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ABSTRACT

Introductory-level material on municipal wastewater treatment facilities and processes is presented. Course topics include sources and characteristics of municipal wastewaters; objectives of wastewater treatment; design, operation, and maintenance factors; performance testing; plant staffing; and laboratory considerations. Chapter topics include Pretreatment, Sedimentation and Flotation, Trickling Filters, Activated Sludge, Sludge Digestion and Handling, Waste Treatment Ponds, Disinfection and Chlorination, Flow Measurements, Plant Safety and Good Housekeeping, and Sampling. (CO)

United States Environmental Protection Agency

National Training and Operational Technology Center
Cincinnati OH 45268

EPA-430/1-79-008
September 1979

Water

EPA

Orientation to Municipal Wastewater Treatment

Training Manual

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Orientation to Municipal Wastewater Treatment

This course is for persons unfamiliar with municipal wastewater treatment facilities and processes, who require a basic course to provide an overview knowledge in this area. For some students this training should be preparatory to other wastewater treatment courses we offer. Some workers in regulatory agencies will find this course valuable for administrative or clerical support functions.

After completing the course, the student will have basic knowledge about the principal methods of municipal wastewater treatment currently in use; significant new or developing methods; and the general design, operational, and maintenance features of municipal wastewater treatment facilities. Incidental to other aspects of the course, the participant will acquire a working vocabulary associated with wastewater treatment facilities and unit processes.

U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Water Program Operations
National Training and Operational Technology Center

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CONTENTS

INTRODUCTION

The material herein consists of extracts from a manual used in a home study program for wastewater treatment plant operators, developed by Sacramento State College, in cooperation with the California Water Pollution Control Association, under a Technical Training Grant from the Water Quality Office, U. S. EPA. Only a small portion of the content of the manual is included. Much material dealing with details of plant operation and maintenance, laboratory analyses, Mathematics, Analysis and Presentation of Data, and Report Writing, has not been included, since it is not considered pertinent to the objectives of this course.

If you are interested in obtaining the complete home study manual, or in participating in the home study program write to:

Professor Kenneth Kerri
Department of Civil Engineering
Sacramento State College
6000 Jay Street
Sacramento, California 95819

Title of the manual is "Operation of Wastewater Treatment Plants: A Field Study Training Program"

Charge for the manual alone is $25.00. Charge for taking the course is $30.00.

CHAPTER 2. WHY TREAT WASTES?

2.0 PREVENTION OF POLLUTION

The operator's main job is to protect the many users of receiving waters. He must do the best he can to remove any substances which will unreasonably affect these users.

Many people think <u>any</u> discharge of waste to a body of water is pollution. However, with our present system of using water to carry away the waste products of home and industry, it would be impossible and perhaps unwise to prohibit the discharge of all wastewater to oceans, streams, and groundwater basins. It is possible under present day technology to treat wastes in such a manner that existing or potential receiving water uses are not unreasonably affected. Definitions of pollution include any interference with beneficial reuse of water or failure to meet water quality requirements. Any questions or comments regarding this definition must be settled by the appropriate enforcement agency.

2.1 WHAT IS PURE WATER?

Water is a combination of two parts hydrogen and one part oxygen, or H_2O. This is true, however, only for "pure" water such as might be manufactured in a laboratory. Water as we know it is not "pure" hydrogen and oxygen. Even the distilled water we purchase in the store has measurable quantities of various substances in addition to hydrogen and oxygen. Rain water, even before it reaches the earth, contains many substances. These substances, since they are not found in "pure" water, may be considered "impurities". When rain falls through the atmosphere, it gains nitrogen and other gases. As soon as the rain flows overland it begins to

Fig. 2.1 Water + Impurities

dissolve from the earth and rocks such substances as calcium, magnesium, sodium, chlorides, sulfates, iron, nitrogen, phosphorus, and many other materials. Organic matter (matter derived from plants and animals) is also dissolved by water from contact with decaying leaves, twigs, grass, or small insects and animals. Thus it should be realized that a fresh flowing mountain stream may pick up many natural "impurities", some possibly in harmful amounts, before it ever reaches civilization or is affected by the waste discharges of man. Many of these substances, however, are needed in small amounts to support life and be useful to man. Concentrations of impurities must be controlled or regulated to prevent harmful levels in receiving waters.

QUESTIONS

2.1A What are some of the dissolved substances in water?

2.1B How does water pick up dissolved substances?

2.2 TYPES OF WASTE DISCHARGES

The waste discharge that first comes to mind in any discussion of stream pollution is the discharge of domestic wastewater. Wastewater contains a large amount of organic waste.[1] Industry also contributes substantial amounts of organic waste. Some of these organic industrial wastes come from vegetable and fruit packing; dairy processing; meat packing; tanning; and processing of poultry, oil, paper and fiber (wood), and many more.

[1] Organic waste (or-GAN-nick). Waste material which comes from animal or vegetable origin. Organic waste generally will be consumed by bacteria and other small organisms. Inorganic wastes are chemical substances of mineral origin and may contain carbon and oxygen, whereas organic wastes contain mainly carbon and hydrogen along with other elements.

Another classification of wastes is inorganic wastes.[2] Domestic wastewater contains inorganic material as well as organic, and many industries discharge inorganic wastes which add to the mineral content of receiving waters. For instance, a discharge of salt brine (sodium chloride) for water softening will increase the amount of sodium and chloride in the receiving waters. Some industrial wastes may introduce inorganic substances such as chromium or copper, which are very toxic to aquatic life. Other industries (such as gravel washing plants) discharge appreciable amounts of soil, sand or grit, which also may be classified as inorganic waste.

There are two other major types of wastes that do not fit either the organic or inorganic classification. These are heated (thermal) wastes and radioactive wastes. Waters with temperatures exceeding the requirements of the enforcing agency may come from cooling processes used by industry and from thermal power stations generating electricity. Radioactive wastes are usually controlled at their source, but could come from hospitals, research laboratories, and nuclear power plants.

QUESTIONS

2.2A Several of the following contain significant quantities of organic material. Which are they?

a. Domestic Wastewater
b. Cooling Water from Thermal Power Stations
c. Paper Mill Wastes
d. Metal Plating Wastes
e. Tanning Wastes

2.2B List four types of pollution.

2.3 EFFECTS OF WASTE DISCHARGES

Certain substances not removed by wastewater treatment processes can cause problems in receiving waters. This section reviews some of these substances and discusses why they should be treated.

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[2] Inorganic waste (IN-or-GAN-nick). Waste material such as sand, salt, iron, calcium, and other mineral materials which are not converted in large quantities by organism action. Inorganic wastes are chemical substances of mineral origin and may contain carbon and oxygen, whereas organic wastes are chemical substances of animal or vegetable origin and contain mainly carbon and hydrogen along with other elements.

2.30 Sludge and Scum

If certain wastes (including domestic wastewater) do not receive adequate treatment, large amounts of solids may accumulate on the banks of the receiving waters, or they may settle to the bottom to form sludge deposits or float to the surface and form rafts of scum. Sludge deposits and scum are not only unsightly; but if they contain organic material, they may also cause oxygen depletion and be a source of odors. Primary treatment[3] units in the wastewater treatment plant are designed and operated to remove the sludge and scum before they reach the receiving waters.

2.31 Oxygen Depletion

Most living creatures need oxygen to survive, including fish and other aquatic life. Although most streams and other surface waters contain less than 0.001% dissolved oxygen (10 milligrams of oxygen per liter of water, or 10 mg/l),[4] most fish can thrive if there are at least 5 mg/l and other conditions are favorable. When oxidizable wastes are discharged to a stream, bacteria begin to feed on the waste and decompose or break down the complex substances in the waste into simple chemical compounds. These bacteria also use dissolved oxygen (similar to human respiration or breathing) from the water and are called aerobic bacteria.[5] As more organic waste is added, the bacteria reproduce

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[3] Primary treatment. A wastewater treatment process consisting of a rectangular or circular tank which allows those substances in wastewater that readily settle or float to be separated from the water being treated.

[4] Milligrams per liter, mg/l (MILL-i-GRAMS per LEET-er). A measure of the concentration, by weight of a substance per unit volume. For practical purposes, one mg/l is equal to one part per million parts (ppm). Thus, a liter of water with a specific gravity of 1.0 weighs one million milligrams; and if it contains 10 milligrams of dissolved oxygen, the concentration is 10 milligrams per million milligrams, or 10 milligrams per liter (10 mg/l), or 10 parts of oxygen per million parts of water, or 10 parts per million (10 ppm).

[5] Aerobic bacteria (AIR-O-bick back-TEAR-e-ah). Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration, such as atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as in water molecules, H_2O, cannot be used for respiration by aerobic bacteria.

rapidly; and as their population increases, so does their use of oxygen. Where waste flows are high the population of bacteria may grow large enough to use the entire supply of oxygen from the stream faster than it can be replenished by natural diffusion from the atmosphere. When this happens fish and most other living things in the stream which require dissolved oxygen die.

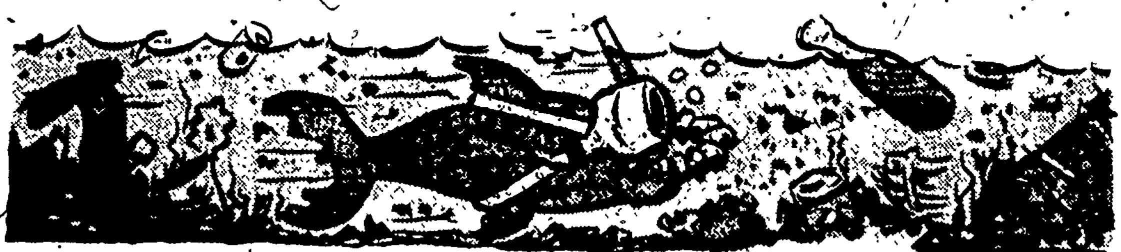

Fig. 2.2 Oxygen depletion

Therefore, one of the principal objectives of wastewater treatment is to prevent as much of this "oxygen-demanding" organic material as possible from entering the receiving water. The treatment plant actually removes the organic material the same way a stream does, but it accomplishes the task much more efficiently by removing the wastes from the wastewater. Secondary treatment[6] units are designed and operated to use natural organisms such as bacteria in the plant to stabilize[7] and remove organic material.

Another effect of oxygen depletion, in addition to the killing of fish and other aquatic life, is the problem of odors. When

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[6] Secondary treatment. A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated.

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

all the dissolved oxygen has been removed, anaerobic bacteria[8] begin to use the oxygen which is combined chemically with other elements in the form of chemical compounds, such as sulfate (sulfur and oxygen), which are also dissolved in the water. When anaerobic bacteria remove the oxygen from sulfur compounds, hydrogen sulfide (H_2S) is released which has a "rotten egg" odor. This gas is not only very odorous, but it also erodes concrete and can discolor and remove paint from homes and structures. Hydrogen sulfide also may form explosive mixtures with air and is capable of paralyzing your respiratory center. Other products of anaerobic decomposition (putrefaction: PU-tree-fack-SHUN) also can be objectionable.

2.32 Other Effects

Some wastes adversely affect the clarity and color of the receiving waters, making them unsightly and unpopular for recreation.

Many industrial wastes are highly acid or alkaline, and either condition can interfere with aquatic life, domestic use, and other uses. An accepted measurement of a waste's acidity or alkalinity is its pH.[9] Before wastes are discharged they should have a pH similar to that of the receiving water.

Waste discharges may contain toxic substances, such as heavy metals or cyanide, which may affect the use of the receiving water for domestic purposes or for aquatic life.

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[8] Anaerobic bacteria (AN-air-O-bick back-TEAR-e-ah). Bacteria that live and reproduce in an environment containing no "free" or dissolved oxygen. Anaerobic bacteria obtain their oxygen supply by breaking down chemical compounds which contain oxygen, such as sulfate (SO_4) and nitrate (NO_3).

[9] pH. Technically, this is the logarithm of the reciprocal of the hydrogen-ion concentration, which will be explained in Chapter 14, Laboratory Procedures and Chemistry. For now, it is sufficient to understand that pH may range from 0 to 14, where 0 is most acid and 14 is most alkaline, and 7 is neutral. Most natural waters have a pH between 6.5 and 8.5.

Taste- and odor-producing substances may reach levels in the receiving water which are readily detectable in drinking water or in the flesh of fish.

Treated wastewaters contain nutrients[10] capable of encouraging excess algae and plant growth in receiving waters. These growths hamper domestic, industrial, and recreational uses. Conventional wastewater treatment plants do not remove a major portion of the nitrogen and phosphorus nutrients.

QUESTIONS

2.3A What causes oxygen depletion when organic wastes are discharged to the water?

2.3B What kind of bacteria cause hydrogen sulfide gas to be released?

2.33 Human Health

Up to now we have discussed the physical or chemical effects that a waste discharge may have on the uses of water. More important, however, may be the effect on human health through the spread of disease-producing bacteria and viruses. Initial efforts to control human wastes evolved from the need to prevent the spread of diseases. Although untreated wastewater contains many billions of bacteria per gallon, most of these are not harmful to humans, and some are even helpful in wastewater treatment processes. However, humans who have a disease which is caused by bacteria or viruses may discharge some of these harmful organisms in their body wastes. Many serious outbreaks of communicable diseases have been traced to direct contamination of drinking water or food supplies by the body wastes from a human disease carrier.

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[10] Nutrients. Substances which are required to support living plants and organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen and phosphorus. Nitrogen and phosphorus are difficult to remove from wastewater by conventional treatment processes because they are water soluble and tend to recycle.

Some known examples of diseases which may be spread through wastewater discharges are:

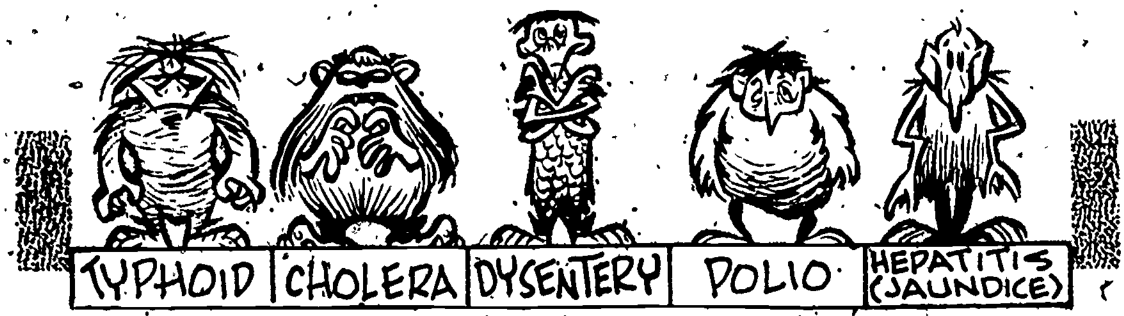

Fig. 2.3 Diseases.

Fortunately these organisms that grow in the intestinal tract of diseased humans are not likely to find the environment in the wastewater treatment plant or receiving waters favorable for their growth and reproduction. Although many of these pathogenic organisms[11] are removed by natural die-off during the normal treatment processes, sufficient numbers can remain to cause a threat to any downstream use involving human contact or consumption. If these uses exist downstream, the treatment plant must also include a disinfection[12] process.

The disinfection process historically employed is the addition of chlorine. Proper chlorination of a well-treated waste will usually result in essentially a complete kill of these pathogenic organisms. The operator must realize, however, that

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11 Pathogenic organisms (path-o-JEN-nick OR-gan-iz-ums). Bacteria or viruses which can cause disease. There are many types of bacteria which do not cause disease and which are not called pathogenic.

12 Disinfection (DIS-in-feck-shun). The process by which pathogenic organisms are killed. There are several ways to disinfect, but chlorination is the most frequently used method in water and wastewater treatment.

breakdown or malfunction of equipment could result in the discharge at any time of an effluent which contains pathogenic organisms.

QUESTIONS

2.3C Where do the disease-causing organisms in wastewater come from?

2.3D What is the term which means "disease-causing"?

2.3E What is the most frequent means of disinfecting treated wastewater?

2.4 SOLIDS IN WASTEWATER

One of the primary functions of a treatment plant is the removal of solids from wastewater.

2.40 Types of Solids

In Section 2.2 you read about the different types of pollution: organic, inorganic, thermal, and radioactive. For a normal municipal wastewater which contains domestic wastewater as well as some industrial and commercial wastes, the concern of the treatment plant designer and operator usually is to remove the organic and inorganic suspended solids, to remove the dissolved organic solids (the treatment plant does little to remove dissolved inorganic solids), and to kill the pathogenic organisms by disinfection. Thermal and radioactive wastes require special treatment.

Since the main purpose of the treatment plant is removal of solids from the wastewater, a detailed discussion of the types of solids is in order. Figure 2.4 will help you understand the different terms.

2.41 Total Solids

For discussion purposes assume that you obtain a one-liter sample of raw wastewater entering the treatment plant. Heat this sample enough to evaporate all the water and weigh all the solid material left (residue); it weighs 1000 milligrams. Thus, the total solids concentration in the sample is 1000 milligrams per liter (mg/l). This weight includes both dissolved and suspended solids.

2.42 Dissolved Solids

How much is dissolved and how much is suspended? To determine this you could take an identical sample and filter it through a very fine-mesh filter such as a membrane filter or fiberglass. The suspended solids will be caught on the filter, and the dissolved solids will pass through with the water. You can now evaporate the water and weigh the residue to determine the weight of dissolved solids. In Fig. 2.4 the amount is shown as 800 mg/l. The remaining 200 mg/l is suspended solids. Dissolved solids are also called filterable residue.

2.43 Suspended Solids

Suspended solids are composed of two parts: settleable and nonsettleable. The difference between settleable and nonsettleable solids depends on the size, shape, and weight per unit volume of the solid particles; larger-sized particles tend to settle more rapidly than smaller particles. It is important to know the amount of settleable solids in the raw wastewater for design of settling basins (primary units), sludge pumps, and sludge handling facilities. Also, measuring the amount of settleable solids entering and leaving the settling basin allows you to calculate the efficiency of the basin for removing the settleable solids. A device called an Imhoff Cone[13] is used to measure settleable solids in milliliters per liter, ml/l. (The example in Fig. 2.4 shows a settleable solids concentration of 130 mg/l. The settled solids in the Imhoff Cone had to be dried and weighed by proper procedures to determine their weight.

It is possible to calculate the weight of nonsettleable solids by subtracting the weight of dissolved and settleable solids from the weight of total solids. In Fig. 2.4 the nonsettleable solids concentration is shown as 70 mg/l. Suspended solids are also called nonfilterable residue.

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[13] Imhoff Cone. A clear cone-shaped container marked with graduations used to measure the volumetric concentration of settleable solids in wastewater.

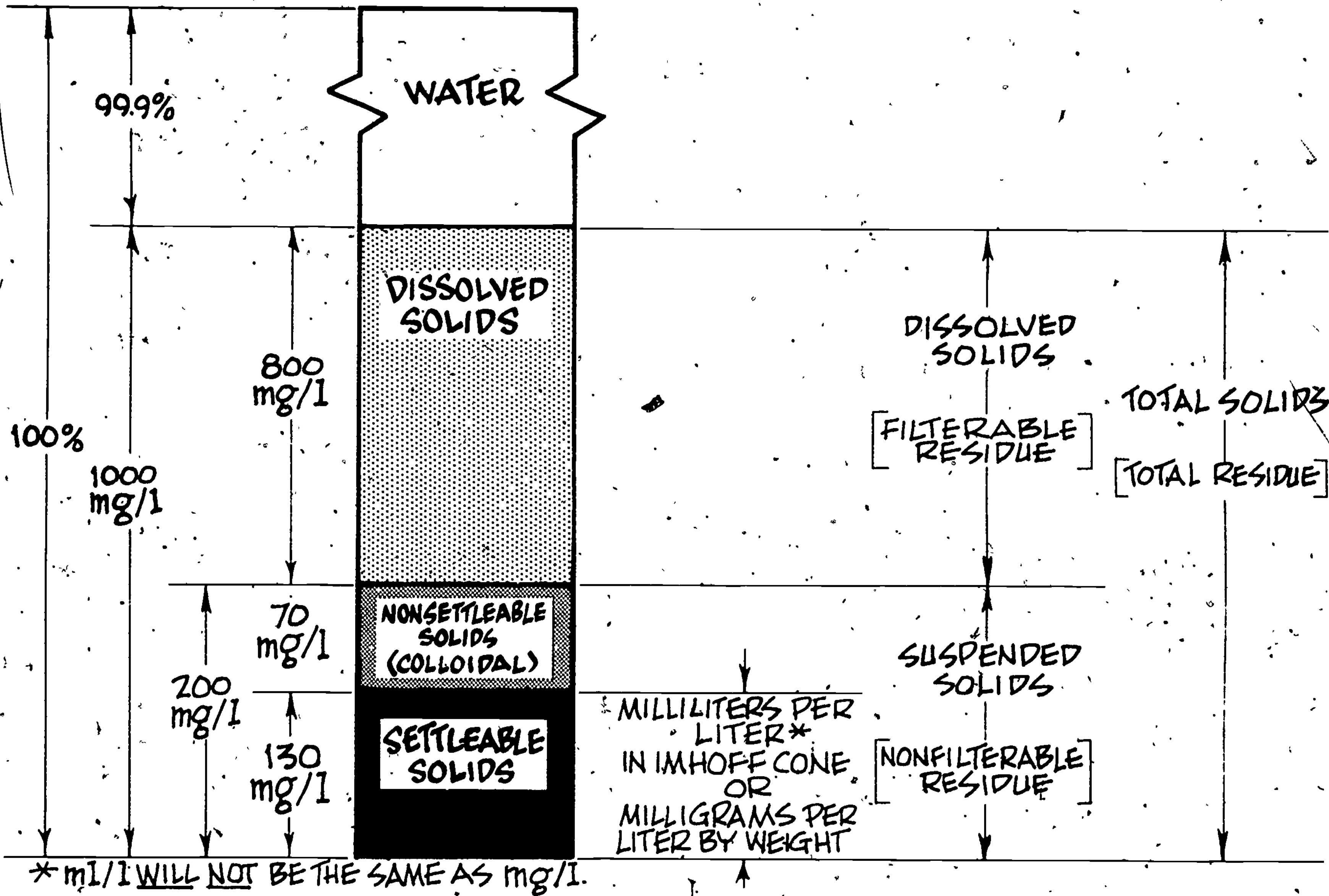

Fig. 2.4, Composition of solids in raw wastewater

2.44 Organic and Inorganic Solids

For total solids or for any separate type of solids, such as dissolved, settleable, or nonsettleable, the relative amounts of organic and inorganic matter can be determined. This information is important for estimating solids handling capacities and for designing treatment processes for removing the organic portion in waste. The organic portion can be very harmful to receiving waters.

2.45 Floatable Solids

There is no standard method for the measurement and evaluation of floatable solids. Since treatment units are designed to remove these solids, it is important for you to be aware of floatable solids in raw wastewater and treated effluent. Floatable solids are undesirable in the plant effluent from an aesthetic viewpoint because the sight of floatables in receiving waters indicates the presence of inadequately treated wastewater.

2.5 ADDITIONAL READING

For a detailed discussion of the physical and chemical composition of wastewater you may wish to refer to:

1. MOP 11, pp 4-7
2. New York Manual, pp 1-10
3. Texas Manual, pp 1-18

QUESTIONS

2.4A An Imhoff Cone is used to measure ______________ solids.

2.4B Why is it necessary to measure settleable solids?

2.4C Total solids are made up of ______________ and ______________ solids, both of which contain organic and inorganic matter.

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CHAPTER 3. WASTEWATER FACILITIES

3.0 COLLECTION, TREATMENT, DISPOSAL

Facilities for handling wastewater are usually considered to have three major components or parts: collection, treatment, and disposal. For a municipality, these components make up the "sewerage" system or wastewater facilities; but for an individual industry which handles its own wastewater, the same three components are necessary. This training course is directed primarily to plant operators for municipalities, so the discussion in this and later chapters will be in terms of municipal wastewater facilities.

3.1 COLLECTION OF WASTEWATER

Collection and transportation of wastewater to the treatment plant is accomplished through a complex network of pipes and pumps of many sizes.

Major water using industries which contribute waste to the collection system may affect the efficiency of a wastewater treatment plant, especially if there are periods during the day or during the year when these industrial waste flows are a major load on the plant. For instance, canneries are highly seasonal in their operations; therefore, it is possible to predict the time of year to expect large flows from them. A knowledge of the location of commercial and industrial dischargers in the collection system may enable an operator to locate the source of a problem in the plant influent, such as oil from a refinery or a gas station.

The length of time required for wastes to reach your plant can also affect treatment plant efficiency. Hydrogen sulfide gas (rotten egg gas) may be released by anaerobic bacteria feeding on the wastes if the flow time is quite long and the weather is hot; this can cause odor problems, damage concrete in your plant, and make the wastes more difficult to treat. (Solids won't settle easily, for instance.) Wastes from isolated subdivisions located far away from the main collection network often have this "aging" problem.

3.10 Sanitary, Storm, and Combined Sewers

For most sewerage systems the sewer coming into the treatment plant carries wastes from households and commercial establishments in the city or district, and possibly some industrial waste. This type of sewer is called a sanitary sewer.[1] All storm runoff from streets, land, and roofs of buildings is collected separately in a storm sewer,[2] which normally discharges to a water course without treatment. In some areas only one network of sewers has been laid out beneath the city to pick up both sanitary wastes and storm water in a combined sewer.[3] Treatment plants that are designed to handle the sanitary portion of the wastes sometimes must be bypassed during storms due to inadequate capacity, allowing untreated wastes to be discharged into receiving waters. Separation of combined sewers into sanitary and storm sewers is very costly and difficult to accomplish.

Even in areas where the sanitary and storm sewers are separate, infiltration[4] of groundwater or storm water into sanitary sewers through breaks or open joints can cause high flow problems at the treatment plant. Replacement or sealing of leaky sections of sewer pipe is called for in these cases. The treatment plant operator is generally the first to know about infiltration problems because of the unusually high flows he observes at the plant during periods of storm water runoff.

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[1] Sanitary Sewer (SAN-eh-tar-ee SUE-er). A sewer intended to carry wastewater from homes, businesses, and industries.

[2] Storm Sewer. A separate sewer that carries runoff from storms, surface drainage, and street wash, but that excludes domestic and industrial wastes.

[3] Combined sewer. A sewer designed to carry both sanitary wastewaters and storm or surface water runoff.

[4] Infiltration (IN-fill-TRAY-shun). Groundwater that seeps into pipes through cracks, joints, or breaks.

Sanitary sewers are normally placed at a slope sufficient to produce a velocity of approximately two feet per second. This velocity will usually prevent the deposition of solids that may clog the pipe or cause odors. Manholes are placed every 300 to 500 feet to allow for inspection (Fig. 3.1) and cleaning of the sewer.

Fig. 3.1 Manholes allow inspection of the collection system

When low areas of land must be sewered or where pipe depth under the ground surface becomes excessive, pump stations (Fig. 3.2) are normally installed. These pump stations lift the wastewater to a higher point from which it may again flow by gravity, or the wastewater may be pumped under pressure directly to the treatment plant. A large pump station located just ahead of the treatment plant can create problems by periodically sending large volumes of flow to the plant one minute, and virtually nothing the next minute.

QUESTIONS

3.1A Why should the operator be familiar with the wastewater collection and transportation network?

3.1B List three types of sewers.

3.1C What problem may occur when it takes a long time for wastewater to flow through the collection sewers to the treatment plant?

3.1D Why are combined sewers a problem?

3.2 TREATMENT PLANTS

Upon reaching a wastewater treatment plant, the wastewater flows through a series of treatment processes (Fig. 3.3) which remove the wastes from the water and reduce its threat to the public health before it is discharged from the plant. The number of treatment processes and the degree of treatment usually depend on the uses of the receiving waters. Treated wastewaters discharged into a small stream used for a domestic water supply and swimming will require considerably more treatment than wastewater discharged into water used solely for navigation.

To provide you with a general picture of treatment plants, the remainder of this chapter will follow the paths a drop of wastewater might travel as it passes through a plant. You will be introduced to the names of the treatment processes, the kinds of wastes the processes treat or remove, and the location of the processes in the flow path. Not all treatment plants are alike; however, there are certain typical flow patterns that are similar from one plant to another.

When wastewater enters a treatment plant, it usually flows through a series of pretreatment processes--screening, shredding, and grit removal. These processes remove the coarse material from the wastewater. Flow-measuring devices are usually installed after pretreatment processes to record the flow rates and volumes of wastewater treated by the plant.

Next the wastewater will generally receive primary treatment. During primary treatment some of the solid matter carried by the wastewater will settle out or float to the water surface, where it can be separated from the wastewater being treated.

Secondary treatment processes usually follow primary treatment and commonly consist of biological processes. This means that organisms living in the controlled environment of the process are used to partially stabilized (oxidize) organic matter not removed by previous treatment processes and to convert it into a form which is easier to remove from the wastewater.

Waste material removed by the treatment processes goes to solids handling facilities and then to ultimate disposal.

Waste treatment ponds may be used after pretreatment, primary treatment, or secondary treatment. Ponds are frequently constructed in rural areas where there is sufficient available land.

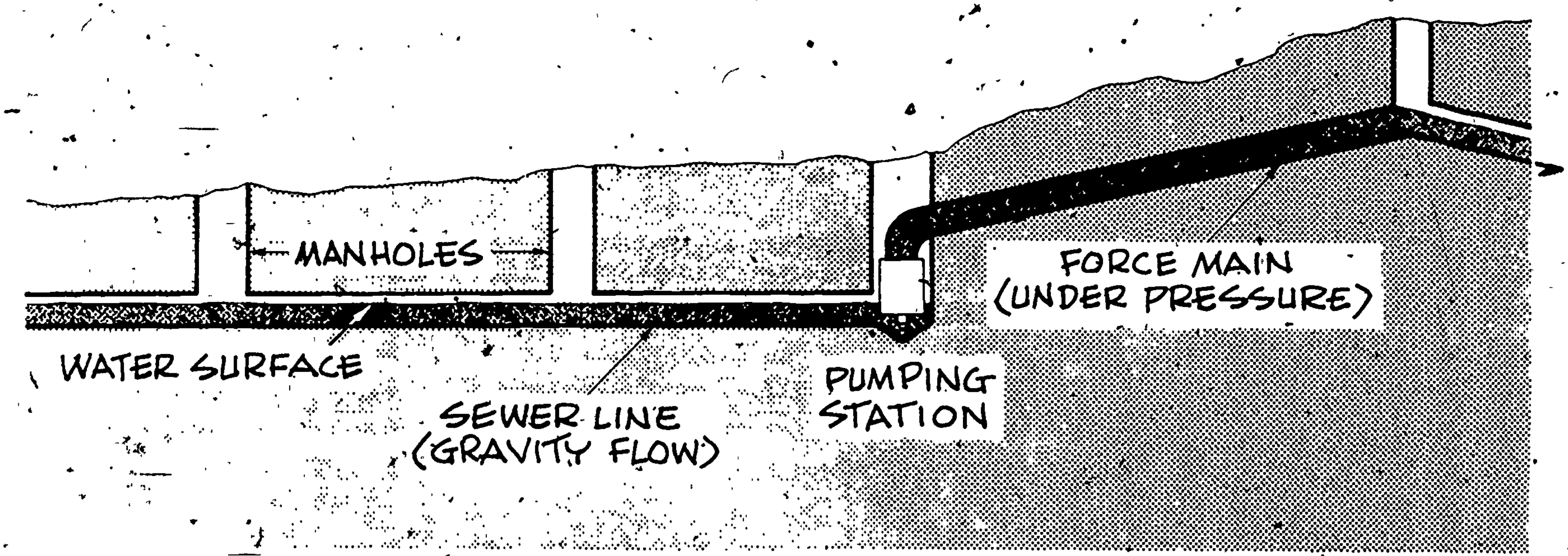


Fig. 3.2 Collection sewer profile

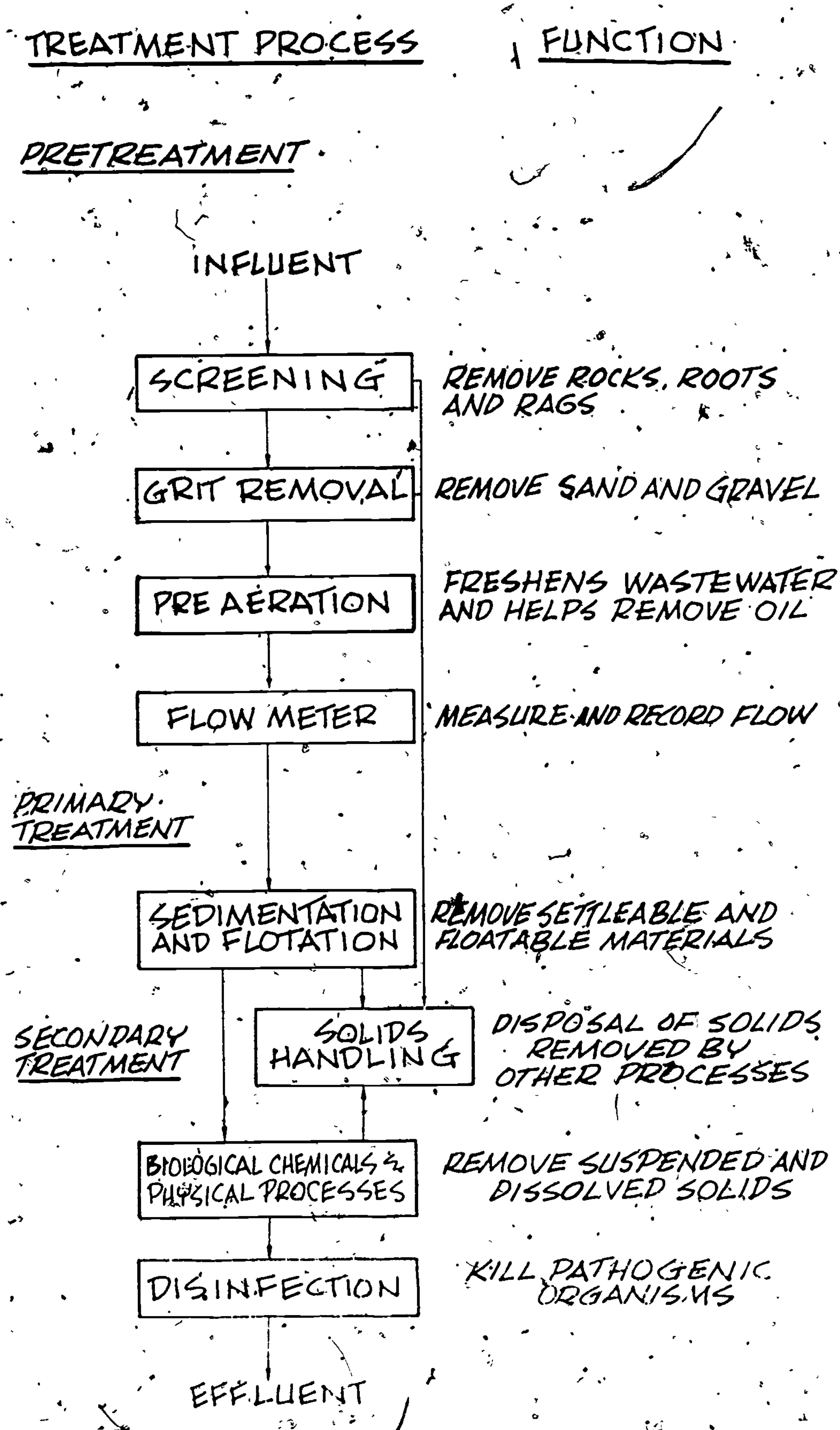
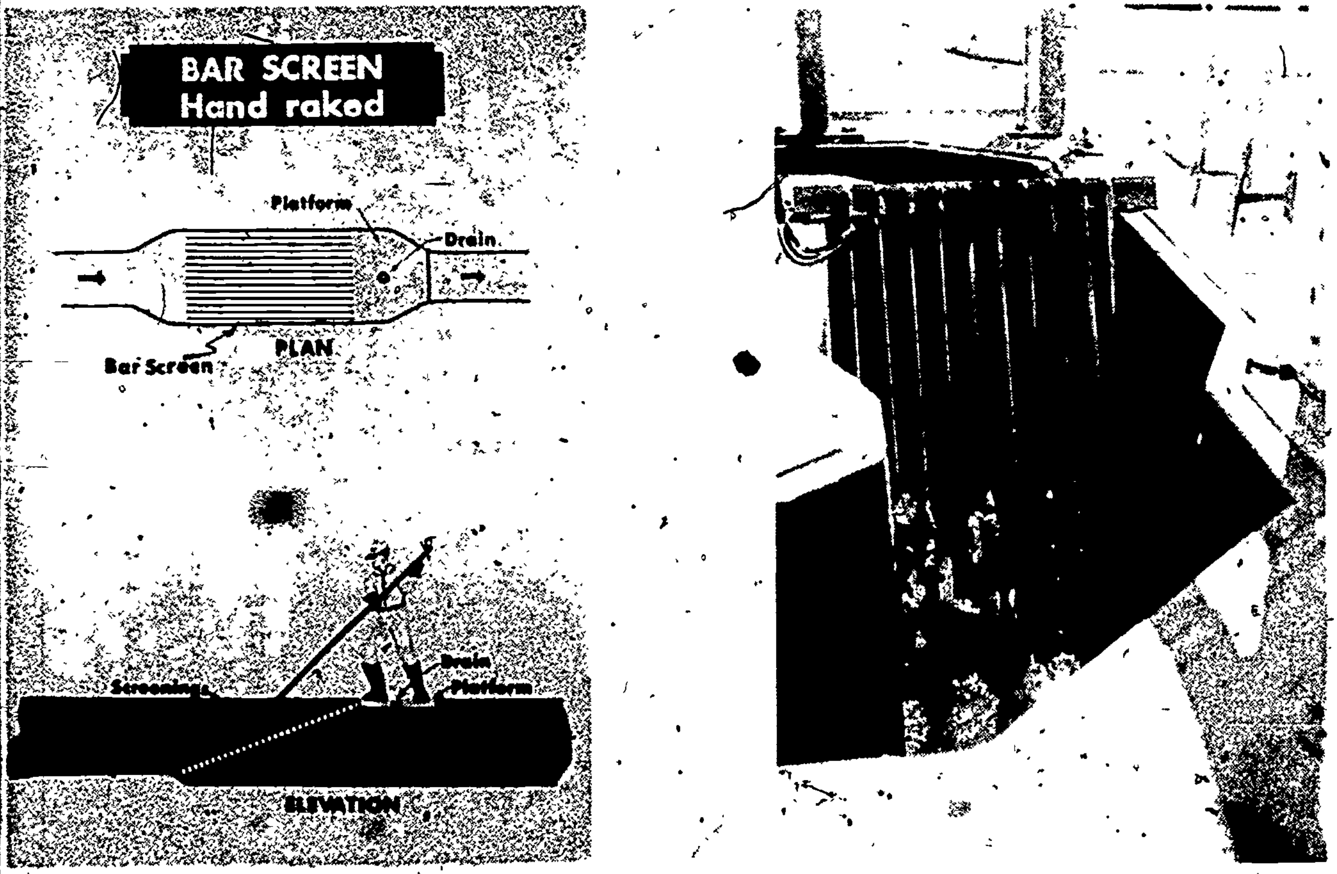


Fig. 3.3 Flow diagram of wastewater treatment plant processes



(Courtesy Water Pollution Control Federation)

Fig. 3.4 Bar screens

Advanced methods of waste treatment are being developed for general cleanup of wastewater or removal of substances not removed by conventional treatment processes. They may follow the treatment processes previously described, or they may be used instead of them. Before treated wastewater is discharged to the receiving waters, it should be disinfected to prevent the spread of disease.

In the following sections these treatment processes will be briefly discussed to provide an overall concept of a treatment plant. Details will be presented in later chapters to provide complete information on each of these processes.

3.3 PRETREATMENT

3.30 General

Pretreatment processes commonly consist of screening, shredding,[5] and grit removal to separate coarse material from the wastewater being treated.

3.31 Screening

Wastewater flowing into the treatment plant will occasionally contain pieces of wood, roots, rags, and other debris. To protect equipment and reduce any interference with in-plant flow, debris and trash are usually removed by a bar screen (Fig. 3.4). Most screens in treatment plants consist of parallel bars placed at an angle in a channel in such a manner that the wastewater flows through the bars. Trash collects on the bars and is periodically raked off by hand or by mechanical means. In most plants these screenings are disposed of by burying or burning. In some cases they are automatically ground up and returned to the wastewater flow for removal by a later process.

Fig. 3.5 Screened & ground

[5] Shredding. A mechanical treatment process which cuts large pieces of wastes ~~into~~ smaller pieces so they won't plug pipes or damage equipment (comminution).

3.32 Shredding

Devices are also available which cut up or shred material while it remains in the wastewater stream. The most common of these are the barminutor (Fig. 3.6) and the comminutor (Fig. 3.7). One of these devices usually follows a bar screen.

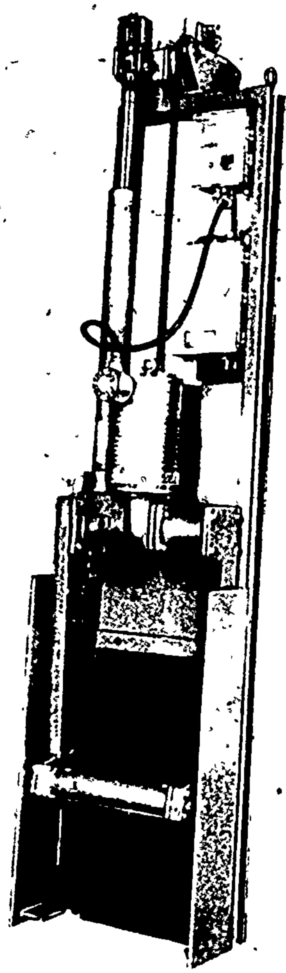


Fig. 3.6 Barminutor

Fig. 3.7 Comminutor

(Courtesy Chicago Pump)

3.33 Grit Chambers

Most sewer pipes are laid at a slope steep enough to maintain a wastewater flow of two feet per second (fps). If the velocity is reduced slightly below that, say to 1.5 fps, some of the larger, heavier particles will settle out. If the velocity is reduced to about 1 fps, heavy inorganic material such as sand, eggshells, and cinders will settle; but the lighter organic material will remain in suspension. The settled inorganic material is referred to as grit.[6] Grit should be removed early in the treatment process because it is abrasive and will rapidly wear out pumps and other equipment. Since it is mostly inorganic, it cannot be broken down by any biological treatment process and thus should be removed as soon as possible.

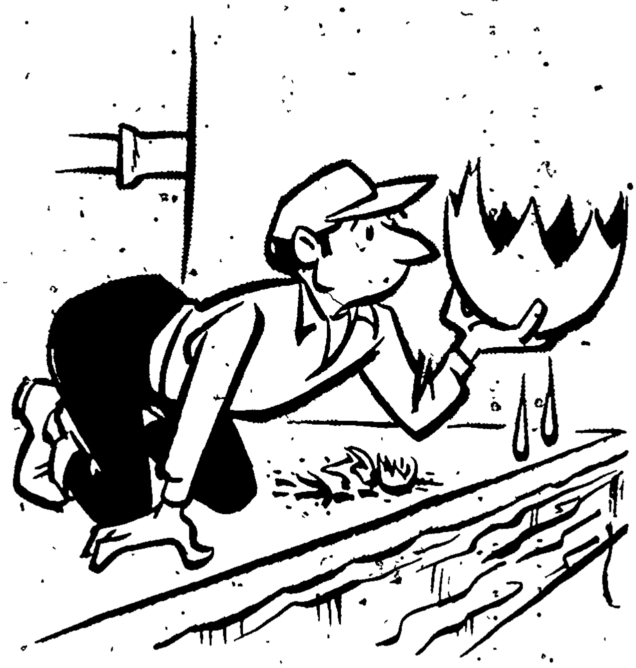


Fig. 3.8 Removal of eggshells

Grit is usually removed in a long, narrow trough called a Grit Chamber (Fig. 3.9). The chamber is designed to provide a flow-through velocity of 1 fps. The settled grit may be removed either by hand or mechanically. Since there is normally some organic solid material deposited along with the grit, it is usually buried to avoid nuisance conditions. Some plants are equipped with "grit washers" that clean some of the organic material out of the grit so that organic solids can remain in the main waste flow to be treated.

Many treatment plants have aerated grit chambers in which compressed air is added through diffusers to provide better separation of grit and other solids. Aeration in this manner also "freshens" a "stale" or septic wastewater, helping to prevent odors and assist the biological treatment process.

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[6] Grit. The heavy mineral material present in wastewater, such as sand, gravel, cinders, and eggshells.

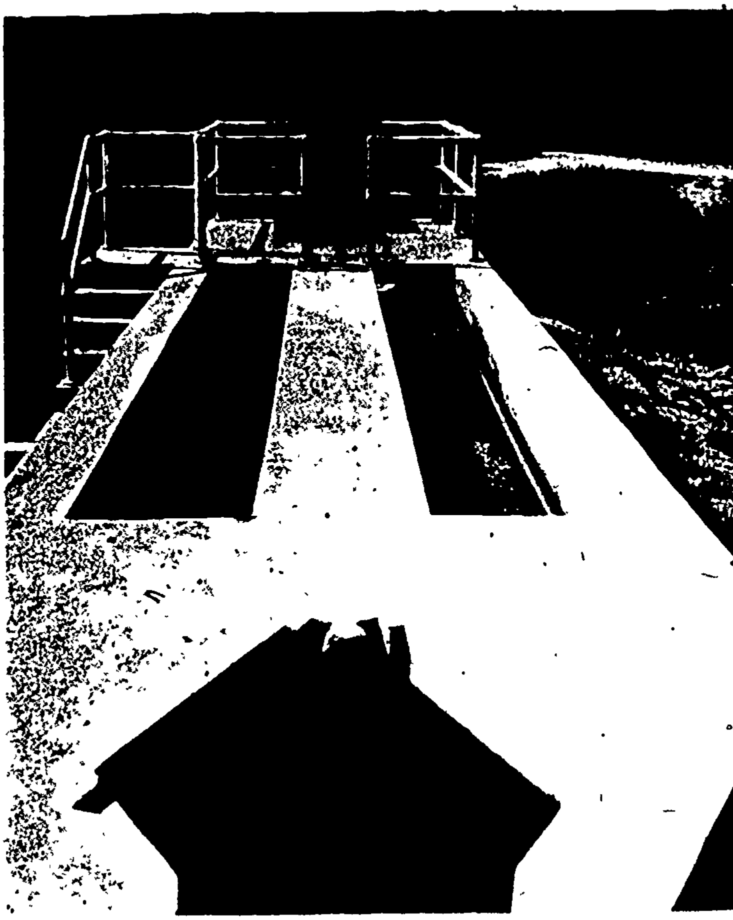

Fig. 3.9 Grit chamber

WPCF MOP No. 11,
Operation of Wastewater Treatment Plants.

QUESTIONS

3.3A Why is grit removed early in the treatment process?

3.3B What is usually done with grit which has been removed from the wastewater?

3.4 FLOW MEASURING DEVICES

Although flow measuring devices are not for treating wastes, it is necessary to know the quantity of wastewater flow so adjustments can be made on pumping rates, chlorination rates, aeration rates, and other processes in the plant. Flow rates must be known, also, for calculation of loadings on treatment processes and treatment efficiency. Most operators prefer to have a measuring device at the headworks of their treatment plant.

The most common measuring device is a Parshall Flume (Fig. 3.10). Basically it is a narrow place in an open channel which allows the quantity of flow to be determined by measuring the depth of flow. It is a widely used method for measuring wastewater because its smooth constriction does not offer any protruding sharp edges or areas where wastewater particles may catch or collect behind the metering device.

Another measuring device used in open channels is a weir[7] (Fig. 3.10). A weir is a wall placed across the channel over which the waste may fall. It is usually made of thin metal and may have either a rectangular or V-notch opening. Flow over the weir is determined by the depth of waste going through the opening. A disadvantage of a weir is the relatively dead water space that occurs just upstream of the weir. If the weir is used at the head end of the plant, organic solids may settle out in this area. When this occurs odors and unsightliness can result. Also, as the solids accumulate the flow reading may become incorrect.

A good measuring device for flows of treated or untreated wastewater is a Venturi meter (Fig. 3.10). It is a special section of contracting pipe, and it measures flow in much the same way as a Parshall Flume. It does not offer any sharp obstructions for particles to catch on. Magnetic flow meters (Fig. 3.10) also are being used successfully to measure wastewater flows.

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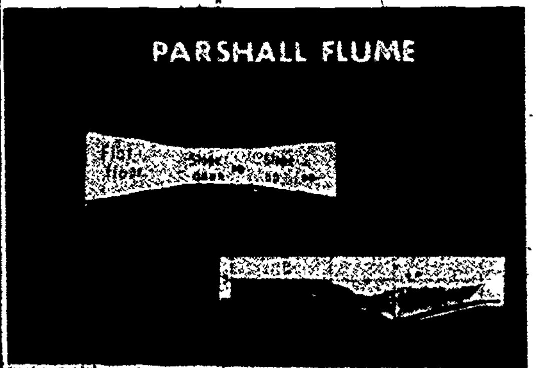
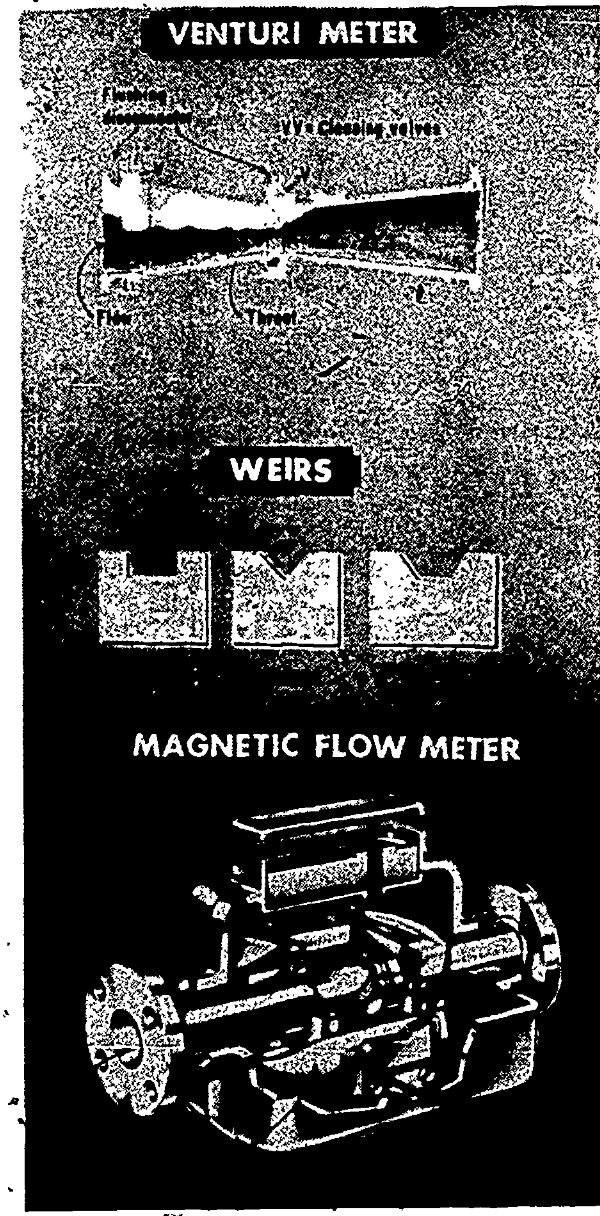
[7] Weir (weer). A vertical obstruction such as a wall or plate, placed in an open channel and calibrated in order that a depth of flow over the weir can easily be converted to a flow rate in MGD (million gallons per day).



End Photo of Parshall Flume



(Drawings courtesy of Water Pollution Control Federation)

Fig. 3.10 Flow meters

3.5 PRIMARY TREATMENT

We have previously discussed the reduction in velocity of the incoming waste to approximately one foot per second in order to settle out heavy inorganic material or grit. The next step in the treatment process is normally called sedimentation or primary treatment. In this process the waste is directed into and through a large tank or basin. Flow velocity in these tanks is reduced to about 0.03 foot per second, allowing the settleable solids to fall to the bottom of the tank, thus making the wastewater much clearer. It has therefore become common practice to call these sedimentation tanks "clarifiers". The first clarifier that the wastewater flows into is called a primary clarifier. We will discuss later the need for another clarifier after the biological treatment process. This second clarifier is called a secondary clarifier.

Clarifiers normally are either rectangular (Fig. 3.11) or circular (Fig. 3.12). Primary clarifiers are usually designed to provide 1.5 to 2 hours detention time.[8] Secondary clarifiers usually provide slightly more time.

Generally the longer the detention time provided, the more removal of solids that takes place. In a tank with two hours detention time, approximately 60 percent of the suspended solids in the raw wastewater will either settle to the bottom or float to the surface and be removed. Removal of these solids will usually reduce the Biochemical Oxygen Demand (BOD)[9] of the waste approximately 30 percent. The exact removal depends on the amount of BOD contained in the settled material.

All primary clarifiers, no matter what their shape, must have a means for collecting the settled solids (called sludge[10]) and

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8 Detention Time. The time required to fill a tank at a given flow or the theoretical time required for a given flow quantity of wastewater to flow through the tank.

9 Biochemical Oxygen Demand or BOD (BUY-o-KEM-ik-cull OX-zi-gen de-MAND). The BOD indicated the rate of oxygen utilized by wastewater under controlled conditions of temperature and time.

10 Sludge (sluj). The settleable solids separated from liquids during processing or deposits on bottoms of streams or other bodies of water.

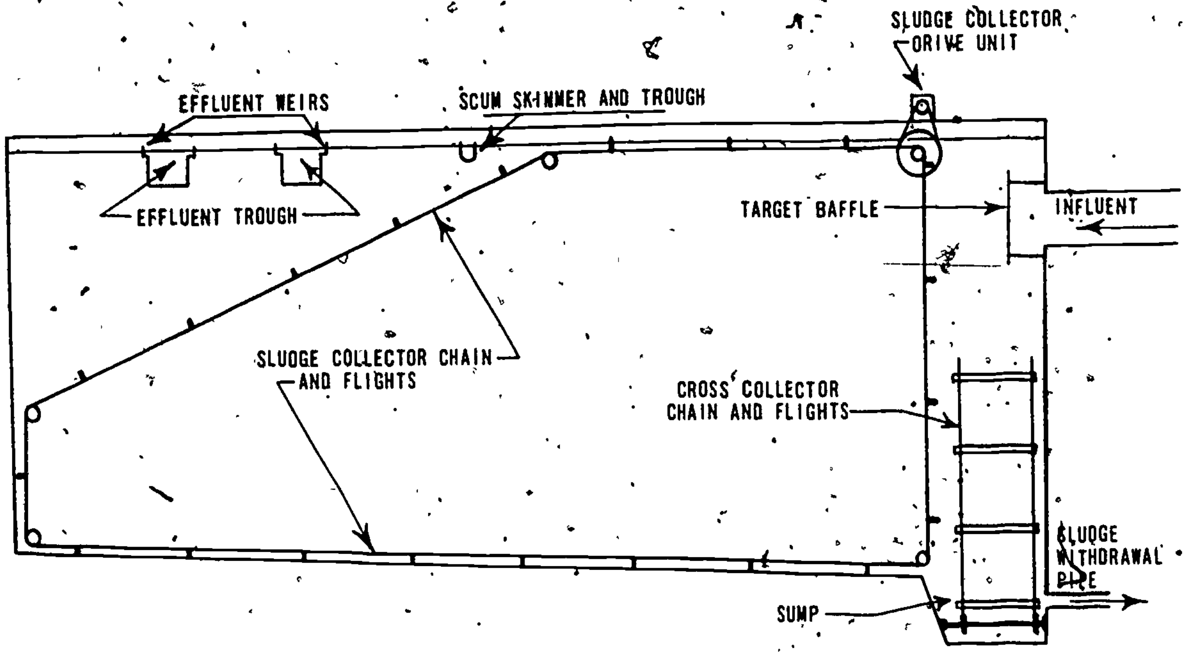

Fig. 3.11 Rectangular clarifier

(Courtesy Jeffrey)

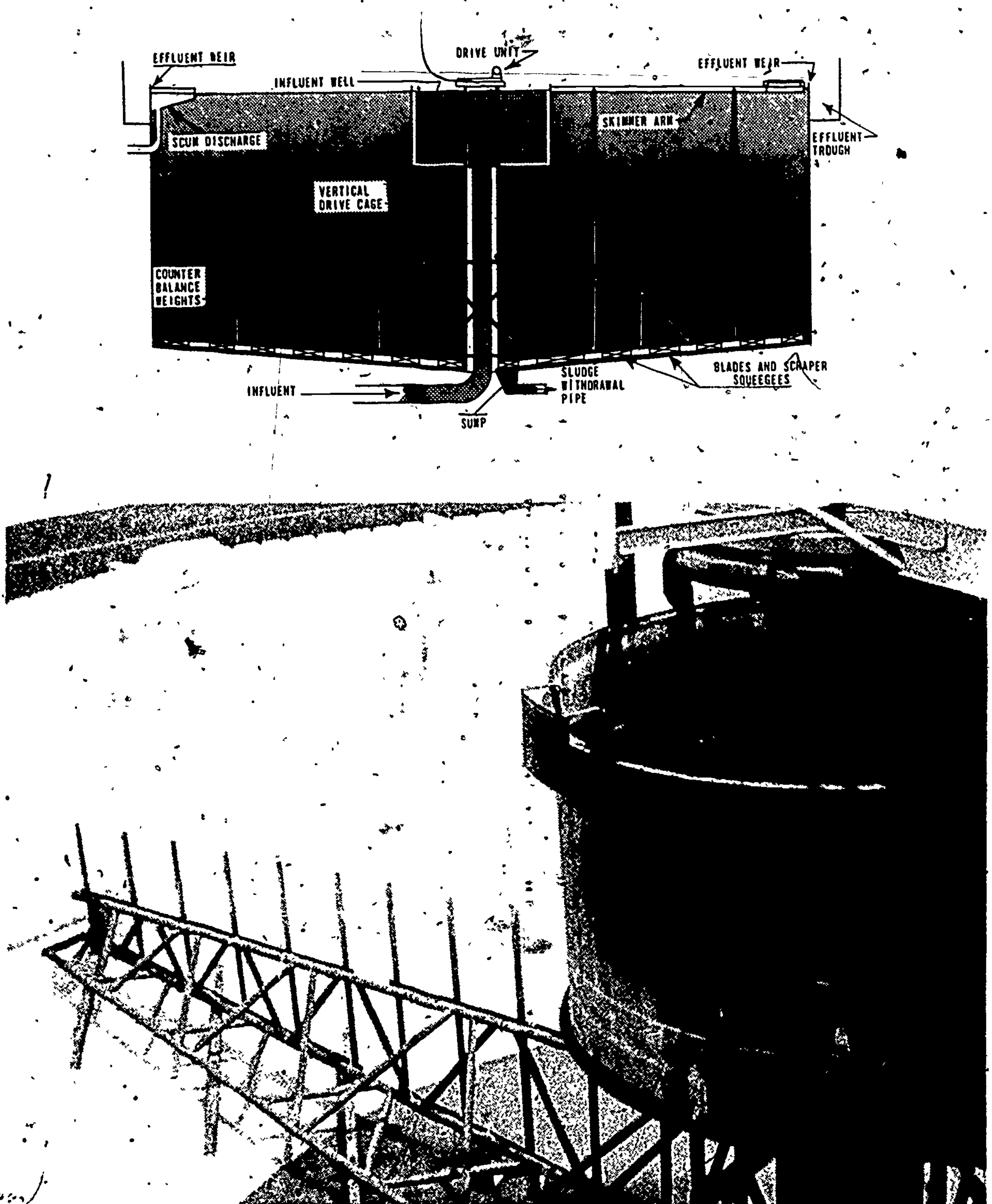

Fig. 3.12 Circular clarifier

the floating solids (called scum). In rectangular tanks, sludge and scum collectors are usually wooden beams ("flights") attached to endless chains. The collector flights travel on the surface, in the direction of the flow, conveying grease and floatable solids down to the scum trough to be skimmed off to the solids (sludge) handling facilities. The flights then drop below the surface and return to the influent end along the bottom, moving the settled raw sludge to the sludge hopper. The sludge is periodically pumped from the hopper to the sludge handling facilities.

In circular tanks, scrapers or "plows", attached to a rotating arm, rotate slowly around the bottom of the tank. The plows push the settled sludge toward the center and into the sludge hopper. Scum is collected by a rotating blade at the surface. As in the case of the rectangular tank, both scum and sludge are usually pumped to the solids or sludge handling facilities.

The clear surface water of the primary tank flows out of the tank by passing over a weir. The weir must be long enough to allow the treated water to leave at a low velocity; if it leaves at a high velocity, particles settling to the bottom or those already on the bottom may be picked up and carried out of the tank.

QUESTIONS

3.5A What is the purpose of "flights" or "plows" in a clarifier?

3.5B What happens to the sludge and scum collected in a primary clarifier?

3.6 SECONDARY TREATMENT

3.60 General

In many treatment plants the wastewater flows out of the primary clarifier into another unit where it receives secondary or biological treatment. This means that the wastewater is exposed to living organisms (such as bacteria) which eat the dissolved and nonsettleable organic material remaining in the waste. The two processes used almost universally for biological treatment are the trickling filter and activated sludge. These are both aerobic biological treatment processes, which means the organisms require dissolved oxygen (Fig. 3.13) in order to live, eat, and reproduce.

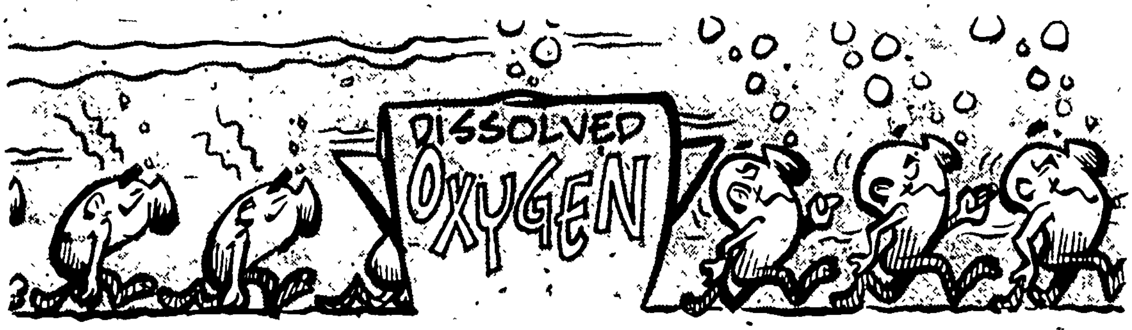

Fig. 3.13 Organisms require dissolved oxygen

3.61 Trickling Filter

The trickling filter is one of the oldest and most dependable of the biological treatment processes. Most of these plants are removing 65 to 85% of the BOD and suspended solids present in the influent.

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The trickling filter is a bed of $1\frac{1}{2}$ to 5-inch rock, slag blocks, or specially manufactured "media"[11] over which settled wastewater from the primary clarifier is distributed (Fig. 3.14). The settled wastewater is usually applied by an overhead rotating distributor and trickles over and around the media as it flows downward to the effluent collection channel. Since the media and the voids in between them are large (usually 2.5- to 4-inch diameter), and since the applied wastewater no longer has any large particles (they settled out in the clarifier), the trickling filter does not remove solids by a filtering action. It would be more correct to call the filter a biological contact bed or biological reactor since this is the function it performs. The filter bed offers a place for aerobic bacteria and other organisms to attach themselves and multiply as they feed on the passing wastewater. This process of feeding on, or decomposing, waste is exactly the same as the process occurring in the stream when waste is discharged to it. In the trickling filter, however, the organisms use the oxygen which enters the waste from the surrounding air, rather than using up the stream's supply of dissolved oxygen. Thus the voids between the media must be large so sufficient oxygen can be supplied by circulating air.

The wastewater being distributed on the filter usually has passed through a primary clarifier, but it still contains approximately 70 percent of its original organic matter, which represents food for organisms. For this reason a tremendous population of organisms develops on the media. This population continues to grow as more waste is applied. Eventually the layer of organisms on the media gets so thick that some of it breaks off (sloughs off) and is carried into the filter effluent channel. This material is normally called humus. Since it is principally organic matter, its presence in a stream would be undesirable. It is usually removed by settling in a secondary clarifier. Humus sludge from the secondary clarifier is usually returned to the primary clarifier to be resettled and pumped to the sludge handling facilities along with the "raw" sludge which settles out as previously described.

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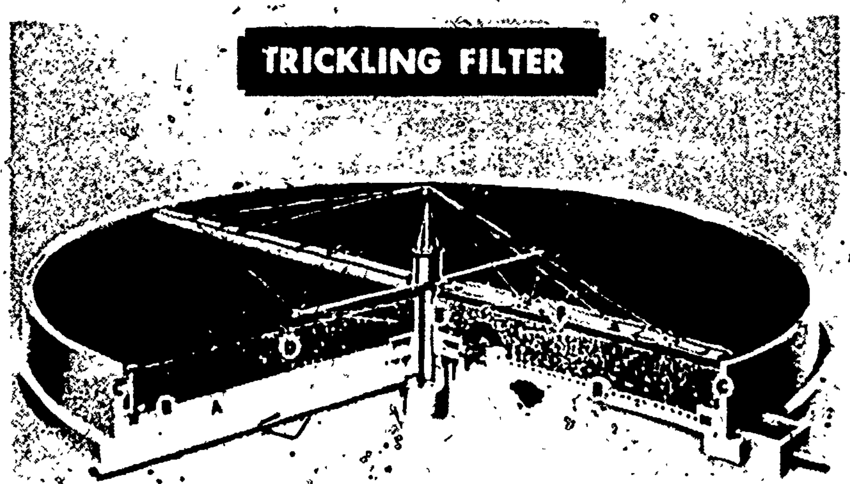
[11] Media. The material in a trickling filter over which settled wastewater is sprinkled and then flows over and around during treatment. Slime organisms grow on the surface of the media and treat the wastewater.



A. FILTER FLOOR
B. UNDERDRAINAGE
C. WALLS
D. MEDIA
E. DISTRIBUTOR SUPPORT INFLUENT
F. DISTRIBUTOR ARM
G. VENT

(Courtesy Water Pollution Control Federation)

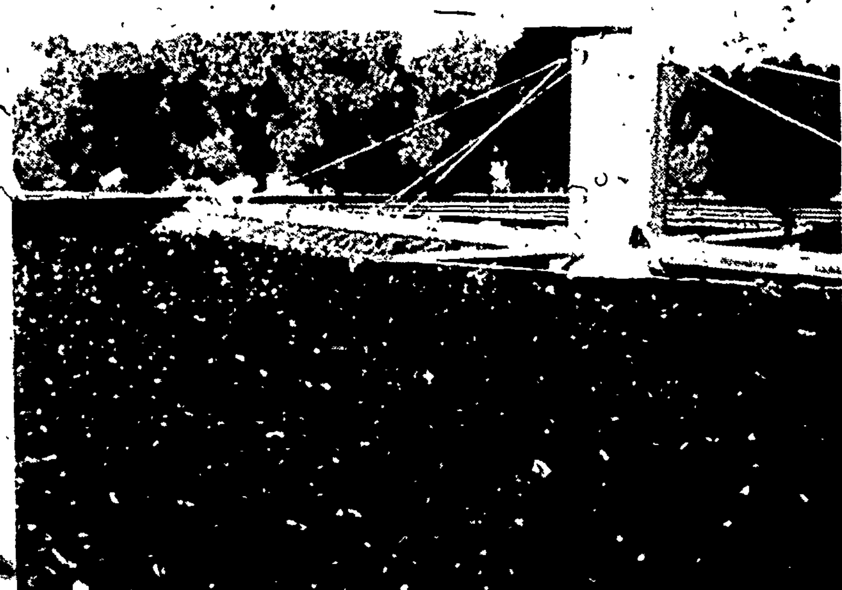


Fig. 3.14 Trickling filter

3.62 Activated Sludge

Another biological treatment unit that is used in secondary treatment, following the primary clarifier, is the aeration tank. When aeration tanks are used with the sedimentation process, the resulting plant is called an activated sludge plant. The activated sludge process is widely used by large cities and communities where land is expensive and where large volumes must be highly treated, economically, without creating a nuisance to neighbors. The activated sludge plant is probably the most popular biological treatment process being built today for larger installations or small package plants. These plants are capable of BOD and suspended solids reduction of up to 90 or 99%. The activated sludge process is a biological process, and it serves the same function as a trickling filter. Effluent from a primary clarifier is piped to a large aeration tank (Fig. 3.15). Air is supplied to the tank by either introducing compressed air into the bottom of the tank and letting it bubble through the wastewater and up to the top, or by churning the surface mechanically to introduce atmospheric oxygen.

Aerobic bacteria and other organisms thrive as they travel through the aeration tank. With sufficient food and oxygen they multiply rapidly, as in a trickling filter. By the time the waste reaches the end of the tank (usually 4 to 8 hours), most of the organic matter in the waste has been used by the bacteria for producing new cells. The effluent from the tank, usually called "mixed liquor", consists of a suspension containing a large population of organisms and a liquid with very little BOD. The activated sludge forms a lacey network that captures pollutants.

The organisms are removed in the same manner as they were in the trickling filter plant. The mixed liquor is piped to a secondary clarifier, and the organisms settle to the bottom of the tank while the clear effluent flows over the top of the effluent weirs. This effluent is usually clearer than a trickling filter effluent because the suspended material in the mixed liquor settled to the bottom of the clarifier more readily than the material in a trickling filter effluent. The settled organisms are known as activated sludge. They are extremely valuable to the treatment

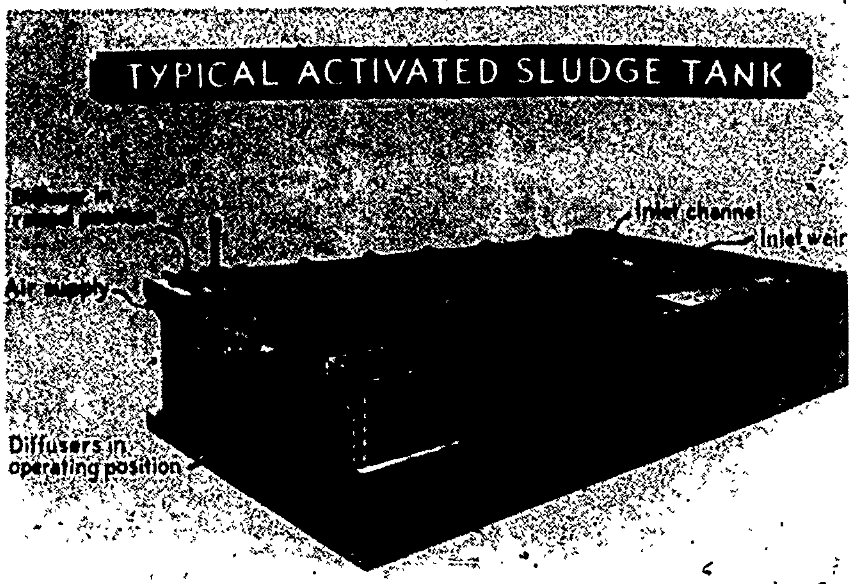


Fig. 3.15 Aeration tank

process. If they are removed quickly from the secondary clarifier, they will be in good condition and hungry for more food (organic wastes) (Fig. 3.16). They are therefore pumped back (recirculated) to the influent end of the aeration tank where they are mixed with the incoming wastewater. Here they begin all over again to feed on the organic material in the waste, decomposing it and creating new organisms.

Fig. 3.16 Hungry organisms ready for more food

Left uncontrolled, the number of organisms would eventually be too great, and therefore some must periodically be removed. This is accomplished by pumping a small amount of the activated sludge to the primary clarifier. The organisms settle in the clarifier along with the raw sludge and are removed to the sludge handling facilities.

There are many variations of the conventional activated sludge process, but they all involve the same basic principle. These variations will be discussed in Chapter 7, Activated Sludge.

3.63 Secondary Clarifiers

As previously mentioned, trickling filters and activated sludge tanks produce effluents that contain large populations of microorganisms and associated materials (humus). These microorganisms must be removed from the flow before it can be discharged to the receiving waters. This task is usually accomplished by a secondary clarifier. In this tank the trickling filter humus or activated sludge separates from the liquid and settles to the

bottom of the tank. It is removed to the primary clarifier to be resettled with the primary sludge or returned to the beginning of the secondary process to continue treating the wastewater. The clear effluent flows over a weir at the top of the tank.

QUESTIONS

3.6A Would it be a good idea to use trickling filter media of various sizes so it could pack together better?

3.6B Why is a secondary clarifier needed after a trickling filter or aeration tank?

3.6C Activated sludge can be pumped from the secondary clarifier to ______________________.

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3.7 SOLIDS HANDLING AND DISPOSAL

3.70 General

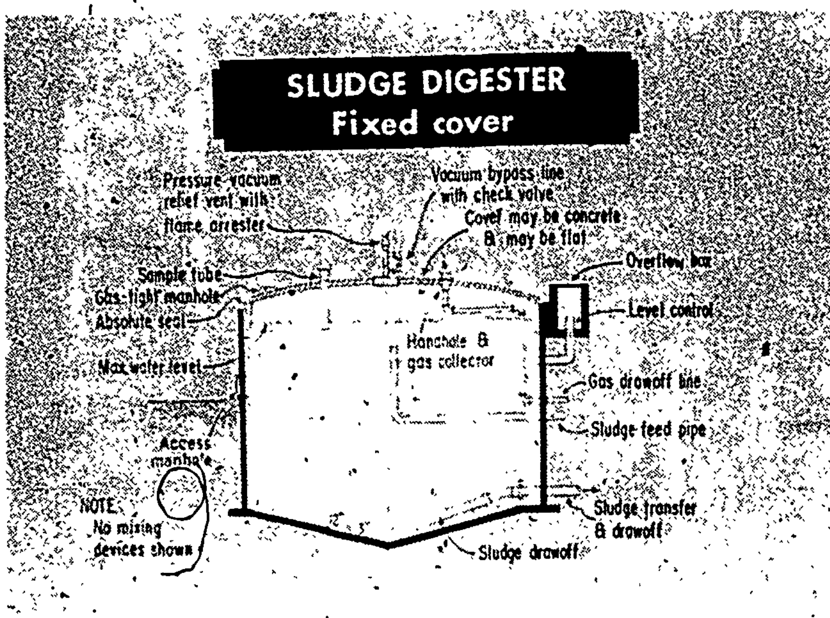
Solids removed from wastewater treatment processes are commonly broken down by a biological treatment process called sludge digestion. After digestion and dewatering the remaining material may be used for fertilizer or soil conditioner. Some solids, such as scum from a clarifier, may be disposed of by burning or burial.

3.71 Digestion and Dewatering

Settled sludge from the primary clarifier and occasionally settled sludge from the secondary clarifier are periodically pumped to a digestion tank. The tank is usually completely sealed to exclude any air from getting in (Fig. 3.17). This type of digester is called an anaerobic digester because of the anaerobic bacteria that abound in the tank. Anaerobic bacteria thrive in an environment devoid of dissolved oxygen by using the oxygen which is chemically combined with their food supply.

Two major types of bacteria are present in the digester. The first group starts eating on the organic portion of the sludge to form organic acids and carbon dioxide gas. These bacteria are called "acid formers". The second group breaks down the organic acids to simpler compounds and forms methane and carbon dioxide gas. These bacteria are called "gas formers". The gas is usually used to heat the digester or to run engines in the plant. The production of gas indicates that organic material is being eaten by the bacteria. A sludge is usually considered properly digested when 50 percent of the organic matter has been destroyed and converted to gas. This normally takes approximately 30 days if the temperature is kept at about 95°F.

Most digestion tanks are mixed to continuously bring the food to the organisms, to provide a uniform temperature, and to avoid the formation of thick scum blankets. When a digester is not being mixed the solids settle to the bottom, leaving an amber-colored liquid above the sludge known as supernatant. The



(Courtesy Water Pollution Control Federation)

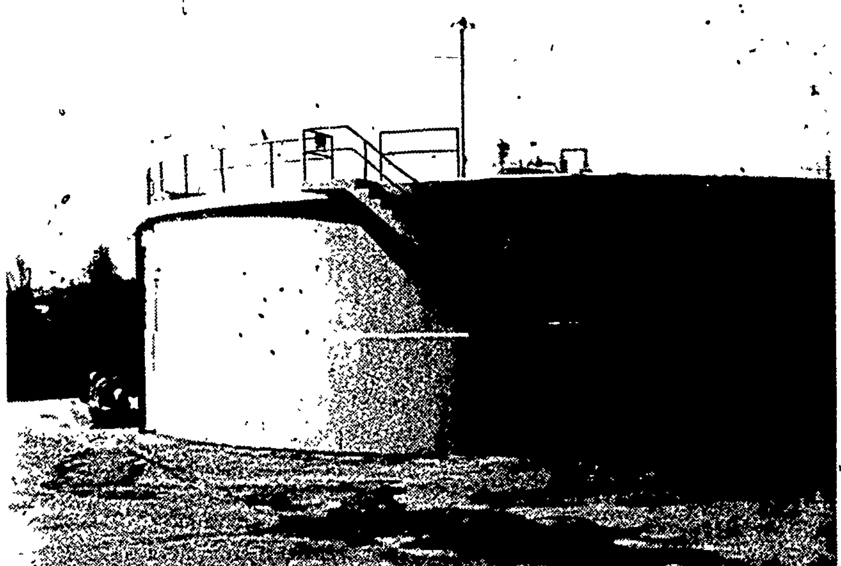


Fig. 3.17 Sludge digester

supernatant is displaced from the tank each time a fresh charge of raw sludge is pumped from the primary clarifier. The displaced supernatant usually is returned from the digester back to the plant headworks and mixed with incoming raw wastes. Supernatant return should be slow to prevent overloading or shock loading of the plant.

Above the supernatant level a scum blanket will usually develop. Scum blankets consist of grease, soap, rubber goods, hair, petroleum products, plastics, and filter tips from cigarettes. These scum blankets may contain most of the added food or sludge. Digestion organisms are usually below the supernatant and little digestion will occur if the organisms and food don't get together. Control of scum blankets consists of mixing the digester contents and burning or burying skimmings instead of pumping them to the digester.

Above the scum blanket or normal water level is the gas collection area. Digester gas is normally about 70% methane and 30% carbon dioxide. When mixed with air, digester gas is extremely explosive (Fig. 3.18).

Fig. 3.18 Don't allow digester gas and air to mix

In most newer plants digesting takes place in two tanks. The first or primary digester is usually heated and mixed. Rapid digestion takes place along with most of the gas production. In the secondary tank, the digested sludge and supernatant are allowed to separate, thus producing a clearer supernatant and better digested sludge.

Digested sludge from the bottom of the tank is periodically removed for dewatering. This is accomplished in sand drying beds (Fig. 3.19), lagoons, centrifuges, and vacuum filters (Fig. 3.20). The sludge is then burned, buried, or used as fertilizer on certain crops (not on crops which are eaten without cooking). Sludge that has been adequately digested drains readily and is not offensive.

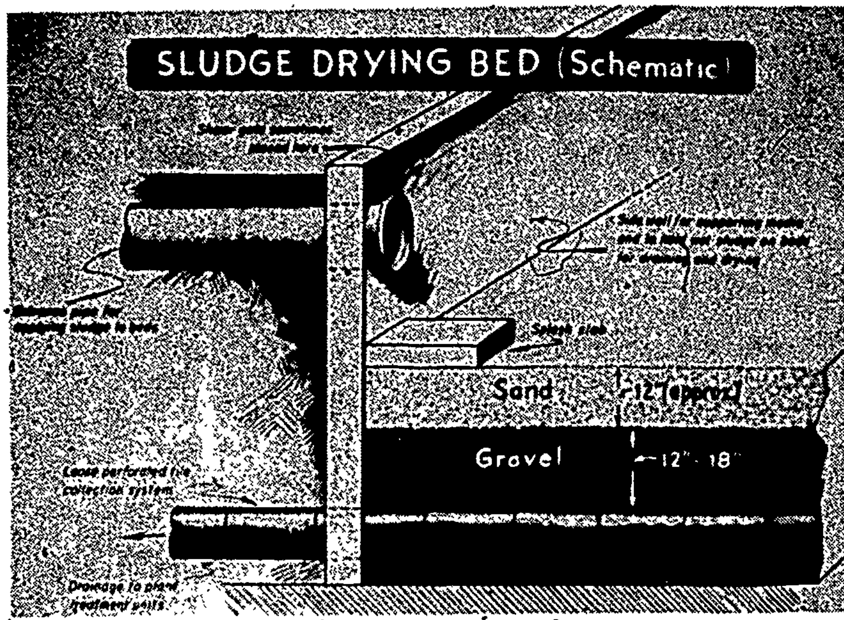


Fig. 3.19 Sludge drying bed

(Courtesy Water Pollution Control Federation)

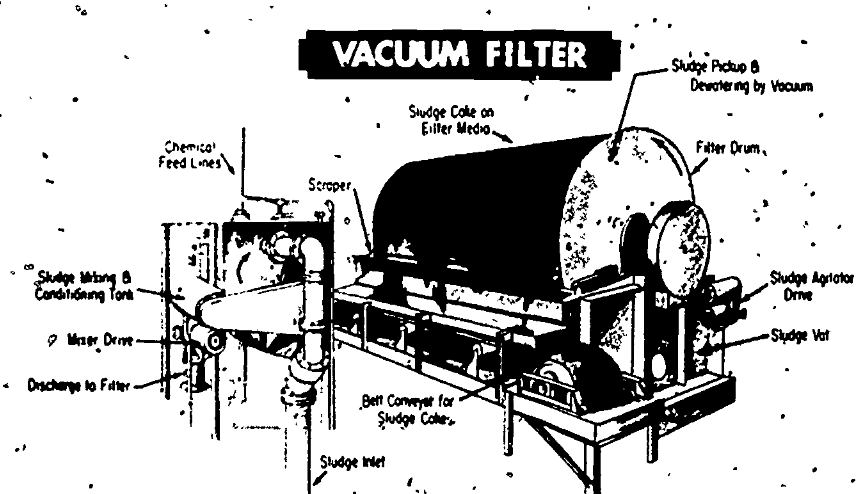


Fig. 3.20 Vacuum filter

(Courtesy Water Pollution Control Federation)

Some of today's activated sludge treatment plants are equipped with aerobic digesters. An aerobic digester is ususally an open tank with compressed air being blown through the sludge. Destruction of organic matter is accomplished by bacteria which require dissolved oxygen to survive. One advantage of this process is that there is no explosive gas being produced. On the other hand, this is also a disadvantage since the anaerobic digester gas is used as a fuel for boilers and engines around the plant. Aerobic sludge from an aerobic digester doesn't thicken as readily as sludge from an anaerobic digester. Aerobic sludge filters about as well as an equivalent concentration of anaerobic sludge.

3.72 Incineration

Burning of wet sludge by wet oxidation or of dewatered sludge are possible methods of ultimate disposal; however, the process must not create an air pollution problem. To prevent skimmings from clarifiers causing operational problems, incineration or burial are used.

QUESTIONS

3.7A What two basic types of bacteria are present in an anaerobic digester?

3.7B Why are digesters mixed?

3.7C List some of the ways to dispose of digested sludge.

3.8 WASTE TREATMENT PONDS

A special method of biological treatment deserving attention is wastewater treatment ponds (Fig. 3.21). They do not resemble the concrete and steel structures or the mechanical devices that have been previously discussed. But these simple depressions in the ground are capable of producing an effluent comparable to some of the most modern plants with respect to BOD and bacteria reduction.

In some treatment plants, wastewater being treated may flow through a coarse screen and flow meter before it flows through a series of ponds. In other plants the ponds may be located after primary treatment, while in some plants they are placed after trickling filters. The type of treatment processes and the location of ponds are determined by the design engineer on the basis of economics and the degree of treatment required to meet the water quality standards of the receiving waters.

When wastewater is discharged to a pond, the settleable solids fall to the bottom just as they do in a primary clarifier. The solids begin to decompose and soon use up all the dissolved oxygen in the nearby water. A population of anaerobic bacteria then continues the decomposition, much the same as in an anaerobic digester. As the organic matter is destroyed, methane and carbon dioxide are released. When the carbon dioxide rises to the surface some of it is used by algae, which convert it to oxygen by the process of photosynthesis.[12] This is the same process used by living plants. Aerobic bacteria, algae, and other microorganisms feed on the dissolved solids in the upper layer of the pond much the same way they do in a trickling filter or aeration tank. Algae produce oxygen for the other organisms to use.

Some shallow ponds (3 to 6 feet deep) have dissolved oxygen throughout their entire depth. These ponds are called aerobic ponds. They usually have a mechanical apparatus adding oxygen plus their oxygen supply from algae.

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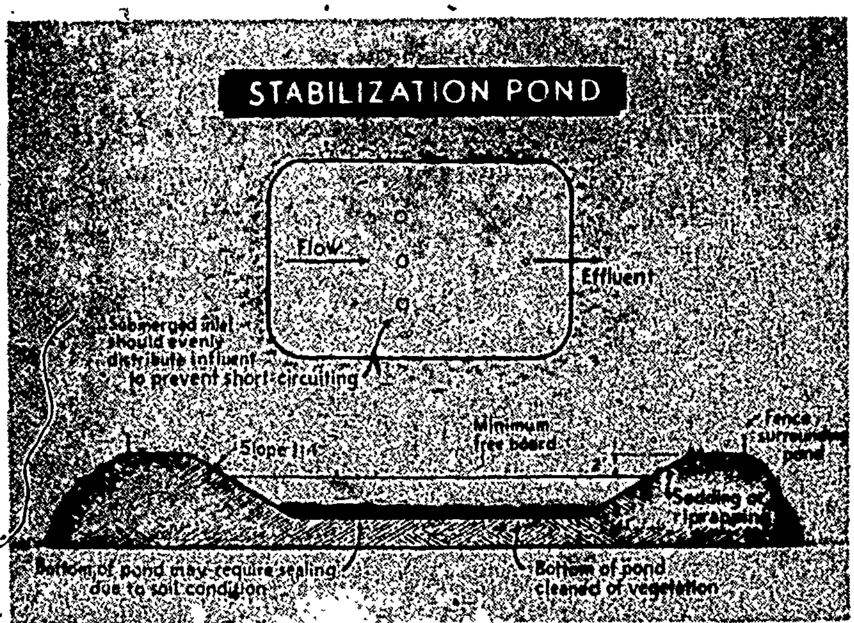
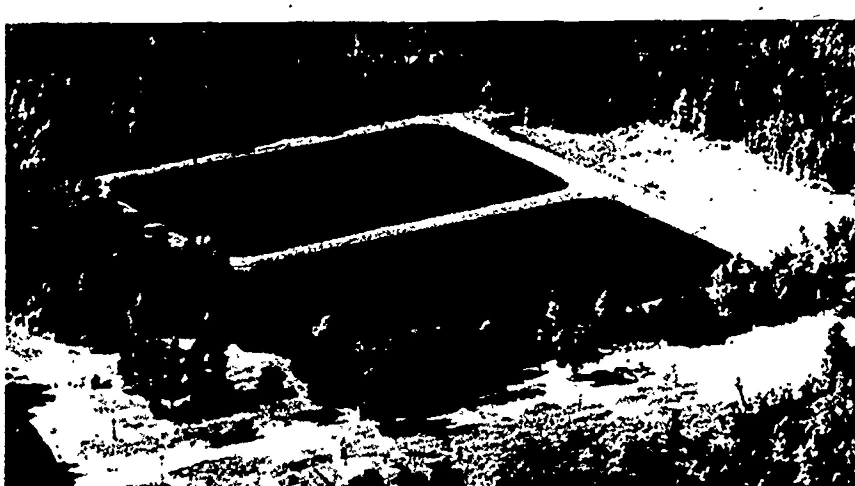
[12] Photosynthesis (foto-SIN-tha-sis). A process in which chlorophyll (green plant tissue) converts carbon dioxide and inorganic substances to oxygen and additional plant material utilizing sunlight for energy. Land plants grow by the same process.



(Courtesy Water Pollution Control Federation)



(Courtesy Water and Sewage Works Magazine)

Fig. 3.21 Pond

Deep (8 to 12 feet), heavily loaded ponds may be devoid of oxygen throughout their depth. These ponds are called anaerobic ponds. At times, these ponds can be quite odorous, and they are used in sparsely populated areas only.

Ponds that contain an aerobic top layer and an anaerobic bottom layer are called facultative ponds. These are the ponds normally seen in most areas. If they are properly designed and operated, they are virtually odor free and produce a well-oxidized (low BOD) effluent.

Occasionally ponds are used after a primary treatment unit. In this case, they are usually called oxidation ponds. When they are used to treat raw wastewater, they are called raw wastewater lagoons or waste stabilization ponds.

The effluent from ponds is usually moderately low in bacteria. This is especially true when the effluent runs from one pond to another or more (series flow). The long detention time, usually a month or more, is required in order for harmful bacteria and undesirable solids to be removed from the pond effluent. If the receiving waters are used for water supply or body contact sports, chlorination of the effluent may still be required.

QUESTION

3.8A How are facultative ponds similar to:

1. a clarifier?
2. a digester?
3. an aeration tank?

3.9 ADVANCED METHODS OF TREATING WASTEWATER

The treatment processes described so far in this chapter are considered conventional treatment processes. As our population grows and industry expands, more effective treatment processes will be required. Advanced methods of waste treatment may follow conventional processes, or they may be used instead of these processes. Sometimes advanced methods of waste treatment are called tertiary (TER-she-AIR-ee) treatment because they frequently follow secondary treatment. Advanced methods of waste treatment include coagulation-sedimentation (used in water treatment plants), adsorption, and electrodialysis. Other new treatment processes that may be used in the future include reverse osmosis, chemical oxidation, and the use of polymers.

Advanced methods of treatment are used to reduce the nutrient content (nitrates and phosphates) of wastewater to prevent blooms of algae in lakes, reservoirs, or streams. Carbon filters are used to reduce the last traces of organic materials. In some parts of the arid west advanced methods are used to enable the use of the plant effluent for recreational reservoirs.

QUESTION

3.9A If wastewater from a secondary treatment plant were coagulated with alum or lime and settled in a clarifier, would this be considered a method of advanced waste treatment?

3.10 DISINFECTION

Although the settling process and biological processes remove a great number of organisms from the wastewater flow, there remain many thousands of bacteria in every milliliter of wastewater leaving the secondary clarifier. If there are human wastes in the water, it is possible that some of the bacteria are pathogenic, or harmful to man. Therefore, if the treated wastewater is discharged to a receiving water that is used for a drinking water supply or swimming or wading, the water pollution control agency or health department will usually require disinfection of the effluent prior to discharge.

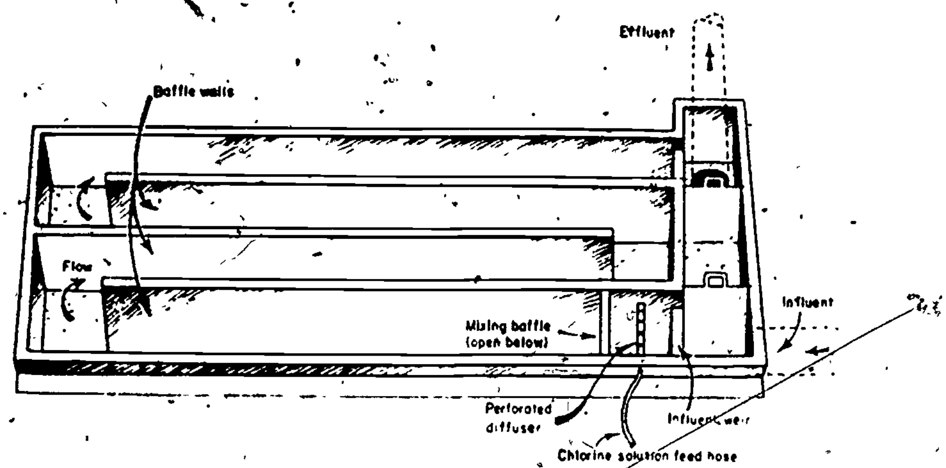
Disinfection is usually defined as the killing of pathogenic organisms. The killing of all organisms is called sterilization. Sterilization is not accomplished in treatment plants as the final effluent after disinfection always contains some living organisms due to the inefficiency of the killing process.

Disinfection can be accomplished by almost any process that will create a harsh environment for the organisms. Strong light, heat, oxidizing chemicals, acids, alkalies, poisons, and many other substances will disinfect. Most disinfection in wastewater treatment plants is accomplished by chlorine, which is a strong oxidizing chemical.

Chlorine gas is used in most treatment plants although some of the smaller plants use a liquid chlorine solution as their source. The dangers in using chlorine gas, however, have prompted some of the larger plants to switch to hypochlorite solution (bleach) even though it is more expensive.

Chlorine gas is withdrawn from pressurized cylinders containing liquid chlorine and mixed with water or treated wastewater to make up a strong chlorine solution. Liquid hypochlorite solution can be used directly. The strong chlorine solution is then mixed with the effluent from the secondary clarifier. The effluent is then directed to a chlorine contact basin. The basin can be any size or shape, but better results are obtained if the tank is long and narrow. This shape prevents rapid movement or short circuiting through the tank. Square or rectangular tanks can be baffled to achieve this effect (Fig. 3.22). Tanks are usually designed to provide approximately 20 to 30 minutes theoretical contact time, although the trend is to longer times. If the plant's outfall line is of sufficient length, it may function as an excellent contact chamber since short circuiting will not occur.

CHLORINE CONTACT BASIN



(Courtesy Water Pollution Control Federation)

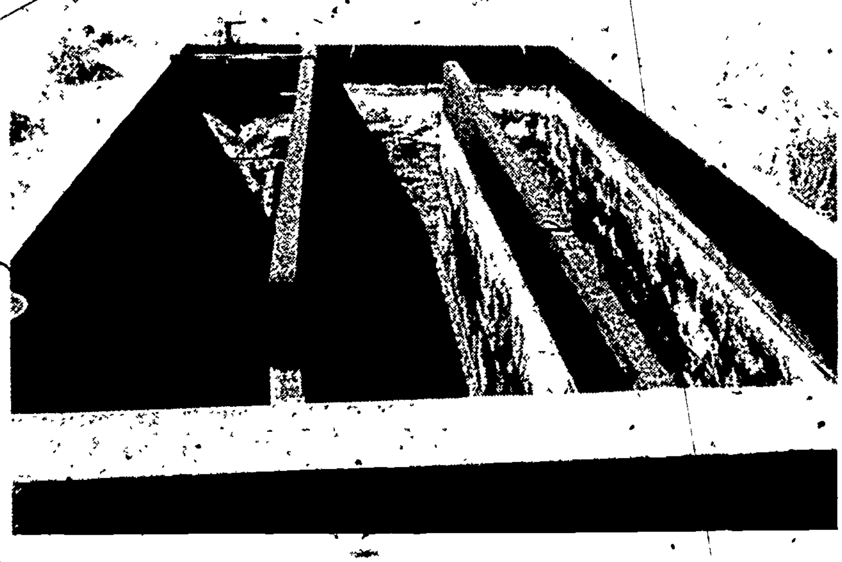


Fig. 3.22 Chlorine contact basin

3.11 ADDITIONAL READING

Some books you can read to obtain further information on the treatment plant and the various processes involved are:

a. MOP 11

b. New York Manual

c. Texas Manual

d. Sewage Treatment Practices, by Bloodgood

e. Babbitt, Harold E., and E. Robert Bauman, Sewerage and Sewage Treatment, John Wiley and Sons, New York, Eighth Edition, 1958. $10.75.

f. Summary Report, Advanced Waste Treatment, July 1964 - July 1967, U. S. Department of Interior, FWPCA, WP-20-AWTR-19. Available from the Publications Office, Ohio Basin Region, Environmental Protection Agency, Water Quality Office, Cincinnati, Ohio 45226.

g. Santee Recreation Proceedings, Santee, California, U.S. Department of Interior, FWPCA, WP-20-7 (1967). Available from Publications Office source given in (f) above.

h. A Primer on Waste Water Treatment, prepared by the Office of Public Information, Federal Water Quality Administration, CWA-12, October 1969. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $0.55.

4.1 INTRODUCTION TO PRETREATMENT

In various ways, a little or a lot of almost everything finds its way into sewers and ends up at the wastewater treatment plant. Cans, bottles, pieces of scrap metal, sticks, rocks, bricks, plastic toys, plastic lids, caps from toothpaste tubes, towels and other rags, sand--all are found in the plant influent.[1]

These materials are troublesome in various ways. Pieces of metal, rocks, and similar items will cause pipes to plug, may damage or plug pumps, or jam sludge collector mechanisms in settling tanks (clarifiers).[2] Sand, eggshells, and similar materials (grit) can plug pipes, cause excessive wear in pumps, and use up valuable space in the sludge digesters.[3]

If a buried or otherwise inaccessible pipe is plugged, or a sludge collector mechanism jams, or a critical pump is put out of commission, serious consequences can result. Reduced plant efficiency allows a heavy pollutional load on the receiving waters, causing health hazards to downstream water users, sludge deposits in stream or lake (with resultant odors and unsightliness), and sometimes causing the death of fish and other aquatic life. Also, a good deal of hard (sometimes rather unpleasant) work is involved, and usually there are heavy (and unbudgeted) expenses.

With these things in mind, it is evident that an important part of a wastewater treatment plant is the equipment used to remove the rocks and other materials as early as possible. These items of equipment are screens, racks, comminutors, and grit removal devices and are called pretreatment facilities. See Fig. 4.1 for location of these processes in a typical plant.

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[1] Influent (IN-flu-ent). Wastewater or other liquid--raw or partly treated--flowing into a reservoir, basin, treatment process, or treatment plant.

[2] Clarifier (KLAIR-i-fire) (settling tank, sedimentation basin). A tank or basin in which wastewater is held for a period of time so that the heavier solids settle to the bottom and the lighter material will float to the water surface.

[3] Digester (die-JEST-er). A tank in which sludge is placed to allow sludge digestion to occur. Digestion may occur under anaerobic (more common) or aerobic conditions.

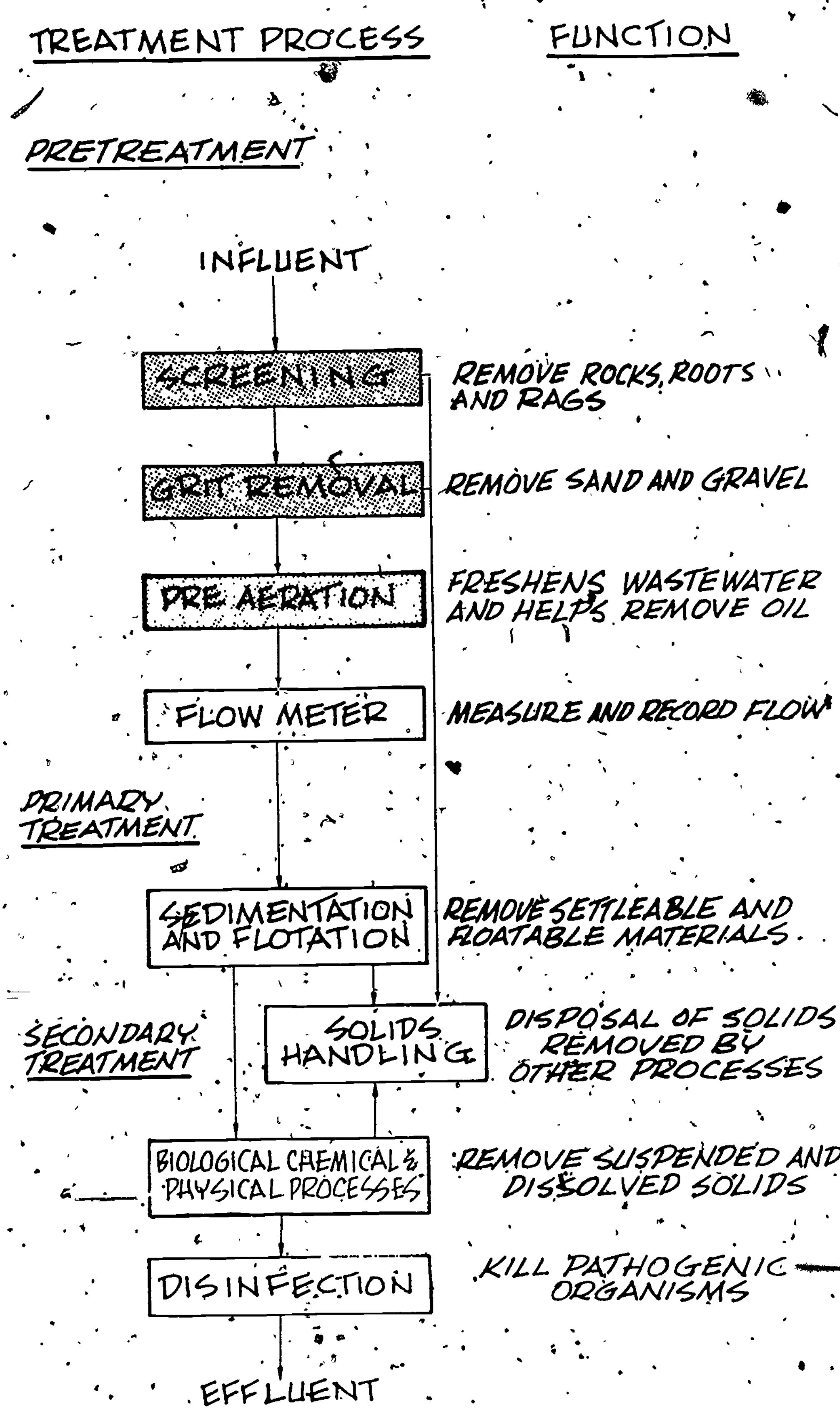

Fig. 4.1 Flow diagram of typical plant

4.2 SCREENS AND RACKS

Parallel bars may be placed at an angle in a channel in such a manner that the wastewater will flow through the bars, but the large solids will be caught on the bars. These bars are commonly called racks when the spacing between them is 3" to 4" or more. When the spacing is about 1" to 2", they are usually called bar screens.

4.20 Manually Cleaned Bar Screens

Manually cleaned bar screens (Fig. 4.2) require frequent attention. As debris collects on the screen, it blocks the channel, causing the wastewater to back up into the sewer. This, in turn, causes organic materials[4] to settle out; the dissolved oxygen[5] is depleted; and septic[6] conditions develop, producing hydrogen sulfide which causes a rotten egg odor and is corrosive to concrete, metal, and paint. If cleaning of the screens is infrequent, the sudden rush (when they do get cleaned) of septic wastewater creates a sudden "shock" load on the plant, sometimes resulting in a poor quality plant effluent.[7]

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[4] Organic Material. Material which comes from animal or vegetable sources. Organic material generally can be consumed by bacteria and other small organisms. Inorganic materials are chemical substances of mineral origin and may contain carbon and oxygen, whereas organic materials contain mainly carbon and hydrogen along with other elements.

[5] Dissolved Oxygen. Atmospheric oxygen dissolved in water or wastewater, usually abbreviated DO.

[6] Septic (SEP-tick). Wastewater devoid of dissolved oxygen. If severe, the wastewater turns black, giving off foul odors and creating a large oxygen demand.

[7] Effluent (EF-lu-ent). Wastewater or other liquid--raw, partially or completely treated--flowing from a basin, treatment process, or treatment plant.

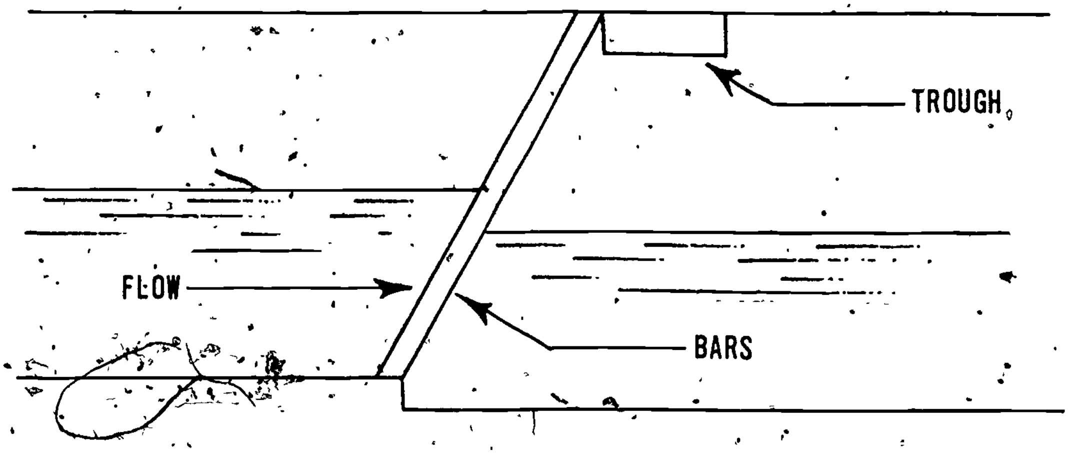


Fig. 4.2 Manually cleaned bar screen

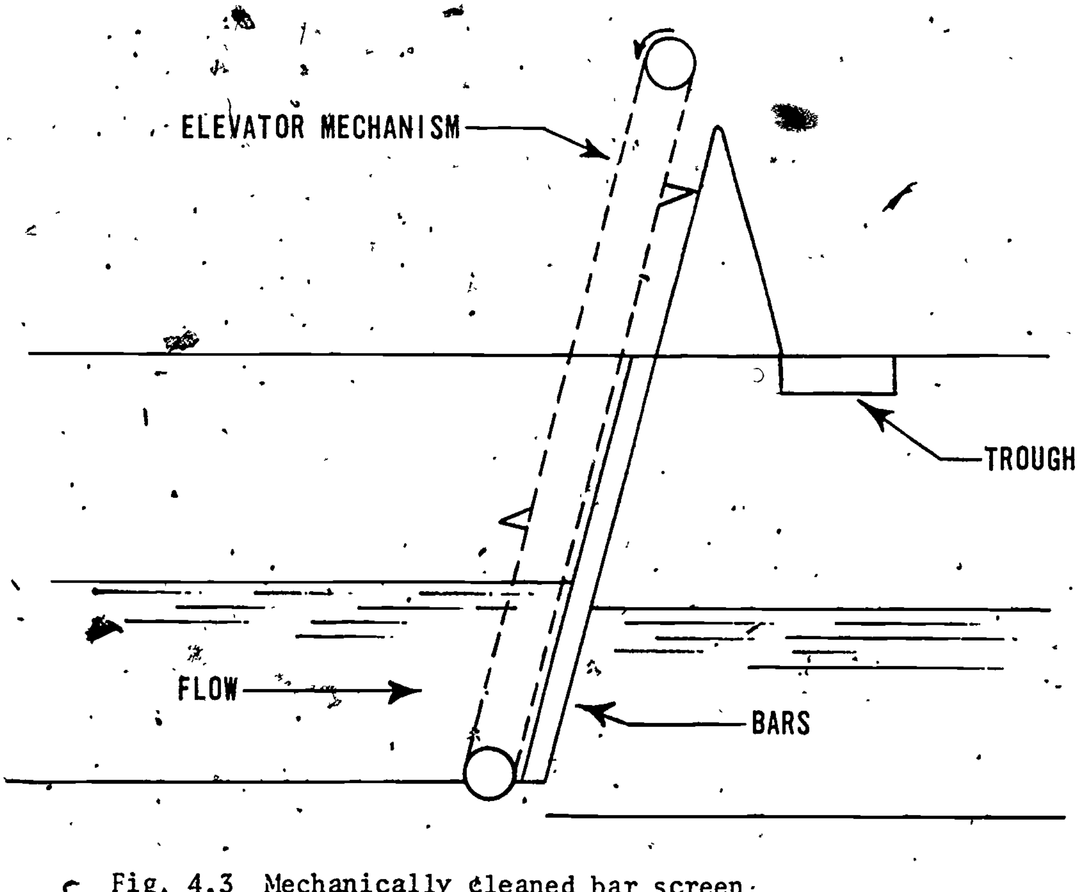


Fig. 4.3 Mechanically cleaned bar screen

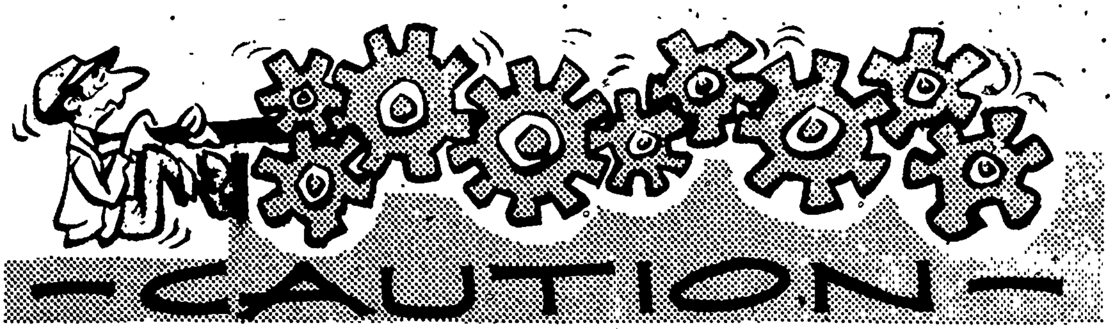
Cleaning of bar screens is accomplished with a rake with tines (prongs) which will fit between the bars. Extreme caution should be taken when raking the screen--footing may be poor due to the water and grease underfoot, lack of enough room to stand, location of the receptacle for the debris, etc. You should look this area over carefully to spot hazards and take corrective action.

Good housekeeping, a guard rail, a hanger or other storage for the rake, good footing, etc. will greatly reduce the possibility of injury.

4.21 Mechanically Cleaned Screens

Mechanically cleaned screens (Fig. 4.3) overcome the problem of wastewater backing up and greatly reduce the time required to take care of this part of your plant. There are various types of mechanisms in use, the more common being traveling rakes which bring the debris up out of the channel and into hoppers or other receptacles. You should keep these units well lubricated and adjusted. Follow the manufacturer's recommendations carefully. A few minutes spent in proper maintenance procedures can save hours or days of trouble and help to keep the plant operating efficiently.

Occasionally some debris will be present which the equipment cannot remove. Periodic checks should be made so that these materials can be removed by hand. To determine if some material is stuck in the screen, divert the flow through another channel or "feel" across the screen with a rake or similar device.



Always shut the unit off first. Never reach into the operating range of machinery while it is running. Slow-moving equipment is especially hazardous. Because it moves slowly, it does not appear dangerous. However, most geard-down machinery is so powerful that it can crush almost any obstruction. A HUMAN HAND, FOR INSTANCE, OFFERS LITTLE RESISTANCE TO THIS TYPE OF EQUIPMENT.

Various other mechanical methods are in use, involving actual coarse screens or perforated sheet metal. These units are automatically cleaned with scrapers, rotating brushes, water sprays, or air jets. The screens may be in the form of belts, discs, or drums set in a channel so that the wastewater flows through the submerged portion, with the collected debris being removed as it passes the brushes or sprays.

4.3 DISPOSAL OF SCREENINGS

The material removed from the screens is very offensive and hazardous. It produces obnoxious odors and draws rats and flies. Burial, incineration, and shredding or grinding are three common methods of disposal. If the screenings are buried, at least six inches of earth cover must be provided immediately. The final earth cover must be deep enough to prevent flies from reaching the screenings through cracks caused by settling. At small plants with manually cleaned bar screens, an enterprising operator can make a "press" from a piece of steel pipe or casing, using a heavy screw, rack and pinion, or even an automobile jack to provide pressure, to dewater the screenings before disposal. The practice of using grinders (shredders, disintegraters, etc.) to cut up screenings and return them to the effluent can impose a great load on following treatment processes.

4.4 COMMINUTION (com-min-OO-shun)

Comminutors are devices which act as a cutter and a screen. Their purpose is to shred (comminute) the solids and leave them in the wastewater. This overcomes problems of screenings disposal. As with screens, they are mounted in a channel, and the wastewater flows through them. The rags, etc., are shredded by cutters (teeth) until they can pass through the openings. Pieces of wood and plastic are rejected and must be removed by hand. Most of these units have a shallow pit in front of them to catch rocks and scrap metal. The flow to the comminutor should be shut off periodically and the debris removed from the trap. The frequency of checking the trap can be determined from experience. However, it is not wise to allow more than a few days between checks.

A comminutor consists of a rotating drum with slots for the wastewater to pass through (Fig. 4.4). Cutting teeth are mounted in rows on the drum. The teeth pass through cutter bars or "combs" with very small clearances so that a shearing action is obtained. The wastewater passes into the vertically mounted drum through the slots in the drum and flows out the bottom. A rubber seal, held in place by a bolted-down ring, prevents leakage under the drum. This seal should be checked whenever the rock and scrap metal trap is checked.

Some comminutors also have a mercury seal (Fig. 4.5) to keep water out of the bearings. This is because these units are designed so that, at their rated capacity, the top of the drum will be under several inches of water. This <u>head loss</u>[8] will be specified in the manufacturer's instructions. The mercury seal should be checked annually or after a particularly heavy flow. Drain the mercury; weigh it (the amount of mercury will be specified by weight); and if it is dirty, strain it through some heavy material (such as denim or chamois) before putting it back in the comminutor. (You will probably have to

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[8] Head Loss. "Head" is a common term used in discussing pumps. It is a way of expressing pressure in terms of the height of vertical column of water. In this case, the head loss is the height to which the water must build up in front of the drum until there is sufficient pressure to force that particular amount of water through the slots (Fig. 4.4).

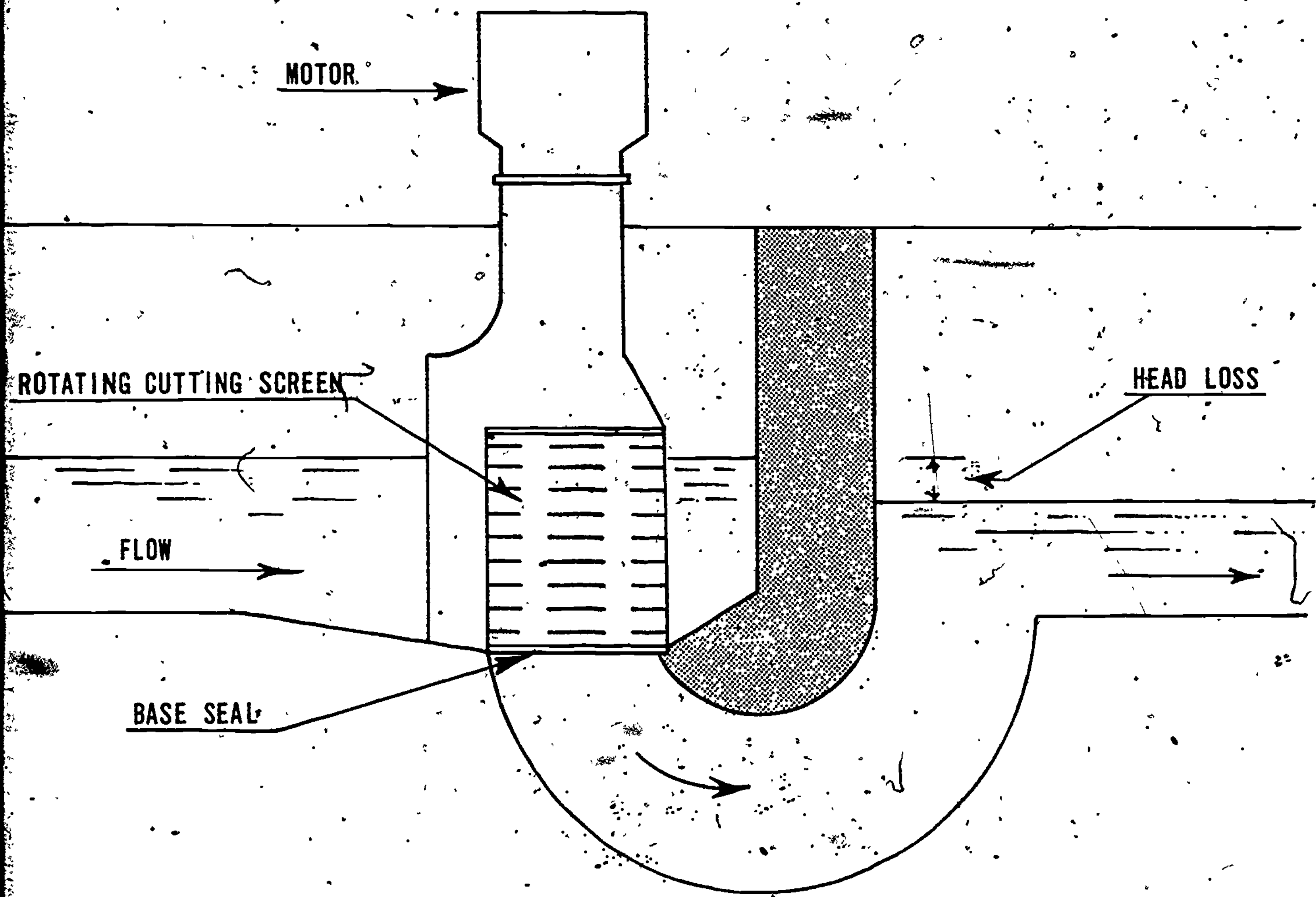

Fig. 4.4 Comminutor

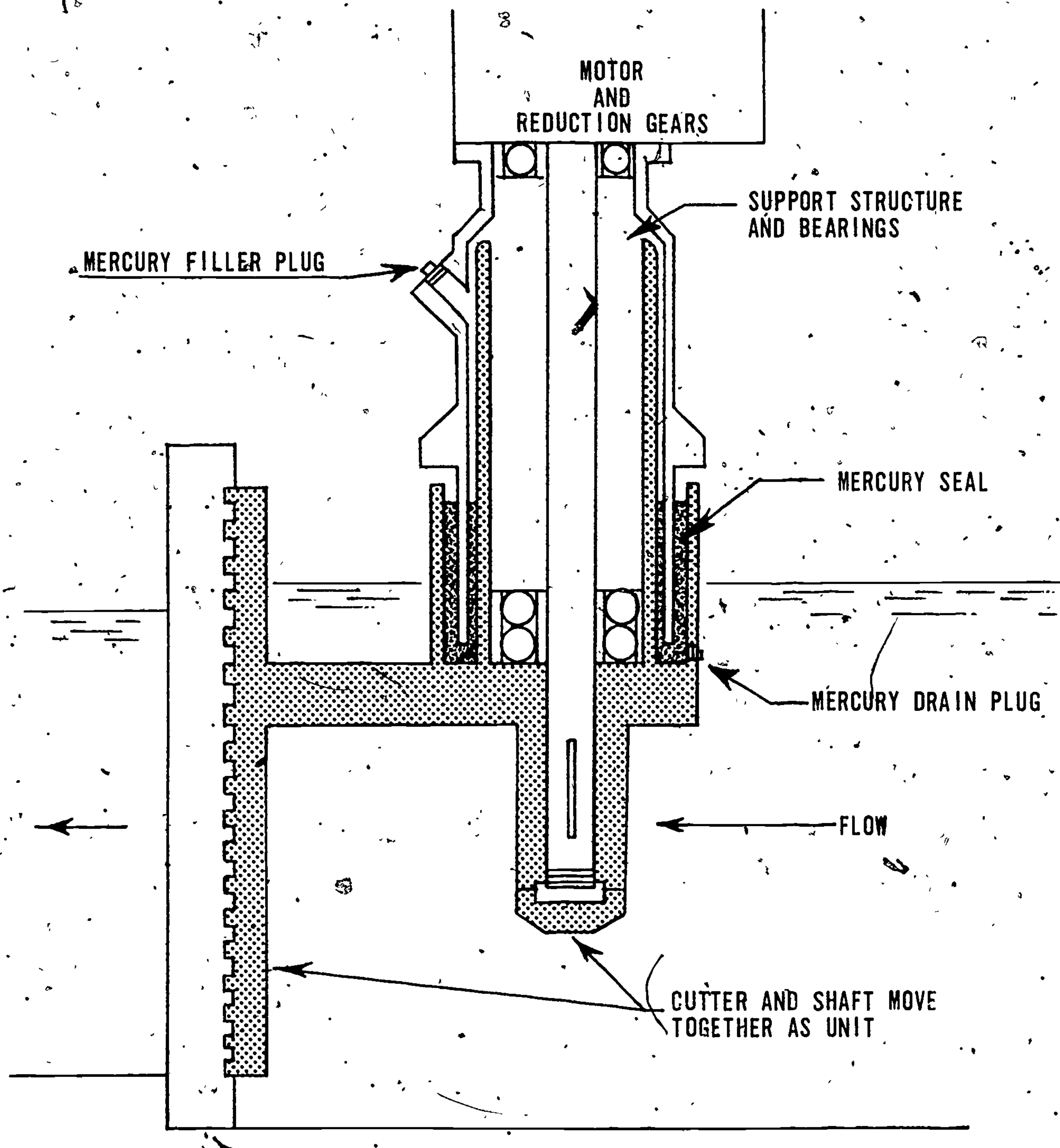

Fig. 4.5 Mercury seal in comminutor

squeeze the mercury through the cloth or, if laboratory equipment is available, use a suction flask.) Add more mercury if needed.

Mercury is poisonous. Breathing the fumes can be fatal or cause loss of hair and teeth. Wash up thoroughly after handling it. Remove gold rings, etc., from your hands first, as they may end up coated with mercury. If your ring is thus coated, it will have to be heated to burn off the mercury. If you must handle or work with mercury, be sure to work over a large tray in order to catch any spills. Plenty of fresh air ventilation is an absolute <u>must</u>.

There are many variations of the comminutor. One of the more common ones has the trade name of "barminutor" (Fig. 4.6). This unit consists of a bar screen made of U-shaped bars and a rotating drum with teeth and "shear bars". The rotating drum travels up and down the bar screen. Careful attention must be given to maintaining the oil level in these machines; otherwise, water may get into the bearings. Consult the manufacturer's instructions for detailed procedures.

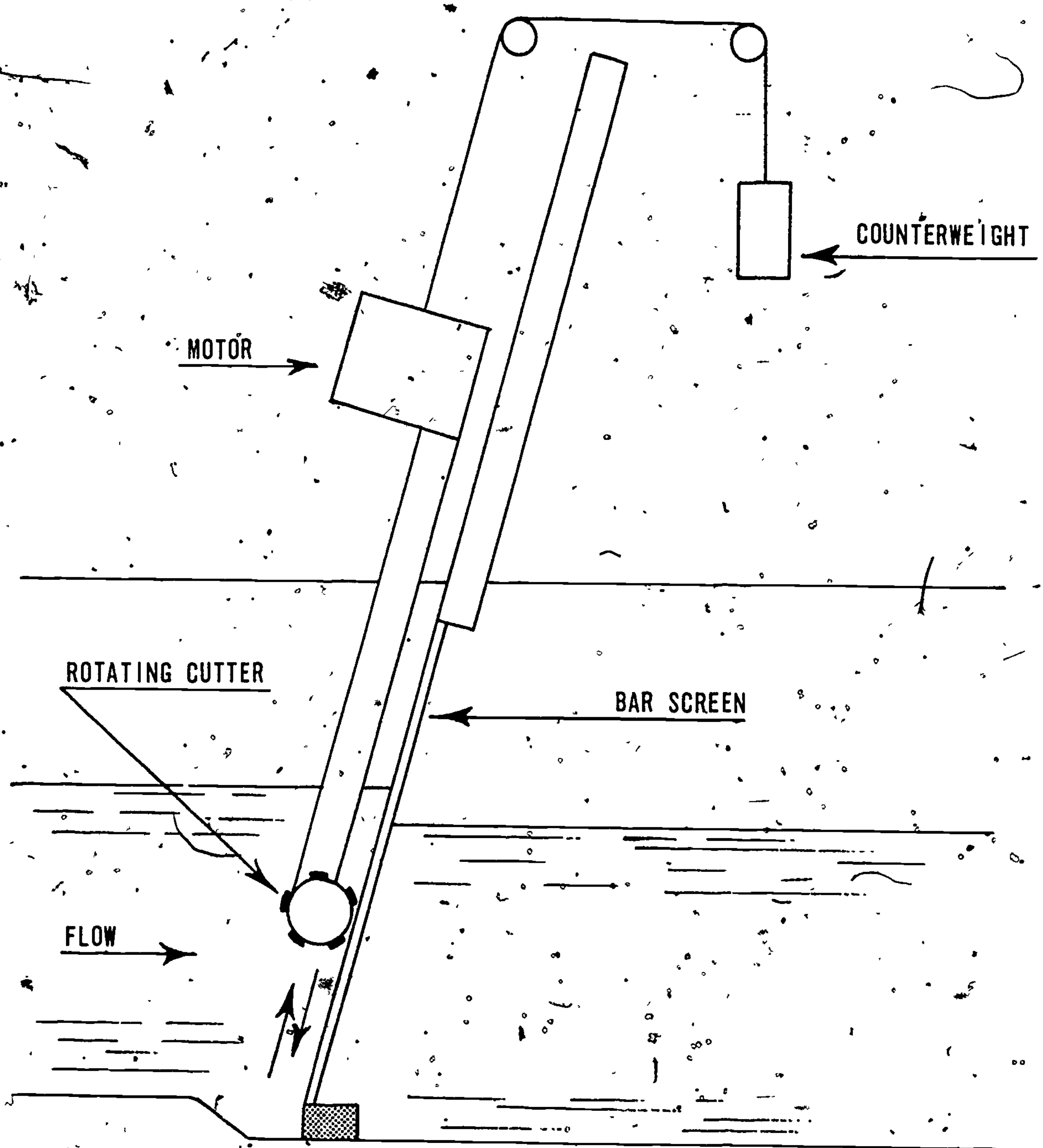

Fig. 4.6 Barminutor

4.5 GRIT REMOVAL

Grit (sand, eggshells, cinders, etc.) is the heavier mineral matter in wastewater which will not decompose or "break down". It causes excessive wear in pumps. A mixture of grit, tar, grease and other cementing materials can form a solid mass in pipes and digesters that will not move by ordinary means. Consequently, grit should be removed as soon as possible after reaching the plant.

4.6 GRIT CHAMBERS (Fig. 4.7)

The simplest means of removing grit from the wastewater flow is to pass it through channels or tanks which allow the velocity of flow to be reduced to a range of 0.7 to 1.4 ft/sec. The objective is to allow the grit to settle to the bottom, while keeping the lighter organic solids moving along to the next treatment unit. Experience has shown that a flow-through velocity of one foot per second (ft/sec) is best.

Velocity is controlled by several means. With multiple-channel installations, the operator may vary the number of channels (chambers) in service at any one time to maintain a flow velocity of approximately one ft/sec in the grit chambers. Other methods involve the use of proportional weirs (Fig. 4.8) at the outlet for automatic regulation.

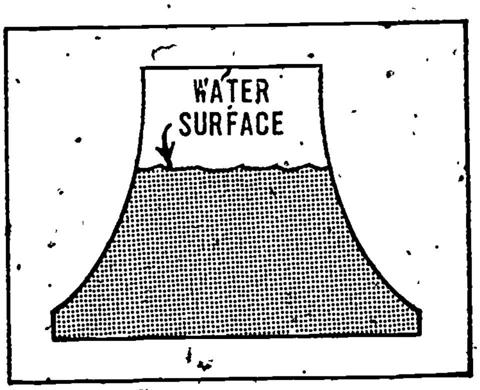

Fig. 4.8 Proportional weir

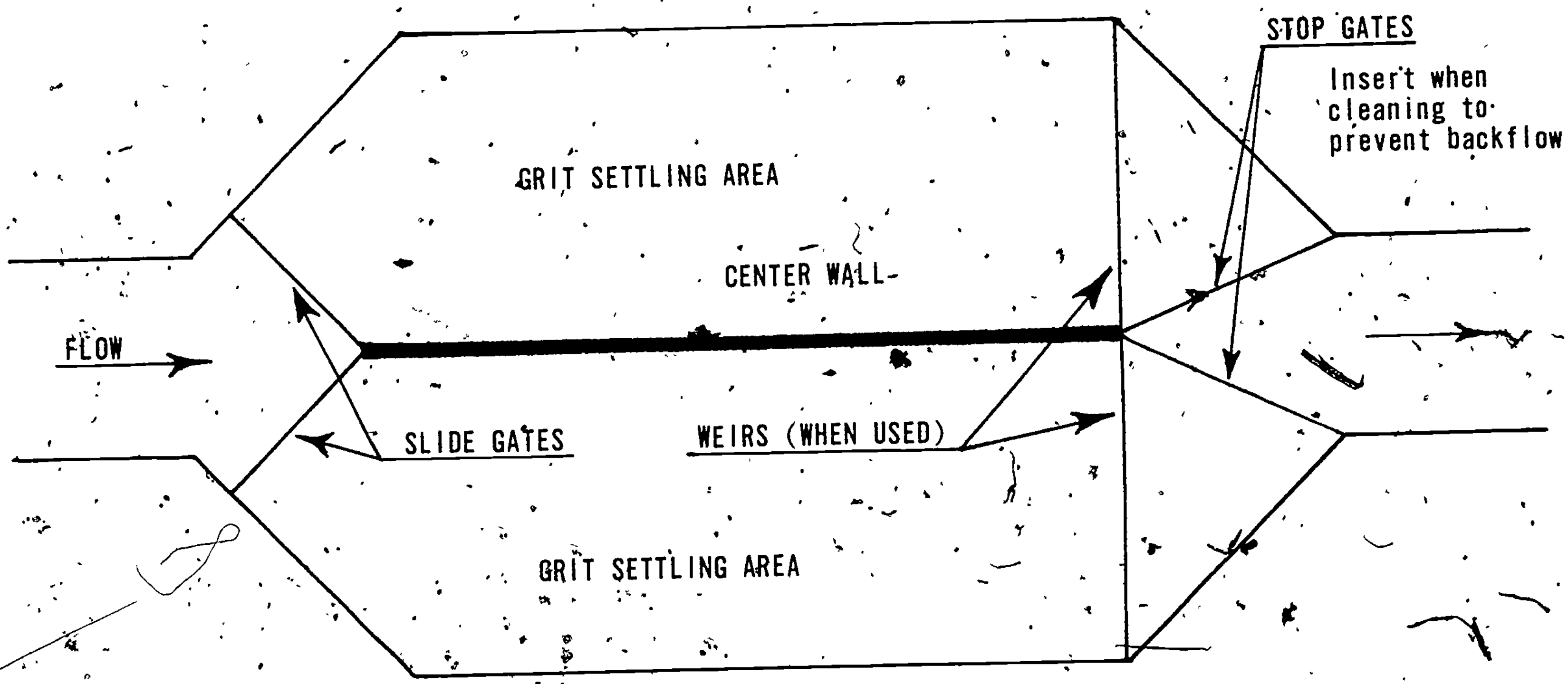

Fig. 4.7. Grit Chamber

The proportional weir in Fig. 4.8 will tend to decrease the velocity in the grit chambers when the flows increase because the exit area will decrease, thus increasing the depth of water flow in the channel. If the operator wishes to increase the velocity in a grit chamber, he could use a proportional weir and turn it over so the exit area increased as the flow increased. This would tend to keep the depth of water flow in the channel low and cause higher velocities. A barrier with a variable height at the outlet of the grit chamber can be used instead of a proportional weir to regulate velocities.

Flow velocities also may be regulated by the shape of the grit chamber instead of placing devices at the outlet. Some grit chambers have cross-sectional shapes similar to a proportional weir. The operator may regulate the velocities in a grit chamber by using boards to change cross-sectional shape, but he should seriously consider any maintenance or operational problems that might develop when trying to keep the grit chamber clean.

A simple method of estimating the velocity is to place a stick in the channel and time its travel for a measured distance. Calculate as follows:

$$\text{Velocity, ft/sec} = \frac{\text{Distance traveled, ft}}{\text{Time, sec}}$$

Example:

A stick travels 25 feet in 20 seconds:

Solution:

$$\begin{aligned}\text{Velocity, ft/sec} &= \frac{\text{Distance, ft}}{\text{Time, sec}}\\ &= \frac{25\text{ ft}}{20\text{ sec}}\\ &= 1.25\text{ ft/sec}\end{aligned}$$

$$\begin{array}{r} 1.25 \\ 20\overline{)25.00} \\ \underline{20} \\ 5\,0 \\ \underline{4\,0} \\ 1\,00 \\ \underline{1\,00} \\ 0 \end{array}$$

The actual velocity probably will be slightly higher than your estimate, but it is a very quick way to check the grit chamber velocity.

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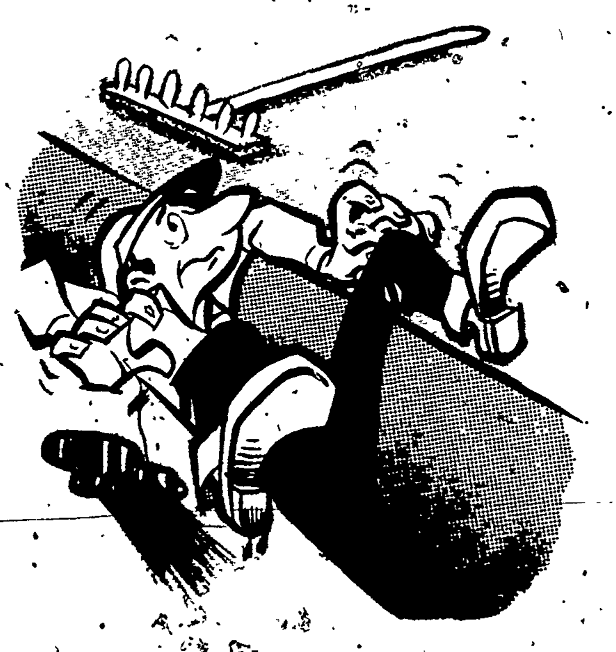
Removal of grit ranges from use of a scoop shovel to various types of collectors and conveyors. For hand-cleaned chambers, the frequency of cleaning is determined by experience. If the channel can be removed from service during the cleaning operation, the job is made easier, and no grit is washed into the plant.

Since there is always a small amount of organic matter in the grit chamber, disposal of grit should be treated the same as screenings. Burial is the most satisfactory disposal method. Failure to quickly cover grit results in odors and attracts flies and rats.



Cleaning grit chambers manually can be quite hazardous. Take precautions against slipping and back strain. Beware of dangerous gases when working in covered grit chambers.

There are many types of mechanical grit collector mechanisms. Common ones are chain-driven scrapers (called "flights") (Fig. 4.10) that are moved slowly along the bottom and up an incline out of the water to a hopper, or along the bottom to an underwater trough where a screw conveyor lifts the grit to a storage hopper or truck. Some designs use conveyor belts with buckets attached.

An aerated grit chamber is actually a tank with a sloping bottom and a hopper or trough in the lower end (Fig. 4.11). Air is injected along the wall of the tank above the trough. The rolling action of the water in the tank moves the grit along the bottom to the grit hopper. Grit is removed from the hopper by a conveyor system.

Aerated grit chambers are most frequently found at activated sludge plants where there is a readily available air supply, and the pre-aeration helps to "freshen" the wastewater. The older wastewater becomes the more difficult it is to treat. A freshening process tends to make later processes more effective.

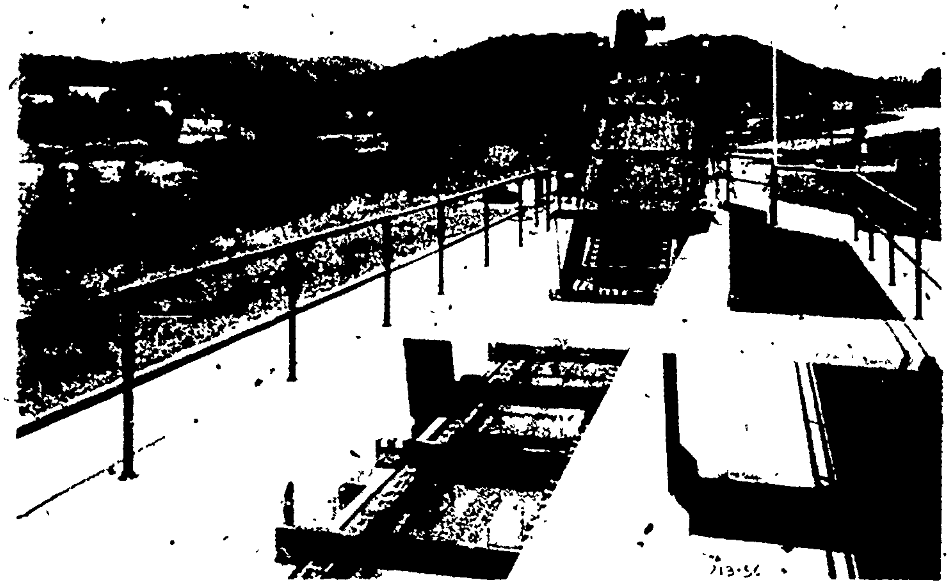


Fig. 4.10 Chain-driven scrapers (flights)

(Courtesy Jeffrey Mfg. Co.)

A grit chamber with a slower flow velocity than recommended may allow appreciable organic matter to settle out with the grit. This mixture of grit and organic matter is called detritus.[10] In some plants grit chambers are called detritus tanks. Organic matter may be separated from the grit by blowing air through or washing the detritus to resuspend the organic matter. Centrifuges also are used to separate grit from sludge or organic matter from grit.

[10] Detritus (de-TRI-tus). The heavy, coarse material carried by wastewater.

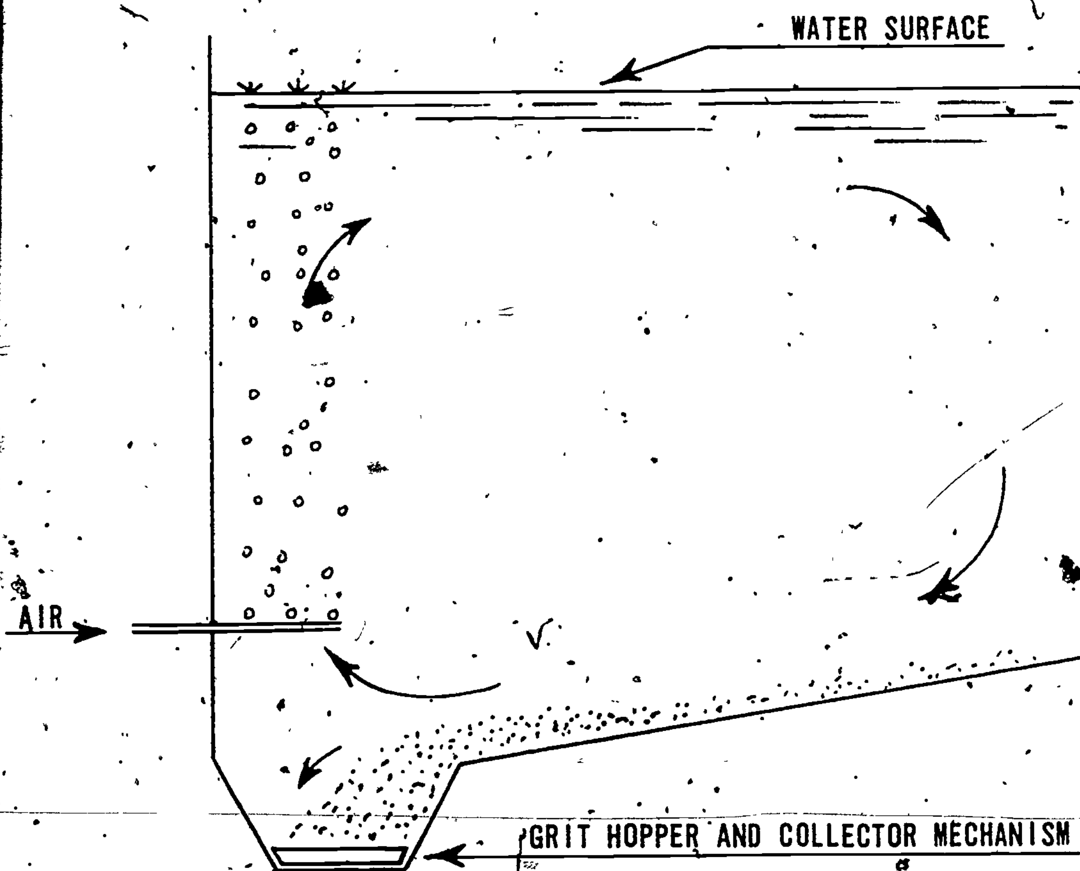


Fig. 4.11 Aerated grit chamber

4.7 QUANTITIES OF GRIT

Plants having well-constructed separate wastewater collection systems can usually expect to average 1 to 4 cu ft of grit per million gallons. These quantities have been rising in recent years due to household garbage grinders. They can also be expected to increase during storm periods.

Plants receiving waste from combined collection systems can expect to average 4 to 15 cu ft of grit per million gallons with peaks during storm periods many times higher. Grit collected during storm periods has been reported at over 500 cu ft per million gallons, probably the result of flow from broken sewers or open channels.

Records of grit quantities should be kept in the same manner as for screenings.

QUESTION

4.7A Your plant has an average flow of 2.0 MGD. An average of 4 cu ft of grit is removed each day. How many cu ft of grit per MG of flow are removed?

4.8 GRIT WASHING

In some cases it is necessary or desirable to use grit as fill material. Since a small amount of organic material settles out with the sand, etc., it becomes necessary to "wash" the grit. There are a number of devices built for this purpose. Most use water to wash the grit as it is being removed from the grit chamber (Fig. 4.12). In aerated grit chambers, the grit is ordinarily free enough of organics that it may be considered "washed". Chapter 5 of the Water Pollution Control Federation's Manual of Practice No. 11 has additional information and should be read carefully by the operator.

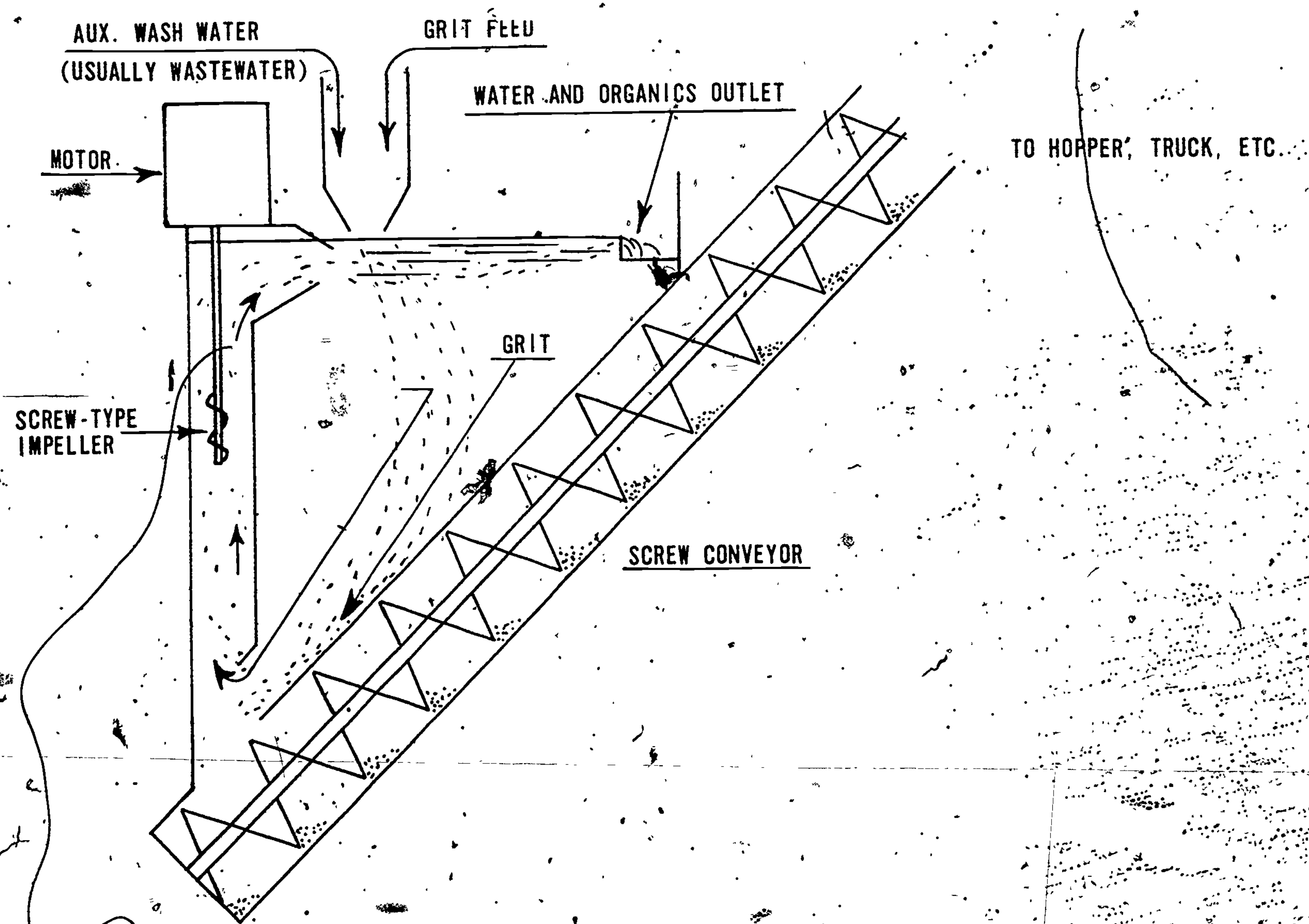


Fig. 4.12 Grit washer

QUESTION

4.8A Why is it sometimes necessary or desirable to "wash" grit?

4.9 PREAERATION

Preaeration is a wastewater treatment process used to freshen wastewater, remove gases, add oxygen, promote flotation of grease, and aid coagularion. The freshening of wastewater improves the effectiveness of following treatment processes. The process is usually located before primary sedimentation (Fig. 4.1). Other processes used to accomplish freshening include ozonation and prechlorination.

Preaeration consists of aerating wastewater in a channel or separate tank for 10 to 30 minutes. Aeration may be accomplished by either mechanical surface aeration units or diffused air system.[11] Air application rates with a diffused air system normally range from 0.5 to 1.0 cu ft of air per gallon of wastewater treated.

4.10 ADDITIONAL READING

a. MOP 11, pages 17-24

b. New York Manual, pages 27-29

c. Texas Manual, pages 160-173

d. Sewage Treatment Practices, by Bloodgood, pages 19-22 and 26-34

[11] See Chapter 7, Activated Sludge, for a discussion of aeration facilities.

CHAPTER 5. SEDIMENTATION AND FLOTATION

(Lesson 1 of 3 Lessons)

5.0 INTRODUCTION

Raw or untreated wastewater contains some materials which will settle to the bottom or float to the water surface readily when the wastewater velocity is allowed to become very slow. Sewers are designed to allow the raw wastewater to flow rapidly to prevent this from happening. Grit chambers (see Chapter 4) are designed to allow the wastewater to flow at a slightly slower rate than in the sewers so that heavy, inorganic grit will settle to the bottom where it can be removed. Settling tanks decrease the wastewater velocity far below the velocity in a collection sewer.

In most municipal wastewater treatment plants, the treatment unit which immediately follows the grit chamber (see Figs. 5.1 and 5.2 for typical plant layout) is the sedimentation and flotation unit. This unit is sometimes called a settling tank, sedimentation tank, or clarifier. The most common name is primary clarifier, since it helps to clarify or clear up the wastewater.

A typical plant (Figs. 5.1 and 5.2) may have clarifiers located at two different points. The one which immediately follows the bar screen or comminutor or grit chamber (some plants don't have all of these) is called the primary clarifier, merely because it is the first clarifier in the plant. The other, which follows the biological treatment unit (if there is one), is called the secondary clarifier. The two types of clarifiers operate almost exactly the same way. The reason for having two types is that the biological treatment unit converts more solids to the setteable form, and they have to be removed from the treated wastewater.

The main differen[illegible] between the two types of clarifiers is in the sludge density ha[illegible]ed. Primary sludges are usually denser than secondary sludges[illegible]ffluent from a secondary clarifier is normally clearer than primary effluent.

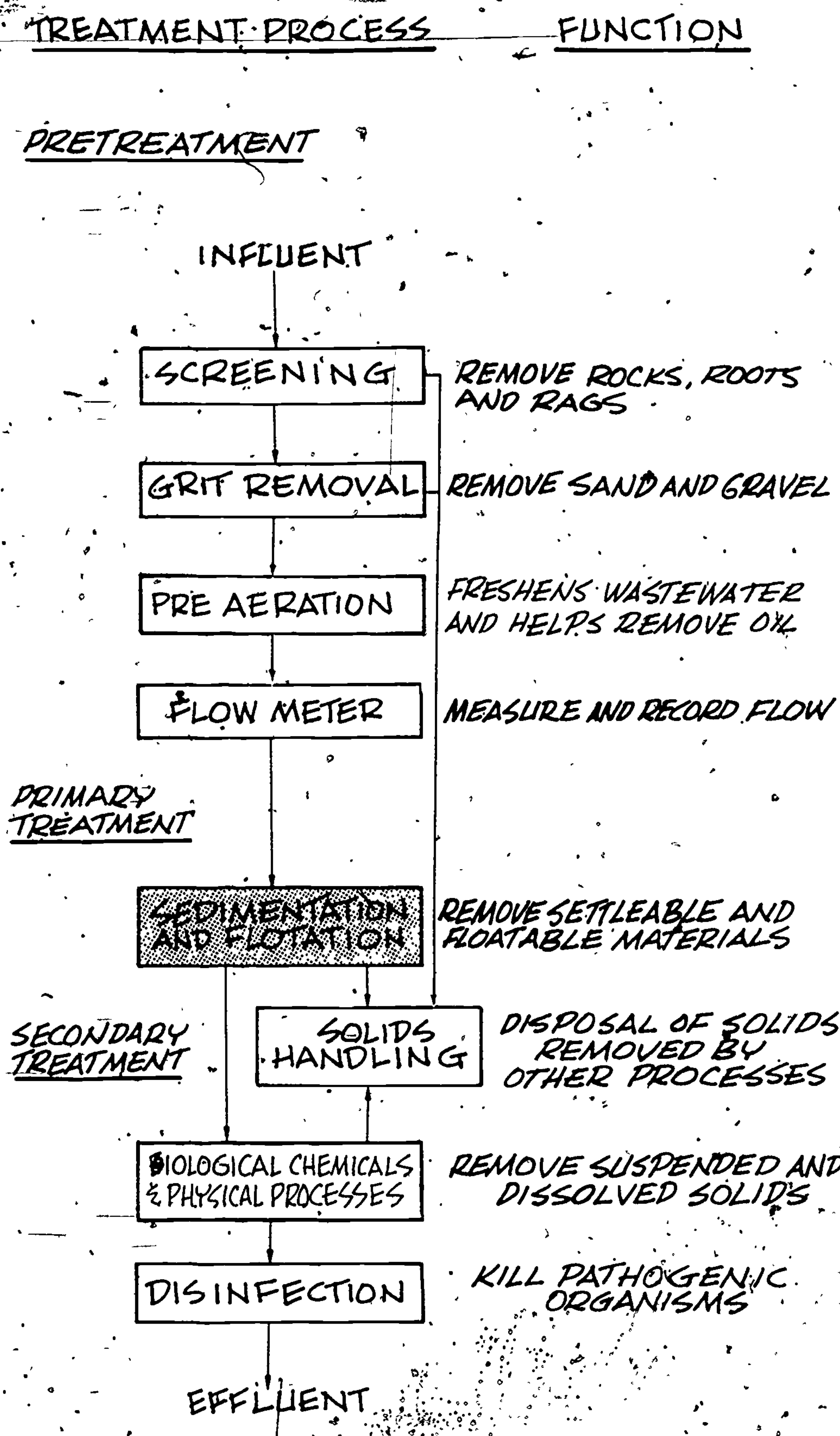


Fig. 5.1 Flow diagram of typical plant

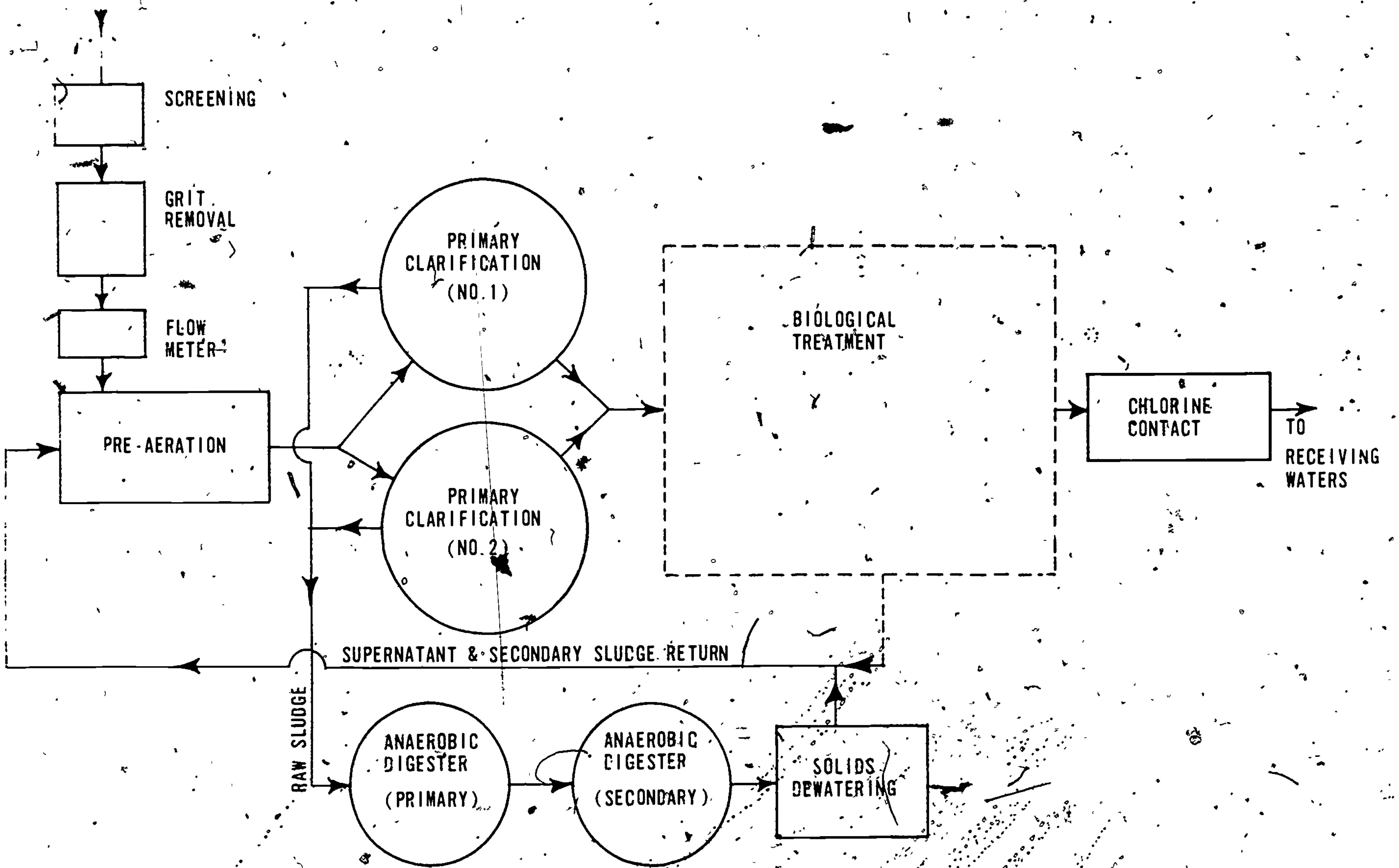


Fig. 5.2 Plan diagram of a typical primary wastewater treatment plant

Solids which settle to the bottom of a clarifier are scraped to one end (in rectangular clarifiers) or to the middle (circular clarifiers) into a sump. From the sump the solids are pumped to the sludge handling or sludge disposal system. Systems vary from plant to plant and include sludge digestion, vacuum filtration, incineration, land disposal, lagoons and burial. Figures 5.3 and 5.4 show detailed sketches of rectangular and circular clarifiers.

Disposal of skimmed solids varies from plant to plant. They may be buried with material cleaned off the bar screen, incinerated, pumped to the digester, or they may be even sold for their grease and oil content. Pumping skimmed solids to a digester is not considered good practice because skimmings can cause operational problems in digesters.

This chapter contains information on start-up, daily operation, and maintenance procedures; sampling and laboratory analyses; some problems to look out for; safety; and basic principles of sedimentation and flotation. You may wish to refer to the two chapters containing details of laboratory analyses and mathematics for further information.

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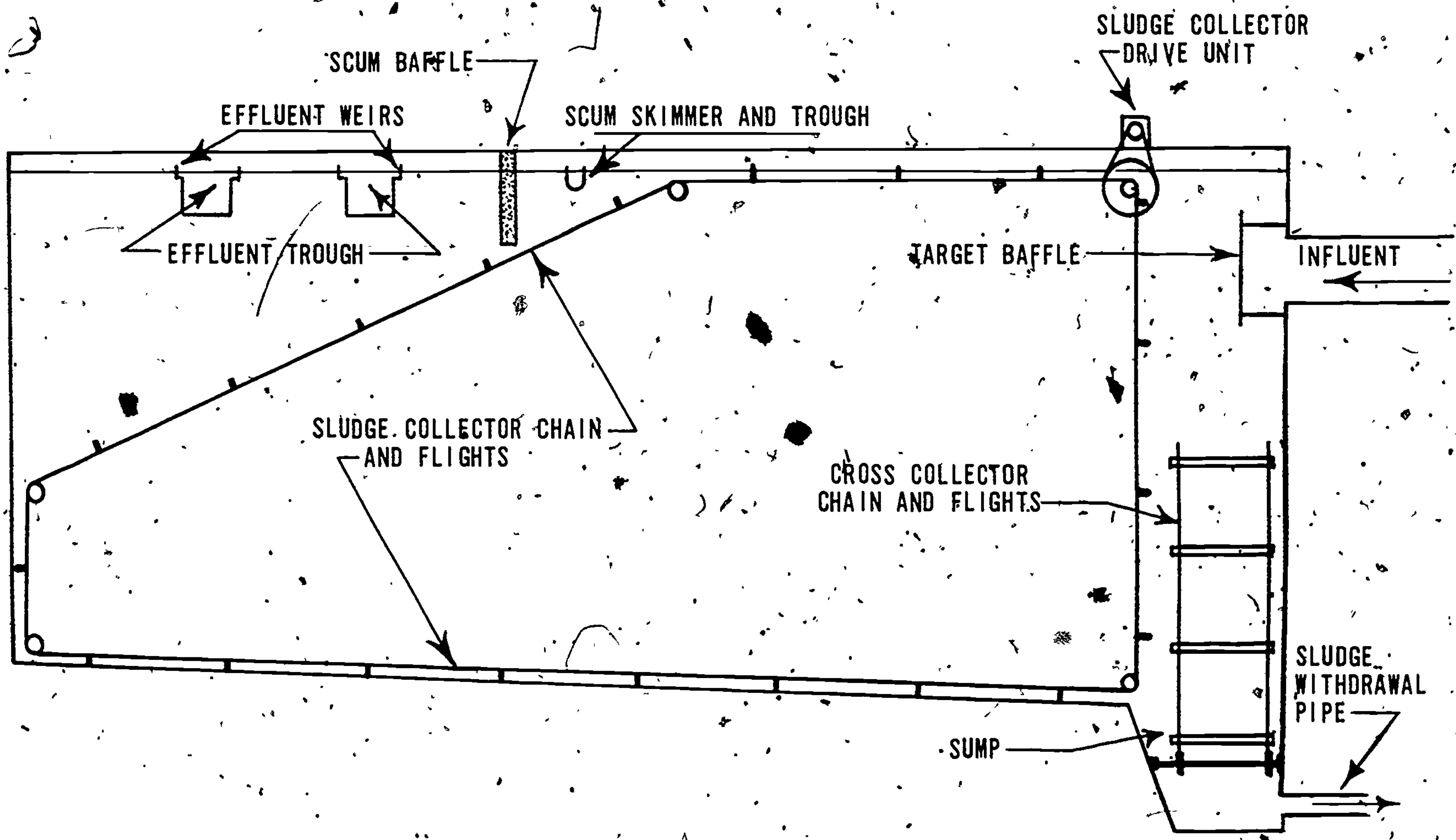

Fig. 5.3 Rectangular sedimentation basin

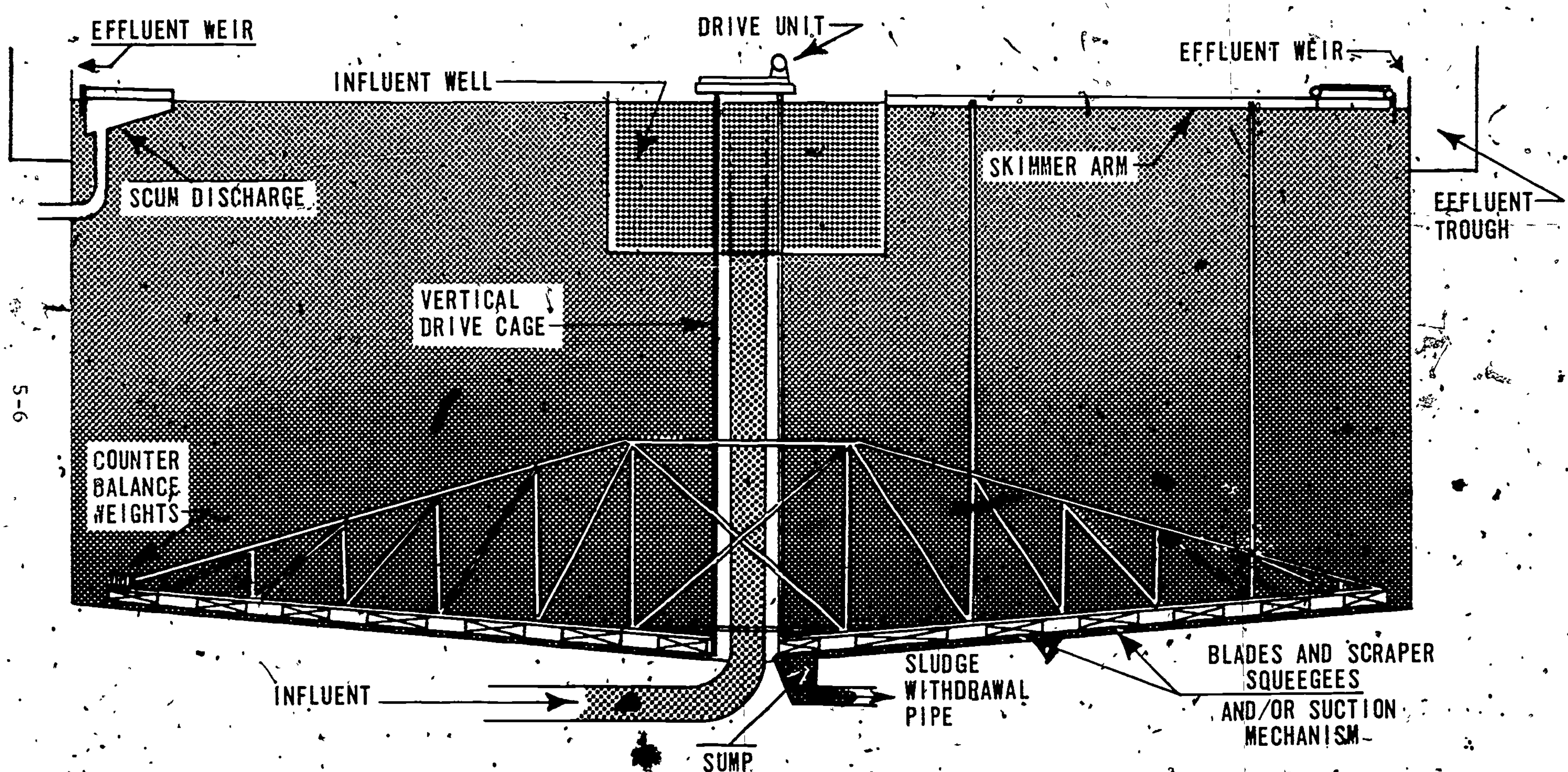

Fig. 5.4 Circular clarifier

5.2 SAMPLING AND LABORATORY ANALYSIS

5.20 General

Proper analysis of representative samples is the only conclusive method of measuring the efficiency of clarifiers. Tests may be conducted in the plant at the site where the sample is collected or in the laboratory. The particular tests depend upon whether the effluent from the clarifier goes to another treatment process or is discharged to receiving waters.

The frequency of testing and the expected ranges will vary from plant to plant. Strength of the wastewater, freshness, characteristics of the water supply, weather, and industrial wastes will all serve to affect the "common" range of the various test results.

Tests	Frequency	Location	Common Range
1. Dissolved Oxygen (DO)	Daily	Effluent	0 - 2 mg/l
2. Settleable Solids	Daily	Influent Effluent	5 - 15 ml 0.5 - 4 ml
3. pH	Daily	Influent Effluent	6.5 - 8.0* 6.5 - 8.0*
4. Temperature	Daily	Influent	50 - 85°*
5. BOD	Weekly (Minimum)	Influent Effluent	150 - 400 mg/l 60 - 160 mg/l
6. Suspended Solids	Weekly (Minimum)	Influent Effluent	150 - 400 mg/l 60 - 150 mg/l
7. Chlorine Residual (if needed)	Daily	Plant Effluent	0.5 - 3.0 mg/l
8. Coliform Group Bacteria (if needed)	Weekly	Effluent	500,000 - 100,000,000 per 100

*Depends on region, water supply and discharges to the collection system

5.21 Sampling

Samples of the influent to the clarifier and the effluent from it will give you information on the clarifier efficiency for

removal of solids, bacteria, and BOD. As with all sampling, the purpose is to collect samples which represent the true nature of the wastewater or stream being sampled. The amount of solids, BOD, bacteria, and the clarity and pH will probably vary throughout the day, week, and year. You must determine these variations in order to understand how well your clarifier is doing its job.

5.22 Calculation of Clarifier Efficiency

To calculate the efficiency of any wastewater treatment process, you need to collect a sample of the influent and the effluent of the process, preferably composite samples for a 24-hour period. The particular water quality indicators (BOD, suspended solids) you are interested in are measured and the efficiency is calculated. You can calculate the efficiency of a clarifier in removing several different items, such as efficiency in removing BOD or efficiency in removing suspended solids. Calculations of treatment efficiency are for process control purposes. Your main concern must be the quality of the plant effluent, regardless of percent of wastes removed.

Example:

The influent BOD to a primary clarifier is 200 mg/1, and the effluent BOD is 140 mg/1. What is the efficiency of the primary clarifier in removing BOD?

Formula:

$$\text{Efficiency, \%} = \frac{(\text{In} - \text{Out})}{\text{In}} 100\%$$

$$= \frac{(200\ \text{mg/1} - 140\ \text{mg/1})}{200\ \text{mg/1}} 100\%$$

$$= \frac{(60\ \text{mg/1})}{200\ \text{mg/1}} 100\%$$

$$= (.30)\ 100\%$$

$$= 30\%\ \text{BOD Removal}$$

5.23 Typical Clarifier Efficiencies

Following is a list of some typical percentages for primary clarifier efficiencies:

	Expected Removal Efficiency
Settleable solids	90% to 95%
Suspended solids	40% to 60%
Total solids	10% to 15%
Biochemical oxygen demand	25% to 35%
Bacteria	25% to 75%

pH will generally not be affected significantly by a clarifier. You can expect wastewater to have a pH of about 6.5 to 8.0, depending on the region, water supply and wastes discharged into the collection system.

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Clarifier efficiencies are affected by many factors, including:

1. Types of solids in the wastewater, especially if there is a significant amount of industrial wastes.

2. Age of wastewater when it reaches the plant. Older wastewater becomes stale or septic, and solids do not settle properly because gas bubbles form under them.

3. Rate of wastewater flow as compared to design flow.

4. Mechanical conditions and cleanliness of clarifier.

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5.3 SLUDGE AND SCUM PUMPING

The particles which settle to the floor of the clarifier are called sludge. The accumulated sludge should be removed frequently, and this is accomplished by mechanical cleaning devices and pumps in most tanks. (See Fig. 5.3 and 5.4) Mechanically cleaned tanks need not be shut down for cleaning. Septic conditions[3] may develop rapidly in primary clarifiers if sludge is not removed at regular intervals. The proper interval is dependent on many conditions and may vary from thirty minutes to eight hours, and as much as twenty-four hours in a few instances. Experience will dictate the proper frequency of removal. Sludge septicity can be recognized when sludge gasification[4] causes large clumps of sludge to float on the water surface. Septic sludge is generally very odorous and acid (has a low pH).

Excess water should be eliminated from the sludge if possible because of its effects on the volume of sludge pumped and on digester operation. A good thick primary sludge will contain from 4.0 to 8.0 percent dry solids as indicated by the Total or Suspended Solids Test in the laboratory. Conditions which may affect sludge concentration are the specific gravity, size and shape of the particles, and temperature, and turbulence in the tank.

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[3]Septic conditions (SEP-tick). A condition produced by anaerobic organisms. If severe, the wastewater turns black, giving off foul odors and creating a heavy oxygen demand.

[4]Sludge gasification. A process in which soluble and suspended organic matter are converted into gas. Sludge gasification will form bubbles of gas in the sludge and cause large clumps of sludge to rise and float on the water surface.

Withdrawal (pumping) rates should be slow in order to prevent pulling too much water with the sludge. While the sludge is being pumped, take samples frequently and examine them visually for excess water. If the samples show a "thin" sludge, it is time to stop pumping. Practice learning to recognize the differences between thin or concentrated sludges. There are several methods for determining "thick" or "thin" sludge without a laboratory analysis:

1. Sound of the sludge pump. The sludge pump will usually have a different sound when the sludge is thick than when it is thin.

2. Pressure gauge readings. Pressure will be higher on the discharge side of the pump when sludge is thick.

3. Sludge density gauge readings.

4. Visual observation of a small quantity (gallon or less).

5. Watch sludge being pumped through a site glass in the sludge line.

When you learn to use the indicators listed above, you should compare them frequently with lab tests. The laboratory Total Solids Test is the only accurate method for determining exact density. However, this analytical procedure is too slow for controlling a routine pumping operation. Many operators use the centrifuge test to obtain quick results.

Floating material (scum) may leave the clarifier at the effluent unless a method has been provided for holding it back. A baffle is generally provided in the tank at some location to collect scum. Primary clarifiers often have a scum collection area where the scum is skimmed off by some mechanical method, usually a skimming arm or a paddle wheel. If mechanical methods are not provided, use hand tools such as skimming dipper attached to a broom handle.

Frequently check the scum trough to be sure it is working properly. Clean the box with a brush and hot water. Scum may be disposed of by burning or burial.

CHAPTER 5. SEDIMENTATION AND FLOTATION

(Lesson 2 of 3 Lessons)

5.6 PRINCIPLES OF OPERATION

5.60 General

Sedimentation and flotation units are designed to remove physically those solids which will settle easily to the bottom or float easily to the top. Sedimentation is usually the principal basis of design in such units and will be discussed in more detail in this section. Flotation of fats, oils, hair, and other light material also is very important to protect the esthetics of receiving waters.

The sedimentation and flotation units commonly found are:

1. Primary clarifiers
2. Secondary clarifiers
3. Flotation units
4. Imhoff tanks

This section will describe each unit individually as it relates to another process or as a process by itself.

5.61 Primary Clarifiers

The most important function of the primary clarifier is to remove as much settleable and floatable material as possible. Organic settleable solid removal is very important because it causes a high demand for oxygen (BOD) in receiving water or subsequent biological treatment units in the treatment plant.

Many factors influence the design of clarifiers. Settling characteristics of suspended particles in water are probably the most important considerations. The design engineer must consider the speed at which particles will settle in order to determine the correct dimensions for the tank. Rapid movement of water (velocity) will hold most particles in suspension and carry them along until the velocity of water is slowed sufficiently for particle settling. The rate of downward travel (settling) of a particle is dependent on the weight of the particle in relation

to the weight of an equal volume of water (specific gravity),[5] the particle size and shape, and the temperature of the liquid. Organic settleable solids are seldom more than 1 to 5 percent heavier than water; and, therefore, their settling rates are slow.

If the horizontal velocity of water is slowed to a rate of 1.0 to 2.0 feet of travel per minute (grit chamber velocities were around 1 ft/sec) most particles with a specific gravity of 1.05 (5% more than water) will settle to the bottom of the container. Specific gravity of water is 1.000 at 4.0 degrees Celsius (formally Centigrade) or 39°F; it weighs 8.34 lbs per gallon. Wastewater solids with a specific gravity of 1.05 will weigh 8.76 lbs per gallon (1.05 times 8.34 lbs equals 8.76 lbs per gallon). The relationship of the particle settling rate to liquid velocity may be explained very simply by use of a sketch (Fig. 5.5).

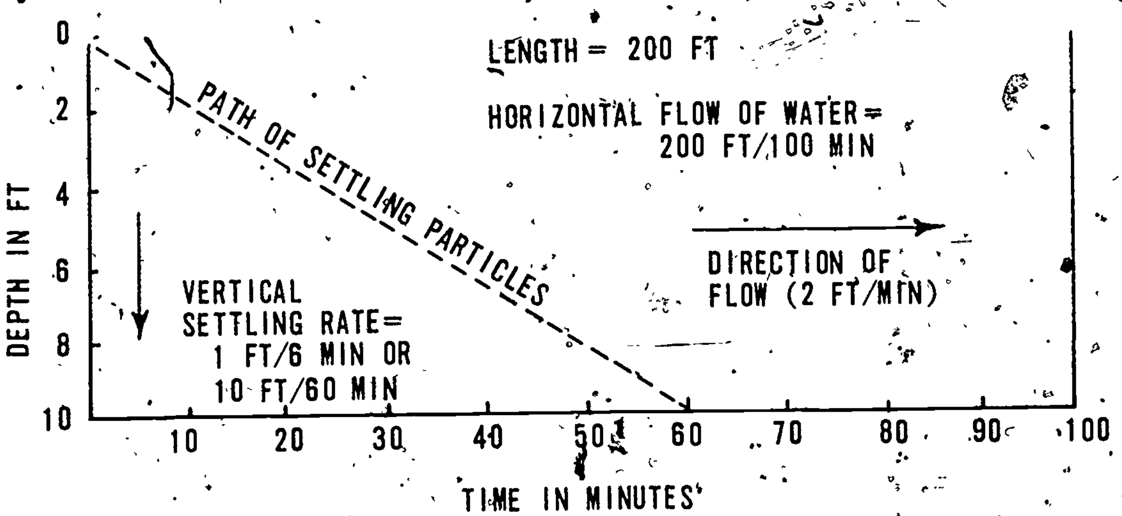

Fig. 5.5 Path of settling particle

Suppose the liquid velocity is horizontal at the rate of 2.0 feet per minute and the tank is 200 feet long. It will take 100 minutes (200 ft divided by 2.0 ft/min) to travel through the tank. If the particle, during its diagonal course of travel, settles vertically toward the

---

5 Specific gravity. Weight of a particle or substance in relation to the weight of water. Water has a specific gravity of 1.000 at 4°C (or 39°F). Wastewater particles may have a specific gravity of from 0.8 to 2.6. If the specific gravity of a particle is less than one it will tend to float, and if greater than one it will tend to sink. Most organic sludges have a specific gravity between 1.01 and 1.05.

bottom of the tank at a rate of 1.0 foot in 6 minutes, it will rest on the floor of the tank in 60 minutes if the tank is 10 feet deep. If the particle settles at the rate of 10 feet in 60 minutes, it should settle in the first 60 percent portion of the tank because the liquid surrounding it requires 100 minutes to flow through the tank.

There are many factors which will influence settling characteristics in a particular clarifier. A few of the more common ones are as follows:

Temperature. Water expands as temperature increases (above 4°C) and contracts as temperature decreases (above 4°C). Below 4°C the opposite is true. In general, as water temperature increases, settling rate of particles increases; and, as temperature decreases, so does the settling rate. Molecules[6] of water react to temperature changes. They are closer together when liquid temperature is lower; thus, density[7] increases and water becomes heavier per given volume because there is more of it in the same space. As water becomes more dense, the density difference between water and solid particles becomes less; and therefore the particles settle slower. This is illustrated in Fig. 5.6.

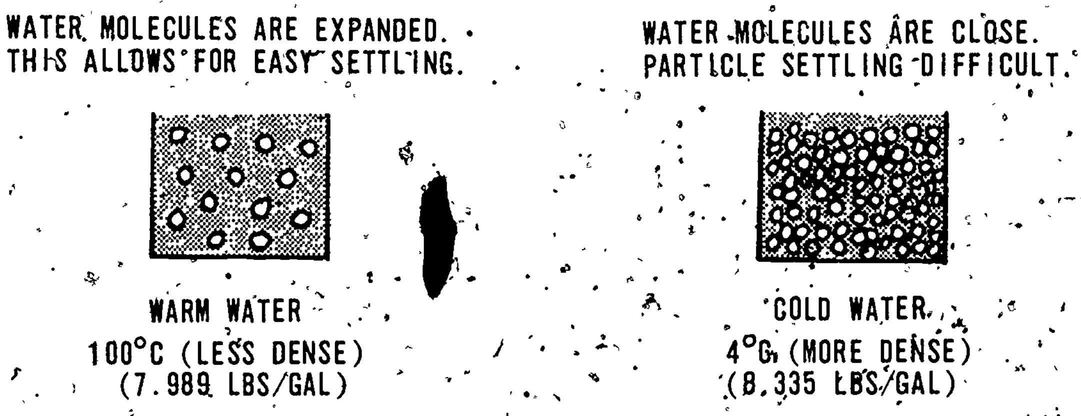

Fig. 5.6 Influence of temperature on settling

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[6] Molecules (MOLL-ee-kules). The smallest portion of an element or compound retaining or exhibiting all the properties of the substance.

[7] Density (DEN-sit-tee). The weight per unit volume of any substance. The density of water (at 4°C) is 1.0 gram per cubic centimeter (gms/cc) or about 62.4 lbs per cubic foot. If one cubic centimeter of a substance (such as iron) weighs more than 1.0 gram (higher density), it will sink or settle out when put in water. If it weighs less (lower density, such as oil), it will rise to the top and float. Sludge density is normally expressed in gms/cc.

Short Circuits. As wastewater enters the settling tank, it should be evenly dispersed across the entire cross section of the tank and should flow at the same velocity in all areas toward the discharge end. When the velocity is greater in some sections than in others, serious "short circuiting" may occur. The high velocity area may decrease the detention time in that area, and particles may be held in suspension and pass through the discharge end of the tank because they do not have time to settle out. On the other hand, if velocity is too low, undesirable septic conditions may occur. Short circuiting may easily begin at the inlet end of the sedimentation tank (Fig 5.7). This is usually prevented by the use of weir plates, baffles, port openings, and by proper design of the inlet channel. Short circuiting also may be caused by turbulence and stratification of density layers due to temperature or salinity.

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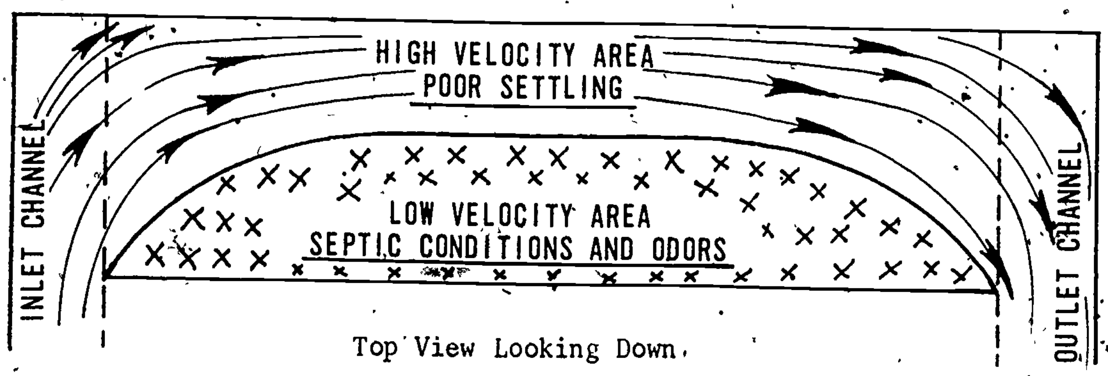
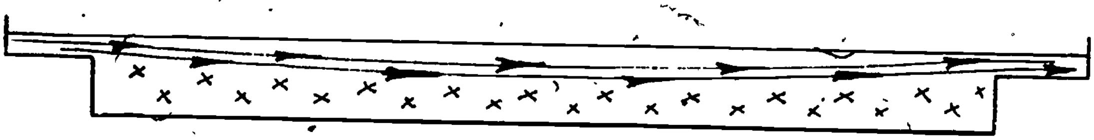
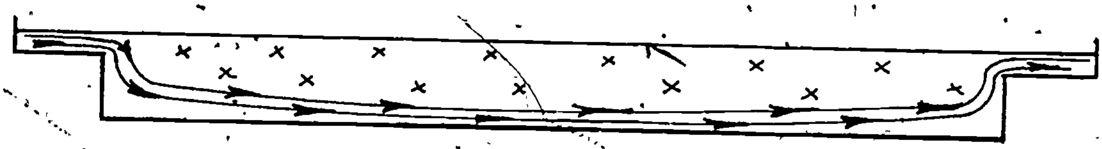


Top View Looking Down.



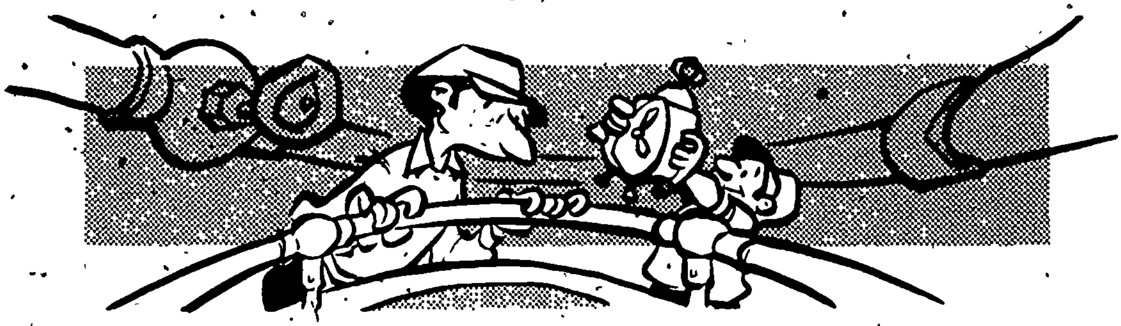
Side View - Warm Influent



Side View - Cold Influent

Fig. 5.7 Short circuiting

Detention Time.[8] Wastewater should remain in the clarifier long enough to allow sufficient settling time for solid particles. If the tank is too small for the quantity of flow and the settling rate of the particles, too many particles will be carried out the effluent of the clarifier. The relationship of "detention time" to "settling rate" of the particles is important. Most engineers design for about 2.0 to 3.0 hours of detention time. This is, of course, flexible and dependent on many circumstances.



Detention time can be calculated by use to two known factors:

1. Flow in gallons per day (gpd)
2. Tank dimensions

Example:

The flow is 3.0 million gallons per day (MGD), or 3,000,000 gal/day. Tank dimensions are 60 feet long by 30 feet wide by 10 feet deep. What is the detention time?

[8] Detention Time. The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

Formulas:

$$\text{Detention Time, hrs} = \frac{\text{Tank Volume, cu ft} \times 7.5 \text{ gal/cu ft} \times 24 \text{ hr/day}}{\text{Flow, gal/day}}$$

$$\text{Tank Volume, cu ft} = \text{Length, ft} \times \text{Width, ft} \times \text{Depth, ft}$$

Calculations:

$$\begin{aligned}\text{Tank Volume, cu ft} &= \text{Length, ft} \times \text{Width, ft} \times \text{Depth, ft}\\ &= 60 \text{ ft} \times 30 \text{ ft} \times 10 \text{ ft}\\ &= 18{,}000 \text{ cu ft}\end{aligned}$$

$$\begin{aligned}\text{Detention Time, hrs} &= \frac{\text{Tank Volume, cu ft} \times 7.5 \text{ gal/cu ft} \times 24 \text{ hr/day}}{\text{Flow, gal/day}}\\ &= \frac{18{,}000 \text{ cu ft} \times 7.5 \text{ gal/cu ft} \times 24 \text{ hr/day}}{3{,}000{,}000 \text{ gal/day}}\\ &= \frac{3{,}240{,}000 \text{ gal-hr/day}}{3{,}000{,}000 \text{ gal/day}}\\ &= 1.08 \text{ hours}\end{aligned}$$

$$\begin{array}{r} 24\\ \times 7.5\\ \hline 120\\ 168\\ \hline 180.0 \end{array} \qquad \begin{array}{r} 18{,}000\\ 180\\ \hline 1{,}440{,}000\\ 1\ 800\ 0\\ \hline 3{,}240{,}000 \end{array}$$

Evaluation. If detention time is only 1.08 hours and if laboratory tests indicate poor removal of solids, then additional tank capacity should be placed into operation (if available) in order to obtain additional detention time. You must realize that flows fluctuate considerably during the day and night and any calculated detention time is for a specific flow.

Discussion. The formula given in this section allows you to calculate the theoretical detention time. Actual detention time is less than the detention time calculated using the formula and can be measured by the use of dyes, tracers, or floats.

Weir Overflow Rate. Wastewater leaves the clarifier by flowing over weirs and into effluent troughs (launders)[9] or some type of weir arrangement. The number of lineal[10] feet of weir in relation to the flow is important to prevent short circuits or high velocity near the weir or launder which might pull settling solids into the effluent. The weir overflow rate is the number of gallons of wastewater that flow over one lineal foot of weir per day. Most designers recommend about 10,000 to 20,000 gallons per day per lineal foot of weir. Higher weir overflow rates have been used for materials with a high settling rate or for intermediate treatment. Secondary clarifiers and high effluent quality requirements generally need lower weir overflow rates than primary clarifiers. The calculation for weir overflow rate requires two known factors:

1. Flow in gpd

2. Lineal feet of weir

Example:

The flow is 5.0 MGD in a circular tank with a 90-foot weir diameter.[11] What is the weir overflow rate?

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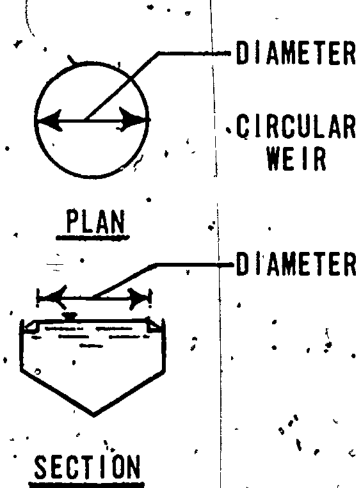
9 Launders (LAWN-ders). Sedimentation tank effluent troughs. When the flow leaves a sedimentation unit, it usually flows into a trough after it leaves the tank. The top edge of the trough over which wastewater flows as it enters the trough is considered a weir.

10 Lineal (LIN-e-al). The length in one direction of a line. For example, a board 12 feet long has 12 lineal feet in its length.

11 Weir Diameter (weer). Circular clarifiers have a circular weir within the outside edge of the clarifier. All the water leaving the clarifier flows over this weir. To find the length of this weir, the weir diameter must be known. The diameter is the length of a line from one edge of a weir to the opposite edge and passing through the center of the circle formed by the weir.



Formulas:

$$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow Rate, gpd}}{\text{Length of Weir, ft}}$$

Length of Circular Weir = 3.14 x Weir Diameter, ft

Calculations:

Length of Circular Weir, ft = 3.14 x (Weir Diameter, ft)

= 3.14 x 90 ft

= 283 Lineal Feet of Weir

$$\begin{array}{r} 3.14 \\ \underline{90} \\ 282.60 \end{array}$$

$$\text{Weir Overflow, gpd/ft} = \frac{\text{Flow Rate, gpd}}{\text{Length of Weir, ft}}$$

$$= \frac{5{,}000{,}000 \text{ gal/day}}{283 \text{ ft}}$$

= 17,668 gpd/ft

$$\begin{array}{r} 17{,}668 \\ 283 \overline{)5{,}000{,}000} \\ \underline{2\ 83} \\ 2\ 170 \\ \underline{1\ 981} \\ 189\ 0 \\ \underline{169\ 8} \\ 19\ 20 \\ \underline{16\ 98} \\ 2\ 220 \\ 2\ 264 \end{array}$$

Surface Settling Rate or Surface Loading Rate. This term is expressed in terms of gpd/sq ft of tank surface area. Some designers and operators have indicated that the surface loading rate has a direct relationship to the settleable solids removal efficiency in the settling tank. The suggested loading rate varies from 300 to 1200 gpd/sq ft, depending on the nature of the solids and the treatment requirements. Low loading rates are frequently used in small plants in cold climates. In warm regions, low rates may cause excessive detention which could lead to septicity. The calculation for surface loading rate requires two known factors:

1. Flow in gpd
2. Square feet of liquid surface area

Example:

The flow in a secondary plant is 5.0 MGD in a tank 90 feet long and 35 feet wide. What is the surface loading rate?

Formula:

$$\text{Surface Loading Rate, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Area, sq ft}}$$

Calculations:

$$\text{Surface Area, sq ft} = \text{Length, ft} \times \text{Width, ft}$$
$$= 90 \text{ ft} \times 35 \text{ ft}$$
$$= 3150 \text{ sq ft}$$

$$\text{Surface Loading Rate, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Area, sq ft}}$$
$$= \frac{5{,}000{,}000 \text{ gpd}}{3150 \text{ sq ft}}$$
$$= 1587 \text{ gpd/sq ft}$$

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Detention Time, Weir Overflow Rate, and Surface Loading Rate are three mathematical methods of checking the performance of existing facilities against the design values. However, laboratory analysis of samples is the only reliable method of measuring clarifier efficiency. If laboratory results indicate a poorly operating clarifier, the mathematical methods may help you to identify the problem.

QUESTIONS

5.6A What is "short circuiting" in a clarifier?

5.6B Why is "short circuiting" undesirable?

5.6C How can "short circuiting" be corrected?

5.6D A circular clarifier has a diameter of 80 feet and an average depth of 10 feet. The flow of wastewater is 4.0 MGD. Calculate the following:

1. Detention Time, in hours
2. Weir Overflow Rate, in gpd/ft
3. Surface Loading Rate, in gpd/sq ft

CHAPTER 5. SEDIMENTATION AND FLOTATION

(Lesson 3 of 3 Lessons)

5.62 Secondary Clarifiers or Final Settling Tanks

Secondary clarifiers usually follow a biological process in the flow pattern of a treatment plant. (See Figs. 5.1 and 5.2.) The most common biological processes are the Activated Sludge Process[12] and the Trickling Filter.[13]

In some plants a chemical process may be used instead of a biological process, but the latter is far more common for municipal treatment plants.

The final settling tank is sometimes referred to as a "humus tank" when used after a trickling filter to settle out sloughings[14] from the filter media. Filter sloughings are a product of biological action in the filter; the material is generally quite high in BOD and will degrade the effluent quality unless it is removed. The specific description of trickling filters is covered in Chapter 6.

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[12] Activated Sludge Process (ACK-ta-VATE-ed sluj). A biological wastewater treatment process in which a mixture of wastewater and activated sludge is aerated and agitated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation, and wasted or returned to the process as needed.

[13] Trickling Filter. A treatment process in which the wastewater trickles over media that provide the opportunity for the formation of slimes which clarify and oxidize the wastewater.

[14] Sloughings (SLUFF-ings). Trickling filter slimes that have been washed off the filter media. They are generally quite high in BOD and will degrade effluent quality unless removed.

Secondary clarifier detention times are about the same as for primary clarifiers, but the surface loading and weir overflow rates are generally lower due to the less dense characteristics of secondary sludges. The following are ranges of loading rates for secondary clarifiers used after biological filters:

Detention Time - 1.0 to 2.0 hours

Surface Loading Rate - 300 to 1200 gpd/sq ft

Weir Overflow Rate - 5,000 to 15,000 gpd/lineal ft

The amount of solids settling out in a secondary clarifier following a trickling filter will be very irregular due to a number of varying conditions in the biological treatment process. In general, you can expect to pump about 30% to 40% as much sludge from the secondary clarifier as from the primary; thus, total sludge pumping will increase by that amount. These figures indicate how the trickling filter "creates" settleable solids which were not present in the raw wastewater in settleable form.

The sludge in the secondary settling tank will usually have a completely different appearance and characteristics than the sludge collected in a primary settling tank. It will usually be much darker in color, but should not be grey or black. A grey sludge usually indicates insufficient biological stabilization (treatment). Sludge will turn black if it is allowed to stay in the secondary clarifier too long. If this happens, then the return sludge or waste sludge pumping rate should be increased or the time of pumping lengthened or made more frequent. Secondary sludges generally require continuous or frequent pumping at a rate sufficient to maintain a reasonably concentrated sludge and a low sludge blanket in the clarifier.

The particle sizes may be very irregular with generally good (rapid) settling characteristics. The sludge may appear to be a <u>fluffy humus</u> type of material and will usually have little or no odor if sludge removal occurs at regular intervals. The sludge collected in the final settling tanks is sometimes disposed of by transferring to a primary settling tank to be mixed with primary sludge, and it is sometimes transferred directly to the digestion system, depending on the particular plant design and the characteristics of the sludge.

Final settling tanks which follow the activated sludge process are designed similarly to those used for the trickling filter, except that they are more conservative in design because the sludge tends to be less dense. Their purpose is identical, except that the particles to be settled are received from the aeration tank rather than the trickling filter. Most final sedimentation tanks used with the activated sludge process are

mechanically cleaned due to the importance of rapidly returning sludge to the aeration tank. (This is explained in Chapter 7, Activated Sludge.) The sludge volume in the secondary tank will be greater from the activated sludge process than from the trickling filter process.

The standard laboratory tests used to measure solids removal in primary settling tanks are used also for secondary settling tanks.

QUESTIONS

5.6E Why are secondary clarifiers needed in secondary treatment plants?

5.6F What usually is done with the sludge that settles out in secondary clarifiers?

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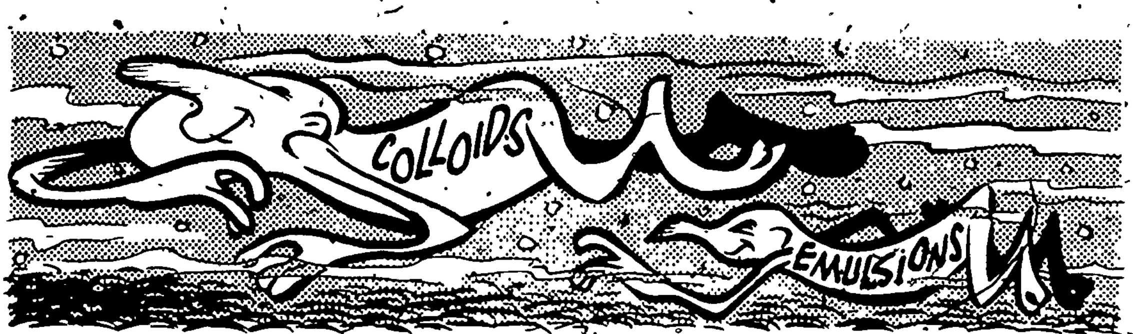
5.7 FLOTATION PROCESSES

Wastewater always contains some solids in suspended form that neither settle nor float to the surface and therefore remain in the liquid as it passes through the clarifier. Dissolved solids will, of course, travel through the clarifiers because they are unaffected by these units. There are two other types of solids in wastewater known as "Colloids" and "Emulsions" that are very difficult to remove.



A "colloid" is a particle held in suspension due to its very small size and its electrical charge. It is usually less that 200 millimicrons[15] in size, and generally will not settle readily. If organic, it exerts a high oxygen demand, so its removal is desirable.

An "emulsion" is a liquid mixture of two or more liquid substances not normally dissolved in one another, but one liquid held in suspension in the other. It usually contains suspended globules of one or more of the substances. The globules usually consist of grease, oil, fat, or resinous substances. This material also exerts a high oxygen demand.

One method for removing emulsions and colloids is by a "flotation process", pumping air into the mixture to cause the suspended material to float to the surface where it can be skimmed off.

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[15] Millimicron (MILL-e-MY-cron). One thousandth of a micron or a millionth of a millimeter.

The particles can be flocculated[16] with air or chemical coagulants[17] and forced or carried to the liquid surface by minute air bubbles. Figure 5.8 shows the chain of events in the flotation process.

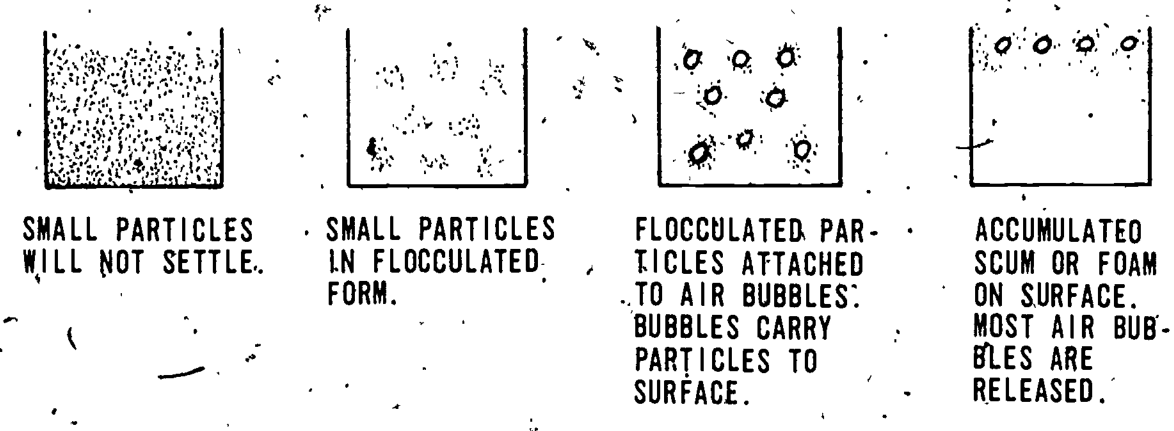

Fig. 5.8 Flotation process.

Most of the air bubbles are released at the liquid surface. Particles are removed in the form of scum or foam by skimming.

There are two common flotation processes in practice today:

1. Vacuum Flotation. The wastewater is aerated for a short time in a tank where it becomes saturated with dissolved air. The air supply is then cut off and large air bubbles pass to the surface and into the atmosphere. The wastewater then flows to a vacuum chamber which pulls out dissolved air in the form of tiny air bubbles which float the solids to the top.

2. Pressure Flotation. Air is forced into the wastewater in a pressure chamber where the air becomes dissolved in the liquid. The pressure is then released from the wastewater, and the wastewater is returned to atmospheric pressure where the dissolved air is released from solution in the form of tiny air bubbles. These air bubbles rise to the surface and, as they rise, they carry solids to the surface.

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[16] Flocculated (FLOCK-you-lay-ted). An action resulting in the gathering of fine particles to form larger particles.

[17] Coagulants (ko-AGG-you-lents). Chemicals added to destabilize, aggregate, and bind together colloids and emulsions to improve settleability, filterability, or drainability.

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Any flotation process is based upon release of gas bubbles in the liquid suspension (Fig. 5.8) under conditions in which the bubbles and solids will associate with each other to form a combination with a lower specific gravity than the surrounding liquid. They must stay together long enough for the combination to rise to the surface and be removed by skimming.

QUESTIONS

5.7A Why is the "flotation process" used in some wastewater treatment plants?

5.7B Would you place the flotation process before or after primary sedimentation?

5.7C Give a very brief description of:

1. Colloid
2. Emulsion

5.7D Give a brief description of the Vacuum Flotation process.

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5.8 IMHOFF TANKS

Imhoff tanks are rarely constructed today. Your plant may consist of only an Imhoff tank if it serves a very small community or if it was constructed many years ago. It is quite possible that you may never have operating responsibility for one of these units. They will be discussed for general knowledge and for the few operators who will have operating responsibility for them.

The Imhoff tank combines sedimentation and sludge digestion in the same unit. There is a top compartment where sedimentation occurs and a bottom compartment for digestion of settled particles (sludge). The two compartments are separated by a floor and a slot designed to allow settling particles to pass through to the digestion compartment (Fig. 5.9).

Wastewater flows slowly through the upper tank as in any other standard rectangular sedimentation unit. The settling solids pass through the slot to the bottom sludge digestion tank. Anaerobic digestion of solids is the same as in a separate digester. Gas bubbles are formed in the digestion area by bacteria. As the gas bubbles rise to the surface they carry solid particles with them. The slot is designed to prevent solids from passing back into the upper sedimentation area as a result of gasification where they would pass out of the unit with the effluent.

The same calculations previously used for clarifiers can be used to determine loading rates for the settling area of the Imhoff tank. (Chapter 8, Sludge Digestion, will explain the anaerobic process in the sludge digestion area of this unit.) Some typical values for design and operation of Imhoff tanks are:

<u>Settling Area</u>

Wastewater Detention Time	- 1.0 to 4.0 hours
Surface Settling Rate	- 600 to 1200 gpd/sq ft
Weir Overflow Rate	- 10,000 to 20,000 gpd/ft
Suspended Solids Removal	- 45% to 65%
BOD Removal	- 25% to 35%

<u>Digestion Area</u>

Digestion Capacity	- 1.0 to 3.0 cu ft/person
Sludge Storage Time	- 3 to 12 months

11:

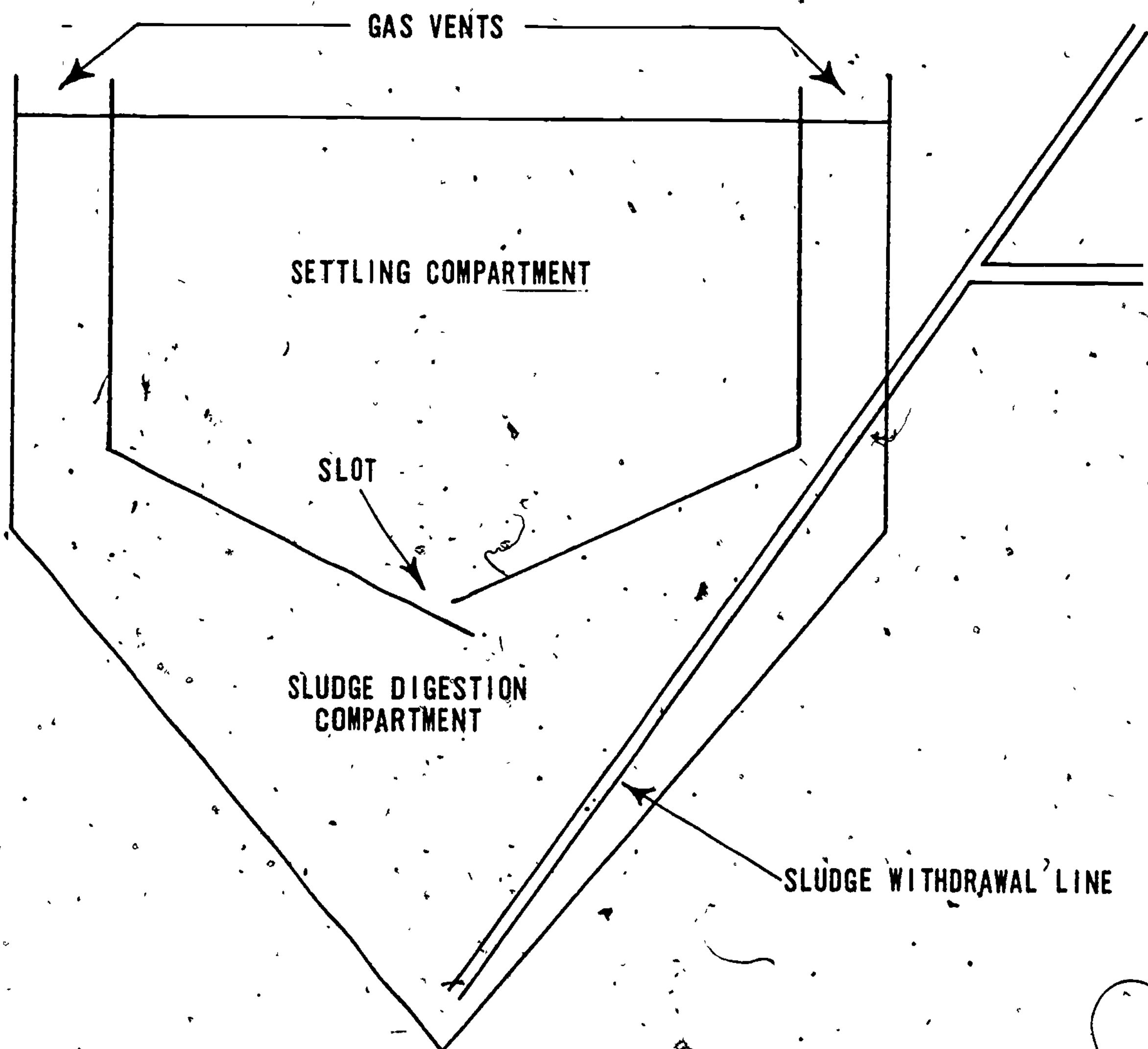

Fig. 5.9 Imhoff tank

Here are a few operational suggestions:

1. In general, there is no mechanical sludge scraping device for removing settled solids from the floor of the settling area. Solids may accumulate before passing through the slot to the digestion area. It may be necessary to push the accumulation through the slot with a squeegee or similar device attached to a long pole. Dragging a chain on the floor and allowing it to pass through the slot is another method for removing the sludge accumulation.

2. Scum from the sedimentation area is usually collected by hand tools in a separate container for disposal. It may also be transferred to the gas venting area where it will work down into the digestion compartment. Scum in the gas vents should be kept soft and broken up by soaking it periodically with water or by punching holes in it and mixing it with the liquid portion of the digestion compartment. The addition of 10 pounds of hydrated lime per 1000 connected population per day may be helpful for controlling odors from the gas vent area and also for adjusting the chemical balance of the scum for easier digestion.

3. Some Imhoff tanks have the piping and valving to reverse the direction of flow from one end toward the other end. If possible, the flow should be reversed periodically for the purpose of maintaining an even sludge depth in the digestion compartment. The sludge level in the digestion area must be lower than the slot in the floor of the settling area to prevent plugging of the slot. A line of gas bubbles directly over the slot indicates the sludge level in the digestion chamber is too high.

4. The explanation of sludge digestion in Chapter 8 will supply information that can be applied to the digestion area in the Imhoff tank. Neither sludge mixing nor heating devices are used in an Imhoff tank. Sludge loading rates, withdrawal rates, laboratory tests, and visual appearance of sludges are very similar to what they are in an unheated digester. If visual appearance is the only method you have of judging the sludge, it is safe to assume that if sludge in the digestion area is relatively odorless or has a musty smell and is black or very dark in color, the process is working satisfactorily.

The laboratory testing program for an Imhoff tank should be complete enough to identify operational problems and to supply necessary information to regulatory agencies. The following minimum program is suggested, assuming adequate laboratory facilities, personnel, and size of the system.

SUGGESTED ANALYSIS	USUAL RANGE	TYPICAL REMOVAL %
Settling Area		
Settleable Solids	3.0 - 10.0 ml/l	75 - 90
Suspended Solids	200 - 400 mg/l	45 - 65
pH	6.7 - 7.3	
Alkalinity	100 - 300 mg/l	
BOD	200 - 500 mg/l	25 - 35
Digestion Area		
pH	6.7 - 7.3	
Alkalinity	1000 - 3000 mg/l	
Vol. Acids	100 - 500 mg/l	

Efficiency of operation can be determined by measuring the settleable solids, suspended solids, or BOD of the influent and effluent.

QUESTIONS

5.8A What are the two components of an Imhoff tank?

5.8B Describe the sludge from an Imhoff tank which is operating properly.

5.8C How could you maintain a fairly level sludge blanket in the digester portion of an Imhoff tank?

5.8D How can you force settled material into the digestion compartment?

5.9 SEPTIC TANKS

Septic tanks are used mostly for treating the wastewater from individual homes or from small populations (such as camps) where sewers have not been provided. They operate very much ~~like an~~ Imhoff tank except there is not a separate digestion compartment. Detention time is usually long (12 to 24 hours) and most settleable solids will remain in the tank. They must be pumped out and disposed of periodically to prevent the tank from filling up. Part of the solids in the septic tank are liquified and discharged with the wastewater into the soil mantle. Conditions are not favorable for rapid gasification and most waste stabilization occurs in the soil.

Septic tank effluent is usually disposed of in underground perforated pipes called "leach lines", and sampling of effluent may be impossible. The ability of the soil mantle to leach the septic tank effluent is the critical factor in subsurface waste disposal systems.

For additional information on septic tanks, refer to the Manual of Septic Tank Practice, U.S. Public Health Service, Washington, D.C.

CHAPTER 6. TRICKLING FILTERS

(Lesson 1 of 3 Lessons)

6.0 INTRODUCTION

6.00 General Description

In the initial chapters of this course, you have learned about physical methods of wastewater treatment. In general, these techniques (processes) consist of the screening of large particles, settling of heavy material, and floating of light material by preliminary and primary treatment units (screen, grit chamber, clarifier). Although primary treatment is very efficient for removing settleable solids, it is not capable of removing other, lighter suspended solids or dissolved solids which may exert a strong oxygen demand on the receiving waters.

In order to remove the very small suspended solids (colloids) and dissolved solids, most waste treatment plants now being built include "secondary treatment".[1] This additional process increases overall plant removal of suspended solids and BOD to 90% or more. The two most common secondary treatment processes are trickling filters and activated sludge. This chapter will deal with trickling filters.[2]

[1] Secondary treatment. A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated.

[2] Trickling filters are sometimes called biofilters, accelo filters, or aero-filters, depending on the recirculation pattern.

Figures 6.1 and 6.2 show where a trickling filter is usually located in a plant.

More trickling filters have been built in this country than any other type of secondary treatment device. Most trickling filters are large in diameter, shallow, cylindrical structures filled with stone and having an overhead distributor. (See Fig. 6.3.) Many variations of this design have been built. Square or rectangular filters have been constructed with fixed sprinklers for wastewater distribution.

6.01 Principles of Treatment Process

Trickling filters, or biological oxidation beds, consist of three basic parts:

1. The media (and retaining structure)
2. The underdrain system
3. The distribution system

The media provide a large surface area upon which a biological slime growth develops. This slime growth, sometimes called a zoogleal film,[3] contains the living organisms that break down the organic material. The media may be rock, slag, coal, bricks, redwood blocks, molded plastic, or any other sound, durable material. The media should be of such sizes and stacked in such a fashion to provide voids for air to ventilate the filter and keep conditions aerobic. For rock, the size will usually be from about two inches to four inches. Although actual size is not too critical, it is important that the media be uniform in size to permit adequate ventilation. The depth ranges from about three to eight feet.

The underdrain system has a sloping bottom, leading to a center channel, which collects the filter effluent. It also supports the media and permits air flow. Common methods are the use of spaced redwood stringers, or any of a number of prefabricated blocks of concrete, vitrified clay, or other material.

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[3] Zoogleal Film (ZOE-glee-al). A complex population of organisms that form a slime growth on the trickling filter media and break down the organic matter in the wastewater. These slimes consist of living organisms, silt, and other debris. Slime growth is a more common definition.

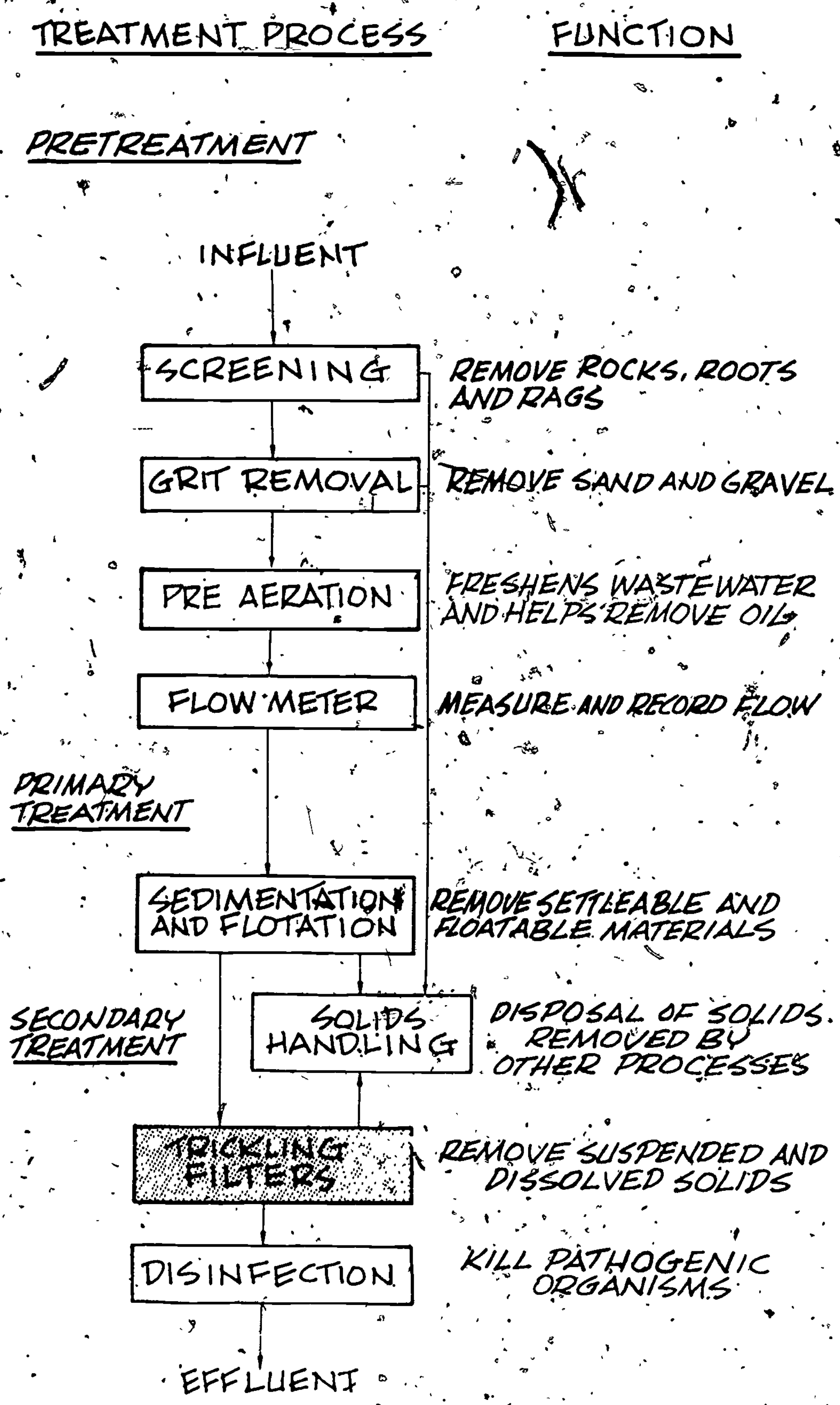


Fig. 6.1 Flow diagram of treatment plant

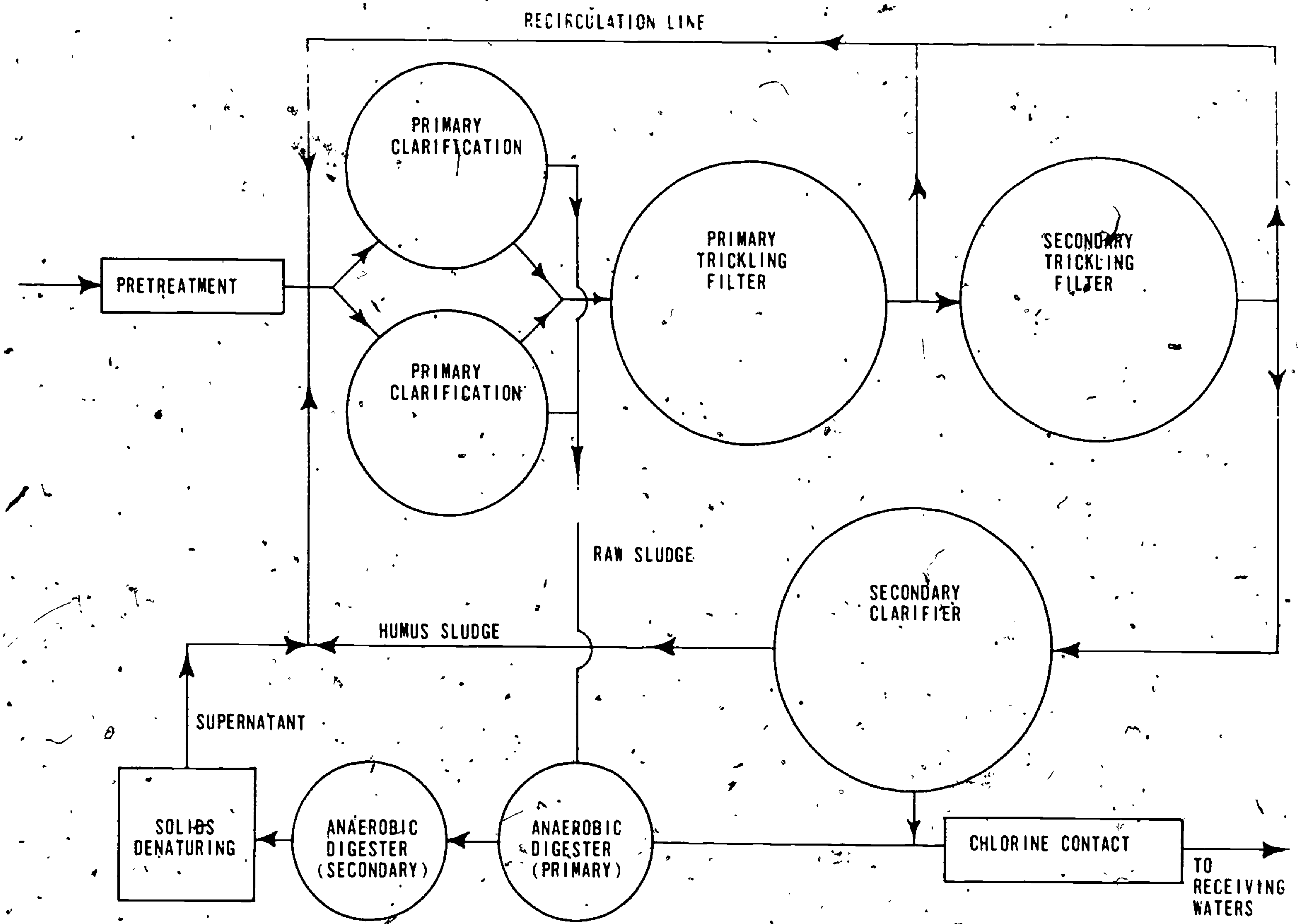


Fig. 6.2 Plan to typical trickling filter plant

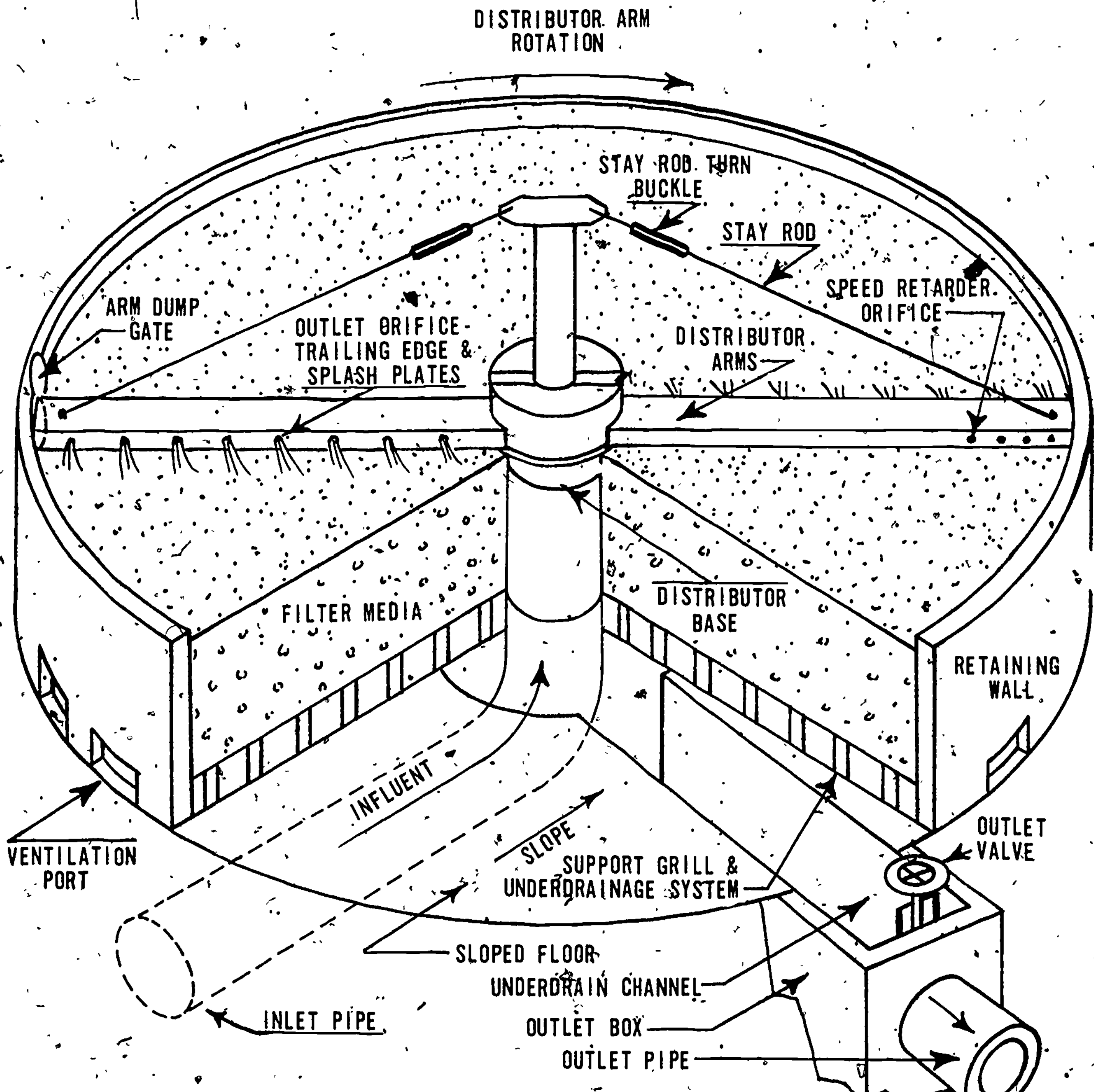


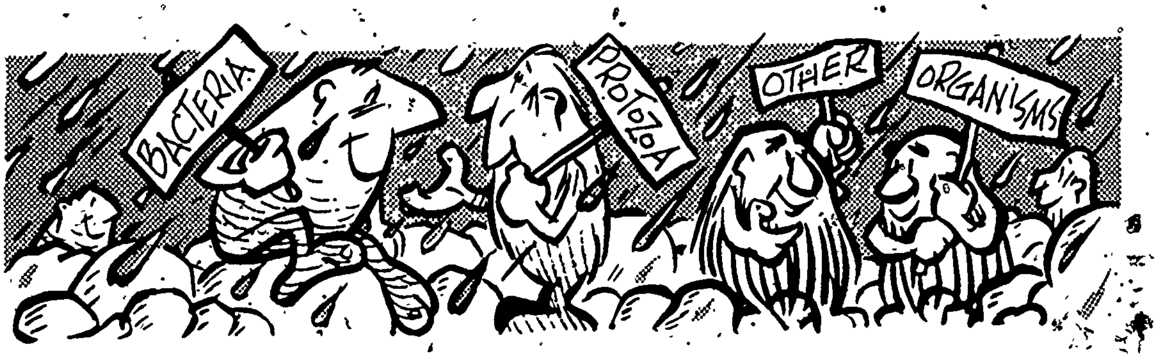
Fig. 6.3 Trickling filter

The distribution system, in the vast majority of cases, is a rotary-type distributor which consists of two or more horizontal pipes supported a few inches above the filter media by a central column. The wastewater is fed from the column through the horizontal pipes and is distributed over the media through orifices located along one side of each of these pipes (or arms). Rotation of the arms is due either to the "jet-like" or rotating water sprinkler reaction from wastewater flowing out the orifices or by some mechanical means. The distributors are equipped with a mercury or mechanical type seal at the center column to prevent leakage and protect the bearings, guy rods for seasonal adjustment of the pipes (arms) to maintain them in a horizontal position, and quick-opening gates at the end of each arm to permit easy flushing.

Today the fixed nozzle distribution system is not as common as the rotary type. Each fixed nozzle consists of a circular orifice with an inverted cone-shaped deflector mounted above the center which breaks the flow into a spray. Some types have a steel ball in the inverted cone. (See Fig. 6.5.) The fixed nozzle system requires an elaborate piping system to insure relatively even distribution of the wastewater. Flow is usually intermittent and is controlled by automatic siphons which regulate the flow from dosing tanks. (See Fig. 6.5.) The nozzles extend six to twelve inches above the media and are shaped so that an overlapping spray pattern exists at the start of dosing when the head in the dosing tank is the greatest. The pattern is carefully worked out to provide a relatively even distribution of the wastewater.

6.02 Principles of Operation

The maintenance of a good growth of organisms on the filter media is crucial to successful operation.



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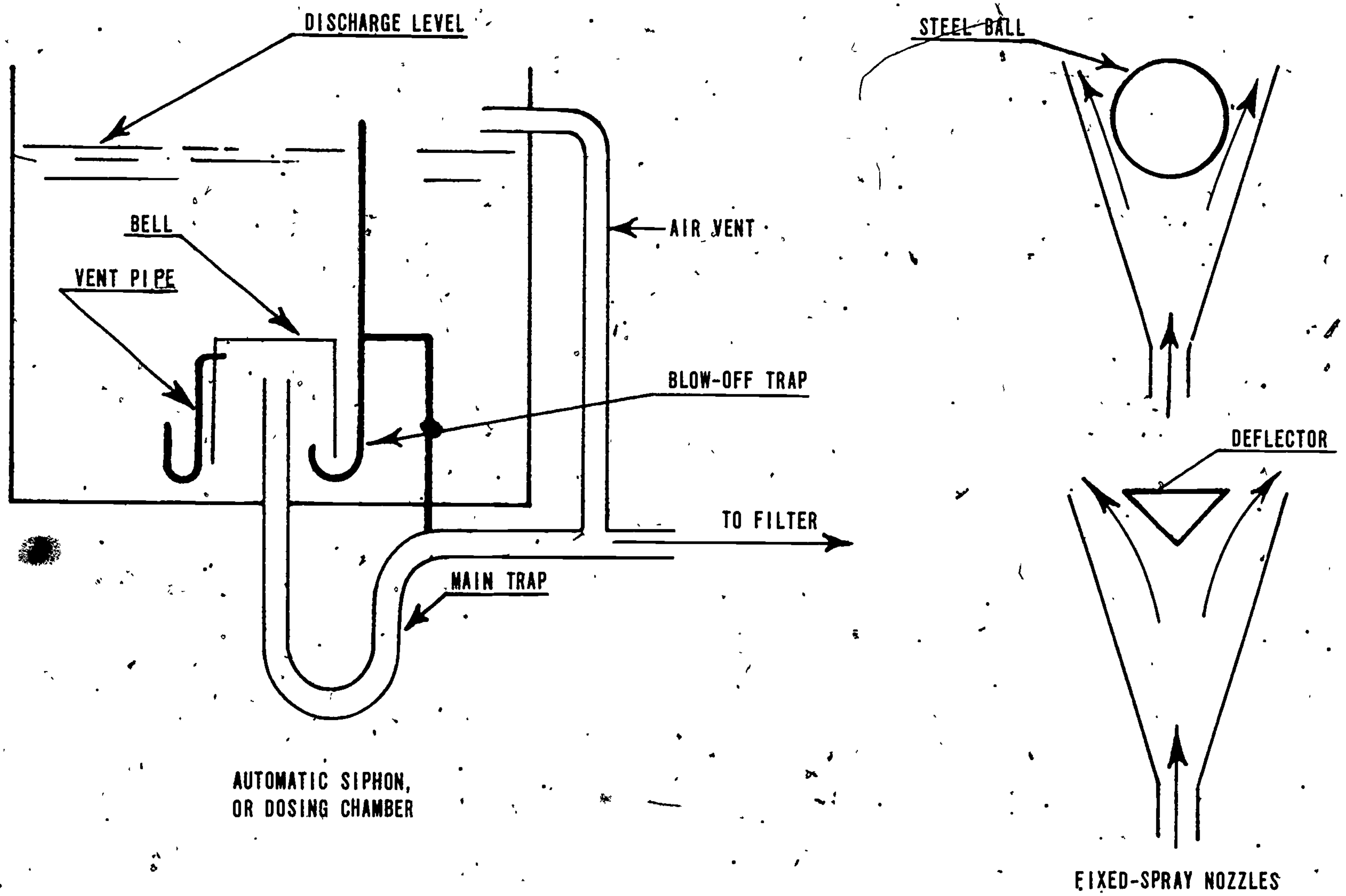


Fig. 6.5 Siphon and nozzle details for fixed spray filters

The term "filter" is rather misleading, indicating that solids are separated from liquid by a straining action, but this is not the case. Passage of wastewater through the filter causes the development of a gelatinous coating of bacteria, protozoa, and other organisms on the media. This growth of organisms absorbs and utilizes much of the suspended colloidal and dissolved organic matter from the wastewater as it passes over the growth in a rather thin film. Part of this material is utilized as food for production of new cells, while another portion is oxidized to carbon dioxide and water. Partially decomposed organic matter together with excess and dead film is continuously or periodically washed (sloughed) off and passes from the filter with the effluent.

For the oxidation (decomposition) processes to be carried out, the biological film requires a continuous supply of dissolved oxygen, which may be absorbed from the air circulating through the filter voids (spaces between the rocks or other media). Adequate ventilation of the filter must be provided; therefore the voids in the filter media must be kept open. Clogged voids can create operational problems, including ponding and reduction in overall filter efficiency.

A method of increasing the efficiency of trickling filters is to add recirculation. Recirculation is a process in which filter effluent is recycled and brought into contact with the biological film more than once. Recycling of filter effluent increases the contact time with the biological film and helps to seed the lower portions of the filter with active organisms. Due to the increased flow rate per unit of area, higher velocities occur which tend to cause more continuous and uniform sloughing of excess growths, thus preventing ponding and restriction of ventilation. This increased hydraulic loading also decreases the opportunity for snail and filter fly breeding. It has been observed that the thickness of the biological growth is directly related to the organic strength of the wastewater (the higher BOD, the thicker the layers of organisms). By the use of recirculation, the strength of wastewater applied to the filter can be diluted, thus preventing excessive build-up.

Recirculation may be constant or intermittent and at a steady or fluctuating rate. Recycling may be practiced only during periods of low flow to keep rotary distributors in motion, to prevent drying of the filter growths, or to prevent freezing. Recirculation in proportion to flow may be utilized to reduce the strength of the wastewater applied to the filter while steady recirculation of a constant amount keeps the distributors in operation and also tends to even out the highs and lows of organic loading, but involves higher pumping costs.

It is generally agreed that any organic waste which can be successfully treated by other aerobic biological processes can be treated on trickling filters. This includes, in addition to domestic wastewater, such wastewaters as might come from food processing, textile and fermentation industries, and certain pharmaceutical processes. Industrial wastewaters which cannot be treated are those which contain excessive concentrations of toxic materials, such as pesticide residues, heavy metals, and highly acidic or alkaline wastes.

For maximum efficiency, the slime growths on the filter media should be kept fairly aerobic. This can be accomplished by proper design of the wastewater collection system and proper operation of primary clarifiers, or by pretreatment of the wastewater by aeration or addition of recycled filter effluent. The air supply to the slimes may be improved by increased air or wastewater recirculation. The thin slime growth may be aerobic on the surface, but anaerobic next to the media. A trickling filter media of rock or slag can accumulate slimes only on the outside surface, but manufactured media provides considerably more surface area per unit of dead space.

The temperature of the wastewater and of the climate also affects filter operation, with temperature of the wastewater being the more important. Of course, temperature of the wastewater will vary with the weather. Within limits, activity of the organisms increases as the temperature rises. Therefore, higher loadings and greater efficiency are possible in warmer climates if aerobic conditions can be reasonably maintained in the filter.

6.12 Daily Operation

Once growth on the media has been established and the plant is in "normal operation", very little routine operational control is required. Careful daily observation is important. Items to be checked daily are:

1. Any indication of ponding
2. Filter flies
3. Odors
4. Plugged orifices
5. Roughness or vibration of the distributor arms
6. Leakage past the mercury seal

Occasionally the underdrains should be checked for accumulation of debris in order to prevent stoppages.

Refer to the appropriate paragraphs in the following section on operational problems for procedures to correct these conditions.

Operation of clarifiers is interconnected with trickling filter operation. If the recirculation pattern permits, it is a good idea to return filter effluent to the primary clarifier. This is a very effective odor control measure. In some plants, increasing the recirculation rate will increase the hydraulic loading on the clarifier. Be sure the hydraulic loading remains within the engineering design limits. If the hydraulic loading is too low, septic conditions may develop in the clarifier, while excessively high loadings may wash solids out of the clarifier.

Recirculation during low inflow periods of the day and night may help to keep the slime growths wet, minimize fly development and wash off excessive slime growths. It may be necessary to reduce or stop recirculation during high flow periods to avoid clarifier problems from hydraulic overloading. Recirculation of final clarifier effluent dilutes influent wastewater and recirculated sludge improves slime development on the media.

You should, by evaluating your own operating records, adjust the process to obtain the best possible results for the least cost. Use the lowest recirculation rates that will yield good results (but not cause ponding or other problems) to conserve power. Power costs are a large item in a plant budget. Also, reduced hydraulic loadings mean better settling in the clarifiers, resulting in less chlorine usage in plants which disinfect the final effluent, since organic matter exerts a high chlorine demand. If filter effluent, rather than secondary clarifier effluent, is recirculated, the hydraulic loading on the secondary clarifier is not affected.

6.2 SAMPLING AND ANALYSIS

6.20 General

The trickling filter is a biological treatment unit and therefore loadings and efficiencies of the unit are normally determined on the basis of influent characteristics (inflow and biochemical oxygen demand (BOD) test) and required quality of effluent or receiving waters (dissolved oxygen and solids).

The frequency of each test and expected ranges will vary from plant to plant. Strength of the wastewater, freshness, characteristics of the water supply, weather, and industrial wastes will all serve to affect the "common" range of the various test results.

6.21 Typical Trickling Filter Plant Lab Results

	Test	Frequency	Location	Common Range
1.	Dissolved Oxygen	Daily	Prim. Effl.	1.0 - 2.0 mg/l
2.	Settleable Solids	Daily	Influent	5 - 15 ml/l
3.	pH	Daily	Influent Final Effl.	6.8 - 8.0 7.0 - 8.5
4.	Temperature	Daily	Influent	---
5.	BOD	Weekly (Minimum)	Influent Prim. Effl. Final Effl.	150 - 400 mg/l 60 - 160 mg/l 15 - 40 mg/l
6.	Suspended Solids	Weekly (Minimum)	Influent Prim. Effl. Final Effl.	150 - 400 mg/l 60 - 150 mg/l 15 - 40 mg/l
7.	Chlorine Residual	Daily	Final Effl.	0.5 - 2.0 mg/l
8.	Coliform Bacteria	Weekly (Minimum)	Final Effl., Chlorinated	50 - 700/100 ml ---
9.	Clarity	Daily	Final Effl.	1 - 3 ft

NOTES: Results of tests listed on the previous page as "Primary Effluent" may vary at different plants due to the many variations in recirculation patterns and activities of the waste dischargers into the collection system.

Settleable solids tests of the effluent may be required by some regulatory agencies. If your plant is operating efficiently, the settleable solids will be so low as to be unreadable. In this case, record as "Trace".

Dissolved Oxygen and Settleable Solids or Clarity Tests on trickling filter effluent are sometimes useful in evaluating problems when they occur. The operator should know what range is "common" for his plant.

An easy test that should be made periodically by the operator is to check the distribution of wastewater over the filter. Pans of the same size are placed level with the rock surface at several points along the radius of a circular filter. The distributor arm should then be run long enough to almost fill the pans. The arm is then stopped and the amount or depth of water in each pan is measured. The amount in each pan should not differ from the average by more than 5%. If the distribution is not uniform, the orifices must be adjusted.

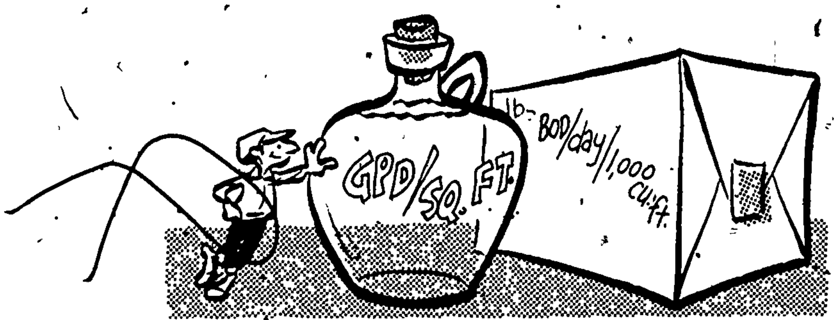
CHAPTER 6. TRICKLING FILTERS

(Lesson 3 of 3 Lessons)

6.6 CLASSIFICATION OF FILTERS

6.60 General

Depending upon the hydraulic and organic loadings applied, filters are classified as standard-rate, high-rate, or roughing filters. Further designations, such as single-stage, two-stage, series or parallel, and others are used to indicate the flow pattern of the plant. The hydraulic loading applied to a filter is the total volume of liquid, including recirculation, expressed as gallons per day per square foot of filter surface area (gpd/sq ft). The organic loading is expressed as the pounds of BOD applied per day per 1000 cubic feet of filter media (lbs BOD/day/1000 cu ft). Where recirculation is used, an additional organic loading will be placed on the filter; however, this added loading is omitted in most calculations because it was included in the influent load.



6.61 Standard-Rate Filters

The standard-rate filter is operated with hydraulic loading range of 25 to 100 gals/day/sq ft, and an organic BOD loading of 5 to 25 lbs/day/1000 cu ft. The filter media is usually 6 to 8 feet in depth, with application to the filter by a rotating distributor, although many are equipped to provide some recirculation during low flow periods.

The filter growth is often heavy and in addition to the bacteria and protozoa[10] many types of worms, snails, and insect larvae can be found.

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[10] Protozoa (pro-toe-ZOE-ah). A group of microscopic animals, principally of one cell, that sometimes cluster into colonies.

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The growth usually sloughs off at intervals, noticeably in spring and fall. The effluent from a standard-rate filter treating municipal wastewater is usually quite stable with BODs as low as 20 to 25 mg/l.

6.62 High-Rate Filters

High-rate filters were the result of trying to reduce costs associated with standard-rate filters or attempting to treat increased wasteloads with the same facility. Studies indicated that essentially the same BOD reductions could be obtained at the higher design loadings.

High-rate filters are normally 3 to 5 feet deep with recommended loadings being 100 to 1000 gal/day/sq ft and 25 to 300 lbs BOD/day/1000 cu ft. These filters are designed to receive wastewater continually, and practically all high-rate installations utilize recirculation.

Due to the heavy flow of wastewater over the media, more uniform sloughing of the filter growths occurs. This sloughed material is somewhat lighter than from a standard-rate unit and therefore more difficult to settle. Effluent with BODs as low as 20 to 50 mg/l is sometimes produced by plants treating municipal wastewater.

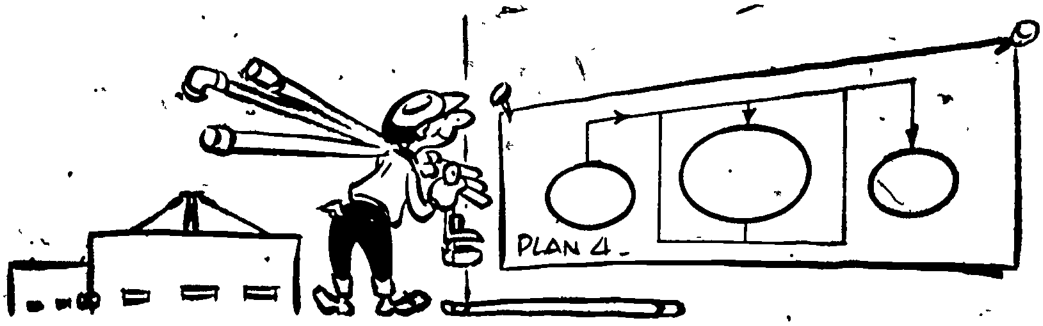
6.63 Roughing Filter

A roughing filter is actually a high-rate filter receiving a very high organic loading. Any filter receiving an organic loading of over 300 lbs of BOD/day/1000 cu ft of media is considered to be in this class. This type of filter is used primarily to reduce the organic load on subsequent oxidation processes such as a second-stage filter or activated sludge process. Many times they are used in plants which receive strong organic industrial wastes. They are also used where an intermediate (50-70% BOD removal) degree of treatment is satisfactory.

Operation of the filter is basically the same as for the high-rate filters with recirculation. Overall BOD reductions are much lower, but reductions per unit volume of filter media are greater.

6.64 Filter Staging

Fig. 6.7 shows various filter and clarifier layouts. The decision as to the number of filters (or stages) required is one of design rather than operation. In general, however, at smaller plants



where the flow is fairly low, the strength of the raw wastewater is average, and effluent quality requirements are not too strict, a single-stage plant (one filter) is often sufficient and most economical. In slightly overloaded plants the addition of some recirculation capability can sometimes improve the effluent quality enough to meet receiving water standards without the necessity of adding more stages.

In two-stage filter plants, two filters are operated in a series. Sometimes a secondary clarifier is installed between the two filters. Recirculation is almost universally practiced at two-stage plants with many different arrangements being possible. Choice of recirculation scheme used is based on consideration of which arrangement produces the best effluent under the particular conditions of wastewater strength and other characteristics. (See Fig. 6.7.)

QUESTIONS

6.6A What are the three general classifications of trickling filters?

6.6B What are the principal differences between standard-rate and high-rate filters?

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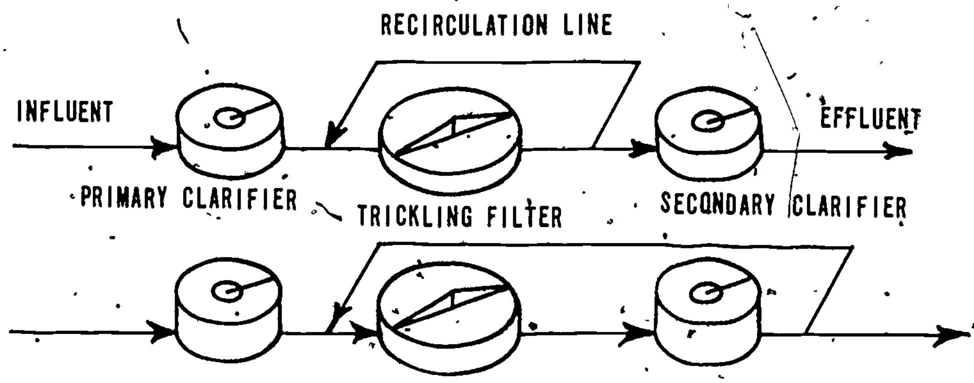
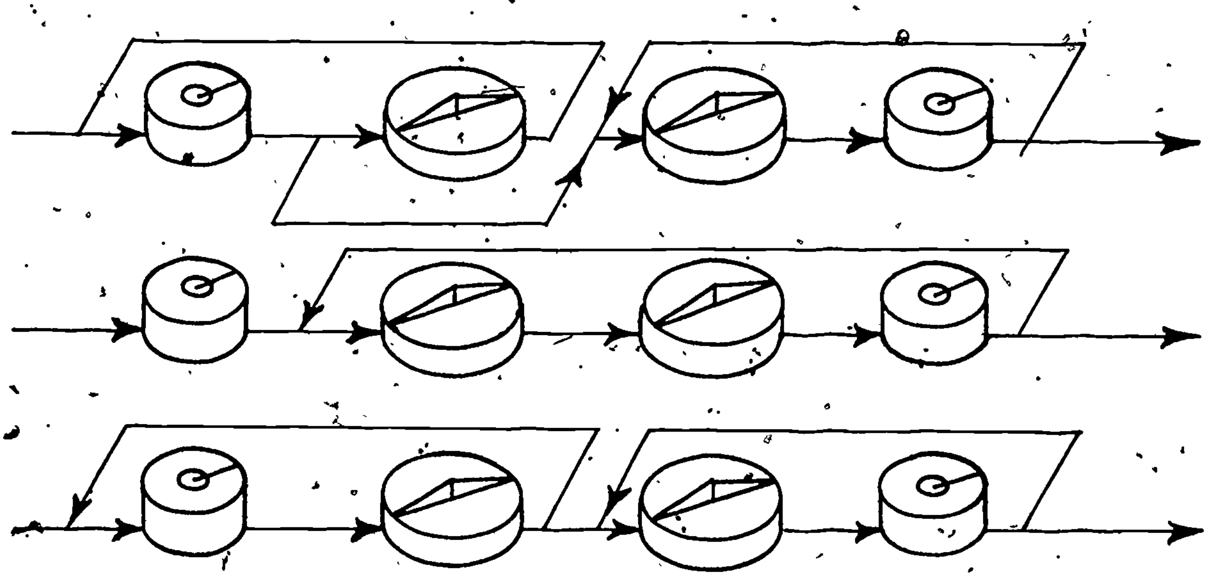


Typical Single-Stage Recirculation Patterns



Typical Two-Stage Recirculation Patterns

Fig. 6.7 Trickling filter recirculation patterns

6.7 LOADING PARAMETERS

6.70 Typical Loading Rates

STANDARD-RATE FILTER:

Media	- 6 to 8 ft depth, growth sloughs periodically.
Hydraulic Loading	- 25 to 100 gal/day/sq ft
Organic (BOD) Loading	- 5 to 25 lbs BOD/1000 cu ft

HIGH-RATE FILTER:

Media	- 3 to 5 ft depth, growth sloughs continually
Hydraulic Loading	- 100 to 1000 gal/day/sq ft
Organic (BOD) Loading	- 25 to 300 lbs BOD/1000 cu ft

6.71 Computing Hydraulic Loading

In computing hydraulic loadings, several bits of information must be gathered. To figure the hydraulic loading, we must know:

1. The gallons per day applied to the filter, and
2. The surface area of the filter.

NOTE: Hydraulic loadings are expressed as:

gal/sq ft/day,[11] or

gal/day/sq ft = gpd/sq ft.[11]

Both expressions mean the same. The hydraulic rate indicates the number of gallons of wastewater per day applied to each square foot of surface area or the gallons of water applied to each square foot each day.

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[11] Loadings as well as test results should always be presented using the same units. Theoretically a rate should have the time unit last (gal/sq ft/day); however, because flows are calculated as gal/day, it is easier to understand if loadings are reported as gal/day/sq ft. The Water Pollution Control Federation's MOP No. 6, *Units of Expression for Wastes and Waste Treatment*, uses both terms.

Suppose we have a high-rate filter that is fed by a pump rated at 2100 gpm, and the filter diameter is 100 feet.

$$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Surface Area, sq ft}}$$

For our problem, we must obtain the flow rate in gpd and surface area[12] in square feet or ft^2.

(a) $$\text{Flow Rate, gpd} = 2100\ \frac{\text{gal}}{\text{min}} \times \frac{60\ \text{min}}{\text{hr}} \times \frac{24\ \text{hrs}}{\text{day}}$$

$$= 3{,}024{,}000\ \text{gal/day}$$

(b) $$\text{Surface Area, sq ft} = 0.785 \times (\text{Diameter, ft})^2$$

$$= 0.785 \times 100\ \text{ft} \times 100\ \text{ft}$$

$$= 7850\ \text{sq ft}$$

(c) $$\text{Hydraulic Loading, gpd/sq ft} = \frac{\text{Flow Rate, gpd}}{\text{Surface Area, sq ft}}$$

$$= \frac{3{,}024{,}000\ \text{gpd}}{7850\ \text{sq ft}}$$

$$= 385\ \text{gpd/sq ft}$$

$$\begin{array}{r|l} & 385 \\ \hline 7850 & 3{,}024{,}000. \\ & 2\ 355\ 0 \\ \hline & 669\ 00 \\ & 628\ 00 \\ \hline & 41\ 000 \\ & 39\ 250 \\ \hline & 1\ 750 \end{array}$$

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[12] $$\text{Area of a Circle, sq ft} = \underline{0.785} \times \underline{\text{Diameter, ft}} \times \underline{\text{Diameter, ft}},\ \text{or}$$

$$= 0.785\ D^2$$

It is important to note in computing hydraulic loadings that when filter effluent is recirculated to the filter influent, recirculated flow must be added to the primary clarifier effluent flow in order to calculate the total hydraulic loading. When filter effluent is recirculated ~~to the~~ primary clarifier influent, recirculated flow must be added to the clarifier influent flow.

6.72 Computing Organic (BOD) Loading

Using the same filter as in the above example of hydraulic loading, assume that the laboratory test results show that the wastewater being applied to the filter has a BOD of 100 mg/l. We need to know the pounds of BOD applied per day and the volume of the media in cu ft.

NOTE: Organic (BOD) loadings are expressed as:

lbs BOD/1000 cu ft/day, or

lbs BOD/day/1000 cu ft.

Both expressions mean the same. The organic loading indicates the pounds of BOD applied per day to the volume of filter media for treatment.

$$\text{Organic (BOD) Loading, lbs BOD/day/1000 cu ft} = \frac{\text{BOD Applied, lbs/day}}{\text{Volume of Media in 1000 cu ft}}$$

To solve this problem we must first calculate the BOD applied in lbs/day and volume of media in cu ft.

$$\begin{aligned}\text{Volume of Media, cu ft} &= \text{(Surface Area, sq ft) (Depth, ft)}\\ &= \text{(7850 sq ft) (3 ft)}\\ &= \text{23,550 cu ft}\end{aligned}$$

$$\begin{aligned}\text{Volume of Media, in 1000 cu ft} &= \text{23.5 (1000 cu ft units)}\\ &= \text{23.5 thousand cubic feet}\end{aligned}$$

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$$\text{BOD Applied, lbs/day} = (\text{BOD, mg/l})\ (\text{Flow, MGD})\ (8.34\ \text{lb/gal})$$ [13]

$$= \frac{100\ \text{mg}}{\text{M mg}} \times 3{,}024\ \frac{\text{M gal}}{\text{day}} \times \frac{8.34\ \text{lb}}{\text{gal}}$$

$$= 2522\ \text{lbs BOD/day}$$

$$\begin{array}{r} 3.024 \\ \underline{8.34} \\ 12096 \\ 9072 \\ \underline{24192} \\ 25.22016 \end{array}$$

$$\text{Organic BOD Loading, lbs BOD/day/1000 cu ft} = \frac{\text{BOD Applied, lbs BOD/day}}{\text{Volume of Media (in 1000 cu ft)}}$$

$$= \frac{2522\ \text{lbs BOD/day}}{23.5\ (1000\ \text{cu ft})}$$

$$= 107\ \text{lbs BOD/day/1000 cu ft}$$

$$\begin{array}{r} 107. \\ 23.5\ \overline{)\,2522.0} \\ \underline{235} \\ 172\ 0 \\ 164\ 5 \end{array}$$

In computing BOD loadings, it is standard practice to ignore the BOD of the recirculated effluent, where recirculation is used. To attempt to perform this calculation (using the recirculated load) is complicated and makes it difficult to compare your loadings and resulting effluent quality with other plants.

---

[13] The units of this formula can be proved by remembering that one liter equals one million milligrams.

$$\frac{\text{mg}}{\text{L}} = \frac{\text{mg}}{1{,}000{,}000\ \text{mg}} = \frac{\text{mg}}{\text{M mg}}$$

Therefore,

$$\frac{\text{mg}}{\text{L}}\ \text{BOD} \times \text{MGD} \times 8.34\ \frac{\text{lb}}{\text{gal}} = \frac{\text{mg BOD}}{\text{M mg}} \times \frac{\text{M gal}}{\text{day}} \times \frac{\text{lb}}{\text{gal}} = \text{lb BOD/day.}$$

CHAPTER 7. ACTIVATED SLUDGE

(Lesson 1 of 8 Lessons)

7.0 INTRODUCTION

7.00 General

When wastewater enters an activated sludge plant, the pretreatment processes (Chapter 4) remove the coarse or heavy solids (grit) and other debris, such as roots, rags, and boards. Primary clarifiers (Chapter 5) remove much of the floatable and settleable material. Normally settled wastewater is treated by the activated sludge process, but in some plants the raw wastewater flows from the pre-treatment processes directly to the activated sludge process.

7.01 Definitions

ACTIVATED SLUDGE (Fig. 7.1). Activated sludge consists of sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms in aeration tanks in the presence of dissolved oxygen. The term "activated" comes from the fact that the particles are teaming with bacteria, fungi, and protozoa.

ACTIVATED SLUDGE PROCESS (Fig. 7.1). The term activated-sludge process refers to a method or process of wastewater treatment. In this treatment process there is maintained a biological culture consisting of a large number of organisms. All of them require food (wastewater or substrate) and oxygen to make the process work. The bacterial population is maintained at some mass (solids concentration)[1] to balance the food available from the wastewater for the microorganisms[2] (food/microorganism ratio) with the oxygen input capability of the plant equipment.

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[1] Solids Concentration. The solids in the aeration tank carry bacteria that feed on wastewater.

[2] Microorganisms. Very small organisms that can be seen only through a microscope. Some microorganisms use the wastes in wastewater for food and thus remove or alter much of the undesirable matter.

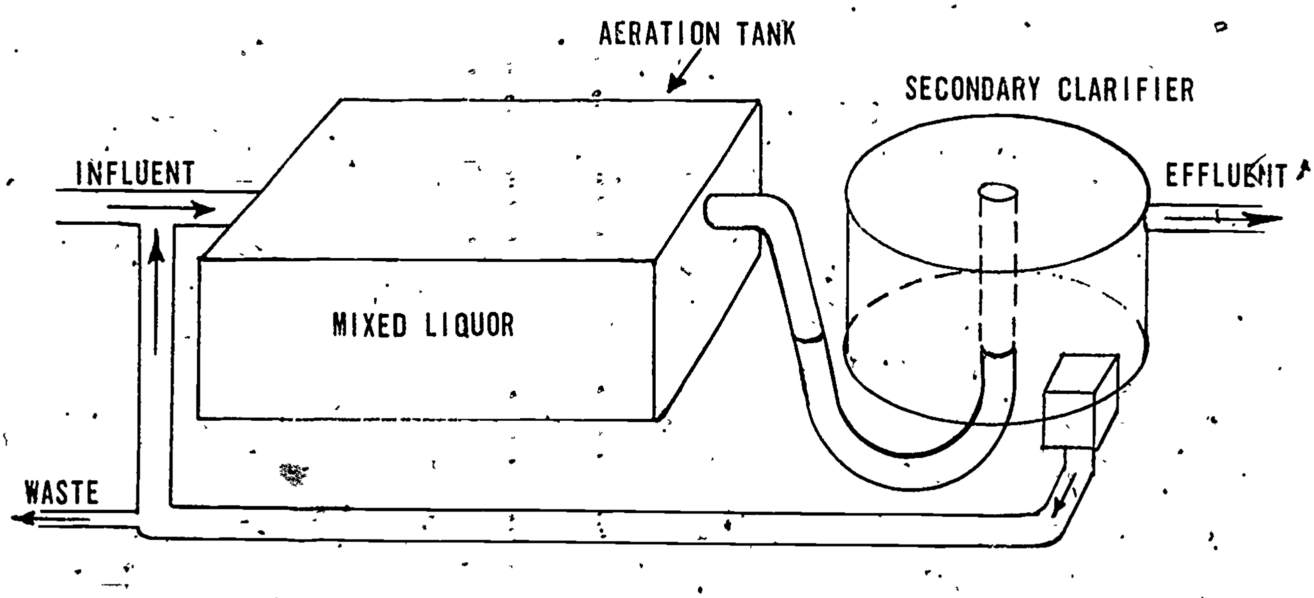
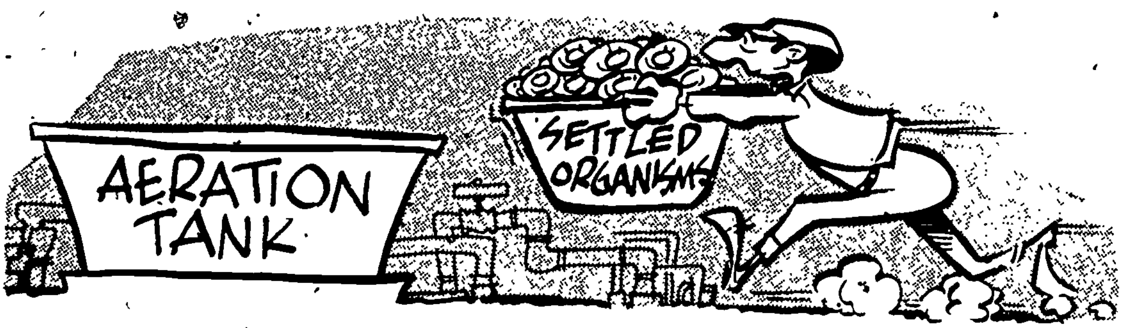


Fig. 7.1 Activated sludge and activated sludge process

7.02 Process Description

Secondary treatment in the form of the activated sludge process (Figs. 7.2 and 7.3) is aimed at oxidation and removal of soluble or finely divided suspended materials that were not removed by previous treatment. This is accomplished in an aeration tank by aerobic organisms within a few hours when the water is being treated while it flows through the tank. Soluble or finely divided suspended solids are intended to be stabilized[3] in the aeration tank by partial oxidation to form carbon dioxide, water, sulfates, and nitrates. Remaining solids are intended to be converted to a form where they can be settled and removed as sludge during clarification.



After the aeration period the wastewater is routed to a secondary settling tank for a liquid-organism (water-solids) separation. Settled organisms are quickly returned back to the aeration tank. The resultant clarifier effluent is usually chlorinated and discharged from the plant.

Conversion of dissolved and suspended material to settleable solids is the main objective of high-rate activated sludge processes, while low-rate processes stress oxidation. The oxidation may be by chemical or biological processes. In the activated sludge process, the biochemical oxidation carried out by living organisms is stressed. The same organisms also are effective in conversion of substances to settleable solids if the plant is operated properly.

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

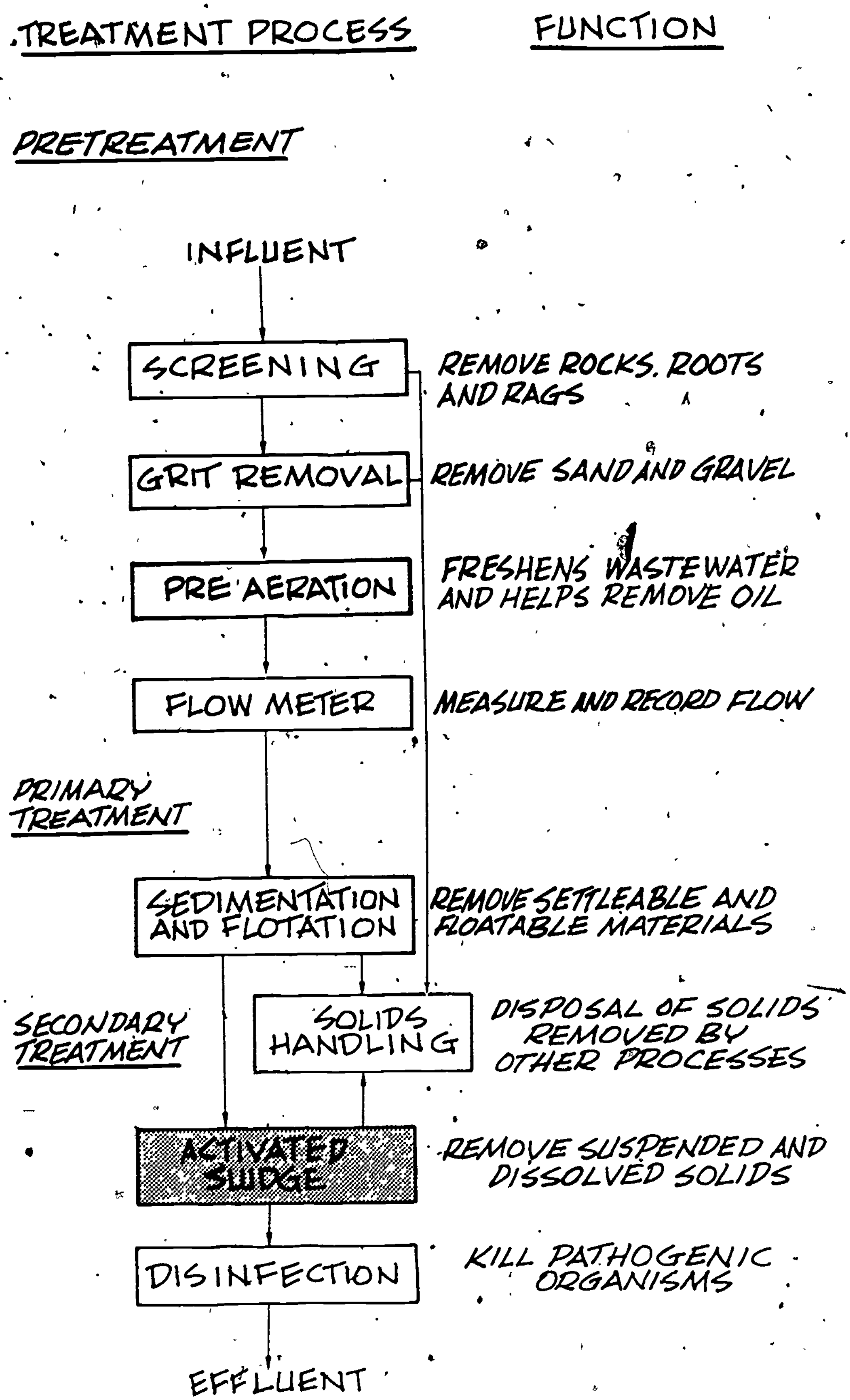


Fig. 7.2 Flow diagram of a typical plant

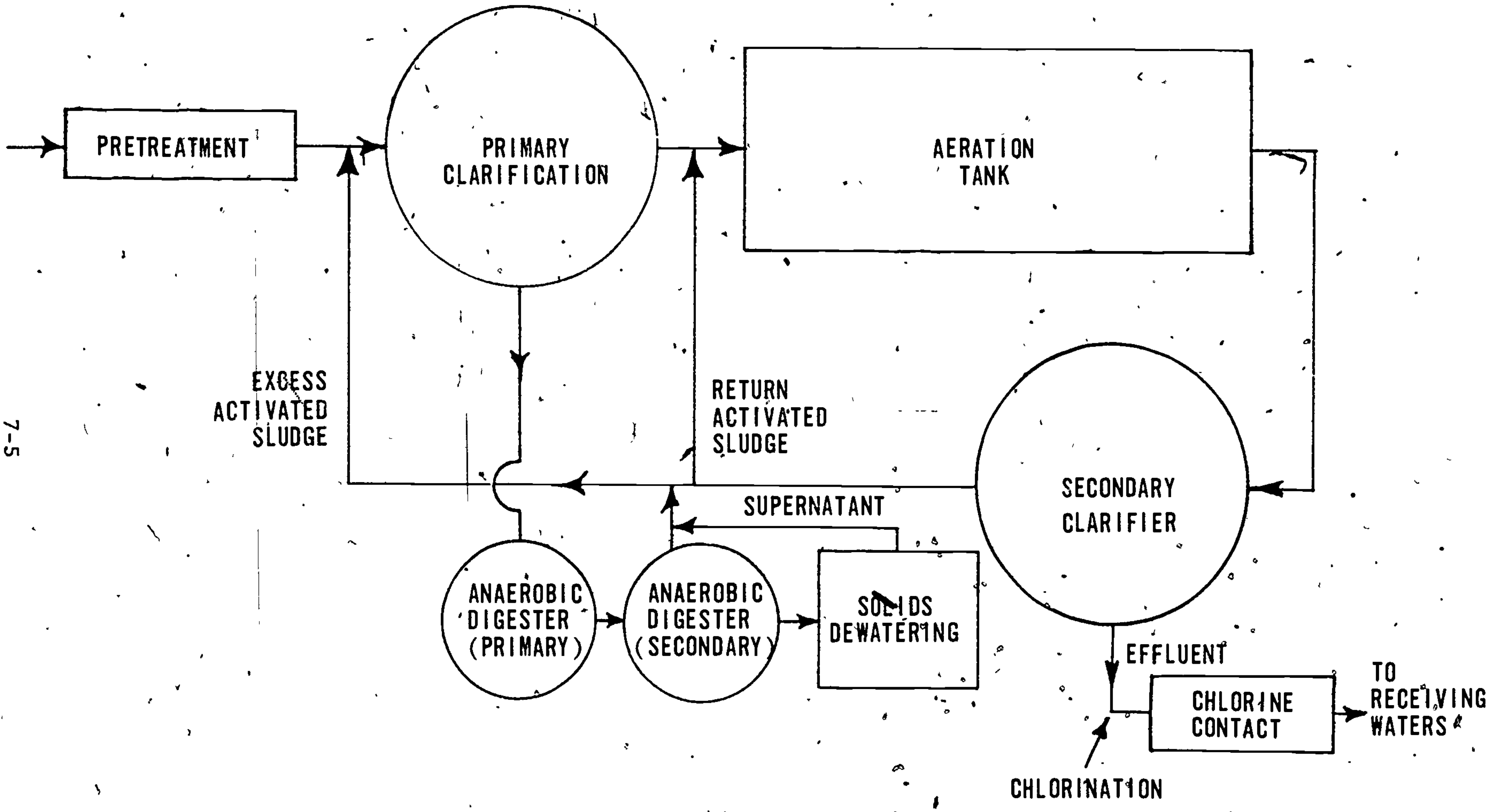


Fig. 7.3 Plan layout of a typical activated sludge plant

7.1 REQUIREMENTS FOR CONTROL

Control of the activated sludge process is based on evaluation of and action upon several interrelated factors to favor effective treatment of the influent wastewater. These factors include:

1. Effluent quality requirements.
2. Wastewater flow, concentration, and characteristics of the wastewater received.
3. Amount of activated sludge (containing the working organisms) to be maintained in the process relative to inflow.
4. Amount of oxygen required to stabilize wastewater oxygen demands and to maintain a satisfactory level of dissolved oxygen to meet organism requirements.
5. Equal division of plant flow and waste load between duplicate treatment units (two or more clarifiers or aeration tanks).
6. Transfer of the pollutional material (food) from the wastewater to the floc mass (solids or workers) and separation of the solids from the treated wastewater.
7. Effective control and disposal of inplant residues (solids, scums, and supernatants) to accomplish ultimate disposal in a nonpollutional manner.
8. Provisions for maintaining a suitable environment for the work force of living organisms treating the wastes. Keep them healthy and happy.

Effluent quality requirements may be stated by your regularoty agency in terms of percentage removal of wastes. Current regulations frequently specify allowable quantities of wastes that may be discharged. These quantities are based upon flow and concentrations of significant items such as solids, oxygen demand, coliform bacteria, nitrogen, and oil as specified by your regulatory agencies.

The effluent quality requirements largely determine the mode of activated sludge operation and the degree of control required. For example, if an effluent containing 50 mg/l of suspended solids and BOD (refers to five-day BOD) is satisfactory, a high-rate activated sludge process is likely to be applicable. If the limit

is 10 mg/l, the high-rate process would not be suitable. If a high degree of treatment is required, very close process control and additional treatment after the activated sludge process may be needed.

Flow concentrations and characteristics of the influent are subject to limited control by the operator. Municipal ordinances may prohibit discharge to the collection system of materials significantly damaging to treatment structures or safety. Control over wastes dumped into the collection system requires inspection to insure compliance. It may be necessary to require alternate means of disposal, pretreatment, or controlled discharge of significantly damaging items to permit dilution to an acceptable level by the time the waste arrives at the treatment plant.

The material entering the aeration tanks is mixed with the activated sludge to form a mixture of sludge, carrier water, and influent solids. These solids come from roofs or streets in combined sewer systems and also from the discharges from homes, factories, and businesses. Included in the return sludge solids are many different types of helpful living organisms that were grown during previous contact with wastewater. These organisms are the workers in the treatment process. They use the incoming wastes for food and as a source of energy for their life processes and for the reproduction of more organisms. These organisms will use more food contained in the wastewater in treating the wastes. The activated sludge also forms a lacy mass that entraps many materials not used as food.

Some organisms (workers) will require a long time to use the available food in the wastewater at a given waste concentration. Many organisms will compete with each other in the use of available food (waste) to shorten the time factor and increase the portion of waste stabilized. The ratio of food to organisms is a primary control in the activated sludge process. Organisms tend to increase with waste (food) load and time spent in the aeration tank. Under favorable conditions the operator will remove (sludge wasting) the excess organisms to maintain

the required number of workers for effective waste treatment. Therefore, removal of organisms from the treatment process (sludge wasting) is a very important control technique.

Oxygen, usually supplied from air, is necessary to sustain the living organisms and for oxidation of wastes to obtain energy for growth. Insufficient oxygen will inactivate aerobic organisms, make facultative[4] organisms work less efficiently, and favor production of foul-smelling intermediate products of decomposition and incomplete reactions.

An increase in organisms in an aeration tank will require greater amounts of oxygen. More food in the influent encourages more organism activity and more oxidation; consequently, more oxygen is required in the aeration tank. An excess of oxygen is required for complete waste stabilization. Therefore, the dissolved oxygen (DO) content in the aeration tank is an essential control test. Some minimum level of oxygen must be maintained to favor the desired type or organism activity to achieve the necessary treatment efficiency.

Flows must be distributed evenly among two or more similar treatment units. If your plant is equipped with a splitter box or a series of boxes, it will be necessary to periodically check and estimate whether the flow is being split as intended.

Activated sludge solids concentrations in the aerator and the secondary clarifier should be determined by the operator for process control purposes. Solids are in a deteriorating condition as long as they remain in the secondary clarifier. Depth of sludge blanket in the secondary clarifier and concentrations of solids in the aerator are very important for successful wastewater treatment. Centrifuge tests will give a quick estimate of solids concentrations and locations in the units. Precise solids tests should be made periodically for comparison with centrifuge solids tests. Before any changes are made in the mode of operation, precise solids measurements should be obtained. Settleability tests show the degree and volume of solids settling that may be obtained in a secondary clarifier; however, visual plant checks show what is actually happening.

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[4] Facultative (FACK-ul-tay-tive). Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials.

Primary clarifiers remove easily settleable or floatable material. Activated sludge tends to convert soluble solids to suspended cell mass material and to gather and agglomerate[5] particles too fine to settle rapidly into readily separated material. If the soluble solids transfer fails, then the process fails to provide a satisfactory effluent.

There must be organisms, oxidizing conditions, and suitable time to cause the conversion of soluble solids and to agglomerate the fine particles to form a floc mass.

This floc mass consists of millions of organisms (10^{12} to 10^{18}/100 ml in a good activated sludge), including bacteria, fungi, yeast, protozoa, and worms. When a floc mass is returned to the aerator from the final clarifier, the organisms grow as a result of taking food from the inflowing wastewater. The surface of the floc mass is irregular and promotes the transfer of wastewater pollutants into the solids by means of mechanical entrapment, absorption, adsorption, or adhesion. Many substances not used as food also are transferred to the floc mass, thus improving the quality of the plant effluent.

Material taken into the floc mass is partially oxidized to form cell mass and oxidation products. Ash or inorganic material (silt and sand) taken in by the floc mass increases the density of the mass. Mixing in the aerator promotes collisions and thus produces larger floc masses. The net effect after the aeration period is to form a floc mass which will separate from the wastewater and settle to the bottom of the secondary clarifier. This sludge contains most of the residual contaminants and organisms.

Growth of organisms and accumulated residues produce solids for disposal (waste activated sludge). Certain materials are converted and removed from the wastewater to the atmosphere in the form of stripped gases (carbon dioxide or other volatile gases), and also as water and as solids (sludge). To produce a good effluent the operator must strive to minimize the return of these solids (other than as return sludge) to the process. They must be removed from the wastewater being treated and disposed of in the plant by a manner which prevents any material from returning to the plant flow. For example, maintain as high a concentration of solids in the return sludge as possible to reduce the amount of water needed to return these solids back to the aerator. Don't pump waste activated sludge

[5] Agglomerate. To cause the growing or coming together of dispersed suspended matter into larger flocs or particles which settle rapidly.

directly to an anaerobic digester because it will return to the aeration tank as supernatant with an added load on the organisms. The organisms have already attempted to treat the solids once and won't be too effective next time. If screenings are removed at the headworks, don't grind them up and return them to the plant flow. Once material is removed from the wastewater, keep it out, except as necessary to maintain the process.

To maintain the working organisms in the activated sludge, you <u>must</u> provide a suitable environment. Intolerable concentrations of acids, bases, and other toxic substances are undesirable and may kill the working organisms. Unduly fluctuating loads may cause overfeeding, starvation, and other factors that are all capable of upsetting the activated sludge process. Insufficient oxygen can cause an unfavorable environment which results in decreased organism activity.

An outstanding example of a toxic substance added by operators is the uninhibited use of chlorine for odor control (prechlorination). Chlorination is for disinfection. Chlorine is a toxicant and should not be allowed to enter the activated sludge process because it is not selective with respect to type of organisms damaged. It may kill the organisms that you should be retaining as workers. Chlorine is effective in disinfecting the plant effluent after treatment by the activated sludge process.

The successful operation of an activated sludge plant requires the operator to be aware of the many factors influencing the process and to check them repeatedly. The actual control of the process as outlined in this section is relatively simple. Control consists of maintaining the proper solids (floc mass) concentration in the aerator for the waste (food) inflow by adjusting the waste sludge pumping rate and regulating the oxygen supply to maintain a satisfactory level of dissolved oxygen in the process.

QUESTIONS

7.1A Why is air added to the aeration tank in the activated sludge process?

7.1B What happens to the air requirement in the aeration tank when the strength (BOD) of the incoming water increases?

7.1C What factors could cause an unsuitable environment for the activated sludge process in an aeration tank?

END OF LESSON 1 OF 8 LESSONS

on

ACTIVATED SLUDGE

CHAPTER 7. ACTIVATED SLUDGE

(Lesson 2 of 8 Lessons)

7.2 BASIC VARIABLES AND RECORD KEEPING

7.20 General

Wastewater flows and constituents fluctuate daily. The activated sludge plant operator attempts to maintain the process at some balanced state that will be capable of handling the minor variations in flows or wastewater characteristics and produce the desired quality of effluent. To accomplish this goal he must establish his process on known data and knowledge obtained at other plants and relate them to his plant. After his plant becomes operational, he then must relate his control procedures to his own experience. The variations that affect his operation are derived from two sources: (1) the dischargers to the collection system and (2) inplant operational variables.

7.21 Variables in Collection System

7.210 Combined Sewer Systems

During storms the treatment plant will receive an increase in flow which may cause the following problems:

1. Reduced wastewater time in treatment units (hydraulic overload).
2. Increased amounts of grit and silt which lower the volatile (food) content of the solids.
3. Increased organic load during initial washout of accumulated sewer deposits.
4. Rapid changes in wastewater temperature and solids content.

7.211 Waste Dischargers to the System

Various industries and businesses can cause considerable fluctuation in flows and waste characteristics entering a plant. You should become

acquainted with the managers of plants whose discharges could upset your treatment processes. Convince these men in a friendly manner how vital it is to your plant processes and the receiving waters for you to be notified of any potentially harmful discharges. Try to obtain their cooperation and request them to notify you whenever an accidental spill, a process change, or a cleaning operation occurs which could cause undesirable waste discharges. This requires diplomacy to obtain cooperation from dischargers to regulate their own discharges and to reduce the number of midnight dumps.

7.212 Maintenance of the Collection System

Advance notice of collection system maintenance crew activities can be very helpful. If a lift station has been out of service for a period of time, large volumes of septic wastewater could cause a shock load on your treatment processes. Similar problems could be created when a blockage in a line is cleared or a new line is connected to the system. Analysis of inflow quantities and characteristics when these flows reach a treatment plant can indicate whether or not they will cause a serious problem.

7.22 Operational Variables

Continual review of laboratory test results is essential in determining whether a treatment plant is discharging effluent of the required quality in terms of such water quality indicators as COD, suspended solids, and nitrogen. If the desired quality of the plant effluent is not achieved, the operator must determine what factor or factors have changed to upset plant performance and thus reduce efficiency.

Important factors that could have changed include:

1. Higher COD or BOD load applied to the aerator (influent load).

2. More difficult to treat wastes have adversely changed influent characteristics.

3. Unsuitable mixed liquor suspended solids concentration in the aerator.

4. Lower or higher rate of wasting activated sludge.

5. Unsuitable rate of returning sludge to the aerator could adversely influence mixed liquor suspended solids.

6. Higher solids concentrations in digester supernatant[6] returned to the plant flow, or return too rapid.

7. Dropping of oxygen concentration in the aerator below desirable levels.

Examination of plant records should reveal the items which have changed that could have upset the treatment process.

QUESTIONS

7.2A What two major variables affect the way an activated sludge plant is operated?

7.2B. What variables in the collection system can affect the operation of an activated sludge plant?

7.2C What problems can be caused in an activated sludge plant when excessive storm water flows through the process?

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[6] Supernatant (sue-per-NAY-tent). Liquid removed from settled sludge. Commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to the influent wet well or the primary clarifier.

7.24 Typical Lab Results for an Activated Sludge Plant

Typical results of lab tests for an activated sludge plant are provided to assist in the evaluation of lab results and plant performance. Remember that every plant is different and is influenced by different conditions.

Test	Location	Common Range	
COD	Influent	300 - 700	mg/l
	Primary Effl.	200 - 400	mg/l
	Final Effl. (Conv. Act. Sl.)	30 - 70	mg/l
BOD	Influent	150 - 400	mg/l
	Primary Effl.	100 - 280	mg/l
	Final Effl. (Conv. Act. Sl.)	10 - 20	mg/l
SUSPENDED SOLIDS	Influent	150 - 400	mg/l
	Primary Effl.	60 - 160	mg/l
	Mixed Liquor	1000 - 4500	mg/l
	Return Sludge	2000 - 10,000	mg/l
	Final Effl. (Conv. Act. Sl.)	10 - 20	mg/l
DISSOLVED OXYGEN	Mixed Liquor	2 - 4	mg/l
	Final Effl. (Outfall)	2 - 6	mg/l
CHLORINE RESIDUAL (30 min.)	Final Effl.	0.5 - 2.0	mg/l*
COLIFORM GROUP BACTERIA, MPN	Final Effl. (Chlorinated)	23 - 700/100	ml
CLARITY (Secchi Disc)	Final Effl.	3 - 8	ft
pH	Influent	6.8 - 8.0	
	Effluent	7.0 - 8.5	

* Regulatory agencies normally specify a chlorine residual remaining after a certain time period.

7.25 Design Variables

Several different types of activated sludge plants have been built using various flow arrangements, tank configurations, or oxygen application equipment. However, all of these variations are essentially modifications of the basic concept of conventional activated sludge.

7.250 Aeration Methods

Two methods are commonly used to supply oxygen from the air to the bacteria--mechanical aeration and diffused aeration. Both methods are mechanical processes with the difference being whether the mechanisms are at or in the aerator or at a remote location.

Mechanical aeration devices agitate the water surface in the aerator to cause spray and waves by paddle wheels mixers, rotating brushes, or some other method of splashing water into the air or air into the water where the oxygen can be absorbed.

Mechanical aerators in the tank tend to be lower in installation and maintenance costs. Usually they are more versatile in terms of mixing, production of surface area of bubbles, and oxygen transfer per unit of applied power.

Diffused air systems use a device called a diffuser which is used to break up the air stream from the blower system into fine bubbles in the mixed liquor. The smaller the bubble, the greater the oxygen transfer due to the greater surface area of rising air bubbles surrounded by water. Unfortunately, fine bubbles will tend to regroup into larger bubbles while rising unless broken up by suitable mixing energy and turbulence.

7.251 Variation of Activated Sludge Process

The activated sludge plant may be operated in any one of three operational zones on the basis of "sludge age"[10] which is an expression of pounds of organic loading added per day per pound of organisms maintained in the particular process. Sludge age is a control guide that is widely used and is an indicator of the length of time a pound of solids is maintained under aeration in the system. If the amount of solids under aeration remains fairly constant, then an increase in the influent solids load will decrease the sludge age. Use of this measure of sludge age is recommended for the new activated sludge plant operator because of the ease in understanding this approach. The experienced operator may not accept this method of control because it ignores the soluble COD that is related to the solids production but not measured by suspended solids tests on the influent.

The following values are typical sludge ages for different types of municipal activated sludge plants with negligible industrial wastes. Actual loadings must be related to the type of waste and local situation.

1. High Rate. A high-rate activated sludge plant operates at the highest loading of food to microorganisms; the sludge age ranges from 0.5 to 2.0 days. Due to this higher loading the system produces a lower quality of effluent than the other types of activated sludge plants. This system requires greater operational surveillance and control and is more easily upset.

2. Conventional. Conventional activated sludge plants are the most common type in use today. The loading of food to microorganisms is approximately 50% lower than in a high-rate plant, and the sludge age ranges from 3.5 to 7.0 days. This method of operation produces a high quality of effluent and is capable of absorbing some shock loads without effluent quality being adversely affected.

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[10] Sludge Age, days =

$$\frac{(\text{Suspended Sol. in Mixed Liq., mg/l})\ (\text{Aerator Vol., MG})\ (8.34\ \text{lbs/gal})}{(\text{Suspended Sol. in Primary Effl., mg/l})\ (\text{Flow, MGD})\ (8.34\ \text{lbs/gal})}$$

$$= \frac{\text{Suspended Solids Under Aeration, lbs}}{\text{Suspended Solids Added, lbs/day}}$$

3. Extended Aeration. Extended aeration is commonly employed in smaller package-type plants or so-called complete oxidation systems. These are the most stable of the three processes due to the light loading of food to microorganisms, and the sludge age is commonly greater than ten days. Effluent suspended solids commonly are higher than found under conventional loadings.

For a summary of the loadings for different types of activated sludge processes, see Table 7-1.

There are other variations of activated sludge processes such as contact stabilization, step-feed, Kraus and complete mix which are discussed in Section 7.9.

QUESTIONS

7.2G List two methods of supplying oxygen from air to bacteria in the activated sludge process.

7.2H Write the formula for calculating sludge age.

END OF LESSON 2 OF 8 LESSONS

on

ACTIVATED SLUDGE

TABLE 7-1

AERATION TANK CAPACITIES AND PERMISSIBLE LOADINGS*

PROCESS	PLANT DESIGN FLOW, MGD	AERATION RETENTION PERIOD, HOURS BASED ON DESIGN FLOW	PLANT DESIGN LOAD lb BOD/day	AERATOR LOADING lb BOD per day/lb MLSS	SLUDGE AGE, DAYS
Modified or "HIGH-RATE"	All	2.5 up	2000 up	1/1 (or less)	0.5 - 2.0
Conventional	To 0.5 0.5 to 1.5 1.5 up	7.5 6.0 to 7.5 6.0	To 1000 1000 to 3000 3000 up	1/2 to 1/4	3.5 - 7.0
Extended Aeration	All	24	All	As high as 1/10 to As low as 1/20	10 or Longer

* Recommended Standards for Sewage Works (10 State Standards), Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, 1968 Edition, published by Health Education Service, P. O. Box 7283, Albany, New York 12224. Price, $1.00.

CHAPTER 7. ACTIVATED SLUDGE

(Lesson 8 of 8 Lessons)

7.8 AERATOR LOADING PARAMETERS

7.80 General

Sludge age has been suggested as the method for controlling the solids in the activated sludge process. Other operational controls used successfully by operators include the waste load (food)/sludge volatile solids (organisms) ratio and the mean cell residence time (MCRT). Mathematically, one can show that aerator loadings based on sludge age, food/organism ratio, and MCRT are theoretically similar. In each case the operator selects a number or value for the parameter to start with on the basis of experience and data available from other plants. He then adjusts this value until he finds an operating range which produces the best quality effluent for his plant.

In each case, the critical factor is the food/organism relationship which cannot be precisely estimated for any specific plant. The operator attempts to maintain in the aerator tank sufficient solids (organisms) to use up the incoming waste (food). He doesn't want too many organisms nor too few organisms in the aeration tank in relation to the incoming food. Operation of the activated sludge process requires removing the organisms (settled activated sludge) from the secondary clarifier as quickly as possible. The organisms are either returned to the aerator to use the incoming food, or they are wasted. Therefore, a critical decision is to determine the amount of solids to be wasted. This procedure has been discussed and an example provided in Section 7.52 for the sludge age/aerator loading parameter. Select a method to operate your plant and stick with it. Don't continually try to switch from one method to another.

7.81 Food/Organism Ratio

The food-to-organism loading ratio is based upon the food provided each day to the microorganism mass in the aerator. Food (waste) provided is preferably measured by the COD of the influent to the aerator. COD is recommended because test results are available

within four hours and process changes can be made before the process becomes upset. Many operators load aerators on the basis of the BOD test, but results five days later are too late for operational control. The ratio of food load provided each day to the volatile solids in the aerator is the reciprocal of the sludge age (see Table 7-1, Section 7.25). Typical loading parameters have been established for the three operational zones of activated sludge and are summarized as follows:

1. High-Rate

   COD: 1 lb COD per day/1 lb of MLVSS[18] under aeration.

   BOD: >0.5* lb BOD per day/1 lb of MLVSS under aeration.

2. Conventional

   COD: 0.5 to 1.0 lb COD per day/1 lb of MLVSS under aeration.

   BOD: 0.25 to 0.5 lb BOD per day/1 lb of MLVSS under aeration.

3. Extended Aeration

   COD: <0.2* lb COD per day/1 lb MLVSS under aeration.

   BOD: 0.05 to 0.10 lb BOD per day/1 lb MLVSS under aeration.

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* > means greater than. Greater than 0.5 lb BOD.
  < means less than. Less than 0.2 lb COD.

7.82 Calculation of Food/Organism Aerator Loading

Determine the amount of mixed liquor volatile suspended solids to be maintained in the aerator of the conventional plant studied in this chapter. Assume a food/organism ratio of 0.5 lb COD per day/1 lb of mixed liquor volatile suspended solids under aeration. Frequently this loading is expressed as 50 lbs COD per day/100 lbs of MLVSS.

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[18] MLVSS means Mixed Liquor Volatile Suspended Solids.

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Information needed:

1. Average COD of primary effluent, 150 mg/l
2. Average daily flow, 4.0 MGD
3. Average volatile content of mixed liquor suspended solids, 80%

Find pounds of COD provided aerator per day.

Aerator Loading, lbs COD/day = Prim. Effl. COD, mg/l x Daily Flow, MGD x 8.34 lbs/gal

= 150 mg/l x 4.0 MGD x 8.34 lbs/gal

= 5004 or 5000 lbs COD/day

Find desired pounds of Mixed Liquor Volatile Suspended Solids under aeration, based upon 0.5 lb COD per day/1 lb of MLVSS.

$$\text{MLVSS, lbs} = \frac{\text{Primary Effluent COD, lbs/day}}{\text{Loading Factor in lbs COD/day/1 lb MLVSS}}$$

$$= \frac{5000 \text{ lbs COD/day}}{0.5 \text{ lb COD/day/lb MLVSS}}$$

$$= \frac{5000}{0.5/\text{lbs MLVSS}}$$

= 10,000 lbs MLVSS under aeration

The MLVSS is a measure of the organisms in the aerator available to work on the incoming waste (food). When operating your plant on the basis of MLVSS, you should determine any flucuations that may occur during the week and make appropriate adjustment.

If the COD load applied to the aerator increases or drops to a significantly different level for two consecutive days, a new mixed liquor solids value should be calculated and activated sludge wasting adjusted to achieve the new value of solids desired under aeration. Calculation of waste sludge rates is outlined in Sections 7.52 and 7.53.

7.83 <u>Mean Cell Residence Time (MCRT)</u>

Another approach for solids control used by operators is the Mean Cell Residence Time (MCRT) or Solids Retention Time (SRT). This is a refinement of the sludge age. Both terms are almost the same. The equation for MCRT is:

$$\text{MCRT, days} = \frac{\text{Pounds of Suspended Solids in Total Secondary System}}{\text{Lbs of Susp Sol Wasted/day + Lbs of Susp Sol Lost in Effl/day}}$$

The most desirable MCRT for a given plant is determined experimentally just as with the use of sludge age or the mixed liquor volatile suspended solids concentration. The desired MCRT for conventional plant operation should fall between 5 and 15 days. (Don't confuse this time with the recommended range for Sludge Age of 3.5 to 10 days.)

A way of determining MCRT for the example plant in this chapter would be as follows:

Required Data:

1.	Aerator	=	1,000,000 gals
2.	Final clarifier volume	=	500,000 gals
	Total secondary system volume	=	1.5 MG
3.	Wastewater flow to aerator	=	4.0 MGD
4.	Waste sludge flow for past 24 hrs	=	0.075 MGD
5.	Mixed liquor suspended solids concentration	=	2400 mg/l
6.	Waste sludge (or return sludge) suspended solids concentration	=	6200 mg/l
7.	Final effluent suspended solids concentration	=	12 mg/l

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7.84 Calculation of Mean Cell Residence Time

$$\text{MCRT, days} = \frac{\text{Suspended Solids in Total Secondary System, lbs}}{\text{Susp Sol Wasted, lbs/day + Susp Sol Lost in Effl, lbs/day}}$$

$$\text{MCRT} = \frac{\text{Susp Sol in Mixed Liq, mg/l} \times (\text{Aerator, MG + Final Clarifier Vol, MG}) \times 8.34\ \text{lbs/gal}}{(\text{Susp Sol in Waste, mg/l} \times \text{Waste Rate, MGD} \times 8.34\ \text{lbs/gal}) + (\text{Susp Sol in Effl, mg/l} \times \text{Plant Flow, MGD} \times 8.34\ \text{lbs/gal})}$$

$$= \frac{2400\ \text{mg/l} \times (1.0\ \text{MG} + 0.5\ \text{MG}) \times 8.34\ \text{lbs/gal}}{(6200\ \text{mg/l} \times 0.075\ \text{MGD} \times 8.34\ \text{lbs/gal}) + (12\ \text{mg/l} \times 4.0\ \text{MGD} \times 8.34\ \text{lbs/gal})}$$

$$= \frac{2400\ \text{mg/l} \times 1.5\ \text{MG} \times 8.34\ \text{lbs/gal}}{(6200\ \text{mg/l} \times 0.075\ \text{MGD} \times 8.34\ \text{lbs/gal}) + (12\ \text{mg/l} \times 4.0\ \text{MGD} \times 8.34\ \text{lbs/gal})}$$

$$= \frac{30{,}024\ \text{lbs}}{3878\ \text{lbs/day} + 400\ \text{lbs/day}}$$

$$= \frac{30{,}024\ \text{lbs}}{4278\ \text{lbs/day}}$$

$$= 7.0\ \text{days}$$

If you are operating the plant on the basis of MCRT and the plant operates satisfactorily at the MCRT of 8, 9, 10, 11, or even 15 days, the main method of control is to adjust the waste sludge rate to maintain the MCRT at the desired number of days.

Rearranging the equation on the previous page, calculation of the sludge waste rate from the system merely means plugging in the chosen MCRT (use 7 days) and solids figures.

Example:

$$\text{Waste Sludge, lbs/day} = \frac{\text{Susp Sol in System, lbs}}{\text{MCRT, days}} - \text{Susp Sol in Effl, lbs/day}$$

$$= \frac{2400 \text{ mg/l} \times 1.5 \text{ MG} \times 8.34 \text{ lbs/gal}}{7 \text{ days}} - 12 \text{ mg/l} \times 4.0 \text{ MGD} \times 8.34 \text{ lbs/gal}$$

$$= \frac{30{,}024 \text{ lbs}}{7 \text{ days}} - 400 \text{ lbs/day}$$

$$= 4289 \text{ lbs/day} - 400 \text{ lbs/day}$$

$$= 3889 \text{ lbs/day}$$

The waste sludge pumping rate of 3878 lbs/day appears to be correct to maintain a Mean Cell Residence Time of 7 days.

QUESTIONS

7.8A Why is it sometimes necessary to waste some activated sludge?

7.8B If you calculate that your plant has 12,000 pounds of mixed liquor volatile suspended solids under aeration and you need 9,000 pounds under aeration, how many pounds should be wasted?

7.8C What should be the waste sludge pumping rate (GPM) if a plant should be wasting 3000 pounds per day and the concentration of return sludge is 6000 mg/l?

7.8D Estimate the waste sludge rate (lbs/day) from an activated sludge plant operating at an MCRT of 10 days. The system contains 40,000 pounds of suspended solids and the effluent has a suspended solids concentration of 10 mg/~~l at~~ a flow of 5 MGD.

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7.9 MODIFICATIONS OF THE ACTIVATED SLUDGE PROCESS

7.90 Reasons for Other Modes of Operation

Modification of the conventional activated sludge process has been developed to improve operational results under certain circumstances. Some of these conditions may be:

1. Current or actual loadings are in excess of design loading for conventional operation.

2. Wastewater constituents require added nutrients to properly treat influent waste load.

3. Flow or strength of waste varies seasonally.

7.91 Contact Stabilization (Fig. 7.9)

Operation of an activated sludge plant on the basis of contact stabilization requires two aeration tanks. One tank is for separate reaeration of the return sludge for a period of at least four hours before it is permitted to flow into the other aeration tank to be mixed with the primary effluent requiring treatment. Loading factors are the same as for conventional activated sludge, but at times the solids in the aeration tank may be almost twice as high as normal ranges in conventional plants.

If the solids content in aeration tank "A" (mixed liquor aerator, Fig. 7.9) and aeration tank "B" (return sludge aeration only) are combined, the loading ratio of food/organisms is the same as conventional operation, but if you only look at aeration tank "A" where the load is applied, we approach double the load ratio established for conventional activated sludge.

Contact stabilization attempts to have organisms assimilate and store large portions of the influent waste load in a short time (as short as 30 minutes). The activated sludge is separated from the treated wastewater in the secondary clarifier and returned to the reaeration tank "B". No new food is added to the reaeration tank and the organisms must use the waste material they collected and stored in the first aeration tank. When the stored food is used up, the organisms begin searching for more food and are ready to be returned to tank "A".

Process controls for a contact stabilization plant are the same as those described for a conventional plant in this chapter. When a plant has exceeded design flows, or is subject to periodic high

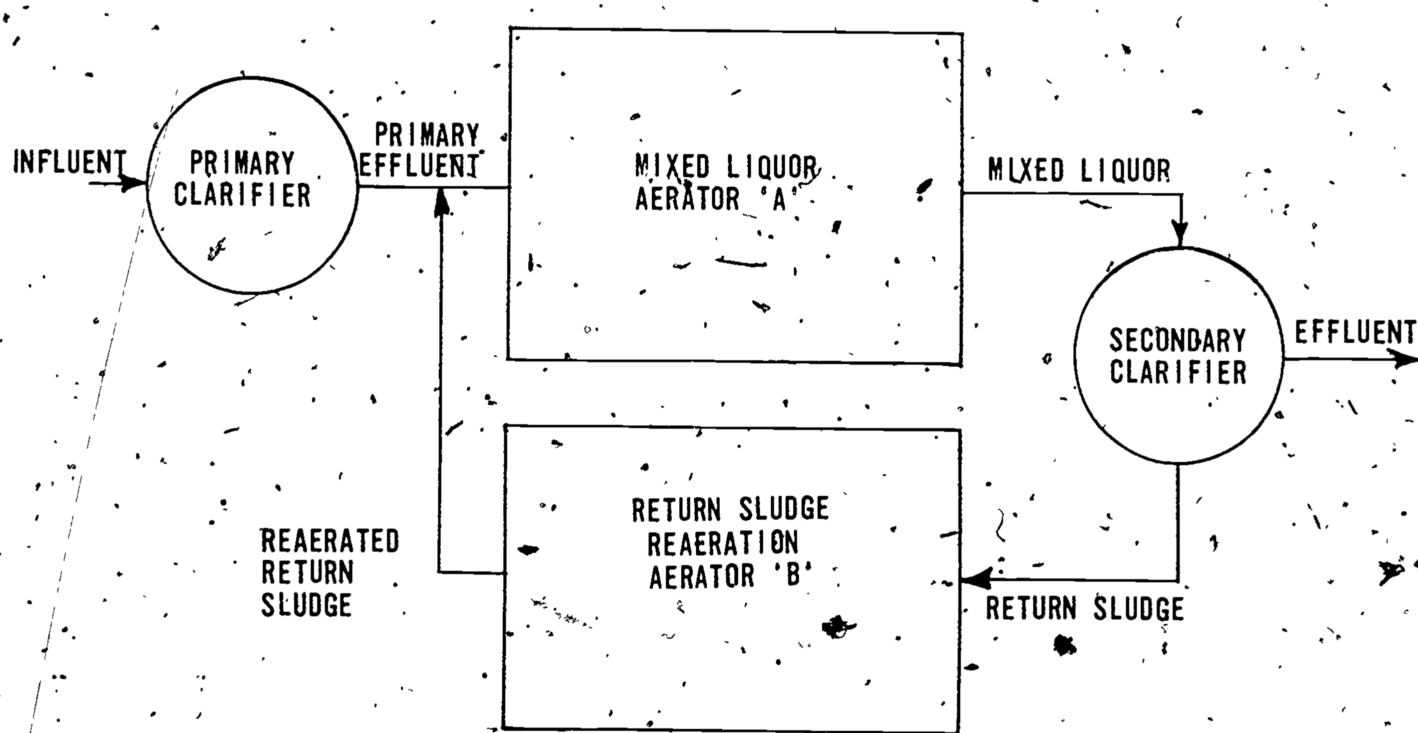


Fig. 7.9 Plan layout of contact stabilization plant

flows or shock waste loads, then contact stabilization is capable of treating the plant influent because a ready reserve of organisms is available in the reaeration tank "B".

7.92 Kraus Process (Fig. 7.10)

The Kraus process is a modification of conventional activated sludge, and the process is patented by its developer. The process is widely used when the wastewater contains a much greater ratio of carbonaceous to nitrogenous material than found in normal domestic wastewater.

This imbalance commonly occurs when wastes from canneries or dairies are treated. When the organisms use all of a limiting constituent, they refuse to remove the remaining portions of the other constituents. Normally this nutrient deficiency is nitrogenous material which is readily available in anaerobic digester supernatant and sludges. Feeding anaerobic digester supernatant or digester sludge to the aeration system will usually supply the proper nutrients to maintain the balance. The method of application is very important.

In the Kraus process, the return sludge is sent to the reaeration aerator ("B") to be mixed with the digested sludge from a completely mixed digester. In the reaeration tank ("B"), the digested sludge and the return sludge are mixed, reaerated, and then sent to the mixed liquor aerator ("A"). The amount of digested sludge introduced to the system is determined by laboratory evaluation and by carbonaceous material removal through the system.

The same controls apply as described for controlling a conventional activated sludge plant. The main objective is to properly balance nutrients; however, one added advantage (similar to contact stabilization) is the ability to maintain a large mass of organisms under aeration in a relatively smaller system.

7.93 Step-Feed Aeration (Fig. 7.11)

Step-feed aeration actually is a step-feed process based on conventional activated sludge loading parameters. The difference between step-feed and conventional operation is that in conventional activated sludge the primary effluent and return sludge are introduced at one point only, the entrance to the aeration tanks. In step-feed aeration the return sludge is introduced separately and in many cases allowed a short reaeration period by itself at the entrance to the tank. The primary effluent is admitted to the aeration tanks at several different locations. These locations distribute

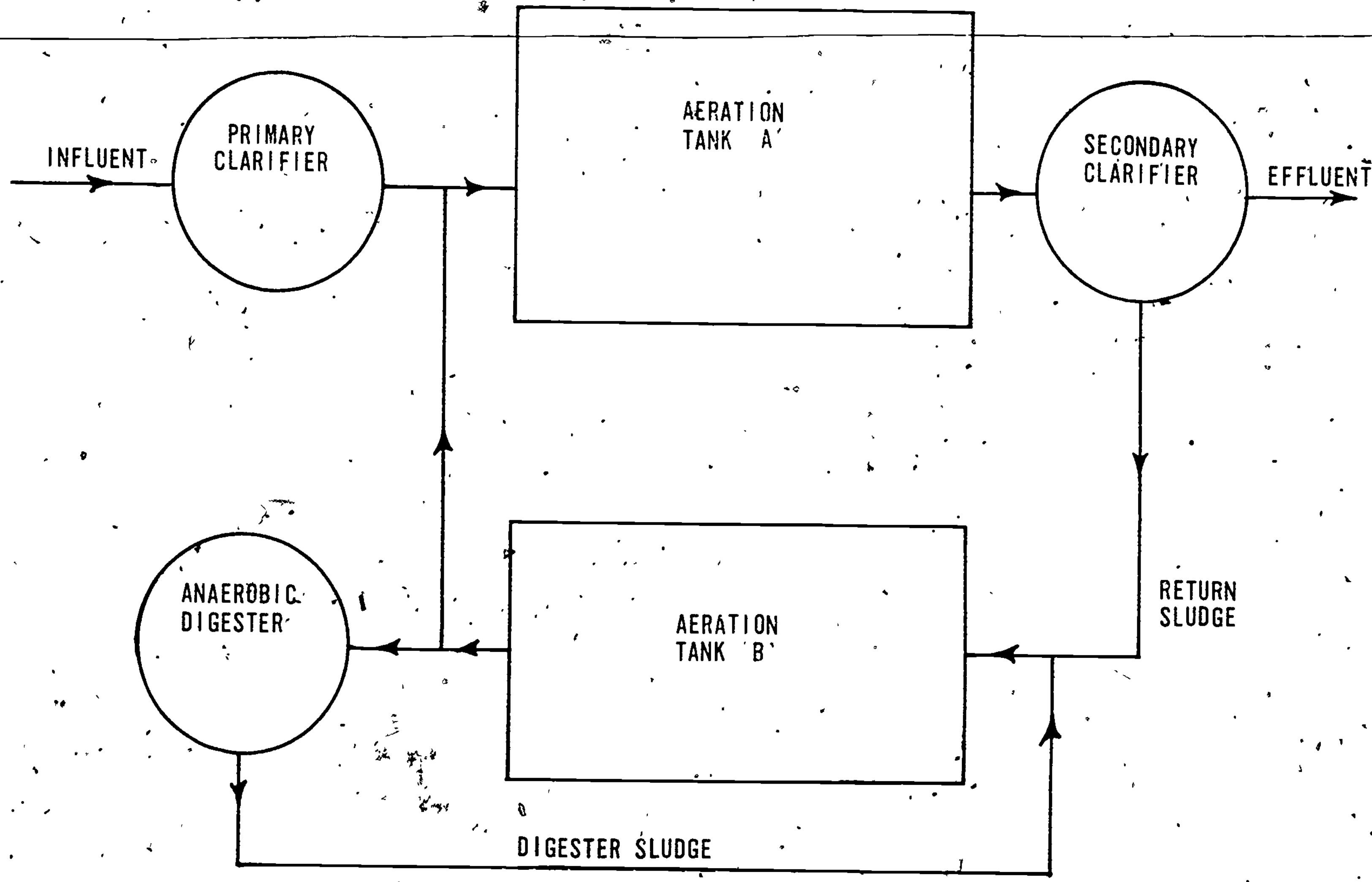
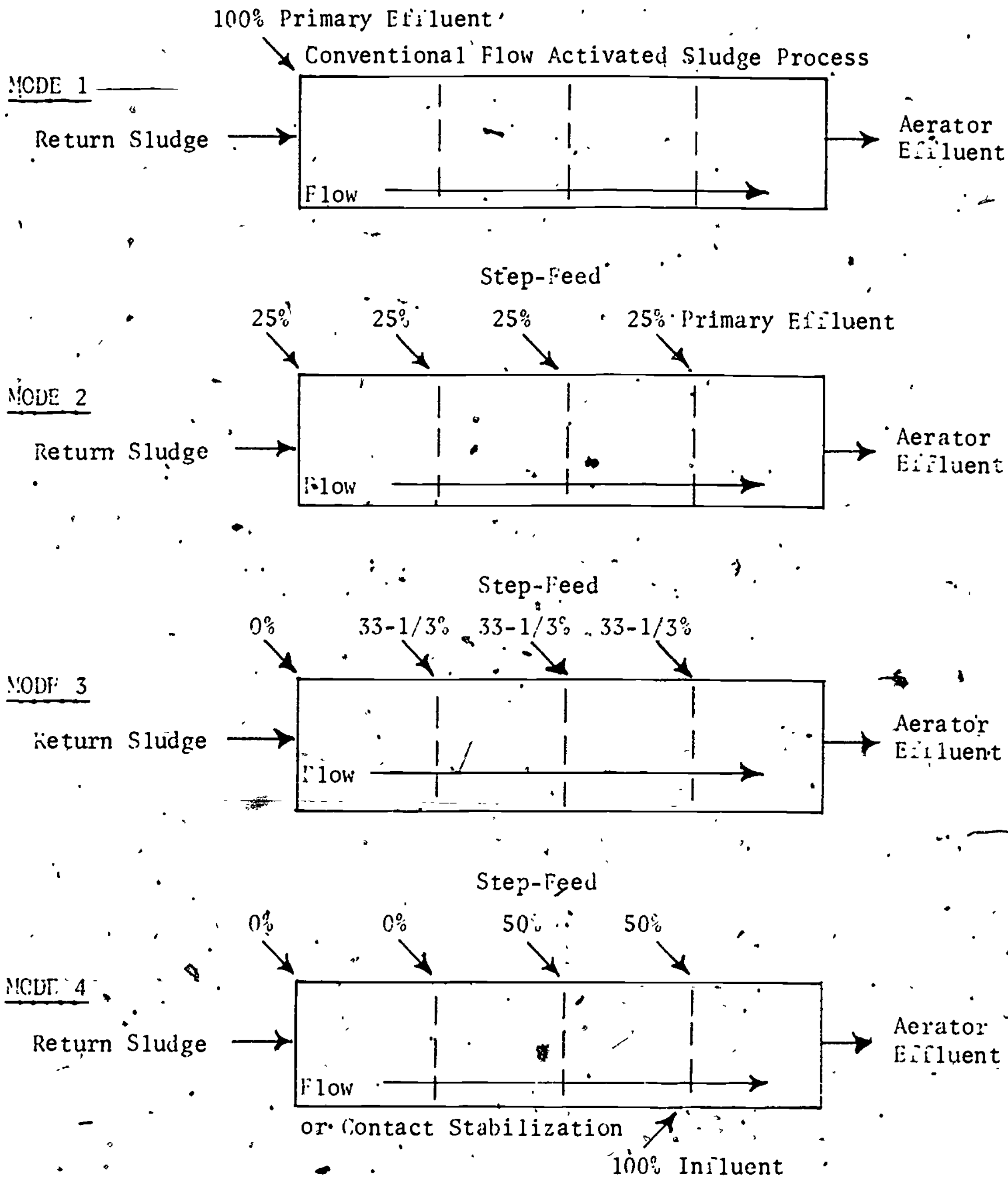


Fig. 7.10 Kraus process

MODES OF FLOW



Several possible modes of feeding primary effluent to the aeration tanks. Some tanks may have more or fewer points of discharge into the tank.

Fig. 7.11 Modes of step aeration

the waste load over the aeration tank and reduces oxygen sags in an aerator. If you introduce the influent near the outlet end of the aeration tank, the process will become similar to contact stabilization.

Step-feed aeration distributes the oxygen demand from the wastewater over the entire aerator instead of concentrating it at the inlet end. Some of its advantages over conventional operation include less aeration volume to treat the same volumes of wastewater, better control in handling shock loads, and better control of the solids entering the secondary clarifiers. When a conventional plant is operating above design loads and the secondary clarifiers cannot handle the solids load, switching to step-feed aeration or contact stabilization allows the operator to maintain the desired amount of solids under aeration. Successful operation requires good waste storage transfer into the solids in the short time interval before the waste reaches the effluent end of the aeration tank.

This mode of operation is controlled by the same procedures used for the conventional process except that the mixed liquor suspended solids determinations must be made at each point of wastewater addition to measure the waste content and dilution factor provided by the primary effluent to determine the total pounds of solids in the aeration tank.

7.94 Complete Mix (Fig. 7.12)

The complete mix mode of operation is a design modification of tank mixing techniques to insure equal distribution of applied waste load, dissolved oxygen, and return sludge throughout the aeration tank. The theory of this modification is that all parts of the aeration tank should be similar in terms of amounts of food, organisms, and air. This is accomplished by providing diffuser location and application points of influent and return sludge to the aerator at several locations. Providing a similar condition throughout the entire aeration tank allows a food/organism ratio of 1/1 and still produces effluent qualities comparable to conventional operation. Generally, smaller aeration tanks are more completely mixed than larger ones. Usually aeration is more efficient in a complete mix facility such as illustrated in Fig. 7.12 because of the locations of the air headers.

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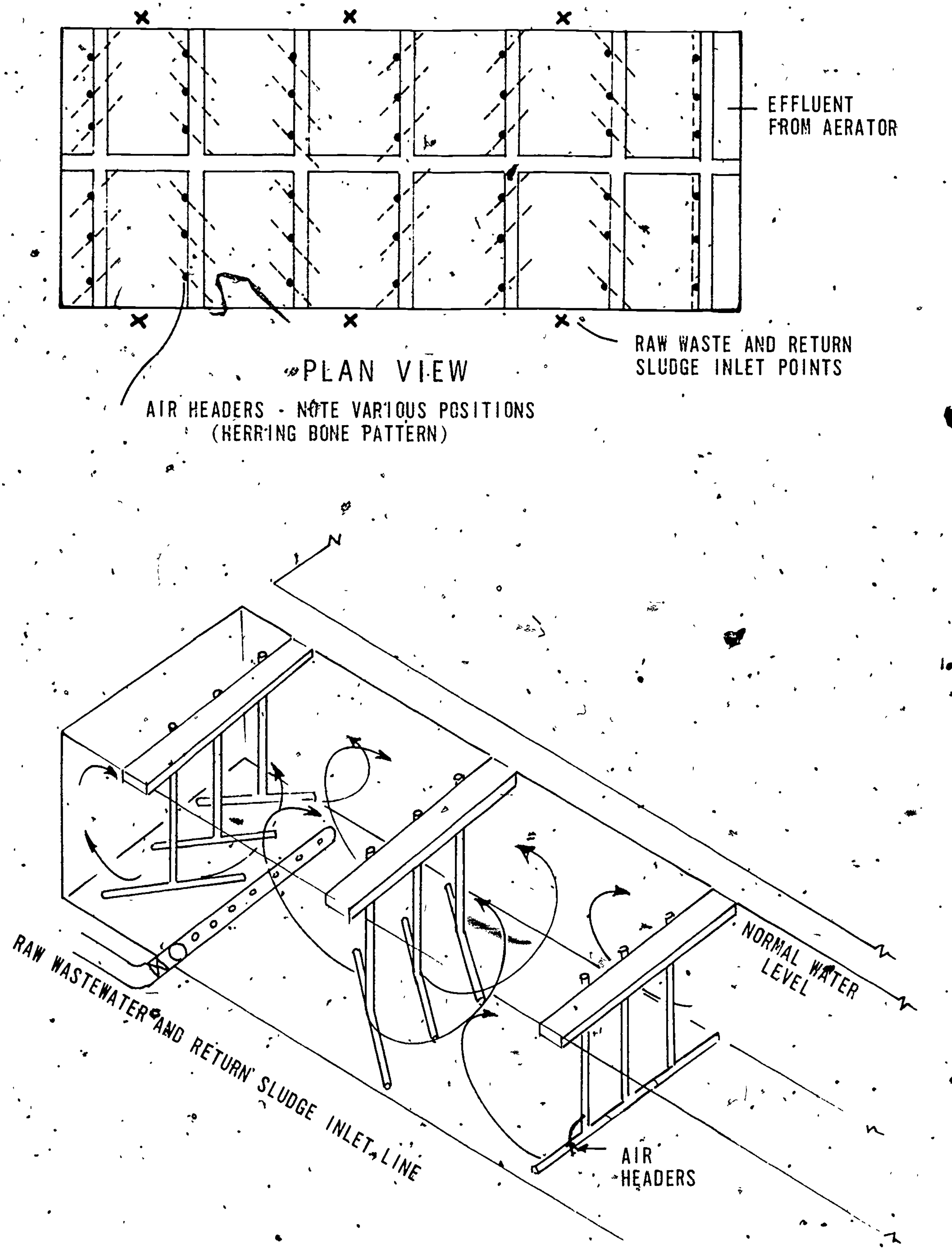

Fig. 7.12 Air header locations in complete mix

7.95 Modified Aeration (Fig. 7.13)

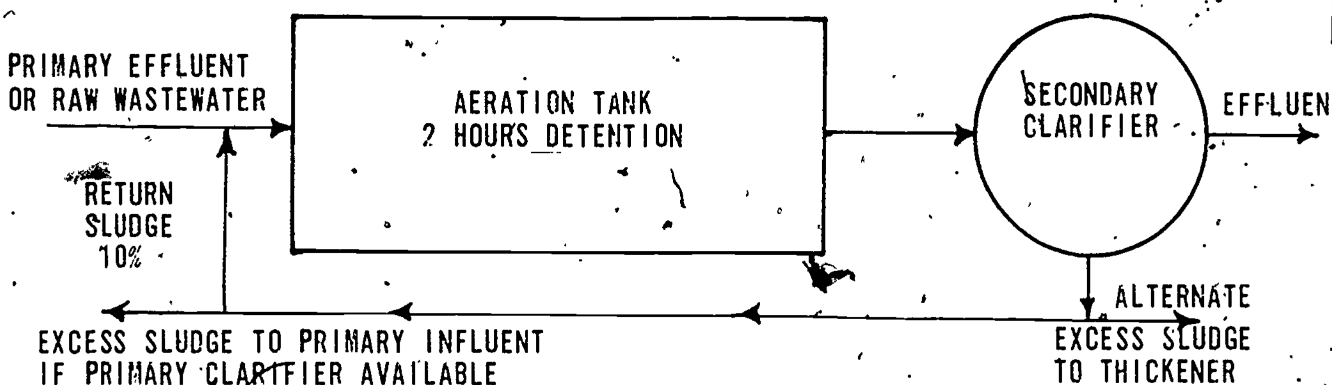

Fig. 7.13 Modified aeration

Modified aeration is also known as high-rate activated sludge. Frequently it is used as intermediate treatment where the discharge requirements demand higher treatment than primary, but not as high as conventional activated sludge, in terms of BOD and suspended solids removals.

Either raw wastewater or primary effluent is applied to an aeration tank with a detention time of two hours and a mixed liquor suspended solids concentration of less than 1000 mg/1. Air requirements are lower because of fewer organisms (solids) under aeration. Effluent quality ranging from primary treatment to conventional activated sludge treatment can be achieved by the operator by controlling the air supply, aeration period, and the pounds of solids under aeration.

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7.10 ACKNOWLEDGEMENT

Mr. F. J. Ludzack, Chemist, National Training Center, Federal Water Quality Administration, provided many helpful comments to the development of this chapter. His contributions are gratefully appreciated.

7.11 ADDITIONAL READING

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d. <u>Sewage Treatment Practices</u>, pages 55-62.

e. Jenkins, D., and Garrison, W.E., "Control of Activated Sludge by Mean Cell Residence Time," JWPCF, Vol. 40, No. 11, p. 1905 (November 1968).

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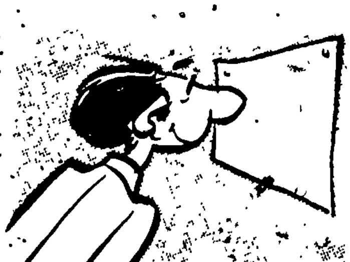

END OF LESSON 8 OF 8 LESSONS

on

ACTIVATED SLUDGE

CHAPTER 8. SLUDGE DIGESTION AND HANDLING

(Lesson 1 of 5 Lessons)

8.0 INTRODUCTION

Settled solids removed from the bottom and floating scums removed from the top of clarifiers and sedimentation tanks are a watery, odorous mixture called raw sludge and scum. Frequently this raw sludge is pumped to a sludge digester for treatment before disposal. In the anaerobic sludge digester, the most common kind, bacteria decompose the organic solids in the absence of dissolved oxygen. Figure 8.1 shows the location of an anaerobic sludge digester in a typical plant. Figures 5.2, 6.2, and 7.2 also show plan views of the location of sludge digestion and handling facilities in relation to other treatment processes.

8.00 Purpose of Sludge Digestion

Anaerobic digestion[1] reduces wastewater solids from a sticky, smelly mixture to a mixture that is relatively odor free, readily dewaterable,[2] and capable of being disposed of without causing a nuisance.

In the process organic solids are liquefied, the solids volume is reduced, and valuable methane gas is produced in the digester by the action of two different groups of bacteria living together in the same environment. One group consists of saprophytic organisms,[3] commonly referred to as "acid formers". The second group, which utilized the

[1] Anaerobic Digestion (AN-air-O-bick). Wastewater solids and water (about 5% solids, 95% water) are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen. At least two general groups of bacteria act in balance: saprophytic bacteria (see Footnote 3) and methane fermenters break down the acids to methane, carbon dioxide, and water.

[2] Dewaterable. A material is considered dewaterable if water will readily drain from it. Generally raw sludge dewatering is more difficult than water removal from digested sludge.

[3] Saprophytic Organisms (SAP-pro-FIT-tik). Organisms living on dead or decaying organic matter. They help natural decomposition of the organic solids in wastewater.

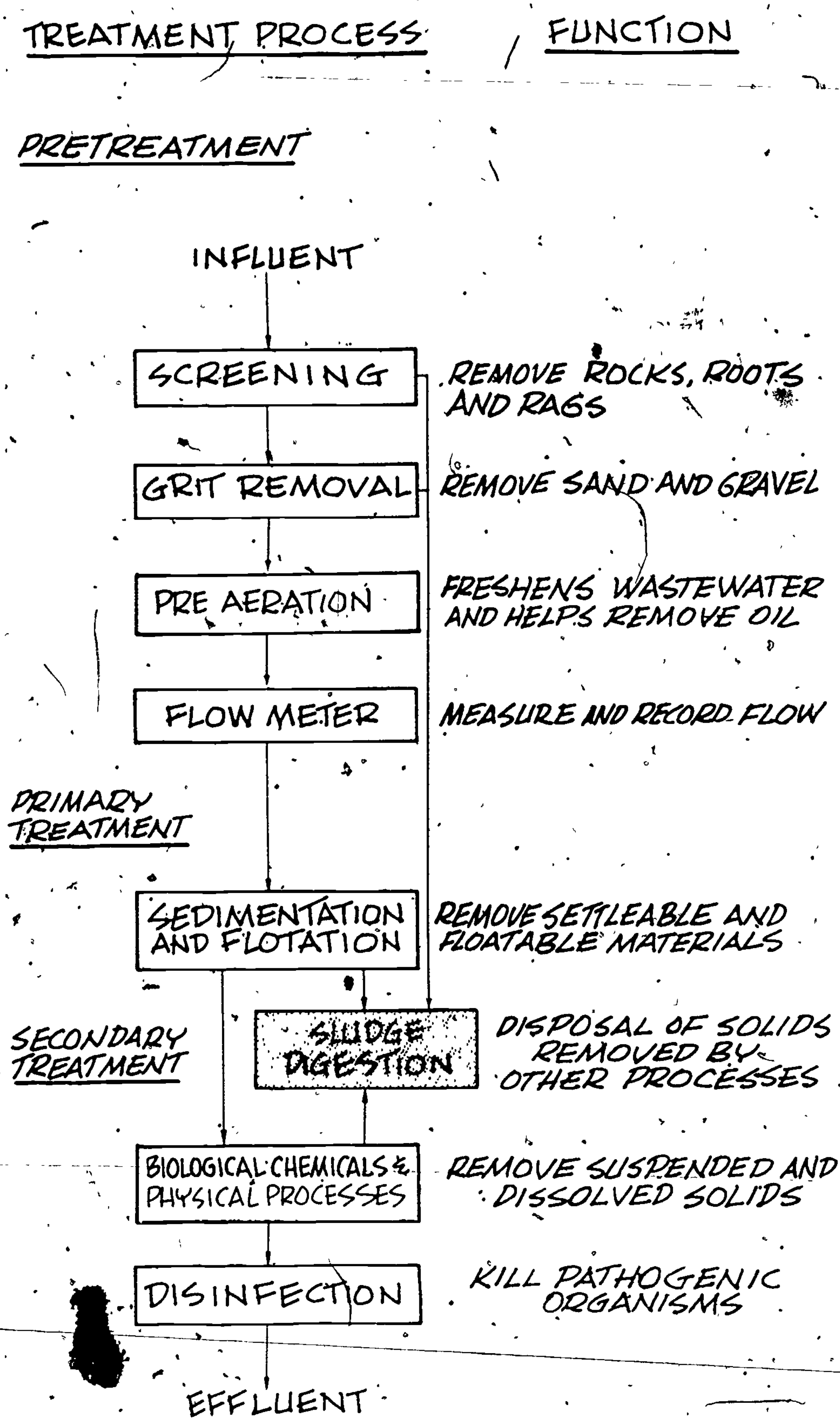

Fig. 8.1 Flow diagram of typical plant

acid produced by the saprophytes, are the "methane fermenters". The methane fermenters are not as abundant in raw wastewater as are the acid formers. The methane fermenters desire a pH range of 6.5 to 8.0 and will reproduce only in that range.

The object of good digester operation is to maintain suitable conditions in the digester for a growing (reproducing) population of both acid formers and methane fermenters. You must do this by the control of food supply (organic solids), volatile acid/alkalinity relationship, mixing, and temperature. Generally, you have done your job properly if the digester reduces the volatile (organic) solids content by between 40 and 60% of what they were in the raw sludge.

To obtain the desired degree of organic solids reduction may require from 5 to 120 days of digestion time. The time required depends on how good a job you are required to do on digesting the sludge, and on the adequacy of mixing, the organic loading rate, and the temperature at which the bacterial culture is maintained.

8.01 How Sludge Digestion Works (by William Garber)

The equations shown in Fig. 8.2 illustrate one way of outlining what happens in a digester. These equations indicate two general types of reactions:

1. Acid forming reactions which proceed at a rate dependent upon temperature, pH, and food conditions.

2. Methane fermentation reactions which proceed at a rate dependent upon temperature, pH, and food conditions.

You must try to operate an anaerobic sludge digester so that the rate of acid formation and methane fermentation are approximately equal; otherwise the reaction will get out of balance. The most common condition of unbalance that occurs is that the methane fermenters, which are sensitive anaerobes, fail to keep pace and the digester becomes acid because the rate at which acids are converted is too low.

The literature has been full of terms such as "Standard-Rate" and "High-Rate" digestion. These terms refer to digester loading and not to the rates of bacterial action. In "High-Rate" systems, mixing is used to obtain the best possible distribution of the substrate (food) and seed (organism) so that more bacterial reaction can occur.

RAW SLUDGE COMPLEX SUBSTRATE CARBOHYDRATES FATS PROTEINS	+	MICROORGANISMS "A" PRINCIPALLY ACID FORMERS SAPROPHYTIC FACULTATIVE	→	CO_2, H_2O, INTERMEDIATE DEGRADATION PRODUCTS	+	ORGANIC ACIDS CELLULAR AND OTHER INTERMEDIATE DEGRADATION PRODUCTS

8-4

ORGANIC ACIDS CELLULAR AND 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

Fig. 8.2 Reactions in a digester

Mixing is the most important factor in the so-called "High-Rate" processes, and it is considered to accomplish the following:

1. Utilize as much of the total content of a digester as possible.

2. Quickly distribute the raw sludge food throughout the volume of sludge in the tank.

3. Put the microorganisms in contact with the food.

4. Dilute the inhibitory by-products of microbiological reactions throughout the sludge mass.

5. Achieve good pH control by distributing buffering alkalinity throughout the digestion tank.

6. Obtain the best possible distribution of heat through the tank.

7. Minimize the separation of grit and inert solids to the bottom or floating scum material to the top.

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) utilizes psychrophilic (cold temperature loving) bacteria.[4] Temperature of the sludge inside tends to adjust to the outside temperature. However, below 50°F little or no bacterial activity occurs and the necessary reduction in sludge volatiles (organic matter) will not occur. When the temperature increases above 50°F, bacterial activity increases to a measurable rate and digestion starts again. The bacteria appear to be able to survive temperatures well below freezing with little or no harm. The psychrophilic upper range is around 68°F. Digestion in this range requires from 50 to 180 days, depending upon the degree of treatment (solids reduction) required. Few digesters are designed today to operate in this range, but there are many still in use, including most Imhoff tanks and similar unheated digesters with no mixing devices. Generally these digesters are not very effective in digesting sludge.

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[4] Psychrophilic Bacteria (organisms) (sy-kro-FILL-lick). A group of bacteria that thrive in temperatures below 68°F.

The middle range of organisms are called the mesophilic (medium temperature loving) bacteria[5]; they thrive between about 68°F and 113°F. This is the most common operational range, with temperatures usually being maintained at about 95°F to 98°F. Digestion at that temperature may take from 5 to 50 days or more (normally around 25 to 30 days), depending upon the required degree of volatile solids reduction and adequacy of mixing. The so-called "High-Rate" processes are usually operated within the mesophilic temperature range. These are nothing more than procedures to obtain good mixing so that the organisms and the food can be brought together to allow the digestion processes to proceed as rapidly as possible. With the most favorable conditions the time may be no more than five days for an intermediate level of digestion.

The third range of organisms are called thermophilic (hot temperature loving) bacteria,[6] and they thrive above 113°F. The time required for digestion in this range falls between 5 and 12 days, depending upon operational conditions and degree of volatile solids reduction required. However, the problems of maintaining temperature, sensitivity of the organisms to temperature change, and some reported problems of poor solids-liquid separation are reasons why only a few plants have actually been operated in the thermophilic range.

You cannot merely raise the temperature of the digesters and have a successful operation in another range. The bacteria must have time to adjust to the new temperature zone and to develop a balanced culture before continuing to work. An excellent rule for digestion is never change the temperature more than one degree a day to allow the bacterial culture to become acclimated (adjust to the temperature changes).

Secondary digestion tanks are sometimes used to allow liquids (supernatant)[7] to separate from the solids, to provide a small amount of additional digestion, and to act as a "seed" source (the settled, digested sludge). However, digestion tanks generally have too small a "surface area to depth" ratio to be good sedimentation tanks. Separation of solids from liquids is more efficient in

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[5] Mesophilic Bacteria (mess-O-FILL-lick). A group of bacteria that thrive in a temperature range between 68°F and 113°F.

[6] Thermophilic Bacteria (thermo-FILL-lick). A group of bacteria that thrive in temperatures above 113°F.

[7] Supernatant (sue-per-NAY-tent). In a sludge digestion tank, the supernatant is the liquor between the surface scum and the settled sludge on the bottom of the tank.

lagoons or in tanks designed for separation. If a significant amount of digestion occurs in the secondary tank, the result may be poor separation of solids. Secondary digesters should be used for solids concentration and for a reservoir of alkalinity and seed sludge which may be returned to the primary digester when needed.

You have certain other items you can use for control in addition to mixing and temperature selection. These include:

1. Varying the sludge concentration or water added to the system.

2. Varying the rate and frequency of feeding, with continuous feed the most desirable.

3. Closely controlling grit and skimming in order that capacity of the tank is affected as little as possible by these materials.

4. Cleaning regularly to maintain capacity.

5. A good maintenance program to maintain the maximum degree of flexibility.

6. Maintaining records and laboratory control in order that process condition is known at all times.

Although digestion is a complex process and only a portion of its theory is understood, enough is known to allow you to exercise good operational control. For sludge digestion as for any of the wastewater processes, remember that for the most successful operation you need to do the following:

1. Understand the theory of the process so you know what you are basically trying to do.

2. Know your facilities thoroughly so that you can attain maximum flexibility of operation.

3. Keep careful records and use laboratory analyses to follow the process continually.

4. Maintain your facilities in the best possible condition at all times.

8.1 COMPONENTS IN THE ANAEROBIC SLUDGE DIGESTION PROCESS

To understand and operate an anaerobic sludge digester, the operator must be familiar with the location and function of the various components of the digestion facility.

8.10 Pipelines and Valves

Raw sludge pipelines are usually constructed of cast iron or steel to withstand pumping pressures. In recent years glass-lined or epoxy-lined sludge lines have been used to alleviate the problem of grease deposits. These deposits cut capacity and may cause stoppages. Some plants use "go-devil" type cleaners and/or hot chemical solutions such as T.S.P. instead.

The valves used in sludge and scum lines are mostly of the plug type. They give positive control where a gate or butterfly valve may become blocked by rags or other material which will not allow the valve to seat. In some cases a gate or butterfly valve is indicated because a quick closing plug valve could result in water hammer and damage the pipeline.

CAUTION

NEVER START A POSITIVE DISPLACEMENT PUMP AGAINST A CLOSED VALVE, BECAUSE EXCESSIVE PRESSURE MAY RESULT IN DAMAGING THE LINE OR THE PUMP. ALL PUMPS SHOULD BE EQUIPPED WITH PRESSURE CUT-OFF DEVICES, BUT SOMETIMES THESE DEVICES FAIL OR ALLOW THE PRESSURE TO BUILD UP HIGH ENOUGH TO CAUSE DAMAGE. A SLUDGE LINE SHOULD NEVER BE ISOLATED BY CLOSING THE VALVES ON EACH END FOR SEVERAL DAYS BECAUSE GAS PRODUCTION CAN GENERATE SUFFICIENT PRESSURES TO CAUSE THE LINE TO FAIL. ALSO, THE SOLIDS WILL FORM AN ALMOST IMMOVABLE MASS IN THE LINE.

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QUESTIONS

8.10A Why are plug type valves used in sludge lines?

8.10B Why should a positive displacement pump never be started against a closed valve?

8.10C Why should a sludge line never be closed at both ends?

8.11 The Digester

Digestion tanks may be cylindrical or cubical in shape. Most tanks constructed today are cylindrical. The floor of the tank is sloped so that sand, grit, and heavy sludge will tend to be removed from the tank. Most digesters constructed today have either fixed or floating covers.

A. Fixed Cover Tanks

A fixed cover tank has a stationary roof, generally slab, conical, or cone-shaped, and constructed of concrete or steel. Both types of covers are normally designed to maintain no more than an eight-inch water column of gas pressure on the tank roof (Fig. 8.3), but some are designed for pressures of 25 inches or more. The domed cover is designed to hold a larger volume of gas. Any type of mixing device may be used with a fixed cover tank, and the tank must be equipped with pressure and vacuum relief valves.

A fixed cover digester can have an explosive mixture in the tank when sludge is withdrawn if proper precautions are not taken to prevent air from being drawn into the tank. Each time a new charge of raw sludge is added, an equal amount of supernatant is displaced because the tank is maintained at a fixed level.

B. Floating Cover

A floating cover moves up and down with the tank level and gas pressure. Normally the vertical travel of the cover is about eight feet, with stops (corbels) or landing edges for down (lowering) control and

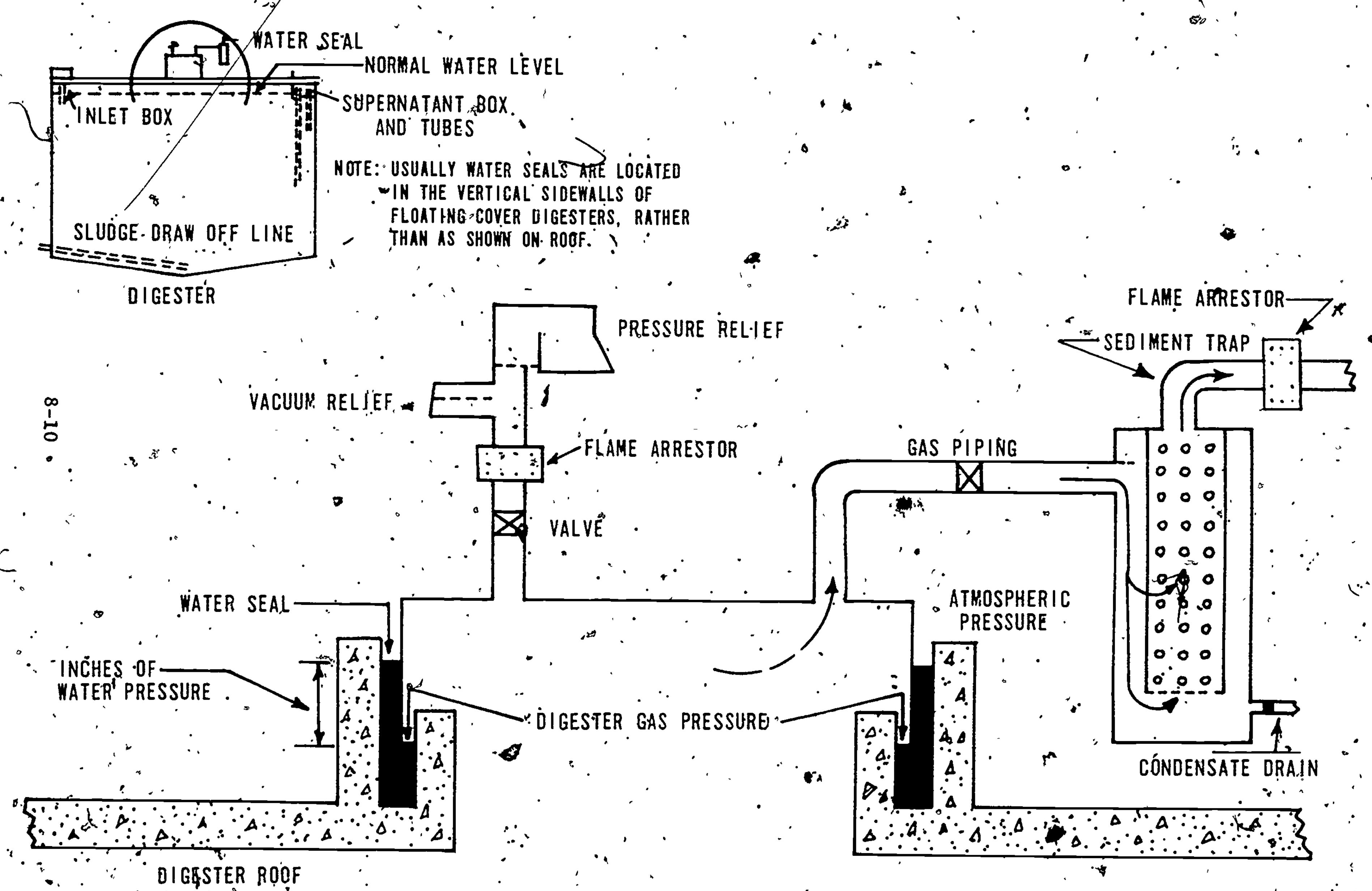

Fig. 8.3 Water seal on digester

maximum water level for upward travel. Maximum water level is controlled by an overflow pipe that must be kept clear to prevent damage to the floating cover by overfilling. Gas pressure is dependent upon the weight of the cover. The advantages of a floating cover include less danger of explosive mixtures forming in the digester, better control of supernatant withdrawal, and better control of scum blankets. Disadvantages include higher construction and maintenance costs.

C. Digester Depth

A typical operation depth for digesters is around 20 feet (side wall water level depth). The bottom slopes downward to the center of the tank. A gas space of two to three feet is usually provided above normal liquid sludge level, but some floating covers allow more room for gas storage.

D. Raw Sludge Inlet

Typically the raw sludge feed is piped to the top of the primary digester and admitted on the side opposite the supernatant overflow pipe (Fig. 8.4) to the secondary digester. Typically this line also carries any recirculated digester sludge in the system so that the raw sludge is immediately seeded with bacteria as it enters the tank.

E. Supernatant Tubes (Fig. 8.4)

On a fixed cover digester there may be three to five supernatant tubes set at different levels for supernatant removal. Normally only one tube is used at a time. The tube used is selected to return the supernatant liquor with the lowest quantity of solids back to the primary clarifier, or to sludge drying beds, provided space is available.

A single adjustable tube is also used at some plants. On the floating cover digester there is usually only one supernatant tube. This may be adjusted to pull supernatant liquor from various levels of the tank by raising or lowering the tube. In smaller plants the supernatant withdrawal may be done only once or twice a day, because the floating cover allows the tank to handle volume changes. An adjustable tube usually allows a supernatant with the least solids content to be selected. The digester should be visually checked a minimum of once per day for liquor levels to prevent overfilling and structural damage to the tank.

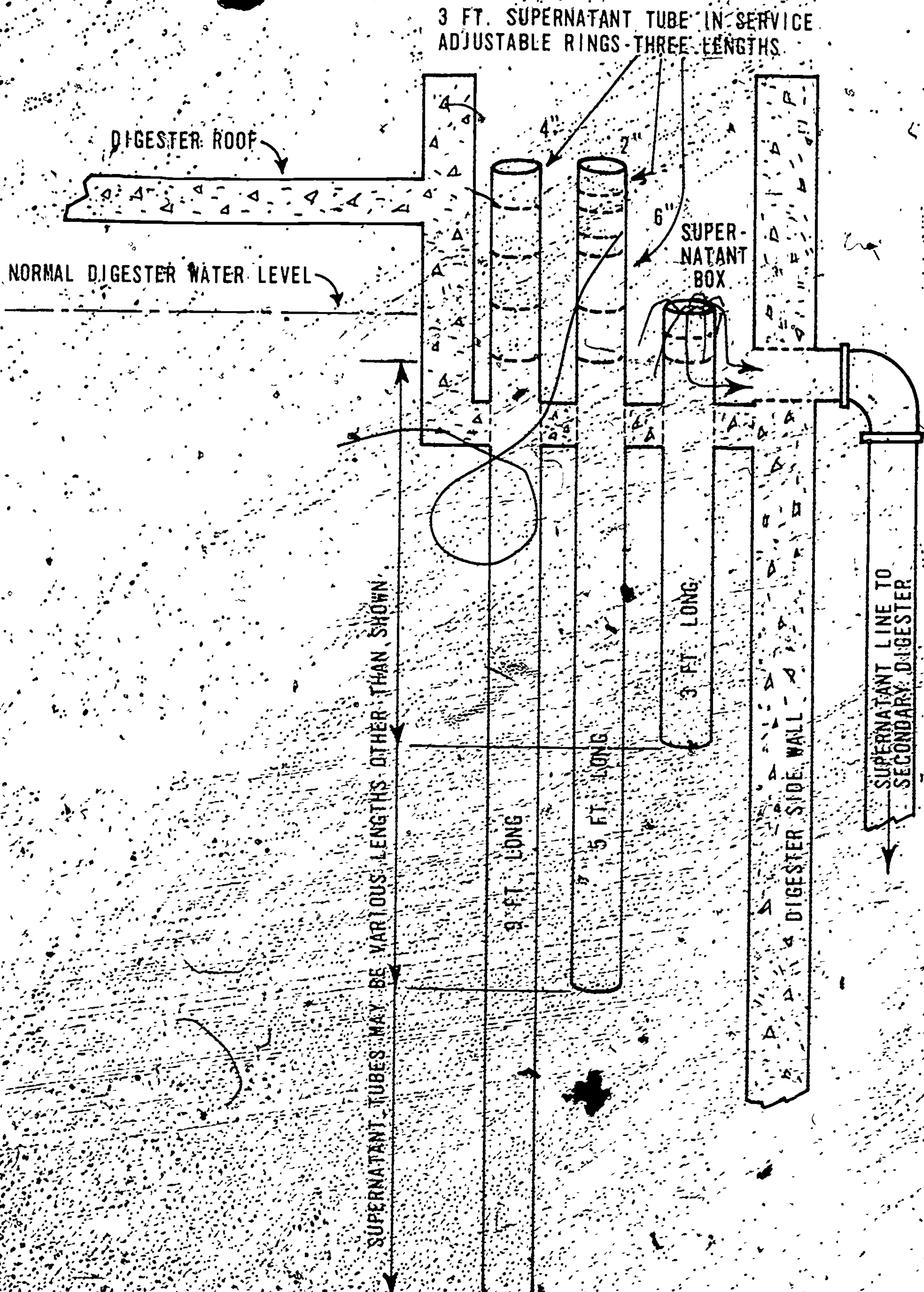

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Fig. 8.4 Supernatant tubes and box

F. Sludge Draw-off Lines

The sludge draw-off lines are typically placed on blocks along the sloping floor of the digester. Sludge is withdrawn from the center of the tank. Very seldom are they placed under the floor of the digester because they would not be accessible in case of blockages. These lines are normally six inches in diameter and equipped with plug valves. The lines are used to transfer the digester sludge periodically to a sludge disposal system of either drying beds or some type of dewatering system. These lines also transfer seed sludge from the secondary digester to the primary digester and recirculate bottom sludge to seed and break up a scum blanket.

QUESTIONS

8.11A Why should you maintain no more than an eight-inch water column of gas pressure on the roof of a ~~fixed~~ cover digester?

8.11B Why must a fixed cover digester be equipped with pressure and vacuum relief valves?

8.11C What are the advantages of a floating cover in comparison with a fixed cover digester?

8.11D Why is it desirable to mix recirculated digester sludge with raw sludge?

END OF LESSON 1 OF 5 LESSONS

on

SLUDGE DIGESTION AND HANDLING

8.12 Gas System (Fig. 8.5)[8]

The anaerobic digestion process produces 7 to 12 cubic feet of gas for every pound of volatile matter destroyed, depending upon the characteristics of the sludge. The gas consists mainly of methane (CH_4) and carbon dioxide (CO_2). The methane content of the gas in a properly functioning digester will vary from 65 to 70%, with carbon dioxide running around 30 to 35% by volume. One or two percent of the digester gas is composed of various other gases.

Digester gas (due to the methane) possesses a heat value of approximately 500 to 600 BTU[9] per cubic foot, whereas natural gas with a higher methane content may range from 900 to 1200 BTU per cubic foot.

Digester gas is utilized in plants in various ways: for heating the digesters, for heating the plant buildings, for running engines, for air blowers for the activated sludge process, or for electrical power for the plant.

WARNING

DIGESTER GAS CAN BE EXTREMELY DANGEROUS IN TWO WAYS. WHEN MIXED WITH OXYGEN IT CAN FORM EXPLOSIVE MIXTURES, AND IT ALSO CAN CAUSE ASPHYXIATION OR OXYGEN STARVATION. SMOKING, OPEN FLAMES, OR SPARKS MUST NOT BE TOLERATED AROUND THE DIGESTERS OR SLUDGE PUMPING FACILITIES.

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[8] Many figures in this section were made available courtesy of VAREC, Inc., 301 East Alondra Blvd., Gardena, California 90247. Mention of commercial products or manufacturers is for illustrative purposes and does not imply endorsement by Sacramento State College, EPA/WQO, or any other state or federal agency.

[9] BTU: British Thermal Unit. The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

The gas system removes the gas from the digester to a point of use, or to be burned in the waste gas burner as excess. The following items are components of the gas system.

A. Gas Dome

This is a point in the digester roof where the gas from the tank is removed. On fixed cover tanks there may also be a water seal (Fig. 8.3) incorporated to protect the tank structurally from excess positive pressure,[10] or vacuum created by withdrawal of sludge or gas too rapidly.

If gas pressure is allowed to build up to 11 inches of water column pressure, it will escape around the water seal to the atmosphere without lifting the roof. If sludge is drawn or gas used too rapidly, the vacuum could exceed eight inches and break the water seal, thus allowing air to enter the tank. Without the water seal, the vacuum could become great enough to collapse the tank. Air in the tank creates an explosive condition. In addition, sulphuric acid corrosion is often found where air is consistently in contact with the gas. The pipeline between the gas storage tank and the digester will protect the digester from water seal leaks, if the line is clear. When liquids are pumped into the digester, gas can go out the line to the storage tank and when liquids are pumped out of the digester, gas can return through the line.

QUESTIONS

8.12A What are the two main gaseous components of digester gas after gas production has become well established?

8.12B What are some uses of digester gas?

8.12C Why must the digester gas be controlled with extreme caution?

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[10] Positive Pressure. A positive pressure is a pressure greater than atmospheric. It is measured as pounds per square inch (psi) or as inches of water column. A negative pressure (vacuum) is less than atmospheric and is sometimes measured in inches of mercury.

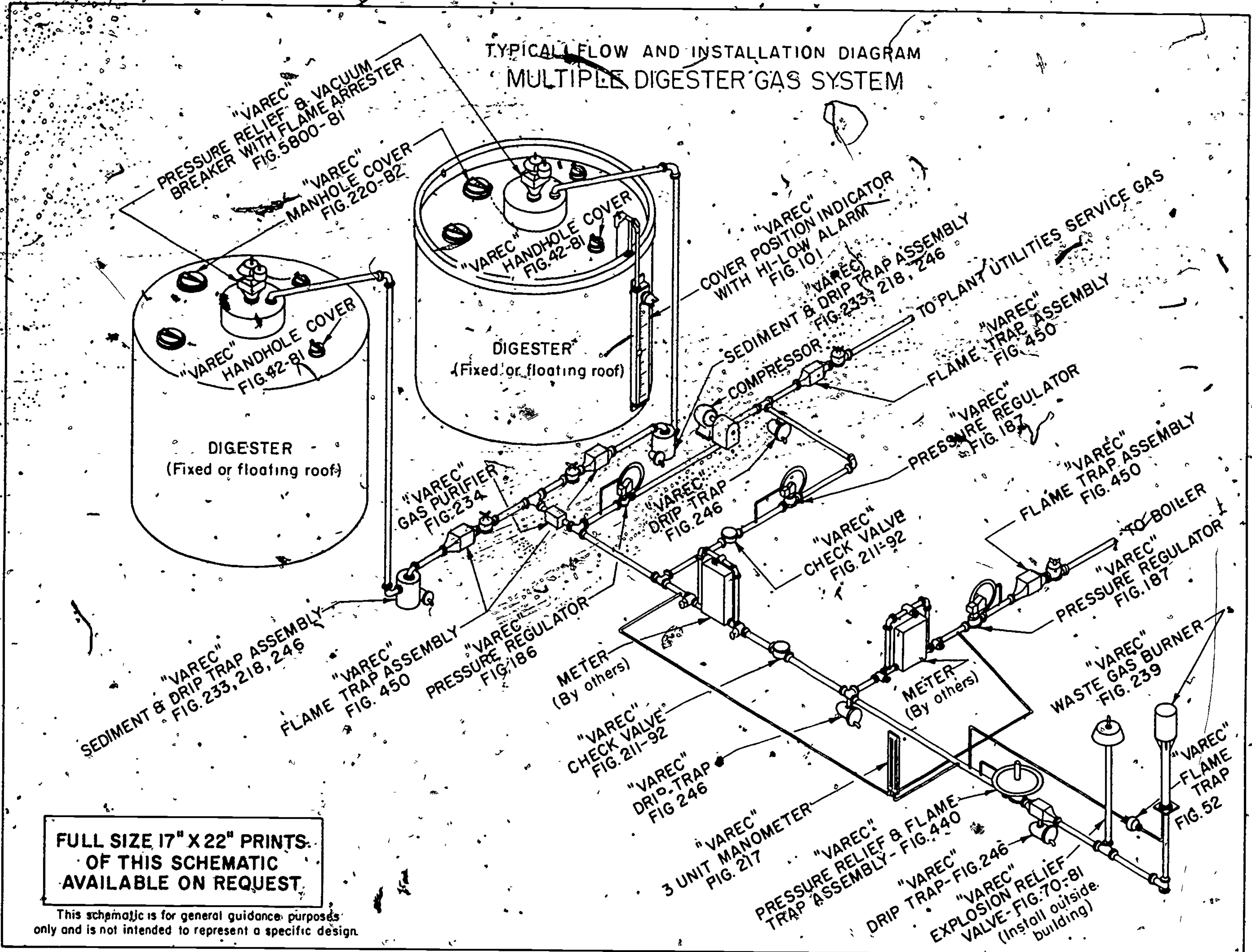

Fig. 8.5 Digester gas system
Courtesy of VAREC

B. Pressure Relief and Vacuum Relief Valves
(Fig. 8.6, VAREC Fig. No. 5800-81)

The pressure relief valve and the vacuum relief valve both are attached to a common pipe, but each works independently. The pressure relief valve is equipped with a seat and weighted with lead washer weights. Each weight is stamped with its equivalent water column height[11] such as 1" H_2O or 3" H_2O. There should be sufficient weights, combined with the weight of the pallet, to equal the designed holding pressure of the tank. The gas pressure is normally established between six inches and eight inches of water. If the gas pressure in the tank exceeds the pop-off setting, then the valve will open and vent to the atmosphere for a couple of minutes, through the pressure relief valve. This should occur before the water seal blows out. The water seal can be broken when a tank is overpumped or gas removal is too slow.

The vacuum relief valve operates similarly to the pressure relief valve except that it relieves negative pressures to prevent the tank from collapsing. Operating of either one of these valves is undesirable, because this allows the mixing of digester gas with air and can create an explosion outside the tank if the pressure relief valve opens and inside the tank if the vacuum relief opens.

WARNING

A GAS MIXTURE RATIO OF 5.7 TO 13.5% DIGESTER GAS TO AIR IS EXPLOSIVE (LOWER AND UPPER LIMITS).

These two valves should be checked at least every six months for proper operation.

[11] Water Column Height. When pressure builds up in a digester, the gas pressure would force water up a tube of water connected to the outside of the digester. The higher the water column height, the greater the gas pressure.

PRESSURE RELIEF AND VACUUM BREAKER VALVE WITH FLAME ARRESTER

for Use on Digesters and Gas Holders

The "Varec" Figure No. 5800-81 unit consists of a Figure No. 2000-81 Pressure Relief and Vacuum Breaker Valve and a Figure No. 50-91 Flame Arrester. Maximum protection against excessive pressure and vacuum is afforded and accidental ignition of sludge gas within the digester and gas holder from external sources is eliminated.

Valve is light weight and corrosion resistant construction. Interior parts are readily accessible for inspection and maintenance purposes. Pallets are dead weight loaded and include replaceable synthetic rubber sludge gas resistant seat inserts to insure gas tight seating and long life service with minimum maintenance. Seat rings, pallets and guide posts are anodized for extra corrosion protection and are removable.

Flame arrester consists of a flame arresting bank assembly enclosed within a gas-tight housing. The bank consists of a multiple number of individual corrugated stamped sheets and is readily removable from the housing for inspection and cleaning purposes. The arrester is listed by Underwriters Laboratories and is approved by Associated Factory Mutual Laboratories.

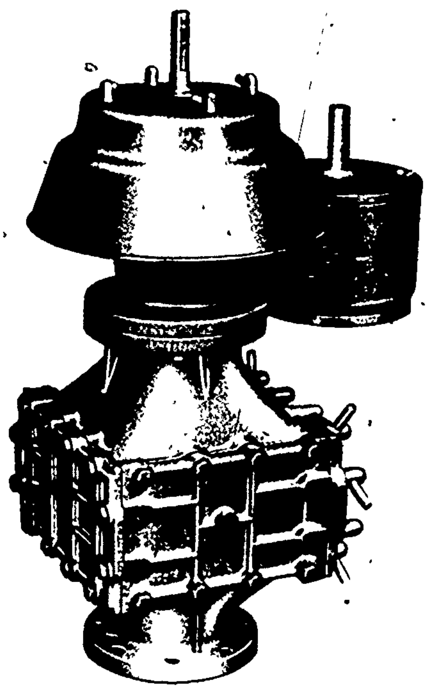

FIGURE NO. 5800-81

SETTINGS

Valves are furnished with variable pressure settings from 2" to 10" of water in increments of 1" of water. Vacuum setting is 2" of water unless otherwise specified.

STANDARD MATERIALS OF CONSTRUCTION

Valve is substantially aluminum (impervious to the attack of sludge gas) throughout except for synthetic rubber pallet seat inserts and steel studs, nuts and screws.

Flame arrester bank is all aluminum and the housing consists of cast aluminum ends and cast iron side and cover plates. Gaskets are graphited asbestos.

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C. Flame Arrestors (Fig. 8.8, VAREC Fig. No. 450)

A typical flame arrestor is a rectangular box holding approximately 50 to 100 corrugated aluminum plates with punched holes. If a flame should develop in the gas line, it would be cooled below the ignition point as it attempted to pass through the baffles, but gas could flow through with little loss in pressure.

> To prevent explosions, flame arrestors should be installed:
>
> 1. Between vacuum and pressure relief valves and the digester dome.
> 2. After sediment trap on gas line from digester.
> 3. At waste gas burner.
> 4. Before every boiler, furnace, or flame.
>
> Flame arrestors should be serviced every three months by valving the gas off, pulling one end plate, and sliding the baffle cartridge out of the housing. A build-up of scale, salts from condensate, and residue build-up on the plates restricts gas flow.

The cartridge in the flame arrestor is designed to slide open so the baffles may be separated and washed without complete dismantling. When the unit is reassembled it should be tested for leaks by swabbing a soapsuds solution over potential leaky areas and inspecting for bubbles.

D. Thermal Valves

Another protective device installed near a flame source and near the gas dome is the thermal valve. This valve is round, with a weighted seat attached to a stem. The stem sets on a fusible disk holding the seat up. If enough heat is generated by a flame, the fusible element melts and drops the stem and valve seat to cut off gas flow. Most valves are equipped with a wing nut on top of the valve body. If the wing nut is removed, it uncovers a glass tube which shows visually if the stem is up. If the stem cannot be seen, then the valve is closed, and no gas can flow. If this occurs, the valve is removed and heated in boiling water to remove the melted

fusible slug. A new slug is installed (slightly larger than an aspirin tablet), the stem replaced on top of it, and the valve is ready for service. These valves should be dismantled at least once a year in order to be positive that the stem is free to fall and not gummed up with residue or scale from the gas.

Figure 8.9 (VAREC Fig. No. 440) shows a flame arrestor connected to a pressure relief valve.

QUESTIONS

8.12G How would you service a flame arrestor?

8.12H Why should you check the thermal valves at least once a year?

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FLAME TRAP ASSEMBLY

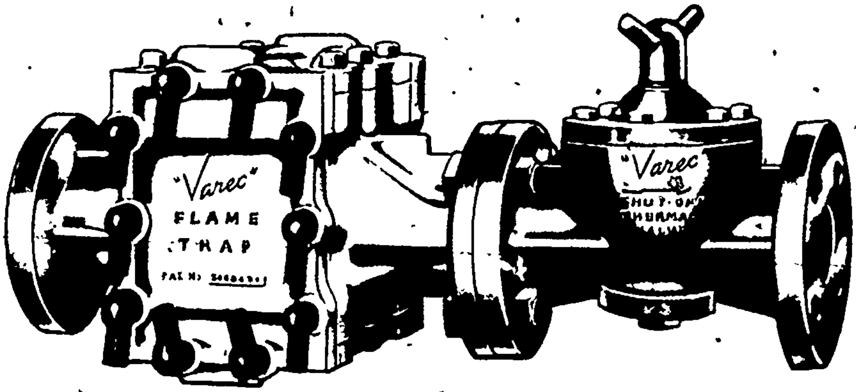

FIGURE NO. 450

Assembly consists of "Varec" Flame Trap Fig No 53-81 and Thermal Operated Shutoff Valve Fig. No. 430.

It is usually installed in all gas lines to gas utilization equipment, as close as possible to the points of combustion, and in lines leading from each digester and gasholder May be installed in either horizontal or vertical pipelines.

It is designed to arrest and stop flame propagation and to stop explosion waves, thus insuring protection of major equipment

FEATURES

Simple and positive flame trap. The fusible element melts at 260° and stops gas flow within 15 seconds. Compression type fusible element prevents shutoff valve closing unless contacted by flame. Three extra fusible elements shipped with each unit.

Since this unit is manufactured of aluminum, it resists the attack of any of the corrosive elements common to sludge gas.

Indicator rod shows when valve is in normal open position.

The "Varec" Flame Trap, Fig. No. 53-81 of this unit is listed by the Underwriters' Laboratories and approved by Associated Factory Mutual Laboratories,

Net free area through flame arresting bank is approximately four times corresponding pipe size. Each passageway has a net free area of approximately 0.042 sq. inches. By actual test these units have more flow capacity with less pressure drop than any known contemporary device.

Flow capacity curves are shown on the following page to assist in selecting the correct size of equipment.

Flame Trap element is easy to inspect and clean. It has good vertical and horizontal drainage. Drip Trap connection is provided in case Unit is installed at low point in line

MATERIALS OF CONSTRUCTION

Flame Trap Housing — aluminum and cast iron
Flame Trap Element — aluminum
Thermal Valve Body & Cover — aluminum
Guide Stem — stainless steel
Sight Glass — pyrex
Cover and cap gaskets — graphited asbestos
Sight glass gasket — synthetic rubber
Spring — stainless steel

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PRESSURE RELIEF AND FLAME TRAP ASSEMBLY

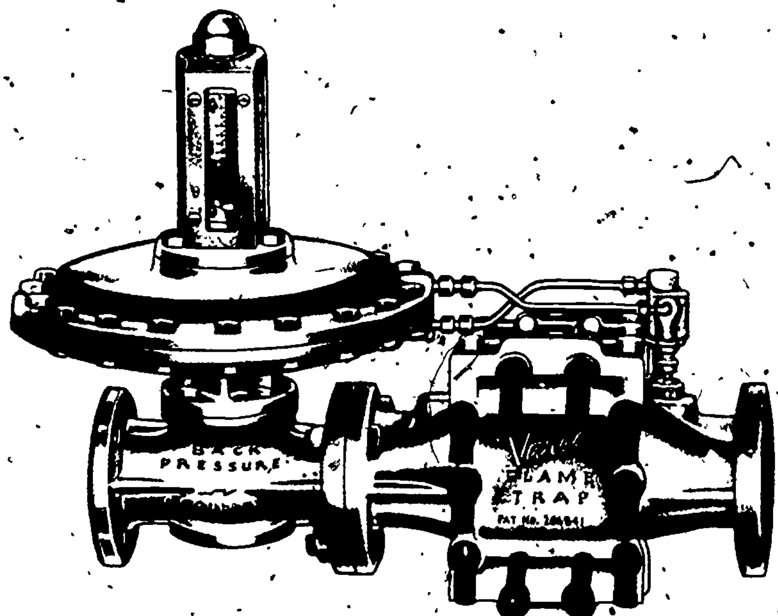

FIGURE NO. 440

Assembly consists of "Varec" Figure No. 386 Back Pressure Regulator, a "Varec" Figure No. 53-81 Flame Trap and a Thermal Shutoff Control unit.

It is usually installed in the waste gas line, just upstream of the waste gas burner.

It is designed to maintain a predetermined back pressure throughout the gas system so that only surplus gas is wasted, and to stop flame and explosion waves.

FEATURES

Simple, foolproof, sensitive in operation and a positive flame trap. The fusible element melts at 260°F. and stops gas flow within 15 seconds. Compression type fusible element prevents shutoff valve closing unless contacted by flame. Three extra fusible elements supplied with each unit.

Since the main bodies of the unit are constructed of aluminum and the stems, needle valve, and other important moving parts are of 18.8 stainless steel, this unit resists the attack of any of the corrosive elements common to sludge gas.

The "Varec" Flame Trap Fig. No. 53-81 of this unit is listed by the Underwriters' Laboratories and approved by Associated Factory Mutual Laboratories. The Flame Trap element is easy to inspect and clean. Drip Trap connection is provided in case unit is installed at a low point in line.

Net free area through flame arresting bank is approximately four times corresponding pipe size. Each passageway has a net free area of approximately 0.042 sq. inches. By actual test these units have more flow capacity with less pressure drop than any known contemporary device.

Flow capacity curves are shown on the following page to assist in selecting the correct size of equipment.

The Back Pressure Regulator unit is equipped with setting indicator so operator can easily adjust setting to requirements.

RANGE OF OPERATION

Range of operation is 2 to 12 inches water. Special springs available for higher operating pressures. Equipment supplied by factory set at 6 inches of water if not specified otherwise. Operator can adjust to his requirements.

MATERIALS OF CONSTRUCTION

Regulator Body — cast aluminum
Diaphragm Case — cast aluminum
Bonnet — cast aluminum
Spring — Cadmium-plated steel
Diaphragm — corded synthethic rubber
Cap — brass
Thermal Shutoff Valve — aluminum, brass & stainless steel
Flame Trap Housing — heavy cast aluminum ends and cast iron side and cover plates
Flame Trap Element — aluminum

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E. Sediment Traps

A sediment trap is a tank, 12 to 15 inches in diameter and two to three feet in length. It is usually located on top of the digester near the gas dome. The inlet gas line is near the top of the tank and on the side. The outlet line comes directly from the top of the sediment tank. The sediment trap is also equipped with a perforated inner baffle, and a condensate drain near the bottom. The gas enters the side at the top of the tank, passes down and through the baffle, then up and out the top. Moisture is collected from the gas in the trap, and any large pieces of scale are trapped before entering the gas system. The trap should be drained of condensate frequently but may have to be drained twice a day during cold weather, because greater amounts of water will be condensed.

F. Drip Traps--Condensate Traps
(Fig. 8.10, VAREC Fig. Nos. 245 and 246)

Digester gas is quite wet and in traveling from the heated tank to a cooler temperature the water condenses. The water must be trapped at low points in the system and removed; or it will impede gas flow and cause damage to equipment, such as compressors, and interfere with gas utilization. Traps are usually constructed to have a storage space of one to two quarts of water. All drip traps on gas lines should be located in the open air and be of the manual operation type. Traps should be drained at least twice a day and possibly more often in cold weather. Automatic drip traps are not recommended because many automatic traps are equipped with a float and needle valve orifice and corrosion, sediment, or scale in the gas system can keep the needle from seating. The resulting leaks may create gas concentrations with a potential hazard to life and equipment.

G. Gas Meters

Gas meters may be of various types, such as bellows, diaphragm, shunt flow, propeller, and orifice plate or differential pressure. They are described in detail in the metering section of Chapter 11, Maintenance.

H. Manometers

Manometers are installed at several locations to indicate gas pressure within the system in inches of a water column.

I. Pressure Regulators (Fig. 8.11, VAREC Fig. No. 387)

Pressure regulators are typically installed next to and before the waste gas burner. Such regulators are usually of the diaphragm type and control the gas pressure on the whole digester gas system. They are normally set at eight inches of water column by adjusting the spring tension on the diaphragm. Whenever an adjustment of a pressure setting is made, check the gas system pressure with a manometer for the proper range. If the gas pressure in the system is below eight inches of water column, no gas flows to the waste burner. When the gas pressure reaches eight inches of water column, the regulator opens slightly, allowing gas to flow to the burner. If the pressure continues to increase, the regulator opens further to compensate. The only maintenance this unit requires is on the thermal valve on the discharge side which protects the system from back flashes. This unit is spring loaded and controlled by a fusible element that vents one side of the diaphragm, thus stopping the gas flow when heated. Maintenance includes checking for proper operation of the regulator and of the fusible element. Gas regulators are also placed at various points in the system to regulate the gas pressure to boilers, heaters, and engines. Diaphragm conditions in the regulators should be checked at periodic intervals.

J. Waste Gas Burner (Fig. 8.12)

Waste gas burners are used to burn the excess gas from the digestion system. The waste gas burner is equipped with a continuous burning pilot flame, so that any excess gas will pass through the gas regulator and be burned. The pilot flame should be checked daily to be sure that it has not been blown out by wind. If the pilot is out, gas will be vented to the atmosphere creating an odorous and potentially explosive condition.

QUESTIONS

8.12I How frequently should you drain a sediment trap?

8.12J Why must drip or condensate traps be installed in gas lines?

8.12K What is a deficiency in automatic drip and condensate traps?

8.12L How would you adjust the gas pressure of the digester gas system?

8.12M Why should the pilot flame in the waste gas burner be checked daily?

DRIP TRAPS

Automatic

Varec Drip Traps are for collection and safe removal of condensate from gas lines and equipment. Drip traps should be installed at all low points in gas pipe systems where condensation will collect.

The Varec Figure No. 245 Automatic Drip Trap employs a float operated needle valve which automatically drains off collected condensate. This feature is particularly desirable where a closed discharge to drain is permissible and where condensate occurs too frequently for manual operation.

Standard construction is alum. body and cover, stainless steel ball float and needle valve assembly and graphited asbestos gasket. Available with ½", ¾", 1" NPT connections.

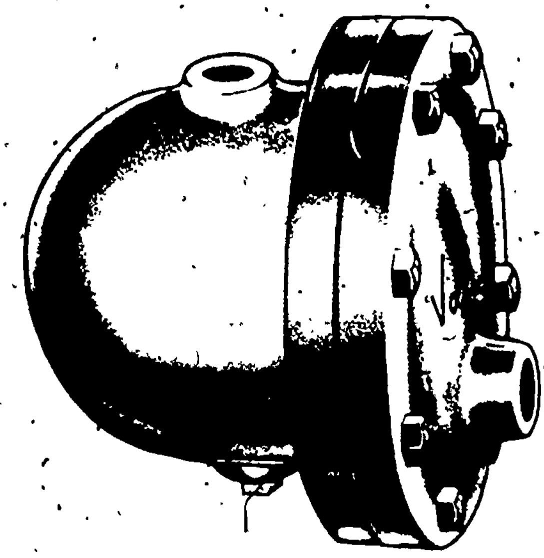

FIG. NO. 245 AUTOMATIC

Rotating Disc Type

The Varec Figure No. 246 Drip Trap is manually operated. Handle rotates disc from open inlet position to drain position. Ports and disc are so arranged that gas cannot escape regardless of disc position. Both ports and shaft are positively sealed by synthetic rubber "O" rings. Vent hole is provided to allow inflow of air to bowl while draining.

Standard construction is cast aluminum bowl and handle. Aluminum cover plate and disc are anodized. Other working parts are stainless steel. Heavy duty construction throughout. Available in 2½ quart capacity with 1" NPT connections.

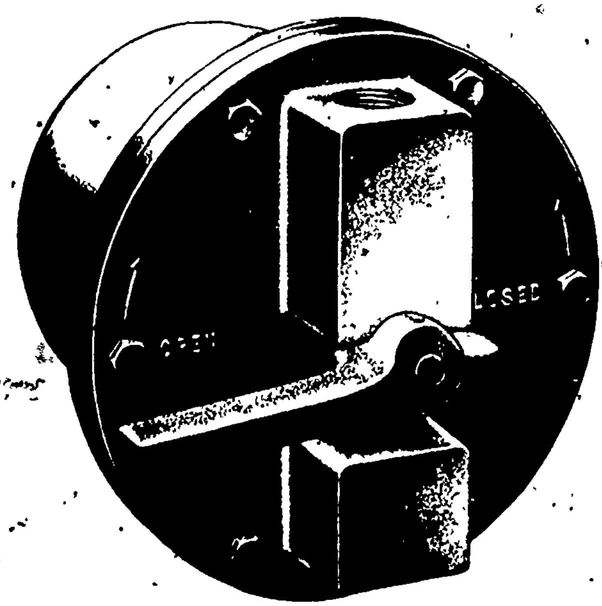

FIG. NO. 246
ROTATING DISC TYPE

BACK PRESSURE REGULATOR SINGLE PORT

The Figure No. 386 Regulator Valve is designed to control upstream pressure in sludge gas lines. Positive shut-off as well as accurate control is provided. Pointer type indicator, in weather-proof bonnet, facilitates setting adjustment. No weights or dismantling necessary to make adjustment.

Valve is the single port type operated by a spring loaded diaphragm.

Setting range is 2" W.C. to 12" W.C. as standard. Higher settings available (20" W.C. maximum) on special order

MATERIALS OF CONSTRUCTION:

Heavy cast aluminum valve body, diaphragm housing and pallet, stainless steel operating shaft, heavy corded synthetic rubber diaphragm and cadmium plated steel spring.

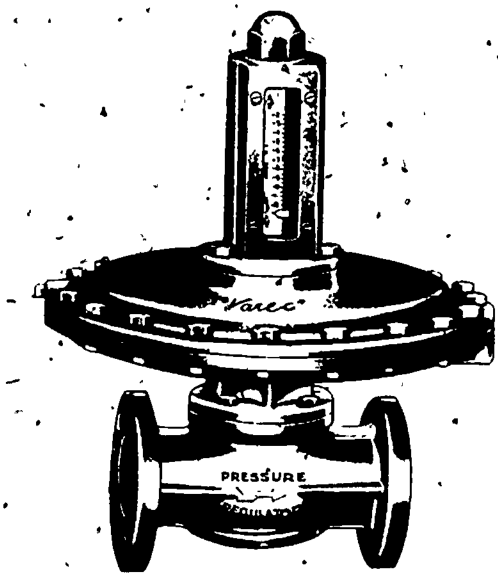

FIGURE NO. 386

PRESSURE (REDUCING) REGULATOR SINGLE PORT

The Figure No. 387 Regulator Valve is designed to control downstream pressure in sludge gas lines. Positive shut-off as well as accurate control is provided. Pointer type indicator, in weather-proof bonnet, facilitates setting adjustment. No weights or dismantling necessary to make adjustment.

Valve is single port type operated by a spring loaded diaphragm.

Setting range is 2" W.C. to 12" W.C. as standard. Higher settings available (20" W.C. maximum) on special order.

MATERIALS OF CONSTRUCTION:

Heavy cast aluminum valve body, diaphragm housing and pallet, stainless steel operating shaft, heavy corded synthetic rubber diaphragm and cadmium plated steel spring.

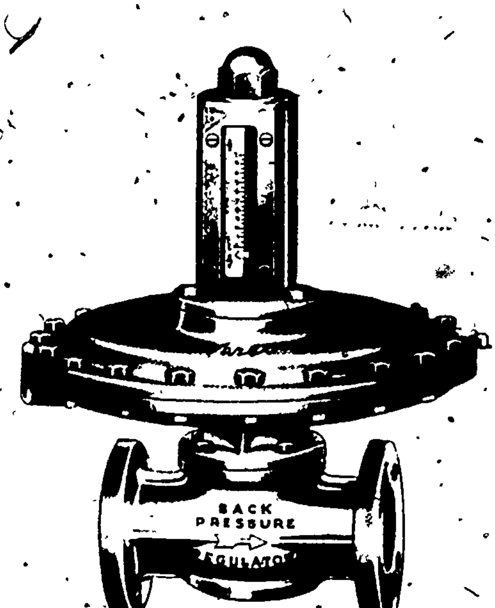

FIGURE NO. 387

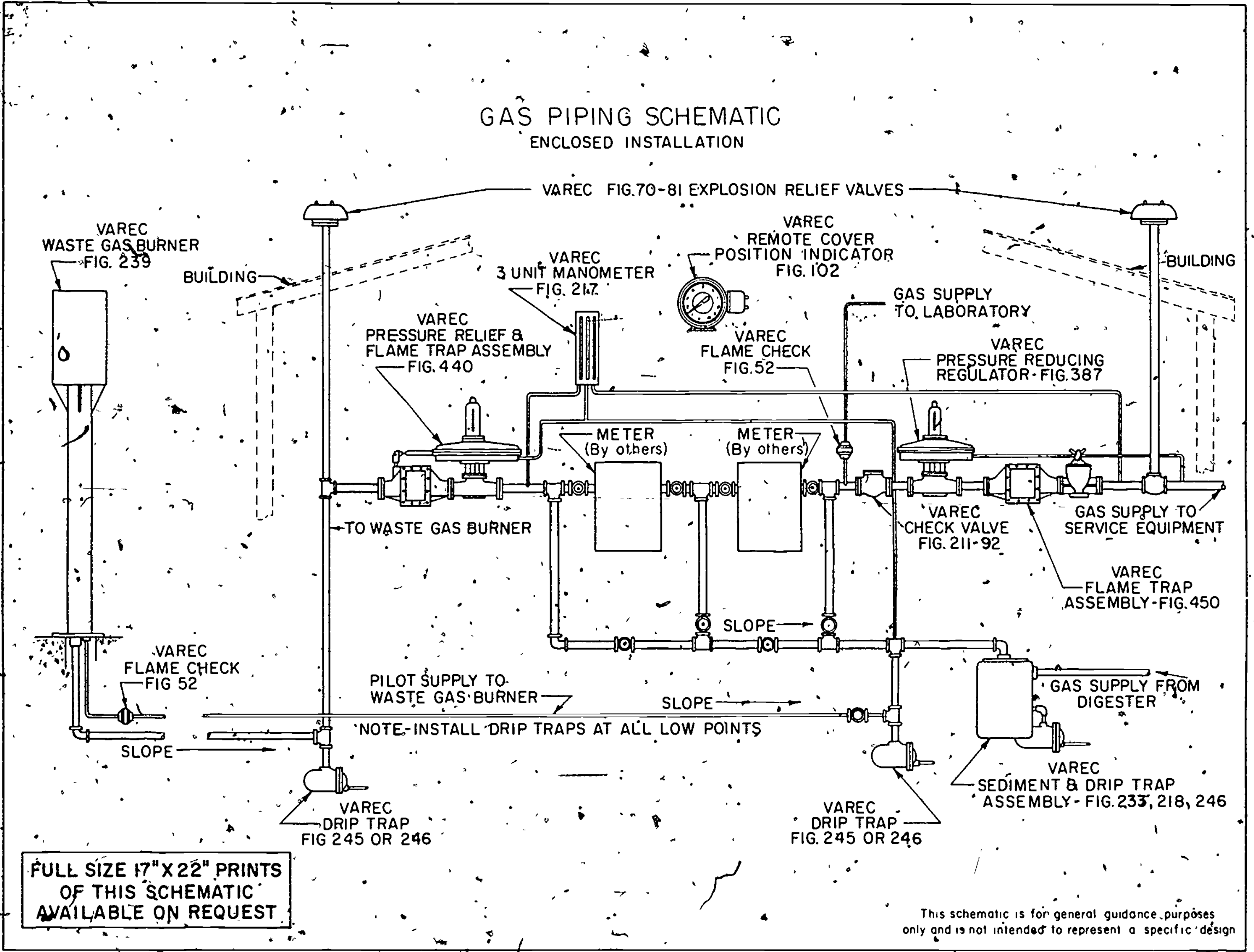

Fig. 8.12 Waste gas burner

Courtesy of VAREC

8.13 Sampling Well (Thief Hole)

(Fig. 8.13, VAREC Fig. Nos. 42-81 and 48-81)

The sampling well consists of a 3- or 4-inch pipe (with a hinged seal cap) that goes into the digestion tank, through the gas zone, and is always submerged a foot or so into the digester sludge. This permits the sampling of the digester sludge without loss of digester gas pressure, or the creation of dangerous conditions caused by the mixing of air and digester gas. However, caution must be used not to breathe gas which will always be present in the sample well and will be released when first opened. A sampling well is sometimes referred to as a "thief hole".

8.14 Digester Heating

Digesters can be heated in several ways. Newer facilities typically provide digesters that are heated by recirculating the digester sludge through an external hot water heat exchanger. Digester gas is used to fire the boiler, which is best maintained between 140 and 180°F for proper operation. The hot water is then pumped from the boiler to the heat exchanger where it passes through one jacket system, while the recirculating sludge passes through an adjacent jacket, picking up heat from the hot water. In some units the boiler and exchanger are combined and the sludge also is passed through the unit.

Circulation of 130°F water through pipes or heating coils attached to the inside wall of the digester is another method of heating digesters, although not too common in newer plants. This approach creates problems of cooking sludge on the pipes and insulating them, thus reducing the amount of heat transferred. Some facilities use submerged combustion of the gas with heat exchange between the hot gaseous products evolved and the liquid sludge.

Other plants inject steam directly into the digesters for heating. The steam is produced in separate boilers or is recovered in connection with vapor phase cooling of engines. Careful treatment of the evaporated water to prevent scaling of the system is necessary so the practice is generally confined to plants with good laboratory control.

QUESTIONS

8.13A Why should a digester have a special sampling well?

8.14A What causes a reduction in the amount of heat transferred from coils within the digester?

SAMPLING HATCH or HANDHOLE COVER

Non-sparking Gas-tight

VAREC Sampling Hatches or Handhole Covers are for use on digester covers or roofs. Insurance requirements are complied with in that this equipment is non-sparking, self-closing and gas-tight. Construction is non-corrosive in sludge gas service.

Above photo shows simplicity of operation

Figure No. 42-81 incorporates a standard 125 lb. A.S.A. flanged base for mounting. It is of extra heavy construction, basically of aluminum throughout. Specialty features are included such as a safety foot pedal for quick opening, a hand wheel which may be padlocked closed, and a synthetic rubber insert in cover to insure a gas-tight seal.

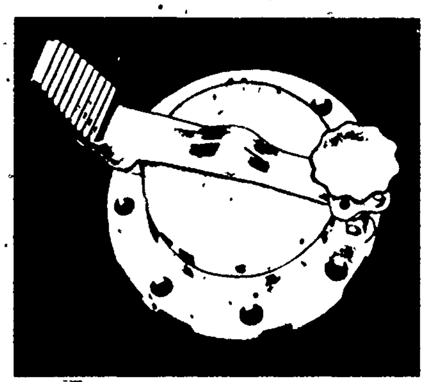

Figure No. 42-81
Flanged Base

Figure No. 48-81 is substantially same as Figure No. 42-81 in that it includes all the specialty features and is of same materials of construction. However, the base is for Standard Pipe Thread mounting.

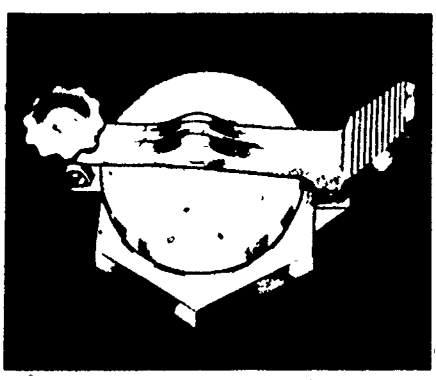

Figure No. 48-81
Screwed Base

8.15 Digester Mixing

Mixing is very important in a digester. The ability of the mixing equipment to keep the tank completely mixed speeds digestion greatly. Several important objectives are accomplished in a well-mixed digester.

a. Inoculation[12] of the raw sludge immediately with microorganisms.

b. Prevention of a scum blanket from forming.

c. Maintenance of homogeneous contents within the tank, including even distribution of food, organisms, alkalinity, heat, and waste bacterial products.

d. Utilization of as much of the total contents of the digester as possible and minimization of the build-up of grit and inert solids on the bottom.

A. Gas Mixing

This type of mixing is the most generally used in recent years, and various approaches have been patented by manufacturers. Gas is pulled from the tank, compressed, and discharged through gas outlets or orifices within the digester, or at some point several feet below the sludge surface. The gas rising to the surface through the digesting sludge carries sludge with it, creating a gas lift with a rolling action of the tank contents. The gas mixer may be operated on either a start and stop or a continuous basis, depending upon tank conditions. The components required for gas mixing include inlet and discharge gas lines, a positive displacement compressor, and a stainless steel gas line header in the digester. The gas header is equipped with a cross arm to hold a specified number of gas outlets, and may be mounted in a draft tube. The gas compressor is sized for the digester and may range from 30 to 200 cfm of gas.

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[12] Inoculation (in-NOCK-you-LAY-shun). Introduction of a seed culture into a system.

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Work with "natural gas evolution" mixing at the Los Angeles County Sanitation District's plants has indicated that loadings of over 0.4 pounds of volatile solids per cubic foot per day were possible, but that if the loading dropped below 0.3 pounds immediate stratification occurred. In terms of gas recirculation, adequate mixing has been calculated from this study to be of the order of 500 cfm (cubic feet per minute) per 100,000 cubic feet of tank capacity if released at about a 15-foot depth. If released at a 30-foot depth, about 250 cfm per 100,000 cubic feet of tank capacity should be satisfactory. If hydraulic processes are used, either by recirculation or by draft tubes and propellers, then something like 30 HP per 100,000 cubic feet of tank capacity is required.

Maintenance requires that the condensate be drained from the lines at least twice a day, that the diffusers be cleaned to prevent high discharge pressures, and that the compressor unit be properly lubricated and cooled.

QUESTIONS

8.15A Why should a digester be kept completely mixed?

8.15B What maintenance is necessary for the proper operation of digester mixing by the use of gas?

B. Mechanical Mixing

Propeller mixers are found mainly on fixed cover digesters. Normally two or three of these units are supported from the roof of the tank with the props submerged 10 to 12 feet in the sludge. An electric motor drives the propeller stirring the sludge.

Draft tube propeller mixers are either single or multiple unit installations. The tubes are of 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 of the tank. The bottom of the draft tube may be straight or equipped with a 90° elbow. The 90° elbow type is placed so that the discharge is along the outside wall of the tank to create a vortex (whirlpool) action.

The electric motor driven propeller is located about two feet below the top of the draft tube. This type unit usually has reversible motors so the prop may rotate 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 discharged over the top of the draft tube to the surface.

If two units are in the same tank, an effective operation for breaking up a scum blanket is operating one unit in one direction and the other unit in the opposite direction, thereby creating a push-pull effect. The draft tube units are subject to shaft bearing failure due to the abrasiveness of sludge, and due to corrosion by hydrogen sulfide (H_2S) in the digester gas. Maintenance consists of lubrication and, if belt-driven, adjustment of belt tension.

A limitation of draft tube type mixers is digester water level. If the water level is maintained at a constant elevation, a scum blanket forms on the surface. The scum blanket may be a thick layer and the draft will only pull liquid sludge from under the blanket, not disturbing it. Lowering the level of the digester to just three or four inches over the top of the draft tube forces the scum to move over and down the draft tube. This applies mainly to single direction mixers.

Pumps are sometimes used to mix digesters. This method is common in smaller tanks. When external heat exchangers are employed, 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 200 to 1000 gpm.

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

Maintenance of the pump requires normal lubrication and a good pump shaft sealing water system. The digested sludge is abrasive and pump packing, shafts, wearing rings, and impellers are rapidly worn. Another problem associated with pump mixing is the clogging of the pump impeller with rags, rubber goods, and plastic material. A pump may run for days not pumping due to clogging because the operator was not checking the equipment for proper operation.

Pressure gauges should be installed on the pump suction and discharge pipes. When a gauge reading different than normal occurs, the operator has an indication that some condition has changed that requires checking.

QUESTIONS

8.15C How would you break up a scum blanket in a digester with two or more draft tube propeller mixers?

8.15D Why should pressure gauges be installed on mixing pump suction and discharge lines?

END OF LESSON 2 OF 5 LESSONS

on

SLUDGE DIGESTION AND HANDLING

CHAPTER 8. SLUDGE DIGESTION AND HANDLING

(Lesson 3 of 5 Lessons)

8.2 OPERATION OF DIGESTERS

A digester can be compared with your own body. Both require food; but if fed too much, both become upset. Excess acid will upset both. Both like to be warm, with a body temperature of 98.6°F near optimum. Both have digestive processes that are similar. Both discharge liquid and solid waste. Both utilize food for cell reproduction and energy. If something causes upsets in a digester, just think how you would react if it happened to you — and recall what would be the proper remedy. The remedies for curing upset digesters will be discussed throughout this chapter.

8.20 Raw Sludge and Scum

Raw sludge is normally composed of solids settled and removed from the primary and secondary clarifiers. Raw sludge contains carbohydrates, proteins, and fats, plus organic and inorganic chemicals that are added by domestic and industrial uses of water.

Solids are composed of organic (volatile) and inorganic material with the volatile content running from about 60% to 80% of the total, by weight. Some plants do not have grit removal equipment; so the bulk of the inert (inorganic) material such as sand, eggshells, and other debris will end up on the bottom of the digester occupying active digestion space. The rate of debris accumulation is predictable so that the amount is a function of the period of time between digester cleanings. Where cleaning has been neglected, a substantial portion of the active volume of the digester becomes filled with inert debris. Scum-forming products, such as kitchen grease, soaps, oils, cellulose, plastics, and other floatable debris, are generally all organic in nature but may create problems if the scum blanket in the digester is not controlled. Control is by providing adequate mixing and heat.

Several products end up in the digester that are not desirable because the bacteria cannot effectively utilize or digest them, and they cannot be readily removed by the normal process. These products include:

1. petroleum products and mineral oils
2. rubber goods
3. plastics (back sheets to diapers)
4. filter tips from cigarettes
5. hair
6. grit (sand and other inorganics)

Consequently, these items tend to accumulate in the digester and, without adequate mixing, may form a hard, floating mat and a substantial bottom deposit. On the other hand, a well-mixed tank may also present operational problems. For example, the material shredded by a comminuter or barminuter may become balled together by the mixing action and plug the digester supernatant lines.

Scum from the primary clarifiers is comprised mainly of grease and other floatable material. It may be collected and held in a scum box and then pumped to the digester once a day, or it may be added continuously or at a frequency necessary to maintain the proper removal of scum from the raw wastewater flow. Many operators prefer not to pump scum to the digesters, but to dispose of it by burning or burial. Scum may also refer to the floating and gas buoyed material found on the surface of poorly mixed digesters. This material may contain ~~much~~ cellulose, rubber particles, mineral oil, plastic, and other debris. It may become 5 to 15 feet thick in a digester, but should not occur in a properly operating digester. A thick scum layer will reduce the active digestion capacity of a digester.

8.21 Starting a Digester

When wastewater solids are first added to a new digester, naturally occurring bacteria attack the most easily digestible food available, such as sugar, starches, and soluble nitrogen. The anaerobic acid producers change these foods into organic acids, alcohols, and carbon dioxide, along with some hydrogen sulfide. The pH of the sludge drops from 7.0 to about 6.0 or lower. An "acid regression stage"[13] then starts and lasts as long as six to eight weeks. During this time ammonia and bicarbonate compounds are formed, and the pH gradually increases to around 6.8 again, establishing an environment for the methane fermentation or alkaline fermentation phase. Organic acids are available to feed the methane fermenters. Large quantities of methane gas are produced as well as carbon dioxide, and the pH increases to 7.0 to 7.2. Once alkaline fermentation is well established, strive to keep the digesting sludge in the 7.0 to 7.2 pH range.

[13] Acid Regression Stage. A time period when the production of volatile acids is reduced. During this stage of digestion ammonia compounds form and cause the pH to increase.

If too much raw sludge is added to the digester, the acid fermenters will predominate, driving the pH down and creating an undesirable condition for the methane fermenters. The digester will go sour or acid again. When a digester recovers from a sour or acid condition, the breakdown of the volatile acids and formation of methane and carbon dioxide is usually very rapid. The digester may then foam or froth, forcing sludge solids through water seals and gas lines and causing a fairly serious operational problem. A sour digester usually requires 30 to 60 days to recover.

As noted at the beginning of this section, the first group of organisms must do its part before food is available to the next group. Once the balance is upset, so is the food cycle to the next group. When the tank reaches the methane fermentation phase, there is sufficient alkaline material to buffer the acid stage and maintain the process. Operational actions such as poor mixing, addition of excess food, excess water supplied to dilute the alkaline buffer, over-drawing digested sludge, or improper temperature changes can cause souring again.

The simplest way to start a digester is with seed sludge (actively digesting material) from another digester. The amount of seed to use is dependent upon factors such as mixing processes, digester sizes, and sludge characteristics, but amounts between 10 and 50% of the digester capacity have been used.

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8.22 Feeding

Food for the bacteria in the digester is the sludge from the primary and secondary clarifiers. Make every effort to pump as thick a sludge to the digester as possible. This may be accomplished by holding a blanket of sludge as long as possible in the primary clarifier, long enough to allow sludge concentration, but not long enough for sludge to start rising. In some plants concentration is accomplished in separate sludge thickening or flotation tanks.

Better operational performance occurs when the digester is fed several times a day, rather than once a day because you are avoiding temporary overloads on the digester and you are using your available space more effectively. If the plant is producing only 500 gallons of 6% sludge a day, one feeding may be allowable; however, for volumes much greater than 500 gallons a day, several pumpings a day should be used. This not only helps the digestion process, but maintains better conditions in the clarifiers, permits thicker sludge pumping, and prevents coning[14] in the primary clarifier hopper. On fixed cover digesters frequent feeding spreads the return of digester supernatant over the entire day instead of a return in one slug with possible upset of the secondary treatment system. Sludge is usually concentrated by holding a thick blanket on the bottom of the clarifier; but if sludge sets for a prolonged period, lowest layers may stick to the bottom and will no longer flow with the liquid. When pumping is attempted, liquid flows but solids remain in the hopper in a cone around the outlet.

It is never desirable to pump thin sludge or water to a digester. A sludge is considered thin if it contains less than 4% solids (too much water). Reasons for not pumping a thin sludge include:

1. Excess water requires more heat than may be available.
2. Excess water reduces holding time of the sludge in the digester.
3. Excess water forces seed and alkalinity from the digester, jeopardizing the system due to insufficient buffer[15] for the acids in the raw sludge.

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[14] Coning (CONE-ing). A condition that may be established in a sludge hopper during sludge withdrawal when part of the sludge moves toward the outlet while the remainder tends to stay in place. Development of a cone or channel of moving liquid surrounded by relatively stationary sludge.

[15] Buffer. A measure of the ability or capacity of a solution or liquid to neutralize acids or bases. This is a measure of the capacity of water or wastewater for offering a resistance to changes in the pH. Buffer capacity is measured by titration with standard alkali and acid until the pH reaches some reference or end point (a pH of 4.5 or 8.5). The higher the volume (ml) of known reagent requirements, the higher the buffer capacity.

Sludge concentrations above about 12% solids will usually not digest well in conventional digestion tanks since adequate mixing cannot be obtained. This, in turn, leads to improper distribution of food, seed, heat, and metabolic products so that the souring and a stuck[16] digester results. However, most plants have difficulty in obtaining a raw sludge of 8% solids. Where a trickling filter or activated sludge process is used as the secondary system, sludges may have a solids range from 1 to 3%. A good activated sludge is likely to be oxidized to the point of negligible action in an anaerobic digester.

Feeding a digester must be regulated on the basis of laboratory test results in order to insure that the volatile acid/alkalinity reltaionship does not start to increase and become too high. See Section 8.4B.

QUESTIONS

8.22A How would you attempt to pump as thick a sludge as possible to a digester?

8.22B Why should sludge be pumped occasionally throughout the day rather than as one slug each day?

8.22C Why should the pumping of thin sludge be avoided?

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[16] Stuck. A "stuck" digester does not decompose the organic matter properly. Some operators refer to it as constipated. It is characterized by low gas production, high volatile acid/alkalinity relationship, and poor liquid-solids separation. A digester in a stuck condition is sometimes called a "sour" digester.

8.23 Neutralizing a Sour Digester

The recovery of a sour digester can be accelerated by neutralizing the acids with a caustic material such as soda ash, lime, or ammonia, or by transferring alkalinity in the form of digested sludge from the secondary digester. Such neutralization increases the pH to a level suitable for growth of the methane fermenters and provides buffering material which will help maintain the required volatile acids/alkalinity relationship and pH. When ammonia is added to a digester, an added load is eventually placed on the receiving waters. The application of lime will increase the solids handling problems. Soda ash is more expensive than lime, but doesn't add as much to the solids deposits. Transferring secondary digester sludge has the advantage of not adding anything extra to the system that was not there at an earlier time and, if used properly, will reduce both the effluent load and the solids handling problem.

If digestion capacity and available recovery time are great enough, it is probably preferable to simply reduce loading while heating and mixing so that natural recovery occurs. However, there are often conditions in which such neutralization is necessary.

When neutralizing a digester, the prescribed dose must be carefully calculated. Too little will be ineffective, and too much is both toxic and wasteful. In considering dosage with lime, the small plant without laboratory facilities could use as a rough guide a dosage of about one pound of lime added for every 1000 gallons of sludge to be treated. Thus, a 188,000-gallon digester full of sludge would receive 188 pounds of lime. A more accurate method is to add sufficient lime to neutralize 100% of the volatile acids in the digester liquor.

8.24 Enzymes[17]

In recent years several products containing "commercial" enzymes or other biocatalysts (BUY-o-CAT-a-lists) have been marketed for starting digesters, controlling scum, or simply to maintain operation. Such biocatalysts or enzymes have never been shown to be effective in controlled tests and could, in fact, cause as much harm as good. A biological system such as found in the digesters develops a balanced enzyme and biocatalyst system for the conditions under which it is operating. The quantities of natural enzymes developed within the digesting sludge are many, many times greater than any amount you could either add or afford to purchase.

8.25 Foaming

Large amounts of foam may be generated during start-up by the almost explosive generation of gas during the time of acid recovery. Foaming is the result of active gas production while solids separation has not progressed far enough (insufficient digestion). It is encouraged during start-up by overfeeding. Foaming can be prevented by adequate mixing of the digester contents before foaming starts.

Bacteria can go to work very quickly when they have the proper environment. Almost overnight they can generate enough gas to

create a terrific mess of black foam and sludge. The foam not only plugs gas piping systems, but can exert excess pressures on digester covers, cause odor problems, and ruin paint jobs on tanks and buildings.

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[17] Enzymes (EN-zimes). Enzymes are substances produced by living organisms that speed up chemical changes.

To clean up the mess, first drop the level of the digester a couple of feet by withdrawing some supernatant. Next, cut off the gas system and flush it with water. Then hose the outside of the digester off as soon as possible or the paint will be stained a permanent grey. Drain and refill the water seal to remove the water fouled by the foaming. Use a strainer type skimming device to remove any rubber goods and plastic materials that have entered the water seal.

To control the foaming the best method is to stir the tank gently to release as much of the trapped gas from the foam as possible. Some operators even stop mechanical mixing equipment and stir with long, wooden poles. Try not to add too much water from the cleaning hoses as this reduces the temperature and dilutes the tank, which could create conditions for more foaming later. Do not feed the tank heavily, preferable not at all, until the foaming has subsided.

Foaming may occur when a thick sludge blanket is broken up, temperature changes radically, or the sludge feeding to the digester is increased. Avoid any conditions that give the acid formers the opportunity to produce more food than the methane fermenters can handle, because when the methane fermenters are ready, they may work too fast.

If there had been adequate mixing, foaming problems would not have developed. Start mixing from top to bottom of the tank before foaming starts, not afterwards.

8.26 Gas Production

When a digester is first started, extremely odorous gases are produced, including a number of nitrogen and sulphur compounds such as skatole, indole, mercaptans, and hydrogen sulfide. Many of these are also produced during normal digestion phases, but they are generally so diluted by carbon dioxide and methane that they are hardly noticeable. Their presence can be determined by testing if so desired.

During the first phases of digester start-up, most of the gas is carbon dioxide (CO_2) and hydrogen sulfide (H_2S). This combination will not burn and therefore is usually vented to the atmosphere. When methane fermentation starts and the methane content reaches around 60%, the gas will be capable of burning. Methane production eventually should predominate, generating a gas

with 65% to 70% methane and 30% to 35% CO_2 by volume. Digester gas will burn when it contains 56% methane, but is not usable as a fuel until the methane content approaches 62%. When the gas produced is burnable, it may be used to heat the digester as well as for powering engines and for providing building heating.

QUESTIONS

8.24A What is the function of enzymes in digestion?

8.25A How would you attempt to control a foaming digester?

8.25B What preventive measures would you take to prevent foaming from recurring?

8.26A Why is the gas initially produced in a digester not burnable?

8.27 Supernatant and Solids

Plants constructed today are typically equipped with two separate digestion tanks or one tank with two divided sections. One tank is called the primary digester and is used for heating, mixing, and breakdown of raw sludge. The second tank, or secondary digester, is used as a holding tank for separation of the solids from the liquor. To accomplish such separation, the secondary tank must be quiescent (qui-ES-sent) (without mixing).

Most of the sludge stabilization work is accomplished in the primary digester, and 90% of the gas production occurs there. It is desirable to very thoroughly mix the primary tank, but it is undesirable to return the digested mixture to the plant as a supernatant. Therefore, 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.

In the primary digester the binding property of the sludge is broken, allowing the water to be released. In the secondary digester the digested sludge is allowed to settle and compact, with some digestion continuing. When the solids settle they leave a light amber colored liquor zone between the top of the settled sludge and the surface of the digester. By adjusting or selecting the supernatant tube, the liquor with the least solids is returned to the plant.

The settled solids in the secondary digester are allowed to compact so that a minimal amount of water will be handled in the sludge dewatering system. These solids are excellent seed or buffer sludge in case the primary digester becomes upset. A reserve of 30 to 100 thousand gallons should always be held in the secondary digester. This represents a natural enzyme reserve and may save the system during a shock load. Primary and secondary sludge digesters should be operated as a complement to each other. If you need more seed or buffering capacity in the primary digester, it should be taken from the secondary digester.

The secondary tanks should be mixed frequently, preferably after sludge has been withdrawn and supernatant will not be returned to the plant. Usually secondary digesters are provided with mixers or recirculating pumps, preferably arranged for vertical mixing. This periodic mixing prevents coning of solids on the bottom of the tank and the formation of a scum blanket on the top. Mixing also helps the release of slowly produced gas that may float solids or scum.

If your plant has only one digester, stop mixing for one day before withdrawing digested sludge to drying beds.

8.28 Rate of Sludge Withdrawal

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 of water column). If the draw-off rate is too fast, the gas pressure drops due to volume expansion.

> WARNING: If continued, a negative pressure develops on the system (vacuum). This may create an explosive hazard by drawing air into the digester. If the primary digester has a floating cover, the sludge may be drawn down to where the cover rests on the corbels without danger of losing gas pressure.

Some operators prefer to pump raw sludge or wastewater to a digester during digested sludge drawoff to maintain a positive pressure. If gas storage lines permit it, return gas to the digester to maintain pressure in the digester.

QUESTIONS

8.27A What is the purpose of the secondary digester?

8.27B When raw sludge is pumped to the primary digester, what happens in the secondary digester?

8.27C How is the level of supernatant withdrawal selected?

8.28A How would you determine the rate of sludge withdrawal?

END OF LESSON 3 OF 5 LESSONS

on

SLUDGE DIGESTION AND HANDLING

CHAPTER 8. SLUDGE DIGESTION AND HANDLING

(Lesson 4 of 5 Lessons)

8.3 DIGESTER SLUDGE HANDLING

After sludge has passed through a digestion system, it must be dewatered and disposed of.

Small treatment plants are usually provided with sludge drying beds, while larger plants utilize mechanical dewatering and drying systems. Discharge by pipeline or barge to the ocean is sometimes used.

8.30 Sludge Drying Beds (See Fig. 8.14)

The drying process is accomplished through evaporation and percolation of the water from the sludge after it is spread on a drying bed. The drying bed is constructed with an underdrain system covered with coarse crushed rock. Over the rock is a layer of gravel, and then a layer of pea gravel covered with six to eight inches of sand.

Before sludge is applied, loosen the compacted sand layer by using a sludge fork with tines eight to twelve inches long. Stick the tines of the fork into the sand bed and rock it back and forth several times. This is to loosen the sand only, and care should be taken that the gravel and sand layer are not mixed. After the whole surface of the bed is loosened, rake it with a garden rake to break up the sand clods. Then level the bed by raking or dragging a 4" x 6" or 2" by 12" board on ropes to smooth the surface.

Sludge is then drawn to the bed from the bottom of the secondary digester. Draw the sludge slowly so as not to create a negative pressure in the digester and to prevent coning of sludge in the bottom of the digester. A thick sludge of 8% solids travels slowly, and if the draw-off rate is too fast, the sludge around the pipe flows out and the thicker sludge on the bottom moves too slow to fill the void. Consequently, the thinner sludge above the draw-off pipe moves in; and when it does, the supernatant level is reached, thus allowing almost nothing but water to go to the drying bed. The thin sludge and supernatant flowing down to the draw-off pipe washes a hole (shaped like a cone) in the bottom sludge. When this occurs it sometimes may be remedied by "bumping". This is accomplished by quickly closing and opening the draw-off valve on a gravity flow system, which creates a minor shock wave and sometimes washes the heavier sludge into the cone. If the digested sludge is pumped to the drying bed, quickly start and stop the pump using the power switch to create the "bumping" action.

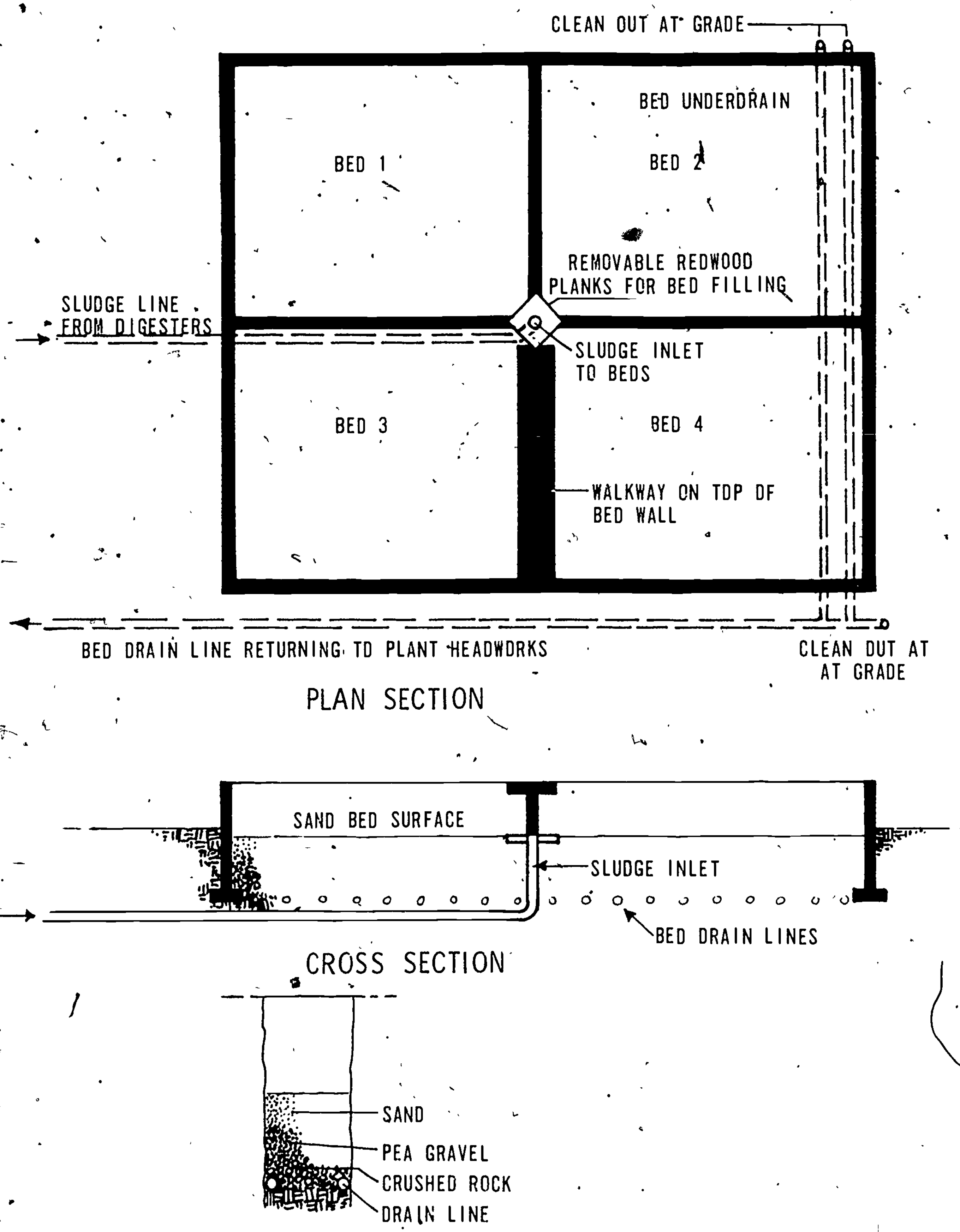


Fig. 8.14, Sludge drying bed

To draw sludge slowly is time consuming and requires frequent checks to be sure it does not thicken and stop flowing completely or cone and run too fast.

The sludge being drawn to the bed is sampled at the beginning of the fill, when the bed is half full, and just before the bed is filled to the desired level. The samples may be mixed together or analyzed separately for total and volatile solids.

The depth to which the sludge is applied is normally around 12 inches, but sometimes it is as deep as 18 inches in arid regions. If it is deeper, the time required for drying is too long. A bed filled with 20 inches of sludge would require approximately the same time to dry as a bed loaded with 14 inches, dried and removed and filled with another load 14 inches deep.

WARNING

NO SMOKING OR OPEN FLAMES SHOULD BE ALLOWED IN THE VICINITY WHERE SLUDGE IS BEING DRAWN FOR DRYING.
THE SLUDGE STILL CONTAINS SOME METHANE GAS. THIS IS SHOWN ON A FRESH BED OF SLUDGE BY THE NUMBER OF SMALL HOLES AND BUBBLES ON THE SURFACE OF THE SLUDGE. THERE HAVE BEEN CASES OF EXPLOSIONS AND FIRES CAUSED BY AN OPERATOR THROWING A LIGHTED MATCH OR CIGARETTE ONTO A DRYING BED OF SLUDGE FROM A DIGESTER.

After a bed of sludge is drawn, the sludge draw-off line should be flushed and cleared with water so the solids won't cement in the line and one end of the line left open for gas to escape, if it forms. Be sure to drain the line if freezing is a problem.

In warm weather, a good sand bed will have the sludge dry enough for removal within four weeks. The water separates from the sludge and drains down through the sand. Evaporation also dries the sludge and will cause it to crack.

When the sludge has formed cracks clear to the sand, it may then be removed by hand with forks. The one major drawback of sand beds is that heavy equipment, such as a skip loader, cannot be used because the weight could damage the underdrain system. Also, the scraping action could mix the sand with the gravel or remove some of the sand with the dried sludge which will have to be replaced.

Some operators lay 2" x 12" boards across the sand for wheelbarrows or light trucks and fork the sludge cake into them to haul to a disposal site. The dried sludge cake is normally three to six inches thick and is not heavy unless a large amount of grit was present in the sludge. The operator calculates the amount of cake in cubic feet by the depth of the dry sludge cake and surface area of the bed. The total dry pounds is arrived at from the total solids in the sludge samples when the sludge was drawn.

Dried sludge makes an excellent soil conditioner and a low-grade fertilizer. However, in many states air dried digested sludge may only be used on lawns, shrub beds, and orchards and cannot be used on root crop vegetables unless heat dried (at 1450°F), or unless it has been in the ground that the crop is to be planted in for over one year. It is always best to check with the state or local health department before dried sludge is used on a food crop.

If a bed of "green" sludge (partially digested) is accidentally drawn, it will require special attention. The water will not drain rapidly, odors will be produced, and the water held provides an excellent breeding ground for nuisance insects. Flies, rat-tail maggots, psychoda flies, and mosquitoes will breed profusely in this environment. An application of dry lime spread over the bed by shovel, and a spraying of a pesticide, is beneficial. The sludge from such a bed should never be used for fertilizer.

Dry sludge cake will burn at a slow smoldering pace, producing quite an offensive odor; therefore, don't allow it to catch fire.

WARNING

IF A SLUDGE POWDER OR DUST IS PRESENT AND KICKED INTO THE AIR IT WILL EXPLODE, SIMILAR TO A RUST EXPLOSION IN A FLOUR MILL. ONCE SLUDGE BEGINS BURNING IT IS EXTREMELY DIFFICULT TO EXTINGUISH. WATER SPRAYS ARE BEST USED IN EXTINGUISHING A SLUDGE FIRE.

8.31 Blacktop Drying Beds (See Fig. 8.15)

This type of bed has become prevalent in the past few years and has several advantages if designed properly. It is made of blacktop or asphalt with both sides sloping gradually to the center to a one-foot wide drain channel. The drain channel runs the full length of the bed with a three- or four-inch drain line on the bottom. The drain line is covered with rock, gravel, and sand as in a sand bed. The drain line usually has a cleanout at the upper end, and a control valve on the discharge end.

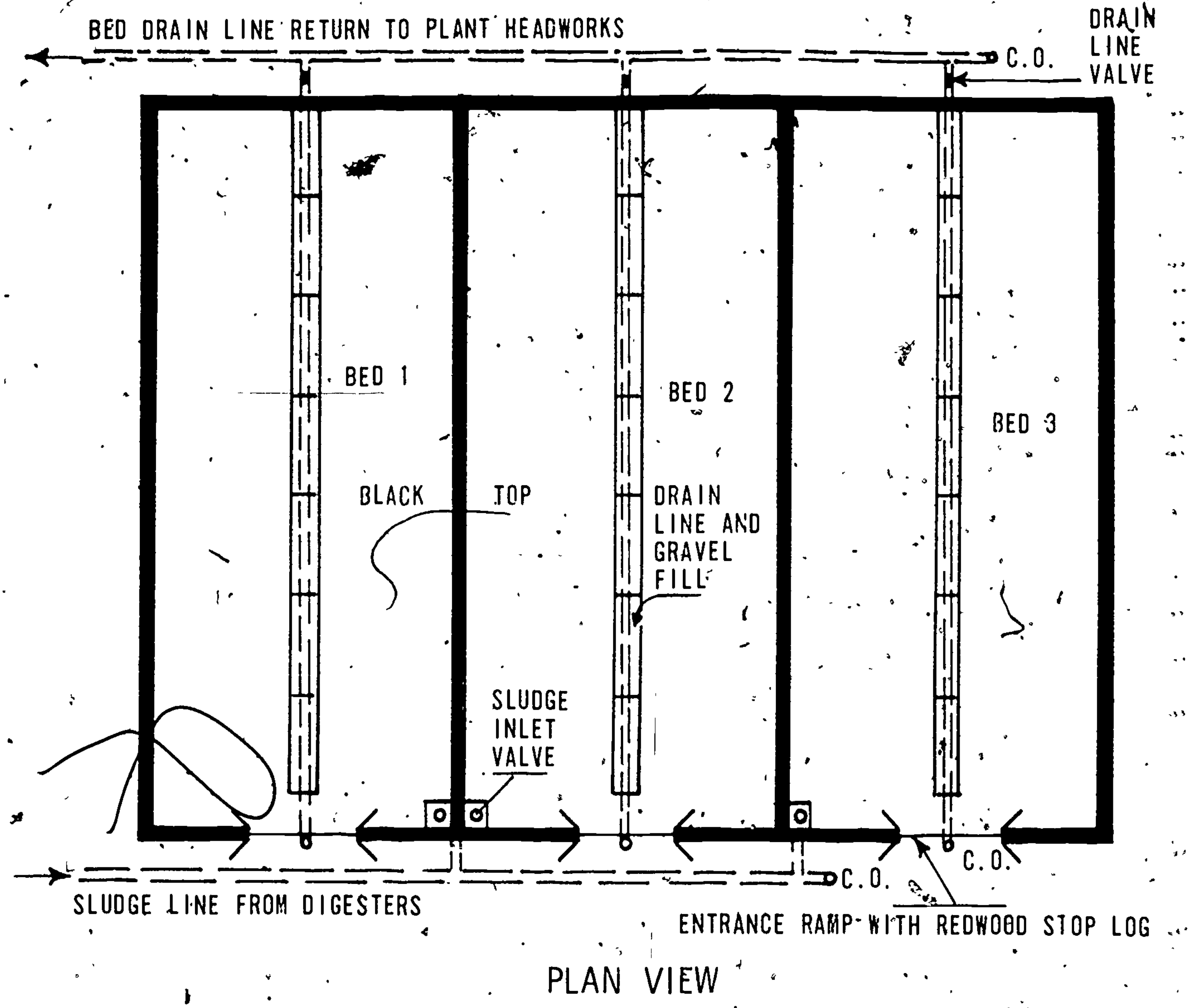
When the bed is to be used, the cleanout on the drain line is removed and the line is flushed with clear water and the cleanout cover replaced. It is recommended that the drain line valve be closed and the drain line and drain channel be filled with water to the top of the sand, so that the sand is not sealed with sludge. Sludge is then admitted to the bed. Some plants have operated successfully without pre-filling the collection system with water.

The depth the sludge is applied to the bed is between 18 and 24 inches.

The sludge is sampled in the same way as when using a sand bed, except one additional sample is taken in a glass jar or beaker and set aside. By watching the jar of sludge, you can observe at some time during the first 24 to 36 hours that the sludge will rise to the top, leaving liquor on the bottom. This is primarily caused by the gas in the sludge. (Later, the sludge will again settle to the bottom and the liquor will be on the surface.) The drain valve on the drying bed should be opened when the sludge separates and rises to the top of the jar. The liquor collected in the sludge bed drains is normally returned to the primary clarifiers.

After the sludge has started to crack and has a crust, drying time may be reduced by driving a vehicle through the bed to mix the sludge. When the cake is dry a skip loader is used to clean the bed.

Blacktop beds may be able to handle two to three times as much sludge as sand beds in a given period of time.



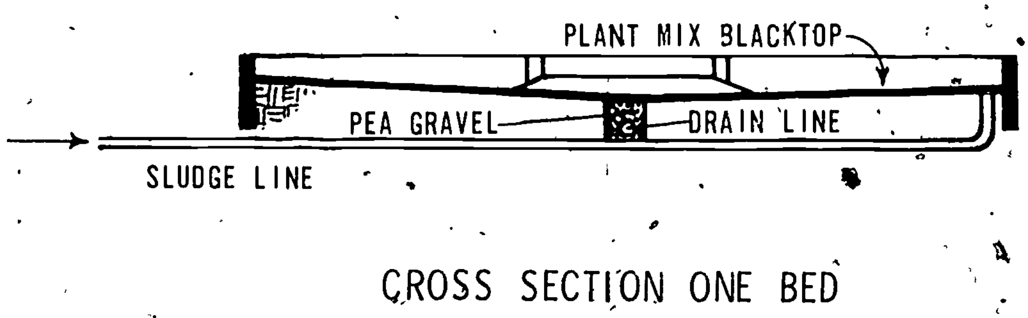


Fig. 8.15 Blacktop drying bed

8.32 Sludge Lagoons

Sludge lagoons are deep ponds that hold digested sludge and, in some instances, supernatant. Digested sludge is drawn to the lagoon periodically and may require a year or two to fill. When the lagoon is full, sludge is discharged into another lagoon while the first one dries. This drying period can require a year or two before the sludge is removed. Some large cities have used lagoons for many years, avoiding the use of covered secondary digestion tanks.

QUESTIONS

8.31A How would you attempt to reduce drying time in blacktop beds?

8.32A How does a sludge lagoon operate?

8.33 Withdrawal to Land

Wet sludge can be spread on land to reclaim the land or on farm land and ploughed in as a soil conditioner and fertilizer. Used with lagoons this gives a flexible system. This is an excellent method of sludge disposal wherever applicable, because it returns the nutrients to the land and completes the cycle as intended by nature.

Transporting sludge to the disposal site is accomplished by tank truck or pipeline. The application of wet sludge to the land depends upon the topography and the crop to be raised on that land. When applied to grass or low ground cover crops, application may be by spraying from the back of the tank truck while driving over the land, by the use of irrigation piping, or by shallow flooding.

The best method, but most costly, is leveling the land, constructing ridges and furrows, and then pumping the sludge down the furrows similar to irrigation practices used in arid regions. This method is not only capable of reclaiming land unsuitable for growing plants and trees, but may yield crops equal to or greater than those raised with commercial fertilizers.

Some precautions that must be practiced with this method of sludge disposal include:

1. Never apply partially digested ("green") sludge or scum.
2. Residential areas must not be located near land disposal sites.
3. Land disposal sites must not be located on a flood plain where the sludge may be washed into the receiving waters during flooding.
4. Domestic water wells must not be located on the land receiving the sludge.
5. Root crop vegetables must not be grown on the land.
6. Cooperation with the landowner as to application time, drying, and covering must be guaranteed.
7. Access to the land during wet weather must be provided.

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8.34 Mechanical Dewatering

In plants where large volumes of sludge are handled and drying beds are not feasible, mechanical dewatering may be used. Mechanical dewatering falls into two methods: vacuum filters and centrifuges. Each is capable of reducing the moisture content of sludge to 60% to 80%, leaving a wet, pasty cake containing 20% to 40% solids. This cake may then be disposed of as land fill, barged to sea, dried in furnaces for fertilizer, or incinerated to ash in furnaces or wet oxidation units.

A. Vacuum Filters [Fig. 8.17].

For digested sludge to be dewatered by this method usually requires a conditioning of the sludge by the addition of chemicals. Elutriation (e-LOO-tree-a-shun) is the washing of the digested sludge in plant effluent in a suitable ratio of sludge to effluent. Elutriation may be accomplished in from one to three separate tanks, similar to small rectangular clarifiers. The sludge is pumped to the elutriation tank and mixed with plant effluent. Next this mixture is admitted to the other tanks to establish a counter-current wash. The sludge is then allowed to settle and is collected by flights and pumped to the next elutriation tank. After one to three washings it is then pumped to the conditioning tanks. The main purpose of the elutriation tanks is to remove the fine sludge particles which require large amounts of chemicals for coagulation. It also removes amino acids and salts which may have a small coagulant demand. After elutriation the sludge will react with the chemicals better and produce better cake. The elutriate (effluent from elutriation tanks) is returned to the primary clarifiers and may result in a very heavy recirculating load since it is chiefly fine solids. Many treatment plants have discontinued the practice of elutriation. Although the process saves approximately $1 per ton of dry solids handled on chemical costs, the costs are excessive for treating the elutriate (wash water) in the biological treatment processes.

Sludge conditioning is accomplished by the addition of various coagulants or flocculating agents such as ferric chloride, alum, lime, and polymers. In the conditioning tank the amount of chemical solution added is normally established by laboratory testing of sludge grab samples by adding various chemical concentrations to the grab samples to obtain a practical filtration rate by vacuum. This test establishes the operating rate for the chemical feed pumps or rotameters from the chemical head tanks, which is normally less than 10% of the dry sludge solids rate to the conditioning tank. (Both rates could be in pounds per 24 hours.) In this tank the

chemical is mixed into the sludge by gentle agitation for several minutes. The conditioned sludge then flows to the filter bath where it is continuously and gently agitated. After operation has started, chemical feed is regulated according to cake appearance and behavior.

Filter drums are 10 to 18 feet in diameter, and 12 to 20 feet in length. They may use cloth blankets of dacron, nylon, or wool, or use steel coil springs in a double layer, to form the outer drum covering and filter media. The drum inside is a maze of pipe work running from a metal screen and wood surface skin, and connecting to a rotating valve port at each end of the drum.

Cloth blankets are stretched and caulked to the surface of the filter drums with short sections of 1/4" cotton rope at every screen section. The sides of the blanket are also stretched and stapled to the end of the drums. The nap[18] of the blanket should be out. After the blanket is stretched completely around the drum, it is then wrapped with two strands of 1/8" stainless steel wire, approximately 2" apart for the full length of the drum.

The installation of a blanket may require several days, and it lasts from 200 to 20,000 hours. The life of the blanket depends greatly on the blanket material, conditioning chemical, backwash frequency, and acid bath frequency. An improper adjustment of the scraper blade, or accidental tear in the blanket, will usually require its replacement.

Both cloth blankets and coil spring filters require a high pressure wash after 12 to 24 hours of operation, and in some instances, an acid bath after 1000 to 5000 operating hours.

The filter drum is equipped with a variable speed drive to turn the drum from 1/8 to 1 rpm. Normally, the lower rpm range is used to give the filter time to pick up sufficient sludge as it passes through the conditioned sludge tub under the filter. Normally less than 1/5 of the filter surface is submerged in the tub and pulling sludge to the blanket or springs by vacuum to form the cake mat. As that area passes through the conditioned sludge, the vacuum holds a layer 1/8 to 1/2 inch thick of sludge to the media, and continues to pull the water from the sludge to approximately 210 degrees from the bottom point of the filter after it leaves the vat. This is the drying cycle. At this point the vacuum is released and a light air pressure (3.0 psi) is applied to the inside of the blanket, lifting the sludge

[18] Nap. The soft, fuzzy surface of the fabric.

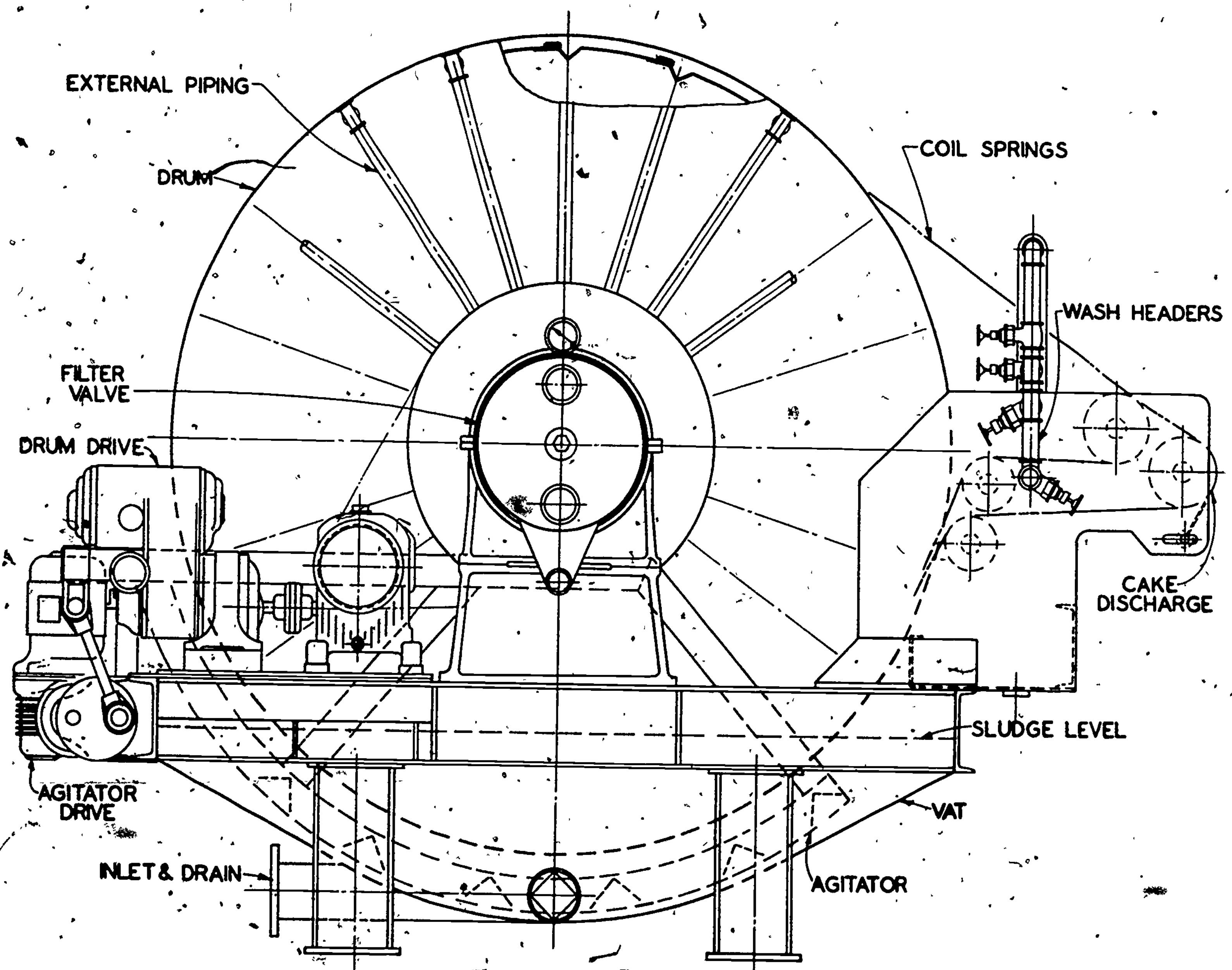

Fig. 8.17 Coilfilter elevation

Courtesy of Komline-Sanderson Engineering Corporation

so that it falls from the blanket into a hopper or conveyor belt. The drum then rotates past a scraper blade to remove sludge that did not fall. The applied air is then phased out as that section starts into the filter tub, and vacuum is applied in order to pick up another coating of sludge.

The thickness of the sludge cake and moisture content depend upon the sludge, chemical feed rate, drum rotation speed, mixing time, and condition of the blanket or coil springs. A filter may blank out (lose sludge cake) for any of the above reasons or due to the loss of vacuum or filtrate pumps. Filtrate is the liquor separated from the sludge by the filter; it is returned to the primary clarifiers.

QUESTIONS

8.33A What are some of the advantages of applying sludge to land?

8.34A How is sludge disposed of in many large plants or areas where drying beds are not feasible?

8.34B How would you prepare digested sludge for drying by vacuum filtration?

8.34C How would you determine the chemical feed rate to condition sludge?

8.34D What factors influence the life of a filter blanket?

B. Centrifuge

Centrifuges are gaining in popularity for dewatering raw or primary sludges for furnaces or incineration units. Their use on digested sludge is becoming more widespread and is expected to replace vacuum filters as the prime digested sludge dewatering device. Most digested sludges are conditioned with polymers before being fed to a centrifuge.

Centrifuges are various sized cylinders that rotate at high speeds. The sludge is pumped to the center of the bowl where centrifugal force established by the rotating unit separates the lighter liquid from the denser solids. The centrate[19] is returned to the primary clarifiers, and the sludge cake is removed to a hopper or to a conveyor for disposal.

The feed rate, pool depth, centrifuge rpm, and other factors determine the condition of the discharge cake or slurry and the quality of centrate. The centrate usually contains a high amount of suspended solids that become difficult to handle in the primary clarifiers and digesters. A large amount of grit in the sludge greatly increases the wear rate on the centrifuge. Similar to the wash water from the elutriation process, centrate from vacuum filters also exerts a difficult load on biological treatment processes.

QUESTIONS

8.34E Centrifuges are commonly used to dewater what types of sludges?

8.34F How would you regulate the condition of the sludge cake from a centrifuge?

END OF LESSON 4 OF 5 LESSONS

on

SLUDGE DIGESTION AND HANDLING

[19] Centrate. The liquor leaving the centrifuge after most of the solids have been removed.

8.4 DIGESTER CONTROLS AND TEST INTERPRETATION

A. Temperature

A thermometer is usually installed in the recirculated sludge line from the digester to the heat exchanger. This thermometer will accurately measure the temperature of the digester contents when circulation is from bottom to top. The temperature from the digester is recorded and should be maintained between about 95 and 98°F for mesophilic digestion. Never change the temperature more than 1°F per day. Accurate temperature readings also may be taken from the flowing supernatant tube or from the heat exchanger sludge inlet line. The same temperature should be maintained at all levels of the tank.

B. Volatile Acid/Alkalinity Relationship

The volatile acid/alkalinity relationship is the key to successful digester operation. As long as the volatile acids remain low and the alkalinity stays high, anaerobic sludge digestion will occur in a digester. Each treatment plant will have its own characteristic ratio for proper sludge digestion (generally less than 0.1). When the ratio starts to increase, corrective action must be taken immediately. This is the first warning that trouble is starting in a digester. If corrective action is not taken immediately or is not effective, eventually the CO_2 content of the digester gas will increase, the pH of the sludge in the digester will drop, and the digester will become sour.

A good procedure is to measure the volatile acid/alkalinity relationship at least twice a week, plot the volatile acid/alkalinity relationship against time, and watch for any adverse trends to develop. Whenever something unusual happens, such as an increased solids load from increased waste discharges or a storm, the volatile acids/alkalinity relationship should be watched closely.

The volatile acid/alkalinity relationship is an indication of the buffer capacity of the digester contents. A high buffer capacity is desirable and is achieved by a low ratio which exists when volatile acids are low and the alkalinity is high (120 mg/l volatile acids/2400 mg/l alkalinity). Excessive feeding of raw sludge to the digester, removal of digested sludge, or a shock load such as produced by a storm flushing out the collection system may unbalance the volatile acid/alkalinity relationship.

A definite problem is developing when the volatile acid/alkalinity relationship starts increasing. Once the relationship reaches the vicinity of 0.5/1.0 (1000 mg/l volatile acids/2000 mg/l alkalinity), serious decreases in the alkalinity usually occur. At a relationship of 0.5/1.0 the concentration of CO_2 in digester gas will start to increase. When the relationship reaches 0.8 or higher, the pH of the digester contents will begin to drop. When the relationship first starts to increase, ample warning is given for corrective action to be taken before problems develop and digester control is lost.

Response to an Increase in Volatile Acid/Alkalinity Ratio:

When the ratio starts to increase, extend mixing time of digester contents, control heat more evenly, and decrease sludge withdrawal rates. Mixing should be vertical mixing from the bottom of the tank to the top of any scum blanket. If possible, some of the concentrated sludge in the secondary digester should be pumped back to help correct the ratio. In addition, the primary digester should not be operated as a continuous overflow unit when raw sludge is added, but it should be drawn down to provide room for some sludge from the secondary digester too. During heavy rains when extra solids are flushed into the plant, it may be necessary to add some digested sludge to the primary digester. Use the volatile acid/alkalinity ratio as a guide to determine the amount of digested sludge that should be returned to the primary digester for control purposes.

C. Digester Gas (CO_2 and Gas Production)

This is a useful test to record. The change of CO_2 in the gas is an indicator of the condition of the digester. Good digester gas will have a CO_2 content of 30 to 35%. The volatile acid/alkalinity relationship will start to increase before the carbon dioxide (CO_2) content begins to climb. If the CO_2 content exceeds 42%, the digester is considered in poor condition and the gas is close to the burnable limit (44 to 45% CO_2).

Gas production in a properly operating digester should be constant if feed is reasonably constant. If the volume produced gradually starts falling, trouble of some sort is indicated.

D. pH

pH is normally run on raw sludge, recirculated sludge, and supernatant. This information is strictly for the record and not for plant control. The raw sludge, if stale, will be acid and run in the range of 5.5 to 6.8. Digester liquors should stay around 7.0 or higher. pH is usually the last indicator to change and gives little warning of approaching trouble. It is therefore the least desirable control method.

QUESTIONS

8.4A Where would you obtain the temperature of a digester?

8.4B Why is the volatile acid/alkalinity relationship very useful in digester control?

8.4C What should be done when the volatile acid/alkalinity relationship starts to increase?

8.4D Why is pH a poor indicator of approaching trouble in a digester?

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E. Solids Test

Samples are collected of the raw sludge, recirculated sludge, and supernatant. Each sample is tested for total solids and volatile solids.

The information from these tests is used to determine the pounds of solids handled through the system, the digester loading rates, and the percent of reduction of the organic matter destroyed by the digester. All of these tests are necessary for the maintenance of close digester operation.

F. Volume of Sludge

Volumes of sludge are needed to determine the pounds of solids handled through the system. In smaller plants which use a positive displacement pump, the volume of raw sludge is determined by the volume the pump displaces during each revolution. For instance, a 10-inch piston pump with a 3-inch stroke will discharge one gallon per revolution. These pumps are equipped with a counter on the end of the shaft and are seldom operated faster than 50 gpm.

J. Digester Supernatant

The total solids test is run on the digester supernatant to determine the solids load returned to the plant. The total solids in the digester supernatant should be kept below 1/2 of 1% (0.005 or 5000 mg/1). High solids content in the supernatant usually indicates that too much seed or digested sludge is being withdrawn from the digester. This kind of withdrawal could increase the volatile acid/alkalinity relationship which is also undesirable.

Another simple method for checking supernatant is to draw a sample into a 1000 ml graduate and let it stand for four or five hours. The sludge on the bottom of the graduate should be below 50 ml, with an amber colored liquor above it. If supernatant solids are allowed to build too high, an excessive solids and BOD load is placed on the secondary system and primary clarifier. Sludge withdrawn from the secondary digester or supernatant removal tubes should be changed to a different level in the digester where the liquor contains the least amount of solids when the supernatant load becomes too heavy on the plant.

Plants should be designed to allow all sludge solids and liquids to go to a lagoon or some such system for final or ultimate disposal, rather than returning them to the plant.

K. Computing Digester Loadings

Digester loadings are reported as pounds of volatile matter per cubic foot or 1000 cubic feet of digester volume per day. The loading rate should be around 0.15 to 0.35 pounds of volatile solids per cubic foot in a heated and mixed digester. For an unmixed or cold digester, the loading rate should not exceed 0.05 pounds of volatile matter per cubic foot, assuming that each cubic foot contains approximately 0.5 pounds of predigested solids.

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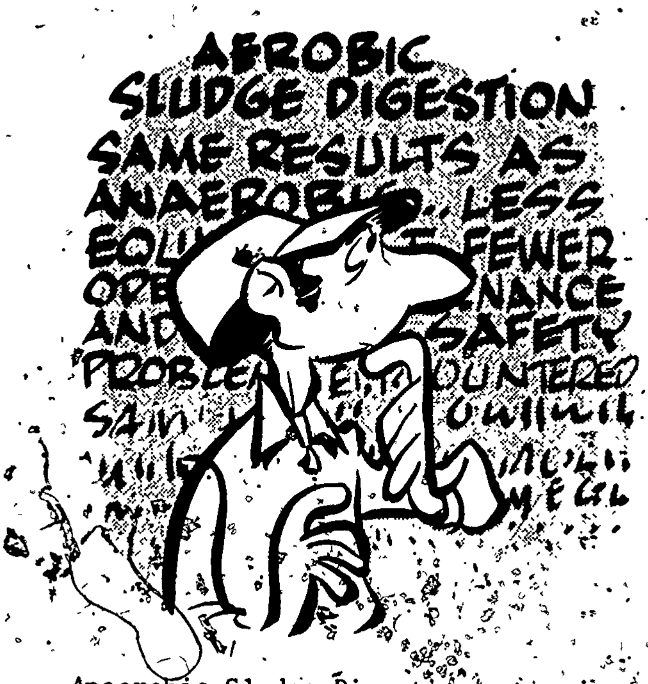
8.6 AEROBIC SLUDGE DIGESTION

8.60 Introduction

Aerobic digestion of solids occurs, whether intentional or not, in any of the conventional secondary treatment processes. In the extended aeration process, the aerobic digestion process is continued almost to the maximum obtainable limit of volatile matter reduction. A separate aerobic digester is intended mainly to insure that residual solids from aerobic biological treatment processes are digested to the extent that they will not cause objectionable odors during disposal. The aerobic digester is a separate operation following other processes to extend decomposition of solids and regrowth of organisms to a point where available energy in active cells and storage of waste materials are sufficiently low to permit the material to be considered stable enough for discharge to some ultimate disposal operation. Neither aerobic nor anaerobic sludge digestion completes the oxidation of volatile materials in the digester.



Important comparisons between aerobic and anaerobic sludge digestion are summarized in the following sections.

Anaerobic Sludge Digestion

1. Does not use aeration as part of the process.
2. Works best on fresh wastes that have not been treated by prior stabilization processes.
3. Uses putrefaction as a basic part of the process.

4. Tends to concentrate sludge and improves drainability.

5. Produces methane gas that provides energy for other operations.

6. Generates major digestion products consisting of solids, carbon dioxide, water, methane, and ammonia.

7. Produces liquids that may be difficult to treat when returned to the plant.

8. Generates sludges that need additional stabilization before ultimate disposal.

Aerobic Sludge Digestion

1. Has lower equipment costs, but operating costs are higher.

2. Tends to produce less noxious odors.

3. Produces liquids that usually are easier to treat when returned to the plant.

4. Generates major digestion products consisting of residual solids, carbon dioxide, water, sulfates, and nitrates. Most of these products are close to the final stabilization stage.

5. May achieve nitrogen removal by stopping aeration long enough to allow the conversion of nitrates to nitrogen gas. Aeration must be restarted before sulfates are converted to sulfides (H_2S).

6. Tends to work better on partially stabilized solids from secondary processes that are difficult to treat by the anaerobic digestion process.

7. Produces a sludge that has a higher water content. Aerobic sludges are difficult to concentrate higher than 4 percent solids.

8. Uses oxygenation and mixing provided by aeration process equipment.

9. Has less hazardous cleaning and repairing tasks.

10. Works by aerobic decay which produces less odors when operated properly.

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8.61 Process Description

Aerobic digestion tanks may be either round or rectangular, eighteen to twenty feet deep, with or without covers, depending on geographical location and climatic conditions. The tanks use aeration equipment (mechanical or diffused air) to maintain aerobic conditions. Each tank has a sludge feed line at mid-depth of the tank, a sludge draw-off line at the bottom of the tank, and a flexible, multilevel supernatant draw-off line to remove liquor from the upper half of the tank.

Covers are used in colder climates to help maintain the temperature of the waste being treated. Covers should not be used if they reduce evaporative cooling too much and the liquid contents become too warm. When the liquid becomes too warm offensive odors may develop and the process effluent will have a very poor quality.

Aerobic digestion requires the waste solids to be held at least twenty days in the digester. Detention time depends on the origin of the sludge being treated. Twenty days will provide sufficient digestion time for sludges from an extended aeration process where the sludges are already well digested. Sludges from a contact stabilization process require more than twenty days. When temperatures are very low the sludge may have to be held until the weather warms in the spring.

8.62 Operation

Aerobic digesters are operated under the principle of extended aeration from the activated sludge process, relying on the mode or region called endogenous[22] respiration. Aerobic digestion consists of continuously aerating the sludge without the addition of new food, other than the sludge itself, so the sludge is always in the endogenous region. Aeration continues until the volatile suspended solids are reduced to a level where the sludge is reasonably stable, does not create a nuisance or odors, and will readily dewater.

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[22] Endogenous (en-DODGE-en-us): A diminished level of respiration in which materials previously stored by the cell are oxidized.

8.64 Operational Problems

A. Scum

The aerobic digesters will have to be skimmed periodically to remove floating grease and other material that will not digest. This material should be disposed of by incineration or burial with the scum collected from the primary clarifier.

B. Odors

Odors should not be a problem in aerobic digestion unless insufficient oxygen is supplied or a shock load reaches the aerobic digestion tanks. If an odor problem does occur, a very effective cure is to recycle sludge from the bottom of the second or third tank back to the first tank. This is also good practice in activated sludge plants that have bulking problems because sludge from the last aerobic digester responds very quickly when returned to an aerator.

C. Floating Sludge

Floating sludge may become quite thick in the second and third tanks when aeration is stopped during removal of the supernatant. To avoid clogging, the supernatant draw-off line should be installed so the withdrawal point is from two to six feet below the water surface. The floating sludge is a problem only during supernatant removal. Scum and solids must be removed from the supernatant to prevent interference with other treatment processes and degradation of the plant effluent.

8.65 Maintenance Problems

Usually this process requires very little maintenance. Routinely hose the side walls of open tanks for appearance and fly control.

A. Diffuser Maintenance

If diffused air is used for aeration, only open orifice or nozzle type diffusers should be installed because of the daily stopping of air flow during supernatant removal.

B. Aeration Equipment

Aeration equipment should be operated continuously except when settling is needed for supernatant removal. Both settling and supernatant removal should be accomplished in 0.5 to 1.5 hours.

QUESTIONS

8.6A Why do some plants have aerobic digesters?

8.6B What are some of the advantages of aerobic digestion in comparison with anaerobic digestion?

8.6C What dissolved oxygen levels should be maintained in aerobic digesters?

8.7 ADDITIONAL READING

a. MOP 11, pages 39-88.

b. New York Manual, pages 85-116.

c. Texas Manual, pages 303-396 and 413-444.

d. Sewage Treatment Practices, pages 63-79.

e. Anaerobic Sludge Digestion, WPCF Manual of Practice No. 16, Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D.C. 20016. Price $1.50 to members; $3.00 to others. Indicate your member association when ordering.

f. Dague, Richard R., Digester Control, J. Water Pollution Control Federation, Vol. 40, No. 12, p 2021 (December 1968).

g. Sludge Dewatering, WPCF Manual of Practice No. 20, Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D.C. 20016. Price $3.00 to members; $6.00 to others. Indicate your member association when ordering.

END OF LESSON 5 OF 5 LESSONS

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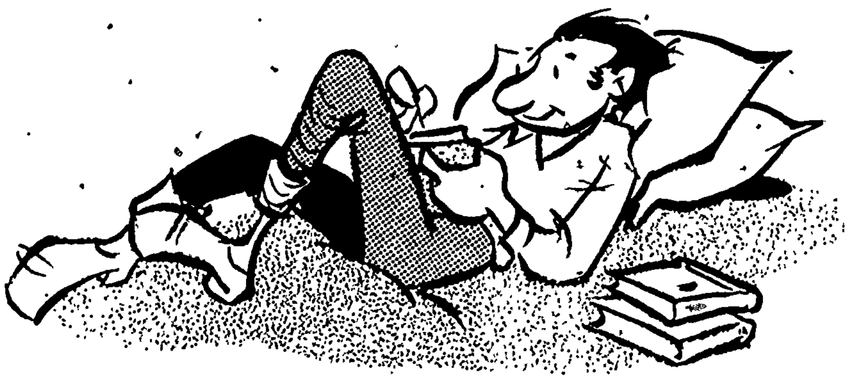
SLUDGE DIGESTION AND HANDLING



CHAPTER 9. WASTE TREATMENT PONDS

USED FOR TREATMENT OF WASTEWATER AND OTHER WASTES

(Lesson 1 of 3 Lessons)

9.1 INTRODUCTION

Shallow ponds (three to five feet deep) are often used to treat wastewater and other wastes instead of, or in addition to, conventional waste treatment processes. (See Figs. 9.1 and 9.2 for typical plant layouts.) Wastes which are discharged into ponds are treated or stabilized[1] by several natural processes acting at the same time. Heavy solids settle to the bottom where they are decomposed by bacteria. Lighter suspended material is broken down by bacteria in suspension.

Dissolved nutrient materials, such as nitrogen and phosphorous, are utilized by green algae which are actually microscopic plants floating and living in the water. The algae utilize carbon dioxide (CO_2) and bicarbonates to build body protoplasm. In so growing they need nitrogen and phosphorous in their metabolism much as land plants do. Like land plants, they release oxygen and some carbon dioxide as waste products.

In recent years, ponds have become more popular as treatment facilities. Extensive studies of their performance have led to a better understanding of the natural processes by which ponds treat wastes. Information is also available which can help operators to regulate the pond processes for efficient waste treatment.

9.2 HISTORY OF PONDS IN WASTE TREATMENT

The first wastewater collection systems in the ancient Orient and in ancient Europe were discharged into adjacent bodies of water. These systems accomplished their intended purpose until overloading, as in modern systems, made them objectionable.

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

In ancient times, ponds and lakes were purposefully fertilized with organic wastes to encourage the growth of algae which, in turn, greatly increased the production of fish due to the food supply provided by the algae. This practice still persists and is a recognized art in Germany.

Evidently, the first ponds constructed in the United States were built for the purpose of excluding waste waters from intrusion into places where they would be objectionable. Once constructed, these ponds performed a treatment process that finally became recognized as such. The tendency over the years has been to equate pond-treatment efficiency with the non-emission of odors. Actually, the opposite is true as the greatest organic load destroyed per unit of area (high treatment efficiency) may be accompanied by objectionable odors.

Armed with the current scientific knowledge of ponding and utilizing the experience of both successes and failures, engineers have designed and constructed a great number of ponds performing a variety of functions since 1958. Ponds that have been designed with adequate engineering, backed by the research of a qualified biological consultant, and operated in a purposeful manner have produced successful results.

Ponding of wastewater as a complete process offers the following advantages for smaller installations, provided land is not costly and the location is isolated from residential, commercial, and recreational areas:

1. Does not require expensive equipment.

2. Does not require highly trained operating personnel.

3. Is economical to construct.

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INF. → FLOW METER → BAR SCREEN → PONDS → DISINFECTION → EFF.

FLOW METER	BAR SCREEN	PONDS	DISINFECTION
Measure, record flow	Remove coarse material	Biological Process	Chlorine Contact (Kill pathogenic organisms)

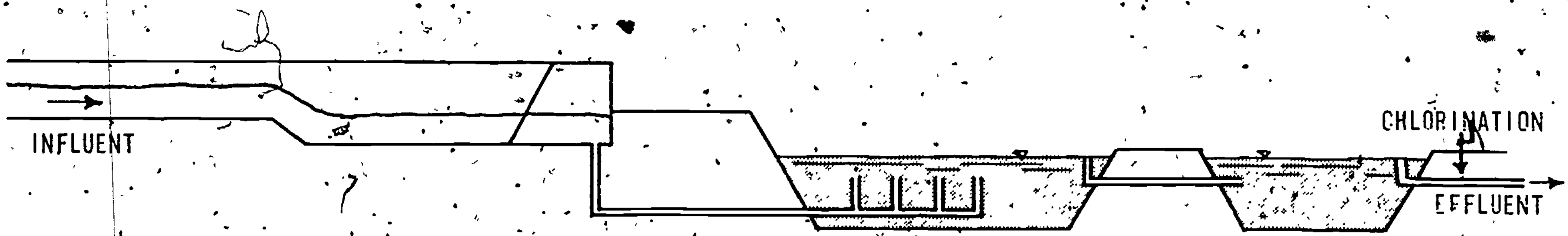

Fig. 9.1 Typical plant; ponds only

4. Provides treatment that is equal to or superior to some conventional processes.

5. Makes a satisfactory short-term method of treating wastewater on a temporary basis until a permanent plant can be constructed.

6. Is adaptable to fluctuating loads.

7. Is probably the most trouble-free of any treatment process when utilized correctly, provided a consistently high quality effluent is not required.

QUESTIONS

9.2A If a pond is giving off objectionable odors, are the wastes being effectively treated? Explain your answer.

9.2B Discuss the advantages of ponds.

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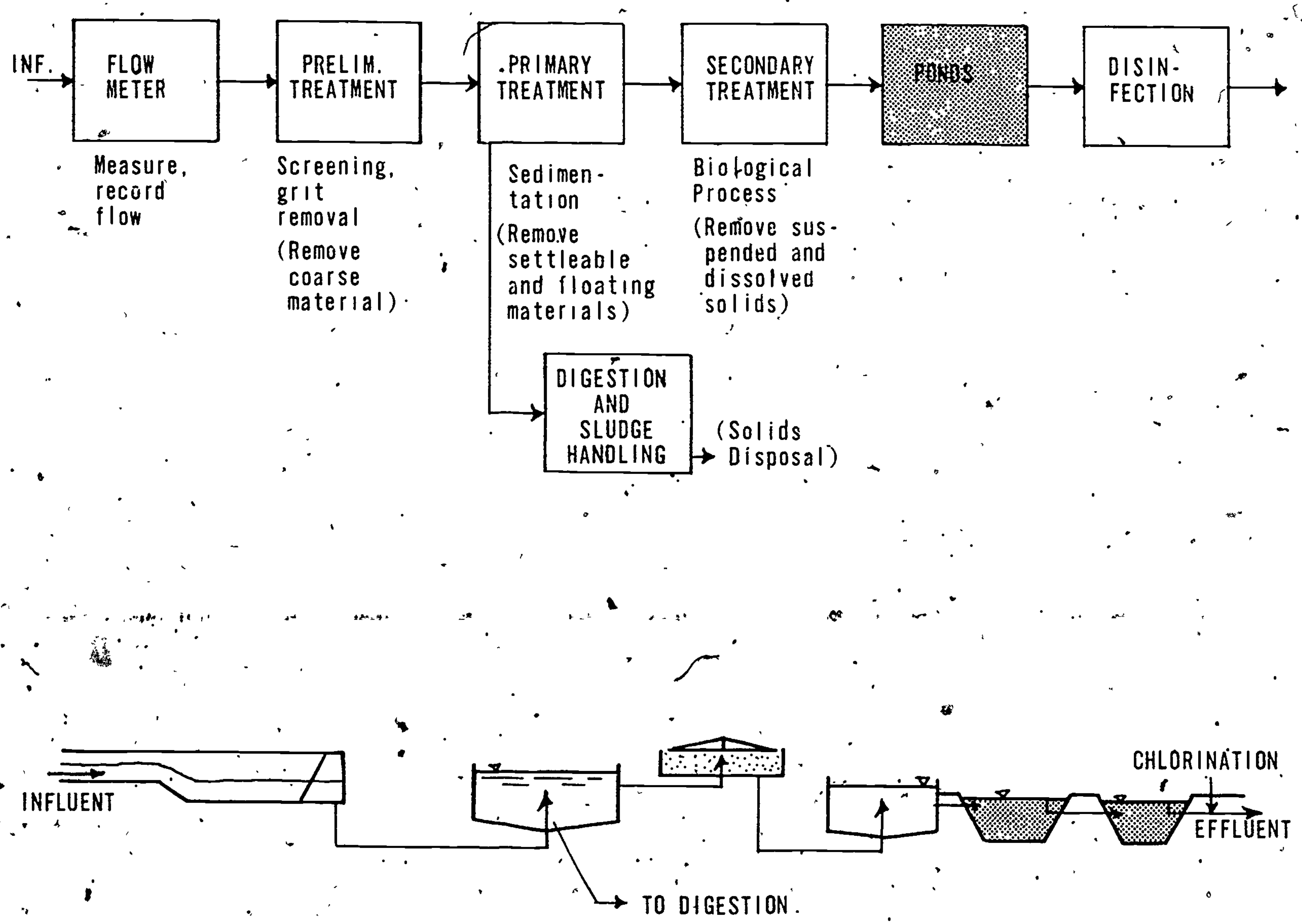

Fig. 9.2 Typical plant; ponds after secondary treatment

9.3 POND CLASSIFICATIONS AND USES

Ponding of raw wastewater, as a complete treatment process, is used to treat the wastes of single families as well as large cities up to the size of the city of Melbourne, Australia, which handles 78 million gallons of wastewater per day. Ponds designed to receive wastes with no prior treatment are often referred to as raw wastewater (sewage) lagoons or stabilization ponds. This requires sizable areas of land.

Ponds are quite commonly used in series (one pond following another) after a primary wastewater treatment plant to provide additional clarification, BOD removal, and disinfection. These ponds are sometimes called oxidation ponds.

Ponds are sometimes used in series after a trickling filter plant, thus giving a form of "tertiary"[2] treatment. These are sometimes called polishing ponds.

Ponds placed in series with each other can provide a high quality effluent which is acceptable for discharge into most watercourses, if stringent disinfection standards are not required.

It is possible to have a great many different variations in ponds due to depth, operating conditions, loading, etc., and a bold line of distinction is often impossible. Current literature generally uses three broad pond classifications: aerobic, anaerobic, and facultative.

Aerobic ponds are characterized by having dissolved oxygen distributed throughout their contents practically all of the time. They usually require an additional source of oxygen other than the rather minimal amount that can be diffused from the atmosphere at the water surface. The additional source of oxygen may be supplied by algae, by mechanical agitation of the surface, or by bubbling air through the pond.

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[2] Tertiary (TER-she-AIR-ee). Tertiary refers to the third treatment process or the process following a secondary treatment process, such as a trickling filter. Some refer to tertiary treatment as advanced waste treatment, meaning processes that remove wastes not normally removed by conventional (secondary) treatment processes.

Anaerobic ponds, as the name implies, are usually without any dissolved oxygen throughout their entire depth. Treatment depends on fermentation of the sludge at the pond bottom. This process, under certain conditions, can be quite odorous, but it is highly efficient in destroying organic wastes. Anaerobic ponds are mainly used for industrial processing wastes, although some domestic waste ponds find their way into this category when they become badly overloaded.

Facultative (FACK-ul-tay-tive) ponds are the most common type in current use. The upper portion (supernatant) of these ponds is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant. Facultative ponds are most common because it is almost impossible to maintain completely aerobic or anaerobic conditions all the time at all depths of the pond.

Pond uses may be classified according to detention time. A pond with a detention time of less than three days will perform in ways similar to a sedimentation or settling tank. Some algal growth will occur in the pond, but it will not have a major effect on the treatment of the wastewater.

Prolific algal growth will be observed in ponds with detention periods from three to around 20 days, but large amounts of algae will be found in the pond effluent. In some effluents, the stored organic material may be greater than the amount in the influent. Detention times in this range merely allow the organic material to change form and delay problems until the algae settle out in the receiving waters. Effluent BODs may show considerable reductions from influent BOD concentrations, but this is because BOD is a rate estimate (oxygen used during a 5-day period). The rate of oxygen used is temporarily slowed down, but will increase when anaerobic decomposition of settled dead algal cells starts.

Longer detention periods in ponds provide time for algal sedimentation, hopefully in ponds with anaerobic conditions on the bottom and aerobic conditions on the surface. Combined aerobic-anaerobic treatment provided by long detention periods produces definite stabilization of the influent.

QUESTIONS

9.3A What is the difference between raw wastewater (sewage) lagoons, oxidation ponds, and polishing ponds?

9.3B What is the difference between the terms aerobic, anaerobic, and facultative?

9.3C Describe three possible uses of ponds.

9.4 EXPLANATION OF TREATMENT PROCESS

Waste disposal ponds are classified according to their dissolved oxygen content. Oxygen in an aerobic pond is distributed throughout the entire depth practically all the time. An anaerobic pond is predominantly devoid of oxygen most of the time because oxygen requirements are much greater than the oxygen supply. In a facultative pond, the upper portion is aerobic most of the time, whereas the bottom layer is predominantly anaerobic.

In aerobic ponds, organic matter contained in the wastewater is first converted to carbon dioxide and ammonia, and finally, in the presence of sunlight, to algae. Algae are simple one-cell microscopic plants which are essential to the successful operation of both aerobic and facultative ponds.

By utilizing sunlight through photosynthesis,[3] the one-celled plant uses the oxygen in the water molecule to produce free oxygen, making it available to the aerobic bacteria that inhabit the pond. Each pound of algae in a healthy pond is capable of producing 1.6 pounds of oxygen on a normal summer day. Algae subsist on carbon dioxide and other nutrients in the wastewater. Algae occur in a pond without seeding and multiplying greatly under favorable conditions.

In anaerobic ponds, the organic matter is first converted by a group of organisms called the "acid producers" to carbon dioxide, nitrogen, and organic acids. In an established pond, at the same time, a group called the "methane fermenters" breaks down the acids and other products of the first group to form methane gas and alkalinity. Water is another end product of organic reduction.

In a successful facultative pond, the processes characteristic of aerobic ponds occur in the surface layers, while those similar to anaerobic ponds occur in its bottom layers.

During certain periods sludge decomposition in the anaerobic zone is interrupted and it begins to accumulate. If sludge accumulation

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[3] Photosynthesis. A process in which organisms with the aid of chlorophyll (green plant enzyme) convert carbon dioxide and inorganic substances to oxygen and additional plant material, utilizing sunlight for energy. Land plants grow by the same process.

occurs and decomposition does not set in, it is probably due to lack of suitable bacteriological population, low pH,[4] presence of inhibiting substances, or a low temperature. Under these circumstances the acid production will continue at a slower rate, but the rate of gas (methane) production slows down considerably.

Sludge storage in ponds is continuous with small amounts stored during warm weather and larger amounts when it is cold. During low temperatures the bacteriological population cannot multiply fast enough to handle the waste. When warm weather comes, the "acid producers" start in decomposing the accumulated sludge deposits built up during the winter. If the organic acid production is too great, a lowered pH will occur with the possibilities of an upset pond and resulting hydrogen sulfide odors.

Hydrogen sulfide is ordinarily not a problem in properly designed and operated ponds because it dissociates (divides) into hydrogen and hydrosulfide ions at high pH and may form insoluble metallic sulfides or sulfates. It is because of this high degree of dissociation and the formation of insoluble metallic sulfides that ponds having a pH above 8.5 do not emit odors, even when hydrogen sulfide is present in relatively large amounts.

All of the organic matter that finds its way to the bottom of a stabilization pond through the various processes of sludge decomposition is subject to methane fermentation, provided that proper conditions exist or become established.

In order for methane fermentation to exist, an abundance of organic matter must be deposited and continually converted to organic acids. An abundant population of methane bacteria must be present. They require a pH level within the sludge of from 6.5 to 7.5, alkalinity of several hundred mg/l to buffer (neutralize) the organic acids (volatile acid/alkalinity relationship), and suitable temperatures.

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[4] pH. pH is an expression of the intensity of the alkaline or acid strength of water. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration.

$$pH = \text{Log}\ \frac{1}{(H^+)}$$

The pH may range from 0 to 14, where 0 is the most acid, 14 the most alkaline, and 7 is neutral. Most natural waters usually have a pH between 6.5 and 8.5.

Once methane fermentation is established, it accounts for a considerable amount of the organic load removal.

QUESTIONS

9.4A How is oxygen produced by algae?

9.4B Where does the algae found in a pond come from?

9.4C What happens to unstable organic matter in a pond?

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9.5 POND PERFORMANCE

The treatment efficiencies that can be expected by ponds vary more than most other treatment devices. Some of the many variables are:

1. Physical Factors

    a. type of soil
    b. surface area
    c. depth
    d. wind action
    e. sunlight
    f. temperature
    g. short circuiting
    h. inflow variations

2. Chemical Factors

    a. organic material
    b. pH
    c. solids
    d. concentration and nature of waste

3. Biological Factors

    a. type of bacteria
    b. type and quantity of algae
    c. activity of organisms
    d. nutrient deficiencies
    e. toxic concentrations

The performance expected from a pond depends upon its design. The design, of course, is determined by the waste discharge requirements or the water quality standards to be met in the receiving waters. Overall treatment efficiency may be about the same as primary treatment (only settling of solids), or it may be equivalent to the best secondary biological treatment plants. Some ponds, usually those located in hot, arid areas, have been designed to take advantage of percolation and high evaporation rates so that there is no discharge.

Depending on design, ponds can be expected to provide BOD removals of from 50 to 90%. Facultative ponds, under normal design loads with 50 to 60 days detention time, will usually remove approximately 90 to 95% of the coliform bacteria and 70 to 80% of the BOD load approximately 80% of the time.

Physical sedimentation by itself has been found to remove approximately 90% of the suspended solids in three days, and about 80% of the dissolved organic solids in ten days. However, in a pond with a healthy algae and bacteria population, a phenomenon known as bioflocculation[5] can occur which will remove approximately 85% of both suspended and dissolved solids within hours. Bioflocculation is accelerated by increased temperature, wave action, and high dissolved oxygen content.

Pond detention times are sometimes specified by regulatory agencies to assure adequate treatment and removal of bacteria. Many agencies specify effluent or receiving water quality standards in terms of median and maximum MPN values that should not be exceeded. In critical water use areas chlorination or other means of disinfection can be used to further reduce the coliform level.

A pond is generally regarded as not fulfilling its function when it creates a visual or odor nuisance, or leaves a high BOD, solids, grease, or coliform group bacteria concentration in the discharge.

QUESTIONS

9.5A What is bioflocculation?

9.5B What biological factors influence the treatment efficiency of a pond?

9.5C What factors indicate that a pond is not fulfilling its function (operating properly)?

END OF LESSON 1 OF 3 LESSONS

on

WASTE TREATMENT PONDS

[5] Bioflocculation. A condition whereby organic materials tend to be transferred from the dispersed form in wastewater to settleable material by mechanical entrainment and assimilation.

CHAPTER 9. WASTE TREATMENT PONDS

(Lesson 2 of 3 Lessons)

9.6 STARTING THE POND

One of the most critical periods of a pond's life is the time that it is first placed in operation. If at all possible, at least one foot of water should be in the pond before wastes are introduced. The water should be turned into the pond in advance to prevent odors developing from waste solids exposed to the atmosphere. Thus a source of water should be available when starting a pond.

It is a good practice to start ponds during the warmer part of the year because a shallow starting depth allows the contents of the pond to cool too rapidly if nights are cold. Generally speaking, the warmer the pond contents, the more efficient the treatment processes.

Algal blooms will normally appear from seven to twelve days after wastes are introduced into a pond, but it generally takes at least 60 days to establish a thriving biological community. A definite green color is evidence that a flourishing algae population has been established. After this length of time has elapsed, bacterial decomposition of bottom solids will usually become established. This is generally evidenced by bubbles coming to the surface near the pond inlet where most of the sludge deposits occur. Although the bottom is anaerobic, travel of the gas through the aerobic surface layers generally prevents odor release.

Wastes should be discharged to the pond intermittently during the first few weeks with constant monitoring of the pH. The pH in the pond should be kept above 7.5 if possible. Initially the pH of the bottom sludge will be below 7 due to the digestion of the sludge by acid-producing bacteria. If the pH starts to drop, discharge to the pond should be diverted to another pond or diluted with make-up water if another pond is not available until the pH recovers. A high pH is essential to encourage a balanced anaerobic fermentation (bacterial decomposition) of bottom sludge. It also is indicative of high algal activity since removal of the carbonates from the water in algal metabolism tends to keep the pH high. A continuing low pH indicates acid production which will cause odors.

QUESTIONS

9.6A Why should at least one foot of fresh water cover the pond bottom before wastes are introduced?

9.6B Why should ponds be started during the warmer part of the year if at all possible?

9.6C What does a definite green color in a pond indicate?

9.6D When bubbles are observed coming to the pond surface near the inlet, what is happening in the pond?

9.7 DAILY OPERATION AND MAINTENANCE

Because ponds are deceptively simple, they are probably neglected more than any other type of wastewater treatment process. Many of the complaints that arise from ponds are the result of neglect or poor housekeeping. Following are listed the day-to-day operational and maintenance duties that will help to insure peak treatment efficiency and to present your plant to its neighbors as a well-run waste treatment facility.

9.70 Scum Control

Scum accumulation is a common characteristic of ponds and is usually the greatest in the spring of the year when the water warms and vigorous biological activity resumes. Ordinarily, wind action will dissipate scum accumulations and cause them to settle; however, in the absence of wind or in sheltered areas, other means must be used. If scum is not broken up, it will dry on top and become crusted. It is not only more difficult to break up then, but a species of blue-green algae is apt to become established on the scum which can give rise to disagreeable odors. If scum is allowed to accumulate, it can reach proportions where it cuts off a significant amount of sunlight from the pond.

Rafts of scum cause a very unsightly appearance in ponds and can quite likely become a source of botulism that will have a devastating effect on waterfowl and shore birds which may be attracted to the facility.

Many methods of breaking up scum have been used, including agitation with garden rakes from the shore, jets of water from pumps or tank trucks, and the use of outboard motors on boats in large ponds. Scum is broken up most easily if it is attended to promptly.

9.71 Odor Control

It is probably inevitable that, at some time, odors will come from a wastewater treatment plant no matter what kind of process is used. Most odors are caused by overloading (see Section 9.117 to determine pond loading) or poor housekeeping practices and can be remedied by taking corrective measures. However, there are times, such as when unexpected shutdowns occur, that plant processes may be upset and cause odors. For these unexpected occurrences it is strongly advised that a careful plan for emergency odor control be available. Odors usually occur during the spring warmup in colder climates because biological activity is reduced during cold weather.

For ponds, recirculation from aerobic units, the use of floating aerators, and heavy chlorination should be considered as means to reduce odors. Recirculation from an aerobic pond to the inlet of an anaerobic pond (1 part recycle flow to 6 parts influent flow) will reduce or eliminate odors. Usually floating aeration and chlorination equipment are too expensive to have setting idle waiting for an odor problem to develop. Odor masking chemicals also have been promoted for this purpose and have some uses for concentrated specific odor sources. However, in almost all cases, process procedures of the type mentioned previously are preferable. In any event, waiting until the emergency arises before planning for odor control is poor procedure. Often several days are needed to receive delivery of materials or chemicals if they are required. Try to have possible alternate methods of control ready to go if they are needed.

In some areas, sodium nitrate has been added to ponds as a source of oxygen to prevent odors. To be effective, sodium nitrate must be dispersed throughout the water in the pond. Once mixed in the pond it acts very quickly because many common organisms (facultative groups) may use the oxygen in nitrates instead of dissolved oxygen. Liquid sodium hydrochloride or chlorine solution is a faster acting solution, but not necessarily the best chemical because it will interfere with biological stabilization of the wastes.

9.72 Weed Control

Weed control is an essential part of good housekeeping and is not a formidable task with modern herbicides and soil sterilants. Weeds around the edge are most objectionable because they allow a sheltered area for mosquito breeding and scum accumulation. In most average ponds there has been little need for mosquito control when edges are kept free of weed growth. Aquatic weeds, such as tules, will grow in depths shallower than three feet, so an operating pond level of at least this depth is necessary. Tules may emerge singly or well scattered but should be removed promptly by hand as they will quickly multiply from the root system. Weeds also can hinder pond circulation.

9.73 Insect Control

Mosquitoes will breed in sheltered areas of standing water where there is vegetation or scum to which the egg rafts of the female mosquito can become attached. These egg rafts are fragile and will not withstand the action of distrubed water surfaces such as caused by wind action or normal currents. Keeping the water edge clear of vegetation and keeping any scum broken up will normally give adequate control. Shallow, isolated pools left by a receding pond level should be drained or sprayed with a larvacide.

Any of several minute shrimp-like animals may infest the pond from time to time during the warmer months of the year (March-November). These predators live on algae and at times will appear in such numbers as to almost clear the pond of algae. During the more severe infestations there will be a sharp drop in the dissolved oxygen of the pond, accompanied by a lowered pH. This is a temporary condition because the predators will outrun the algae supply, and there will be a mass die-off of insects which will be followed by a rapid greening up of the pond again.

Ordinarily there should be no great concern about these infestations because they soon balance themselves; however, in the case of a heavily loaded pond, a sustained low dissolved oxygen content may give rise to noxious odors. In that event any of several commercial sprays can be used with excellent control. Dibrom-8 has been used with good results.

Chironomid midges are often produced in wastewater ponds in sufficient numbers to be serious nuisances to nearby residential areas, farm workers, recreation sites, and industrial plants. When emerging in large numbers they may also create traffic hazards. At present the only satisfactory control is through the use of insecticides such as parathion, Abate, Sursban, and Fenthion. Control measures are time consuming and may be difficult, particularly if there is a discharge to a receiving stream. If possible, lower the level in the ponds enough to contain a day's inflow before applying an insecticide. Holding the insecticide for at least one day will kill more insects and reduce the effect of the insecticide on receiving waters. For better results, insecticides should be applied on a calm day and any recirculation pumps should be stopped.

9.74 Levee Maintenance

Levee slope erosion caused by wave action is probably the most serious maintenance problem. If allowed to continue, it will result in a narrowing of the levee crown which will make accessibility with maintenance equipment most difficult.

If the levee slope is composed of easily erodable material, the only long-range solution is the use of bank protection such as stone riprap or broken concrete rubble.

Levee tops should be crowned so that rain water will drain over the side in a sheet flow rather than flowing a considerable distance along the levee crown and gathering enough flow to cause erosion when it finally spills over the side and down the slope.

If the levees are to be used as roadways during wet weather, they should be paved or well graveled.

9.75 Headworks and Screening

It is important to clean the bar screen as frequently as possible. The screen should be visited at least once or twice a day with more frequent visits during storm periods. Screenings should be disposed of daily in a sanitary manner, such as by burial, to avoid odors and fly breeding.

Many pond installations have grit chambers at the headworks to protect raw wastewater lift pumps, or prevent plugging of the influent lines. There are many types of grit removal equipment. Grit removed by the various types of mechanical equipment or by manual means will usually contain small amounts of organic matter and should therefore be disposed of in a sanitary manner. Disposal by burial is the most common method.

9.76 Some Operating Hints

1. Anaerobic ponds should be covered and isolated for odor control and followed by aerobic ponds. Floating polystyrene planks can be used to cover anaerobic ponds and can be painted for protection from the sun. These will help to confine odors and heat and tend to make the anaerobic ponds more efficient.

2. Placing ponds in series tends to cause the first pond to become overloaded and may never allow it to recover; the overload may be carried to the next pond in series. Feeding ponds in parallel allows you to distribute the incoming load evenly between units. Whether ponds are operated in series or in parallel[6] should depend on the loading situation.

   When operating ponds in series, the accumulation of solids in the first pond may become a serious problem after a long period of use. Periodically the flow should be routed around the first pond. This pond should then be drained and the solids removed and buried.

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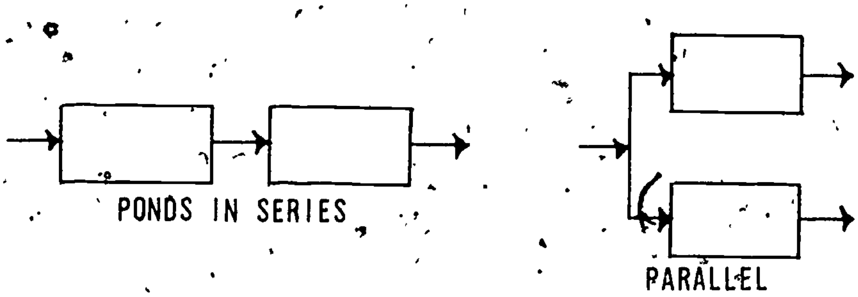

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3. It can be helpful to provide for a large amount of recirculation, say 25 to 100%. This allows the algae and other aerobic organisms to become thoroughly mixed with incoming raw wastewater. At the same time, good oxygen transfer can be attained by passing the incoming water over a deck or other type of aerator. This procedure can cause heat loss, however.

4. Heavy chlorination at the recirculation point can assist in odor control, but will probably interefere with treatment.

5. As with any treatment process, it is necessary to measure the important parameters (DO fluctuations during a 24-hour period and solids) at frequent, regular intervals and plot them so that you have some idea of the direction the process is taking in time to take corrective action when necessary.

6. When solids start floating to the surface of a pond during the spring or fall overturn, the pond should be taken out of service and cleaned. Measurement of the sludge depth on the bottom of a pond also will indicate when a pond should be cleaned.

7. Before applying insecticides or herbicides, be sure to check with appropriate authorities regarding the long term effects of the pesticide you plan to use. Do not apply pesticides that may be toxic to organisms in the receiving waters.

QUESTIONS

9.7A Why should scum not be allowed to accumulate on the surface of a pond?

9.7B How can scum accumulations be broken up?

9.7C What are the causes of odors from a pond?

9.7D What precaution would you take to be prepared for an odor problem which might develop?

9.7E Why are weeds objectionable in and around ponds?

9.7F How can weeds be controlled and removed in and around ponds?

9.7G Why should insects be controlled?

9.7H Why should a pond be lowered before an insecticide is applied?

9.7I Why are the contents of ponds recirculated?

9.8 SURFACE AERATORS

Surface aerators have been used in two types of applications:

1. To provide additional air for ponds during the night or during cold weather, or for overloaded ponds.

2. To provide a mechanical aeration device for ponds operated as an aerated lagoon. Aerated lagoons operate similar to an activated sludge aeration tank without returning any settled activated sludge.

In both cases the aerators are operated by time clocks with established on-off cycles. Laboratory tests on the dissolved oxygen in a pond indicate the time period for on and off cycles to maintain aerobic conditions in the surface layers of the pond. Adjustments in the on-off cycles are necessary when changes occur in the quantity and quality of the influent and seasonal weather conditions. Some experienced operators have correlated their lab test results to pond appearance and regulate the on-off cycles using the following rule: If the pond has foam on the surface, reduce the operating time of the aerator; and if there is no evidence of foam on the pond surface, increase the operating time of the aerator.

Maintenance of surface aerators should be conducted in accordance with manufacturer's recommendations.

9.9 SAMPLING AND ANALYSIS

9.90 General

Probably the most important sampling that can be accomplished easily by any operator is routine pH and dissolved oxygen analysis. It is very desirable to make pH, temperature, and dissolved oxygen tests several times a week, and occasionally during the night, throughout operation of the pond. These values should be recorded because they will serve as a valuable record of performance. The time of day should be varied occasionally for the tests so that the operator becomes familiar with the pond's characteristics at various times of the day. Usually the pH and dissolved oxygen will be lowest just at sunrise. Both will get progressively higher as the day goes on, reaching their highest point in late afternoon.

It is especially important to remember to avoid getting any atmospheric oxygen into the sample taken to measure dissolved oxygen. This is most necessary when samples are taken in the early morning or if the dissolved oxygen in the pond is low from overloading. If possible, measure the dissolved oxygen with an electric probe, being careful not to allow the membrane on the end of the probe to be exposed to the atmosphere.

Ponds often have clearly developed individuality, each being a biological community that is unique unto itself. Identical adjacent ponds receiving the same influent in the same amount often have a different pH and a different dissolved oxygen content at any given time. One pond may generate considerable scum while its neighbor is devoid of scum. For this reason, each pond should be given routine testing as regards to pH and dissolved oxygen. Such testing may indicate an unequal loading because of the internal clogging of influent or distribution lines that might not be apparent from visual inspection. Tests also may indicate differences or problems that are being created by a build-up of solids or solids recycle.

As an operator becomes familiar with operating a pond, he can soon learn to correlate the results of some of the chemical tests with visual observations. A deep green sparkling color generally indicates a high pH and a satisfactory dissolved oxygen content. A dull green color or lack of color generally indicates a declining pH and a lowered dissolved oxygen content. A grey color indicates the pond is being overloaded.

9.91 Frequency and Location of Lab Samples

The frequency of testing and expected ranges of test results vary considerably from pond to pond, but you should establish those ranges within which your pond functions properly. Test results will also vary during the hours of the day. Table 9-1 summarizes the typical tests, locations, and frequency of sampling.

Tests of pH, DO, and temperature are important indicators of the condition of the pond, whereas BOD, coliform, and solids tests measure the efficiency of the pond in treating wastes. BOD is also used to calculate the loading on the pond.

In order to estimate the organic loading on the pond, the operator must have some knowledge of the biochemical oxygen demand (BOD) of the waste and the approximate average daily flow. Influent BOD and solids will vary with time of day, day of week, and season, but a pond is a good equalizer if not overloaded. Recirculation will help an overloaded pond.

TABLE 9-1

FREQUENCY AND LOCATION OF LAB SAMPLES

Test	Frequency	Location	Common Range
pH*	Daily	Pond	7.5+
Dissolved Oxygen (DO)*	Daily	Pond Effluent	
Temperature	Daily	Pond	
BOD	Weekly	Influent Effluent	
Coliform Group Bacteria	Weekly	Effluent	
Chlorine Residual	Daily	Effluent	0.5-2.0 mg/l
Suspended Solids	Weekly	Influent Effluent	
Dissolved Solids	Weekly	Influent Effluent	

*pH values above 9.0 and DO levels over 15 mg/l are not uncommon.

BODs should be measured on a weekly basis. Samples should be taken during the day at low flow, medium flow, and high flow. The average of these three tests will give a reasonable indication of the organic load of the wastewater being treated. If it is suspected that the BOD varies sharply during the day or from day to day, or if unusual circumstances exist, the sampling frequency should be increased to obtain a clear definition of the variations. If the pond DO level is supersaturated the sample must be aerated to remove the excess oxygen before the BOD test is performed.

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9.92 Expected Treatment Efficiencies[7]

Table 9-2 is provided as a guide to indicate probable removal efficiencies of typical ponds.

TABLE 9-2

EXPECTED RANGES OF REMOVAL BY PONDS

Item	Detention Time	Expected Removal
BOD		50 to 90%
BOD (facultative pond)[8]	50 to 60 days	70 to 80%[9]
Coliform Bacteria (facultative pond)	50 to 60 days	90 to 95%
Suspended Solids	After 3 days	90%
Dissolved Solids	After 10 days	80%

[7] Waste Removal, % $= \frac{(\text{In} - \text{Out})}{\text{In}} \times 100\%$

[8] Facultative Pond (FACK-ul-tay-tive). The most common type of pond in current use. The upper portion (supernatant) is aerobic while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.

[9] Expected removal approximately 80% of the time with poorer removals during the remainder of the time.

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9.11 DESIGN CRITERIA

A review of some common design criteria will give an insight to the theory and operation of a pond.

9.110 Location

The general considerations for the location of other types of wastewater treatment plants also apply to the location of ponds. Isolation should be as great as can be economically provided. Attention to the direction of prevailing winds with due regard for present and projected downwind residential, commercial, and recreational development is of utmost importance.

9.111 Chemistry of Waste

Before the design of any pond is undertaken, it should be determined whether there are any possible toxic effects (interfere with algal or bacterial growth) from the waste. Some natural water supplies may have a high sulfur content or other chemicals that limit the possibility of desired sludge decomposition.

Certain wastes, such as dairy products and wine products, are difficult to treat because of their low pH. Any processing waste should be carefully investigated before one can be certain that it can be successfully treated by ponding. Some process wastes contain powerful fungicides and disinfectants that may have a great inhibitive effect on the biological activity in a pond.

9.112 Headworks and Screening

A headworks with a bar screen is desirable to remove rags, bones, and other large objects that might lodge in pipes or control structures.

A trash shredder is a luxury that may not be warranted. Any material that gets past an adequate bar screen will in all probability not harm the influent pump. Any fecal matter will be pulverized in going through the pump.

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9.113 Flow Measuring Devices

It is highly desirable that an influent measuring device be installed to give a direct reading on the daily volume of wastes that are introduced into the ponds. This information, along with a BOD measurement of the influent, is required to estimate the organic loading on the pond. Comparison of influent and effluent flow rates is necessary for estimating percolation and evaporation losses.

A measuring device provides basic data for prediction of future plant expansion needs or for detecting unauthorized or abnormal flows. Reliable, well-kept records on flow volume help justify budgets and greatly assist an engineer's design of a plant expansion or new installation.

9.114 Inlet and Outlet Structures

Inlet structures should be simple and foolproof and should be standard manufactured articles so that replacement parts are readily available. Telescoping friction fit tubes (see Fig. 9.4) for regulating spill or discharge height should be avoided because a biological growth may become attached and prevent the tubes from telescoping if they are not cleaned regularly.

A submerged inlet will minimize the occurrence of floating material and will help conserve the heat of the pond by introducing the warmer wastewater into the depths of the pond. Warm wastewater introduced at the bottom of a cold water mass will channel to the surface and spread unless it is promptly and vigorously mixed with cold water. Warm wastewater spilled onto the surface of the pond will spread out in a thin layer on the surface and not contribute to the warmth of the lower regions of the pond where heat is needed for bacterial decomposition. Inlet and outlet structures should be so located in relation to each other to minimize possible short circuiting.

Valves that have stems extending into the stream flow should be avoided. Stringy material and rags will collect and form an obstruction and may render the valve inoperative.

Free overfalls (Fig. 9.5) at the outlet should be avoided to minimize release of odors, foaming, and gas entrapment which may hamper pipe flows. Free overfalls should be converted to submerged outfalls if they are causing nuisances and other problems.

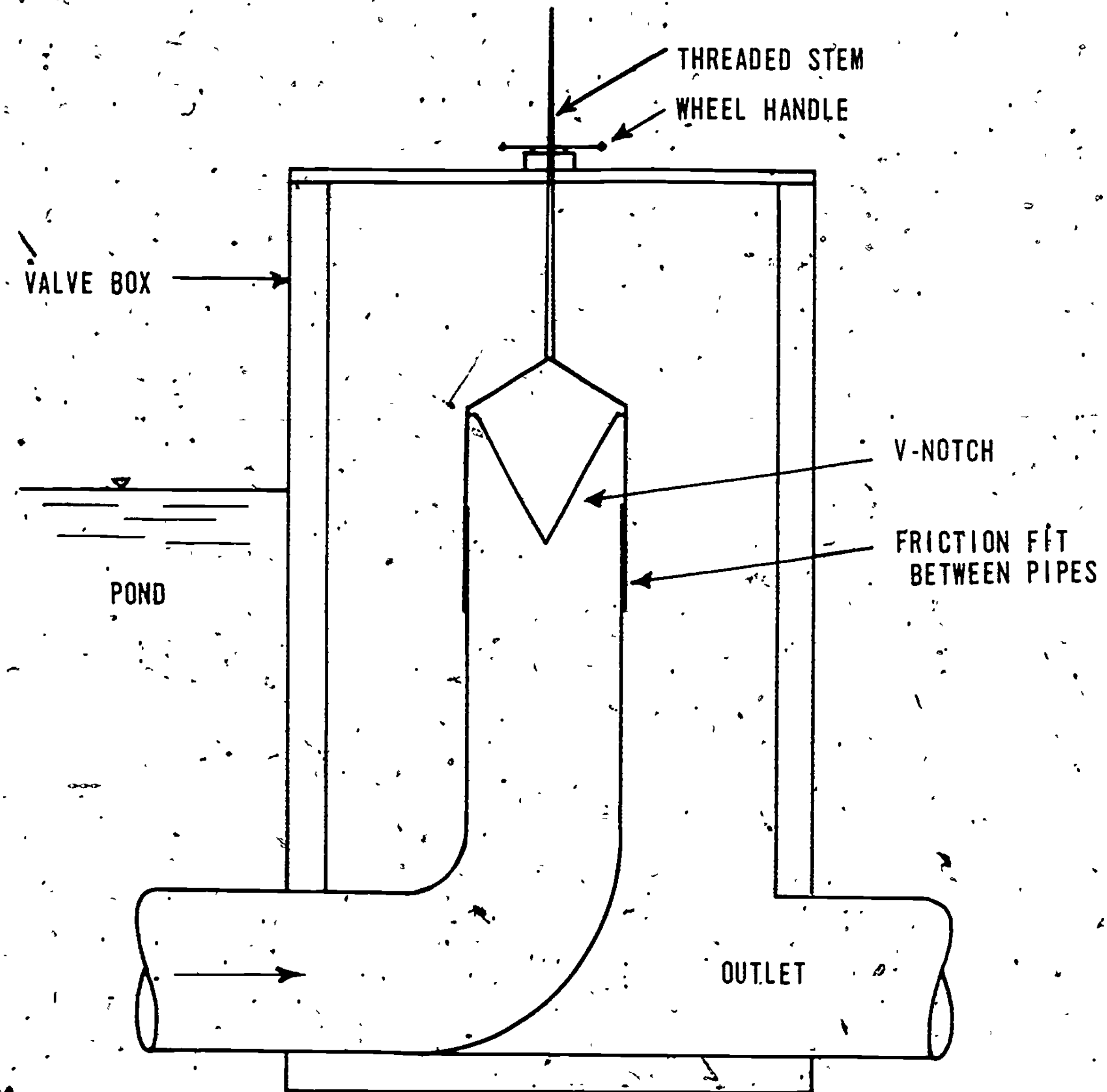

Fig. 9.4 Telescoping friction fit tubes for regulating discharge

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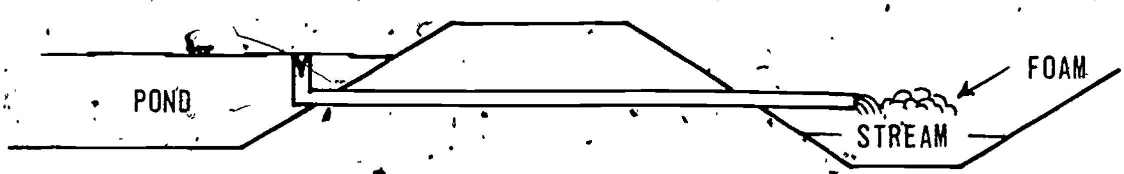
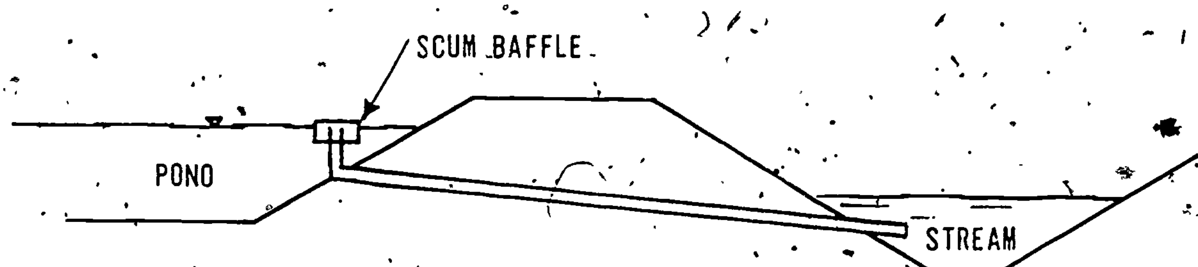


FREE OVERFALL--UNDESIRABLE



SUBMERGED OUTLET--NO FOAMING PROBLEMS

Fig. 9.5 Free overflow and submerged outlet

If a pond has a surface outlet, floating material can be kept out of the effluent by building a simple baffle around the outlet. The baffle can be constructed of wood or other suitable material. It should be securely supported or anchored.

9.115 Levee Slopes

The selection of the steepness of the levee slope must depend on several variables. A steep slope erodes quicker from wave wash unless the levee material is of a rocky nature or else protected by riprap. However, a steep slope minimizes waterline weed growth. It is more difficult to operate equipment and to perform routine maintenance on steep slopes. A gentle slope will erode the least from wave wash, is easier to operate equipment on, and is easier to perform routine maintenance on. However, waterline weed growth will have a much greater opportunity to flourish.

9.116 Pond Depths

The operational depth of ponds deserves considerable attention. Depending upon conditions, ponds of less than three feet of depth may be completely aerobic if there are no solids on the bottom (unlikely) because of the depth of sunlight penetration. This means that the treatment of wastes is accomplished essentially by converting the wastes to algae cell material. Ponds of this shallow depth are apt to be irregular in performance because algae blooms will increase to such proportions that a mass die-off will occur with the result of all algae precipitating to the bottom and thereby adding to the organic load. Such conditions could lead to the creation of an anaerobic pond. The bottoms of shallow ponds will become anaerobic when solids collect on the bottom and after sunset.

Discharges from shallow, aerobic ponds contain large amounts of algae. To operate efficiently these ponds should have some means of removing the algae grown in the pond before the effluent is discharged to the receiving waters. If the algae are not removed from the effluent, the organic matter in the wastewater is not removed or treated and the problem is merely transferred to some downstream pool.

An observed phenomenon of lightly loaded, shallow secondary ponds and tertiary ponds is that they are apt to become infested with filamentous algae and mosses that not only limit the penetration of sunlight into the pond but hamper circulation of the pond's contents and clog up inlet and outlet structures. When the loading is increased, this condition improves.

Pond depths of four feet or more allow a greater conservation of heat from the incoming wastes to foster biological activity, as the ratio between pond volume and pond area is more favorable. In facultative ponds, depths over four feet provide a physical storage for dissolved oxygen accumulated during the day to carry over through the night when no oxygen is released by the algae, unless floating algae and poor circulation keep all the oxygen near the surface. This physical storage of DO is very important during the colder months when nights are long.

A pond operating depth of at least three feet is recommended to prevent tule and cattail growth. Ponds less than three feet deep

should be lined to prevent troublesome weed growth. Weeds that emerge along the shore line can be effectively controlled by spraying with any of several products available.

QUESTIONS

9.11A Why are some wastes not easily treated by ponds?

9.11B What is the minimum recommended pond operating depth?

9.11C Why should the inlet to a pond be submerged?

9.11D Why should the outlet be submerged?

9.11E How could problems created by a surface outlet be reduced or corrected?

9.11F Why [illegible] free overfalls be avoided?

9.11G Why are shallow ponds apt to be irregular in performance?

9.11H Why should the influent to a pond be metered?

9.117 Pond Loading

The waste loading on a pond is generally spoken of in relation to its area, and may be stated in several different ways:

1. lbs of BOD per day per acre = lbs BOD/day/acre
   (This is called organic loading.)

2. inches (or feet) of depth added per day
   (This is called hydraulic loading or overflow rate.)

or 3. persons (or population served) per acre
   (This is called population loading.)

Detention time is related directly to pond hydraulic loading, which is actually the rate of inflow of wastewater. It may be expressed as million gallons per day (MGD), or as the number of acre-inches per day or acre-feet per day (one acre-foot covers one acre to a depth of one foot or twelve inches and is equal to 43,560 cu ft). We must know the pond volume in order to determine detention time; this is most easily computed on an acre-foot basis.

A. Detention Time

$$\text{Detention (in days)} = \frac{\text{Pond Volume (ac-ft)}}{\text{Influent Rate (ac-ft/day)}}$$

This equation does not take into consideration water which may be lost through evaporation or percolation. Detention time may vary from 30 to 120 days, depending on the treatment requirements to be met.

B. Population Loading

Loading calculated on a population-served basis is expressed simply as:

$$\text{No. of Persons per Acre} = \frac{\text{Population Served, persons}}{\text{Area of Pond, ac}}$$

The population loading may vary from 50 to 500 persons per acre, depending on many local factors.

C. Hydraulic Loading

The hydraulic loading or overflow rate is expressed as:

$$\text{Inches per day} = \frac{\text{Inflow (ac-in per day)}}{\text{Pond Area, ac}}$$

The hydraulic loading may vary from half an inch to several inches per day, depending on the organic load of the influent.

NOTE: If the wastewater inflow rate is known in million gallons per day (MGD), it can be converted to an equivalent number of acre-inches per day as follows:

$$\text{Inflow, acre-inches per day} = (\text{Inflow, MGD}) \times 36.8$$ [10]

If the pond detention time is known, the hydraulic loading can also be calculated, as follows:

$$\text{Inches per day} = \frac{\text{Depth of Pond, in}}{\text{Detention Time, days}}$$

D. Organic Loading

The organic loading is expressed as:

$$\text{Organic Load (lbs BOD per day per acre)} = \frac{(\text{BOD, mg/l})(\text{Flow, MGD})(8.34\ \text{lbs/gal})}{\text{Pond area, ac}}$$ [11]

Typical organic loadings may range from 10 to 50 lbs BOD per day per acre.

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10 $1\ \text{MGD} = \frac{1{,}000{,}000\ \text{gal}}{\text{day}} \times \frac{1\ \text{cu ft}}{7.48\ \text{gal}} \times \frac{1\ \text{ac}}{43{,}560\ \text{sq ft}} \times \frac{12\ \text{in}}{1\ \text{ft}} = 36.8\ \frac{\text{ac-in}}{\text{day}}$

11 Recall lbs/day = (Conc. mg/M mg)(M gal/day)(8.34 lbs/gal)

9.12 ACKNOWLEDGMENT

Liberal use has been made of the many papers presented by Professor W. J. Oswald of the University of California at Berkeley on the subject of the treatment of wastes by ponding.

9.13 ADDITIONAL READING

a. New York Manual, page 71

b. Texas Manual, pages 283-302

c. <u>Raw Sewage Lagoons in California</u>, by California State Department of Public Health, Bureau of Sanitary Engineering, Berkeley, California, May 1969.

d. Waste Stabilization Lagoons - Design, Construction, and Operation Practices Among Missouri Basin States, Missouri Basin Engineering Health Council, 1960. Reproduced by U.S. Public Health Service, Region VI, Kansas City, Missouri.

END OF LESSON 3 OF 3 LESSONS

on

WASTE TREATMENT PONDS

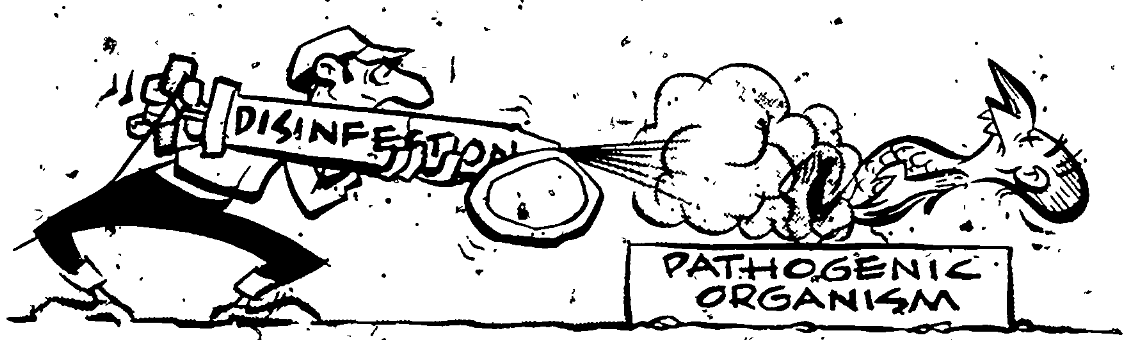
CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 1 of 4 Lessons)

10.0 PRINCIPLES OF WASTEWATER DISINFECTION WITH CHLORINE

10.00 Introduction

Wastewater contains organisms from both the healthy and sick people discharging their wastes into the collection system. Disease-producing organisms are potentially present in all wastewaters, and these organisms must be removed or killed before treated wastewater can be discharged to the receiving waters. The purpose of disinfection is to destroy pathogenic organisms[1] and thus prevent the spread of water-borne diseases.



The conventional waste treatment processes described in previous chapters remove pathogens from wastewater in varying degrees. The destruction and removal of pathogens is brought about in several ways:

1. Physical removal through sedimentation and filtration
2. Natural die-away of organisms in an unfavorable environment during storage
3. Destruction by chemicals introduced for treatment purposes

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[1] Pathogenic (path-o-JEN-nick) Organisms. Bacteria or viruses which can cause disease (typhoid, cholera, dysentery). There are many types of bacteria which do not cause disease and which are not called pathogenic. Many beneficial bacteria are found in wastewater treatment processes actively cleaning up organic wastes.

Although the number of microorganisms in polluted waters is reduced by treatment processes and natural purification, the term disinfection is used in practice to describe treatment processes that have, as their major objective the killing of pathogenic organisms (Fig. 10.1). Because chlorine and some of its compounds disinfect so well, and because they are available at reasonable cost, they have been used almost to the exclusion of other disinfecting agents. This chapter on disinfection will be concerned primarily with the principles and practice of chlorine disinfection.

10.01 Disinfection

The main use of chlorine in domestic waste treatment is disinfection. Strictly defined, disinfection is the destruction of all pathogenic organisms, while sterilization is the total destruction or removal of all microorganisms. When wastewater effluents are discharged to receiving waters which may be used as a source of public water supply, shellfish growing areas, or for recreational purposes, treatment for the destruction of pathogenic organisms is required to minimize the health hazards of pollution of these receiving waters. Such treatment is known as disinfection.

Chlorination for disinfection purposes requires killing essentially all of the pathogens in the domestic waste effluent. Many other sensitive organisms in contact with chlorine are destroyed too. No attempt is made to sterilize wastewater, which is both unnecessary and impractical. In some instances sterilization would be detrimental where other treatment, dependent upon the activity of the saprophytes,[2] follows chlorination. Chlorine is a nonselective killer. It affects organisms on the basis of sensitivity, growth rate, concentration and exposure time.

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[2] Saprophytes (SAP-pro-fights). Organisms living on dead or decaying organic matter; they help natural decomposition of the organic solids in wastewater.

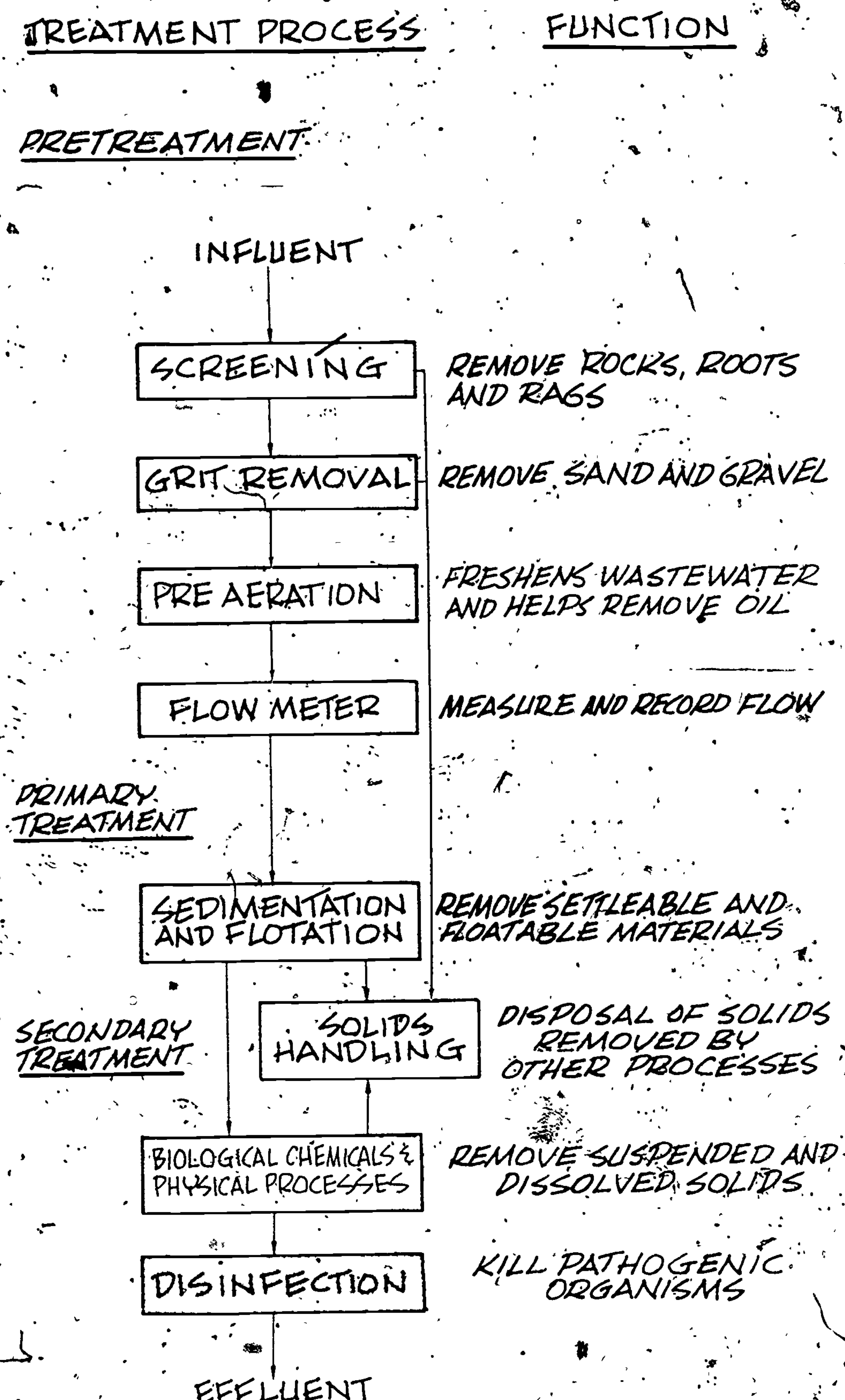

Fig. 10.1 Typical flow diagram of wastewater treatment plant

To accomplish disinfection, sufficient chlorine must be added to satisfy the chlorine demand[3] and leave a residual chlorine[4] that will destroy bacteria. The residual must be maintained for a sufficient "contact time" to insure killing the pathogens. For most wastewater, extending chlorine contact time can be more effective than increasing dosages.

Special laboratory equipment is necessary to measure the effectiveness of chlorination for reducing the number of bacteria. The tests require several days to complete. Thus bacterial examinations are not generally practical for the day-to-day control of the application of chlorine. For many years disinfection requirements often specified an orthotolidine[5] chlorine residual of 0.5 milligrams per liter after a chlorine contact time of thirty minutes. Compliance with this requirement generally resulted in MPNs[6] of about 3000 coliform[7] organisms per 100 ml (California, 1966). However, this resulting MPN may vary considerably (several orders of magnitude) from plant to plant. Considering dilution with water having a low coliform content, this standard appeared suitable when public contact with the waters was limited. Today people are living more intimately with wastewater than ever before. Wastewater effluents are

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[3] Chlorine Demand. Chlorine demand is the difference between the amount of chlorine added to wastewater and the amount of residual chlorine remaining after a given contact time. Chlorine demand may change with dosage, time, temperature, nature and amount of impurities in water. Chlorine Demand = Chlorine Applied - Chlorine Residual.

[4] Residual Chlorine. Residual Chlorine is the amount of chlorine remaining after a given contact time and under specified conditions.

[5] Orthotolidine (or-THO-TOL-i-dine). Orthotolidine is a colorimetric indicator of chlorine residual in which a yellow-colored compound is produced.

[6] MPN. MPN is the Most Probable Number of coliform group organisms per unit volume expressed as density of organisms per 100 ml.

[7] Coliform (COAL-i-form). The coliform group of organisms is a bacterial indicator of contamination. This group has as one of its primary habitats the intestinal tract of human beings. Coliforms also may be found in the intestinal tract of warm-blooded animals, and in plants, soil, air, and the aquatic environment.

used for irrigating lawns, parks, cemeteries, freeway planting, golf courses, college campuses, athletic fields, and other public areas. Recreational lakes used for boating, swimming, water skiing, fishing, and other water sports are frequently made up partially and, in a few cases, solely of treated effluents. As public contact has increased and diluting waters have decreased or become of poor quality, it has become obvious that more consideration must be given to disinfection practices.

QUESTIONS

10.0A What is the purpose of disinfection? Why is this important?

10.0B How are pathogenic bacteria destroyed or removed from water?

10.0C Why is chlorination used for disinfection?

10.0D Why are wastes not sterilized?

10.02 Reaction of Chlorine in Wastewater

In order to determine where in the treatment process and how much chlorine should be applied to accomplish the purpose desired, it is necessary to know the action of chlorine when added to wastewater.

Chlorine is an extremely active chemical that will react with many compounds to produce may different products. If a small amount of chlorine is added to wastewater, it will react rapidly with such substances as hydrogen sulfide, thiosulfates (industiral wastes), and ferrous iron. Under these conditions, chlorine is converted to chloride and little or no disinfection will result. If enough chlorine is added to react with all of these substances, called reducing compounds, a little more chlorine added will react with ammonia or other nitrogenous compounds present and form chloramines, which have disinfecting action. Again, if enough chlorine is added to react with all the reducing compounds and all the nitrogenous matter, this chlorine will react with organic matter to produce chlororganic compounds[8] or other combined forms of chlorine, which have slight disinfecting action. Finally, if enough chlorine is added to react with all of the above compounds, any additional chlorine will form free available chlorine (HOCl) which has the highest disinfecting action. (Fig. 10.2, Page 10-9)

The exact mechanism of this disinfection action is not fully known. In some theories, chlorine is considered to exert a direct action against the bacterial cell, thus destroying it. A more recent theory is that the toxic character of chlorine inactivates the enzymes[9] upon which the living microorganisms are dependent for utilizing their food supply. As a result, the organisms die of starvation. From the point of view of wastewater treatment, the mechanism of the action of chlorine is much less important than its effects as a disinfecting agent.

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[8] Chlororganic (chlor-or-GAN-nick). Chlororganic compounds are organic compounds combined with chlorine. These compounds generally originate from or are associated with living or dead organic materials

[9] Enzymes (EN-zimes). Enzymes are substances produced by living organisms that speed up chemical changes.

The quantity of reducing substances, both organic and inorganic, in wastewater varies, so the amount of chlorine that has to be added to wastewater for different purposes will vary. The chlorine used by these organic and inorganic reducing substances is defined as the chlorine demand. It is equal to the amount added minus that remaining as combined chlorine after a period of time, which is generally thirty minutes. Thus,

Chlorine Demand = Chlorine Dose - Chlorine Residual

Although significant kill of sensitive organisms occurs while the chlorine demand is being satisfied, disinfection is caused primarily by that amount remaining after the chlorine demand has been satisfied. This quantity of chlorine in excess of the chlorine demand is defined as residual chlorine and is expressed as milligrams per liter (mg/l).

It should be noted that in wastewater treatment chlorination is not normally to the "break point" (Fig. 10.2) so that a free residual would exist. The "break point" for good secondary effluent would be a chlorine dosage of approximately 150 mg/l. Thus we are talking primarily about a combined residual. However, with some of the more advanced treatment processes in which a high degree of nitrification occurs, treatment to free chlorine residuals beyond the break point is possible at a chlorine dose of less than 25 mg/l.

Both <u>chlorine addition</u> and <u>contact time</u> are essential for organism kill. Experimental determination of the best combination of combined residual and contact time is necessary to insure both proper chlorination and minimum use of chlorine. Changes in pH affect the disinfection ability of chlorine and the operator must reexamine the best combination of chlorine addition and contact time when the pH fluctuates.

It must be emphasized that wastewaters are not and need not be carried to a free residual for effective bactericidal action at the present time in most locations. With increasingly stringent receiving water standards requiring higher quality effluents in the future, the need for disinfection to the free chlorine residual is a distinct possibility. Complete disinfection ("kill" of pathogenic bacteria and viruses) is assured mainly by chlorination to a free available chlorine residual.

Calculation of the chlorine dosage and chlorine demand is illustrated in the following problem.

EXAMPLE:

A chlorinator is set to feed 50 pounds of chlorine per 24 hours; the wastewater flow is at a rate of 0.85 MGD, and the chlorine as measured by the OT (orthotolidine) tests after thirty minutes of contact is 0.5 mg/l. Find the chlorine dosage and chlorine demand in mg/l.

$$\text{Chlorine Feed or Dose, mg/l} = \frac{50 \text{ lbs chlorine/day}}{0.85 \text{ MG/day}}$$

$$\begin{array}{r} 59. \\ 0.85 \overline{) 50.00} \\ \underline{42\ 5} \\ 7\ 50 \\ 7\ 65 \end{array}$$

$$= 59 \text{ lbs chlorine per MG}$$

$$= \frac{59 \text{ lbs chlorine/MG}}{8.34 \text{ lbs/gal}}$$

$$= 7.1 \text{ lbs chlorine/million pounds water}$$

= 7.1 ppm (parts per million parts)

$$= 7.1 \text{ mg/l}$$

$$\text{Chlorine Demand, mg/l} = \text{Chlorine Dose, mg/l} - \text{Chlorine Residual, mg/l}$$

$$= 7.1 \text{ mg/l} - 0.5 \text{ mg/l}$$

$$= 6.6 \text{ mg/l}$$

QUESTIONS

10.0E How does chlorine react with wastewater?

10.0F How much chlorine must be added to wastewater to produce disinfecting action?

10.0G How is the chlorine demand determined?

10.0H How is the chlorine dosage determined?

10.0I Calculate the chlorine demand of treated domestic wastewater if:

Flow Rate = 1.2 MGD

Chlorinator = 70 lbs of chlorine per 24 hours

Residual = 0.4 mg/l after thirty minutes

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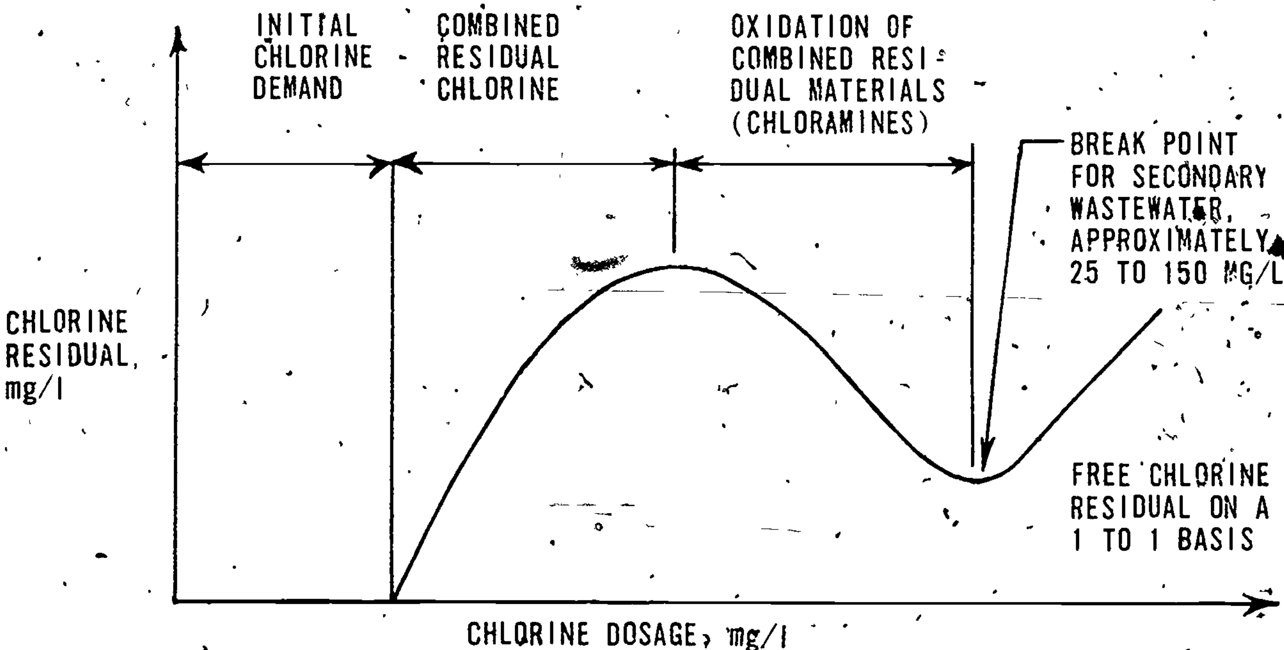

Fig. 10.2 Break-point chlorination curve

10.03 Rules of Disinfection

The State of California presently (1969) specifies the coliform MPN in the effluent as a primary standard for effectiveness of disinfection. It has been established that the bacteria causing enteric[10] diseases are less resistant to the chlorine than the non-pathogenic intestinal bacteria, designated as the coliform group. For this reason the destruction of the coliform group of bacteria generally provides an effective criterion of wastewater disinfection. However, certain viruses, spores, and pathogenic bacteria inside solids may be more resistant than coliform group bacteria to chlorine. When a chlorine residual criterion is also set, it is considered to be a secondary standard and is valid only if, and as long as, bacterial kill meets the MPN standard. One sample is not as meaningful as a series of samples indicating trends.

Studies have shown great variation in MPNs in chlorinated wastewater samples even under apparently similar conditions. These variations occur for numerous reasons, some of which are as follows:

1. MPN does not directly measure the true number of coliform bacteria present, but rather is an expected or probable number based on analysis of samples from a large population (all of the wastewater flowing by the sampling point).

2. Small samples from large amounts of a source are not representative unless the source is uniform, and certainly wastewater is far from uniform.

3. Many variables affect the number of coliform bacteria present in a chlorinated waste: numbers and characteristics of bacteria prior to chlorination, concentration and nature of the specific agent accomplishing the disinfection, accessibility of the disinfectant to the microorganisms, and various environmental factors.

4. The test is not always performed under ideal conditions. For example, culture media dilutions or other factors may be unfavorable for valid coliform counts.

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[10] Enteric: Intestinal

Several different methods including MPNs, membrane filters, and fecal coliforms may be specified for defining adequate disinfection. The format used is geared to fit the specific discharge and the downstream uses of the receiving waters. Check with your state regulatory agency for the requirements applicable to your plant.

Because of limited laboratory facilities available at most wastewater treatment plants, the following statement has been included in disinfection requirements issued in California:

> "Methods other than bacterial testing for the demonstration of effectiveness of disinfection will be accepted after the discharger has provided sufficient laboratory data showing that statistically sound correlation[11] exists at all times between bacterial results and measurements produced by the alternate proposed method."

Many of the smaller dischargers in California have asked the State for assistance in correlating chlorine residual and coliform MPN. The State has conducted studies at several plants. The studies have not been of a research nature, but were conducted for the purpose of determining whether disinfection as being practiced at the specific plants was adequate to protect the public health. Following are some of the findings from these studies:

1. It is difficult to maintain a consistently high degree of disinfection at most wastewater treatment plants. Chlorination is apparently more effective in a well-clarified effluent than one in which significant suspended solids are present. A lump of solids may consume available chlorine before the chlorine penetrates the particle. Organisms imbedded within the particle are thus protected from the chlorine and are not disinfected.

2. Thorough mixing of chlorine solution with the wastewater is essential to achieve maximum efficiency of coliform kill for a given chlorine dosage.

3. Higher chlorine residuals (after a given contact time) are required for primary treated wastes than for secondary treated wastes to effect a comparable coliform quality.

4. Two-stage chlorination (pre- and post-chlorination) provides more consistent production of low coliform density than postchlorination alone.

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[11] Correlation: Relationship

5. Generally speaking, a correlation exists between chlorine residual and coliform density. (Coliform densities decrease with increased chlorine residuals.) The individualities of wastewater treatment plants and their effluent conditions, as well as sampling and analysis techniques, make it difficult to apply a correlation determined from one plant to other plants.

6. Chlorine residuals, and corresponding feed rates, required to afford a desired disinfection level vary from day to day and from morning to afternoon at most treatment plants.

7. Increases in chlorine residuals above a certain point do not appear to reduce coliform densities significantly.

8. Increases in detention time above a certain point do not appear to reduce coliform densities significantly.

9. The actual contact time in most chlorine contact chambers is considerably less than the theoretical contact time.

10. Samples of wastewater chlorinated in a laboratory do not give results comparable to those obtained in chlorine contact chambers.

11. The better the treatment the more effective the disinfection at a given chlorine dosage.

10.04 Chlorine Requirement

The object of disinfection is the destruction of pathogenic bacteria, and the ultimate measure of the effectiveness is the bacteriological result. The measurement of residual chlorine does supply a tool for practical control. If the residual chlorine value commonly effective in most wastewater treatment plants does not yield satisfactory bacteriological kills in a particular plant, the residual chlorine that does must be determined and used as a control in that plant. In other words, the 0.5 mg/l residual chlorine, while generally effective, is not a rigid standard but a guide that may be changed to meet local requirements.

One special case would be the use of chlorine in the effluent from a plant serving a tuberculosis hospital. Studies have shown that a residual of at least 2.0 mg/l should be maintained in the effluent from this type of institution, and that detention time should be

at least two hours at the average rate of flow instead of the thirty minutes which is normally used for basis of design. Two-stage chlorination may be particularly effective in this case.

It will generally be found that in a domestic waste the following dosages of chlorine are a reasonable guideline to produce chlorine residual adequate for disinfection. Individual plants may require higher or lower dosages, depending upon type and amount of suspended and dissolved organic compounds in the chlorinated sample.

TYPE OF TREATMENT	DOSAGE (Based on Average Flow)
Primary plant effluent	20 - 25 mg/l
Trickling filter plant effluent	15 mg/l
Activated sludge plant effluent	8 mg/l
Sand filter effluent	6 mg/l

QUESTIONS

10.0J Which is more resistant to chlorination, bacteria causing enteric diseases or non-pathogenic intestinal bacteria, designated as the coliform group?

10.0K Why does one find great variation in MPNs in chlorinated wastewater samples even under apparently similar conditions?

10.0L What are some of the findings of studies attempting to correlate chlorine residual and coliform MPN?

10.0M How is the effectiveness of the chlorine residual for a particular plant determined?

END OF LESSON 1 OF 4 LESSONS

on

DISINFECTION AND CHLORINATION

CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 2 of 4 Lessons)

10.1 PCINTS OF CHLORINE APPLICATION

10.10 Collection System Chlorination

One of the primary benefits of up-sewer chlorination is to prevent the deterioration of structures. Other benefits include odor and septicity control, and possibly BOD reduction to decrease the load imposed on the wastewater treatment processes. In some instances, the maximum benefit may result from a single application of chlorine at a point on the main intercepting sewer before the junction of all feeder sewer lines. In others, several applications at more than one point on the main intercepting sewer or at the upper ends of the feeder lines may prove most effective. Chlorination should be considered as a temporary or emergency measure in most cases, with emphasis being placed on proper design. Aeration also is effective in controlling septic conditions in collection systems. Although many problems result from improper design or design for future capacity requirements, the need for hydrogen sulfide protection exists under the best of conditions.

10.11 Prechlorination

Prechlorination is defined as the addition of chlorine to wastewater at the entrance to the treatment plant, ahead of settling units and prior to the addition of other chemicals.

In addition to its application for aiding disinfection and odor control at this point, prechlorination is applied to reduce plant BOD load, as an aid to settling, to control foaming in Imhoff units, and to help remove oil. Current trends are away from prechlorination to up-sewer aeration for control of odors.

10.12 Plant Chlorination

Chlorine is added to wastewater during treatment by other processes, and the specific point of application is related to the results desired. The purpose of plant chlorination may be for control and prevention of odors, corrosion, sludge bulking, digester foaming, filter ponding, filter flies, and as an aid in sludge thickening. Here again, chlorination should be an emergency measure.

10.13 Postchlorination

Postchlorination is defined as the addition of chlorine to municipal or industrial wastewater following other treatment processes. This point of application should be before a chlorine contact unit[12] and after the final settling unit in the treatment plant. This is the most effective place for chlorine application after treatment and on a well clarified effluent. Postchlorination is employed primarily for disinfection. As a result of chlorination for disinfection, some reduction in BOD may be observed; however, chlorination is rarely practiced solely for the purpose of BOD reduction.

QUESTIONS

10.1A What is the purpose of up-sewer chlorination?

10.1B Where should chlorine be applied in sewers?

10.1C What are the reasons for prechlorination?

10.1D Why might chlorine be added to wastewater during treatment by other processes?

10.1E What is the objective of postchlorination?

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[12] Chlorine Contact Unit. A baffled basin that provides sufficient detention time for disinfection to occur.

10.2 CHLORINATION PROCESS CONTROL

10.20 Chlorinator Control

The control of chlorine flow to points of application is accomplished by six basic methods and a seventh method which combines two of the basic six.

10.200 Manual Control

Feed rate adjustment and starting and stopping of equipment is done by hand.

10.201 Start-Stop Control

Feed rate adjustment by hand, starting and stopping (by interrupting injector water supply) controlled by starting of wastewater pump, flow switch, level switch, etc.

10.202 Step-Rate Control

Chlorinator feed rate is varied according to the number of wastewater pumps in service. As each pump starts, a pre-set quantity of chlorine is added to the flow of chlorine existing at starting time. This system can be applied conveniently with installations employing up to eight pumps.

10.203 Timed Program Control

Chlorine feed rate is varied on a timed step-rate basis, regulated to correspond to the times of flow changes or by using a time-pattern transmitter which employs a revolving cam cut to match a flow pattern.

10.204 Flow Proportional Control

Chlorinator feed rate is controlled by a system which converts wastewater flow information into a chlorinator control value. This can be accomplished by a variety of flow metering equipment, including all process control instrumentation presently available and nearly all metering equipment now in use on wastewater systems.

10.205 Chlorine Residual Control

Chlorine feed rate is controlled to a desired chlorine residual (usually combined chlorine) level. After mixing and reaction time (about five minutes maximum), a wastewater sample is titrated by an amperometric[13] analyzer-recorder (or indicator). As the residual chlorine level varies above or below the desired (setpoint) level, the chlorinator is caused to change its feed rate to bring the chlorine residual back to the desired level.

10.206 Compound Loop Control

Any "automatic" control system (step-rate, timed program, flow proportional, or residual) can be employed in two ways: (1) by positioning the feed rate valve, or (2) by varying the vacuum differential across the feed rate valve. Compound loop control employs both controls simultaneously. For instance, a flow proportional (or step-rate, or timed program) control system may position the feed rate valve, and a residual control system may vary the vacuum differential across the feed rate valve. Thus, changes in flow cause changes in feed rate valve position, but changes in chlorine demand may occur without any flow change. When this happens the residual analyzer detects a change in chlorine residual and by varying the vacuum differential across the feed rate valve causes the chlorinator to change rates to meet the desired chlorine residual level.

Various combinations of compound loop control can be employed. Generally speaking, the part of the system requiring the fastest response should be applied to valve positioning (since it responds faster). If flow changes are rapid, flow control should be by valve position. If flow and demand change rates are nearly the same, the magnitude of change may dictate the selection of control.

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13 Amperometric (am-PURR-o-MET-rick). A method of measurement that records electric current flowing or generated, rather than recording voltage. Amperometric titration is an electrometric means of measuring concentrations of substances in water.

The selection of control methods should be based on treatment costs and treatment results (required or desired). A waste discharger must normally meet a disinfection standard. A small treatment plant might do this with a compound loop control system costing several thousand dollars, but may save less than one hundred dollars a year in chlorine consumed. In this case the expense would not be justified. A manual system might be employed which would meet the maximum requirements and over-chlorinate at a minimum requirement periods. It is not unheard of for a plant to have maximum chlorine residual requirements because of irrigation and/or marine life tolerances. In these cases the uncontrolled or promiscuous application of chlorine cannot be considered, no matter how large the added cost.

A chlorine residual level may be required at some point downstream from the best residual control sample point. In this case a residual analyzer should be used to monitor and record residuals at this point. It may also be employed to change the control set point of the controlling residual analyzer.

Ultimate control of dosage for disinfection rests on the results desired, that is, the bacterial level or concentration acceptable or permissible at the point of discharge. Determination of chlorine requirements according to the current edition of *Standard Methods for the Examination of Water and Wastewater* is the best method of control. You must remember that the chlorine requirement or chlorine dose will vary with wastewater flow, time of contact, temperature, pH, and major waste constituents such as hydrogen sulfide, ammonia, and amount of dead and living organic matter.

QUESTIONS

10.2A How can chlorine gas feed be controlled?

10.2B Control of chlorine dosage depends on the bacterial ______________ desired.

10.2C Define amperometric.

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10.23 Chlorine Solution Discharge Lines, Diffusors, and Mixing

10.230 Solution Discharge Lines

Solution discharge lines are made from a variety of materials depending upon the requirements of service. Two primary requisites are that it must be resistant to the corrosive effects of chlorine solution and of adequate size to carry the required flows. Additional considerations are pressure conditions, flexibility (if required), resistance to external corrosion and stresses when underground or passing through structures, ease and tightness of connections, and the adaptability to field fabrication or alteration.

Development of plastics in the past several years has contributed greatly to chemical solution transmission. Polyvinyl chloride (PVC) pipe and black polyethylene flexible tubing have all but eliminated the use of rubber hose. Both are generally less expensive and both outlast rubber in normal service. The use of hose is almost exclusively limited to applications where flexibility is required or where extremely high back pressures exist.

PVC and polyethylene can be field fabricated and altered. PVC should be Schedule 80 to limit its tendency to cold flow and partially collapse under vacuum conditions, or for higher pressure ratings if required. Schedule 80 PVC may be threaded and assembled with ordinary pipe tools or may be installed using solvent welded fittings.

Rubber lined steel pipe has been used for many years where resistance to external stresses is required. It cannot be field fabricated or altered and is thus somewhat restricted in application. PVC lining of steel pipe has not yet become economically competitive, but other plastics have been developed which can readily compete with rubber lining and are adaptable to field fabrication and alteration.

Never use neoprene hose to carry chlorine solutions because it will become hard and brittle in a short time.

10.231 Chlorine Solution Diffusors

These diffusors are normally constructed of the same materials used for solution lines. Their design is an extremely important part of a chlorination program. This importance is almost completely related to the mixing of the chlorine solution with the wastewater being treated; however, strength, flexibility, etc., also must be given

consideration. In most circular, filled conduits flowing at 0.25 ft/sec (or greater) a solution injected at the center of the pipeline will mix with the entire flow in ten pipe diameters. Mixing in open channels can be accomplished by the use of a hydraulic jump (Fig. 10.4) or by sizing diffusor orifices so that a high velocity (about 16 ft/sec) is attained at the diffusor discharge. This accomplishes two things: (1) introducing a pressure drop to get equal discharge from each orifice, and (2) imparting sufficient energy to the surrounding wastewater to complete the mixing. Generally speaking, a diffusor should be supplied for each two to three feet of channel depth.

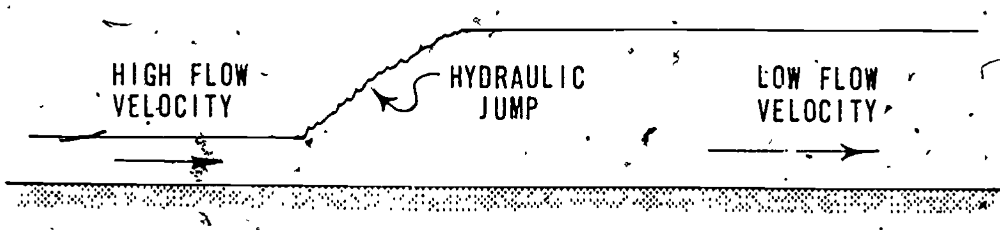

Fig. 10.4 Hydraulic jump

10.232 Mixing

Mixing is extremely important ahead of a chlorine contact tank or a residual sampling point. Since a contact tank is usually designed for low velocity, little mixing occurs after wastewater enters it. It is therefore necessary to achieve mixing before the contact tank is entered. The same is true for a chlorine residual sampling point; otherwise erratic results will be obtained by the residual analyzing system.

QUESTIONS

10.2H Why does little mixing of the chlorine solution with wastewater occur in chlorine contact basins?

10.2I Chlorine solution discharge lines may be made of ____________ or ____________

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CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 3 of 4 Lessons)

10.3 SAFETY AND FIRST AID

All persons handling chlorine should be thoroughly aware of its hazardous properties. Personnel should know the location and use of the various pieces of protective equipment and be instructed in safety procedures. For additional information on this topic, see the Water Pollution Control Federation's Manual of Practice No. 1, *Safety in Wastewater Works*, and the Chlorine Institute's *Chlorine Manual*, 4th edition.[19]

10.30 Chlorine Hazards

Chlorine is a gas, heavier than air, extremely toxic and corrosive in moist atmospheres. Dry chlorine gas can be safely handled in steel containers and piping, but with moisture must be handled in corrosion-resisting materials such as silver, glass, teflon, and certain other plastics. Chlorine gas at container pressure should never be piped in silver, glass, teflon, or any other plastic material. The gas is very irritating to the mucous membranes of the nose, to the throat, and to the lungs; a very small percentage in the air causes severe coughing. Heavy exposure can be fatal. (See Table 10-1.)

WARNING

WHEN ENTERING A ROOM THAT MAY CONTAIN CHLORINE GAS, OPEN THE DOOR SLIGHTLY AND CHECK FOR THE SMELL OF CHLORINE. NEVER GO INTO A ROOM CONTAINING CHLORINE GAS WITH HARMFUL CONCENTRATIONS IN THE AIR WITHOUT A SELF-CONTAINED AIR SUPPLY, PROTECTIVE CLOTHING AND HELP STANDING BY. HELP MAY BE OBTAINED FROM YOUR CHLORINE SUPPLIER AND YOUR LOCAL FIRE DEPARTMENT.

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[19] Write to: Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D.C. 20016; price to WPCF members, \$0.75; others, \$1.50. The Chlorine Institute, Inc., 342 Madison Avenue, New York, New York 10017; price \$0.75.

TABLE 10-1

PHYSIOLOGICAL RESPONSE TO CONCENTRATIONS OF CHLORINE GAS[20]

Effect	Parts of Chlorine Gas Per Million Parts of Air By Volume (ppm)
Slight symptoms after several hours' exposure	1
Detectable odor	3
60-minute inhalation without serious effects	4
Noxiousness	5
Throat irritation	15
Coughing	30
Effects dangerous to one-half to one hour	40
Death after a few deep breaths	1000

[20] Adapted from data in U.S. Bureau of Mines Technical Paper 248 (1955).

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10.31 Why Chlorine Must Be Handled With Care

You must always remember that chlorine is a hazardous chemical and must be handled with respect. Concentrations of chlorine gas in excess of 1000 ppm may be fatal after a few breaths.

Because the characteristic sharp odor of chlorine is noticeable even when the amount in the air is small, it is usually possible to get out of the gas area before serious harm is suffered. This feature makes chlorine less hazardous than gases such as carbon monoxide, which is odorless, and hydrogen sulfide, which impairs your sense of smell in a short time.

Inhaling chlorine causes general restlessness, panic, severe irritation of the throat, sneezing, and production of much saliva. These symptoms are followed by coughing, retching and vomiting, and difficulty in breathing. Chlorine is particularly irritating to persons suffering from asthma and certain types of chronic bronchitis. Liquid chlorine causes severe irritation and blistering on contact with the skin.

10.32 Protect Yourself From Chlorine

Every person working with chlorine should know the proper ways to handle it, should be trained in the use of self-contained breathing apparatus, and should know what to do in case of emergencies.

WARNING

CANNISTER TYPE 'GAS MASKS' ARE USUALLY INADEQUATE AND INEFFECTIVE IN SITUATIONS WHERE CHLORINE LEAKS OCCUR AND ARE THEREFORE NOT RECOMMENDED FOR USE UNDER ANY CIRCUMSTANCES. **SELF-CONTAINED AIR OR OXYGEN SUPPLY TYPE BREATHING APPARATUS ARE RECOMMENDED.**

Here are some items you should always remember in order to protect yourself and others from possible injury:

a. In an emergency, only authorized persons with adequate safety equipment should be in the danger area. Have your fire department examine your chlorine handling facilities and safety equipment so they will be aware of what you have and the possible dangers. They are well trained in the use of breathing apparatus and may be able to help you in an emergency, especially if they are familiar with chlorine hazards.

b. In any chlorine atmosphere, short shallow breathing is safer than deep breathing. Recovery from exposure depends on the amount of chlorine inhaled, so it is important to keep that amount as small as possible.

c. Clothing contaminated with liquid or gaseous chlorine continues to give off chlorine gas and irritate the body even after leaving a contaminated area. Therefore, contaminated clothing should be removed immediately and the exposed parts of the body washed with a large amount of cool water.

The use of a breathing apparatus is advisable during these operations. All caution should be taken to prevent any liquid from coming in contact with clothing not designed for protection, because the liquid can penetrate the cloth and cause skin problems.

d. Learn the correct way of using the breathing apparatus, practice using it regularly, and take safety drills seriously. What you learn may save your life. The fire department is well trained in the use of breathing apparatus and can be very helpful in training.

e. If you have found a chlorine leak and left the area before the leak was stopped, you should use an apparatus with a separate air supply when you return and repair the leak. Never rely on a cannister type mask for protection in repairing chlorine leaks. Cannister masks are not recommended because they do not supply oxygen. They only remove chlorine, if they are effective. Some agencies allow the use of cannister type masks; however, most operators who have had experience repairing chlorine leaks do not use cannister masks because of their short shelf life (approximately three to four months) and inability to provide adequate protection against high concentrations of chlorine. Extensive ventilation is recommended.

f. Cooperate in taking care of all safety equipment, handling it carefully, and returning it to its proper storage place after use. Defective equipment, or equipment which you can't find when you need it, will not protect you.

g. Always be sure that you know the location of first aid cabinets, breathing apparatus, showers, and other safety equipment. Review emergency instructions regularly to be sure you know them.

h. Notify your police department that you need help if it becomes necessary to stop traffic on roads and to evacuate persons in the vicinity of a chlorine leak.

10.33 First Aid Measures

a. Be sure you know the location of breathing apparatus, first aid kits, and other safety equipment at all times.

b. Remove clothing contaminated with liquid chlorine at once. Carry patient away from gas area--if possible to a room with a temperature of 70°F. Keep patient warm, with blankets if necessary. Keep him quiet.

c. Place patient on his back with his head higher than the rest of his body.

d. Call a doctor and fire department immediately. Immediately begin appropriate treatment.

e. Eyes. If even small quantities of chlorine have entered the eyes, hold the eyelids apart and flush copiously with lukewarm running water. Continue flushing for about fifteen minutes. Do not attempt any medication except under specific instructions from a physician.

f. Skin. Get patient under a shower immediately, clothes and all. Remove clothing while the shower is running. Wash the skin with large quantities of soap and water. Do not attempt to neutralize chlorine with chemicals. Do not apply salves or ointments except as directed by a physician.

g. Inhalation. If the patient is breathing, place him in a comfortable position; keep him warm and at rest until a physician arrives.

If breathing seems to have stopped, begin artificial respiration immediately. Mouth-to-mouth resuscitation or any of the approved methods may be used. Oxygen should be administered if equipment and trained personnel are available.

Automatic artificial respiration is considered preferable to manual, but only when administered by an experienced operator.

Rest is recommended after severe chlorine exposure.

h. Throat Irritation. Drinking milk will relieve the discomforts of throat irritation from chlorine exposure. Chewing gum or drinking spirits of peppermint also will help reduce throat irritation. Follow emergency rules given by your physician. In the absence of such rules, the first aid steps above are suggested.

Taken in part from Chlorine Safe Handling Pamphlet, published by The Chemical Division of PPG Industries, Inc.

QUESTIONS

10.3A What are the hazards of chlorine gas?

10.3B What type of breathing apparatus is recommended when repairing a chlorine leak?

10.3C What first aid measures should be taken if a person comes in contact with chlorine?

10.4 CHLORINE HANDLING

10.40 Chlorine Containers

10.400 Cylinders

Cylinders containing 100 to 150 pounds of chlorine are convenient for the average small consumer. These cylinders are usually of seamless steel construction (Fig. 10.5).

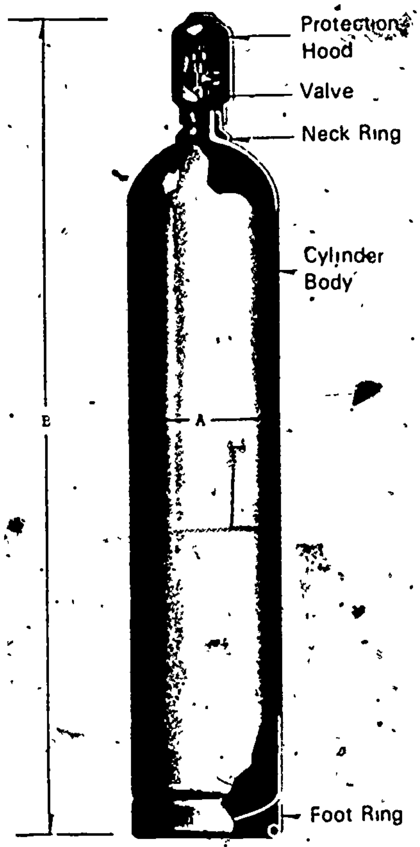
A fusible plug is placed in the valve, below the valve seat. This plug is a safety device. The fusible metal softens or melts at 158° to 165°F, to prevent building up of excessive pressures and the possibility of rupture due to a fire or high surrounding temperatures.

Cylinders will not explode and can be handled safely.

The following are procedures for handling chlorine cylinders.

1. Move cylinders with a properly balanced hand truck with clamp supports that fasten at least two-thirds of the way up the cylinder.
2. 100- and 150-pound cylinders can be rolled in a vertical position. Lifting of these cylinders should be avoided except with approved equipment. Never lift with chains, rope slings, or magnetic hoists.
3. Protective cap should always be replaced when moving a cylinder.
4. Cylinders should be kept away from direct heat (steam pipes, radiators, etc.).
5. Cylinders should be stored in an upright position.

Chlorine Cylinder



Net Cylinder Contents	Approx. Tare, Lbs.*	Dimensions, Inches.	
		A	B
100 Lbs.	73	8 1/4	54 1/2
150 Lbs.	92	10 1/4	54 1/2

*Stamped tare weight on cylinder shoulder does not include valve protection hood.

Fig. 10.5 Chlorine cylinder

(Courtesy of PPG Industries, Inc., Chemical Division)

10.401 Ton Tanks

Ton tanks are of welded construction and have a loaded weight of as much as 3700 pounds. They are about 80 inches in length and 30 inches in outside diameter. The ends of the tanks are crimped inward to provide a substantial grip for lifting clamps (Fig. 10.7).

The following are some characteristics of and procedures for handling ton tanks.

Most ton tanks have eight openings for fusible plugs and valves [Fig. 10.7]. Generally, two operating valves are located on one end near the center and six or eight fusible metal safety plugs, three or four on each end. These are designed to melt within the same temperature range as the safety plug in the cylinder valve.

WARNING

IT IS VERY IMPORTANT THAT FUSIBLE PLUGS SHOULD NOT BE TAMPERED WITH UNDER ANY CIRCUMSTANCES AND THAT THE TANK SHOULD NOT BE HEATED. ONCE THIS PLUG OPENS, ALL OF THE CHLORINE IN THE TANK WILL BE RELEASED.

Ton tanks are shipped by rail in multi-unit tank cars. Single units may be transported by truck or semi-trailer.

Ton tanks should be handled with a suitable lift clamp in conjunction with a hoist or crane of at least two-ton capacity (Fig. 10.7).

Ton tanks should be stored and used on their sides, above the floor or ground, on steel or concrete supports. They should not be stacked more than one high.

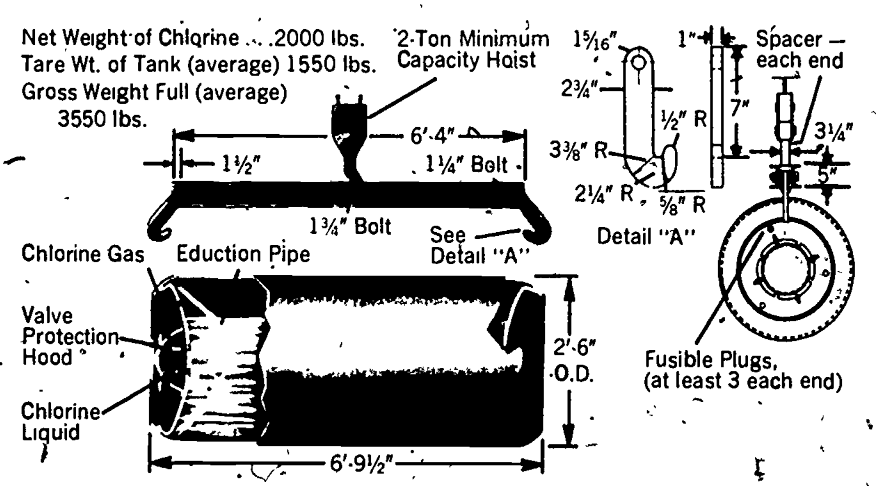


Fig. 10.7 Ton tank lifting beam

(Courtesy of PPG Industries, Inc., Chemical Division)

Ton tanks should be placed on trunnions which are equipped with rollers so that the withdrawal valves may be positioned, one above the other. The upper valve will discharge chlorine gas, and the lower valve will discharge liquid chlorine (see Fig. 10.7). Trunnion rollers should not exceed 3-1/2 inches in diameter so that the containers will not rotate too easily and be turned out of position. Roller shafts should be equipped with a zerk type lubrication fitting and slotted for even lubrication. Roller bearings are not advised because of the ease with which they rotate. Locking devices are not required when these rules are observed.

10.402 Chlorine Tank Cars

Chlorine tank cars are of 16-, 30-, 55-, 85-, or 90-ton capacity. All have four-inch cork board insulation protected by a steel jacket. The dome of the standard car contains four angle valves plus a safety valve. The two angle valves located on the axis line of the tank are equipped for discharging liquid chlorine. The two angle valves at right angles to the axis of the tank deliver liquid chlorine.

The following are some procedures for unloading chlorine tank cars.

Unloading of tank cars should be performed by trained personnel in accordance with Interstate Commerce Commission (ICC) regulations.

In most situations chlorine is withdrawn from tank cars as a liquid and then passed through chlorine evaporators. Sometimes dry air is passed into the tank car through one of the gas valves to assist in liquid withdrawal. This practice is referred to as "air padding".

QUESTIONS

10.4A How may chlorine be delivered to a plant?

10.4B What is the purpose of the fusible plug?

CHAPTER 10. DISINFECTION AND CHLORINATION

(Lesson 4 of 4 Lessons)

10.5 CHLORINATION EQUIPMENT AND MAINTENANCE (by J. L. Beals)

10.50 Chlorinators

Chlorine may be delivered from a feeder by one of two methods:

1. Solution feed, commonly practiced, in which the chlorine gas is controlled, metered, introduced into a stream of injector water, and then conducted as a solution to the point of application.

2. Direct feed, sometimes called dry feed, in which the gas is introduced directly through a suitable diffuser at the point of application. This method is used only when a source of injector water at adequate pressure, or power for an injector pump, is not available. Operating difficulties experienced in metering dry chlorine gas directly to the point of application make this type of equipment a "last resort".

Following are the common types of feeders used in wastewater treatment plants.

10.500 Vacuum-Solution Feed Chlorinators

This type of equipment (Fig. 10.10) comprises in excess of 90% of all gas chlorination equipment in service today in water and wastewater treatment operations. The primary advantage of vacuum operation is safety. If a failure or breakage occurs in the vacuum system, the chlorinator either stops the flow of chlorine into the equipment or allows air to enter the vacuum system rather than allowing chlorine to escape into the surrounding atmosphere. In case the chlorine inlet shut-off fails, a vent valve discharges the incoming gas to the outside of the chlorinator building.

The operating vacuum is provided by a hydraulic injector. The injector operating water absorbs the chlorine gas, and the resultant chlorine solution is conveyed to a chlorine diffusor through corrosion resistant conduit.

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A vacuum chlorinator also includes a vacuum regulating valve to dampen fluctuations and give smooth operation. A vacuum relief prevents excessive vacuum within the equipment.

A typical vacuum control chlorinator is shown in Fig. 10.10. Chlorine gas flows from a chlorine container to the gas inlet (located above the circled Y in the middle right of the figure). After entering the chlorinator the gas passes through a spring loaded pressure regulating valve which maintains the proper operating pressure. A rotameter is used to indicate the rate of gas flow. The rate is controlled by a V-notch variable orifice. The gas then moves to the injector where it is dissolved in water and leaves the chlorinator as a chlorine solution (HOCl) ready for application.

10.501 Partial Vacuum, Pressure Type, and Pulsating Type Chlorinators

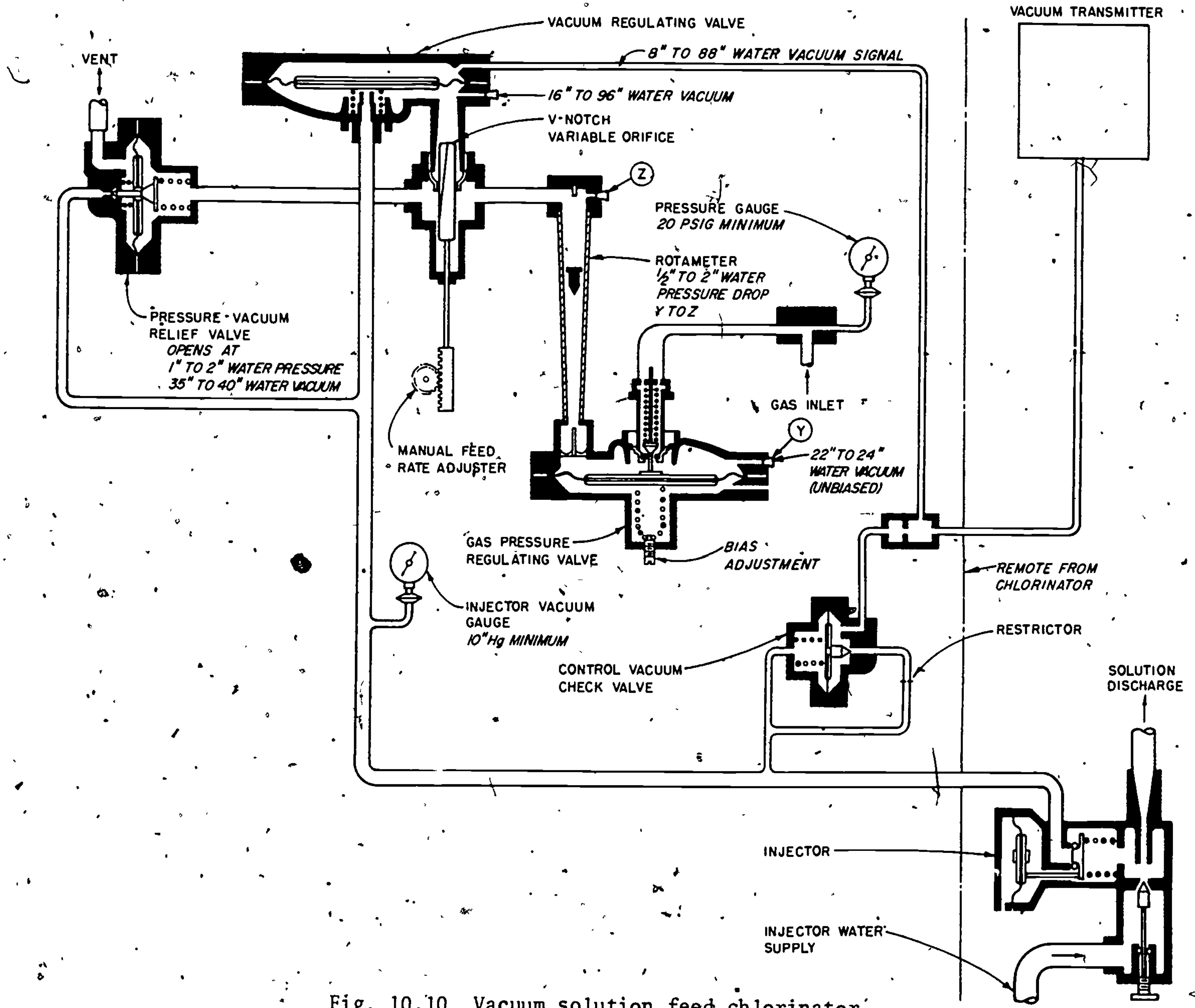
Aside from the pressure type which has been described previously, these types of equipment are limited in application and few remain in service. Pulsating and partial vacuum chlorinators are primarily designed for extremely low feed rates. Vacuum-solution feed equipment can feed less than 0.25 lbs/day. The reduced cost of hypochlorination has almost eliminated their use.

10.51 Hypochlorinators

Hypochlorinators are devices that are used to feed chlorine in the form of calcium, sodium, or lithium hypochlorite. Hypochlorites are available as liquids or various forms of solids (powder, pellets), and in a variety of containers or in bulk.

QUESTION

10.5A How is chlorine delivered (fed) to the point of application?



2,000 LB. CAPACITY V-NOTCH CHLORINATOR

Variable Vacuum Control
Control Vacuum From Main Injector

FLOW DIAGRAM

Fig. 10.10 Vacuum solution feed chlorinator

(Courtesy Wallace & Tiernan)

10.6 OTHER USES OF CHLORINE

10.60 Odor Control

Chlorination of wastewater for odor control is used to inhibit the growth of odor-producing bacteria and to destroy hydrogen sulfide (H_2S), the most common odor nuisance, which has the smell of rotten eggs. Hydrogen sulfide, in addition to creating an odor nuisance, can be an explosion hazard when mixed with air in certain concentrations. Breathing H_2S can impair your ability to smell, and too much will paralyze your respiratory center, causing death in severe cases. It also can cause corrosion of metals and concrete, being particularly damaging to electrical equipment even in low concentrations.

The presence of hydrogen sulfide may be detected in significant quantities in any collection and treatment system where sufficient time is allowed for its development. It may be expected to be present most often in new systems where flows are extremely low in comparison with design capacity, and particularly in lift stations where pump operating cycles may be at a low frequency. Collection systems which serve large areas often allow time for H_2S development even when operating at design capacity.

The purpose of this section is not to discuss the reasons for odor production, but rather their elimination or control by chlorination; however, the correction of an odor problem will usually require a decision being made between system modification and treatment. Sometimes both may be required. Choices of this type often hinge on the costs involved, and it will frequently be found that modifications to major system components are far more costly than treatment. When this is the case, chlorination is usually the most economical solution. Other solutions include the use of air or ozone.

Sulfides develop whenever given time to do so. The rate of sulfide production increases with temperature (about 7% on the average with each 1°C increase in wastewater temperature).

The odors which are controllable with chlorine are specifically hydrogen sulfide which can be inactivated by chlorination at levels well below the chlorine demand point. This is commonly referred to as "sub-residual chlorination". The reason that this is true is based on the fact that the $Cl_2 + H_2S$ reaction precedes most other chlorine-consuming reactions. Since it is known that bacterial kills occur at sub-residual levels, it is logical that odor-producing bacteria can be reduced in numbers

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without satisfying the chlorine demand. This can be accomplished without significantly interfering with organisms beneficial to the treatment processes.

The quantities of chlorine required to accomplish control of odors vary widely from plant to plant and at any given plant fluctuate over a broad range. Hydrogen sulfide is generally found in higher concentrations when flows are low. For this reason it is usually not economical to chlorinate for odor control in direct proportion to flow. Tests should be run over periods which include all the various conditions which could possibly affect odor production in order that a basis for treatment may be established.

When the requirements are known, the primary concern is to apply chlorine at the proper location. The best locations are generally up-sewer ahead of the plant influent structures, and up-sewer ahead of lift stations. This is done to allow mixing and reaction time before the waste reaches a point of agitation.

Sometimes force mains empty into the gravity sections of a collection system several hours after pumping. If odor problems result, a treatment point should be placed upstream at a point where the sewer is still under pressure and flowing full; thus treatment can be completed before odors are released to the atmosphere.

Hydrogen sulfide should not be considered merely an odor nuisance. It must always be kept in mind that it can create an explosion hazard, it can paralyze your respiratory center, and it should always be considered a source of corrosion. For these reasons, odor masking agents should not be used except possibly as additional treatment for odors not eliminated by chlorination. Excessive use of masking agents could prevent detection of a serious problem condition.

10.61 Protection of Structures

The destruction of hydrogen sulfide in wastewater also reduces the production of sulfuric acid that is highly corrosive to sewer systems and structures. This is particularly significant where temperatures are high and time of travel in the sewer system is unusually long. The treatment is similar to that for odor control: chlorination sufficient to prevent hydrogen sulfide

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formation or to destroy hydrogen sulfide that has been produced (about 2 mg/l chlorine per mg/l of hydrogen sulfide). Sulfide problems also may be corrected by oxygenation in sewers. The choice between oxygenation and chlorination will usually depend on the costs involved.

10.62 Aid to Treatment

Among its many uses, chlorine improves treatment efficiency in the following ways.

10.620 Sedimentation

Prechlorination at the influent of a settling tank improves clarification by improving settling rate, reducing septicity[23] of raw wastewater, and increasing grease removal. Maximum grease removal is achieved when chlorination is combined with aeration ("aero-chlorination"). It is an expensive procedure, and some studies have indicated that benefits are minimal. Generally grease removal in this manner is considered a beneficial side effect or "bonus" reaction to chlorine which is essentially applied for other reasons. Excess chlorination ahead of secondary processes can inhibit the bacterial action critical to the process and decrease sedimentation efficiency.

10.621 Trickling Filters

Continuous chlorination at the filter influent controls slime growths and destroys filter fly larvae (Psychoda). Generally the chlorine is applied to produce a residual of 0.5 mg/l (continuous) at the orifices or nozzles. Caution should be used because some filter growth may be severely damaged by excessive chlorination. Suspended solids will increase in a trickling filter effluent after chlorination for filter fly control. Also, it will be difficult to evaluate filter performance on the basis of BOD removals because chlorine can interfere with the BOD test. As a general statement, it would be well to look closely at

[23] Septicity (sep-TIS-it-tee) is the condition in which organic matter decomposes to form foul-smelling products associated with the absence of free oxygen.

loadings, operation, and general adequacy of the process when filter fly chlorination is continuously necessary, because continuous chlorination may be an expensive alternative for adequate design and operation.

10.622 Activated Sludge

Chlorination of return sludge reduces bulking of activated sludge that is caused by overloading. The point of application should be where the return sludge will be in contact with the chlorine solution for about one minute before the sludge is mixed with the incoming settled wastewater. Chlorine is also commonly used to control filamentous organisms. Again, chlorine used in this manner is an expensive alternative for adequate design and operation. The main effort should be directed toward process improvement, considering chlorination mainly as an emergency solution. Never forget that chlorine is toxic to organisms that are needed to treat the incoming wastes.

10.623 Reduction of BOD

Chlorination of raw wastewater to produce residual of 0.5 mg/l after 15 minutes of contact may cause a reduction of 15 to 30% in the BOD of the wastewater (Baity, 1929). Generally a reduction of at least 2 mg/l of BOD is obtained for each mg/l of chlorine absorbed up to the point at which the residual is produced. Snow (1952) has shown that the BOD reduction also depends on the condition of the wastewater. He reported a 10% reduction in fresh wastewater and a 25 to 40% reduction in stale wastewater. Both real and apparent effects of chlorination are evident in the wastewater and in the test bottle.

QUESTIONS

10.6A How can odors be controlled? Why?

10.6B How can sulfuric acid damage to structures be minimized or eliminated? Why?

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10.7 ACKNOWLEDGMENTS

Portions of the information contained in this chapter were taken in part from Chapter 17, Disinfection and Chlorination, Water Pollution Control Federation Manual of Practice No. 11; and from Chapter 7, Chlorination of Sewage, Manual of Instruction for Sewage Treatment Plant Operators (New York Manual). Both publications are excellent references for additional study. Mr. J. L. Beals provided many helpful comments.

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PPG Industries, Inc., Chemical Division, "Chlorine Safe Handling Pamphlet".

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U.S. Bureau of Mines, Technical Paper 248 (1955).

U.S. Public Health Service, "Drinking Water Standards" (1962).

Water Pollution Control Federation, Manual of Practice No. 1, "Safety in Waste Water Works".

Water Pollution Control Federation, Manual of Practice No. 4, "Chlorination of Sewage and Industrial Wastes" (under revision).

Water Pollution Control Federation, Manual of Practice No. 11, "Operation of Waste Water Treatment Plants" (1968).

10.9 ADDITIONAL READING

a. MOP 11, pages 127-135.

b. New York Manual, pages 73-83.

c. Texas Manual, pages 397-412.

d. "Chlorine--Safe Handling", PPG Industries, Inc., Chemical Division, One Gateway Center, Pittsburgh, Pennsylvania 15222.

e. Chlorination Guide, Water and Sewage Works Magazine, Scranton Publishing Company, 355 East Wacker Drive, Chicago, Illinois 60601. Price, $1.25.

f. Chlorine Manual (4th edition), The Chlorine Institute, Inc., 342 Madison Avenue, New York, New York 10017. Price $0.75.

g. Safety in Waste Water Works, MOP No. 1, Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D.C. 20016. Price to WPCF members, $0.75; others, $1.50.

Films on chlorine safety also are available from the Chlorine Institute and PPG Industries, Inc.

END OF LESSON 4 OF 4 LESSONS

on

DISINFECTION AND CHLORINATION

CHAPTER 11. MAINTENANCE

(Lesson 6 of 6 Lessons)

11.2 FLOW MEASUREMENTS--METERS AND MAINTENANCE

11.20 Flow Measurements, Use and Maintenance

Flow measurement is the determination of the quantity of a mass in movement within a known length of time (Fig. 11.19). Usually the mass-which may be solid, liquid, or gas is contained within physical boundaries such as tanks, pipelines, and open channels or flumes. The limits of such physical or mechanical boundaries provide a measurable dimensional area that the mass is passing through. The speed at which the mass passes through these boundaries is related to dimensional distance and units of time; it is referred to as velocity. Therefore, we have the basic flow formula:

$$\text{Quantity} = \text{Area} \times \text{Velocity}$$

$$Q = AV$$

or

$$Q\text{, cu ft/sec} = (\text{Area, sq ft})(V\text{, ft/sec})$$

The performance of a treatment facility cannot be evaluated or compared with other plants without flow measurement. Individual treatment units or processes in a treatment plant must be observed in terms of flow to determine their efficiency and loadings. Flow measurement is important to plant operation as well as to records of operation. It is essential that the devices used for such measurement be understood, be used properly, and most important, be maintained so that information obtained is accurate and dependable.

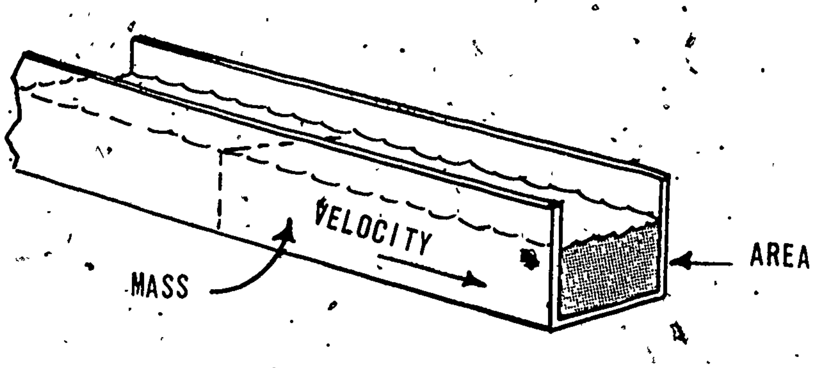

Fig. 11.19 Flow mass

11.21 Manufacturers' and Operators' Responsibilities

Equipment and instrument manufacturers should be required to furnish instruction manuals and parts lists. In the parts list it should be required that the manufacturer designate recommended spare parts, and such parts should be obtained and be available for use.

Instrumentation and flow measurement devices should be considered as fragile mechanisms. Rough handling will damage the units in as serious a manner as does neglect. Treat the devices with care, keep them clean, and they will perform their designated functions with accuracy and dependability.

11.22 Various Devices for Flow Measurement

The selection of a type of flow metering device, and its location, is made by the designer in the case of new plant construction. It is also possible that a metering device will have to be added to an existing facility. In both cases the various types available, their limitations, and criteria for installation should be known. Often the criteria for installation must be understood for the proper use and maintenance of a fluid flow meter. Metering devices commonly used in treatment facilities include:

Type	Common Name	Application
Constant Differential	Rotameter	Liquids and Gases a. Chlorination
Head Area	Weirs Rectangular Cipoletti V-Notch Proportional	Liquids--partially filled channels, basins, or clarifiers a. Influent b. Basin control c. Effluent d. Distribution
	Flumes Parshall Palmer-Bowlus Nozzles	Liquids--partially filled pipes and channels a. Influent b. Basin control c. Effluent d. Distribution
Velocity Meter	Propeller	Liquids--channel flow, clean water piped flow

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Type*	Common Name	Application
Velocity Meter	Magnetic	Liquids and sludge in closed pipe a. Influent b. Basin control c. Sludge recirculation d. Distribution
	Shuntflo	Gases--closed pipe a. Digester gas
Differential Head	Venturi Tube Flow Nozzle Orifice	Gases and liquids in closed pipes a. Influent b. Basin control c. Effluent d. Digester gas e. Distribution
Displacement	Piston Diaphragm	Gases and liquids in closed pipes a. Plant water b. Digester gas

*A description of how each device works is in reality a definition of the meter type.

Constant Differential--A mechanical device called the "float" is placed in a tapered tube in the flow line. The difference in pressures above and below the float causes the float to move with flow variations. Instantaneous rate of flow is read out directly on a calibrated scale attached to the tube.

Head Area--A mechanical constriction or barrier is placed in the open flow line causing an upstream rise in liquid level. The rise or "head" (H) is a function of velocity of flow and when referenced to empirical flow formula provides an indication of the flow rate. When first starting to pump sludge in a long line, the pressure may increase considerably before the sludge starts flowing.

Velocity Meters--The velocity of the liquid flowing past the measurement point through a given area gives a direct relation to flow rate. The propeller type is turned by fluid flow past propeller vanes which move gear trains. These gear trains are used to indicate the fluid velocity or flow rate. The velocity of liquid flow past the probes of a magnetic meter is related to electrical formula and read out as the flow rate through secondary instrumentation. (See Section 11.24.) Pitot tubes are used to measure the velocity head (H) in flowing water to give the flow velocity ($V = \sqrt{2gH}$). (Fig. 11.20)

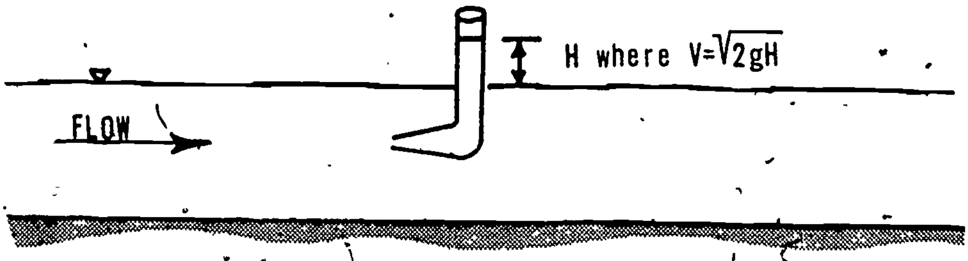

Fig. 11.20 Pitot tube

Differential Producers--A mechanical constriction (Fig. 11.21) in pipe diameter (reduction in pipe diameter) is placed in the flow line shaped to cause the velocity of flow to increase through the restriction. When the velocity increases, a pressure drop is created at the restriction. The difference between line pressure at the meter inlet and reduced pressure at the throat section is used to determine the flow rate which is indicated by a secondary instrument.

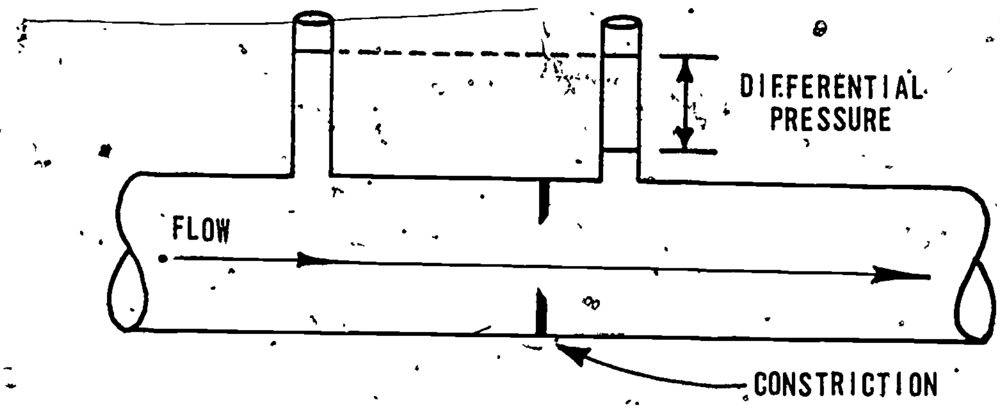

Fig. 11.21 Differential producer

Displacement Units--Liquids or gas enters, fills a tank or chamber of known dimensions, activates a mechanical counter, and empties the tank in readiness for another filling. Mechanical gearing activated by chamber fill and evacuation actuates a counter which is referenced to time and thus flow rate is determined.

11.23 Meter Location

The selection of a particular type of meter or measuring device and its location in a particular flow line or treatment facility is usually a decision made by the plant designer. Ideally the flow should be in a straight section before the meter. In open channels the flow should not be changing directions, nor should waves be present in the metering section above the measuring device. Valves, elbows, and other items that chould disrupt the flow ahead of a meter can upset the accuracy and reliability of a flow meter. Most flow meters are calibrated (checked for accuracy) in the factory, but they also should be checked in their actual field installation. When a properly installed and field calibrated meter starts to give strange results, check for obstructions in the flow channel and the flow metering device.

QUESTIONS

11.2A What is flow measurement?

11.2B Write the fundamental flow formula.

11.2C Why should flow be measured?

11.2D List several types of flow measuring devices.

11.2E If a flow meter does not read properly, what items should be checked as potential causes of error?

11.24 Conversion and Readout Instruments and Controls

Conversion and readout instrumentation is used to convert the initial measurement (for example, depth of water) to a more commonly used number or value (depth of water in a Parshall flume to flow of water in MGD). The type of device depends upon what the sensor (device) measures and what kind of results are desired. Often the conversion device only will transmit the signal (depth of water) to another meter which will interpret the signal and convert it to a usable number (flow in MGD). Instruments used with flow measurement equipment are classified as transmitters, receivers, recorders, controllers, and summators or totalizers. All of the different devices available are too numerous to list. Most devices used today will fall into the classifications outlined in the following paragraphs.

11.240 Mechanical Meters

Mechanical meters are those devices which measure the variable flow indicator and convert this value into a usable number. Conversion of the flow variable to a scale or meter giving the usable number may be by gear trains, hydraulic connections, magnetic sensing, electrical connections, and many other devices.

11.241 Transmitters

Transmitters send the flow variable, as measured by the measuring device, to another device for conversion to a usable number. Variables are transmitted mechanically, electrically, and pneumatically.

11.242 Receivers

Receivers pick-up the transmitted signal and convert it to a usable number. Receivers may present the measurement as an instantaneous flow rate, record the flow on a chart against time, and total or sum the flow during a time period. Receivers may have one, two, or all three of these features.

11.243 Controllers

Controllers are similar to receivers except they are capable of comparing received signals with other values and sending corrective or adjusting signals when necessary. The compared value may be manually set or it may be based on another received signal. The

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correction or adjustment may be proportional to the size of the deviation of the compared values, may be a gradual adjustment, or may provide a predetermined correction based on the size of the deviation and your objectives.

Selection and adjustment of controllers should be done by a specialist in the field or the manufacturer's representative. Maintenance must be done according to manufacturer's instructions.

11.25 Sensor Maintenance

Each individual sensing meter will have its own maintenance requirements. In any instrument, the sensor is the most common source of problems. Fortunately, the electronics or drive are easy to check. The important and common maintenance requirements are tabulated below in relation to meter types. Not all the maintenance problems can be listed. It is a proven fact that if preventive maintenance is regularly applied the uncommon problem is a rare occurrence.

The most important single item to be considered in maintenance is good housekeeping. This must take many forms since it is applied to various devices. Good housekeeping, the act of providing preventive maintenance for each of the various sensors, includes being sure that foreign bodies are not interfering with the measuring device. Check for and remove deposits which will accumulate from normal use. Repair the sensor or measuring device whenever it is damaged.

Common preventive maintenance suggestions:

Motor Type	Suggested Maintenance
Constant Differential Rotameters	Disassemble and clean tube and float when deposits are observed.
Head Area	
Weirs: Rectangular, Cipoletti, V-Notch, Proportional	Flow formula is based on square clean edges to the meter shape with free fall over the weir. Clean and brush off deposits as accumulated. Keep clear of foreign bodies and interference.

Motor Type	Suggested Maintenance
Head Area	
Flumes: Parshall Palmer-Bowlus Nozzles	Normally used with float wells, keep sensor line between well and flume clean; clean off deposits.
Velocity Meter	
Propeller	Should not be used on anything but clear water. Grease and check yearly.
Shuntflo	Keep dampening chamber fluid level to line; periodically drain to remove collected sediment.
Magnetic	Manufacturers are providing various cleaning mechanisms to clean the internal parts regularly. If you as an operator manually operate, be sure to perform maintenance on schedule; if automatically, check action frequently. Provide for periodic meter removal from line and physically clean meter.
Differential Producers	Venturi, nozzle, and orifice hydraulic connections should be back-flushed regularly. Installation should be arranged for internal surface cleaning on a reasonable schedule.
Displacement	Periodically drain and flush. Keep greased as necessary; check frequently on operation.

External connections between the sensing and conversion and readout devices should be checked to ensure such connections are clean in appearance and connections are firm. Be sure no foreign obstruction will interfere or promote wear. On mechanical connections, grease as directed; on hydraulic or pneumatic connections, disconnect and ensure free flow in the internal passage.

11.26 Conversion and Readout Instrument Maintenance

Both the mechanically actuated unit and the transmitters will have direct sensor connections. Cleaning and checking on a regular schedule is essential to avoid problems with the usual accumulation of foreign material. Maintenance for the internal parts to either device is minimized when the sensor connections are clean and operable. Normal wear will occur and is increased when sediments and deposits are not removed regularly as directed. Lubricate mechanical components as directed by the equipment manufacturers' instrument manuals. Do not over-lubricate, because it causes other difficulties equally as troublesome as under-lubrication.

Receiver maintenance is limited to periodic checking of mechanical parts, proper lubrication, and good housekeeping within the unit. Moisture should be eliminated by heat if required. Pneumatic instruments should be watched carefully to ensure that foreign particles which might be introduced by the air supply do not cause clogging in the actuating elements. Pneumatic systems are usually protected by air filters or traps at the supply source and individual units at the instrument. Filters should be cleaned and blown down on a regular schedule to ensure their efficient operation in cleaning the air supply. In the case of clogging of small orifices and devices of the pneumatic system, do not attempt to pressurize the system at higher than normal operating pressure for cleaning. Such action will damage internal parts. Follow procedures as outlined by the manufacturer and as shown in the instruction manuals.

Most reputable manufacturers are equipped to provide repair service in the case of worn parts, or mechanical failure. It is recommended that major service be left to trained employees of the manufacturer. It is preferred that manufacturers have field service available for repair on the plant premises; however, if such service is not available, the device should be returned to the factory.

Many manufacturers have a maintenance contract service available wherein a trained service employee periodically, on a prescribed schedule, checks the instrument in all ways including accuracy and wear factors. Such periodic checking allows for replacement of parts prior to a complete breakdown. Parts which would normally wear over a time period are replaced by this serviceman who will anticipate such need from an experience factor.

Do not attempt instrument service, parts replacement, or repair work unless you have read the instruction manual thoroughly and you understand what you are doing. Follow the procedures as set forth in the instruction manual carefully.

All instruments are connected to a power supply of some source. That power supply is potentially dangerous unless handled properly. Be sure all electrical power is shut off and secured so that others cannot unintentionally switch the source on. On electrical and electronic devices the electrical power used and/or generated within the device is exceptionally dangerous, both to the man and to the other component equipment. Do not attempt service unless you are qualified to do so.

Recording charts often seem to accumulate at a rapid rate, and a decision must be made whether to store or destroy old records. Inconvenient as it may be, records should be retained. They are the backbone of reference information needed for future planning and plant expansion when necessary. Above all, if properly used, they are an index for efficiency checks unparalleled in value. Storage space may be minimized by preparing summary records, microfilm photocopy, or selective sampling and storage of the usual and unusual.

QUESTIONS

11.2F What is the purpose of transmitting instruments?

11.2G What is the most important item in maintaining flow meters?

11.2H What should you do with old recording chart records?

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CHAPTER 12. PLANT SAFETY AND GOOD HOUSEKEEPING

(Lesson 1 of 3 Lessons)

12.0 INTRODUCTION--WHY SAFETY?

A cat may have nine lives, but you have only one! Protect it! Others may try, but only your efforts in thinking and acting safely can ensure you the opportunity of continuing to live your single life!.

You are working at an occupation that has an accident frequency rate second only to that of the mining industry! Not a very desirable record.

Your employer has the responsibility of providing you with a safe place to work. But you, the operator who has overall responsibility for your treatment plant, must accept the task of seeing to it that your plant is maintained in such a manner as to continually provide a safe place to work. This can only be done by constantly thinking safety.

You have the responsibility of protecting yourself and other plant personnel or visitors by establishing safety procedures for your plant and then by seeing that they are followed. Train yourself to analyze jobs, work areas, and procedures from a safety standpoint. Learn to recognize potentially hazardous actions or conditions. When you do recognize a hazard, take immediate steps to eliminate it by corrective action. If correction is not possible, guard against the hazard by proper use of warning signs and devices and by the establishing and maintaining of safety procedures. As an individual, you can be held liable for injuries or property damage as a result of an accident caused by your negligence.

REMEMBER: "ACCIDENTS DON'T JUST HAPPEN--THEY ARE CAUSED"!! How true it is! Behind every accident there is a chain of events which lead to an unsafe act, unsafe condition, or a combination of both. THINK SAFETY!

Accidents may be prevented by using good common sense, applying a few basic rules, and particularly by acquiring a good knowledge of the hazards peculiar to your job as a plant operator.

The Bell system has one of the best safety records of any industry. A variation of their successful policy statement is:

> "There is no job so important
> nor emergency so great
> that we cannot take time
> to do our work safely."

Although this chapter is intended primarily for the wastewater treatment plant operator, the operators of many small plants have the responsibility of sewer maintenance also. Therefore the safety aspects of both sewer maintenance and plant operation will be discussed.

12.1 KINDS OF HAZARDS

You are equally exposed to accidents whether working on the collection system or working in a treatment plant. As a worker, you may be exposed to:

1. Physical injuries
2. Infections and infectious diseases
3. Oxygen deficiency
4. Toxic or suffocating gases or vapors
5. Radiological hazards
6. Explosive gas mixtures
7. Fire
8. Electrical shock
9. Noise

12.10 Physical Injuries

The most common of physical injuries are cuts, bruises, scrapes, and broken bones. Injuries can be caused by moving machinery. Falls from or into tanks, deep wells, catwalks, or conveyors can be disabling. Most of these can be avoided by the proper use of ladders, hand tools, and safety equipment, and by following established safety procedures.

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12.11 Infections and Infectious Diseases[1]

Although treatment plants and plant personnel are certainly not expected to be "pristine pure", personal cleanliness is a great deterrent to infections and infectious diseases. Immunization shots for protection against typhoid and tetanus are essential.

Make it a habit to thoroughly wash your hands before eating or smoking, or going to the lavatory. If you have any cuts or other broken skin areas on your hands, wear proper protective gloves when in contact with wastewater or sludge in any form. Bandages covering wounds should be changed frequently.

Do not wear your work clothes home, because diseases may be transmitted to your family. Provisions should be made in your plant for a locker room where each employee has a locker. Work clothes should be placed or hung in lockers and not thrown on the floor. Your work clothes should be cleaned at least weekly or more often if necessary.

If your employer does not supply you with uniforms and laundry service and you must take your work clothes home, launder them separately from your regular family wash.

All of these precautions will reduce the possibility of you and your family becoming ill because of your contact with wastewater.

[1] You must attempt to avoid skin infections and infectious diseases such as typhoid fever, dysentery, hepatitis, and tetanus.

12.12 Oxygen Deficiency

Oxygen deficiency may exist in any enclosed, and particularly below grade (ground level), unventilated structure where a gas heavier than air, such as carbon monoxide, has displaced the air.

NEVER ENTER AN ENCLOSED, BELOW GRADE, UNVENTILATED STRUCTURE, WHETHER A MANHOLE, SUMP PUMP, OR OTHER STRUCTURE WITHOUT FIRST CHECKING FOR OXYGEN DEFICIENCY AND PROVIDING VENTILATION.

Ventilation may be provided by fans or blowers. Equipment is available to measure oxygen deficiency and must be used whenever you enter a potentially hazardous area. Try your local fire department for sources of this type of equipment in your area.

12.13 Toxic or Suffocating Gases or Vapors

Toxic or suffocating gases may come from industrial waste discharges or from the decomposition of domestic wastewater. You must become familiar with the waste discharges into your system.

On pages 174 and 175 of The New York Manual, Table 10, Common Dangerous Gases Encountered in Sewers and at Sewage Treatment Plants, contains information on the simplest and cheapest safe method of testing for gases.

12.14 Radiological Hazards

The newest of hazards to plant operators is a result of the increasing use of radioactive isotopes in hospitals, research labs, and various industries. Check your sewer service area for the possible use of these materials. If you are receiving a discharge that may contain a radioactive substance, contact the contributor of the discharge. He will usually cooperate with monitoring this type of waste.

12.15 Explosive Gas Mixtures

Explosive gas mixtures may develop in confined areas in treatment plants from mixtures of air and methane, natural gas, manufactured fuel gas, or gasoline vapors. Explosive ranges can be detected by using a combustible gas indicator. Avoid explosions by keeping open flames away from areas potentially capable of developing explosive mixtures by providing adequate ventilation with fans or blowers.

12.16 Fire

Burns from fires can cause very serious injury. Avoid the accumulation of flammable material and store any material of this type in approved containers at proper locations. Know the location of fire fighting equipment and the proper use of the equipment.

12.17 Electrical Shock

Electrical shock frequently causes serious injury. Do not attempt to repair electrical equipment unless you know what you are doing.

12.18 Noise

Loud noises from gas engines and gas or electric blowers can cause permanent ear damage. Operators and maintenance men must wear the proper ear protecting devices whenever working in noisy areas for any length of time.

QUESTIONS

12.1A How can you prevent the spread of infectious diseases from your job to you and your family?

12.1B What should you do before entering an unventilated, enclosed structure?

12.1C What are potential sources of toxic or suffocating gases or vapors?

CHAPTER 12. PLANT SAFETY AND GOOD HOUSEKEEPING

(Lesson 2 of 3 Lessons)

12.21 Treatment Plants and Pumping Stations

Because hazards found in pumping stations are identical to those found in treatment plants, the items discussed hereafter may be applied to both situations.

12.210 Headworks

Structures and equipment in this category may consist of bar screens, racks, comminuting or grinding equipment, pump rooms, wet pits, and chlorination facilities.

1. Bar Screens or Racks. These may be either manually or automatically cleaned. When manually cleaning screens or racks, be certain that you have a clean, firm surface to stand upon. Remove all slimes, rags, greases, or other material that may cause you to slip. GOOD HOUSEKEEPING IN THESE AREAS IS MANDATORY.

   When raking screens, leave plenty of room for the length of your rake handle so as not to be thrown off balance by striking a wall, railing, or light fixture. Wear gloves to avoid slivers from the rake handle or scraping your knuckles on concrete. Injury may allow an infection to enter your body.

   Place all material in a container that may be easily removed from the structure. Do not allow material to build up on the working surface.

   If your rack area is provided with railings, check to see that they are properly anchored before you lean against them. If removable safety chains are provided, never use these to lean against or as a means of providing extra leverage for removing large amounts of material.

   A hanging or mounting bracket of some type should be used to hold the rake when not in use. Do not leave it lying on the deck.

   If mechanically raked screens or racks are installed, never work on the electrical or mechanical part of this equipment

without first turning the unit off by means of a push-button lockout for momentary stoppages, and by turning off, locking out, and tagging the main circuit breaker if it is necessary to remove or make a major adjustment or repair to the unit.

THE TAG SHOULD BE SECURELY FASTENED TO THE BREAKER HANDLE AND SHOULD BE OF A TERMINOLOGY SUCH AS "DANGER... DO NOT START: MAN WORKING ON EQUIPMENT" (SEE FIGURES 12.2 AND 12.3)

The time and date the unit was turned off should be noted on the tag, as well as the reason it was turned off. The tag should be signed by the man who turned the unit off. No one should then turn on the main breaker and start the unit until the tag has been removed by the person who placed it there, or until he has specific instructions from the person who tagged the breaker. Your local safety equipment supplier can obtain these tags for you.

2. <u>Comminuting or Grinding Equipment</u>. This equipment may consist of barminutors, comminutors, grinders, or disintegrators.

NEVER work on the mechanical or electrical parts of the unit without first locking out the unit at either a push-button lockout or the main circuit breaker of the control panel. Be certain the breaker is properly tagged as explained in the previous section.

Good housekeeping is essential in the area of comminuting equipment. Keep all walking areas clean and free of slimes, oils, greases, or other materials. Hose down all spills immediately. Provide a proper place for equipment and tools used in this area.

See that proper guards are installed and kept in place around cables, cutters, hoists, revolving gears, and high-speed equipment such as grinders. If it is necessary to remove the guards prior to making adjustments on equipment, be certain that they are reinstalled before restarting the unit.

Fig. 12.2 Typical warning tag

(Source: State Compensation Fund of California)

DANGER

MAN WORKING ON LINE

DO NOT CLOSE THIS SWITCH WHILE THIS TAG IS DISPLAYED

SIGNATURE: ______________________

This is the ONLY person authorized to remove this tag.

INDUSTRIAL INDEMNITY/INDUSTRIAL UNDERWRITERS/
INSURANCE COMPANIES

4E210—R66

Fig. 12.3--Typical Warning Tag (Con't).

Source: Industrial Indemnity/Industrial Underwriters/Insurance Cos.

3. Pump Rooms. The same basic precautions apply here as they do to any type of enclosed room or pit where wastewater or gases may enter and accumulate.

Always provide adequate ventilation to remove gases and supply oxygen. If the room is below ground level and provided with only forced air ventilation, be certain the fan is on before entering the area. Wear a harness with a safety line (as for manhole work) when entering pits, wet wells, tanks, and below-ground pump rooms.

The tops of all stairwells or ladders should be protected by a removable safety chain. Keep this chain in place when the stairwell or ladder is not being used.

Never remove guards from pumps, motors, or other equipment without first locking out or turning off equipment at main breaker and properly tagging. Always replace all guards before starting units.

Guards should be installed around all rotating shaft couplings, belt drives, or other moving parts normally accessible.

Maintain good housekeeping in pump room. Remove all oil and grease, and clean up spills immediately.

If you have a multi-level pump building, never remove and leave off equipment removal hatches unless you are actually removing or replacing equipment. Be sure to provide barricades or ropes around the opening to prevent falls. Be extremely cautious when working around openings that have raised edges. These are hazardous because you can stumble over them easily.

Never start a positive displacement pump against a closed valve. On piston pumps, the yoke over the ball check could break and endanger personnel in the vicinity.

All emergency lights used in these areas should be explosion proof. Be sure to keep light shields in place and replace immediately when broken. Permanent lights should be of an approved explosion-proof type. Until the area has been checked for an explosive atmosphere, NO OPEN FLAMES (such as a welding torch) OR SMOKING SHOULD BE ALLOWED.

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CAUTION

UNLESS YOU ARE A QUALIFIED ELECTRICIAN, STAY OUT OF THE INSIDE OF ALL ELECTRICAL PANELS. IF YOU DO NOT KNOW OR ARE NOT FAMILIAR WITH THE EQUIPMENT, LEAVE IT ALONE!

4. Wet Pits--Sumps. Covered wet pits or sumps are potential death traps. Never enter one by yourself. Use a safety harness and have sufficient personnel available to lift you out. Always use forced air to ventilate the area, and check for explosive gases and oxygen deficiency before entering. Also, be particularly alert for hydrogen sulfide gas. Use your nose initially, but do not continue to depend upon it as you will become insensitive to the odor. A small, reasonably priced hydrogen sulfide detection unit may be purchased. Check with your local safety equipment supplier.

   After you have determined the atmosphere is safe, use extreme care in climbing up and down access ladders to pit areas. The application of a nonslip type coating on ladder rungs is helpful. If available, a truck hoist is safer than a ladder for entering pit areas.

   Watch your footing on the floor of pits and sumps. They are very slippery.

   Never attempt to carry tools or equipment up or down ladders into pits or sumps. Always use bucket and handline or sling for this purpose.

   Only explosion-proof lights and equipment should be used in these areas.

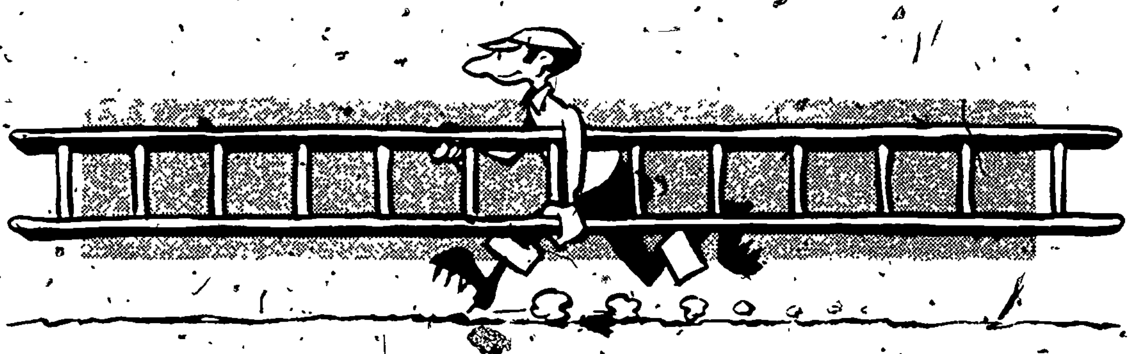
   A good safety practice is to turn off all chlorination, whether located upstream or directly in sump, and allow ample time before entering the area. This, with forced ventilation, will give time for the area to be cleared of chlorine fumes.

12.211 Grit Chambers

Grit chambers may be of various designs, sizes, and shapes; but they all have one thing in common: they get dirty. Good housekeeping is needed! Keep walking surfaces free of grit, grease, oil, slimes, or other material that will make a slippery surface.

Before working on mechanical or electrical equipment, be certain that it is turned off and properly tagged (Figs. 12.2 and 12.3). Install and maintain guards on gears, sprockets, chains, or other moving parts that are normally accessible.

If it becomes necessary to enter the chamber, pit, or tank for cleaning or other work, do so with extreme caution. If this is a covered area, provide and maintain adequate ventilation to remove gases from the area and to supply oxygen to the workers. Use only explosion-proof lights. Always check for explosive gases and oxygen deficiency before entering.



Be sure of your footing when working in these structures. Rubber boots with a nonskid cleat type sole should be worn. Step slowly and cautiously as there is usually an accumulation of slippery material or slimes on the bottom. Use hand holds and railings; if none are available, install them now.

Use ladders, whether vertical or ships ladders, cautiously. If possible, apply nonslip material or coatings to ladder rungs. Keep handrails free of grease and other slippery substances.

If it is necessary to take tools or equipment into the bottom area, lower these in a bucket or sling by handline. Never attempt to carry items up or down a ladder.

Chlorination safety is discussed in Chapter 10.

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12.212 Clarifiers or Sedimentation Basins

The greatest hazard involved in working on or in a clarifier is the danger of slipping. If possible, maintain a good non-skid surface on all stairs, ladders, and catwalks. This may be done by using nonskid strips or coating. Be extremely cautious during freezing weather. A small amount of ice can be very dangerous.

Your housekeeping program should include the brushing or cleaning of effluent weirs and launders (effluent troughs). When it is necessary to actually climb down into the launder, always wear a harness with a safety line and have someone with you. A fall may result in a very serious injury.

Be cautious when working on the bottom of a clarifier. When hosing down, always hose a clean path to walk upon. Avoid walking on the remaining sludge whenever possible.

Always turn off and lock out or turn off and tag clarifier breaker before working on drive unit. If necessary, adjustments may be made on flights or scrapers while the unit is in operation; but keep in mind that, although these are moving quite slowly, there is tremendous power behind their movement. Stay clear of any situation where your body or the tools you are using may get caught under one of the flights or scrapers.

Guards should be installed over or around all gears, chains, sprockets, belts, or other moving parts. Keep these in place whenever the unit is in operation.

Railing should be installed along the tank side of all normal walkways. If the unit is elevated above ground, railings should be installed along the outside of all walkways, also. Check with your State Safety Office for requirements on railing installation.

12.213 Digesters and Digestion Equipment[4]

Digesters and their related equipment include many hazardous areas and potential dangers.

[4] Also see "Safe Work Procedure No. 2, Entering and Working in Digesters", Jour. Water Poll. Control Fed., Vol. 42, No. 3, Part 1, p 466 (March 1970).

No smoking and no open flames should be allowed in the vicinity of digesters, in digestion control buildings, or in any other areas or structures used in the sludge digestion system. This includes pipe galleries, compressor or heat exchanger rooms, and others. All these areas should be posted with signs in a conspicuous place which forbid smoking and open flames. Methane gas produced by anaerobic conditions is explosive when mixed with the proper proportion of air.

All enclosed rooms or galleries in this system should be well ventilated with forced air ventilation. Before entering any enclosed area or pit which is not ventilated, a check should be made for explosive gases and hydrogen sulfide. Do not depend upon your nose for hydrogen sulfide (H_2S) detection in these areas. A small amount of H_2S in the air will make your sense of smell immune to the odor in a short period of time. Use an H_2S detector.

When you are working in these areas, forced air ventilation with a portable blower should be provided. Again, do not go into an area by yourself where H_2S is present. Have someone watch you.

Never enter a partially empty or completely empty digester without first thoroughly ventilating the structure and then checking for an explosive atmosphere and the presence of hydrogen sulfide gas. Explosion-proof lights and nonsparking tools[5] and shoes should always be used when working around, on top of, or in a digester unless it has been completely cleaned and emptied, continuously ventilated by a blower, and constant checks are made of the atmosphere in the tank.

A GOOD SAFETY PRACTICE IS TO:
NEVER ALLOW SMOKING OR OPEN FLAMES
WITHIN AN EMPTY DIGESTER.
(FIG. 12.4)

Be certain that guardrails are installed along the edges of the digester roof or cover in areas where it is necessary to work close to the edge. A fall from the top of a digester could be fatal.

[5] Nonsparking tools are especially manufactured for use in areas where potentially explosive mixtures of gases may be present.

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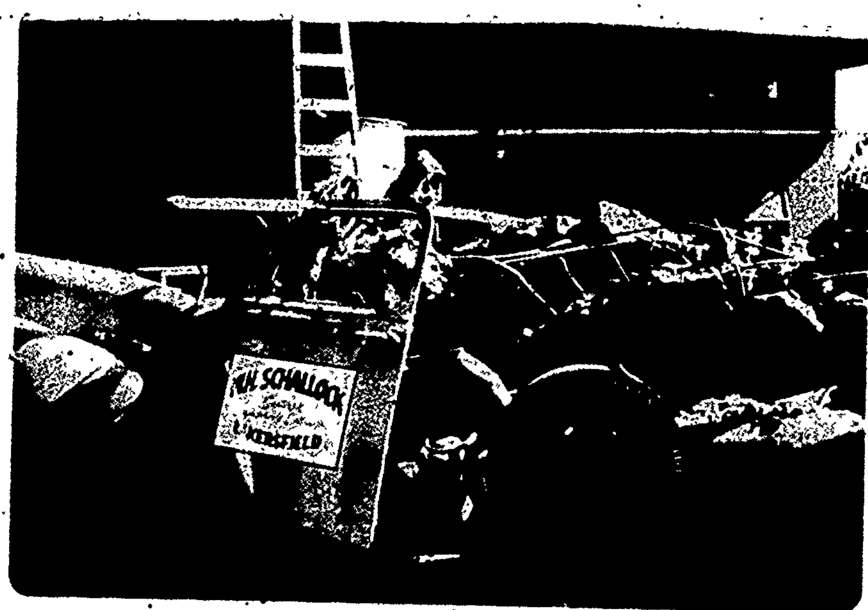
Explosion blew off top of digester



and landed on top of pickup truck

Fig. 12.4 Blown-up digester

When working on equipment such as draft tube mixers, compressors, diffusers, etc., be certain that the unit which operates or supplies gas to these types of equipment is properly locked out and appropriately tagged (Figs. 12.2 and 12.3).

If you have a heated digester, read and heed the manufacturer's instructions before working on the boiler or heat exchanger. Know that the gas valve is turned off before attempting to light the pilot. Be certain that the fire box has been ventilated according to the manufacturer's instructions before lighting the pilot.

CAUTION

WASTE GAS BURNERS ARE NOTED FOR BLOWING OUT IN A MODERATE WIND. BEFORE YOU ATTEMPT TO RELIGHT THE UNIT, BE CERTAIN THAT THE MAIN VALVE HAS BEEN TURNED OFF AND THE STACK ALLOWED TO VENT ITSELF FOR A FEW MINUTES. MANY OPERATORS HAVE HAD THEIR HAIR AND EYEBROWS SINGED FROM A BACKFLASH FROM THIS UNIT.

When it becomes necessary to clean tubes or coils in a heat exchanger, turn the unit supplying hot water off far enough in advance to allow the heat exchanger to cool. Never open the unit without doubly checking the water and sludge temperatures. Be certain that they have cooled down to body temperature or lower.

Before working on any sludge pump, whether it is centrifugal or positive displacement, be certain that the unit is turned off and properly tagged (Figs. 12.2 and 12.3).

Positive displacement pumps should be equipped with an air chamber and a pressure switch to shut the unit off at a preset pressure. <u>Never</u> start a positive displacement pump against a <u>closed discharge valve</u> because pressure could build up and burst a line or damage the pump. If you have closed this valve in order to inspect or clean the pump, double check to be sure that it is open before starting the unit.

Sludge pump rooms should be well ventilated to remove any gases that might accumulate from leakage, spillage, or from a normal pump cleaning. If you spill digesting sludge, clean it up immediately to prevent the possible accumulation of gases.

Provide thorough, regularly scheduled inspection and maintenance of your gas collection system. Inspect drip traps regularly. The so-called "automatic" drip trap is known to jam open frequently, allowing gas to escape.

Good maintenance of flame arrestors will ensure that they will be able to perform their job of preventing a backflash of the flame.

QUESTIONS

12.2J How can the danger of slipping be reduced on slippery surfaces?

12.2K Why should no smoking or open flames be allowed in the vicinity of digesters?

12.2L What safety precautions would you take before entering a recently emptied digester?

12.2M What would you do before relighting a waste gas burner?

12.2N Why should you never start a positive displacement pump against a closed discharge valve?

12.214 Trickling Filters

When it becomes necessary to inspect or service a rotating distributor, stop the flow of wastewater to the unit and allow it to come to rest.

NEVER STAND OR WALK ON THE FILTER MEDIA WHILE THE ROTATING DISTRIBUTOR IS IN MOTION.

Provide an approved ladder or stairway for access to the media surface. Be positive this is free from obstructions such as hose bibs, valve stems, etc.

Extreme caution should be used when walking on the filter media. The biological slimes make the media very slippery. Move cautiously and be certain of your footing.

NEVER ALLOW ANYONE TO RIDE A ROTATING DISTRIBUTOR.

Although a rotating distributor moves fairly slowly, the force behind it is powerful. An operator who has fallen off and been dragged by a distributor is fortunate if he can walk away under his own power.

WARNING

THE MERCURY IN THE SEAL OF A ROTATING DISTRIBUTOR IS EXTREMELY TOXIC.

Always wear rubber gloves when handling mercury. When cleaning mercury, follow the manufacturer's recommendations. Do so only in the open, in a well-ventilated room. Be sure to have a tray under the working area during mercury clean-up. It is extremely difficult to recover mercury from the floor. Dry mercury vaporizes slowly, and mercury vapors also are toxic.

Refrain from smoking and eating when handling mercury. Always wash your hands thoroughly when finished.

When inspecting underdrains, check to determine that the channels or conduits are adequately ventilated. Gases are not normally a problem here, but may be if there is a build-up of solids which have become septic.

If it becomes necessary to jack up a distributor mechanism for inspection or repair, always provide a firm base off the media or drainage system for the jack plate. A firm base may be provided by wooden planks which will spread the weight over a large area. However, sometimes the only way to obtain firm support is to remove the media and use the drainage system as a firm base. Remember you are lifting a heavy weight. Do not attempt inspection or repair work until the distributor has been adequately and properly blocked in its raised position.

12.215 Aerators

Guardrails should be installed on the tank side of usual work areas or walkways. If the tank is elevated above ground, guardrails should also be installed on the ground side of the tank. An operator should never go into unguarded areas by himself.

When working on Y-walls, or other unguarded areas where work is done infrequently, at least a two-man team should do the work. Approved life preservers with permanently attached handlines should be accessible at strategic locations around the aerator. You should wear a safety harness with a life line when servicing aerator spray nozzles and other items around an aerator.

An experiment in England found that if an operator fell into a diffused aeration tank, he should be able to survive because air will collect in the clothing and tend to help keep him afloat.[6] Drownings apparently occur when a person is overcome by the initial shock or there is nothing to grab hold of to keep afloat or to pull oneself out of the aerator.

When removing or installing diffusers, be aware of the limitations of your working area. Inspect and properly position hoists and other equipment used in servicing swing diffusers.

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6 Kershaw, M.A., "Buoyancy of Aeration Tank Liquid", Jour. Water Poll. Control Fed., Vol. 33, No. 11, p 1151 (Nov. 1961).

When it is necessary to work in an empty aerator, lower yourself into the aerator with a truck hoist if one is available. Ladders are awkward and dangerous; but if portable ladders must be used, properly position them so that they will not slip or twist. A good practice is to tie the top of the ladder so that it cannot slip. Be extremely careful when using fixed ladders as they become very slippery. The floor of the aerator also is likely to be extremely slippery.

If your plant is in an area subject to freezing weather, be aware of possible ice conditions around these units and use caution accordingly.

12.216 Ponds

Ponds of any kind present basically the same hazards. Therefore, the following safety measures will apply to ponds in general.

If it is necessary to drive a vehicle on top of the pond levees, maintain the roadway in good driving condition by surfacing it with gravel or asphalt. Do not allow chuck holes or the formation of ruts. Be extremely cautious in wet weather. The material used in the construction of most levees becomes very slippery when wet. Slippery conditions should be corrected using crushed rock or other suitable material.

Never go out on the pond for sampling or other purposes when by yourself. Someone should be standing by on the bank in case you get into trouble. Always wear an approved life jacket when working from a boat or raft on the surface of the pond. And, as in any boating activity, <u>do not stand up in the boat while performing work.</u>

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12.217 Chlorine

CHLORINE GAS IS A HIGHLY IRRITATING AND CORROSIVE GAS.
DANGER....HANDLE WITH CAUTION!

The most common causes of accidents involving chlorine gas are leaking pipe connections and over-chlorinating.

Chlorine bottles or cylinders should be stored in a cool, dry place, away from direct sunlight or from heating units. Some heat is needed to cause desired evaporation and to control moisture condensation on tanks. Chlorine bottles or cylinders should never be dropped or allowed to strike each other with any force. Cylinders should be stored in an upright position and secured with a chain, wire rope, or clamp. They should be moved only by hand truck and should be well secured during moving. One-ton tanks should be blocked so that they cannot roll. They should be lifted only by an approved lifting bar with hooks over the ends of the containers. Never lift a bottle or cylinder with an improvised sling.

Connections to cylinders and tanks should be made only with approved clamp adaptors or unions. Always inspect all surfaces and threads of the connector before making connection. If you are in doubt as to their conditions, do not use the connector. Always use a new approved type gasket when making a connection. The reuse of gaskets very often will result in a leak. Check for leaks as soon as the connection is completed. Never wait until you smell chlorine. If you discover even the slightest leak, correct it immediately, as leaks tend to get worse rather than better. Like accidents, chlorine leaks generally are caused by faulty procedure or carelessness.

Obtain from your chlorine supplier and post in a conspicuous place (outside the chlorination room) the name and telephone number of the nearest emergency service in case of severe leak.

Cylinder storage and chlorinator rooms should be provided with means of ventilating the room. As chlorine is approximately two and a half times heavier than air, vents or an exhaust fan should be provided at floor level. Ideal installations have a blower mounted on the roof to blow air into the room and are vented at the floor level to allow escaped chlorine to be blown out of the building.

Always enter enclosed cylinder storage or chlorinator rooms with caution. If you smell chlorine when opening the door to the area, immediately close the door, turn on ventilation, and seek assistance.

Never attempt to enter an atmosphere of chlorine when by yourself or without an approved air supply and protective clothing. Aid can usually be obtained from your local fire department, which will normally have available a self-contained breathing apparatus which will allow a person to enter safely into an atmosphere of chlorine.

An excellent booklet may be obtained from PPG Industries, Inc., *Chlorine--Safe Handling*.[7] Safety information on chlorine handling is also contained in Chapter 10, Disinfection and Chlorination. Your local chlorine supplier will probably provide you with all the information you need to handle and use chlorine safely. It is your responsibility to obtain, read, and understand safety information and to practice safety.

12.218 Applying Protective Coatings

CAUTION! When applying protective coatings in a clarifier or any other tank or pit, whether enclosed or open topped, use protective equipment to prevent skin burns from vapors from asphaltic or bitumastic coatings. This may involve the use of protective clothing as well as protective creams to be applied to exposed skin areas. An air supply must be used when painting inside closed vessels or in an open deep tank. Many paint fumes are heavier than air; therefore, ventilation must be from the bottom upward.

Check with your paint supplier for any hazards involved in using his products.

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[7] PPG Industries, Inc., Chemical Division, One Gateway Center, Pittsburgh, Pennsylvania 15222.

12.3 SAFETY IN THE LABORATORY[8]

In addition to all safety practices and procedures mentioned in the previous sections of this chapter, the collecting of samples and the performance of laboratory tests require that you be aware of the specific hazards involved in this type of work.

Laboratories use many hazardous chemicals. These chemicals should be kept in limited amounts and used with respect. Your chemical supplier may be able to supply you with a safety manual.

12.30 Collecting Samples

Whenever possible, rubber gloves should be worn when your hands may come in direct contact with wastewater or sludge. When you have finished sampling, always wash the gloves thoroughly before removing them. After removing the gloves, wash your hands thoroughly, using a disinfectant type soap.

NEVER COLLECT ANY SAMPLES WITH YOUR BARE HANDS IF YOU HAVE ANY BROKEN SKIN AREAS SUCH AS CUTS OR SCRATCHES.

Do not climb over or go beyond guardrails or chains when collecting samples. Use sample poles, ropes, etc., as necessary to collect samples.

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[8] Also see "CRC Handbook of Laboratory Safety", by Norman V. Steere, Chemical Rubber Publishing Company, 18901 Cranwood Parkway, Cleveland, Ohio 44128. Price $24.50.

12.31 Equipment Set-Up and Performance of Tests

Following are some basic procedures to follow when working in the laboratory:

1. Use proper safety goggles or face shield in all tests where there is danger to the eyes.

NEVER LOOK INTO THE OPEN END OF A CONTAINER DURING A REACTION OR WHEN HEATING THE CONTAINER.

2. Use care in making rubber-to-glass connections. Lengths of glass tubing should be supported while they are being inserted into rubber. The ends of the glass should be flame polished[9] to smooth them out, and a lubricant such as water should be used. Never use grease or oil. Gloves or some other form of protection for the hands should be used when making such connections. The tubing should be held as close to the end being inserted as possible to prevent bending or breaking. Never try to force rubber tubing or stoppers from glassware. Cut the rubber as necessary to remove it.

3. Always check labels on bottles to make sure that the proper chemical is selected. Never permit unlabeled or undated containers to accumulate around or in the laboratory. Keep storage areas organized to facilitate chemical selection for use. Clean out old or excess chemicals. Separate flammable, explosive, or special hazard items for storage in an approved manner. See Section 12.9, Additional Reading, Reference 10.

ALL CHEMICAL CONTAINERS SHOULD BE CLEARLY LABELED, INDICATING CONTENTS AND DATE BOTTLE WAS OPENED OR SOLUTION PREPARED. ALL POISONS MUST BE LABELED WITH "SKULL AND CROSSBONES" AND ANTIDOTE.

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[9] Flame Polished. Sharp or broken edges of glass (such as the end of a glass tube) are flame polished by placing the edge in a flame and rotating it. By allowing the edge to melt slightly, it will become smooth.

4. Never handle chemicals with the bare hand. Use a spoon or spatula for this purpose.

5. Be sure that your laboratory is adequately ventilated.

ALWAYS WORK IN A FUME HOOD IF WORKING WITH CHEMICALS OR SAMPLES HAVING TOXIC FUMES.

Even mild concentrations of fumes or gases can be dangerous.

6. Never use laboratory glassware for a coffee cup or food dish. This is particularly dangerous when dealing with wastewaters.

7. When handling hot equipment of any kind, always use tongs, asbestos gloves, or other suitable tools. Burns can be painful and can cause more problems (encourage spills, fire, and shock).

8. When working in the lab, avoid smoking and eating except at prescribed coffee breaks or at the lunch period.

ALWAYS THOROUGHLY WASH YOUR HANDS BEFORE SMOKING OR EATING.

9. Do not pipette chemicals or wastewater samples by mouth. Always use a suction bulb on an automatic burette.

10. Handle all chemicals and reagents with care. Read and become familiar with all precautions or warnings on labels. Know and have available the antidote for all poisonous chemicals in your lab.

11. A short section of rubber tube on each water outlet is an excellent water flusher to wash away harmful

chemicals from the eyes and skin. It is easy to reach and can quickly be directed on the exposed area. Eyes and skin can be saved if dangerous materials are washed away quickly.

12. Dispose of all broken or cracked glassware immediately. Chipped glassware may still be used if it is possible to fire polish the chip in order to eliminate the sharp edges. This may be done by slowly heating the chipped area until it reaches a temperature at which the glass will begin to melt. At this point remove from flame and allow to cool.

NEVER HOLD ANY PIECE OF GLASSWARE OR EQUIPMENT IN YOUR BARE HANDS WHILE HEATING.

Always use a suitable glove or tool.

13.

REMEMBER TO ADD ACID TO WATER, BUT **NEVER** THE REVERSE.

14. Wear a protective smock or apron when working in the lab. This may save you the cost of replacing your work clothes or uniform. Protective eye shields should be worn too.

QUESTIONS

12.3A What safety precautions would you take when collecting laboratory samples from a plant influent?

12.3B Why should you always wash your hands before eating?

12.3C Why should chemicals and reagents be handled with care?

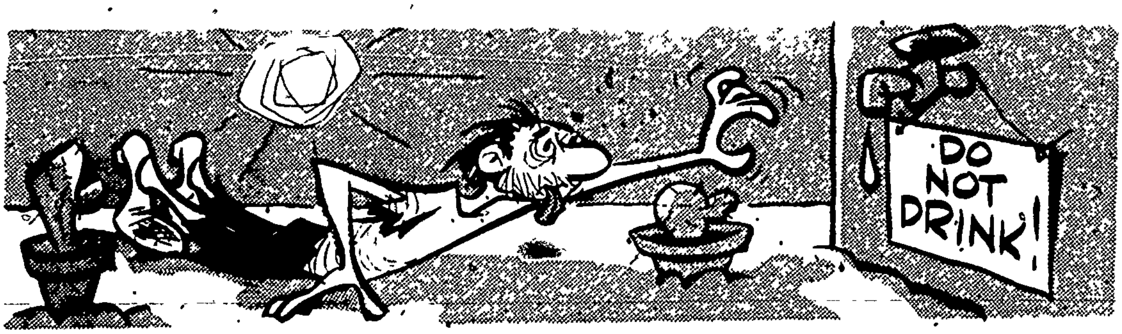
12.5 WATER SUPPLIES

Inspect your plant to see if there are any cross-connections between your potable (drinking) water and items such as water seals on pumps, feed water to boilers, hose bibs below grade where they may be subject to flooding with wastewater or sludges, or any other location where wastewater could contaminate a domestic water supply.

If any of these or other existing or potential cross-connections are found, be certain that your drinking water supply source is properly protected by the installation of an approved back-flow prevention device.

It is a good practice to have your drinking water tested at least monthly for coliform group organisms. Sometimes the best of back-flow prevention devices do fail.

You may find in your plant that it will be more economical to use bottled drinking water. If so, be sure to tack up conspicuous signs that your water is not drinkable. This also applies to all hose bibs in the plant from which you may obtain water other than a potable source. This is a must in order to inform visitors or absent-minded or thirsty employees that the water from each marked location is not for drinking purposes.



QUESTION

12.5A Why do some wastewater treatment plants use bottled water for drinking purposes?

12.6 SAFETY EQUIPMENT AND INFORMATION

Post conspicuously on your bulletin board the location and types of safety equipment available at your plant (such as first aid kit, breathing apparatus, explosiometers, etc.). You, as the plant operator, should be thoroughly familiar with the operation and maintenance of each piece of equipment. You should review these at fixed intervals to be certain that you can safely use the piece of equipment as well as to be sure that it is in operating condition.

Contacts should be made with your local fire and police departments to acquaint them with hazards at your plant as well as to inform them of the safety equipment that is necessary to cope with problems that may arise. Quite often it is possible to arrange a joint training session with these people in the use of safety equipment and the handling of emergencies. They also should know access routes to and around the treatment plant.

If you have any specific problems of a safety nature, do not hesitate to contact officials in your state safety agency. They can be of great assistance to you. And do not forget your equipment manufacturers; their familiarity with your equipment will be of great value to you.

Also posted in conspicuous places in your plant should be such information as the phone numbers of your fire and police departments, ambulance service, chlorine supplier or repairman, and the nearest doctor who has agreed to be available on call. Having these immediately available at telephone sites may save your or a fellow worker's life. Check and make sure these numbers are listed at your plant. If they are not listed, ADD THEM NOW.

QUESTION

12.6A What emergency phone numbers should be listed in a conspicuous place in your plant?

No chapter 13 included in pagination or table of contents.

14.3 SAMPLING, by Joe Nagano, from California Water Pollution Control Association Operators Laboratory Manual

14.30 Importance

Before any laboratory tests are performed, it is highly important to obtain a proper, representative sample. Without a representative sample, a test should not even be attempted because the test result will be incorrect and meaningless. A laboratory test without a good sample will most likely lead to erroneous conclusions and confusion. The largest errors produced in laboratory tests are usually caused by improper sampling, poor preservation, or lack of enough mixing during compositing[5] and testing.

14.31 Accuracy of Laboratory Equipment

Laboratory equipment, in itself, is generally quite accurate. Analytical balances weigh to 0.1 milligram. Graduated cylinders, pipettes, and burettes usually measure to 1% accuracy, so that the errors introduced by these items should total less than 5%, and under the worst possible conditions only 10%. Under ideal conditions let us assume that a test of raw wastewater for suspended solids should run about 300 mg/l. Because of the previously mentioned equipment or apparatus variables, the value may actually range from 270 to 330 mg/l. Results in this range are reasonable for operation. Other less obvious factors are usually present which make it quite possible to obtain results which are 25, 50, or even 100% in error, unless certain precautions are taken. Some examples will illustrate how these errors are produced.

The City of Los Angeles Terminal Island Treatment Plant is a primary treatment facility with a flow of 8 million gallons per day. It has an aerated grit chamber, two circular 85-foot clarifiers of 750,000 gallon capacity, and two digesters 100 and 75 feet in diameter.

[5] Composite (Proportional) Samples (com-POZ-it). Samples collected at regular intervals in proportion to the existing flow and then combined to form a sample representative of the entire period of flow over a given period of time.

Monthly summary calculations based upon the suspended solids test showed that about 8,000 pounds of suspended solids were being captured per day during sedimentation assuming 200 mg/l for the influent and 100 mg/l for the effluent. However, it also appeared that 12,000 pounds per day of raw sludge solids were being pumped out of the clarifier and to the digester. Obviously, if sampling and analyses had been perfect, these weights would have balanced. The capture should equal the removal of solids. A study was made to determine why the variance in these values was so great. It would seem logical to expect that the problem could be due to (1) incorrect testing procedures, (2) poor sampling, (3) incorrect metering of the wastewater or sludge flow, or (4) any combination of the three or all of them.

In the first case, the equipment was in excellent condition. The operator was a conscientious and able employee who was found to have carried out the laboratory procedures carefully and who had previously run successful tests on comparative samples. It was concluded that the equipment and test procedures were completely satisfactory.

14.32 Selection of a Good Sampling Point to Obtain a Representative Sample

A survey was then made to determine if sampling stations were in need of relocation. By using Imhoff cones and running settleable solids tests along the influent channel and the aerated grit chamber, one could quickly recognize that the best mixed and most representative samples were to be taken from the aerated grit chamber rather than the influent channel.

The settleable solids ran 13 ml/l in the aerated grit chamber against 10 ml/l in the channel. By the simple process of determining the best sampling station, the suspended solids value in the influent was corrected from 200 mg/l to the more representative 300 mg/l. Calculations, using the correct figures, changed the solids capture from 8,000 pounds to 12,000 pounds per day and a balance was obtained.

This study clearly illustrates the importance of selecting a good sampling point in securing a truly representative sample. It emphasizes the point that even though a test is accurately performed, the result may be entirely erroneous and meaningless insofar as use for process control is concerned, unless a good representative sample is taken. Furthermore, a good sample is highly dependent upon the sampling station. Whenever possible,

select a place where mixing is thorough and the wastewater quality is uniform. As the solids concentration increases, above about 200 mg/l, mixing becomes even more significant because the wastewater solids will tend to separate rapidly with the heavier solids settling toward the bottom, the lighter solids in the middle, and the floatables rising toward the surface. If, as is usual, a one-gallon portion is taken as representative of a million-gallon flow, the job of sample location and sampling must be taken seriously.

14.33 Time of Sampling

Let us consider next the time and frequency of sampling. In carrying out a testing program, particularly where personnel and time are limited due to the press of operational responsibilities, testing may necessarily be restricted to about one test day per week. If the operator should decide to start his tests early in the week, by taking samples early on Monday morning he may wind up with some very odd results.

One such incident will be cited. During a test for ABS (alkyl benzene sulfonate), samples were taken early on Monday morning and rushed into the laboratory for testing. Due to the detention time in the sewers, these wastewater samples actually represented Sunday flow on the graveyard shift, the weakest wastewater obtainable. The ABS content was only 1 mg/l, whereas it would normally run 8 to 10 mg/l. So the time and day of sampling is quite important, and the samples should be taken to represent typical weekdays or even varied from day to day within the week for a good cross-section of the characteristics of the wastewater.

14.34 Compositing and Preservation of Samples

Since the wastewater quality changes from moment to moment and hour to hour, the best results would be obtained by using some sort of continuous sampler-analyzer. However, since operators are usually the sampler-analyzer, continuous analysis would leave little time for anything but sampling and testing. Except for tests which cannot wait due to rapid chemical or biological change of the sample, such as tests for dissolved oxygen and sulfides, a fair compromise may be reached by taking samples throughout the day at hourly or two-hour intervals.

When the samples are taken, they should be immediately refrigerated to preserve them from continued bacterial decomposition. When all of the samples have been collected for a 24-hour period, the samples from a specific location should be combined or composited together according to flow to form a single 24-hour composite sample.

To prepare a composite sample, (1) the rate of wastewater flow must be metered and (2) each grab sample must then be taken and measured out in direct proportion to the volume of flow at that time. For example, Table I illustrates the hourly flow and sample volume to be measured out for a 12-hour proportional composite sample.

TABLE I

DATA COLLECTED TO PREPARE PROPORTIONAL COMPOSITE SAMPLE

Time	Flow MGD	Factor	Sample Vol	Time	Flow MGD	Factor	Sample Vol
6 AM	0.2	100	20	12 N	1.5	100	150
7 AM	0.4	100	40	1 PM	1.2	100	120
8 AM	0.6	100	60	2 PM	1.0	100	100
9 AM	1.0	100	100	3 PM	1.0	100	100
10 AM	1.2	100	120	4 PM	1.0	100	100
11 AM	1.4	100	140	5 PM	0.9	100	90
							1140

A sample composited in this manner would total 1140 ml.

Large wastewater solids should be excluded from a sample, particularly those greater than one-quarter inch in diameter.

A very important point should be emphasized. During compositing and at the exact moment of testing, the samples must be vigorously remixed so that they will be of the same composition and as well mixed as when they were originally sampled. Sometimes such remixing may become lax, so that all the solids are not uniformly suspended. Lack of mixing can cause low results in samples of solids that settle out rapidly, such as those in activated sludge or raw wastewater. Samples must therefore be mixed thoroughly and poured quickly before any settling occurs. If this is not done, errors of 25 to 50% may easily occur. For example, on the same mixed liquor sample, one person may find 3,000 mg/l suspended solids while another person may determine that there are only 2,000 mg/l due to poor mixing. When such a composite sample is tested, a reasonably accurate measurement of the quality of the day's flow can be made.

If a 24-hour sampling program is not possible, perhaps due to insufficient personnel or the absence of a night shift, single representative samples should be taken at a time when typical characteristic qualities are present in the wastewater. The samples should be taken in accordance with the detention time

30?

required for treatment. For example, this period may exist between 10 AM and 5 PM for the sampling of raw influent. If a sample is taken at 12 Noon, other samples should be taken in accordance with the detention periods of the serial processes of treatment in order to follow this slug of wastewater or plug flow. In primary settling, if the detention time in the primaries is two hours, the primary effluent should be sampled at 2 PM. If the detention time in the succeeding secondary treatment process required three hours, this sample should be taken at 5 PM.

14.35 Sludge Sampling

In sampling raw sludge and feeding a digester, a few important points should be kept in mind as shown in the following illustrative table.

For raw sludge from a primary clarifier at Los Angeles' Terminal Island Plant, the sludge solids varied considerably with pumping time as shown by samples withdrawn every one-half minute.

TABLE II

DECREASE IN PERCENT TOTAL SOLIDS DURING PUMPING

Pumping Time In Minutes	Total Solids Percent	Cumulative Solids Average
0.5	7.0	7.0
1.0	7.1	7.1
1.5	7.4	7.2
2.0	7.3	7.2
2.5	6.7	7.1
3.0	5.3	6.8
3.5	4.0	6.4
4.0	2.3	5.9
4.5	2.0	5.5
5.0	1.5	5.1

a. Table II shows that the solids were heavy during the first 2.5 minutes, and thereafter rapidly became thinner and watery. Since sludge solids should be fed to a digester with solids as heavy as possible and a minimum of water, the pumping should probably have been stopped at about 3 minutes. After 3 minutes, the water content did become greater that desirable.

b. In sampling this sludge, the sample should be taken as a composite by mixing small equal portions taken every 0.5 minutes during pumping. If only a single portion of sludge is taken for the sample, there is a chance that the sludge sample may be too thick or too thin, depending upon the moment the sample is taken. A composite sample will prevent this possibility.

c. It should also be emphasized again that as a sludge sample stands, the solids and liquid separate due to gasification and flotation or settling of the solids, and that it is absolutely necessary to thoroughly remix the sample back into its original form as a mixture before pouring it for a test.

d. When individual samples are taken at regular intervals in this manner, they should be carefully preserved to prevent sample deterioration by bacterial action. Refrigeration is an excellent method of preservation and is generally preferable to chemicals since chemicals may interfere with tests such as BOD and COD.

14.36 Sampling Devices

Automatic sampling devices are wonderful timesavers and should be employed where possible. However, like anything automatic, problems of which the operator should be aware do arise in their use. Sample lines to auto-samplers may build up growths which may periodically slough off and contaminate the sample with a high solids content. Very regular cleanout of the intake line is required. Another problem occurred at Los Angeles' Hyperion Plant when the reservoir for the automatic sampler was attacked by sulfides. Metal sulfides flaked off and entered the sample container producing misleading high solids results. The reservoir was cleaned and coated with coal-tar epoxy and little further difficulty has been experienced.

300

Manual sampling equipment includes dippers, weighted bottles, hand-operated pumps, and cross-section samplers. Dippers consist of wide-mouth corrosion resistant containers (such as cans or jars) on long handles that collect a sample for testing. A weighted bottle is a collection container which is lowered to a desired depth. At this location a cord or wire removes the bottle stopper so the bottle can be filled. Sampling pumps allow the inlet to the suction hose to be lowered to the sampling depth. Cross-sectional samplers are used to sample where the wastewater and sludge may be in layers, such as in a digester or clarifier. The sampler consists of a tube, open at both ends, that is lowered at the sampling location. When the tube is at the proper depth, the ends of the tube are closed and a sample is obtained from different layers.

Many operators build their own sampler (Fig. 14.1) using the material described below:

1. Sampling Bucket. A coffee can attached to an eight-foot length of 1/2-inch electrical conduit or a wooden broom handle with a 1/4-inch diameter spring in a four-inch loop.

2. Sampling Bottle. Plastic bottle with rubber stopper equipped with two 3/8-inch glass tubes, one ending near bottom of bottle to allow sample to enter and the other ending at the bottom of the stopper to allow the air in the bottle to escape while the sample is filling the bottle.

For sample containers, wide-mouth plastic bottles are recommended. Plastic bottles, though somewhat expensive initially, not only greatly reduce the problem of breakage and metal contamination, but are much safer to use. The wide-mouth bottles ease the washing problem. For regular samples, sets of plastic bottles bearing identification labels should be used.

14.37 Summary

1. Representative samples must be taken before any tests are made.

2. Select a good sampling location.

3. Collect samples and preserve them by refrigeration.

4. If possible, prepare 24-hour composite samples. Mix samples thoroughly before compositing and at the time of the test.

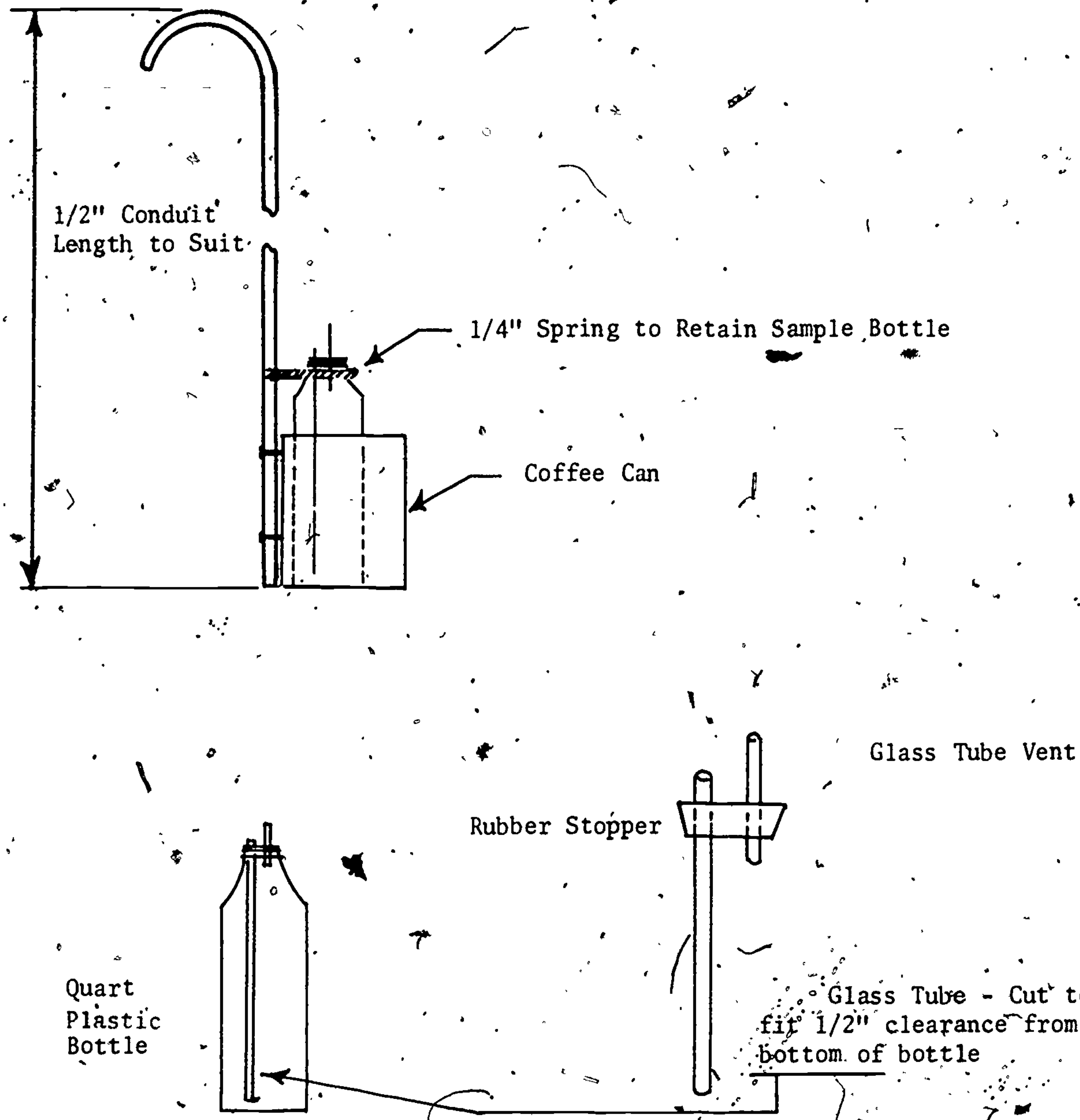


Fig. 14.1 Sampling Bottle