATIONAL DATA WERE PRESENTED FOR THE PERIODS JUST BEFORE, DURING AND AFTER CORRECTION OF THE UPSETS FOR EACH OF THE THREE YEARS. FOR INSTANCE, VOLATILE ACID CONTENT INCREASED FROM 108 TO 2070 MG/L WHILE CO2 INCREASED FROM 27 TO 43 AND GAS PRODUCTION DECREASED FROM 91,600 TO 47,200 CU. FT. DURING THE UPSET OF 1966. THE BREAKING UP OF THE GREASE BLANKET ON THE TOP OF THE DIGESTER AT THE START OF WARM WEATHER INCREASED THE ACTIVITY OF THE ACID-FORMING BACTERIA. CONTROL OF THE UPSETS WAS OBTAINED BY THE ADDITION OF UP TO 600 POUNDS OF LIME AND THE DIVERSION OF THE RAW SLUDGE TO THE SECONDARY DIGESTER. (GALWARDI-TEXAS)

TITLE ASSESSMENT OF THE MAXIMUM CONCENTRATION OF HEAVY METALS IN CRUDE SEWAGE WHICH WILL NOT INHIBIT THE ANAEROBIC DIGESTION OF SLUDGE.

AUTHOR MOSEY, F. E.
CORP AUTH WATER POLLUTION RESEARCH LAB., STEVENAGE (ENGLAND)

AVAIL WATER POLLUTION CONTROL, VOL. 75, NO. 1, P 10-20, 1976. 2 FIG, 7 TAB, 24 REF.

DESC *HEAVY METALS; *ANAEROBIC DIGESTION; *EQUATIONS; SOLIDS REMOVAL; SLUDGE DISPOSAL; *WASTEWATER TREATMENT; SLUDGE TREATMENT.

ABSTRACT A METHOD WAS DEVELOPED TO PREDICT THE EFFECT OF MIXTURES OF HEAVY METALS ON THE ANAEROBIC DIGESTION PROCESS. TWO EQUATIONS OF SIMILAR FORM WERE OBTAINED, ONE INDICATING CONDITIONS UNDER WHICH INHIBITION IS EXPECTED, AND THE OTHER INDICATING CONDITIONS UNDER WHICH THE PROBABILITY THAT DIGESTION WILL NOT BE INHIBITED IS AT LEAST 90%. BOTH EQUATIONS INCLUDE THE CONTENT OF ZINC, NICKEL, LEAD, CADMIUM, COPPER, AND SOLIDS ARRIVING IN DIGESTING SLUDGE. DIGESTION IS ALSO SAFEGUARDED FROM HEAVY METAL INHIBITION WHEN THE TOTAL WEIGHT OF THESE HEAVY METALS IN GRAMS ARRIVING DAILY IN THE CRUDE SEWAGE DOES

NOT EXCEED 4939 TIMES THE AVERAGE DAILY DRY WEIGHT IN TONS OF SOLIDS FED TO THE DIGESTER. INHIBITION OF OTHER STAGES OF TREATMENT OCCURS AT HEAVY METAL CONCENTRATIONS SIMILAR TO THOSE THAT INHIBIT ANAEROBIC DIGESTION. THE EFFECTS ON THE RECEIVING STREAM AND LAND ON WHICH THE SLUDGE IS SPREAD MUST ALSO BE CONSIDERED WHEN FORMULATING SUITABLE CONDITIONS. (SNYDER-FIRL)

TITLE AN ASSESSMENT OF THE MIXING PERFORMANCE OF SEVERAL ANAEROBIC DIGESTERS USING TRACER RESPONSE TECHNIQUES.

AUTHOR SMART, J.

CORP AUTH ONTARIO MINISTRY OF THE ENVIRONMENT, TORONTO. POLLUTION CONTROL BRANCH.

PUB DESC RESEARCH PUBLICATION NO. 72, 1978, 68 P, 17 FIG, 4 TAB, 29 REF, 2 APPEND.

DESC *ANAEROBIC DIGESTION; *MECHANICAL EQUIPMENT; *EVALUATION; *DESIGN CRITERIA; PERFORMANCE; MIXING; WASTEWATER TREATMENT.

ABSTRACT THE MIXING CHARACTERISTIC OF A TYPICAL MODERN ANAEROBIC DIGESTER WERE ASSESSED BY EVALUATING TEN DIFFERENT DIGESTERS. THE DIGESTERS STUDIED REPRESENTED EXTREMES IN PHYSICAL SIZE, AGE, AND CONDITION, AND INCLUDED MOST EQUIPMENT TYPES CURRENTLY IN USE. DIGESTERS TESTED RANGED IN SIZE FROM 754 CU M TO 7667 CU M AND IN SPECIFIC NAMEPLATE POWER FROM 654 W/1000 CU M TO 6561 W/1000 CU M. DIGESTER MIXING RANGED FROM 10% TO 89% DEAD SPACE AND AVERAGED ABOUT 45% DEAD SPACE. FOUR OF THE SEVEN DIGESTERS EXPERIENCED SUBSTRATE SHORT-CIRCUITING RANGING FROM 18 TO 72% OF THE SLUDGE SUBSTRATE INPUT. FOR ALL TEN DIGESTERS, OBSERVED HYDRAULIC RETENTION TIMES RANGED FROM 18 TO 72% OF THE SLUDGE SUBSTRATE INPUT. NO RELATIONSHIPS WERE SEEN BETWEEN MIXING EFFICIENCIES AND DIGESTER SIZES, AGES AND GENERAL CONDITIONS, TYPES OF MIXING EQUIPMENT INSTALLED, AND SPECIFIC APPLIED NAMEPLATE POWER. A REVIEW OF LITERATURE DATA SUGGESTED THAT DIGESTERS WERE GENERALLY OVERDESIGNED AND INDICATED THAT MAXIMUM DIGESTER VOLUME UTILIZATION AND ELIMINATION OF SUBSTRATE SHORT-CIRCUITING BY IMPROVED DESIGN AND MIXING EFFICIENCIES WOULD PERMIT HIGHER APPLIED ORGANIC AND HYDRAULIC LOADINGS. (SMALL-FRC)

TITLE DIGESTION FUNDAMENTALS APPLIED TO DIGESTER RECOVERY--TWO CASE STUDIES.

AUTHOR DAGUE, RICHARD; HOPKINS, ROBERT L.; TONN, ROBERT W.

CORP AUTH IOWA UNIV., IOWA CITY. DEPT. OF CIVIL ENGINEERING.

AVAIL JOURNAL WATER POLLUTION CONTROL FEDERATION, VOL 42, NO 9, P 1666-1675, SEPTEMBER 1970. 2 FIG, 2 TAB, 16 REF.

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DESC *CASE STUDIES; *UPSET RECOVERY; VOLATILE ACIDS; GAS PRODUCTION; *CONTROL; *DIGESTION; *ANAEROBIC DIGESTION; HYDROGEN ION CONCENTRATION; ALKALINITY; AMMONIA; INDUSTRIAL WASTES; WASTE WATER TREATMENT; METHANE

ABSTRACT THE ANAEROBIC DIGESTION SYSTEMS OF CONCERN ARE LOCATED AT CLINTON AND KEOKUK, IOWA. BOTH SYSTEMS RECEIVED 'SIGNIFICANT SOLIDS' FROM GRAIN AND PROCESSING INDUSTRIES. INITIAL CONDITIONS AT CLINTON WERE PH 5.5 TO 6.0, VOLATILE ACIDS 4,000 TO 5,000 MG/L, ALKALINITY 2,000 MG/L, GAS PRODUCTION 0. AT KEOKUK INITIAL CONDITIONS WERE PH 6.0 TO 6.3, VOLATILE ACIDS, 8,000 MG/L, ALKALINITY 3,000 MG/L, GAS PRODUCTION 0. ALKALI WAS ADDED TO RAISE THE PH TO ABOUT 6. THE RECOVERY AT CLINTON SHOWED SIGNIFICANT GAINS ONLY WHEN THE PH WAS GREATER THAN 6.5. PART WAY THROUGH THE RECOVERY PERIOD AT KEOKUK THE ADDITION OF LIME WAS HALTED IN FAVOR OF AQUEOUS AMMONIA. THE USE OF AMMONIA TO NEUTRALIZE 10,000 MG/L OF VOLATILE ACIDS RESULTED IN AMMONIA TOXICITY AND CESSATION OF GAS PRODUCTION. AT THIS TIME THE CONCENTRATION OF AMMONIA IN THE SYSTEM WAS 2,500 MG/L AS NH3. THERE IS NO APPARENT RELATIONSHIP BETWEEN THE CONCENTRATION OF VOLATILE ACIDS IN THE DIGESTER AND THE RANGES OF GAS PRODUCTION. A DEFINITE RELATIONSHIP BETWEEN PH AND THE RATE OF GAS PRODUCTION IS APPARENT; THE MINIMUM PH INDICATED IS 6.5. (HANCUFF-TEXAS)

TITLE THE DISTRIBUTION OF HEAVY METALS IN ANAEROBIC DIGESTION.

AUTHOR HAYES, T. D.

CORP AUTH CORNELL UNIV., ITHACA, NY. DEPT. OF ARGICULTURAL ENGINEERING.

PUB DESC JOURNAL WATER POLLUTION CONTROL FEDERATION, VOL 50, NO 1, P61-72, JANUARY, 1978. 15 FIG, 5 TAB, 21 REF.

DESC *HEAVY METALS; *ANAEROBIC DIGESTION; *TOXICITY; *SEWERAGE SLUDGE; *MODEL STUDIES; BIOMASS; NICKEL; COPPER; LEAD; CHROMIUM; ZINC; CADMIUM; SOLUBILITY; DISTILLATION; WASTE WATER TREATMENT; MUNICIPAL WASTES

ABSTRACT THE DISTRIBUTION OF HEAVY METALS IN ANAEROBIC DIGESTERS WAS INVESTIGATED USING THREE BENCH-SCALE ANAEROBIC DIGESTERS FED WITH SEWAGE CONTAINING VARYING CONCENTRATIONS OF HEAVY METALS. NITRATE SALTS OF CHROMIUM, COPPER, NICKEL, ZINC, CADMIUM, AND LEAD AND DICHROMATE WERE FED TO THE DIGESTERS IN CONCENTRATIONS RANGING FROM 5-15,000 MG/LITER BY STEP OR PULSE FEED APPLICATIONS OVER A PERIOD OF 10 DAYS. SLUDGE SAMPLES TAKEN DURING THE DIGESTION PROCESS WERE SEPARATED INTO SOLUBLE, PRECIPITATED, EXTRACELLULAR, AND INTRACELLULAR FRACTIONS [illegible] HEAVY METAL ANALYSIS. DECREASING GAS GENERATION, METHANE CONCENTRATIONS, AND ORGANIC ACIDS ACCUMULATION WERE MONITORED AS INDICATORS OF ANAEROBIC DIGESTION DISRUPTION BY HEAVY

METALS. THE TOXICITY IM[illegible] THE HEAVY METALS ON ANAEROBIC DIGESTION FOLLOWED THE RELATIO[illegible]NICKEL; COPPER, LEAD, CHROMIUM ZINC, WITH NO TOXIC IMPA[illegible]OBSERVED FOR THE CADMIUM DOSES. HEAVY METAL CONCENTRATIONS IN [illegible]E DIGESTER WERE DISTRIBUTED BETWEEN THE INSOLUBLE OR PRECIPITATED FRACTION AND THE INTRACELLULAR OR BIOMASS FRACTION, WITH LITTLE OF THE METALS EVIDENT IN THE EXTRACELLULAR FRACTION. LEVELS OF HEAVY METALS WHICH WOULD PRODUCE INHIBITION AND TOXICITY DURING ANAEROBIC DIGESTION WERE CALCULATED. (LISK-FIRL)

TITLE	FIELD MANUAL FOR PERFORMANCE EVALUATION AND TROUBLESHOOTING AT MUNICIPAL WASTEWATER TREATMENT FACILITIES.
AUTHOR	CULP, GORDON L.; HEIM, NANCY FOLKS.
PUB DATE	78
AVAIL	SUPERINTENDENT OF DOCUMENTS, U. S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.
DESC	EQUIPMENT; EVALUATION; FACILITIES; MANAGMENT; MANUALS; OPERATIONS (WASTEWATER); WASTEWATER TREATMENT; WATER ANALYSIS; WATER POLLUTION; WATER QUALITY.
DESC NOTE	397P, STOCK NO. 055-001-010-01078-8, PRICE: $5.50.
ABSTRACT	THIS MANUAL IS A TECHNICAL FIELD GUIDE AND REFERENCE DOCUMENT FOR IMPROVING THE PERFORMANCE OF MUNICIPAL WASTEWATER TREATMENT PLANTS. IT DESCRIBES GENERAL PROCEDURES FOR EVALUATING THE PERFORMANCE OF TREATMENT PROCESSES AND EQUIPMENT COMMONLY USED IN MUNICIPAL WASTEWATER FACILITIES. THE MANUAL IS ORGANIZED INTO FOUR SECTIONS. THE FIRST SECTION IS AN INTRODUCTION. THE SECOND CONTAINS A STEP-BY-STEP PROCEDURE FOR ORGANIZING AND CONDUCTING A PLANT VISIT AND EVALUATION. THE THIRD SECTION DISCUSSES VARIOUS UNIT PROCESSES AND HOW THEY AFFECT ONE ANOTHER. IT ALSO PRESENTS INFORMATION ON SAFETY, STAFFING, MONITORING, EMERGENCY PROCEDURES, AND MAINTENANCE. THE FOURTH PART GIVES DESCRIPTIONS, DESIGN CRITERIA AND SHORTCOMINGS, CONTROL CONSIDERATIONS, AND A TROUBLESHOOTING GUIDE FOR EACH UNIT PROCESS.

TITLE	FULL SCALE STUDIES ON THE THERMOPHILIC ANAEROBIC DIGESTION PROCESS.
AUTHOR	SMART, J.; BOYKO, B. I.
CORP AUTH	ONTARIO MINISTRY OF THE ENVIRONMENT, TORONTO.
AVAIL	CANADA-ONTARIO AGREEMENT OF GREAT LAKES WATER QUALITY, RESEARCH REPORT NO. 59, 1977. ENVIRONMENTAL PROTECTION SERVICE, ENVIRONMENT CANADA, OTTAWA, CANADA, 79 P, 7 FIG, 12 TAB, 20 REF, 4 APPEND. 73-1-20.
DESC	*THERMOPHILIC SYSTEM; *MESOPHILIC SYSTEM; *ANAEROBIC DIGESTION; *THERMOPHILIC BACTERIA; *MICROORGANISMS; HEATING; HEAT RESISTANCE; SLUDGE DIGESTION; *WASTE WATER TREATMENT

ABSTRACT A PLANT SCALE THERMOPHILIC ANAEROBIC DIGESTION STUDY WAS CONDUCTED TO ASSESS THE FEASIBILITY AND PERFORMANCE AND TO PROVIDE ECONOMIC GUIDELINES FOR THE PROCESS AS COMPARED WITH THE CONVENTIONAL MESOPHILIC SYSTEM. THE STUDY WAS CONDUCTED IN FOUR DISTINCT PHASES; THE FIRST THREE AT SPECIFIC APPLIED DIGESTER LOADINGS. A FULL SCALE MESOPHILIC SYSTEM, OPERATING ON THE SAME RAW SLUDGE FEED, WAS USED AS A COMPARISON. THE STUDY PROVED FULL SCALE THERMOPHILIC DIGESTION TO BE FEASIBLE AND CAPABLE OF SLUDGE STABILIZATION PERFORMANCE SIMILAR TO THE MESOPHILIC CONTROL UNIT, BUT AT MORE RIGOROUS APPLIED DIGESTER LOADING LEVELS. THE FINAL PHASE OF THE STUDY SHOWED THAT WIDELY AND FREQUENTLY VARYING APPLIED DIGESTER LOADINGS HAD LITTLE EFFECT UPON THE THERMOPHILIC PROCESS, WHICH PROVED TO BE VERY FLEXIBLE IN PRODUCING A GOOD ALL AROUND PERFORMANCE UNDER THE RANGE OF SHOCK LOADINGS APPLIED. WHILE NO ACTUAL OPERATING COST COMPARISON WAS MADE BETWEEN THE TWO DIGESTION SYSTEMS, ESTIMATES OF ENERGY REQUIREMENTS BASED ON THE DATA OBTAINED SHOWED THAT REQUIREMENTS WOULD BE SLIGHTLY GREATER FOR THE THERMOPHILIC PROCESS. HOWEVER, THE MAGNITUDE OF THE INCREASE WAS SUCH THAT CONVERSION OF EXISTING OVERLOAD MESOPHILIC SYSTEMS TO THERMOPHILIC OPERATION WOULD BE FEASIBLE AND ACCEPTABLE IN VIEW OF THE LIKELY BENEFITS TO BE OBTAINED. (WATDOC)

TITLE A GUIDE FOR DEVELOPING STANDARD OPERATING JOB PROCEDURES FOR THE DIGESTION PROCESS WASTEWATER TREATMENT FACILITY. SOJP NO. 10.

AUTHOR SCHWING, CARL M.

PUB DATE 73

AVAIL ERIC DOCUMENT REPRODUCTION SERVICE, P. O. BOX 190, ARLINGTON, VA 22210.

DESC GUIDES; INSTRUCTIONAL MATERIALS; JOB TRAINING; WASTE DISPOSAL; WATER POLLUTION CONTROL; SLUDGE DIGESTION; WASTEWATER TREATMENT; INDUSTRIAL TRAINING; POST SECONDARY EDUCATION; SAFETY; UTILITIES; WATER RESOURCES.

DESC NOTE 49P

ABSTRACT THIS GUIDE DESCRIBED STANDARD OPERATING JOB PROCEDURES FOR THE DIGESTION PROCESS OF WASTEWATER TREATMENT FACILITIES. THIS PROCESS IS FOR REDUCING THE VOLUME OF SLUDGE TO BE TREATED IN SUBSEQUENT UNITS AND TO REDUCE THE VOLATILE CONTENT OF SLUDGE. THE GUIDE GIVES STEP-BY-STEP INSTRUCTIONS FOR PRE-STARTUP, STARTUP, CONTINUOUS OPERATING, SHUTDOWN, AND PREVENTIVE MAINTENANCE PROCEDURES.

TITLE HOW TO KEEP AN OLD PLANT RUNNING

AVAIL WATER AND SEWAGE WORKS, VOL. 123, NO. 12, P 12, DECEMBER, 1976.

DESC DIGESTER SOURING; TONAWANDA (NY); SODIUM BICARBONATE

ABSTRACT A TWO-YEAR SOURING CYCLE IN THE ANAEROBIC SLUDGE DIGESTER WAS RECENTLY BROKEN AT THE TONAWANDA, NEW YORK, SEWERAGE TREATMENT PLANT. A SODIUM BICARBONATE TREATMENT CONSISTING OF A 500 POUND/WEEK SPRING DOSAGE AND THE USE OF A COMBINATION OF NAHCO3 AND SODA ASH OR CONTINUED SODIUM BICARBONATE DOSING ON A YEAR-ROUND BASIS WERE INSTRUMENTAL IN DISCONTINUING THE SOURING. A STABLE PH OF 7 HAS BEEN MAINTAINED. A DROP IN METHANE PRODUCTION WAS THE FIRST INDICATION OF SOURING AND CAUSED INCREASED ACID FORMATION AND A DROP IN PH. THE EFFECT SNOWBALLED UNTIL PH REACHED 6.5 OR LOWER WHERE METHANE FORMATION IS IMPOSSIBLE. TO A PLANT WHERE METHANE GAS FUELS THE DIGESTER, THIS WAS A MAJOR PROBLEM. THE POOR SOLUBILITY OF LIME AND THE LENGTHLY PERIOD IT TOOK TO RAISE PH, AS WELL AS A STABILIZATION PROBLEM MADE IT A POOR SOLUTION. IT WAS ESTIMATED THAT 15 TONS OF SODIUM BICARBONATE ARE USED YEARLY. TEMPERATURE DROPS DO NOT AFFECT BICARBONATE AND IT PERFORMS WELL WHERE LIME WAS POOR. (COLLINS-FIRL)

TITLE KEEP YOUR DIGESTER IN GOOD SHAPE.

AUTHOR BARBER, N. R.

CORP AUTH CHURCH AND DWIGHT CO., INC., PISCATAWAY, NJ

AVAIL WATER AND WASTE ENGINEERING, VOL 14, NO 9, P 55, 59, SEPTEMBER, 1977. 1 FIG

DESC *ANAEROBIC DIGESTION; *CHEMICAL REACTIONS; *CHEMICAL PRECIPITATION; *SLUDGE TREATMENT; LIME; HYDROGEN ION CONCENTRATION; ALKALINITY; TOXICITY; SLUDGE DIGESTION; WASTE WATER TREATMENT

ABSTRACT SODIUM BICARBONATE HAS BEEN USED TO SAFEGUARD AGAINST CHEMICAL MALFUNCTION OF ANAEROBIC DIGESTION CAUSED BY THE ACCUMULATION OF VOLATILE ACIDS AND CARBON DIOXIDE. SINCE NAHCO3 CAN DIRECTLY SHIFT THE EQUILIBRIUM TO ANY DESIRED VALUE WITHOUT FIRST REACTING WITH SOLUBLE CO2, IT HAS BEEN USED AS AN ALTERNATIVE TO LIME, WHICH CAN PRODUCE UNDESIRABLE SIDE EFFECTS SUCH AS VACUUM AND/OR PRECIPITATION. WITH LIME ADDITION, THE REMOVAL OF CO2 FROM THE DIGESTER HEAD ROOM TO REPLENISH THE CO2 TAKEN OUT OF THE SOLUTION CAN CREATE AN INSTATANEOUS VACUUM WHICH PLACES STRESSES ON TANK STRUCTURES. THIS MAY, IN TURN, ALLOW OXYGEN TO ENTER THE SYSTEM WITH RESULTING TOXICITY TO THE ANAEROBIC ORGANISMS IN THE DIGESTER. SCALE FORMATION DUE TO THE PRECIPITATION OF CACO3 AFTER IT REACHES ITS SOLUBILITY LIMIT CAN ALSO PRESENT PROBLEMS. AN EQUATION REPRESENTING THE INCREASE IN BICARBONATE ALKALINITY CAUSED BY THE REACTION OF

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LIME WITH SOLUBLE CO_2 IS PRESENTED. CALCULATIONS INDICATED THAT SCALE FORMATION IS LIKELY AT $CACO_3$ CONCENTRATIONS GREATER THAN 500 MG/LITER OR AT LIME CONCENTRATIONS GREATER THAN 370 MG/LITER. AN EQUATION TO ESTIMATE THE REQUIRED ALKALINITY FOR BUFFERING THE PH AT DIFFERENT LEVELS OF CO_2 PARTIAL PRESSURE IS PRESENTED. $NAHCO_3$, A NATURAL PH CONTROL BUFFER IN ALL AQUEOUS SYSTEMS, HAS A TOXICITY LEVEL IN ANAEROBIC DIGESTION SYSTEMS OF 0.2 MOLES NA/LITER FOR SLUG WASTES WHEN OTHER IONS ARE AT CONCENTRATIONS BELOW 10 MG/LITER. THE PRESENCE OF ANTAGONISTIC IONS SUCH AS K AND CA MAY INCREASE THE TOLERABLE LEVEL OF NA TO DIGESTER ORGANISMS. (SCHULZ-FIRL)

TITLE LIME/SODIUM BICARBONATE TREATMENT INCREASES SLUDGE DIGESTER EFFICIENCY.

AUTHOR BARBER, N. R.

CORP AUTH CHURCH AND DWIGHT CO., INC., PISCATAWAY, NJ

PUB DESC JOURNAL OF ENVIRONMENTAL SCIENCES, VOL. 21 NO. 2, P 28-30, 1978. 2 FIG, 1 TAB, 4 REF.

DESC *ANAEROBIC DIGESTION; *LIME; *SODIUM COMPOUNDS; *METHANE BACTERIA: *ALKALINITY; CARBON DIOXIDE; CATIONS: METHANE; SEWAGE SLUDGE; MICROBIAL DEGRADATION; WASTEWATER TREATMENT; CALCIUM CARBONATE; MUNICIPAL WASTES; ACID BACTERIA

ABSTRACT COMBINED LIME AND SODIUM BICARBONATE TREATMENT OF SEWAGE SLUDGE DURING ANAEROBIC DIGESTION IS EVALUATED. METHANE-FORMING BACTERIA REQUIRE A PH OF 6.8-7.2 FOR OPTIMUM METHANE GENERATION; NEUTRALITY IS MAINTAINED BY CHEMICAL TREATMENT OF THE SLUDGE TO COUNTERACT THE EFFECT OF ACID-FORMING BACTERIA. WHEN ADDED TO THE DIGESTER TO RAISE THE PH, LIME REACTS WITH CO_2 AND CAN CAUSE A VACUUM TO FORM AT DIFFERENT CO_2 PARTIAL PRESSURES. IN IMBALANCED DIGESTERS, THE VACUUM POTENTIAL INCREASES AND AIR MAY FLOW INTO THE DIGESTER WITH TOXIC EFFECTS ON THE METHANE-FORMING BACTERIA. EXCESS LIME ADDITION IN THE PRESENCE OF CO_2 CAN FORM INSOLUBLE CALCIUM CARBONATE WHICH WILL NOT INCREASE ALKALINITY. THE USE OF LIME AND SODIUM CARBONATE IN ANAEROBIC DIGESTION REDUCES THE TOXICITY OF DIVALENT CATIONS. THE COMBINED TREATMENT ALSO REDUCES THE PRESENCE OF HIGH PH PATCHES IN THE SLUDGE LIQUOR. IT IS RECOMMENDED THAT LIME BE ADDED INITIALLY TO INCREASE THE PH TO 6.3-6.5, FOLLOWED BY SODIUM BICARBONATE TO INCREASE PH TO THE OPTIMUM 6.5-7.2. THE CHEMICALS ARE ADDED TO MAINTAIN A DIGESTER ALKALINITY OF 2,500-5,000 MG/LITER AS $CACO_3$ AND A VOLATILE ACID CONCENTRATION OF 300-500 MG/LITER AS ACETIC ACID. SODIUM BICARBONATE ADDITIONS OF 500 MG/LITER/DAY WILL MAINTAIN A SODIUM CONCENTRATION OF 137 MG/LITER; ADDITIONS OF 1,500 LB SODIUM BICARBONATE/1 MILLION GAL ~~INFLUENT~~ SLUDGE WILL INCREASE BICARBONATE ALKALINITY BY 180 MG/LITER WHEN DIGESTER ALKALINITY FALLS BELOW 2,500 MG/LITER. (LISH-FIRL)

TITLE LIME/NA2CO3 TREATMENT IMPROVES SLUDGE DIGESTION.
AUTHOR JACOBSON, A. R.
CORP AUTH ILLINOIS STATE UNIV., NORMAL, COLL. OF APPLIED SCIENCE AND TECHNOLOGY.
PUB DESC PUBLIC WORKS, VOL. 109, NO. 7, P 94, JULY, 1978.
DESC *SODIUM COMPOUNDS; *LIME; *ANAEROBIC DIGESTION; *METHANE BACTERIA; *METHANE; ALKALINITY; AMMONIA; CARBON DIOXIDE; SLUDGE DIGESTION; WASTEWATER TREATMENT; SLUDGE TREATMENT; MUNICIPAL WASTES
ABSTRACT LIME AND SODIUM BICARBONATE TREATMENT OF ANAEROBICALLY DIGESTED SLUDGE PROVIDES THE OPTIMUM PH FOR METHANE-FORMING BACTERIA. A NATURAL BUFFER SYSTEM ESTABLISHED BY DIGESTERS IS BASED ON BICARBONATE ALKALINITY FROM THE REACTION OF AMMONIA AND CARBON DIOXIDE TO FORM AMMONIUM BICARBONATE. THE OPTIMUM PH FOR GROWTH OF METHANE-PRODUCING BACTERIA IS IN THE RANGE OF PH 7.0. LIME WILL ADJUST THE PH OF THE DIGESTER TO 6.3-6.5. SODIUM BICARBONATE FURTHER INCREASES THE PH TO 7.0-7.4. WHEN DIGESTER BICARBONATE ALKALINITY FALLS BELOW 2,500 MG/LITER, A 1,500 LB/MILLION GAL SODIUM BICARBONATE ADDITION WILL INCREASE THE ALKALINITY BY 180 MG/LITER. TREATMENT WITH SODIUM BICARBONATE IN ADDITION TO LIME PREVENTS LIME OVERDOSE OR LOCALIZED PH VARIATIONS. (LISK-FIRL)

TITLE NEW PROBLEMS CAN OCCUR WITH ANAEROBIC DIGESTION.
AUTHOR TAVERY, MARY ANN; NELSON, JOHN
PUB DATE 79
AVAIL WATER AND WASTES ENGINEERING; V16 N12
DESC *WASTEWATER TREATMENT; WATER POLLUTION CONTROL; *OPERATIONS (WASTEWATER); RESEARCH; *ANAEROBIC DIGESTION; *SLUDGE; MAINTENANCE; FACILITY GUIDELINES; ENVIRONMENTAL INFLUENCES; RECYCLING
DESC NOTE 14-15 & 47P
ABSTRACT THIS ARTICLE DISCUSSES THE PROBLEMS ENCOUNTERED BY THE DENVER SEWAGE DISPOSAL DISTRICT IN ATTEMPTING TO STOP SLUDGE FOAMING AND INCREASE SOLIDS/LIQUIDS SEPARATION IN ITS ANAEROBIC DIGESTERS.

TITLE OPERATIONAL CHARACTERISTICS OF ANAEROBIC DIGESTERS AT SELECTED MUNICIPAL WASTEWATER TREATMENT FACILITIES IN THE UNITED STATES.
AUTHOR SPENCER, R. R.; AND OTHERS
PUB DATE DEC 78
AVAIL NATIONAL TECHNICAL INFORMATION SERVICE, OPERATIONS DIVISION, SPRINGFIELD, VA 22161. PRICE: $6.00
DESC *ANAEROBIC DIGESTERS; ACTIVATED CARBON; *ECONOMICS; DIGESTER GAS; *ENERGY; *FACILITIES; *MUNICIPALITIES; METHANE; OPERATIONS (WASTEWATER); *RESEARCH; SLUDGE; *WASTEWATER TREATMENT.

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DESC NOTE 38P
ABSTRACT
ANALYZED ARE THE OPERATION CHARACTERISTICS OF A REPRESENTATIVE SAMPLE OF 60 AMERICAN ANAEROBIC DIGESTERS. EXAMINED ARE GAS PRODUCTION, SOLID RESIDENCE TIME, SLUDGE FLOW AND VOLATILE SOLIDS DESTRUCTION. INCLUDED IS IDENTIFICATION OF DIGESTERS OPERATING AT LESS THAN EXPECTED EFFICIENCY. THE ADDITION OF CARBON TO THESE STRESSED DIGESTERS WILL IMPROVE VOLATILE SOLIDS DESTRUCTION AND GAS PRODUCTION. THE CURRENT AND FUTURE ENERGY VALUE AND USAGE (OR MONOSAGE) IS EVALUATED. DISCUSSED IS THE DESIRABILITY OF USING AND INCREASING WASTE GAS.

TITLE OPERATION OF WASTEWATER TREATMENT PLANTS: A HOME STUDY TRAINING PROGRAM.
PUB DATE 70
AVAIL ERIC DOCUMENT REPRODUCTION SERVICE, P. O. BOX 190, ARLINGTON, VA 22210.
DESC ENVIRONMENTAL EDUCATION; ENVIRONMENTAL TECHNICIANS; INDEPENDENT STUDY; INSTRUCTIONAL MATERIALS; SANITATION; WATER POLLUTION CONTROL; EMPLOYMENT QUALIFICATIONS; EQUIPMENT MAINTENANCE; POLLUTION; PUBLIC HEALTH; SAFETY; WASTEWATER TREATMENT.
DESC NOTE 1,317P
ABSTRACT
THIS MANUAL WAS PREPARED BY EXPERIENCED WASTEWATER TREATMENT PLANT OPERATORS TO PROVIDE A HOME STUDY COURSE TO DEVELOP NEW QUALIFIED WORKERS AND EXPAND THE ABILITIES OF EXISTING WORKERS. THE OBJECTIVE OF THIS MANUAL IS TO PROVIDE THE KNOWLEDGE AND SKILLS NECESSARY FOR CERTIFICATION. PARTICIPANTS LEARN THE BASIC OPERATIONAL ASPECTS OF TREATMENT PLANTS AND THE INFORMATION NECESSARY TO ANALYZE AND SOLVE OPERATIONAL PROBLEMS. EACH OF THE CHAPTERS BEGINS WITH AN INTRODUCTION AND THEN DISCUSSES START-UP, DAILY OPERATION AND INTERPRETATION OF LAB RESULTS. TOPICS DISCUSSED INCLUDE MAINTENANCE, SAFETY, SAMPLING, LABORATORY PROCEDURES, HYDRAULICS, RECORDS, ANALYSIS AND PRESENTATION OF DATA, AND REPORT WRITING. EACH LESSON CONTAINS DISCUSSION AND REVIEW QUESTIONS AND IS COMPLETED WITH AN OBJECTIVE TEST.

TITLE OPERATION OF WASTEWATER TREATMENT PLANTS: A HOME STUDY TRAINING PROGRAM (SECOND EDITION).
PUB DATE 80
AVAIL ERIC DOCUMENT REPRODUCTION SERVICE, P. O. BOX 190, ARLINGTON, VA 22210.
DESC ENVIRONMENTAL EDUCATION; ENVIRONMENTAL TECHNICIANS; INDEPENDENT STUDY; INSTRUCTIONAL MATERIALS; SANITATION; WATER POLLUTION CONTROL; WASTEWATER TREATMENT; EMPLOYMENT QUALIFICATIONS; EQUIPMENT MAINTENANCE; POLLUTION; PUBLIC HEALTH; SAFETY.

DESC NOTE	HC - MANUALS ONLY $70.00 (3 VOLUMES) - PLUS POSTAGE.
ABSTRACT	PRESENTED IS THE SECOND EDITION OF A MANUAL PREPARED BY EXPERIENCED WASTEWATER TREATMENT PLANT OPERATORS TO PROVIDE A HOME STUDY COURSE TO DEVELOP NEW QUALIFIED WORKERS AND EXPAND THE ABILITIES OF EXISTING WORKERS. THE OBJECTIVE OF THESE MANUALS IS TO PROVIDE THE KNOWLEDGE AND SKILLS NECESSARY FOR CERTIFICATION. PARTICIPANTS LEARN THE BASIC OPERATIONAL ASPECTS OF TREATMENT PLANTS AND THE INFORMATION NECESSARY TO ANALYZE AND SOLVE OPERATIONAL PROBLEMS. EACH OF THE CHAPTERS BEGIN WITH AN INTRODUCTION AND THEN DISCUSSES START-UP, DAILY OPERATION AND INTERPRETATION OF LAB RESULTS. TOPICS DISCUSSED INCLUDE MAINTENANCE, SAFETY, SAMPLING, LABORATORY PROCEDURES, HYDRAULICS, RECORDS, ANALYSIS AND PRESENTATION OF DATA, AND REPORT WRITING. EACH LESSON CONTAINS DISCUSSION AND REVIEW QUESTIONS AND IS COMPLETED WITH AN OBJECTIVE TEST.
TITLE	OPERATION OF WASTEWATER TREATMENT PLANTS, MANUAL OF PRACTICE NO. 11.
AUTHOR	ALBERTSON, ORRIE E.; AND OTHERS.
PUB DATE	76
AVAIL	WATER POLLUTION CONTROL FEDERATION, 2626 PENNSYLVANIA AVE., N.W., WASHINGTON, DC 20037.
DESC	INSTRUCTIONAL MATERIALS; POST SECONDARY EDUCATION; SANITATION; WASTE DISPOSAL; WATER POLLUTION CONTROL; WASTEWATER TREATMENT; ENVIRONMENT; POLLUTION; PUBLIC HEALTH; TECHNICAL REPORTS; UTILITIES; WATER RESOURCES.
DESC NOTE	536P
ABSTRACT	THIS BOOK IS INTENDED TO BE A REFERENCE OR TEXTBOOK ON THE OPERATION OF WASTEWATER TREATMENT PLANTS. THE BOOK CONTAINS THIRTY-ONE CHAPTERS AND THREE APPENDICES AND INCLUDES THE DESCRIPTION, REQUIREMENTS, AND LATEST TECHNIQUES OF CONVENTIONAL UNITS PROCESS OPERATION, AS WELL AS THE SYMPTOMS AND CORRECTIVE MEASURES REGARDING PROCESS PROBLEMS. PROCESS SUBJECTS DISCUSSED INCLUDE ROTATING BIOLOGICAL REACTORS, OXYGEN ACTIVATED SLUDGE SYSTEMS, STABILIZATION LAGOONS, AND PHYSICAL-CHEMICAL TREATMENT. MANAGEMENT TOPICS INCLUDED ARE EFFLUENT DISPOSAL, BY-PRODUCTS SOLIDS DISPOSAL, PROCESS MANAGMENT AND CONTROL, ODOR CONTROL, AND ENERGY CONVERSION. THE APPENDICES INCLUDE AN ABBREVIATED GLOSSARY, LABORATORY PROCEDURES, AND UNITS OF MEASUREMENT.
TITLE	PLANT OPERATIONS FOR WASTEWATER FACILITIES, VOL. II, PART C. AN INSTRUCTOR'S GUIDE FOR USE OF INSTRUCTIONAL MATERIAL IN WASTEWATER TECHNOLOGY TRAINING PROGRAMS.
AUTHOR	STOAKES, K. C.; AND OTHERS.

PUB DATE 75
AVAIL ERIC DOCUMENT REPRODUCTION SERVICE, P. O. BOX 190, ARLINGTON, VA 22210.
DESC POST SECONDARY EDUCATION; TEACHING GUIDES; TECHNOLOGY; WASTE DISPOSAL; WATER POLLUTION CONTROL; SEWAGE TREATMENT; OPERATIONS (WASTEWATER); WASTEWATER TREATMENT; EDUCATIONAL OBJECTIVES; ENVIRONMENTAL EDUCATION; TECHNICAL EDUCATION; VOCATIONAL EDUCATION; WASTES.
DESC NOTE 92P
ABSTRACT THIS INSTRUCTOR'S GUIDE, DESIGNED FOR USE WITH THE CURRICULUM, PLANT OPERATIONS FOR WASTEWATER FACILITIES, REPRESENTS A TWO-YEAR WASTEWATER TECHNOLOGY INSTRUCTIONAL PROGRAM BASED ON PERFORMANCE OBJECTIVES DESIGNED TO PREPARE UNDERGRADUATE STUDENTS TO ENTER OCCUPATIONS IN WATER AND WASTEWATER TREATMENT PLANT OPERATIONS AND MAINTENANCE. THIS DOCUMENT, PART C OF FIVE PARTS, COVERS THE TOPICS OF THICKENING, FIRST STAGE DIGESTION, SECOND STAGE DIGESTION AND SLUDGE CONDITIONING. IN THIS GUIDE, THE TOPICS AND IDEAS ARE PRESENTED AS A SERIES OF MODULES, ORGANIZED AROUND 16 GENERAL OBJECTIVES COMMON TO ALL PROCESSES. THE MODULE BEGINS WITH A STATEMENT OF PURPOSE WHICH EXPLAINS WHAT THE STUDENT WILL BE STUDYING. NEXT, ALL THE OBJECTIVES OF THE MODULE AND CODE NUMBERS KEYED TO A COMPUTERIZED LIST OF INSTRUCTIONAL RESOURCES ARE LISTED. ALSO INCLUDED IN EACH MODULE ARE A GLOSSARY OF VERBS AND SECTIONS ON LEARNING AND TESTING CONDITIONS, ACCEPTABLE PERFORMANCE, INSTRUCTOR ACTIVITY AND STUDENT ACTIVITY. RECOMMENDATIONS ON EVALUATION TECHNIQUES ARE INCLUDED.

TITLE PRIMARY TREATMENT AND SLUDGE DIGESTION WORKSHOP.
PUB DATE 77
AVAIL PUBLICATIONS CENTRE, ONTARIO MINISTRY OF GOVERNMENT SERVICES, 880 BAY ST., 5TH FLOOR, TORONTO, ONTARIO, CANADA M7A 1N8.
DESC BEHAVIORAL OBJECTIVES; ENVIRONMENTAL EDUCATION; POLLUTION; WATER POLLUTION CONTROL; WORKSHOPS; SLUDGE; WASTEWATER TREATMENT; ENVIRONMENTAL TECHNICIANS; EQUIPMENT; JOB-SKILLS; SAMPLING; WASTE DISPOSAL; ONTARIO.
DESC NOTE 289P, PRICE: $2.00, ORDERS MUST BE ACCOMPANIED BY CHECK OR MONEY ORDER PAYABLE TO THE TREASURER OF ONTARIO.
ABSTRACT THIS MANUAL WAS DEVELOPED FOR USE AT WORKSHOPS DESIGNED TO UPGRADE THE KNOWLEDGE OF EXPERIENCED WASTEWATER TREATMENT PLANT OPERATORS. EACH OF THE SIXTEEN LESSONS HAS CLEARLY STATED BEHAVIORAL OBJECTIVES TO TELL THE TRAINEE WHAT HE SHOULD KNOW OR DO AFTER COMPLETING THAT TOPIC. AREAS COVERED IN THIS MANUAL INCLUDE: SEWAGE CHARACTERISTICS, COLLECTION, TREATMENT, AND SEDIMENTATION, AEROBIC AND ANAEROBIC DIGESTION, SAMPLING AND INTERPRETATION, MONITORING AND CONTROL, AND SELECTED TESTS.

TITLE RESURRECTING THE DEAD ANAEROBIC DIGESTER.
AUTHOR SNELLING, DONALD P.
PUB DATE AUG 79
AVAIL WATER AND SEWAGE WORKS: V126 N8.
DESC *WASTEWATER TREATMENT; *OPERATIONS (WASTEWATER); *EQUIPMENT; WATER POLLUTION CONTROL; *CHEMICAL REACTIONS; UTILITIES; *ANAEROBIC DIGESTERS
DESC NOTE 66-67P
ABSTRACT DISCUSSED ARE THE CAUSES AND REMEDIES FOR IMBALANCED ANAEROBIC DIGESTERS. THE INFORMATION OUTLINES TESTS, PARAMETERS, AND CORRECTIVE ACTIONS.

TITLE SODIUM BICARBONATE CAN SETTLE MANY WASTE WATER PROBLEM UPSETS.
AUTHOR BARBER, N.
CORP AUTH CHURCH AND DWIGHT CO., INC., PISCATAWAY, NJ
AVAIL POLLUTION ENGINEERING, VOL. 9, NO. 4, P 57-59, APRIL, 1977. 1 FIG.
DESC *SODIUM BICARBONATE; *BICARBONATES; *ANAEROBIC DIGESTION; *AEROBIC TREATMENT; TREATMENT FACILITIES; HYDROGEN ION CONCENTRATION; METHANE; CARBON DIOXIDE; MICROORGANISMS; EQUIPMENT; ALKALINITY; NITRIFICATION; SEDIMENTATION; PHYSICAL PROPERTIES; CHEMICAL PROPERTIES; BIOCHEMICAL OXYGEN DEMAND; ODOR; *WASTEWATER TREATMENT
ABSTRACT SODIUM BICARBONATE HAS BEEN USED BY ENGINEERS TO PREVENT EQUILIBRIUM DISTURBANCES IN SEWAGE TREATMENT PLANTS. IT WAS USED AS A BUFFER TO MAINTAIN THE DESIRED ACID/ALKALI RATIO FOR MAINTENANCE OF AN OPTIMUM ENVIRONMENT FOR MICROBIAL GROWTH. IN ANAEROBIC SYSTEMS, SODIUM BICARBONATE CAN CONTROL PH, INCREASE METHANE PRODUCTION, INCREASE BIODEGRADATION RATES, PRECIPITATE TOXIC METALS, AND AID SOLIDS CONCENTRATION. IT WAS ALSO SUBSTITUTED FOR LIME AND OTHER ALKALIS IN AEROBIC PROCESSES, WHERE IT WAS ABLE TO CONTROL PH AND ALKALINITY, ENHANCE NITRIFICATION, IMPROVE BOD REDUCTION, REDUCE OR ELIMINATE ODORS, ENHANCE SETTLING CHARACTERISTICS, AND PRETREAT INDUSTRIAL WASTES. (COLLINS-FIRL)

TITLE STABILITY AND CONTROL OF ANAEROBIC DIGESTION.
AUTHOR GRAEF, S. P.; ANDREWS, J. F.
CORP AUTH METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO, IL
AVAIL JOURNAL WATER POLLUTION CONTROL FEDERATIN, VOL 46, NO 4, P 666-683, APRIL, 1974. 14 FIG, 24 REF
DESC *OVERLOADS; HYDROCARBONS; CONTROL STRATEGIES; STABILITY; PROCESS CONTROL; *SLUDGE DIGESTION; *ANAEROBIC DIGESTION; CONTROL; *WASTE TREATMENT; *COMPUTER STUDIES; *MODEL STUDIES;

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DESC ORGANIC LOADING; TOXINS; DESIGN STANDARDS; OPERATION AND MAINTENANCE; SLUDGE TREATMENT; METHANE; SLUDGE; ALKALINITY; CARBON DIOXIDE; DIGESTION; CONTROL SYSTEMS,

ABSTRACT THE DYNAMIC RESPONSE OF THE ANAEROBIC DIGESTER TO ORGANIC, TOXIC, AND HYDRAULIC OVERLOADING WAS SIMULATED WITH A HYBRID COMPUTER TO EVALUATE PROCESS STABILITY INDICATORS, DESIGN AND OPERATION FACTORS INFLUENCING PROCESS STABILITY, AND CONTROL STRATEGIES. THE RATE OF METHANE PRODUCTION WAS ONE OF THE BEST INDICATORS FOR DETECTING IMPENDING FAILURE CAUSED BY TOXIC COMPOUNDS. IMPROVED PROCESS STABILITY WITH RESPECT TO ORGANIC OVERLOADING CAN BE ACHIEVED BY INCREASING THE RESIDENCE TIME, ALKALINITY, INFLUENT SLUDGE CONCENTRATION, AND DIGESTED SLUDGE RECYCLE. THREE CONTROL STRATEGIES (SCRUBBING OF CARBON DIOXIDE FROM THE GAS PHASE WITH SUBSEQUENT GAS RECYCLE, ADDITION OF A BASE, AND DIGESTED SLUDGE RECYCLE) WERE INVESTIGATED. CONSIDERATION OF PROCESS STABILITY AND IMPLEMENTATION OF CONTROL STRATEGIES COULD IMPROVE DIGESTER OPERATION, PERMIT INCREASED LOADINGS ON EXISTING DIGESTERS, AND DECREASE THE REQUIRED VOLUMES OF NEW DIGESTERS. (WITT-IPC)

TITLE START-UP OF MUNICIPAL WASTEWATER TREATMENT FACILITIES.

AUTHOR RADER, R. D.; GREEN, R. L.; PAGE, G. L., JR.

CORP AUTH WILEY AND WILSON, INC., LYNCHBURG, VA

AVAIL FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402. PRICE: $1.40. ENVIRONMENTAL PROTECTION AGENCY; WASHINGTON, DC. OFFICE OF WATER PROGRAM, OPERATION REPORT EPA-43019-74-008, DECEMBER, 1973. 92P, 3 FIG, 2 TAB, 42 REF. EPA CONTRACT 68-01-0341

DESC PROCEDURES; PROCESS; SEED SLUDGE; STAFFING; STANDARD OPERATING PROCEDURES; SITE MEETINGS; INVENTORY; *ADMINISTRATIVE DECISIONS; *TREATMENT FACILITIES; *WASTEWATER TREATMENT; *OPERATIONS; *LABORATORY TESTS; *SAMPLING; TESTING; ANALYSIS; CONTROLS; ACTIVATED SLUDGE; TRICKLING FILTER; OXIDATION LAGOON; ANAEROBIC DIGESTION; SAFETY; CHLORINATION; SUSPENDED SOLIDS; HYDROGEN ION CONCENTRATION; ALKALINITY; BIOCHEMICAL OXYGEN DEMAND; CHEMICAL OXYGEN DEMAND; PRE-TREATMENT (WATER); SEWAGE TREATMENT

ABSTRACT THIS MANUAL PROVIDES GUIDANCE FOR PUTTING INTO INITIAL OPERATION A MUNICIPAL WASTEWATER TREATMENT PLANT, A NEW ADDITION TO AN EXISTING TREATMENT PLANT, OR A CHANGE IN THE MODE OF THE TREATMENT PLANT'S OPERATION SO THAT THE TREATMENT PLANT OR PROCESS WILL EFFECTIVELY TREAT THE WASTEWATER IN COMPLIANCE WITH THE SPECIFIC CONDITIONS AND LIMITATIONS ESTABLISHED FOR THE TREATMENT FACILITY. THE MANUAL WAS DEVELOPED AND PREPARED WITH THE AID AND COOPERATION OF WASTEWATER TREATMENT PLANT OPERATORS AND SUPERINTENDENTS,

START-UP EXPERTS, THE ACADEMIC COMMUNITY, MANUFACTURERS AND SUPPLIERS OF WASTEWATER TREATMENT PLANT EQUIPMENT, AND LITERATURE REVIEW OF WASTEWATER TREATMENT PLANT OPERATIONS AND RECOGNIZED START-UP TECHNIQUES. INFORMATION IS PROVIDED ON PREPARING FOR ACTUAL TREATMENT PLANT START-UP. PREPARATIONS FOR START-UP INCLUDE: STAFFING THE PLANT, DEVELOPING STANDARD OPERATING PROCEDURES, DRY- AND WET-RUN TESTING OF EQUIPMENT, ON-SITE OPERATOR TRAINING, SAFETY , AND ESTABLISHING PROCEDURES WHEN CONSTRUCTION IS CONTINUING DURING START-UP. THIS MANUAL DESCRIBES START-UP PROCEDURES FOR SOME OF THE MORE COMMON PRETREATMENT AND PRIMARY TREATMENT UNITS; FOR THE SPECIFIC SECONDARY TREATMENT PROCESSES OF ACTIVATED SLUDGE, TRICKLING FILTERS, STABILIZATION PONDS AND AERATED LAGOONS; AND FOR THE SLUDGE HANDLING UNITS AND THE ANAEROBIC DIGESTION PROCESS. THE START-UP PROCEDURES FOR ADVANCED WASTEWATER TREATMENT UNITS AND PROCESSES ARE NOT CONSIDERED IN THIS MANUAL. (EPA)

TITLE A SURVEY OF THE PERFORMANCE OF SEWAGE SLUDGE DIGESTERS IN GREAT BRITAIN.

AUTHOR SWANWICK, J. D.; SHURBEN, D. G.; JACKSON, S.

CORP AUTH WATER POLLUTION RESEARCH LAB., STEVENAGE (ENGLAND)

AVAIL WATER POLLUTION CONTROL, VOL 68, NO 6, P 639-647, NOV-DEC, 1969. 13 TAB, 4 REF.

DESC *UNHEATED: *MESOPHILIC; OVERLOADING; ANIONIC DETERGENTS: GREAT BRITAIN; *ANAEROBIC DIGESTION; *SEWAGE TREATMENT; *PERFORMANCE; FACILITIES; RETENTION; OPERATION; DESIGN; TEMPERATURE; DETERGENTS; INDUSTRIAL WASTES

ABSTRACT DURING THE LAST FOUR YEARS THE WATER POLLUTION RESEARCH LABORATORY HAS BEEN ASKED TO INVESTIGATE AN INCREASING NUMBER OF DIFFICULTIES WITH ANAEROBIC SLUDGE DIGESTION. A SURVEY HAS MADE IT POSSIBLE TO ACCESS THE TOTAL POPULATION SERVED BY THE ANAEROBIC PROCESS. THIS REPORT IS A FIRST ASSESSMENT OF THE INFORMATION OBTAINED FROM 1400 QUESTIONNAIRES WHICH WERE CIRCULATED TO ALL LOCAL AUTHORITIES AND MAIN DRAINAGE AUTHORITIES. HEATED AND UNHEATED DIGESTERS WERE TREATED SEPARATELY AND ALL PLANTS HAVE BEEN CLASSIFIED ACCORDING TO DIGESTER PERFORMANCE: RETURNS WERE RECEIVED FROM 142 PLANTS WITH HEATED DIGESTERS, SERVING POPULATIONS AMOUNTING TO A TOTAL OF OVER 18 MILLION PEOPLE. THE CAUSES OF 92 CASES OF DIFFICULTY AT 63 SEWAGE PLANTS WERE CLASSIFIED AS: TRADE WASTES 37.2 PERCENT, INADEQUATE DESIGN OR OPERATION 56.2 PERCENT, AND ANIONIC DETERGENTS 6.5 PERCENT. THE CHIEF CAUSE OF DIFFICULTIES ATTRIBUTED TO INADEQUATE DESIGN OR OPERATION RESULTED FROM STRATIFICATION AND LOSS OF SOLIDS FROM THE DIGESTION TANK. OVERLOADING WAS ALSO REPORTED AS THE MAIN

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CAUSE FOR DIFFICULTIES AT A NUMBER OF TREATMENT PLANTS. LOADING RATES OF PRIMARY DIGESTERS WERE ANALYZED AND TABULATED. HOWEVER, NO CORRELATION BETWEEN LOADING AND DIGESTER PERFORMANCE WAS FOUND. RETURNS WERE RECEIVED FROM 104 PLANTS WITH UNHEATED DIGESTERS, SERVING POPULATIONS AMOUNTING TO A TOTAL OF 1.7 MILLION PEOPLE. TWENTY-FOUR WORKS REPORTED DIFFICULTIES CAUSED MAINLY BY OVERLOADING AND LOW WINTER TEMPERATURES. DUE TO THE FREQUENCY OF SHORT RETENTION PERIODS REPORTED, A DETAILED ANALYSIS WAS MADE OF THIS PARAMETER AND THE RESULTS FROM 83 WORKS WERE TABULATED. ALSO, IT WAS NOTED THAT THE ABSENCE OF LABORATORY CONTROL WAS MORE PREVALENT AT SMALLER WORKS. (GALWARDI-TEXAS)

TITLE TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT AMERICAN
INST NAME PUBLIC WORKS ASSOCIATION
FACILITIES. INSTRUCTION NOTEBOOK.
PUB DATE AUG 76
AVAIL NATIONAL TECHNICAL INFORMATION SYSTEM, 5285 PORT ROYAL ROAD, SPRINGFIELD, VA 22161. PRICE: $19.00.
DESC BEHAVIORAL OBJECTIVES; BIOLOGICAL TREATMENT; *ENVIRONMENTAL TECHNICIANS; EQUIPMENT; *INSTRUCTIONAL MATERIALS; JOB SKILLS; *MAINTENANCE; *OPERATIONS (WASTEWATER); *POST SECONDARY EDUCATION; SEDIMENTATION BASINS; SLUDGE; STAFFING; WASTE DISPOSAL; *WASTEWATER TREATMENT; WATER POLLUTION CONTROL
DESC NOTE 672P
ABSTRACT THIS DOCUMENT CONTAINS THE INSTRUCTOR GUIDELINES FOR A COURSE ON OPERATION AND MAINTENANCE PROBLEMS IN WASTEWATER TREATMENT PLANTS. EACH LESSON PLAN MODULE CONTAINS: (1) A SET OF INSTRUCTIONS; (2) LESSON OUTLINE; (3) VISUAL AIDS; (4) NOTEBOOK MATERIALS; (5) HANDOUT; AND (6) GUIDELINES ON THE APPROACH TO THE LESSON. FOR EACH LESSON THE INSTRUCTOR IS PROVIDED WITH A SET OF BEHAVIORAL OBJECTIVES, PRESENTATION OPTIONS, AND SUGGESTED TEST QUESTIONS. LESSON TOPICS INCLUDE: (1) SCREENING AND COMMUNICATION; (2) SEDIMENTATION BASINS; (3) BIOLOGICAL TREATMENT UNITS; (4) SLUDGE CONDITIONING, DEWATERING, AND DISPOSAL; (5) EQUIPMENT; AND (6) STAFFING.

TITLE TROUBLESHOOTING O & M PROBLEMS IN WASTEWATER TREATMENT PLANTS. INSTRUCTOR MANUAL.
INST NAME SOUTHERN ILLINOIS UNIVERSITY AT EDWARDSVILLE, ENVIRONMENTAL RESOURCES TRAINING CENTER, ENVIRONMENTAL PROTECTION AGENCY, CINCINNATI, OH.
PUB DATE 80
AVAIL NATIONAL TECHNICAL INFORMATION SERVICE, 5285 PORT ROYAL ROAD, SPRINGFIELD, VA 22161.
DESC SEWAGE TREATMENT; HANDBOOKS; ACTIVATED SLUDGE PROCESS; ANAEROBIC PROCESSES; DISINFECTION; PERFORMANCE EVALUATION; MAINTENANCE; LIQUID WASTES; SOLID WASTES.

DESC NOTE PB81-142325.

ABSTRACT THE INSTRUCTOR NOTEBOOK IS DESIGNED FOR USE BY INSTRUCTORS WHO WISH TO TEACH A SHORT-TERM EDUCATION/TRAINING COURSE ON THE PROCESS OF TROUBLESHOOTING OPERATION AND MAINTENANCE PROBLEMS IN WASTEWATER TREATMENT FACILITIES. THE MATERIALS ARE GEARED TOWARD PROCEDURES FOR IDENTIFYING AND ISOLATING A PROBLEM, FORMULTATING ALTERNATIVE ACTIONS AND SOLUTIONS, AND COMBINING CORRECTIVE ACTION WITH SHORT AND LONG-RANGE FOLLOWUP. BOTH INTERPERSONAL AND TECHNICAL SKILLS ARE STRESSED IN THIS 15 UNIT COURSE WHICH INCLUDES BOTH INSTRUCTOR AND TRAINEE MATERIALS. THE UNITS COVER THE MAJORITY OF LIQUID AND SOLID WASTE TREATMENT PROCESSES AND OPERATIONS COMMONLY ENCOUNTERED IN MUNICIPAL WASTEWATER TREATMENT FACILITIES.

TITLE WPCF WASTEWATER TREATMENT PLANT OPERATOR TRAINING PROGRAM: BASIC COURSE.

PUB DATE 76

AVAIL WATER POLLUTION CONTROL FEDERATION, 2626 PENNSYLVANIA AVENUE, WASHINGTON, DC 20037.

DESC AUDIOVISUAL AIDS; INSTRUCTIONAL MATERIALS; POLLUTION; POST-SECONDARY EDUCATION; WATER POLLUTION CONTROL; OPERATIONS; WASTEWATER; WASTEWATER TREATMENT; BEHAVIORAL OBJECTIVES; ENVIRONMENT; ENVIRONMENTAL TECHNICANS; JOB SKILLS; PUBLIC HEALTH.

DESC NOTE INCLUDES 287 35MM SLIDES, 10 AUDIO CASSETTES, AND MODERATOR WORKBOOKS - ORDER NO. E0100, $300.00; STUDENT MATERIALS ONLY - ORDER NO. E0010, $7.00.

ABSTRACT THIS TRAINING PROGRAM IS DESIGNED FOR THOSE INDIVIDUALS ALREADY EMPLOYED AS WASTEWATER TREATMENT PLANT OPERATORS AS WELL AS THOSE NEW TO THE FIELD. THE COURSE SERVES AS A BASIC INTRODUCTION AND UTILIZES A SYNCHRONIZED PRESENTATION INCORPORATING SLIDES AND AUDIO CASSETTES. THIS PROGRAM MAY BE USED INDIVIDUALLY OR WITH GROUPS. THE UNITS ARE CONCERNED WITH SEWAGE CHARACTERISTICS, TREATMENT METHODS, TESTS AND SAMPLING, RECORD KEEPING, MAINTENANCE AND SAFETY. AT THE END OF EACH UNIT THE STUDENT IS PROVIDED WITH A SUMMARY AND REVIEW EXERCISE. PRE- AND POST-TRAINING EVALUATION MECHANISMS ARE PROVIDED. A PROGRAM GLOSSARY IS INCLUDED FOR REFERENCE.

TITLE WPCF WASTEWATER TREATMENT PLANT OPERATOR TRAINING PROGRAM, INTERMEDIATE COURSE: STUDENT WORKBOOK, VOL B.

PUB DATE 78

AVAIL WATER POLLUTION CONTROL FEDERATION, 2626 PENNSYLVANIA AVENUE, WASHINGTON, DC 20037.

DESC ENVIRONMENTAL TECHNICIANS; INSTRUCTIONAL MATERIALS; OPERATIONS WASTEWATER; POST-SECONDARY EDUCATION; SLUDGE; TRICKLING FILTERS; WASTE STABILIZATION PONDS; WASTEWATER TREATMENT; AUDIOVISUAL AIDS; CERTIFICATION; JOB SKILLS; POLLUTION; WATER POLLUTION CONTROL.

DESC NOTE 144 P. COURSE MATERIALS: 35MM SLIDES (APPROX. 230), 7 TAPE CASSETTES, ADMINISTRATOR HANDBOOK, CARRYING CASE, AND STUDENT WORKBOOK - ORDER NO. E0293, $300.00; STUDENT WORKBOOK ONLY - ORDER NO. E0294, $3.50.

ABSTRACT THIS DOCUMENT IS ONE IN A SERIES OF SELF-INSTRUCTIONAL WORKBOOKS FOR TRAINING WASTEWATER TREATMENT PLANT OPERATORS IN THE BASIC FUNCTIONS OF FACILITY OPERATION. THE WORKBOOK CONTAINS A PRE- AND POST-TEST QUESTIONNAIRE FOR EACH UNIT AS WELL AS SELF-TESTS AND INTERIM GUIDES. THE UNITS DISCUSSED IN THIS VOLUME ARE WASTE STABILIZATION PONDS, TRICKLING FILTERS, AND SLUDGE HANDLING AND DIGESTION.

PART IV

Reference Materials
(Bibliographic Citation Only)

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A bibliographic citation includes only title, author, availability, and corporate author where applicable. All citations in Part IV are arranged alphabetically by title.

TITLE	AGRICULTURAL AMMONIA FOR STUCK DIGESTERS.
AUTHOR	COOPER, FRED; HINDEN, ERVIN; DUNSTAN, GILBERT H.
CORP AUTH	WASHINGTON STATE UNIVERSITY, PULLMAN. DIVISION OF INDUSTRIAL RESEARCH.
AVAIL	PROCEEDINGS, INDUSTRIAL WASTE CONFERENCE, 20TH, MAY 4, 5, 6, 1965, ENGINEERING BULLETIN OF PURDUE UNIVERSITY, VOL XLIX, NO. 4, JULY 1965, P. 126-130.
TITLE	ANAEROBIC ACIDOGENESIS OF WASTEWATER SLUDGE.
AUTHOR	GHOSH, S., J. R. CONRAD, AND D. L. KLASS.
AVAIL	JOURNAL WATER POLLUTION CONTROL FEDERATION. VOL. 47, P. 30, 1975.
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AUTHOR	GRAEF, S. P.
CORP AUTH	PROCEEDINGS OF THE NATIONAL CONFERENCE OF MUNICIPAL SLUDGE MANAGEMENT.
AVAIL	INFORMATION TRANSFER, INC.; ROCKVILLE, MARYLAND 20852. JUNE 1974.
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AUTHOR	MIGNONE, N. A.
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AUTHOR	KOTZE, J. P.
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CORP AUTH BRITISH COLUMBIA RESEARCH COUNCIL, VANCOUVER.
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