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Municipal point source pollution in the Hackensack Meadowlands estuary

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MUNICIPAL POINT SOURCE POLLUTION
IN THE
HACKENSACK MEADOWLANDS ESTUARY

BY

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ABSTRACT

A study was performed to evaluate the effectiveness of various sewage treatment facilities in the Hackensack Meadowlands District. The study dealt with overall plant efficiencies based on percent removals of suspended solids and Biochemical Oxygen Demand although other parameters were also included.

Samples for this study were obtained from the inlet and outlet channels of the individual plants. The parameters studied were: Suspended Solids, Biochemical Oxygen Demand, Total Nitrogen, Nitrate-Nitrite Compounds, Total Organic Carbon, Orthophosphate-P, Total Oxygen Demand and Fecal Coliform. Results obtained were averaged so as to collectively represent wet and dry weather conditions.

The results indicate that most of the treatment plants in the Hackensack Meadowlands District are out-dated and insufficiently equipped to handle the complex constituents of the municipal and industrial influents. Therefore, according to the results, it is necessary to up-grade these plants in order to sufficiently treat these discharges and meet federal, state and local ordinances.

A number of recommendations are offered with accompanying modified flow diagrams illustrating an up-graded treatment plant.

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"Municipal Point Source Pollution in the Hackensack Meadowlands Estuary"

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INTRODUCTION

No animal can thrive or even survive when it is too intimately surrounded by its own bodily wastes. Among the lower animals, some bury such wastes; others seek new surroundings when the old one becomes intolerable. Mankind from its earliest beginnings has followed the examples of the animal and steadily improved on its method of waste disposal. Today we destroy our wastes, not only for our own comfort and well being but also for the prevention of discomfort and injury to our fellow man; not because the law demands it, but because of our common sense of decency, which makes the law demands it.

The greatest need of a modern city is its water supply. Without it, city life would be virtually impossible. The next most important need is for the removal of the waste materials generated, particularly human excretions resulting from human consumption. The city, after removal of the generated wastes, is not only concerned with the transmission of diseases through the water supply, but also with the creation of nuisances arising from unsightly streams, odors, interferences with recreational activities and other objectionable consequences of waste treatment and disposal. In the case of a disease of bacterial origin, the responsible organism is harbored in the intestines of a carrier or a person actually ill with the disease. Depending upon the method of disposal of the excretion from these persons, the bacterial responsible for typhoid fever, dysentery and cholera may find their way into soil, water, food or milk and when ingested, may again cause disease in another human. Also, these harmful organisms may be introduced into sewage from clinics, hospitals, and research laboratories through the waste sink route.

One might define sewage as the "spent water supply of a community together with the human and household wastes which are removed by water carriage, and supplemented, in some cases, with street washings, surface runoffs, ground water infiltration and/or industrial wastes."[1] The liquid or water-carried wastes originating in residences, business buildings and institutions are called Domestic Sewage. Those resulting from the manufacturing processes employed in industrial establishments are known as Industrial Wastes. In addition, Surface Runoff is water which flows or falls upon the surface of the ground and infiltrates into the sewer systems.

Although sewage is composed largely of water (99.9%), it contains sufficient amounts of substances which are offensive in character and behavior and, very often, dangerous to the public health to make the economic and sanitary disposal of sewage a problem of far-reaching importance. In appearance, sewage resembles dirty, dish water or bath water to which has been added floating matter, such as fecal solids, bits of paper, matches, grease, vegetable debris and fruit skins. Physically, sewage contains matter which is both in suspension and solution. Of the suspended matter, some will settle down when the transporting power of the water is decreased by a reduction of its velocity and some will remain in suspension, even during periods of non-flow conditions.

Chemically, sewage contains substances of animal, vegetable and mineral origins. The animal and vegetable materials are collectively known as Organic Matter and, in large part, are offensive in character and behavior. They are made up of complex chemical substances which are readily broken down by biochemical, and to a lesser degree, and chemical actions into simpler chemical substances. Uncontrolled decomposition of this organic matter, which makes up about 50% of the sewage solids, is accompanied by offensive odors and their noxious conditions in the streams or other bodies of water into which sewage may be discharged.

Biologically, sewage contains vast numbers of living microorganisms, among which the bacteria are dominant. One gallon of sewage may contain as many as 20-250 billion bacteria. Most of these bacteria are harmless to man and are largely engaged in converting the complex organic wastes of sewage into simpler organic or mineral substances. Sewage, however, may contain bacteria or other organisms that have come from sick people. Some disease-producing (pathogenic) microorganisms are commonly present and they are the ones that constitute the real danger of sewage to the public health.

The quality of our water today clearly reflects the effects of our technological age. New chemicals in detergents, fertilizers, insecticides and herbicides, to name a few, are finding their way into water sources. With the use of such products promising to increase in the future, public health officials must take a new look at the domestic water standards and treatment methods of today.

In terms of the quality of sewage, it is important to know the flowrate to a sewage treatment works facility, especially at large and complex plants, both daily and hourly, for the following reasons:

1. To indicate the presence of unusual quantities of surface and ground water, industrial wastes and potable water used.
2. To estimate flows in the future.
3. To indicate the possible need of additional treatment facilities.
4. To calculate operating data:
   A. Sewage flow per capita daily.
   B. Detention time in tanks.
   C. Total quantity of solids handled.
   D. Sludge produced per million gallons of sewage.
   E. Cost of:
      1. Pumping sewerage per million foot-gallons.
      2. Treatment per million gallons.
   F. Quantity of sewage treated per unit of area by trickling filters, contact beds, sand fil-

ters, sedimentation tanks, etc..

G. Hourly and daily organic load on:

1. The sewage plant and its parts.

2. The water receiving the effluent.

5. Indicating operating procedure:

A. Necessity of by-passing some of the effluent.

B. Quantity of chemicals for coagulating purposes.

C. Quantity of chlorine or hypochlorite of lime to use.

D. Quantity of activated sludge to return to aeration tank.

E. Quantity of air to use for:

1. Grease removal.

2. Activated sludge process.

F. Number of sewage pumps and treatment units to keep in service.

Any sewage treatment and disposal system should operate in such a manner that no health hazards are created by the system and, in addition, it should not cause a public nuisance. The system should be of a type that is approved by the health department having jurisdiction and with adequate capacity to render the incoming sewage load harmless and inoffensive at all times.

The Hackensack Meadowlands District is one of New Jersey's most valuable marshland areas. It has been cited by the New Jersey Legislature as a "resource of incalculable oppurtunity."[2]

Situated in the greater metropolitan area of New Jersey-New York, it is one of the few areas in the United States that is an underdeveloped estuary. Within the Hackensack Meadowlands lies the Hackensack River drainage basin which covers approximately half the area of Bergen and Hudson Counties in northeastern New Jersey and the southerly half of Rockland County in New York. Along the river, at various points, treated and untreated liquid wastes from municipal and industrial facilities are discharged directly into it. These contaminants as well as contaminants from other sources have deteriorated the quality of the tidal portion of the river to the extent that pollution imposes a serious environmental detriment to the future development of the Hackensack Meadowlands District.

Currently, most wastewater being discharged into the Hackensack Meadowlands District is treated by primary and secondary treatment processes. This thesis attempts to assess the extent to which this treatment is effective by sampling influent and effluent streams of the major sewage treatment plants located within or discharging into the Hackensack Meadowlands District and conducting laboratory analyses for various water quality parameters. The deviation of this sampling and analysis covers a period beginning in June, 1976 and ending in April, 1977.

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WATER

Supply

Water is used for many purposes in our modern civilization, among them are drinking, cooking, bathing, washing clothes and dishes, air conditioning, general household cleaning, the manufacturing of many products (e.g., paper, steel and synthetic rubber), irrigation and consumption by domestic animals and poultry. The average daily water use in a typical American community is about 200 gallons per person.[3] This is broken down into 75 gallons for domestic use, 75 gallons for industrial use, 30 gallons for commercial use, 10 gallons for public use (i.e., firefighting, street cleaning and park maintenance), and 10 gallons lost by waste and evaporation.

The primary sources of this water, which is replenished by rainfall, are underground waters, rivers and streams, lakes and reservoirs. Although the total quantity of water available on the earth is 340 million cubic miles, or 375,790 million billion gallons, only 9.5 million cubic miles, or 10,500 million billion gallons, is fresh water.[4] The remaining 97.2% of the water is the oceans. Because of the high salt content of ocean water, practically all potable water comes from the freshwater resource. Although freshwater is present in many locations, 75% is not available for use because it is frozen in the polar ice. Another 14% is in the ground at depths of 2,500 feet or greater, and can therefore be tapped only with difficulty. Near to the surface is groundwater, which comprises about 11% of the available freshwater supply. Lakes comprise about 0.30%, soil moisture near the surface 0.60%, rivers 0.03% and water vapor in the atmosphere 0.035%.

The earth's water supply is involved in a never-ending cycle of evaporation and transpiration, condensation and precipitation which is called the water cycle. The liquid water on or beneath the surface of the earth evaporates (and transpires from plants) to become water vapor in the atmosphere. The water vapor condenses to form clouds and, when the proper meteorological conditions prevail, precipitates in the form of rain, snow and ice. The water is thus continuously replenishing the available on the earth.

Transmission and Distribution

The transmission and distribution of water is an integral part of any water-supply system. The movement of the water from its source to the consumer can usually be divided into two segments. The first involves transporting the water from its source to a control collection point where, if necessary, it can be treated. This transportation usually is done in an aqueduct, which can be a channel, pipeline, or tunnel with the water either exposed to the atmosphere or under pressure. The second segment involves the distribution of the water from the collection point to the locations where it is consumed.

Aqueducts

The transport of water at atmosphere pressure is done in channels, which can be opened or covered. Where the land profile hinders the use of channels, pipelines can be used since they can operate under pressure. Pipes can be placed above or under the ground. Tunnels are used principally for mountain and river crossings. The location of an aqueduct is fixed by the source of supply and the area to be served. However, the route between these two points depends on engineering and economic considerations, and the best route may not be the most direct.

Distribution Systems

The distribution system can vary in complexity from the simplest distribution of water inside a home to the complex distribution systems of the largest cities. The latter system will contain pipelines, pumping stations, fire hydrants, valves, reservoirs, service pipes to consumers and meters. It must satisfy the water requirement for a combination of domestic, commercial, industrial and firefighting purposes. Some cities have separate systems for domestic use and fire protection. Domestic water should never be connected to any less pure source, such as a fire protection line, since this could lead to pollution of the drinking-water supply.

Water Pollution

Water pollution may be defined as a change in the chemical or physical condition or the biologival content of the water in a water supply that prevents or limits further use of the water or impairs man' aesthetic enjoyment of the water.[5] Deriving aethestic enjoyment from water by looking at it is, practically, the only human use of the water that allows it to be returned to the stream, lake, river or other source of supply unchanged in quantity and quality. All other uses change the water's physical condition - for example, by heating or adding materials that can be called pollutants. Pollutants are of two general classes: 1). Materials that change with time and water contact and 2). Materials that persist in water unchanged in form. The organic materials of sewage and many industrial wastes, such as pulp and paper waste, represent the first class. Most inorganic salts, such as sodium sulfate, used as a dye in the textile industry, and inert organic materials, such as pesticides, represent the second. Often water that is safe to drink contains barely measureable amounts of pollutants that change its clarity, or produce odors, unpleasant tastes, films or foams that make it unattractive for drinking or for recreational uses such as swimming, fishing or boating.

Until his rivers and lakes became so unclean that he could no longer drink their waters or swim in them, modern man took for granted the availability of the vital resource, water. Until his neighbors in communities downstream or further alongshore began to complain that they could no longer use the water, he dumped his wastewater into rivers and

and lakes with little or no treatment to purify it. However, in the second half of the 20th century, man had begun to regain the strong respect his forefathers had for water.

In the religious rituals of man's primitive ancestors, water was considered a sacred and vital substance and penalties were imposed for those who would abuse it. The Romans, who were excellent hydraulic engineers and who built plumbing and sewer systems for their cities, continued to regard water as a holy substance. They dedicated important springs and wells to various dieties and severely punished anyone who used those water sources without authorization or who fouled them. For many centuries certain waters were considered to have special healing powers and people travelled great distances to spas and watering places where healing waters were available.

From the time of the Industrial Revolution, the uses of water multiplied in number as more goods were manufactured. Societies, such as the United States, which were expanding quickly and which had plentiful resources, used water and other resources freely, without regard for future supply. Water may be said to be a renewable resource, since it returns to the land as rain after it has been purified by evaporation from the sea. This resource, unfortunately, is no longer plentiful enough to meet the needs of growing populations with technology that continuously finds new uses for water. The U.S. demand for water climbed from 200 billion gallons in 1954 to 350 billion gallons per day in 1970 and is expected to reach about 1,000 billion gallons in 2000.[6]

The U.S. Geological Survey predicts that water resources in the U.S. will be sufficient to meet the U.S. demands over the next 50 years only if all possible sources are used - including surface water, ground water, desalinated water and treated wastewater.[7] There already exists many communities whose only available water is polluted. These are new communities that have been built on rivers and lakes that receive sewage from other communities and from industrial plants; they rely on wastewater treatment plants to make the polluted water safe to use.

Sources of Pollution

Communities

An obvious source of water pollution and one that has traditionally received attention is municipal sewage. Municipal water requirements are usually estimated on the basis of the daily average use of the 200 gallons of water per person. This amount represents not only the water used by each person for drinking, cooking, personal hygiene and flushing away person wastes, but also the water used for sprinkling lawns, fighting fires, cleaning streets and other municipal needs. After the water has been used, about the same amount enters the sewers as wastewater. Since each person adds about half a pound of fecal waste matter to the water each day, the first concern of municipalities in treating wastewater at sewage disopsal plants is to eliminate the water's content of pathogens, either by natural processes or by chemical treatment. Bacteria and viruses carried in fecal wastes can cause intestinal diseases such as typhoid, cholera and dysentery, as well as polio and hepatitis, if water carrying them is consumed.

Entering sewers in dissolved form are the soaps, synthetic detergents, bleaches and other chemicals used by the housewife. From homes also come various disposal paper products, including toilet tissue and baby diapers. Homes with garbage disposal units in their kitchen sinks add ground-up vegetables and animal matter to the sewage. From the streets come the water that runs off from rainstorms as well as meltwater from snow and ice. The latter often contains sand and calcium chloride that is used to melt snow and ice in order to clear the streets for traffic.

According to 1970 data from the U.S. Dept. of Housing and Urban Development, the sewage of 10 million people in 1,400 U.S. communities is discharged raw and untreated into the nation's rivers and lakes. Among these communities are many large cities, for example, Memphis, Tenn. and the borough of Manhattan in New York City.[8] The sewage of an additional 85 million people served by sewers receives only primary treatment before it is discharged into the waterways.

Furthermore, thousands of industrial plants in the U.S. discharge their wastewaters into municipal facilities not equipped to deal with the complex chemical composition of the wastes.

Industry

In technologically advanced societies the greatest user of water and the greatest source of wastes added to water is industry. Well over half the water consumed in the U.S. is used in more than 300,000 factories, and the amount of wastes from these factories discharge into streams is three times the amount discharged by all of the people served by sewers in the U.S.[9] Water performs many industrial functions, serving as a raw material, heating and cooling various processes, transporting, sorting and washing materials. Water also carries wastes from all stages of the industrial process - from production of the raw materials, through preparation of intermediate structural materials to the manufacturing and packaging of the finished product.

Because it is cheaper to throw away may of the residues and waste materials of these various stages than to recycle and reuse them, a vast and complex variety of organic and inorganic materials is discharged with industrial wastewaters.

Although the majority of industrial wastes entering natural waters are not toxic or lethal to human beings, their increasing abundance has affected the ecological balance of many of the world's waterways and lakes.

Thermal Pollution

The biggest single use of water is in the production of electricity where water is used primarily to cool and condense steam that is carried away from the turbines in steam electric power generating plants. The temperature of the water is raised an average of $7^{\circ}C$ ($13^{\circ}F$) and the heated water is subsequently discharged into streams and lakes.

Agriculture

The second largest use of water is for irrigation in agriculture. The water that drains from irrigated lands is highly concentrated in dissolved soil solids and salts. Water from these and naturally irrigated farmlands also carries the residuals of all the chemicals used to enhance agriculture. These chemicals include insecticides such as DDT, fungicides sprayed on orchards and crops; herbicides, commonly known as weed killers and other pesticides. They also contain organic and inorganic fertilizers, such as nitrogen, phosphorus, potassium and other plant nutrients.

In addition to these chemicals a large amount of fecal and other organic wastes are dumped into streams wherever beef or dairy cattle, hogs or poultry are raised under modern methods, that is, where the animals are concentrated by the thousands in lots where they are fed. The meat packing, tanning, food processing and canning industries associated with agriculture also produce much organic waste.

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EFFECTS OF POLLUTION

Clean waters are clear, colorless, odorless and tasteless; they contain a variety of fish, plants and animals. Polluted waters are murky, foul-smelling, undrinkable, and very often teeming with life - no fish, but a vast number of bacteria and algae. Nature's own system of purification of water, aeration of running water and settling out of the particles it contains, has been overloaded by man's pollution with dire results.

First, organic materials in wastewaters are decomposed by the enzymes of bacteria that digest the organic debris. These bacteria are aerobic, which means that they require oxygen for survival. This results in an oxygen depletion in any given stream. They utilize the oxygen in the water and give off carbon dioxide as they digest the organic materials. The carbon dioxide and water the two common end products of decomposition, but a variety of other products may also be formed. For example, bacteria may convert nitrogen in nitrogen-containing wastes into ammonia (NH_3) which is subsequently converted to nitrate (NO_3^-), which can then combine with potassium, sodium or other elements to form nitrate salts.

Whether the organic material is fecal matter, vegetable or animal wastes from food-processing plants, or paper fibers and the residue of wood pulp from pulp and paper mills, the process of decomposition is essentially the same. The amount of oxygen dissolved in the receiving waters varies according to temperature and according to the water's salinity and the pressure. At 20°C (68°F), freshwater, if it is agitated vigorously so that it is in contact with the air, can contain 9.2 milligrams of oxygen insolution in one liter of water; however, this capacity decreases if the water is warmer and increases if it is colder. On the average, the decomposition of the organic material contained in 300 milliliters of municipal waste of typical composition requires about 67 milligrams of oxygen in 5 days at 20°C. This average value is called the Biochemical Oxygen Demand (BOD) of the wastewater and is useful in calculating how much oxygen is required for a given volume of discharge of wastewater. The BOD of wastewaters from tanning, meat-packing and sugar-refining factories is much higher than that of municipal wastewater.

If the receiving waters are shallow, rapid-flowing and vigorously mixed, oxygen from the atmosphere replaces the depleted dissolved oxygen and the carbon dioxide is driven out into the atmosphere, so that the effects of the decomposition of organic pollutants are temporary. If, on the other hand, the receiving waters are sluggish, poorly mixed or sealed from the atmosphere, the depletion of oxygen and the increase of carbon dioxide in the water will become evident and various changes will occur. At some point in the oxygen depletion, fish and other oxygen requiring organisms begin to die and their decaying flesh is added to the total organic loading requiring decomposition. Although more fish die from poisoning by industrial and agricultural pollutants, many have died because of oxygen depletion. Fish, like other animals, take in oxygen and give off carbon dioxide; hence, their rate drops if the water in which they swim has been depleted of oxygen and contains high concentrations of dissolved carbon dioxide.

Adding to the workload of the aerobic bacteria and putting further demands on the dissolved oxygen supply are the man-made biodegradable materials. Organic matter, such as human excrement, is naturally biodegradable, but many man-made disposable substances such as detergents and throwaway paper products have had their composition altered by manufacturers to incorporate this feature. The first synthetic detergents, marketed in the 1950's, were not biodegradable. This fact was brought to the public's attention when huge clouds of sudsy foam from these detergents began to pile up at municipal sewage plants, and after being contaminated with germs from the sewage, clogged up the works at some of these treatment facilities. This problem was solved by making the products biodegradable. This solution, unfortunately, has had the disadvantage of adding to the receiving waters' BOD and, therefore, hastening the oxygen depletion process.

Second, the formation of gases such as ammonia which results fromm the microbial decomposition of proteins and human and animal excreta. This gaseous compound, or related compounds, is produced both when oxygen is present and when it is not. In the presence of oxygen, ammonia is oxidized by bacteria to form nitrites and nitrates. If there is no oxygen present, the ammonia persists. If oxygen depletion occurs after the nitrates and nitrites have been formed, these products will be reduced to nitrogen gas, as often happens when water already carrying nitrate receive additional organic material in pooled or impounded areas.

Anaerobic bacteria, which are bacteria that grow in the absence of dissolved oxygen, live in sludges on the bottom of such pools and can use the oxygen present in sulfates to yield hydrogen sulfide gas, the same gas that gives rotten eggs their characteristic bad odor. When there is not enough oxygen available in compounds, other anaerobic bacteria take over. Various types of bacteria ferment the organic matter, producing carbon dioxide gas, hydrogen gas and methane gas, the gas also known as marsh gas. Although not unnecessarily unhealthy, such bubbling, gaseous anaerobic polls are repulsive to the senses.

Third, in certain areas a process that takes nature tens of thousands of years to accomplish is being speeded to completion in very shorter periods of time by man's pollution. This process is called <u>Eutrophication</u>, and it involves the gradual increase of plant life in a lake until the lake turns into a marsh, which fills with mud and dead plant debris and, finally, becomes solid land. This process has occured, with man's help, in just a few years in small ponds and lakes, and is believed to be occuring in Lake Erie, where it will take longer because of the lake's great size.

Eutrophication is hastened when plant growth is stimulated by the nitrogen and phosphorus contained in fertilizers dissolved in agricultural wastewaters, in detergents and cleaning compounds and in other waste products. A lake receiving such wastes becomes more fertile and as its plants increase in number they take up more space that would normally be used by fish. When the algae and other plants die, they fall to the bottom and must be decomposed byaerobic bacteria, thus the dissolved oxygen is used up and the fish die. The lake becomes choked eith floating and attached algae, water weeds and other plants, and small animals that graze on these plants. Blue-green algae gives the water the appearance of pea soup and gives its a bad odor and fishy taste and, in addition, covers rocks with a gelatinous slime.

Fourth, is the accumulation of toxic organic chemicals. The poisonous nature and persistence of chemicals used as pesticides are advantages in the control of mosquitoes and af insects, weeds and other pests that destroy crops. They have proven to be dangerous with ecological disadvantages, however, as residues of the chemicals have accumulated in various organisms and been cycled through the biological food chain. The pesticides unique chemical structures are not subject to the normal processes of chemical and biological degradation. Consequently, when plants or organisms are eaten by predators, the poisonous substances accumulate in the predators' bodies, reaching concentrated levels. Finally, they are subsequently passed onto organisms higher in the food chain as the larger predators devour the flesh of the smaller ones. This process has taken place both on the land and in the water. The substances become dissolved in rainwater and absorbed on soil particles, then they are washed into the ground, ultimately finding their way to the streams that drain the farmlands. Once in the water they begin to accumulate in the bodies of fish and smaller aquatic organisms. Although some of these organisms have developed a tolerance to these poisons, there have been instances of massive dying off of certain species apparentlybecause of the agricultural poisons. Even if the chemicals are not concentrated enough in dosage to be lethal, they may cause death or other harmful effects higher in the food chain. For example, gulls have died after eating many fish containing high concentrations of DDT, and a number of species of other fish-eating birds, including the bald eagle and the pelican, are faced with extinction because of impaired reproduction. The pesticides they consume cause them to form egg shells that are so thin and fragile that their eggs are easily crushed and, therefore, destroyed before they can be hatched.

Fifth, is the effects of the toxic metals mercury, arsenic, cadmium and lead which are also cumulative. Received in repeated small doses, any of these can eventually have the same effect as a single massive dose. Inorganic mercury contained in industrial wastewaters settles into the mud at the bottom of rivers and lakes. Anaerobic bacteria there convert the mercury into poisonous forms, such as methyl mercury $(CH_3)_2Hg$, which can cause severe damage to the nerves and brains of animals, including human beings, as well as genetic mutations. Methyl mercury is volatile and it bubbles up from the mud and into the water where it enters and becomes concentrated in the bodies of fish. Although the fish do not die, people eating mercury-contaminated fish may be poisoned or killed, as were the 137 Japanese from 1953 to 1970.[10] The victims were inhabitants of certain areas of Japan where the diet consists largely of fish from mercury-contaminated waters. Another substance that is well-known as apoison and that enters streams in solution is arsenic. Arsenic is found in small but measurable amounts in so-called "enzyme" soaking compounds and phosphate detergents and in dyes used to make colored facial and toilet tissue. Lead which is used in manufacturing metal products, storage batteries, dyes, paints, glass, gasoline, insecticides and cadmium, used mainly in storage batteries also enter streams with industrial wastewaters.

Finally, metals such as iron and manganese undergo changes in receiving waters due to oxidation by chemical processes, as when rust forms on iron compounds, or by biological processes, as when certain bacteria oxidize iron. Soluble forms of these metals exist in various types of wastewaters. For example, dissolved metals are found in wastewater that leaches from, or percolates through the ground from, mines, scrap metal and ore dumps, and from some natural swamps. When salts of these metals are oxidized in water they become less soluble and form clouded precipitates, or solid particles that begin to settle out of solution. Therefore, the water becomes cloudy and colored. The wastewaters that drain from iron mines or scrap iron dumps, for example, are colored red or orange-brown because of the presence of the precipitate rust.

Inorganic pollutants such as sodium chloride, sodium sulfate and calcium chloride, which are salts formed by the neutralization of acid or alkaline industrial wastes, are not biologically transformable or chemically reactive. Although they undergo no change, they can alter the quality of receiving waters if there is not enough fresh water available to dilute their concentration. "Hard" waters, which are high in mineral content, are undesirable for many uses because the minerals can build up deposits in pipes and boilers in which they are used.

Other inorganic materials, such as zinc and copper, become absorbed on particles of silt and mud at the bottom of the receiving stream and then may be transported with these fine particles by the flowing water. Their toxic effects are much greater in acidic than in neutral or alkaline waters.

Thus, zinc and copper have occured at concentrations lethal to aquatic organisms in the acidic waters draining from coal mines. Just as these metals become toxic in the presence of acid, various pollutants may interact to produce a toxic effect although the same substances acting separately might not be particularly toxic. This is true of copper in the presence of cadmium.

THE POLLUTION OF ESTUARIES

Estuaries have been called places where rivers meet the sea. A typical estuary is the drowned mouth and lower channel reach of a river that empties to the sea. The channel is cut below sea level and is invaded by the sea. Chesapeake Bay, in the eastern United States, is one of the world's greatest estuaries. During the Ice Age, so much water was stored as ice on the continents that sea level at times was several hundred feet lower than at present.

Both tidal action and gravitational forces send seawater up into estuaries, where it mixes with fresh water. The mixing pattern may be complex or simple, depending on tidal range, depth of the estuary, and rate of discharge of the river. Each estuary requires individual study. Estuaries, in general, are being filled by alluvial sediment (soil deposited by water) and organic accumulations. Filling has been in progress for thousands of years and in parts of Chesapeake Bay as much as 100 feet thick.

Not all coastal embayments are estuaries. The Carolina sounds such as Pamlico are enclosed by offshore bars formed by marine wave and current action. Puyet Sound is a fjord gouged out by glacial action. Some embayments have been formed by downwarping of the earth's crust. Nearly all embayments, howvere, have been affected by the rise of sea

sea level during the last 15,000 years, and rivers that enter the sounds in general have true estuaries.

The ecology of estuaries is extremely complex and their biotas are very varied and versatile. They are highly susceptible to changes in stresses and have prominent roles in the water cycle and in the disposition of the dissolved and entrained solids in the rivers that enter them.

Currently, there is increased pressure on local authorities to prevent the fouling of fresh water, and much attention is being paid to finding other outlets for effluent discharges. In the past, it has been mistakenly believed that estuaries can be freely polluted and effluents discharged into them without hindrance. This is no longer so, and legislative acts have been passed so as to protect and preserve the lives of the present estuaries.

It is of the most importance that we ascertain at the start the quality of the water required for the various purposes to which the estuary may be devoted. It is unlikely that all possible uses of estuarine water will be identical throughout the length of the estuary. There is a considerable lack of information on what constitutes toxic levels in an estuary. Estuaries are all tidal, so that discharges ebb and flow. The saline concentration is constantly varying also. The water in an estuary will seldom be changed at each tidal change and it is even possible for toxic materials to be concentrated rather than dispersed by tidal action.

It often happens that pollution travels up and down with the tide like a piston. Modern planning tends to locate industries near the coast so that effluent discharges are made into the sea or adjacent estuaries. The changes of water in an estuary modify discharges, but these changes are not as clear as in fresh waters; for the composition is continually changing by reason of the fluctuation of the salinity. Nor is much known about the dispersal of effluents in tidal waters and their eventual removal to the sea. It may well be that an estuary may be able to tolerate a certain amount of pollution without any diverse effects.

Investigation of the degree of pollution of an estuary is not easy. A plan of sampling has to be designed which takes into account the mixing of the effluent with the diluting water at all stages of the tidal cycle and along various places on the estuary. Depending on the results of the sampling will determine whether the estuary is capable of purging itself of the effluent or whether controls are needed on the concentration and disposal methods of the effluent.

SEWAGE

Sewage is defined as the liquid waste of a community. It consists of waste from toilets, sinks, baths, lavatories and other plumbing features in residences, institutions and business buildings; certain wastes from varying types of manufacturing or industrial plants and, in many, communities, the run-off from the streets and other surfaces that results from storms or street-flushing operations. In general, sewage is essentially water that carries a small percentage of solid material in solution, in suspension or floating on the surface.

Sewage may be classified according to its source, as follows: that from residences, insitutions and business buildings is called Domestic Sewage (also known as Sanitary Sewage or House Sewage); that resulting from manufacturing or industrial processes is known as Industrial Wastes or Trade Waste; and that from run-off during and immediately following storms is called Storm Water or Storm Sewage. In addition, a certain amount of sewage results from cleaning the streets.

Ordinary fresh domestic sewage is gray in color, having somewhat the odor and appearance of soapy dish water. It is somewhat turbid and will contain floating matter which can easily be seen with the naked eye. This floating matter can be distinguished as matches, bits of paper, soap, feces, rags, garbage, oily patches and numerous other materials. The liquid portion of the sewage will contain materials in solution and millions of bacteria and other microscopic organisms.

Stale or septic sewage is sometimes black and with varying intensities of disagreeable odors. The floating materials are more difficult to distinguish and their appearance may be changed from their original form.

The quality of sewage per capita varies within wide ranges. In cities with separate sewers the amount of sewage produced would equal the amount of water consumed. This is not necessarily true as the amount of sewage may vary from 70 to 130% of the water consumption. Where large amounts of water are used for irrigation and sprinkling, it is obvious that it will not reach the sewers, while, on the other hand, many cities have industrial plants which derive their water from sources other than the city supply and discharge their wastes into the city's sewers.

The "strength" of a sewage also depends upon the habits of the population, and as in cities the people are of fairly regular habits the variation of strength is also fairly regular. The strongest sewage often occurs about 10 a.m. for cities and the weakest sewage between 3-6 a.m..

The time during which the sewage remains in the sewer depends on the area and contour of the district to be sewered, and, in particular, on the velocity of flow in the sewer. Variations of flow occur anually, seasonally, daily and hourly.

Annual variations may be caused by increases or decreases of rainfall; this affects the rise and fall of subsoil water in the ground in which the sewers are laid. Population and industrial changes are other factors. In some cases, the effect of autumn and winter rainfall is not felt in the sewers until the following spring. Ideally, all sewers should be water-tight, but the joints of stone ware pipes, etc., owing to contraction and expansion caused by seasonal variations of temperature, permit the formation of hair-line cracks through which the subsoil or ground water gains entrance.

Seasonal variations may be caused by seasonal changes, for instance, holiday resorts during the summer have increased sewage, by the seasonal distribution of rainfall, varying groundwater leakage at various times of the year and, possibly, seasonal industries.

Daily variations depend on inflow of industrial wastes, the sewage flow being usually least on Sundays. Hourly variations depend on the habits of the population served by the system; as previously mentioned, the flow is usually least in early mornings and rises at about 10 a.m..

If the early morning flow is high it is quite possible that a considerable volume of groundwater is entering the sewers.

<u>Pollution Control and Treatment</u>

There are three basic methods of getting rid of wastewater. The first is the oldest and most economical - the dumping of wastewaters into abundantly flowing streams where they will be diluted by freshwater, aerated and assimilated by natural processes. Obviously, this method is no longer adequate; if it were, there would be no problem of water pollution.

The second method, imitating many of the natural processes of the first, is the treatment of wastewaters physically, biologically and chemically, primarily to remove or reduce their content of solids and organic materials. Such treatments are mainly used in municipal sewage plants, which rarely are equipped to treat the complex wastes of industry or agricultural products.

The third method, abatting pollution at its source by modifying processes to reduce wastes, for example, by recycling materials in manufacturing or by using natural predators instead of chemical pesticides, is a popular concept. Because of its great cost to the individual polluter, it will be difficult to put into effect unless it is subsidized by society at large and, as in the second method, money for which comes from local and national taxes.

In choosing among the alternative solutions to the problem of pollution and deciding who shall pay for it, two of the problem's basic causes should be kept in mind - the more people, the more pollution and the higher the standard of living, the more pollution. If the inhabitants of modern technological societies want all the conveniences of modern life, they must either be willing to pay the high costs of preventing or abating pollution or face the consequences of ruination of the natural environment. Although the concerned citizen may point to industry as the villain and ask why industry is slow to pay for the clean-up of pollution, he should remember that he himself is one of the consumers for whom industry produces goods and services. And, ultimately, he will have to pay for clean water, either in higher taxes or in higher prices for consumer goods.

Need for Treatment of Sewage

Sewage is both dangerous to health and a potential nuisance. It is objectional in appearance because it consists of dirty water in which float paper, feces, etc.. The organic material decomposes quickly, especially in warm weather, with the production of disagreeable odors. If raw, or untreated sewage, is discharged into a stream, objectionable deposits may be formed on the bed, decomposing solids may strand along the banks and grease or soap contained in the sewage may rise to the surface of the stream and form scum. Unless the proportion os sewage to water is very small, fish may be killed and the stream may be spoiled for any recreational use. Even if the amount of sewage is small to cause a nuisance, the bacteria in the sewage will prevent the use of the stream as a source of drinking water or as a watering source for cows. Although water that is contaminated by sewage does not ordinarily harm animals that drink it, and milk cannot become infected as a result of the drinking of contaminated water by cows, disease-bearing bacteria may be carried on the bodies of cows that wade in a contaminated stream, and these bacteria may reach the milk supply during the process of milking.

Sewage may contain the bacteria that cause the diseases previously discussed. These bacteria, which are of the class bacilli, are discharged in the feces or urine of a sick person with the disease and thus reach the sewers. It is also possible for the bacilli to be discharged by carriers, or persons who have had the disease earlier and have recovered from it but still discharge the organisms either continually or from time to time. Therefore, sewage is always dangerous because it may also contain the causative organisms of several other diseases. If food or drinking water is contaminated by sewage the disease organism may be swallowed by many people. Contamination of drinking water has been responsible for many outbreaks of typhoid fever in the past.

However, proper sewage treatment serves to reduce, significantly, the number of disease producing organisms which might otherwise be introduced into our waters. In this respect, adequate effluent disinfection represents a final barrier in atte,pting to exclude pathogenic organisms from the aquatic environment.

SEWAGE TREATMENT METHODS

The entire process of getting rid of sewage is called Sewage Disposal, whereas Sewage Treatment is the term employed to denote the steps and processes by which sewage is transformed into a liquid that, under the conditions prevailing in the locality, will meet the demands of sanitation, health and decency. The term Sewage Purification is sometimes used instead of sewage treatment. But, as sewage is very rarely purified completely, the word purification is incorrect.

There are two main objectives to be accomplished by the treatment of sewage. The first is the elimination of disease-producing bacteria to such an extent as may be demanded by local health conditions; the second is the stabilization of the sewage without producing nuisance or odor, or endangering health. To accomplish these objectives, much or nearly all of the organic matter must be taken out or rendered harmless by decomposition and oxidation, and the water, which makes up such a large part of the volume of sewage, must be restored to a degree of purity determined by the local conditions.

Sewage treatment may be said to be carried out in two steps: primary and secondary processes. The primary process is the most common sewage treatment and is simply the removal of floating objects and suspended particles. Floating debris is caught on racks or screens placed in the path of flow of the discharged wastewater. Then sand and other coarse inorganic particles settle in grit chambers, which have inclined floors to trap the grit, or are caught on screens. Grease may be skimmed off the top by various plates, bars, baffles or other devices. The sewage is allowed to stand for a time in sedimentation or settling basins so that fine particles will settle to the bottom. Flocculent particles, which are loose and floating, are sometimes induced to settle by adding chemical coagulents that cause heavier clusters of particles, or flocs, to form. The material that settles on the bottom of the basin is called Sludge; together with other solids collected during treatment it must be disposed of. Sludge, which is 70% organic in composition, may be sent through a tank called a digester, where anerobic bacteria digest it and produce a liquid and the gases methane and carbon dioxide as well as mineralized solids. If there is no digester, the solids may be buried or dumped as landfill, burned (this produces air pollution), or dried and used as humus or fertilizer.

The secondary process or treatment is basically biological. Since primary treatment does not remove organic material, secondary treatment utilizes aerobic bacteria to decompose the suspended and dissolved organic matter. The main object is to put the wastewater in contact with as many bacteria as possible while keeping it aerated so that the bacteria have an adequate supply of dissolved oxygen. This may be done in several ways. First, the wastewater may be filtered through beds of sands, crushed rock, stones or shapes made of ceramic or plastics, with the same effect as would be achieved by allowing it to flow over several miles of a stream's bottom. Bacteria form a slime on the surfaces of the filter fragments and decompose the organic matter in the wastewater as it trickles through, thus reducing by more than 90% the biochemical oxygen demand (BOD).

Second, in the so-called activated-sludge systems up to 98% BOD reduction is accomplished by aerating the wastewater in a tank while vigorously mixing it with highly concentratedbacterial floc, thus speeding up the natural biological mechanisms. Another method of secondary treatment is to allow the wastewater to stand for a long time in oxidation ponds or lagoons, shallow structures where algae consume carbon dioxide and produce the oxygen needed for decomposition. Such ponds require sunshine and certain temperature conditions and reduce the BOD by only 40-70%.

The particular method of sewage treatment to be adopted will depend almost entirely on local conditions. It may consist merely of dilution, or the discharge of the sewage into a stream or large body of water. Where there is a large body of water, dilution may be used as a complete treatment of raw sewage or as a method of disposal for the effluent from treated sewage. Where sufficient dilution for the raw sewage is not available, some other method of treatment is necessary.

The need for sewage treatment is not confined to municipalities. Institutions, camps, hotels and even residences produce sewage which must or should be disposed of safely.

In general, the same processes can be employed for treating insitutional sewage as are used for municipalities, but details will differ. The smaller a plant is, the less operating attention it is likely to get. Less money will be available for constrution and less automatic equipment can be installed. Also, in a very small plant the is the liklihood of being great daily and hourly variations in sewage volume and sewage characteristics. In actual practice, simpler methods of treatment will be employed and the basis of design will be more liberal.

PRIMARY TREATMENT OPERATIONS

Screenings

Screenings were among the first modern devices used to remove harmful material from wastewaters. There remain a few places where screening is the only treatment that wastes undergo before being discharged into the receiving waters. In such instances, the volume of water for dilution is usually large. Most screening devices in sewage treatment plants are used to remove materials which would damage equipment, interfere with the satisfactory operation of a process or equipment, or cause objectionalbe shoreline conditions. Examples of screening devices include bar screens ahead of sewage pumps, meters, grit chambers, and/or sedimentation tanks, fine screens used in place of sedimentation tanks preceeding secondary treatment; and woven wire media screens preceeding trickling filters or following sedimentation to remove floating material.

Where the raw sewage must be pumped, screens usually are found at the inlet to the raw sewage wet well. When pump- is not required, but mechanically cleaned grit chambers are used, screens usually precede them. Many types of materials have been used as screens in sewage treatment plants including slotted or perforated plates, equally spaced bars and woven wire. Screening devices are usually classified as fine screens or coarse screens.

Bar Screens. Coarse Racks.

Coarse racks are used chiefly to remove sizable objects in large plants that would usually injure mechanisms used for cleaning conventional bar screens. They are also used as protective devices ahead of fine screens and comminutors. In the very large plants, hand-cleaned cage-type units that can be lifted from the channel are frequently employed. They are often used in duplicate so that one unit may be kept in service while the other is cleaned. Alternately, mechanically-cleaned trash screens such as those employed for protecting water intakes are used. Hand-cleaned coarse racks or screens are also used in the medium to large plant range.

Clear openings between bars on coarse racks are generally 3 inches where the rack is mechanically cleaned, but may vary from 3-6 inches, depending on plant size and the type of unit which follows. In large plants where the screen channel is relatively deep, the rack is generally vertical, or at a very slight angle. In the smaller plants, where the racks are hand cleaned, they may repose at an angle of 30-60° from the vertical. Here the flatter surface is preferable as it facilitates the hand cleaning.

Standard Bar Screens.

Standard bar screens are used for the same purpose as are coarse racks. The chief difference is the opening between bars. In the case of bar screens, the clear openings will vary between ½-2 inches, the most common being one inch. Because of this comparatively narrow opening, bar screens are generally mechanically cleaned to prevent high head loss due to screening accumulations.

Bar screen slopes vary from 10-45° from the vertical, with 30° being the most common angle. There are, however, screens with curved bars (forming a 90° arc) to conform with the circular path of the rotating cleaning mechanism. The screen channel should be designed so that the velocity of flow through the screen should not exceed 2½-3 ft/sec. at average design flow and should not fall below 1.0 ft/sec. at minimum flow. This practice also applies to coarse screens.

Disposal of Screenings

Screenings from bar screens may be disposed of by: 1) grinding and returning to the raw sewage, 2) incineration, 3) digestion and 4) burial. Where grinding is employed, two types of grinding devices are used: the cutter pump and the "hammer mill" type shredder. In both types, conveying liquid must be provided. Raw sewage is highly satisfactory in both large and small plants.

Special incinerators are offered for sewage screenings. In general, such units have been found satisfactory for medium and large plants, but not for small plants. Although attempts have been made to incinerate screenings along with sludge in conventional sludge incinerators; difficulties have been experienced in such cases unless the screenings are first ground. This also applies to digestion of the screenings either alone or mixed with raw sludge.

Screening burial is a satisfactory method of disposal, especially in small plants, as long as the land is available and precautions are taken to provide suitable disinfection and earth cover such as that employed in the landfill disposal system.

Comminuting Screens

Comminuting screens are devices for screening solids in the sewage flow and cutting the screened solids without removing them from the flow. There are several types of devices for accomplishing this purpose. In one, the screening unit consists of a revolving vertically-slatted drum mounted in a specially-designed channel. In another, the screen consists of semicircular horizontal bars set in a horizontal channel. In a third type, a special flat horizontal bar screen is used.

The advantage of comminuting screens is that they take the place of conventional bar screens equipped with separate grinders and accomplish the grinding operation below the sewage surface, eliminating fly and odor nuisances.

A disadvantage is that they are subject to high wear from grit; and, hence, they are most frequently located in the system following grit chambers. This often causes operating troubles with grit-removal mechanisms. An added disadvantage with certain types is that a special channel construction is required.

Fine Screens

Fine screens currently in use in a sewage treatment plant are of the disc and drum types. Both use, as a screening medium, a perforated plate with round or slotted openings or woven-wire cloth. Perforations are usually 1/16 - 3/4 inches across. In the disk type, a round flat disc rotates on a slightly inclined axis. Sewage flows through the lower section and retained solids are removed by rotating brushes as they are carried above the sewage level on the inclined disc.

In one drum type, a horizontal cylindrical drum rotates transversely to the flow. Sewage passes through the screen and flows out at right angles to the next stage of treatment. In one variation, rotating brushes are mounted on top of the screen for the removal of retained solids. In another, the screening drum rotates rapidly, producing a cascading action that causes the retained solids to drop into a pit where they are removed by a bucket elevator with perforated buckets.

In another drum type, the drum rotates parallel to the flow into the interior at one end and out through the screen at right angles. Solids retained on the inside drum surface are removed by sprayers and conveyed out by means of a screen conveyor.

Depending on the size of the screen openings and the character of the sewage, fine screens are capable of removing from 5-35% of the suspended solids. Normally, however, the removals will be in the range of 20-25%.

Other Screen Types

Other types of screens less widely used at present in the sewage treatment field are the vibrating screen for fone screening, the tangentially-fed curved screen for intermediate size screenings and the so-called micro-strainer for very fine screenings.

A variety of types of vibrating units are offered. All use a flat or slightly inclined screening deck of 20-200 mesh metal cloth. The screen is vibrated either by mechanical or electrical means. The vibrating causes the liquid to pass through the screen and conveys the retained solids to the point of discharged.

The tangentially-fed curved screen consists of a series of spaced wedge-wire bars set perpendicular to the line of flow and arranged in a series of short chords that approximate a 60° arc of a circle. Raw sewage is fed tangentially at the upper end and retained screening discharge is at the lower end of the screen. This type of screen requires a high head and discharges relatively wet screenings. It is, however, of relatively simple construction, is self-cleaning and has no moving parts.

The micro-strainer is a revolving drum-type screen with a special woven-wire cloth having openings as small as 20 microns. Sewage thus flows through the screen and out through the interior at right angles. Retained solids are removed by water sprays into discharge troughs. This type of screen, because of its fine mesh surface, is capable of use for effluent polishings. It may also be used for treating stromwater overflow.

Grit Removal

In a literal sense, the term "grit" may be construed to identify small coarse particles of sand, gravel or other minute pieces of mineral matter. Grit removal devices are used in order to remove these materials from sewage where they could cause undue wear on pumps, sludge disposal systems, etc., clog underflow lines, and segregate in settling and sludge digestion tanks, thus reducing their effective capacity. Strictly speaking, grit also includes some fast-settling organics, but there are non-putrescible solids such as coffee grounds, pulverized egg, shells, seeds and similar material which are not of mineral origin.

In the past, grit chambers have been employed almost exclusively in sewage plants receivings wastes from combined sewers. As the trend toward increased mechanization of sewage treatment plants has continued, greater consideration has been given to equipment protection, with the result that it is now common practice to provide grit chambers for plants serving sanitary as well as combined sewers.

Grit collectors may be rectangular, square or circular in shape. Rectangular units are the most common. It is important that inlet and outlet designs of such units minimize inlet turbulence, high bottom scour, and flow velocity changes with varying flows. Such disturbing factors may be lessened by the use of proper approach channels to even out the flow and the use of proportional flow devices such as the Sutro or Rettger weir or the Parshall flume. A rectangular cutlet weir may be used to control velocity if the bottom sides of the collection tank are sloped inwardly. This design has the advantage of requiring a narrow grit removing mechanism.

In large plants, especially those treating sewage from combined systems, it is desirable to install multiple units so that the number of units in service may be varied depending on flow variations and grit load. In square tanks, greater care must be excercised in distributing the feed to avoid short-circuiting with local high velocities. This may be accomplished by the use of a series of directional flow fins.

Relatively deep circular tanks with steep sloping bottoms have been used in small plants. Such units are fed through the center via a deep feed well and overflow at the periphery.

There are many varied mechanisms for removing settled grit from collection tanks. Among those used widely in the rectangular tanks are the chair-mounted flight, bucket, screw and reciprocating rake conveyors. In square tanks, rotating mechanisms with outward raking blades are most commonly employed. Corner fills are used in such tanks so as to avoid the use of troublesome extension arms on these devices. In some designs, the conveying mechanism carries the grit up to a ramp at the inlet to a suitable point of discharge. In others, the grit is raked to a sump where it is picked up by pumps, bucket elevators or sloping deck screw or rake mechainsm. One such device is a Link-Belt Straightline Grit Collector and Washer (Fig.1).

Grit Washers

Where a clean grit is required, for instance, one low in putrescible solids, washing of the grit to remove relatively slow-settling organic matter is essential. Modern day grit chambers, especially those mechanically equipped, provide for such washing. This may be accomplished by mechanical, hydraulic (air or water) or cyclonic means.

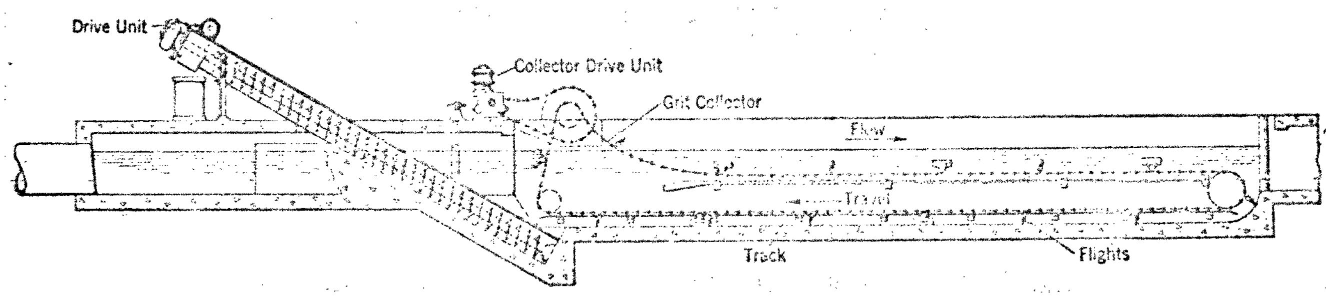

Fig. 1. Link-Belt Straightline Grit Collector and Washer.

The oldest method of separating the light organics, which is still in use, is aeration of the collection tank to maintain a suitable internal velocity. In applying this method, care must be taken to avoid diffuser clogging, especially at the inlet end of the tank where the bulk of the heavier grit settles. Care must also be taken to avoid highly violent aeration so that fine grit is not resuspended.

Mechanical washing involves the vertical conveying of the grit above the liquid level by means of a bucket, screw or rake conveyors, or the jigging of the settled grit to loosen and separate the fine organics. The use of water washing is accomplished by using water, or plant effluent in conjunction with the vertical conveying means.

Cycloni grit washing involves the pumping of the settled grit to a cyclone that comprises a cylindrical feed section and a conical section. The feed enters the feed section tangentially. Liquid containing the lighter organics exists through a center connection at the top. The washed grit discharges at the cone apex. Wash water may also be added to the feed, if desired. When mounted on its side, the cyclone is self-regulating in that very little liquid discharges at the apex when no grit is present.

Futher dewatering of the grit is necessary. This may be accomplished in a sump with a drainage section in small plants or in a small rake or clarifier in larger plants.

The latter has the added advantage that additional washings may be obtained by adding wash water on the deck of the clarifier unit.

Combination Grit Systems

In small plants where the amount of grit is relatively low, grit removal may be accomplished in the clarifier feed inlet or feed well. In another unit, preaeration, grit removal and clarification are combined. Another system eliminates the grit collection tank and provides grit collection and sedimentation in a single clarifier. Dilute underflow from the clarifier is then pumped continuously to a cyclone. The cyclone overflow goes to a sludge thickener, while the apex discharge to a sump or a clarifier.

Grit Volume and Disposal

Grit quantities vary greatly. Annual volumes of 0.20-12.0 ft^3/million gallons have been reported. The average being 3.0. However, daily quantities will frequently average 30 ft^3/ million gallons and will greatly exceed this figure in plants handling combined sewage and drainage.

Combustible matter in the grit will also vary between wide ranges. Where the grit is not washed, the combustibles may run from 40-55% and with washing may run from 1-10%. Adequately washed grit is inoffensive and may be used as landfill. Grit that is not washed is highly putrescible and should be buried. In few instances, unwashed grit is incinerated with sludge cake. This method of treatment is not recommended as it causes undue wear on equipment.

Flotation Units

The adoption of flotation as a method of sewage treatment is increasing as its particular advantages become more apparently known and equipment for its application is made available. Flotation is the treatment used to convert finely divided suspended solids and grease to floating matter. It has been found, in many cases, that the finely divided solids can be removed, with the aid of "floatation agents" in a much shorter time by gravitational rising than by gravitational settling. With the resulting shorter detention period, savings in construction costs may be realized. When used in conjunction with sedimentation, suspended solids may be removed which would normally not settle except after prohibitive periods of quiescence. Flotation has aslo been used for the thickening of waste activated sludge.

Preliminary Treatment

Flotation is being used as a step in the treatment of sewage containing large quanitites of industrial wastes which add a heavy load of finely divided suspended solids and grease to the sewage. This type of process has been found adaptable to cannery, packing-house, oil refinery and laundry wastes. It is particularly suited for treating sewage containing scum-producing material, such as peach-processing waste, because the scum can be removed and handled more easily in a flotation unit than in a conventional clarifier. Flotation is also being used treating typically domestic-type sewage ahead of sedimentation. Grit removal is often incorporated in this process by equipping the unit with sludge-removal facilities. Flotation units have been used in the following manner:

1. As a sole treatment device where sludge-removal facilities are incorporated in the unit. This is possible where removal of grease, floating matter, grit and some suspended solids meets the effluent requirements. In general, this method is not so effective as plain sedimentation.
2. As a pretreatment device ahead of plain sedimentation to provide a primary effluent with a lower grease and suspended solids content for either final disposal or secondary treatment. Grit removal may be incorporated, if desired.
3. As a primary treatment unit ahead of secondary treatment units.
4. For pretreatment of industrial wastes prior to treatment or disposal of the combined industrial and sanitary waste.

Principles of Flotation

Flotation, as applied to municipal sewage treatment, is confined to the use of air as the "floatation agent." Air bubbles are introduced or formed in sewage and tend to adhere to the solid particles. When quiet conditions are provided, the solids rise upward and are floated by the lifting action of the gas bubbles. Air bubbles are added or formed in sewage by the following methods:

1. Aeration.
2. Pressurizing with air followed by release of liquid to atmosphere.
3. Application of a vacuum after saturation with air.

Aeration-Type Units

Air bubbles are added to the sewage by pumping air with a blower or compressor to the bottom of an aeration tank where it is dispersed into the liquid by passage through a diffusing mechanism. Air may also be introduced by mechanical means.

Pressure-Type Units

This process consists of pressuring the sewage flow with air at 1-3 atmospheres and then releasing it at atmospheric pressure in a suitable container. When the pressure of the liquid is reduced, the dissolved gas, in excess of saturation at atmospheric pressure, is released in extremely fine bubbles. These bubbles adhere to and lift suspended matter to the surface very much as in vacuum-type units. There are modifications of this process such as split-treatment and recirculation. In the latter case, part of the effluent from the primary clarifier is pressurized, diffused into the raw sewage, and then introduced into a flotation basin.

The principal unit is the flotation tank where the pressurized flow is released to atmospheric pressure. The unit may be circular or rectangular with proper baffles and a scum-removal and sludge-removal mechanism. Where recirculation is used, primary sedimentation and flotation have been incorporated in the same basin.

Vacuum-Type Units

This process consists of saturating the sewage with air in an aeration tank or permitting air to enter on the suction side of the sewage pump and then applying a partial vacuum. Under vacuum, the solubility of gas in liquid is decreased, and the gas is released from solution as minute bubbles. The bubbles and attached solid particles rise rapidly to the surface forming a thick "float." This material is continuously removed by a skimming mechanism. Grit and other heavy solids settle to the bottom where they are raked to a central sludge sump for removal. Sludge is then treated for grit removal or is pumped to a digester.

The vacuum-type unit consists of a cylindrical tank with a cover in which a constant vacuum of approximately 9 inches of mercury is maintained. The tank is equipped with a scum-removal and sludge-removal mechanism. The floating material is continuously swept to the tank periphery and automatically discharged into the scum trough.

The advantages of this system are:

1. Grease, light solids, grit and heavy solids are removed all in one unit.
2. High overflow rates and low detention periods mean smaller tank sizes resulting in less space requirements and possible savings in construction costs.
3. Odor nuisance is minimized because of the short detention periods and, in pressure and aeration-type units, because of the dissolved oxygen in the effluent.
4. Thicker scum and sludge are obtained, in many cases, from a flotation unit than by gravity settling and skimming.

The disadvantages of the system are:

1. The additional equipment required results in higher operating costs.
2. Flotation units generally do not give as effective treatment as gravity settling tanks.
3. The pressure type has high power requirements which increase operating cost.
4. The vacuum type requires a relatively expensive

airtight structure capable of withstanding 9 inches of mercury. Any leakage to the atmosphere will adversely affect the performance.

5. More skilled maintenance is required for a flotation unit than for a gravity-settling unit.

Flocculation of Sewage

Flocculation of sewage may be defined as the coalescence of finely divided suspended matter by gentle stirring, primarily under the influence of physical forces without the use of chemicals and in the absence of biologically active slime. Under quiescent conditions, coalescence of finely divided suspended or colloidal matter depends on collision of colloids by Brownian movement and on contact of finely divided suspended solids with one another by the sweeping action when more rapidly settling overtake more slowly settling ones. As floc grow in size, their settling velocity ordinarily increases and they are more readily removed. Stirring hastens floc formation by increasing the number of collisions or contacts and by releasing entrapped gases.

Stirring may be by mechanical paddles or mixers, air agitation or other means. The process is sometimes further distinguished as mechanical flocculation when mechanical paddles, impellers or draft tubes are used and as preaeration or "air flocculation" when air agitation is used.

The term preaeration may also include any preparatory aeration of sewage to remove gases, add oxygen or promote grease flotation.

Flocculating units have been used in the following manner:

1. As a pretreatment device ahead of plain sedimentation to increase suspended matter removal or increase effectiveness of settling tank capacity, or both.
2. To reduce biological loading of secondary treatment processes.
3. For plain flocculation in chemical treatment plants during periods when chemical treatment is not needed.

The effect of flocculation depends on the composition of the suspended matter and the oppurtunity for contact, both of which are too complex for any ready evaluation. Suitability of flocculation as a treatment process depends almost entirely upon the nature of the sewage to be treated and can be determined only by experiment. In some cases, particularly where strong sewage containing appreciable amounts of industrial wastes are involved, flocculation may be economically justified in the treatment of raw sewage or trickling filter effluent before settling.

Air Flocculation

Porous diffuser tubes or plates are commonly used for air agitation, but perforated pipes, or jet diffusers and other types of air diffusers may also be used. Porous diffusers may be fixed tubes or plates or removable suspended tubes. With the latter, it is not necessary to dewater and take a unit out of operation for servicing. The diffusers or pipes are generally placed along one side of a longitudinal channel or tank to cause spiral flow. In larger tanks they may be arranged in several parallel longitudinal rows with or without a center curtain wall, to cause double spiral motion in the same tank.

Mechanical Flocculation

Mechanical mixing may be by revolving or reciprocating paddles, radial-flow turbine impellers or draft tubes. Revolving paddles may have either vertical or horizontal shafts. Horizontal shafts may be arranged parallel to or at right angles to the direction of flow with the drive mechanism usually housed in a dry well. Peripheral paddle speed is kept in the range of 0.90-1.20 fps to minimize deposition and yet avoid disintegration of the fragile floc particles. Constant speed drives may also be used to provide easier control. Basin width, length and water depth depend on the rate of flow. Paddle size is related to basin dimensions and path of flow.

Radial-flow impellers usually have vertical shafts. Several units are ordinarily arranged in a rectangular tank with liquid flow through the vortex flow patterns of each impeller. For long rectangular tanks, a horizontal shaft with several impellers may be used. Variable speed drives are used to permit selection of most effective speed with minimum power consumption.

Draft-tube flocculating devices have special impellers to agitate the sewage without destroying the floc formed. Grit and other heavy solids are not kept in suspension in flocculating units. They are generally removed beforehand.

The primary function of agitation in flocculation is mechanical regardless of the method of agitation used. The fundamental requirement is to agitate and maintain all solids in suspension throughout the flocculation unit. Once formed, flocculated particles are quite fragile and must be handled gently until settled. Inlet and outlet disturbances are held to a minimum and velocities in and after the flocculating unit generally are not allowed to exceed the peripheral paddle speed.

Sedimentation

When a liquid containing solid particles is placed in a relatively quiescent state, those particles having a higher specific gravity than the liquid tend to settle. This principle is utilized in the design of sedimentation tanks for treatment of sewage. The object is to remove settleable solids and to reduce the suspended solids content of the sewage. Primary sedimentation tanks are used to reduce the formation of sludge banks in the receiving stream where no further treatment is provided, or as a preliminary step ahead of biological treatment. Intermediate and final sedimentation tanks are used to remove settleable solids produced in biological treatment.

Sedimentation tanks are designed to operate on a continuous basis. They are usually rectangular or circular in shape and are provided with hoppers for the collection of sludge. Most sedimentation tanks are now equipped with mechanical sludge-collecting devices. They are constructed with substantially flat bottoms and have sludge hoppers with relatively steep sides. Sludge settles to the tank florr and moves with the aid of mechanical scrappers into the hoppers for subsequent withdrawal.

Sedimentation embodies the principles and practice of removing solids from suspension by settling and concentrating the suspended matter. As applied to sewage, sedimentation normally occurs in units utilizing only the force exerted by gravity to produce settling. Normally, grit-removal facilities eliminate heavy dispersed particles whose diameters range from 0.21 mm and larger. To the primary sedimentation basin falls the task of removing the bulk of the settleable solids remaining in the sewage.

Raw sewage is a dilute heterogenous suspension whose solids range from totally dispersed to completely flocculated particles. If the suspension consisted of particles either totally or completely flocculated upon entering the sedimentation basin, the tank design would be based solely on area. Actually, the bulk of the solids reaching the primary settling basin is incompletely flocculated particles which are susceptible to flocculation aided by the fluid motion within the sedimentation tanks.

Normally, with the detention periods of 60-120 minutes, primary sedimentation basins, in theory, remove 50-70% of the influent suspended solids. In general, if a time period required to coalesce 50% of the initial solids were doubled, the increased time would produce coalescence of 50% of the particles remaining after the initial detention. Thus, to effect an 85% removal of solids from sewage, even as a homogenous suspension, would mean increasing the nominal detention 1.5-2.5 times that required for a 50-70% removal. Plants showing abnormally high or low removal efficiencies of suspended solids usually can attribute these results to the characteristic of suspension encountered, a marked difference in the ability of the particles to flocculate, and/or the percentage of flocculant material in sussion.

Types of Sedimentation Tanks

Theoretically, sedimentation may be accomplished in either horizontal-flow or vertical-flow tanks. In a horizontal-flow tank, the sewage flow horizontally from the inlet to the outlet, whereas, in a vertical-flow tank, it passes downward through a vertical pipe and then flows upward. A horizontal tank may be operated by continuous flow or by fill and draw.

Nearly all settling tanks in modern sewage-treatment practice are horizontal, continuous-flow tanks. Such tanks are either rectangular or circular. In the case of a rectangular tank, the sewage enters continuously at one end and passes out at the other end, generally over a weir. The sludge is collected by mechanical scrappers and is concentrated at the inlet end of a rectangular tank or the center of a circular tank. It is removed from the tank for further treatment. The effluent floew over the outlet weir and is collected in an outlet pipe for further treatment or for final discharge.

Primary settling tanks, or primary clarifiers, are those that treat raw sewage. Secondary settling tanks, or secondary clarifiers, normally follow secondary treatment devices, such as trickling filters or high-capacity filters, secondary tanks are sometimes called final tanks.

Rectangular Sedimentation Tank

Figure 2, which shows a Rectangular Sedimentation Tank, with a Link-Belt Sludge Collector, was designed for the daily or continuous removal of sludge. The influent channel, a, is conncected to an opening to the trough, b, which is placed across the end of the tank. The section of the trough is decreased from the center of the tank toward the sides, and the sewage flows into the tank through the orifices, c, which are spaced about 24 inches apart. The sewage is thus distributed to all parts of the width of the tank at a uniform rate. As the velocity of the incoming sewage is lessened, the heavier solid material falls into the sump, d. The remaining settleable suspended matter is deposited along the bottom of the tank as the sewage passes toward the outlet end.

A baffled wall, e, which holds back the scum, is placed in front of the outlet weir, and the partially-clarified liquid flows through the effluent channel, f, into an outlet pipe. In some plants, the materials that are deposited on the tank bottom are removed daily or twice a day by a mechanical sludge remover, which is operated for 30-45 minutes at a time by the driving mechanism, g, and the chain, h. In other plants, the apparatus is operated continuously. The removing device consists of two endless chains, i, across which are fastened horizontal flights,

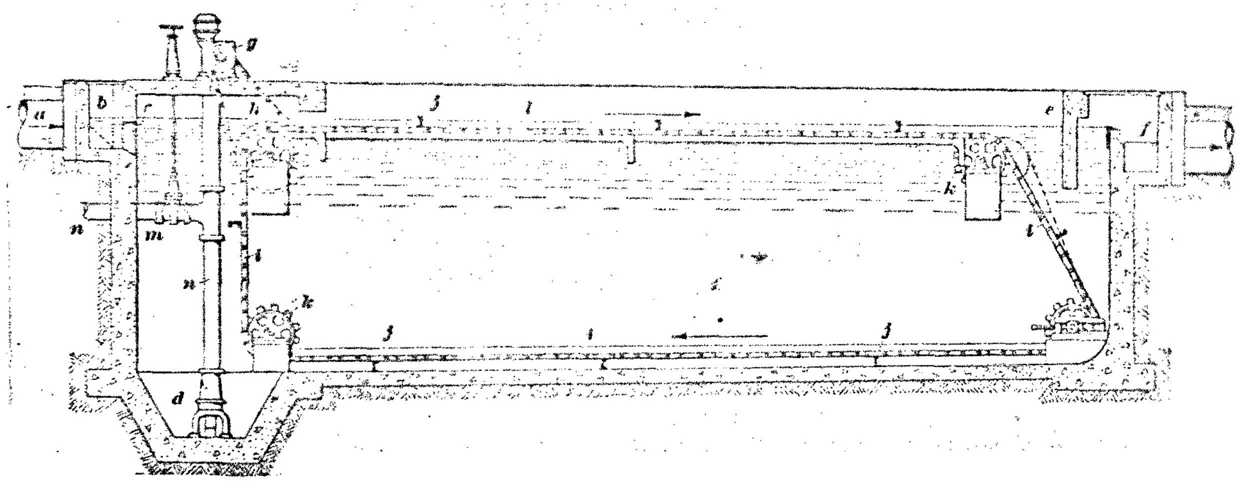

Fig. 2. Rectangular Sedimentation Tank, With Link-Belt Sludge Collector.

or scrappers, j, at equal intervals. The chains, i, revolve around the four wheels, k, in the direction of the arrows, and the flights, j, scrape the sludge into the sump, d. On the return trip, the ends of the flight travel on the tracks, l; and, in this portion, the flights project above the surface of the liquid and push floating materials toward the baffle wall, e, where the scum can be removed by hand. In some tanks, a mechanical skimmer pushes the scum into a trough. When the valve, m, is opened, the sludge is forced out of the sump, d, through the pipe, n, by hydrostatic pressure. The sludge is then carried by gravity or is pumped to a digester tank. There is usually a freeboard allowance of at least 1½ feet above the liquid surface and, in the design of the tank, an additional allowance of 6 inches in depth is provided for the sludge collection apparatus. The minimum capacity of the sludge hopper, or sump, must be sufficient to hold sludge deposit for one cleaning.

Circular Sedimentation Tank

A cross-section of a circular sedimentation tank, equipped with a Dorr sewage clarifier, is shown on Fig. 3. The raw sewage enters the tank through the influent pipe, a, expanding feed decelerator, b, central feed diffuser, c, and perforated circular baffle, d. As the sewage flows toward the wall, the solid materials settle to the bottom,

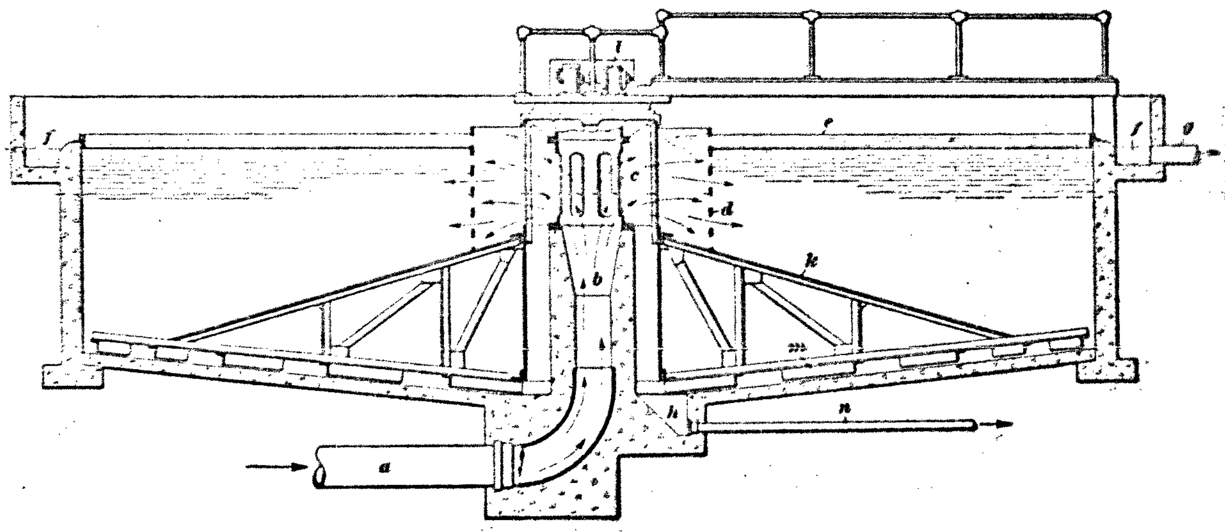

Fig. 3. Circular Sedimentation Tank, With Dorr Clarifier.

and the effluent flows out over the peripheral overflow weir, e, into the effluent channel, f, and from there through the effluent pipe, g.

As a result of the central feeding of the sewage, the heavier particles of solid material settle directly over the sludge hopper, or sump, h, near the center. The raking arms, k, are revolved by the overhead drive unit, l, and, as they move slowly, they concentrate the sludge into the hopper, h, by means of the blades, m. The sludge is drawn off through the pipe, n, placed in the sump, either by gravity or by pumping. The removal of the sludge may be either intermittent or continuous.

Size of Settling Tanks

The size of a settling tank is, of course, determined primarily by the amount of sewage flow, but it also depends on the detention period or the time allowed for settling. Experience and research have shown that, in modern mechanically-equipped sedimentation tanks, it is sufficient to provide a detention period of 2-3 hours, based on the average flow of sewage expected, and that longer detention periods are not justified on the basis of results.

The overflow rate, based on the area of the tank, is another factor that should be considered in design. For primary settling tanks, it is common practice to employ an overflow rate of 1,000-1,250 gallons/24 hours/ft^2 of area of tank surface; and for secondary tanks, a suitable daily rate of 1,000 gallons or less per square foot.

Where the flow of sewage is irregular and the peak loads are high, as is often the case at army posts and air-posts, a larger settling tank capacity may be required, but excessively long detention periods for low rates should be avoided. Generally, the detention period provided in such cases is a compromise, but the detention period for peak flows should not be less than 45 minutes and preferably at least one hour.

Imhoff Tanks

The Imhoff tank, as shown on Fig. 4, provides for both sedimentation and sludge digestion in the same tank. The upper compartment, a, which may be a single chamber or may be divided into two or more chambers, provides for sedimentation; while the lower compartment, c, provides for sludge storage and digestion. In a small sewage treatment plant, such as one designed to treat a flow of not more than 250,000 gallons/day, the Imhoff tank is often desirable. It may be prefeered in such a case, instead of an installation employing plain sedimentation and separate sludge digestion, because the initial cost is frequently less and neglect in operation produces less serious results.

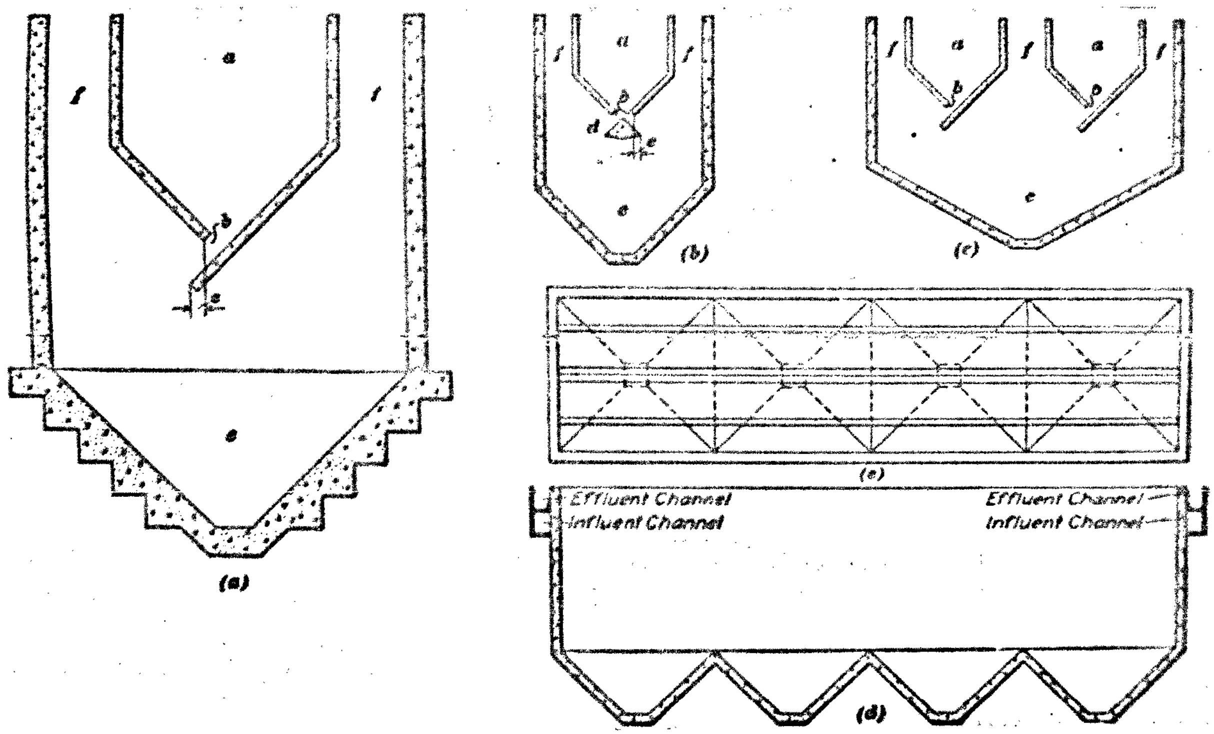

Fig. 4. Imhoff, or Emscher, Tanks.

Before the development of the sedimentation and separate sludge-digestion processes, Imhoff tanks were used in many large installations. They have been largely superceded by more modern and efficient processes, except in the small installations, because the newer methods permit easier control of operation and give better results.

The essential features of the Imhoff tank are shown on the same diagram. As the sewage flows slowly through the sedimentation, or settling chamber, a, the settleable materials sink, slide down the inclined sides of the chamber and pass through the trap, b, into the digestion, or sludge chamber, c. The trap may be arranged by projecting the bottom of one side wall beyond the other, as in view (a), or by introducing a triangular beam as "d" in view (b).

When the decomposition of the solids take place in the sludge chamber, the rising bubbles of gas cannot get back through the trap, b, into the incoming liquid, for they are diverted by the overlap, e, of either the triangular beam, d, or the projection at the bottom of the sedimentation chamber. The bubbles, therefore, rise into the gas chamber, f.

As a result of this arrangement, the sewage flowing through the tank has better oppurtunities for giving up its solids, and also is kept fresh and is not innocculated by the decomposition of the sludge below. In the overlap, e, is adequate, or at least 6 inches, the particles of sludge that are carried up by the rising gases in the digestion chamber are prevented from entering the sedimentation chamber and from disturbing the settling process. Thus, these sludge particles remain in the tank and are allowed to go to further decomposition in the gas chamber, f.

The slope of the bottom of the sedimentation chamber, a, is usually not less than 45°, and should be nearly 60° with the horizontal, so that the settleable solids will slide at once through the slot, b, into the digestion chamber, c. The width of the slot, b, is generally 6-8 inches to allow free passage of the larger particles.

Sometimes it is desirable to construct a double tank, or one with two separate settling chambers, as shown in the cross-section in view (c). A longitudinal section of an Imhoff tank is shown in view (d) and a plan in view (e).

The area and capacity of the gas vents, or gas chambers, are an important consideration in designing an Imhoff tank. Small areas result in heavy scum formations and occasionally cause overflow of the vents. It is the usual practice to make the horizontal area of the gas vents 30 or more percent of the sludge chamber area.

The gas formed in an Imhoff is chiefly methane, and has no considerable fuel value. In some installations, hoods have been mounted over the gas vents to collect the escaping gases which may by used at the plant for driving gas engines, lighting, heating water and laboratory purposes.

The Clarigester

The clarigester, as shown in Fig. 5, is a modernized mechanical tank of the Imhoff type. It consists essentially of a circular clarifier over a sludge digestion tank. As indicated in view (a), the sewage entering the unit through the feedpipe, a, flows into the influent well, b, and from there it is distributed to the clarifier, or settling chamber, c. The clarified effluent flows over the weir, d, and passes into the effluent trough, e, from which it is discharged for further treatment or final disposal. It is first cleared of scum by the rotating skimmer, f. The sludge settles to the bottom, g, of the chamber, c, and is scraped by the blades, h, on the arms, i, into the opening, j, at the center of the tank. It then passes into the sludge-digestion compartment, k.

The digesting sludge is stirred and agitated by the arms, l, at the top and the arms, m, at the bottom, the shaft, n, carrying both mechanisms being rotated slowly by means of the motor and drive on top of the tank. The upper arms, l, are provided with projections, o, which intermesh with corresponding stationary projections, p, on the underside of the bottom, g, of the chamber, c, and

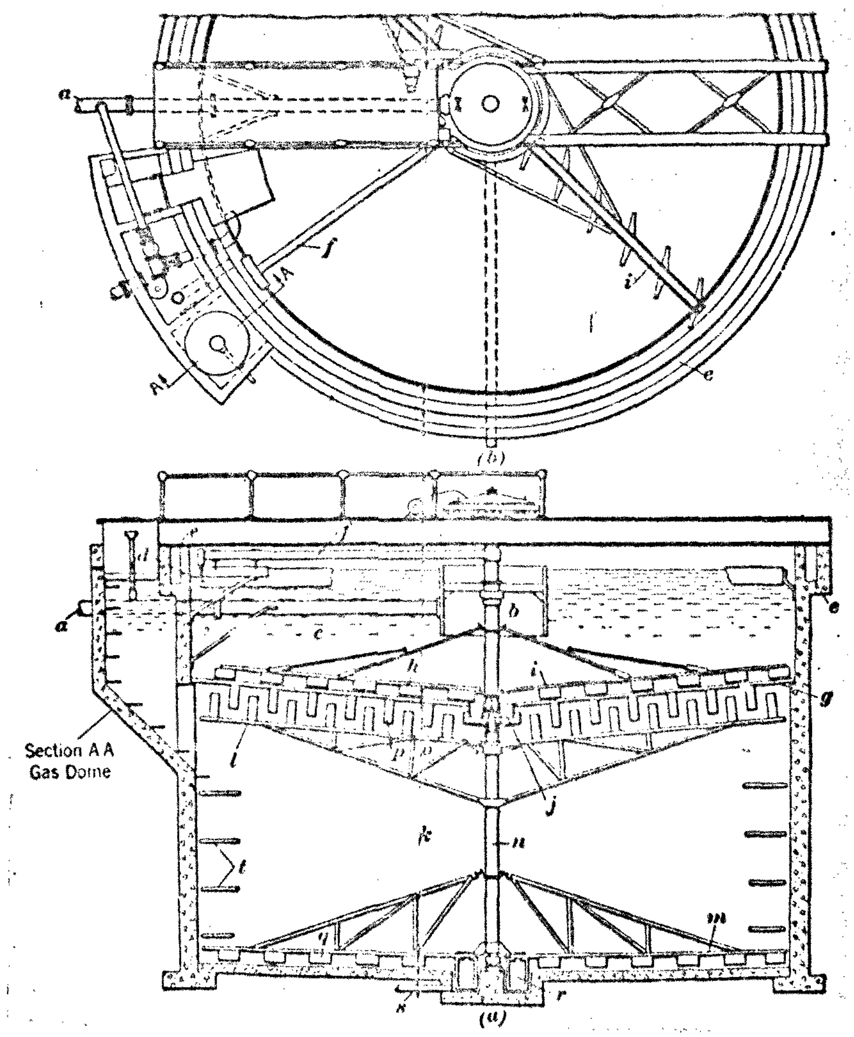

Fig. 5. The Clarigester.

and break up the scum. The lower arms, m, are equipped with blades, q, which scrape the digested sludge at the bottom of the tank to the pockets, r. When the sludge is fully digested, it is received through the sludge pipe, s. Heating coils, t, may be provided.

The clarigester is advantageously used for small installations. However, the sludge can be treated, if desired, and the space required for the sludge digestion can, therefore, be greatly reduced.

Septic Tanks

If the sludge resulting from sedimentation is allowed to remain in the tank in the same chamber with the settling sewage for a period of several months, anaerobic decomposition takes place. A tank operated in such a manner is known as a septic tank. Since the degree of treatment obtained with a septic tank is not good, and since both the effluent and the sludge are offensive, it is not desirable, and in many states it is now contrary to public health regulations, to construct septic tanks for municipal sewage treatment. Their use, therefore, is confined to small institutions.

As the sewage passes over the decomposing sludge in a septic tank, the solids in the sewage become inocculated with anaerobic bacteria and are in turn rapidly decomposed.

Particles of decomposing organic matter are buoyed up by gas and rise. They are either caught in the outflowing current and carried out of the tank or come to the surface and form a mat or scum which in time becomes very thick and heavy. The sludge remaining in the tank becomes dense and is more compact than that in plain sedimentation tanks.

Size and Arrangement of Septic Tanks

The factors governing the size of septic tanks are practically the same as those influencing the construction of sedimentation tanks, except that extra space should be provided for storage of the sludge, which, in the operation of the septic tank, is allowed to remain for several months. Since the same general principles govern the design of both the septic and sedimentation tanks, the length and width of a septic tank will be similar to those of the plain sedimentation tank, as will also the arrangement of the various units.

Many construction features of a septic tank, such as the inlet, outlet and baffles, are similar to those already described for a sedimentation tank and may be either straight or sloping or may contain one or more hoppers. The accompanying diagram, Fig. 6, is one type of septic tank suitable for a small hotel or home. The sewage flows through the inlet, a, into the settling chamber, b. The effluent from this chamber passes over the weir, c, into

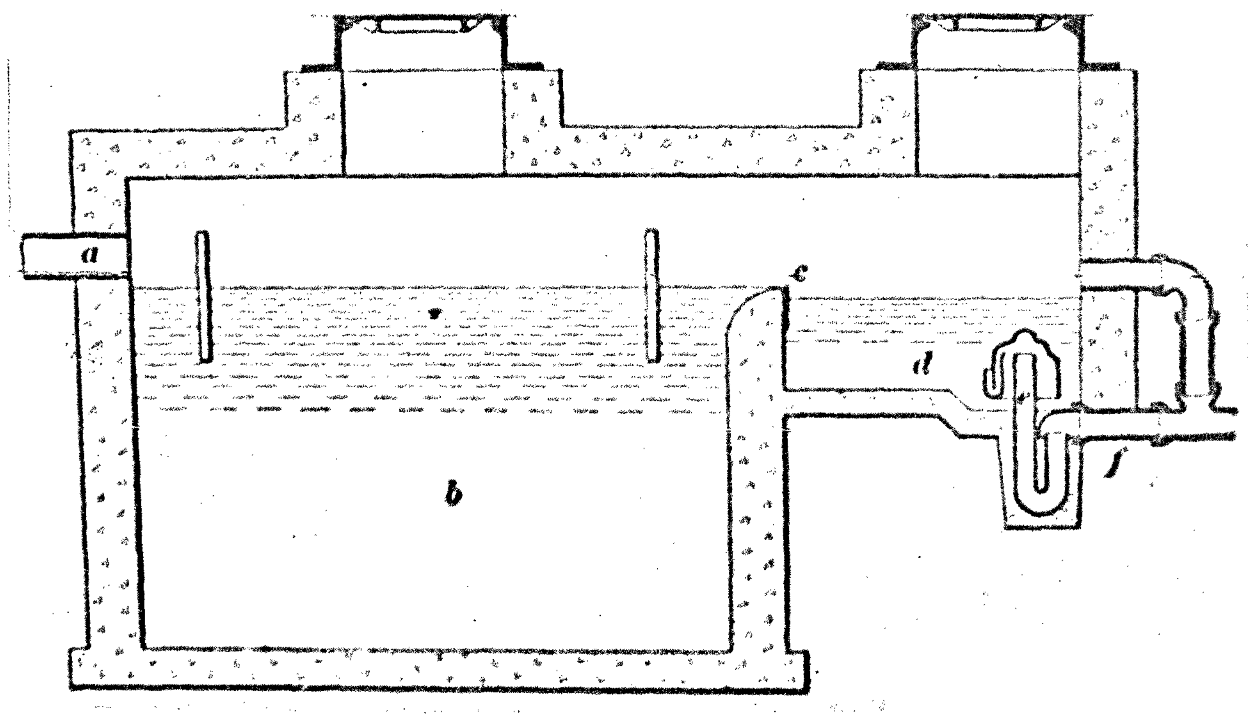

Fig. 6. Small Septic Tank.

the siphon chamber, d, from which it is discharged automatically by the siphon, e, through the outlet pipe, f. Facilities for the convenient removal of sludge may be provided in the larger tanks by constructing a hopper bottom and running a sludge pipe from the lowest point. When a valve is opened, the hydrostatic pressure of the sewage forces the sludge through the pipe to a drying bed.

Septic tanks are often provided with covers in order to keep the sewage warm, to prevent wind agitation, to lessen odors and to prevent children or animals from falling into the tanks. As far as operating results are concerned, no advantage is gained by excluding the air from the surface of the sewage.

It is advantageous to keep the contents of a septic tank as quiet as possible. All inlet and outlet channels and weirs should be kept free and clean from accumulations. When scum and sludge occupy more than 25% of the tank capacity, the sludge should be removed. In general, it is preferable to remove the sludge in the spring and in the fall, and also whenever particles of sludge appear in the effluent.

SECONDARY TREATMENT OPERATIONS

Activated Sludge Processes

There are three basic operations in the activated sludge process: 1) The sewage either raw or settled, is mixed with 20-35% of its volume of biologically active sludge; 2) the mixture is agitated with air or in the presence of air, and 3) final settling is permitted.

Biologically active sludge contains large numbers of aerobic and facultative bacteria, and these bacteria contain an unusual ability to oxidize organic matter. Such sludge is prepared by agitating untreated sewage with sludge for several weeks in the presence of oxygen. This is usually done by passing small air bubbles continuously through the mixture of sewage and sludge. This process of developing the special forms of bacteria is called Activation, and the biologically active sludge containing them is called Activated Sludge.

Once these forms of bacteria have been developed, they multiply rapidly when the activated sludge is added to raw or partially treated sewage in which there is maintained an ample supply of oxygen. As a result, the organic solids in the sewage are rapidly oxidized, while the suspended and colloidal matter tends to coagulate and form a precipitate that is readily settleable. After the precipitate has settled, the resulting effluent is clear and low in organic matter. Further treatment of the effluent, other than chlorination, is not required.

In the treatment of sewage by the activated sludge process, the sewage generally is passed first through clarifiers or primary settling tanks in which the grosser solids are removed. It then flows to the aeration tanks, where it is mixed with activated sludge amounting to between 20 and 35% of the volume of sewage. In the aeration tanks, the sewage is agitated and oxygen is added by admitting compressed air, by stirring or a combination of both methods. The period of aeration normally varies from 4-8 hours, the exact period depending on the strength and the character of the sewage and on the desired degree of treatment.

After aeration, the sewage flows into final clarifying or settling tanks in which the sludge is permitted to settle. The settled sludge is biologically active and a part of it is returned to the inlet end of the aeration tank to inocculate the incoming sewage. The remainder of the settled sludge is treated for final disposal.

Preliminary Treatment of Sewage

The grit and other heavy solids should be removed from the sewage before it enters the aeration tanks. If this is not done, more air is required for further treatment. Moreover, the heavy solids tend to settle on and to clog theaerating devices and thus interfere with their operation; and these solids also tend to collect in the bottom of the tank and there form decomposing deposits which may interfere with the treatment process.

It is, therefore, desirable to have the sewage pass first through grit removal apparatus of the type previously discussed. Preliminary settling is also accomplished in mechanically-equipped clarifiers of the type discussed in the section of <u>Sedimentation</u> under the chapter <u>Primary Treatment Operations</u>.

In many activated sludge plants, allowing the sewage to pass through preliminary settling tanks prior to aeration not only reduces the amount of air required for treatment, and thus lowers the cost of treatment, but also has the following additional advantage: The final disposal of the activated sludge remaining after the demands for return sludge are met is facilitated by mixing it with the fresh sludge from the preliminary settling tanks.

In some places, this excess sludge is mixed with the sewage entering the preliminary settling tanks. It is thought by some engineers that this practice improves settling and also reduces the water content, and, therefore, the volume of the sludge to be handled.

Final Settling Tanks

From the aeration tanks the sewage flows to final settling tanks. These tanks are of the mechanically-cleaned types as discussed in the section on Sedimentation , but some modifications are usually desirable in the design of tanks intended for final settling of aerated sewage. These modifications are:

1. No flights for scum removal since there are no floating solids in a final settling tank. The upper wheel near the outlet end of the tank and the tracks are, therefore, eliminated and the resulting design can be seen in Fig. 7.
2. Since the sludge particles are very light in weight and small in size, a very great length of overflow weir is required in order to reduce the velocity of approach and the capacity of the liquid flowing over the weir.

In the case of a rectangular tank, an H-shaped weir, such as that in Fig. 7, is used. The effluent flows over two or more cross weirs, a, into troughs which discharge into the effluent channel, b. A detention period of about 2 hours is normally provided in final settling tanks for activated-sludge plants.

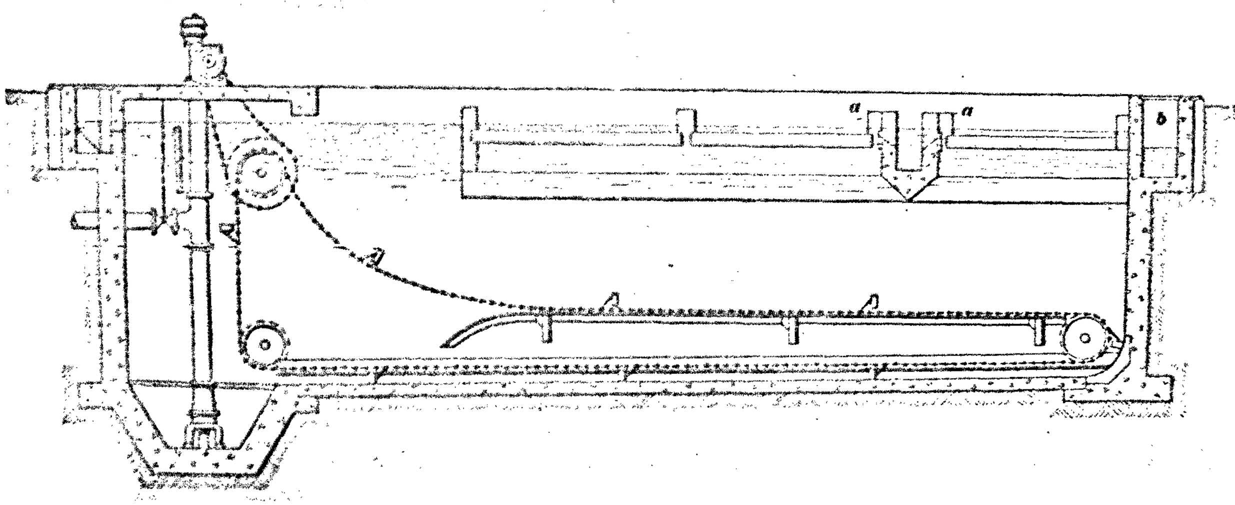

Fig. 7. Final Settling Tank, with Link-Belt Sludge Collector.

Methods of Aeration

The two methods that are in general use for aerating and agitating the mixture of sewage and activated sludge are known, respectively, as diffused-air aeration and mechanical aeration. In the case of diffused-air aeration, both the aeration and agitation are provided by forcing compressed air through the sewage and the sludge.

However, a relatively small amount of the oxygen in the air supplied by this method - probably more than 10% - is used for purification purposes, the remainder of the air provides agitation, which must be sufficiently violent to prevent the settling out of the solids in the sewage as it passes through the aerating tanks. Therefore, mechanical aeration in which the sewage is constantly stirred and exposed to the air by mechanical equipment, may be more economical. In some plants, a combination of air diffusion and mechanical aeration is used.

Types of Tanks for Diffused-Air Aeration

There are two common types of diffused-air aeration in use: the Ridge-and-Furrow type and the Spiral-Flow type. In tanks of the Ridge-and-Furrow type, the air diffusers, which are usually plates, are placed in the bottoms of wedge-shaped depressions and are arranged in rows that extend either perpendicular or parallel to the direction of flow.

In tanks of the Spiral-Flow type, the rows of diffusers, which may either be tubes or plates, extend lengthwise and are placed along one side of the tank. The air, therefore, tends to impart a spiral, or helical motion to the sewage as it passes through the tank.

Typical Ridge-and Furrow Plant

In Figure 8 is shown a plan in view (a), in Figure 9, a longitudinal section in view (b) and a cross-section in view (c) of an activated sludge plant with an aeration tank of the Ridge-and-Furrow type. The sewage is brought to the plant in the sewer, a, to the manhole, b, and the sewer, c, to the inlet manhole, d, in which it is mixed with activated sludge that is introduced through the pipe, e. The mixture of sewage and sludge is raised in an air-lift channel and passed through the fine screens, f. The screened mixture flows through the trough, g, which surrounds the four aerating tanks, h, i, j, and k, and is admitted to the tanks from the troughs by means of the circular openings, l, two of which are located in the bottom of the trough at each end of the tank.

There is a psecial inlet valve, m, view (c) at each opening, and there is a diversion gate, n, in the trough between

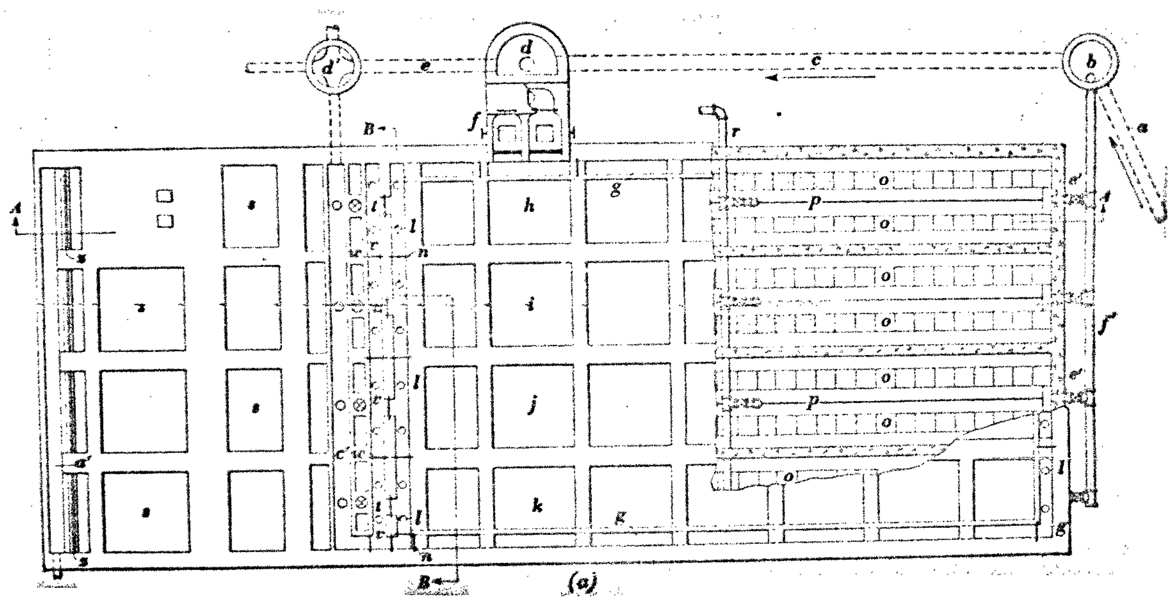

Fig. 8. Activated-Sludge Plant.
Ridge and Furrow Plant.

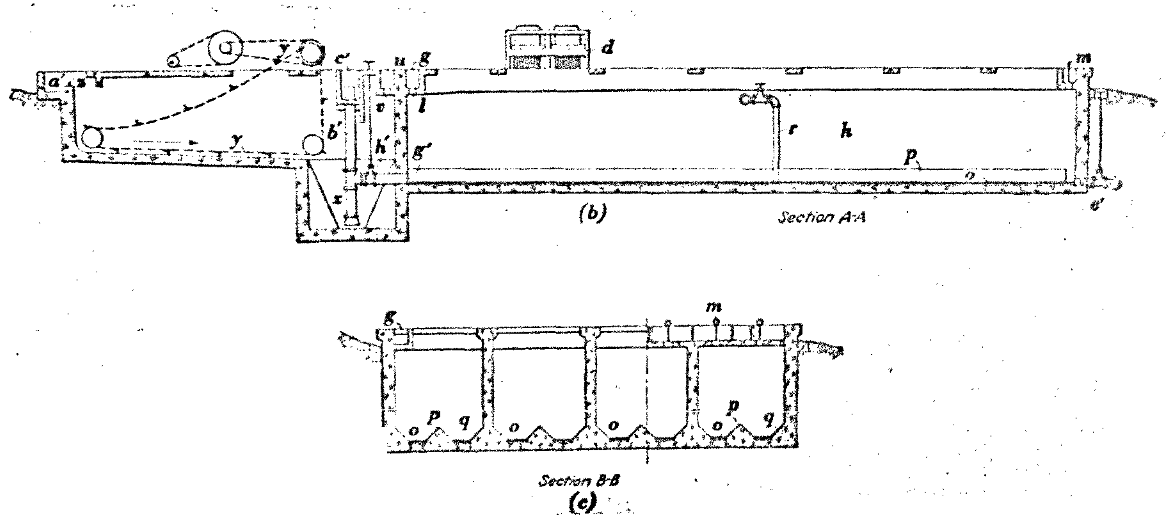

Fig. 9. Activated-Sludge Plant (Cont'd).
Ridge and Furrow Plant.

each pair of adjoining tanks. By means of these valves and gates, the aeration tanks can be operated either in series or in parallel, depending on the desired period of aeration, that is, the sewage can be passed from one tank into another until it passes through all four tanks, or else each of the four tanks may be operated as a separate unit.

As shown in view (c), the bottom of each tank consists of two longitudinal furrows, o, with a ridge, p, between the furrows and slopes, q, at the sidewalls of the tank. In each furrow is a row of diffueser plates. Air is supplied to the diffuser plates by means of pipes connected to the air mainfold, r, running across the tanks. After the sewage has been sufficiently aerated and agitated in the tanks, it is allowed to flow back into the part of the trough, g, that is adjacent to the settling basin, s, by opening the valves for the inlets, l, in that part and inverting the incoming sewage from that part. The gates, t, leading to the adjacent trough, u, are also opened, and the sewage flows first into that trough and then through the openings, v, into the settling basins, s.

By means of the valves for the openings, v, and the gates, w, these basins can also be operated in parallel or in series. As the sewage enters a basin, s, a considerable amount of its sludge settles into the hopper, x, view (b); the remainder of the sludge settle on the sloping floor of the basin, from which it is scraped into the hopper by the apparatus, y. The clarified effluent flows over the weirs, z, into the effluent trough, a', from which it may be discharged into a stream.

The sludge in the hopper, x, rises through the pipes, b', to the sludge-overflow trough, c', from which it flows into the sludge-distributing manhole, d'. A part of the sludge is returned to the manhole, d, for mixing with the incoming raw sewage, and the remainder of the sludge is removed for further treatment.

The contents of an aerating tank may be emptied, when necessary, by closing the valves of the inlets, l, and opening the valves for the drains, e', that discharge into the pipe, f'. Then with the aid of an air jet, the sewage from the pipe, f', is forced into the drain mainhole, b, and from there back into the sewer, c. The pipes, g', and the valves, h', are used when it is desired to remove the sludge that settles in the furrows, o.

Spiral-Flow Tanks

Figure 10 is a cross-sectio of half of a Link-Belt Spiral-Flow Aeration Tank. The tank is divided into 4 compartments, a, each of which is 180 feet long, 18 feet wide and 12 feet

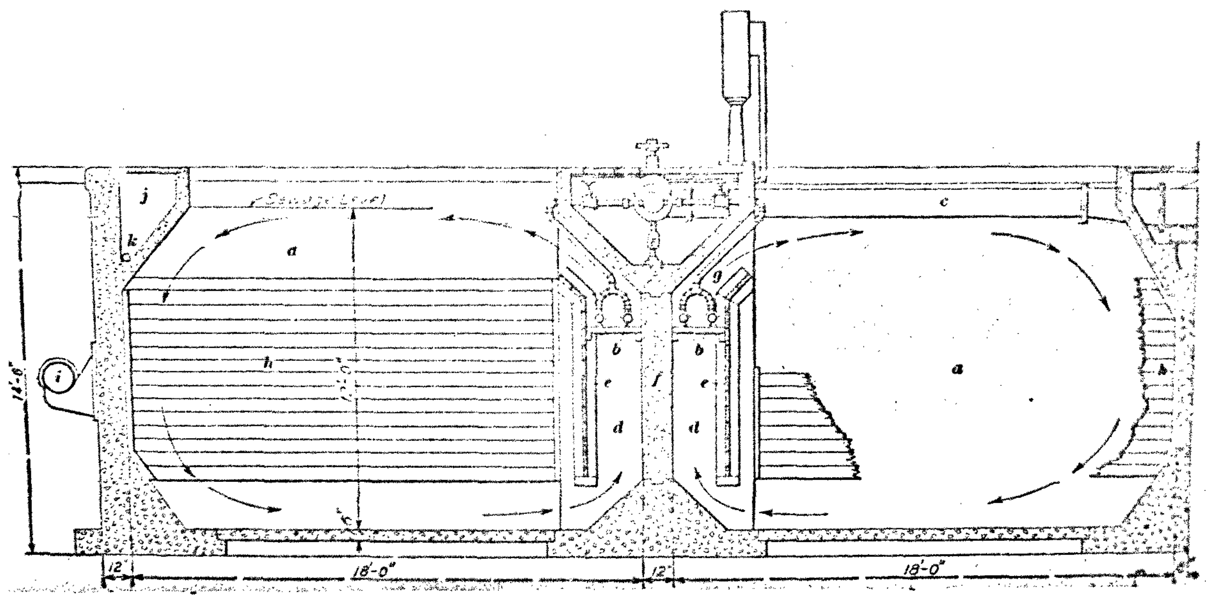

Fig. 10. Link-Belt Spiral-Flow Aeration Tank.

deep, and the compartments are connected in series so that the sewage flows through 720 linear feet of the tanks. Air is supplied to each compartment from two porous tubes, b, 3 inches in diameter, that extend the entire length of the compartment and are fed by the 12 inch air supply pipe, c. These tubes are located along one side of the compartment and about 4 feet below the surface of the sewage.

Also, the corners of the compartments are rounded or beveled. Hence, the air coming from the tubes gives the sewage a rotary motion, as indicated by the arrows; and since deep areas in the tank are eliminated, the deposition of the sludge is prevented. In combination with the normal longitudinal flow of the sewage, the rotary motion produces a spiral, or helical motion. The length of the actual path traveled by the sewage is considerable greater than the length of the compartment, and the efficiency of the air is thus increased.

The circulation of air in each compartment is maintained as follows: An air lift channel, d, is formed by means of the longitudinal wooden baffle, e, which is so placed that it is about 2 feet from the wall, f, and its bottom is a little less than 2 feet above the floor of the tank. Since the sewage above the tubes, b, is made lighter by the air bubbles, the heavier sewage below is constantly forcing an upward flow through the air-lift channel. The area of the channel is reduced slightly at the throat, g, in order to increase the velocity of discharge from the channel and, thus, to speed up the flow of the air and sewage across the top of the aerating compartment, a. Also to prevent short-circuiting in the flow of the sewage, four transverse baffle walls, h, are placed in each compartment, and the sewage must pass over or under these walls as it flows through the tank.

In this installation, a special arrangement is made to permit variation in the location of the point at which activated sludge is returned to the tank from the pipe, i. The part of the tank that precedes this point is utilized for preaeration of the incoming sewage. For the sake of economy in construction, the top portion of the outside wall is made hollow, thus forming a trough, j, which is covered to keep out rain-water, any moisture that may collect in this trough by the drain-pipe, k.

Mechanical Aerators

A mechanical aerator operates so as to produce surface aeration of the sewage by agitation and at the same time give the sewage a circular or helical motion. In one type of aerator, agitation and aeration are caused by a series of revolving paddles fastened to a continuous shaft. These paddles are located near the tank sid and at the liquid surface. As the paddles revolve, the sewage is agitated and given a spiral or helical motion. Sometimes compressed air is also supplied. The effect produced by equipment of this type is indicated in Fig. 11 in views (a) and (b).

The sewage already mixed with activated sludge, flows into the aeration tank, a, over weir, b. The mechanical aerator, c, is turned by outside power and causes a rotary motion in the sewage. This rotation and the horizontal flow give a helical motion to the sewage as it passes down the tank and flows out at "d." The sewage then enters a sedimentation basin, where the sludge settles out.

In addition, there are a number of surface aerators somewhat similar to the Simplex type, as shown in a cross-section in Fig. 12. Such aeration units are generally built in groups and arranged so that series or parallel flow through two or more units is possible. With this arrangement almost any desired degree of treatment is obtainable; and, if very low flows occur, units may be taken out of service. Each tank is usually square in plan and has a hopper-shaped bottom. In the center of the tank is a vertical uptake tube or pipe, a, through which the sewage is forced by an impeller and at the top of which it is discharged in a thin sheet or spray from a revolving head, b.

The Simplex aerator was developed in England, but similar

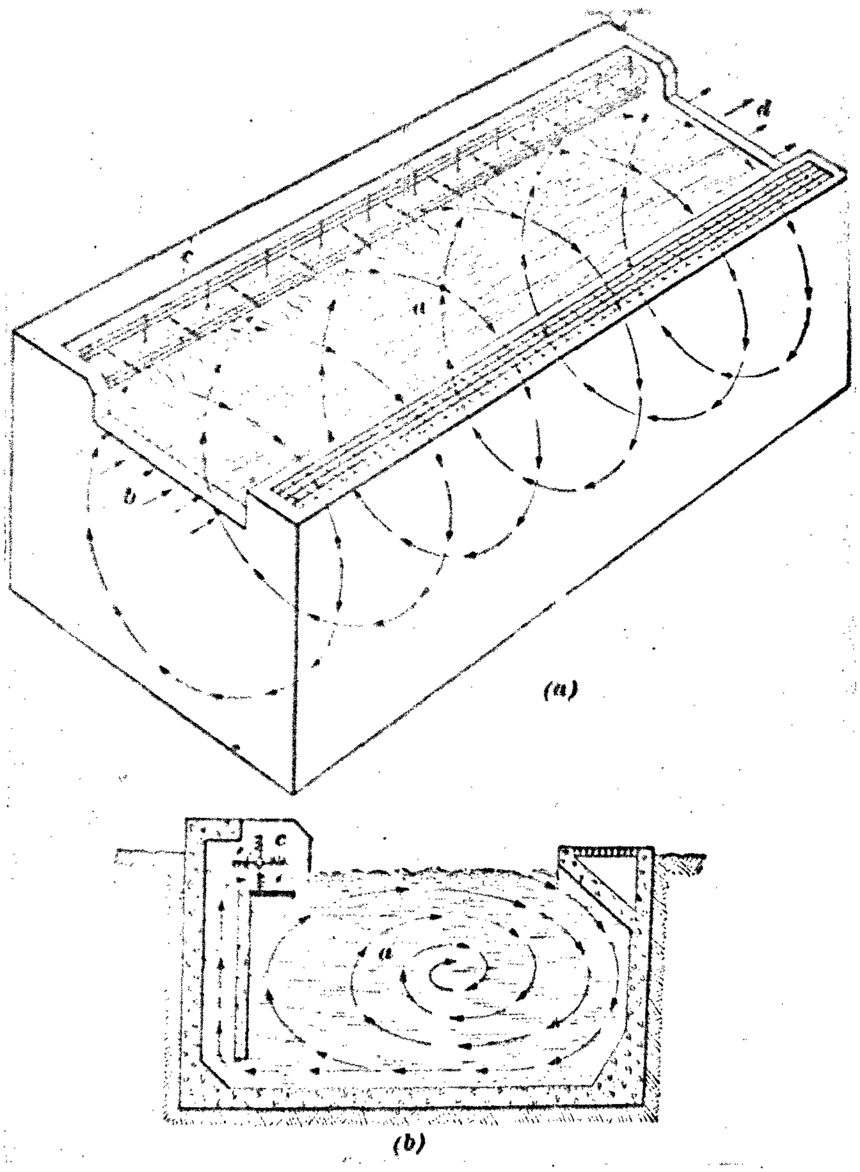

Fig. 11. Spiral-Flow Mechanical Aerator.

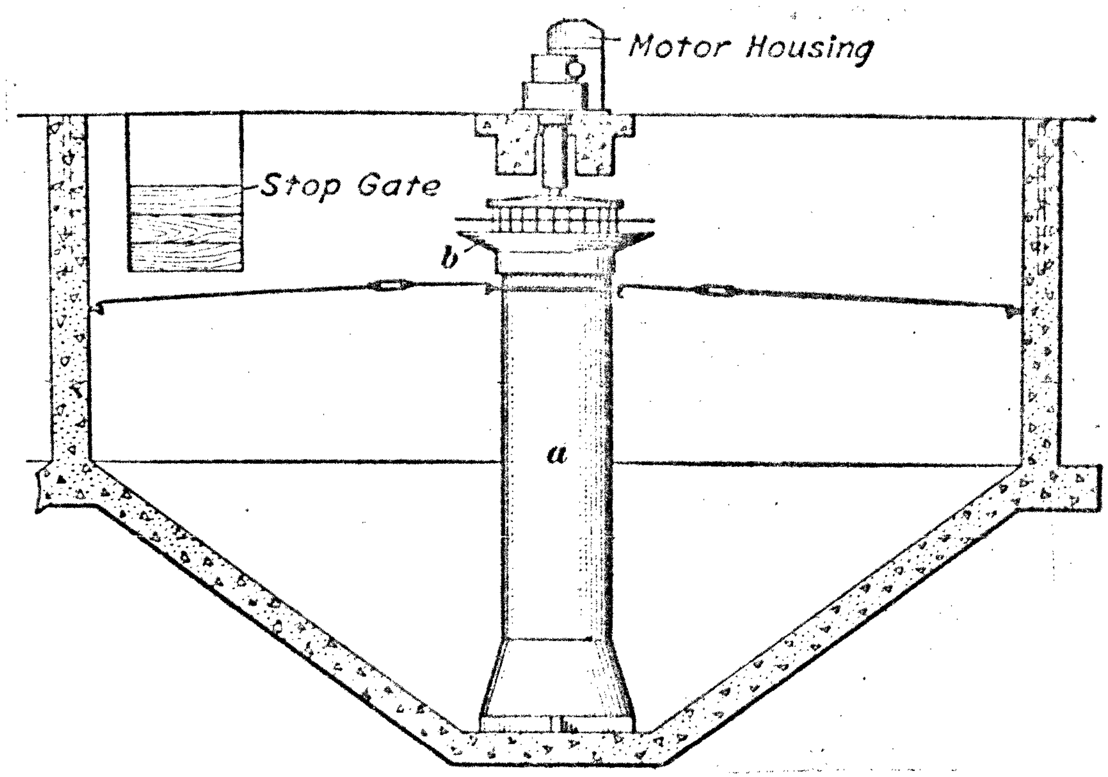

Fig. 12. Simplex Mechanical Aerator.

units are constructed in the U.S. by several manufacturers. Mechanical aerators are especially desirable for activated sludge plants handling less than 750,000 gallons/day. Draft-tube flow may be up or down. Various devices are used to insure good mixing and to aid in aeration.

Advantages and Disadvantages of Activated Sludge Process

One of the important advantages of the activated sludge process is the high degree of treatment that is possible. Where necessary, a highly-treated effluent which has a clear and sparkling appearance can be produced. The flexibility of treatment that is possible with the activated sludge process is another important advantage. This flexibility permits the production of an effluent in accordance with immediate needs by varying the period of aeration.

The disadvantages of the activated sludge process include the following: The relatively high cost of operation/million gallons of sewage; the skill of operation required; the adverse effects on operation of sudden increases in strength or volume of sewage and; the difficulties occasioned by the presence in the sewage of industrial wastes of certain types.

Trickling Filters

The sewage is applied to the surface of the bed in thin sheets or as a spray and trickles down through the stone to the underdrains beneath where it is collected and discharged through an outlet channel. Purification - or oxidation - is effected by bacteria that develop in a gelatinous film, the bacteira stabilizes the organic matter. The air in the gaps of the stones provides the necessary oxygen for the aerobic bacteria.

The construction of a standard type of trickling filter is shown in Fig. 13. Practically all recent installations employ rotary distributors, but other types of distributors have been used. The rotating distributor does not require outside power, but operates by the discharge of the sewage effluent under a very small head.

The distributor arms, a, are supported by diagonal rods, b, which are fastened to the vertical column, c. This column rotates on the base, d, that is connected to the inflow pipe, e. The sewage flows through the distributor arms and from there to the trickling filter by means of a series of flat spray nozzles, f, from which the liquid is discharged in thin sheets. The nozzles are staggered on adjacent distributor arms in order that the sprays will cover overlapping areas as the mechanism rotates. The bottom of the filter is underdrained by means of special blocks or half-tiles, g, which are laid on the concrete floor, h.

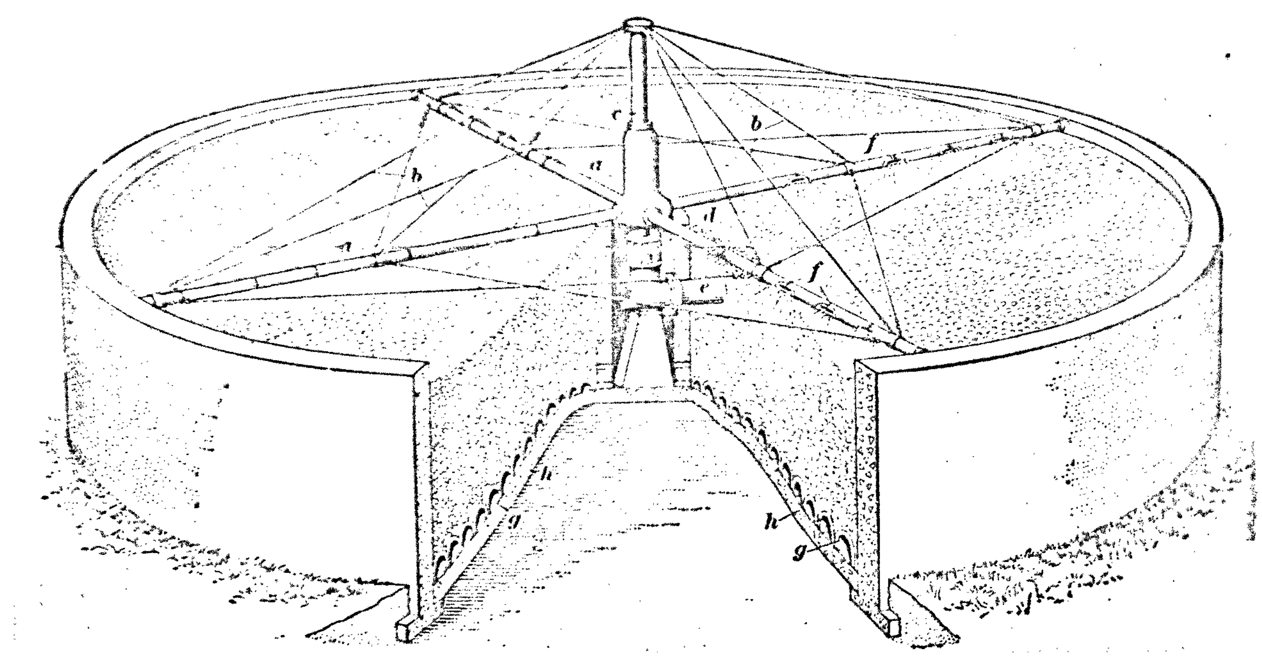

Fig. 13. Trickling Filter with Rotating Distributor.

Types of Filters

Trickling filters may be divided into two general classes which are commonly known as the Standard-Rate Filters and the High-Rate Filters. The principal differences are in the rate of application of the sewage per unit area of filter surface, the organic loading in terms of biochemical oxygen demand per unit volume of filter medium and the utilization in some high-rate filters of the principle of recirculating the filter effluent through the filter.

Standard-Rate Filters

The standard-rate filter, the only kind constructed in the U.S. prior to 1936, is deisgned for hydraulic loadings between 1-4 million gallons/acre/day (25-100 gpd/sq.ft.) of surface area and organic loadings of less than 15 pounds of BOD/1000 cu.ft. of media. This type of filter is usually 6-8 feet deep and may be rectangular or circular.

During normal operation a thick film develops in the standard-rate filter and very little sloughing occurs until a temperature change or a change in rate of flow causes large amounts of the slime to be discharged. This "unloading" normally occurs in the spring and fall. The humus from a standard-rate filter is usually quite stable, settles easily and is often heavily infested with worms. It has very little remaining BOD.

The effluent from a properly operating standard-rate filter which is treating an average domestic sewage is relatively stable, has little or no odor, is high in nitrates and contains almost no nitrites. It will be reasonably clear and should contain suspended solids in the order of 20-25 mg per liter and a BOD of about the same value.

The standard- rate filter is well known for its reliability and its ability to withstand shock loads and heavy overloads for considerable periods of time with a minimum effect upon its efficiency. Its simple operation has given rise to the thought by many that it is foolproof and needs no care at all. Unfortunately, the standard-rate filter has certain inherent disadvantages. For instance, the low rate of application make necessary large and costly filters per unit of sewage treated and requires large land areas for construction.

High-Rate Filters

Man is constantly trying to improve upon existing methods. Such efforts result in modifications, changes and progress. The improvement in efficiency and reduction of construction, as well as operating costs, are always definite advantages. In the same manner, continued efforts to improve the process have produced modifications of materials and operation practices that have resulted in the present day high-rate filters. In the high-rate filter, the rate of feed has been increased, the recirculation ratio increased, and the loading per unit of filter media has been stepped up. These changes are certain modifications of the standard-rate filter.

In depth of filter media, the high-rate filter, range from 3-8 feet, with most filters being 4-5 feet in depth. Because more water must flow down through the filter and more air must circulate upward through the bed, the size of the particles forming the bed is larger in the high-rate filter.

High-rate filters are dosed with a mucher heavier organic loading per unit of media than is the standard-rate filter, and the high-rate filter is shallower. This results in an effluent containing a higher BOD than the effluent from a standard-rate filter under similar conditions. To overcome this, the effluent from the filter is normally mixed with the effluent from the primary settling tank and returned to the filter for additional organic matter. The degree of treatment can, therefore, be regulated within limits by the number of passes through the filter.

Returning all or a portion of the filter effluent is called recirculation and is a characteristic of the high-rate filter system. The recirculated water may be settled or unsettled filter effluent, or it may consist of both types in the same system. The total recirculated flow, when compared to the raw sewage inflow, is known as the Recirculation Ratio.

The rate of adsorption of organic matter in a trickling filter is a function of the BOD concentration and the adsorbing capacity of the biological growth. The greater the rate of loading, the greater the rate of removal; there is, of course, a limit to the ability of the growth material to adsorb organic matter.

There are a few modifications of the basic principles of the high-rate trickling filter. These modified versions are:

1) The Aerofilter.
2) The Biofilter.
3) The Accelo-filter.

Aero-Filter

The Aero-Filter distributes the settled sewage to the filter surface by means of a special type of distributor arrangement which provides an almost continuous "raindrop" application. This is accomplished by increasing the number of distributor arms and speeding up the rotation of the distributor. It is estimated that sewage is being applied to approximately 20% of the filter area at any given time.

Unlike other high-rate filters, a deep filter bed is recommended for the Aero-Filter with little or no recirculation. Eight feet is recommended for two-stage filters with the minimum set at 6 feet. The second filter of a two-stage system may be as shallow as 5 feet.

Recirculation is not practiced at any time other than at low flow except where strong sewage requires dilution in order to maintain a high quality of effluent. Two-stage installations and recirculation are recommended for strong wastes or when a very low BOD content in the plant effluent is required.

Bio-Filter

The Bio-Filter is a process involving circulation and high-rate application to filters which are usually of shallow construction. The filters are normally 4-5 feet deep; and the recirculated sewage may be unsettled or settled effluent or a combination of both. In single-stage Bio-Filter plants, the usual plan of recirculation is from the final settling tank effluent to the incoming raw sewage stream. Such an arrangement requires that the settling basins be constructed large enough to provide the required detention for the combined plant flow and the recirculated flow. As in the other high-rate plants, two-stage treatment is recommended where strong sewage is to be treated, or if local conditions require a high quality effluent.

Accelo-Filter

This is a process based on the principle of direct return of filter effluent to the inlet of that filter or a preceding filter. It is claimed that the direct return of active aerobic organisms, continuously available to the incoming wastes, will result in intensified biological action. Advantages claimed are:

1. Smaller primary and secondary clarifiers are required because no recirculated sewage passes through either basin. This results in lower initial costs.
2. Reseeding the filter with viable filter organisms on a continuous basis accelerates biological action.
3. Higher dosage rates may be used.
4. Clogging and ponding are eliminated.
5. Continuous and uniform dosing reduces septicity and fly breeding.

Final Settling Tanks

The trickling filter removes only a relatively small percent of the solids that are applied to it in the effluent from the primary settling tanks. The principal function of the filter is to change the character of the suspended solids, rather than to remove the suspended matter. The suspended solids in the sewage applied to the filter are, in the main, finely divided and will not settle readily. As a result of oxidation in the filter, the solids are changed to a form which, being heavier and bulkier, will settle if passed through a tank.

Therefore, the effluent from a trickling filter should be treated by post-settlement to remove as much as possible of the suspended material. The extent to which the biochemical oxygen demand is reduced by settling depends largely on the efficiency of removal of the suspended solids. Adequate settling is therefore important. Secondary settling tanks are generally similar in design to primary tanks.

Contact Beds

Contact beds consist of tight tanks containing broken stone. The bed is filled with sewage, allowed to stand full for 1-2 hours, emptied and allowed to stand empty for 2-3 hours. Oxidation of the sewage takes place in the same general manner as in trickling filters, but the rate of operation of contact beds is much lower and the treatment given is not so effective.

The use of contact beds is limited to small institutions, as they are less efficient in operation and, generally, are more costly than are trickling filters. The contact material should comply with the same general specifications as stone for trickling filters. Siphons and time controls permit operation on any desirable schedule of filling, standing full and resting.

Intermittent Sand Filtration

Intermittent sand filtration is treatment of sewage by applying it at intervals to beds of sand that act as filters. By this process of treatment, purification is effected in two ways: First, by the bacterial action in the air gaps of the bed as the sewage passes downward; second, by the mechanical straining action of the sand. The oxidation and stabilization of the decomposable portions of the sewage is carried on by aerobic bacteria.

Since these bacteria work best in the presence of oxygen, it is necessary to apply the sewage to the bed of sand intermittently. Air is then taken into the gaps of the bed between doses of sewage. Also, it is usually necessary to underdrain the bed in order to insure quick removal of the liquids and to allow access of air to the interior of the bed. In some places, untreated sewage is applied directly to the sand beds, but in most cases, the grosser solids are removed from the sewage by screening or sedimentation and the effluent of this primary treatment is applied to the beds.

Under fsvorable conditions of construction and operation, a sand filter yields a final effluent that is practically pure and is not subject to decomposition. However, because of the large area of bed required for the treatment of a unit volume of sewage, this method of treatment is not practical for the needs of municipalities and is suited primarily for institutions and other small installations.

A sand filter consists essentially of a level bed of sand or gravel, a system of troughs or pipes for distributing the sewage over the surface and an adequate underdrainage system. Filters may be classed under two heads: Natural and Artificial. When a bed of sand or gravel is available at the necessary location and elevstion, a sand filter is obtained simply by removing the top soil and grading the bed.

However, there are few sections of the U.S. where the soils conditions are such that natural filters may be used. Artificial filters may be constructed anywhere. The operation and general construction are the same for both kinds of filters.

Construction of Filter Beds

The filter material is preferably a layer of clean, sharp sand with an effective size of 0.3-0.5 mm. Uniformity in the grading of the sand is advantageous. If the sand is composed of grains of different sizes with the finer sand as the top layer; otherwise, clogging will occur in the bed where it cannot be remedied easily. The depth of the sand layer varies from 30-42 inches. Underlying the sand is a bed of gravel to assist in underdrainage. Clay and loamy soils are not suitable for filters.

Area, Size and Shape of Filters

The area for the filter beds required for adequate treatment of the sewage of a community depends on the amount of sewage produced and on the degree of preliminary treatment. Under average conditions, it is feasible to apply to each acre daily from 75,000-100,000 gallons of sewage that has been partially clarified by screening and sedimentation.

The size and shape of the filter will be determined largely topographic conditions, but the operation must also be considered. The beds should not be so large that the plant will be crippled by taking one out of service, and the shape should be such that equal and uniform distribution of the sewage over the surface is possible.

Operation

In Fig. 14 are shown a plan and a section of a typical

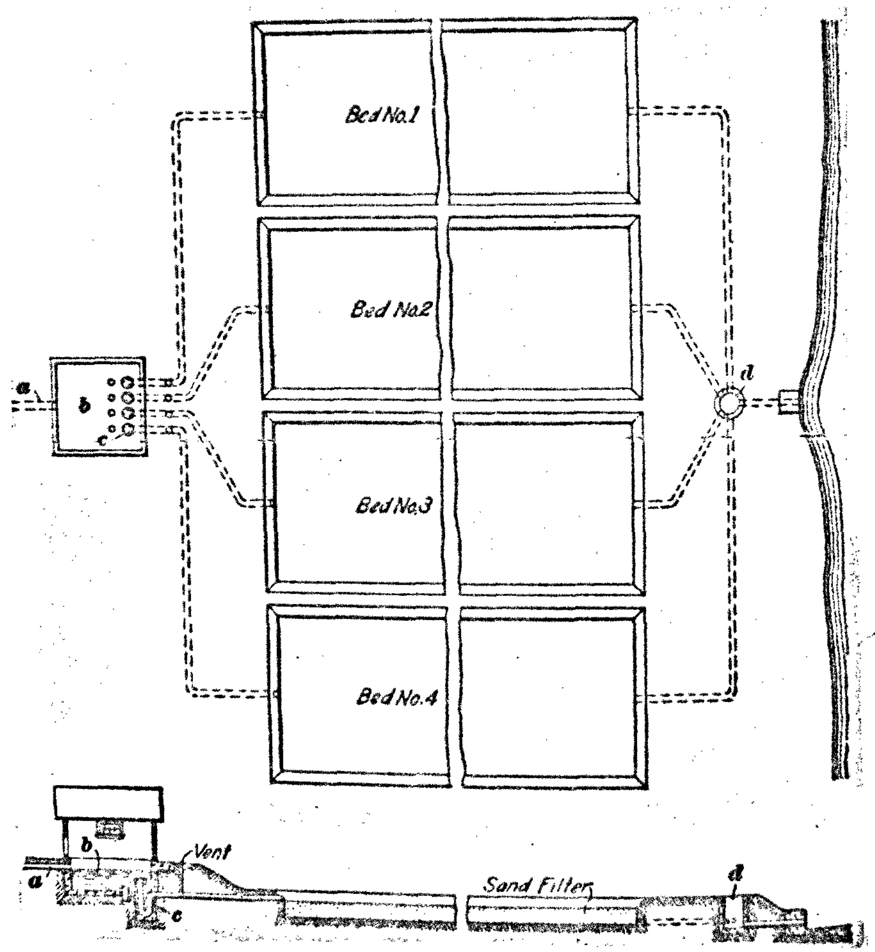

Fig. 14. Plant for Intermittent Sand Filtration.

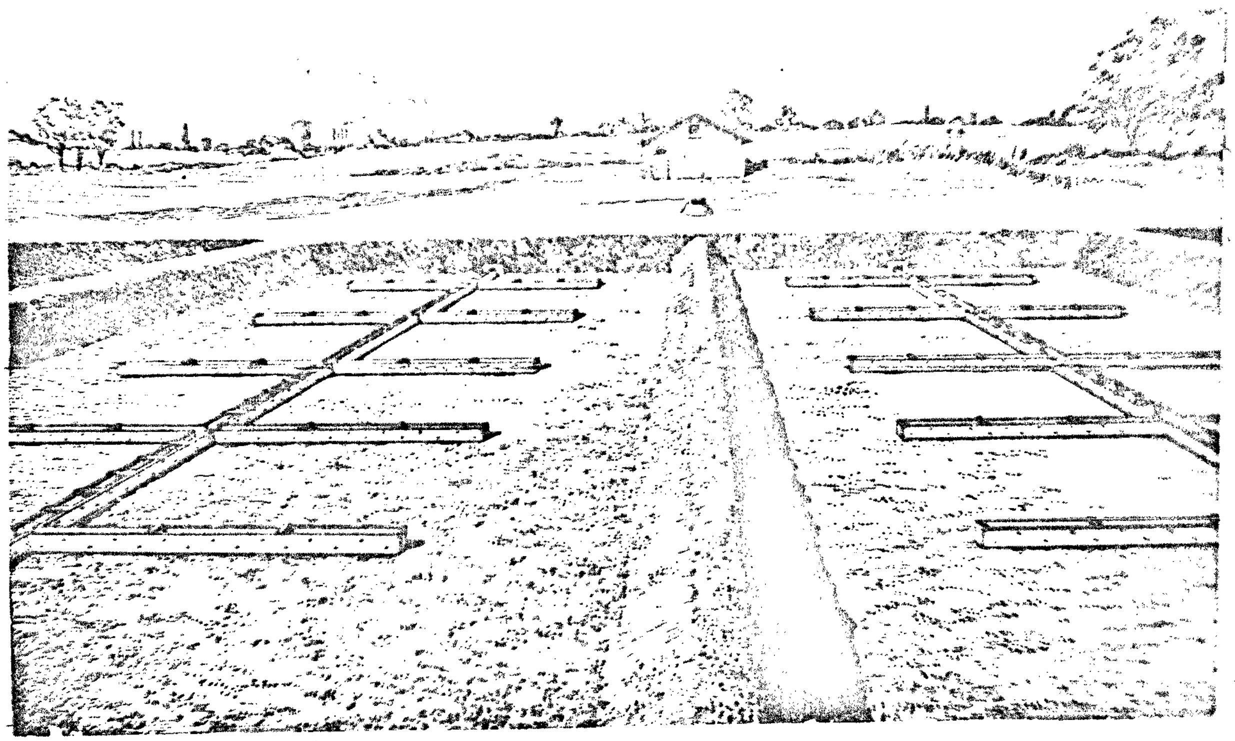

Fig. 15. Distribution System for Intermittent Sand Filtration.

plant layout with four beds. The distribution system and divisions between the beds are illustrated in Fig. 15.

The sewage flows from a settling tank through the inlet, a, into the dosing tank, b, which contains the siphons, c, for controlling the discharge to the beds. The effluents from all the beds is carried to the outlet, d, from where it is discharged into the stream.

Use of Sand Filters in Final Treatment

Sand filters are sometimes used as a final or polishing treatment, following trickling filters or coagulation and settling with chemicals, in order to obtain an effluent that has an attractive appearance and is free from suspended matter. Rates of application of treated sewage may be as high as 400,000-450,000 gallons/day/acre.

At such high rates, the straining action of the sand is most important, there being little oppurtunity for bacterial reduction of organic matter. Beds for these high application rates do not differ in construction from those previously discussed.

Special Types of Filters

Mechanical Sand Filters

A mechanical type of sand filter may be used in place of the sand beds for final treatment. The rate of filtration is $1\frac{1}{2}$-$2\frac{1}{2}$ gallons/minute/sq.ft. of filter surface. The sand bed is about 6 inches in depth. The desired characteristics of the sand depend on the type of effluent it is intended to handle.

In general, the use of such filters in the treatment of domestic sewage should be restricted to the filter effluents which have been settled. Rapid filters have extensive application in the treatment of industrial wastes. When they are used for such purposes, rates of filtration and sand characteristics will be determined by the nature of the waste and the degree of treatment desired.

Hays Process

The Hays Process is a method of treatment by contact aeration. Such a plant includes:

1. A preliminary sedimentation tank.
2. A primary aeration unit in which vertically supported asbestos plates are located over aerators.
3. An intermediate settling tank.

A final settling tank.

Oxidation Ponds

In areas of low rainfall, ponding may be utilized in place of secondary treatment. A number of such units are in service in the southwestern part of the U.S.. The sewage should be settled prior to ponding. A series of ponds - use of 3,4 or 5 appears to be preferred - with a total detention time of about 30 days.

CHEMICAL TREATMENT OF SEWAGE

The process of sedimentation in sewage can be materially aided by chemical precipitation. One or chemicals are addeed to the sewage and, by their reaction with the sewage, there is aformed a precipitate which settles to the bottom of the tank and carries with it much of the suspended matter. In some cases, chemicals are added in order to reduce the load on other processes.

When chemicals are added as coagulants in order to improve sedimentation, the degree of treatment obtained is better than that from plain sedimentation but is not equal to that from trickling or high-rate filters or the activated sludge process. The amount of suspended solids that settles out is greater than for plain sedimentation, but only a small proportion of the dissolved solids is removed by coagulation.

Perhaps the most favorable field for chemical treatment by coagulation is in those places where plain sedimentation provides sufficient treatment during parts of the year, but additional treatment is required during periods of low water or in the summer when bathing beaches must be protected. Chemical treatment of this type is also of value for extending the useful life of sedimentation tanks that are overloaded.

Chemicals Used in Precipitation and Their Chemical Reaction

The chemicals used for the coagulation of sewage include aluminum sulfate, ferric chloride, ferric sulfate and ferrous sulfate. Coagulation is accomplished in the case of aluminum sulfate by the formation of aluminum hydroxide; and in the case of an iron salt by the formation of ferric hydroxide.

Aluminum sulfate has the formula $Al_2(SO_4)_3$. It is obtainable in ground or powder form and is fed dry. It is readily handled and applied to the sewage, it is not corrosive and uniformly good results are obtained from it.

Ferric chloride is available as a liquid containing 39-45%, by weight, of ferric chloride; in crystals with the formula $FeCl_3$, $6H_2O$, which contains 60% of $FeCl_3$, by wieght; and in anhydrous form, which is completely water-free and contains 98% or more, by weight, of $FeCl_3$. It must be applied in the form of a solution through feeders of rubber, glass or other resistant materials because it is corrosive.

Ferric sulfate, which is available under a number of trade names, normally contains 20-25% of ferric iron. It is granular in form, but is soluble in water, and may be applied either dry or as a solution.

Ferrous sulfate, or copperas, comes in the form of greenish crystals, which are usually applied as a solution. When chlorine is added to copperas, the ferrous sulfate is oxidized to ferric sulfate, as follows:

$$6FeSO_4,7H_2O + 3Cl_2 = 2Fe_2(SO_4)_3 + 2FeCl_3 + 42H_2O$$

Hence, chlorinated copperas, which is copperas merged with a chlorine solution, has been widely used in chemical treatment.

The chemical reactions that are involved in the production of precipitates by the use of the various iron salts, when lime is used for adjustment of the pH value of the sewage, are given in the simplied forms:

1. The addition of ferric chloride and lime to the sewage results in the direct production of the insoluble ferric hydroxide, as follows:

$$2FeCl_3 + 3Ca(OH)_2 = 3CaCl_2 + 2Fe(OH)_3$$

2. The addition of ferric sulfate and lime also produce results in the formation of the insoluble ferric hydroxide, as follows:

$$Fe_2(SO_4) + 3Ca(OH)_2 = 3CaSO_4 + 2Fe(OH)_3$$

3. The addition of chlorinated copperas and lime also produces the same results as in 2.

4. The addition of ferrous sulfate and lime to the sewage results in the production of the soluble ferrous hydroxide, as follows:

$$FeSo_4 + Ca(OH)_2 = CaSO_4 + Fe(OH)_3$$

5. The addition of oxygen to the sewage, in the form of minute bubbles and atmospheric air that is absorbed, converts ferrous hydroxide into the insoluble ferric hydroxide, as follows:

$$4FeSO_4 + 4Ca(OH)_2 + O_2 + 2H_2O = 4CaSO_4 + 4Fe(OH)_3$$

The volume of air required for the oxidation of the ferrous hydroxide to the ferric hydroxide depends largely on the efficiency of the aerating mechanism used.

6. It is also possible to produce a solution of ferrous chloride in the treatment plant by passing chlorinated water through towers containing scrap iron. Thus,

$$Fe + Cl_2 = FeCl_2$$

Approximately equal amounts of chlorine and iron are required to produce ferrous chloride. The control of the rate of production consists merely in varying the rate at which chlorine is fed into the towers. If more chlorine is added, ferric chloride should be formed. In practice, it is difficult to produce ferric chloride by this method.

7. The addition of lime and ferrous chloride results in the production of the soluble form of ferrous hydroxide, and by adding oxygen to the sewage, this is converted to the insoluble ferric hydroxide, as follows:

$$4FeCl_2 + 4Ca(OH)_2 + O_2 + 2H_2O = 4CaCl_2 + 4Fe(OH)_3$$

8. When aluminum sulfate is used, the amount of natural alkalinity present in the sewage in the form of bicarbonates is normally sufficient to complete the reaction, and lime is not needed. So,

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 = 3CaSO_4 + Al_2(OH)_6 + 6CO_2$$

No matter which chemical is used, an excess of alkalinity, or a high pH value, may interfere with coagulation, as the floc may be redissolved or otherwise affected. The application of carbon dioxide or an acid, or the recirculation of part of the effluent may help to overcome the difficulty.

Selecting and Applying the Chemical

Actual experiments with the various coagulants should form the basis for the selection of the chemical to be used. The results of the test, in combination with the cost of the chemicals, will indicate the choice. Other factors may include the size of the plant, the proportion of time during which chemicals are used, the character wastes, the water supply, the layout of the plant, the type of supervision available and the degree of treatment necessary.

It is important that every particle of sewage come in contact with the chemical. Thorough, but not violent, mixing of the coagulating chemical with the sewage is desirable in order to obtain economy in chemical dosage. Also, comparatively gentle mixing is generally necessary in order to obtain a floc, or coagulum, that is large enough to settle. After the floc has been formed, provision must be made for a quiescent period, during which the floc can settle and carry down with it the suspended matter in the sewage.

Feeding Chemicals

Ferrous or ferric sulfate may be applied to the sewage equally well in solution or dry; but ferric chloride is best fed in solution, and aluminum sulfate is preferably fed dry.

A large variety of satisfactory devices are available for feeding coagulants, either dry or in solution. Some of these devices can be connected to controls, such as weirs, which make the rate of feed of chemical proportional to the flow of sewage. Also, there has been developed a pH meter, which gives a continuous record of the pH value of the sewage and adjusts the dosage to correspond to fluctuations in the alkalinity.

When choosing a feeder, regardless of the type, consideration should be given to the amount and kind of chemical to be fed; the relative importance of accuracy, the space available and the cost. Reliability and assurance of uninterrupted service should also be considered.

Improving Sludge Digestion with Chemical Admixtures

The most favorable range of pH for sludge digestion is from 6.9-7.2. When the pH value is less than 6, the sludge digests slowly, sometimes with odor and dries poorly on beds. Lime is frequently added to raise the pH value and thereby improve digestion.

Activated carbon has also been successfully used for this purpose in a limited number of plants. When 15-30 pounds of activated carbon per million gallons of sewage is added to the sludge at the entrance to the digestion tank, it has been shown that digestion is stimulated, the production of gas is increased, the temperature of the sludge in the tank is raised and the drying quality of the sludge is improved.

SLUDGE DIGESTION AND MOISTURE

The solid material that settles when sewage is passed through a settling tank or clarifier is called Sludge. The sediment removed from the primary settling tanks treating raw sewage is called Raw Sludge, and that from secondary settling tanks is called Secondary Sludge. Removal of the sludge from a primary or secondary tank is accomplished in the following manner: A collector or scraping mechanism, scrapes the sludge into a sump at the inlet end of a rectangular clarifier or at the center of a circular clarifier. The sludge is then removed from the sump for further treatment either by pumping or by hydrostatic pressure.

Raw sludge is quite odorous, highly decomposable and of the consistency of thin mud. It is extremely obtionalbe and treatment is difficult because it cannot be dried on beds and is not readily dewatered by vacuum or pressure filters. Secondary sludge, although less objectionable than raw sludge, is also decomposable and needs further treatment.

The solid matter in raw sludge drawn from primary settling tanks ordinarily does not exceed 5%, the remainder being water. The moisture content of sludge is highly important, because a sludge with 1% of solids, for the same volume of solids, is 5 times as voluminous as a sludge that has 5% of solids. For a smaller percentage of solids in the sludge, greater hopper space is required in the clarifier, the sludge pump must be run for longer periods, and final treatment of the sludge is more difficult.

Sludge resulting from the activated-sludge process is more voluminous than that from any other sewage treatment method, averaging perhaps only 1% of solids. Sludge resulting from plain sedimentation or chemical treatment may contain from 2-4% of solids. Local conditions here highly important. The frequency of operation of the sludge-collecting devices and the frequency of sludge removal from settling tanks also have an effect on the solids content.

Methods of Treating Sludge

The usual, and generally the most economical and satisfactory method of treating sludge is by digestion; but, in a few places, raw sludge is dewatered by means of vacuum or pressure filters. Digestion is carried on in enclosed tanks, which are usually heated to facilitate the process of digestion. The digestion process results in a complete change in the character of the sludge. The objectionable organic solids are converted to a stable, mineralized form, which is odorless, dark brown and relatively easy to drain and dry. In this form, the sludge may be dried on sand beds without nuisance or may be readily dewatered by means of a vacuum or pressure filter.

<u>Types of Sludge Digestion Tanks</u>

Standard types of sludge-digestion tanks are cylindrical in shape, as shown in Figures 16 and 17. Each tank is covered and is equipped with coils through which hot water is circulated to maintain a temperature of 90° F. In the cover, provision is made to collect the gas given off during digestion.

Most digestion tanks are equipped with other devices for aiding in operation, including devices for stirring or mixing the sludge to promote digestion, devices for sampling the sludge, thermometers for measuring the temperature of the interior of the tank and meters for measuring the amount of gas produced.

In the process of digestion, the ability of the sludge to hold moisture is reduced, and water is released. This water, which is turbid and discolored, is termed the <u>Supernatent Liquid</u>. An overflow for the supernatent liquid is provided in the digester, and this liquid is discharged into the sewer which enters the plant.

Operation of a Single-Stage Digester

In Fig. 16 is shown a cross- section of a single-stage digestion tank. The sludge to be digested is admitted to the tank through the pipe, a, and digested sludge is drawn off through the pipe, b. During the digestion process, the sludge releases some of its moisture, and the supernatent liquid is drawn off through one of the outlets, c. There is also produced a large volume of gas, which is collected in the gas dome, d, and is withdrawn through the pipe, e.

Digestion of sludge is usually stimulated by heating the sludge. Heat is furnished by passing hot water through a series of coils, f, circumferentiall around the tank. Samples of submerged sludge can be collected through the sampling well, g; samples from the part of the tank just below the cover can be obtained through the well, h; and samples of the supernatent liquid that is being withdrawn from the tank can be collected from the small pipes, i.

It is desirable to add fresh sludge at least once a day, and gas is produced at a more uniform rate if the sludge is added in small amounts slowly and at frequent intervals. Digested sludge should be withdrawn at weekly intervals. The supernatant liquid should be drawn from the portion of the tank in which the solid content is least, and the a-

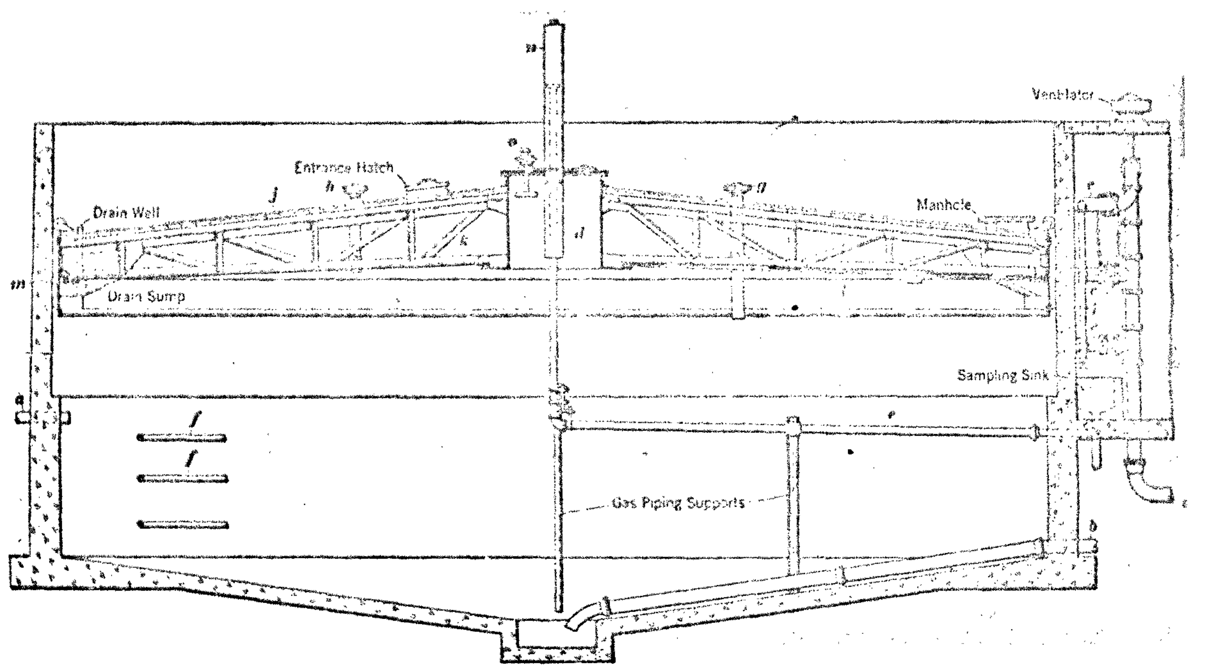

Fig. 16. Single-Stage Digestion Sludge Tank.

mount withdrawn at one time should be that contained in about 1 foot of depth of the tank.

In this type of tank it is found that effective circulation of the sludge particles is obtained by the action of the gas released. It is, therefore, considered unnecessary to stir the contents of the tank; however, some digesters are equipped with mechanical stirring devices. Also, all surface scum is kept submerged.

Operation od a Two-Stage Digester

In order to obtain a clearer supernatant liquid, sludge is frequently digested in two stages, as indicated in Fig. 17. When two-stage digestion is practiced, all of the sludge is put in the primary digester, partly digested sludge and supernatant liquid are transferred, from time to time, to the secondary digester; and digested sludge and clearer supernatant liquid is withdrawn only from the secondary digester. The total cost with two-stage digestion need not be greater than for two tanks operated in parallel.

Although it is the usual practice to provide heat in both digesters, the temperature of the secondary digester is kept 15^{o}-20^{o} F lower than that of the primary tank. As indicated in Fig. 17, the primary tank, a is smaller than the secondary tank, b. Transfer of partially digested sludge to

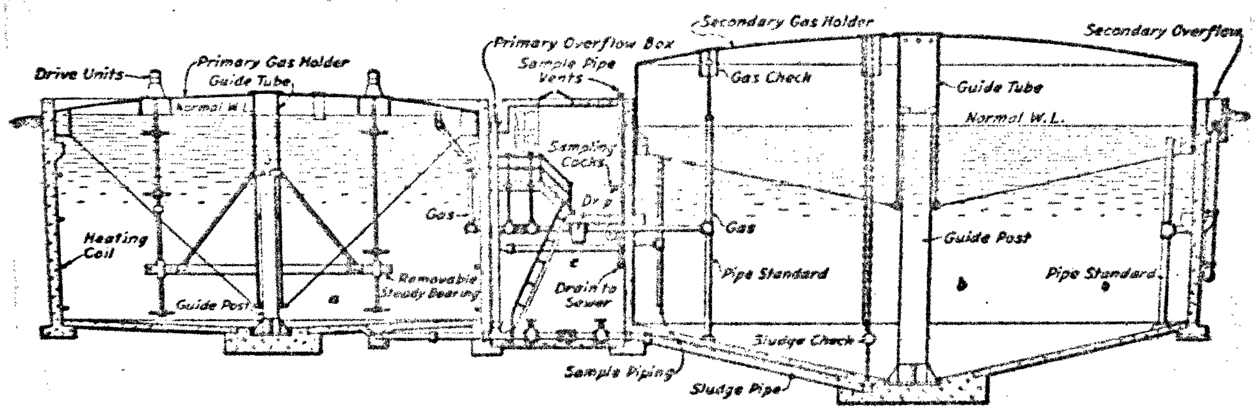

Fig. 17. Dorr Two-Stage Digestion Sludge System.

the tank, b, is accomplished by thepipe, c. Means for stirring the sludge is provided in the primary tank.

Size of Digestion Tanks

The size of a digestion tank depends on the amount of sludge it must handle. Heated tanks for digesting primary sludge should normally provide a capacity of $2\frac{1}{2}$-3 cu.ft. per person contributing the sewers. Unheated tanks should not be used, except for very small installations or under most unusual conditions; if an unheated tank is used, its capacity should be at least 50% greater than that for a heated tank.

Where the activated-sludge process or chemical precipitation is used, the capacity of the digestion tank should be about 50% greater than for a tank handling primary sludge. Where standard-rate or high-rate trickling filters are used and sludge from the secondary settling tank must also be digested, the capacity of the tank should be at least 25% greater than a tank handling primary sludge.

Digestion tanks are normally 20 feet in depth, but the depth may be less for small plants or more for large plants. The number of tanks and approximate diameter of each are fixed by the capacity that must be provided and the depth selected. Except in very large plants, it is usual to provide more than two dugesters, and a single digester is used.

Floating Covers

Digesters usually have floating covers. One type of floating cover is shown in Fig. 16. This cover normally rests on the supernatant liquid in the tank; but, when it is in its lowest position, it is supported either on a continuous ledge or on a number of brackets extending from the wall. The roof covering, j, is supported by steel trusses, k, the lower members of which carry the ceiling plate, l. The roof covering and the trusses are designed for a dead and roof load of 35 lbs./sq.ft..

A rim plate, m, extends from about 3 inches from the top of the cover to about 2 feet below the ceiling plate. This rim plate entraps all gas produced beneath the cover and affords support to the guide bearings. The floating cover maintains at all times a constant gas pressure that is sufficient to feed the burners. In order to permir movement of the cover with respect to the gas pipe, e, a housing, n, is attached to the cover.

A pressure vacuum relief unit, o, is provided to prevent accumulation of gas beneath the ceiling plate in case the pipe, e, becomes clogged, and to prevent excessive vacuum loads on the cover in case material is withdrawn from the tank after the cover has dropped to its lowest position.

Insulating Digestion Tanks

If the digestion tanks are insulated, heat is consumed by keeping radiation losses at a minimum. Placing earth against the sides, and in many cases, also on top of the digester. A brick or tile veneer placed on the outside of the digester wall so as to provide a narrow air space between the brick or tile and the concrete is as efficient as earth banking, and it is advantageous in permitting more attractive construction.

Sludge Thickening

It is generally desirable to have the solids content of sludge as high as possible. An intermediate stage in sludge disposal is thickening, or the reduction of the moisture content. To accomplish this, the sludge is placed in a tank that is equipped with revolving raking arm. The slow passage of these arms through the sludge stirs it gently and releases the entrapped gas and also some of the water, which is drawn off.

Beds for Drying Digested Sludge

The most usual method of drying sludge is on sand beds, which may be either covered or uncovered. Uncovered beds should provide 1-2 sq.ft. per person contributing sewage to the plant. The type of treatment and the geographical location affect the area required per person. There should be several beds, or partitions in large beds, to permit frequent withdrawals of sludge.

Uncovered sludge beds are usually surrounded by a low concrete wall or by an earth embankment. Digested sludge is normally conveyed to the bed through a pipe leading from the digester, valves being provided to permit application to any desired bed. Beds are usually sloped slightly away from the point where the sludge is applied, in order to facilitate the flow of sludge to the distant portions of the bed.

Sludge dried on beds is sometimes ready for removal in 10 days, but it may be left for 3-4 weeks depending on the character of the sludge and the weather. Enough sludge is applied to a bed to make a deposit of 8-12 inches deep. Also, when sludge is ready for removal, it will normally contain about 70% of moisture.

Vacuum Filtration

Figure 18 illustrates one type of vacuum filter plan for dewatering sludge. The incoming sludge flows from the sludge elevator, a, into the tank, b, in which it is kept at a predetermined level; and the revolving drum, c, is so supported in the tank that only the lower quadrant is submerged in the sludge. As the drum revolves, a vacuum is maintained within it by means of the vacuum pump, d, and the liquid that is thus drawn into the drum from the sludge is raised by the filtrate pump, e, and conveyed through the pipeline to any desired plant.

Meanwhile, the sludge on the drum is carried through part of a revolution and is then discharged onto the belt conveyor, f, or into a suitable container. There are several types of vacuum filters, all of which work on the same principle.

Chemical Conditioning of Sludge

Before sludge is admitted to a vacuum filter, it is usually treated with iron salts or aluminum sulfate in order to facilitate the process of dewatering. Ferric chloride greatly increases the filter capacity. The drying of sludge on sand beds is quickened considerably by the addition of ferric chloride at rates of 2-6 lbs./100 lbs. of dry solids, or of aluminum sulfate at somewhat higher rates.

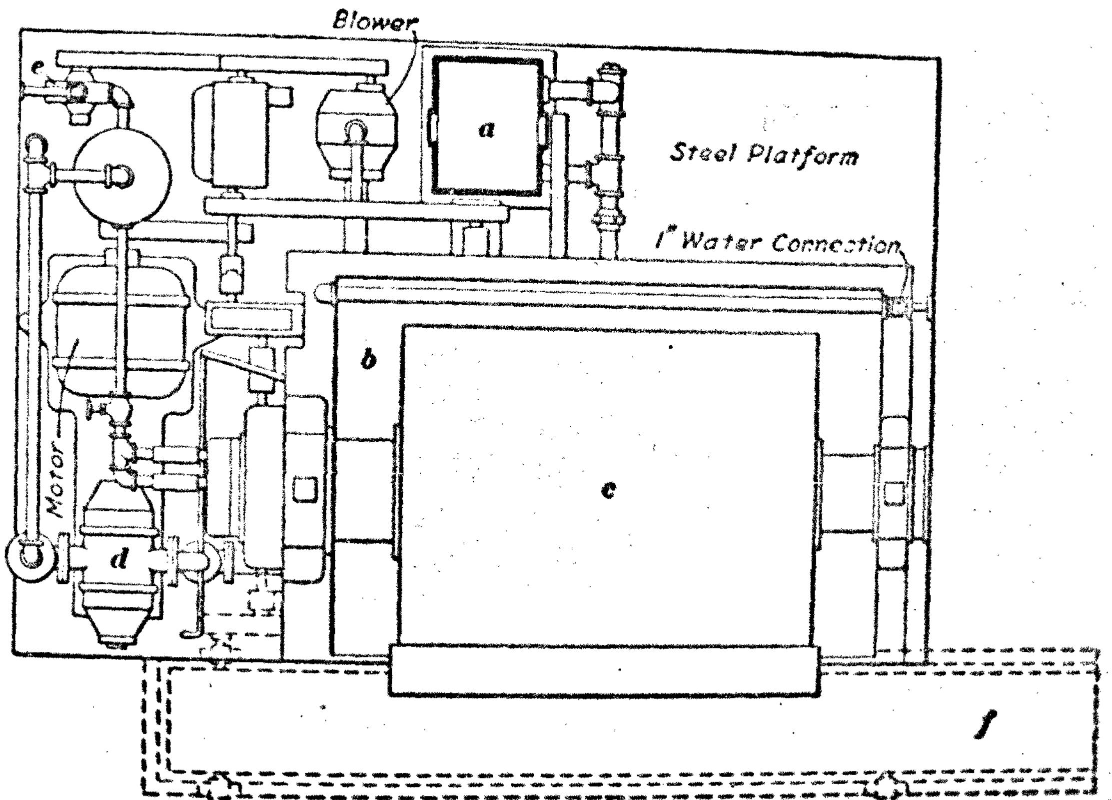

Fig. 18. Oliver Vacuum Filter.

Elutriation of Sludge

By diluting the sludge with one, two or more volumes of pure water, allowing the sludge to settle, and then decanting the supernatant liquid, the effectiveness of coagulants in conditioning the sludge for vacuum filtration is greatly increased.

Other Methods of Dewatering

Mechanical presses and centrifuges are also used to dewater sludge, but not to any considerable extent. There have been developed a number of centrifuges, which rely on the principle of centrifugal separation of solids from liquids, but none of the have proved capable of satisfactory operation on a plant scale at more than a very limited number of installations. Filter presses have also been used for many years in a few places, but do not seem to be adaptable to modern demands.

CHLORINATION OF SEWAGE

Chlorine compounds are practicall the only chemicals used for disinfecting sewage, and they are used for a number of other purposes as well. Chlorination reduces the number of bacteria in sewage effluents and is provided as a final treatment in many plants. Complete sterilization is not possible and, even with chlorination, sewage contains some bacteria.

Other uses of chlorine in sewage treatment include the following:

1. For the control of odors, by preventing the formation of hydrogen sulfide, by reducing the amount of hydrogen that is being rpoduced, or by neutralizing the hydrogen sulfide that has been formed.
2. For the reduction of BOD.
3. For the elimination of ponding in tricklind filters; for the control of trickling filter flies; and, in combination with other chemicals, for the formation of the floc in coagulation.

Chlorine is a gas at ordinary atmospheric pressures; but, when subject to high pressure, it becomes a liquid. It is usually shipped in liquid form in containers of variuos sizes. Small plants use the 100-150 lbs. containers and large plants use the one ton containers. It is also available in the form of a powder known as hypochlorite of lime, or bleach. In this form the powder contains about 30% of available chlorine when fresh. However, the percent varies and the hypochlorite of lime gradually loses its strength. Another form of hypochlorite, called high-test hypo, contains about 65% of available chlorine and retains its strength indefinitely.

Methods of Applying Chlorine

Where liquid chlorine is used, the container is attached to a machine, called a Chlorinator, which takes the chemical out of the cylinder, meters it and delivers it to the raw sewage or effluent. The chlorine is in the form of a gas when it enters the chlorinator, as the relatively high pressure in the cylinder is not maintained in the chlorinator.

There are two general types of chlorinators: the Solution-Feed Chlorinator and the Direct-Feed Chlorinator. By means of a solution feed machine, a measured quantity of chlorine is mixed with a definite quantity of water before it is conducted to the point of application in the treatment plant. With a direct-feed chlorinator, a measured quantity of the chlorine is fed directly into the sewage or effluent without being previously mixed with water.

When of hypochlorite of lime is used, the powder is mixed with water, the lime particles are allowed to settle out, and the mixture of chlorine and water is fed to the sewage at the desired point. Hypochlorite is seldom used for disinfection in sewage-treatment plants because liquid chlorine is cheaper and can be more easily applied.

Solution-Feed Chlorinator

Figure 19 illustrates a solution-feed chlorinator designed to operate under a small vacuum in order to minimize the possibility of leaks. The stream of water enters at "a" and passes through a valve, b, which reduces the pressure to about 25 psi and maintains a constant rate of flow. Just under the vacuum jar, c, the water passes through an injector. The suction thus created is transmitted to the inside of the jar, c, which stands in a tray, d, partly filled with water; and the vacuum inside the jar causes the water level in it to rise above the water level in the tray. This movement of the water surface opens a float valve, e, which allows the chlorine to enter the jar through the connection, f, and the pipeline, g.

As the injector produces a suction, chlorine gas is withdrawn from the jar to the injector and is there mixed with the water. The chlorine solution thus formed is conveyed through the pipe, h, to the sewage to be chlorinated. The meter, i, indicates the rate of flow of the chlorine; "j"

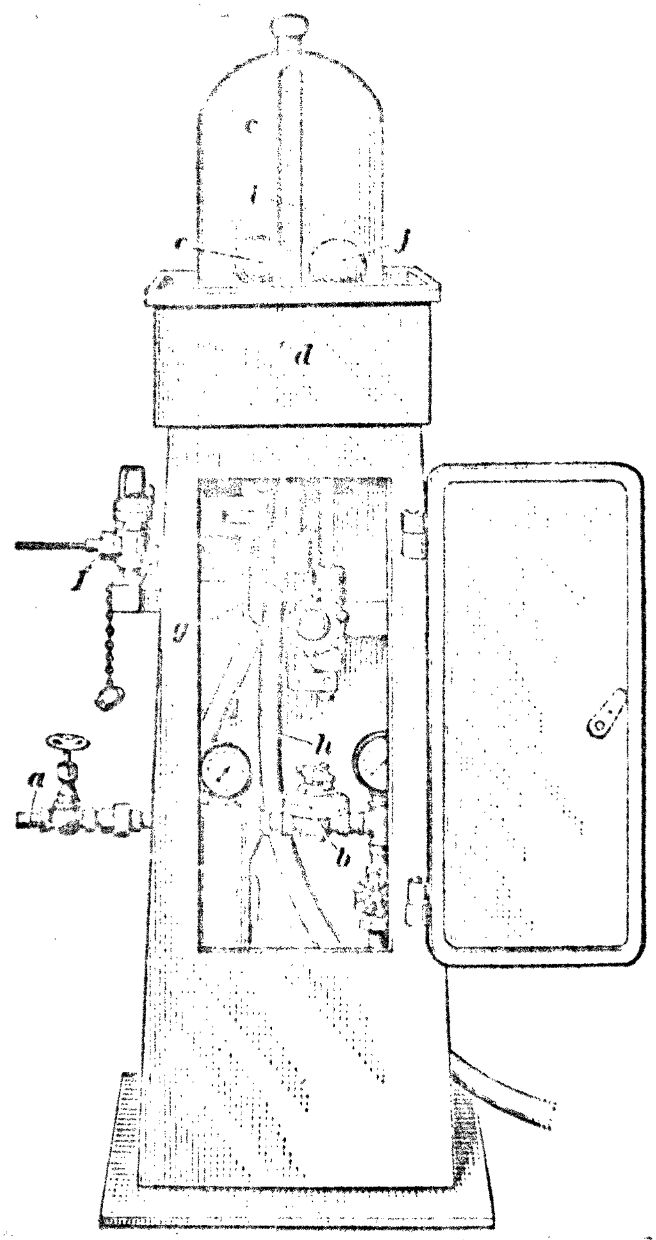

Fig. 19. Wallace and Tiernan
Vacuum-Feed Chlorinator.

is an automatic relief valve, which limits the water level in the vacuum jar.

Direct-Feed Chlorinator

Figure 20 is a view of a direct-feed chlorinator. The chlorine flows from the storage tank through the tubing, a, to the chlorinator where it first passes through a compensator, b, and a control valve, c. Once the control valve is set for a certain flow, the compensator maintains the flow regardless of temperature or pressure changes in the inlet line. Then the chlorine passes the orifice meter, d, which is connected to a manometer, e, that indicates the rate of flow directly. The gauge, f, shows at all times the pressure in the tank of chlorine and the gauge, g, indicates the pressure within the chlorinator.

After the chlorine passes through the meter it is forced through the shut-off valve, h, and into the sight glass, i. This shut-off valve, h, permits the metering device to be disconnected from the sight-glass, i, in case the apparatus is to be put out of service for some time. The sight-glass, i, is filled with anti-flooding material which prevents moisture from coming in contact with the chlorine that remains within the apparatus when it is taken out of service.

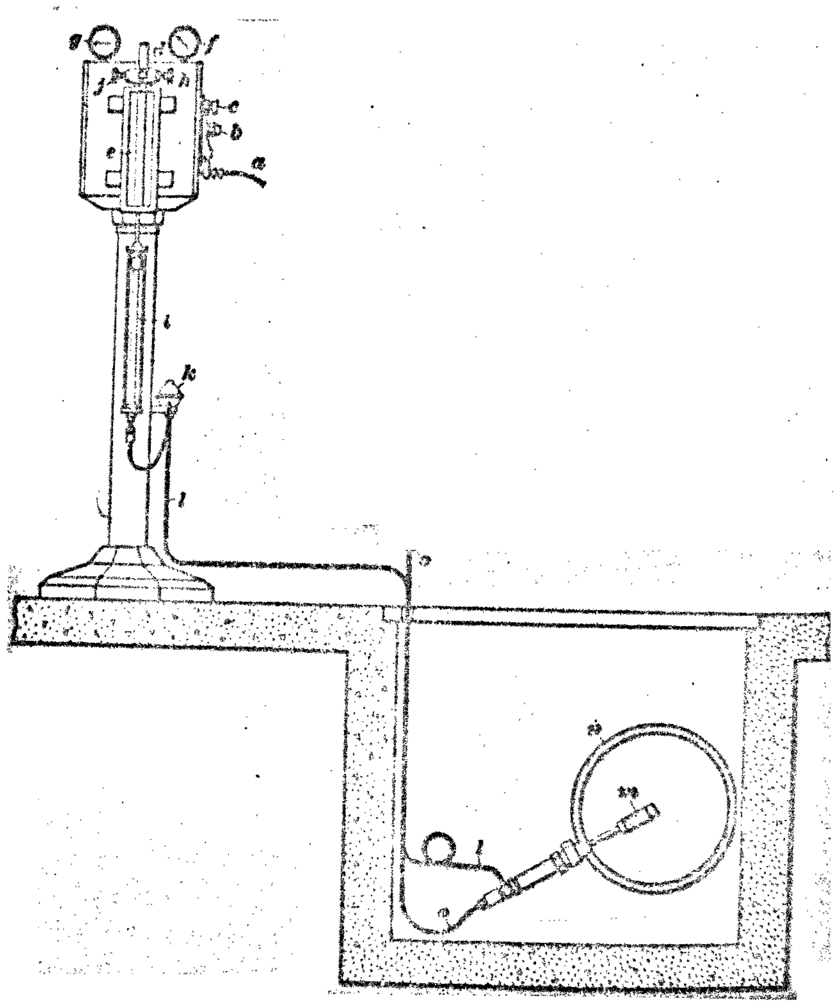

Fig. 20. Wallace and Tiernan Direct-
Feed Chlorinator.

Ther is also a blow-off valve, j, to relieve the pressure within the chlorinator when any of the various parts must be disconnected. The chlorine passes from the sight-glass to the back-pressure valve, k, and from there through a silver tube, l, to a special, diffuser, m, within the sewer, n. This diffuser is heated by electricity which is carried in the rubber-covered cable, o.

Hypochlorinators

At small plants and for special purposes hypochlorinators are used. These devices are designed to feed small amounts of chlorine solution. There are several varieties of these feeders, but the most usual type consists of a small pump which is provided with an adjustment that controls the length of the storke of the pump piston and the amount of chlorine solution delivered.

By regulating the strength of the chlorine and the length of the piston stroke, rates of feed over a wide range may be accurately adjusted. To prevent corrosion due to the action of the solution, the pump has a rubber-lined cylinder or a flexible rubber diaphragm.

Methods of Chlorination

Chlorine may be added to the plant effluent to reduce the bacterial count and to lower the BOD. Such application is termed Post-Chlorination. Chlorine may also be applied to the sewage as it enters the settling tank for the purpose of retarding biological action in the tank and, thus, producing an effluent that is relatively fresh. This method of application is known as Pre-Chlorination.

It is sometimes advisable to dose the raw sewage and the plant effluent; this procedure is called Split-Chlorination. With split-chlorination, the total amount of chlorine required for treatment is greater than the amount required for post-chlorination alone; but, because some of the chlorine applied to the raw sewage is carried through the settling tank, the final dosage required for satisfactory post-chlorination is less than the dosage for post-chlorination alone would normally be.

Contact Tanks

When the application of chlorine is the final treatment at a plant, as where chlorine is added to the effluent from a settling tank at a primary treatment plant, or to the effluent from trickling filters, it is usually necessary to provide some means for thorough mixing the chlorine with the effluent before final discharge from the plant.

Required Amounts of Chlorine

Disinfection

The amount of chlorine that should be applied to sewage to destroy bacteria depends on the strength, the freshness and other characteristics of the sewage and on the amount of treatment already given to that sewage. In general, the required dosage is much smaller for fresh sewage than for stale or septic sewage. Doses of chlorine are measured in parts per million (ppm), a dose of one part per million of chlorine for 1,000,000 gallons of sewage being 8.34 pounds/gallon.

Wehre chlorine is applied for the purpose of disinfecting sewage, the required amount of chlorine for any particular case is usually determined by the desired chlorine residual. For a chlorine residual of 0,2-0.5 ppm, the total dosage of chlorine ordinarily ranges from 18-25 ppm for raw sewage, from 10-18 ppm for effluents from trickling filters or contact beds; 15-20 ppm for effluents from settling tanks and from 6-12 ppm for effluents from sand filters.

Reducing BOD

By destorying nearly all the bacteria in sewage, chlorination not only disinfects the sewage to a considerable degree, but also retards the normal processes of decomposition of organic matter and extends the length of time during which the effluent from the sewage treatment plant will remain stable after being discharged into the receiving stream. The use of sufficient chlorine to give a residual of 0.2-0.5 ppm after about a 15 minute period of contact with the sewage will reduce the 5-day BOD by 15-30%. There is also a reduction in the oxygen demand of about 2 ppm for each ppm of chlorine that is absorbed.

Odor Control

Odor control is most necessary where the sewage has to travel a considerable distance in the sewers and would therefore become septic before reaching the treatment plant if it were not chlorinated. Under these conditions, it is advisable to treat the sewage in the sewer ½-1 mile above the plant. Where the decomposition in the sewer does not progress so far as to produce obnoxious odors at the plant, the chlorine may be added at the entrance to the sedimentation tank.

Various products of decomposition, especially hydrogen sulfide, cause odors in sewage. Chlorine, in proper quantities, will destroy the bacteria that ordinarily break down the sulfur compounds in the sewage, and thus will, at least, reduce the odors.

Where chlorine is used for odor control, a dosage of 5-8 ppm is generally enough to accomplish the result. Quite often, the odor from a sewage treatment plant is serious only between 7 and 10 o'clock in the evening. The odors in such cases may be satisfactorily controlled by chlorinating the sewage from 3-8 p.m..

INDUSTRIAL WASTES

The liquid wastes resulting from manufacturing industrial processes are termed Industrial Wastes; but the term is generally restricted to those wastes which, because of organic content, acidity, salinity, alkalinity, color, solids content, etc., create stream pollution problems. The strength, composition and character of industrial wastes vary greatly for different industries and, often, for different plants manufacturing the same product. Each problem involving the treatment of industrial waste must therefore be considered as almost a separate one. The solution may be influenced by local stream flow conditions, by modifications within the plant to reduce the volume or alter the character of the waste and by the treatability of the waste.

The organic content if industrial waste is measured in the same terms as is that in sewage and the discharge from most processes can be converted into a population equivalent representing the number of people who would contribute sewage containing the same amount of organic material.

Factors in Treatment

In addition to the organic content in terms of population equivalent, other factors may influence the method to be used for treating the waste from a plant. For instance, many plants for canning fruits and vegetables operate on a seasonal basis and for short periods. Such treatment methods as activated sludge and trickling filters, which require some time to reach maximum efficiency, may not be suitable for plants operating for only a few weeks. Excessive alkalinity or acidity may interfere with biological methods of treatment. The nature and amount of solids content of the waste may determine the necessity for using screens and may dictate the methods used for disposal of the solids.

In the case of some wastes which are exceedingly concentrated, that is, a high BOD content, dilution may be necessary before the usual methods can be employed. For instance, the thin slop from a grain distillery may have a BOD concentration as high as 34,000 ppm, and this must be reduced before treatment is economically possible. Some industrial wastes are rendered more treatable by the admixture of domestic sewage.

Before plans for the treatment of wastes are prepared, the industrial plant should be surveyed and the industrial processes studied to determine all possible methods of reducing the pollutional load and increasing the treatability of the waste. Preventable waste and spillage often account for a considerable portion of the strength of the waste and, if good "housekeeping" methods are enforced, the problem of treatment may be materially reduced. Also, the volume of wastes can often be reduced by conservation or re-use of water.

In many plants the most objectionable wastes are comparatively small in volume. If these are treated separately, the remainder of the waste may then be more readily disposed of. Separate treatment of small volumes of wastes, even at high unit costs, often reduces the overall cost of disposal. At some plants, it is possible to mix various waste components and accomplish neutralization or even partial treatment.

Methods of Treatment

Most industrial wastes can be treated with domestic sewage in municipal sewage treatment plants. This is often the economical and satisfactory method of treatment. The additional charge that may be made to the industry for such service will usually be less than the cost of constructing and operating a special plant.

The municipal plant must have ample capacity for the additional industrial load. This will include sedimentation capacity to handle the volume of flow, enough trickling filter or activated sludge capacity for disposing of the solids. Skilled operation will also be necessary, and there should be close coordination with the operation of the industrial plant and the sewage treatment plant. The most likely causes of operating difficulties are sudden heavy loads.

Also, all the usual methods of sewage treatment are employed in treating industrial wastes - sedimentation, low and high-rate trickling filters, activated sludge, sand filters and sludge digestion. In addition, methods of treating industrial wastes include lagooning, the use of fine screens, chemical precipitation and the control of acidity and alkalinity.

Design for industrial-waste treatment follows the general basis for municipal sewage treatment plants, but the details may vary materially in individual cases. High-rate filters using a tile medium, which is more costly than crushed stone but able to take a much heavier loading, has been installed in some canneries and milk-treatment plants.

TABLE 1

Typical Water Pollutants From Some Industries

Industry	Characteristic Wastes Entering Streams or Lakes
Chemical Products	(Extremely varied wastes)
Acids	Various acids
Explosives	Acids, dyes, oils, soaps, organic matter
Pesticides	Organic matter, benzene compounds, acids
Soaps & Detergents	Hydrolyzed fats, dissolved & suspended organics, alkyl sulfates & sulfonates, phosphates, silicates, borates, chlorine, bromine, arsenic
Food Products	(All are high in dissolved & suspended organic matter)
Brewed Beverages	Fermented starches
Canned & Frozen Fruits & Vegetables	Dissolved particles & suspended chunks of raw plant matter; sugars; starches
Carbonated Beverages	Sugars; suspended solids & dissolved detergents from bottle washing
Dairy Products	Whey solids (milk protein, milk sugar, soluble salts), fats
Meat & Poultry	Fecal wastes from pens & stockyards, blood, fat, proteins, & other organic matter from processing
Coal	Sulfuric & other acids from mine drainage; suspended mineral particles removed as impurities during washing & sorting
Iron & Steel	Iron salts, hydrochloric acid, sulfuric acid, phenol, lime, oil
Leather Tanning	Dissolved organics, suspended animal flesh & hair particles,

TABLE 1 (CONT'D)

Typical Water Pollutants From Some Industries (Cont'd)

Industry	Characteristic Wastes Entering Streams or Lakes
	brine soaps, vegetable & mineral tanning chemicals, bases & acids, dyes
Metal Plating & Finishing	Hyfluoric, sulfuric & chromic acids, nickel sulfate, cyanides of copper, zinc, cadmium, silver, oils
Pharmaceuticals	Vitamins & other dissolved & suspended organic matter
Petroleum	Organic matter, phenol, brine, oil, sulfur compounds
Pulp & Paper	Lignosulfonates, wood sugars, sulfite pulping chemicals, inorganic binders & fillers, glue, dyes, acids, bases (Bleaches), paper fibers, pulp, mercury
Rubber (Natural, Synthetic & Reclaimed)	Organic matter, odoriferous sulfur compounds, chlorides, suspended solids
Textiles	Strong bases, dyes, high content of dissolved & suspended organic matter

ADVANCED WASTE TREATMENT

As a result of the research activities undertaken in recent years, new wastewater treatment techniques have been developed and the performance of existing processes improved. An excellent starting place is a review of the characteristics of wastewater. Contrary to popular belief, sewage is only slightly contaminated water. In fact, the usual domestic wastewater is 99.9% water. Unfortunately, water for most uses must contain much lower levels of impurities; hence, although wastewater treatment technology need extract only small quantities of contaminants from wastewater, it must reduce these contaminants to very low levels. This procedure is inherently expensive and places waste treatment technology at a disadvantage in comparison with other areas of industrial chemical technology.

Another characteristic of wastewater which must be considered is the great diversity of specific compounds which make up the impurities. In fact, the variety of contaminants is so great and their concentration so low that only a few substances exist at a measurable level. Much effort is being spent on developing reliable analytical methodology for rigorous analysis of wastewater; however, the progress is not as rapid as would be desired.

Consequently, wastewater analysis is based on identifying classes of substances which have similar environmental effects. The 6 major classes of contaminants are:

1. Suspended Solids
2. Organics (BOD, TOC, COD)
3. Phosphorus Compounds
4. Nitrogen Compounds
5. Microorganisms
6. Electrolytes

The terms BOD, COD, and TOC refer to the three most common tests utilized to measure the organic content of wastewater. BOD measures the organics in terms of the oxygen required by microorganisms to oxidize the organics, COD measures the oxygen required to chemically oxidize the organics and TOC directly measures the amount of organic carbon present. Unfortunately, none of these tests gives a complete determination of organics in wastewater. Over the last few years, the TOC test has started to gain predominance over the others because of the rapidity with which it can be conducted.

<u>Conventional Treatment Availability</u>

Before discussion on the advanced waste treatment can begin, it is necessary that a brief review of the conventional methods of treatment be presented. Therefore, at present, the accepted method of wastewater treatment is as follows:

1. Primary Treatment
2. Primary Treatment
3. Biological Oxidation
4. Secondary Sedimentation
5. Disinfection
6. Sludge Dewatering
7. Ultimate Sludge Disposal

This general system is referred to by various titles such as conventional treatment, biological treatment and primary plus secondary treatment. This system has been developed to remove suspended solids, biodegradable organics and microorganisms from wastewater.

Suspended solids produce sludge banks in rivers, biodegradable organics lower the oxygen resources of lakes and rivers and microorganisms are the source of most water-borne diseases. In the past, it was necessary only to remove most of the above three classes from wastewater prior to discharge to avoid adverse environmental effects. This is no longer true due to the expansion in population, of industry and the much greater demand for recreational and aesthetic uses of water resources.

In the system, wastewater is first passed through preliminary treatment of screening and grit removal. Preliminary treatment is utilized to protect pumps and pipes downstream from harmful large particles and abrasives which are often found in sewage. Next, primary sedimentation is provided to remove relatively large organic solids; followed by biological oxidation, in which a large mass of microorganisms is contacted with the sewage in an aerobic environment. There the microorganisms consume the soluble and colloidal organics producing more microbes, carbon dioxide and water. The two systems which are commonly used for biological oxidation are the trickling filter and the activated sludge processes.

The trickling filter process is basically a fixed-film contacting system in which microorganisms grow on the surface of an inert medium over which the wastewater is sprayed or trickled. Mass transfer of oxygen from the air to the liquid is accomplished by distributing the liquid in thin films. A high active mass of microorganisms is maintained by using a medium with a high surface to volume ratio.

The activated sludge process is a suspended growth system in which a mass culture of organisms is contacted with the wastewater in a mixed flooded reactor tank. Oxygen is introduced into the reactor by diffused air injections or by spraying the liquid through the air with impeller or turbine mixers. In dissolving the oxygen in the liquid, sufficient energy is introduced into the reactor to keep the biological culture in suspension as well.

The microorganisms which are active in biological oxidation are separated from the flow in a secondary sedimentation tank in the form of a slurry and since they are organic matter, they must not be discharged with the effluent. Instead, they are recycled to the head end of the biological oxidation process in order to maintain an adequate population in the unit, the remainder being sent to sludge handling. After passage through the secondary settling tanks, the flow is disinfected, with chlorine or hypochlorite of lime, and discharged.

The final steps in the conventional treatment system are sludge handling and disposal. Disposal usually involves two steps: Dewatering and ultimate discharge to the environment. Dewatering is accomplished by gravity sedimentation (thickening), gravity draining combined with evaporation (drying beds), or mechanical dewatering (vacuum filtration, centrifugation, or pressure filtration). Ultimate disposal of fully dewatered or partially dewatered sludge can be accomplished by land spreading, landfill, incineration, wet oxidation and processing for the recovery of useful by-products.

Biological-Physical Treatment

The simplest of the systems is the microstrainer. These are rotating drums on which woven filter fibres, usually of stainless steel, are mounted. Incoming wastewater flows into the drums along the axis and then passes through the filter cloth which forms the drum surface. Control of headloss is obtained by washing the solids from the screen as that portion of the screen rotates to the top of the device. The backflow liquid is discharged into a trough in the interior of the drum from which it is recycled to the sedimentation basin. Ultraviolet light is mounted above the screen to prevent biological growth from "blinding" the screen. Also, since microstraining is fundamentally a screening process, the process is a function of the screen size. Unfortunatelt, the microstrainer does not perform well unfer shock loading conditions.

Deep Bed Filtration

A somewhat more costly but more reliable upgrading system than the microstrainer is the deep bed filtration system. In this technique, wastewater is forced through several feet of a granular material wherein the suspended solids are deposited. Most of the removal takes place on the surfaces of the grains rather than in the bed pores. The accumulation of solids in the bed eventually produces an excessive pressure load; at this point, the filtration run is stopped and the bed is cleaned. Cleaning always involves an upward flow of water at a rate sufficient to expand the media, thus allowing for the removal of the trapped floc. The nature of wastewater floc is such that it is almost mandatory for an air scour or surface wash, which removes solids which adhere to the grains, to supplement normal backwashing in order to achieve adequate cleaning. Removals obtained from deep bed filtration are only slightly superior to those obtained by microstrainers, however, deep bed filters react well to shock loadings.

Chemical Treatment

Suspended solids and BOD removals across a microstrainer or deep bed filter will rarely exceed 80% because these processes cannot remove colloidal matter from wastewater. Chemical coagulation is the feasible method for removing the colloids. In this process, chemical coagulants are added to the wastewater to entrap the colloids which can then be removed by sedimentation or filtration. Chemical treatment will also coagulate the suspended solids in sewage into large, dense flocs which are also removable by sedimentation. Removal of these coagulated impurities requires solid-liquid separation techniques; consequently, a system which employs chemical treatment for upgrading can be simple or complex depending on the degree of removal and reliability desired.

The simplest system would have chemical addition and flocculation between the biological addition and the secondary sedimentation tank. A more comprehensive system would employ a deep bed filter follwing secondary sedimentation. The most complex system provides chemical addition, flocculation, sedimentation and deep bed filtration after the secondary sedimentation step. Although the chemical treatment system can be much more expensive than microstrainers or deep bed filters, it must be the system of choice where a high degree of colloidal matter exists in the wastewater.

Phophorus Removal

The major sources of phosphorus contributing to eutrophication are domestic sewage and agricultural runoff; domestic sewage is the primary source in critical areas. Phosphorus gains entrance to sewage from human body wastes (primarily urine) and through the use of condensed inorganic phosphate compounds in detergent formulations. Each of these sources accounts for about half of the phosphorus in domestic sewage. Thus, while elimination of phosphorus from detergent formulations would be helpful, it would not be the total answer to the eutrophication problem. Treatment of domestic sewage to remove a significant portion of the phosphorus contributed by human wastes and detergent builders would, however, have a significant effect on eutrophication rates.

Phosphorus Removal in Conventional Treatment

Removal of any pollutant from wastewater requires that it be converted to either an insoluble gas or an insoluble solid, Because none of the chemically stable forms of phosphorus is a gas at room temperature and pressure, removal from wastewater is dependent on formulation of an insoluble solid. Less than 10% of the phosphorus discharged into municipal sewerage systems is insoluble and none of the conventional treatment techniques other than chemical treatment is particularly effective in removing this nutrient. Thus, phosphorus removal in most conventional treatment plants is limited. Primary treatment can remove only the 10% of the insoluble phosphorus. During secondary treatment, phosphorus removal is achieved by synthesis into the biomass followed secondary settling and sludge wasting. However, municipal sewage contains an amount of phosphorus considerably in excess of that required for biomass synthesis during complete utilization of the organic carbon present; thus removals are generally confined to 20-40%.

Phosphorus Removal by Chemical Precipitation

Fortunately, phosphorus forms almost completely insoluble precipitates with a number of substances, so that high levels of removal can be obtained when appropriate doses of the proper chemicals are applied. A large variety of chemicals can be utilised for this purpose, but economic factors dictate the use of salts of iron, aluminum or lime. Other factors affecting the choice of chemicals for phosphorus removal are:

1. Influent phosphorus level
2. Wastewater suspended solids and alkalinity
3. Chemical supply reliability
4. Sludge handling facilities
5. Ultimate disposal methods
6. Compatibility with other treatment process in the plant
7. Potential adverse environmental effects of chemicals used

Nitrogen Control

Nitrogen can exist in an aquatic environment in any of four forms: Organic-N, ammonia-N, nitrite-N and nitrate-N. In sewage, it is found primarily in the first two forms. In nature, biologically-mediated reactions convert organic-N to ammonia-N which in turn is biologically oxidized to nitrite-N and nitrate-N.

The major water quality objective of nitrogen control is to prevent excessive depletion of the dissolved oxygen resources of streams by the biological oxidation of ammonia-N to nitrate-N. Nitrogen control is also important because ammonia-N exerts a chlorine demand which reduces disinfection efficiency, is toxic to fish and other aquatic life and stimulates corrosion of copper piping.

The least expensive method of preventing these adverse conditions is to carry out the biological oxidation to nitrate under controlled conditions in the treatment plant. It is possible to achieve control of ammonia-N and provide a significant degree of nitrification by altering the operation of the conventional activated sludge process. From here, under anaerobic conditions, facultative heterotrophs will utilize the nitrate ion formed as a hydrogen acceptor for the degradation of organic matter. The end product of the nitrogen reduction is nitrogen gas which is essentially insoluble in water. Thus, a combination of nitrification followed by denitrification can achieve nitrogen removal from wastewater.

Organic Carbon Removal

Most organic substances can be removed by most of the processes previously mentioned; however, some of the organics, called refractory organics, cannot be removed by coagulation and sedimentation nor by biological oxidation. At present, two economically feasible methods for removing them have been developed: the Activated-Carbon Adsorption and the Ozonation Methods.

Activated-Carbon Adsorption

The ability of activated carbon to remove soluble organics from wastewater is a consequence of the similarity in surface chemistry between the activated carbon and the organic molecules. There are many other substances capable of adsorbing organics; however, the characteristic of activated carbon which makes it unique is that it has a much higher adsorption capacity than other materials, a property which is due to the extensive internal microporous structure formed during the activation process.

In the activated carbon treatment process, the carbon and wastewater are contacted for a sufficient period of time for adsorption to take place and then separated. Eventually, the activated carbon is exhausted and is removed from the contact vessel to a regeneration step. During regeneration, some of the carbon is consumed or otherwise lost so that make-up must be added.

Ozonation

In addition to the carbon adsorption process, another physical-chemical method of organics removal, ozonation, has been evaluated and found worthy of development. Ozone appears to have many applications in the treatment of industrial wastes containing cyanide, chromium, phenols, etc,. It is a simple process, and the raw materials, electricity and air, are inexpensive or free when using this process.

The use of ozone in the treatment of water is an old process, but the application of this chemical for treatment of wastes from the metal-plating industry is fairly new. The first commercial-size plant using ozone for the destruction of cyanide was installed by the Boeing Company, manufacturers of aircrafts, at their plant in Wichita, Kansas. In this process the cyanide was first oxidised to cyanate, which is about one-thousandth as toxic as cyanide, and the cyanate was then hydrolyzed to CO_2 and NH_3.

Ozone is also used effectively to reduce the concentration of phenols in the wastewater. Plastic industries, oil refineries, chemical companies and coke plants are particularly concerned with the effluent phenol concentration. Unfortunately, the ozonation procedure is several years behind activated carbon in development for lack of necessary information.

Dissolved Inorganics Removal

Any material dissolved in water can be viewed as a pollutant. The broadest range of pollutants are the dissolved solids also known as the inorganics. Dissolved solids range from 100-500 ppm per use depending generally on local conditions. Extensive reuse of wastewater, even for industrial purposes, requires at least partial demineralization. A number of demineralization processes have been evaluated in the EPA advanced waste treatment programs, and only three - electrodialysis, ion exchange and reverse osmosis - were promising enough for additional studies.

Ion-Exchange Process

Ion exchange is the most advanced demineralization system because the basic technology has been in wide use for over 25 years in water treatment applications. Their major function is to remove dissolved solids. In wastewater control, this would correspond to a lowering of the total dissolved solids value. Ions such as Na^{+}, Ca^{++}, and Mg^{++} as well as Cl^{-}, SO_4^{--} and CO_3^{-} can be removed.

In waste treatment, the wastewater should be well clarified and treated with carbon before ion exchange; otherwise, extensive resin fouling will occur. Even with thorough pretreatment, use of strong base anion exchange resins is not recommended.

Electrodialysis Process

This is one of the oldest forms of membrane separation of colloidal matter from wastes by normal pressures acting on the membrane. In its simplest form, as dialysis, it consists in the passage of liquids of different concentrations through a selective membrane.

In sewage application, electrodialysis suffers severe limitations. The anion plates foul quite easily, drastically reducing treatment performance unless the feed has received extensive pretreatment. In addition, as the sewage is demineralized, its electrical resistance increases. This limits the degree of demineralization which can be obtained economically.

Reverse Osmosis Process

Reverse osmosis is a fairly new treatment method that separates pure water from its contaminants rather than removing contaminants from the water. This membrane filter operation is sometimes called Superfiltration or Hyperfiltration. It is distinct from the dialysis type of operation in that high pressures are applied to the wastes being treated to force the liquid through the semipermeable membranes, leaving the solids behind.

Reverse osmosis is a phenomena which occurs naturally whenever a dilute liquid and a concentrated liquid are separated only be a semipermeable material, such as a diaphragm, which selectively permits only one kind of molecule to pass through it. Under normal conditions pure water would diffuse through the membrane into adjacent higher-concentrated liquid, but by the application of pressure to the concentrated solution, the flow goes through in the opposite direction, that is, by reverse osmosis.

This system, originally developed for the desalination of

seawater, has been found applicable to certain industrial wastes, such as the removal of sulfuric or hydrochloric acid from pickling liquors, separation of a high molecular weight hydrocarbon, separation of heavy metals, salts and in general separation of dissolved ionic and nonionic materials from pure water. Unfortunately, this is not a cheap process; but it may well prove to be the best practical solution for the final polish of an industrial waste discharge into waters where restrictions exists or where an especially high-grade water is required for recycle for process work.

THE HACKENSACK MEADOWLANDS DISTRICT

The Hackensack Meadowlands District was established by the enactment of "The Hackensack Meadowland Reclamation and Development Act of 1968." Its boundaries encompass much of the generally vacant and underdeveloped marsh which characterizes the lower Hackensack River valley.

The Hackensack Meadowlands District, located in the lower Hackensack River valley, extends approximately eight miles from the town of Kearny at its southern end to the Borough of Ridgefield on the north. This is shown on Fig. 21. The District encompasses an area of approximately 28 square miles including portions of the municipalities of Carlstadt, East Rutherford, Little Ferry, Lyndhurst, Moonachie, No. Arlington, Ridgefield, Rutherford, So. Hackensack and Teteboro in Bergen County; and portions od Jersey City, Kearny, No. Bergen and Secaucus in Hudson County. Included in the District is that portion of the Hackensack River and its tributaries between River Mile 3.1 and 13.8 (See Fig. 21). Much of its land is at a low elevation, usually less than 10 feet above mean sea level and more than 70% of the natural ground lies below an elevation of 6 feet above mean sea level, with some areas below the level. A major segment of the District is submerged by the intrusion of normal high tides and an occasional high tide which causes as much as 70% of the area to be covered by the contaminated waters of Newark Bay.

Underlying the tidal marshlands of the District are strata of marine, freshwater and glacial deposits laid down 8,000-10,000 years ago, subsequent to the retreat of the Wisconsin Glacier. Triassic sandstone and shale bedrock outcrop in the easternly portion of the District at Laurel Hill and Little Snake Hill. In general, the depth of the bedrock varies widely ranging from near surface to a depth of 220 feet. The major portion of the soil which overlies this bedrock consists of varved clays, overlain with a deposit of organic silt. The surface of the Meadowlands is composed of a peaty deposit which is the residue from vegetation, marsh grasses and other salt water plants which grow there.

The District is ringed and traversed by a network of roads, railroads and utilities which are constructed primarily to serve the surrounding metropolitan area, and is further subdivided by the river tributaries and the drainage ditches which criss-cross the area.

Development in this portion of the Hackensack Area has generally been confined to the higher elevations not affect-by tides or flooding. The areas on the slopes which outline the Meadowlands and the more elevated portions of Secaucus have been intensely developed to almost complete utilization of available land by mixed residential, industrial and commercial construction. The areas in Kearny and Jersey City on both sides of the river mouth have been developed with heavy industrial complexes, but north of Kearny point the Meadowlands are vacant and unused except as a regional disposal area for reuse and solid wastes. Most of the Meadowlands Area has been developed on an industrial level since the greater part of the Meadowlands Area has been zoned for industrial use by local jurisdictions.

The Hackensack River

The portion of the tidal watershed which lies below the Oradell Dam is a tidal estuary subject to tidal fluctuations and to the effects of contaminated salt water carried upstream from the New York Harbor system through Newark Bay. This section of the river is of importance due to the limitations of this report and especially due to the fact that the Hackensack Meadowlands Development Commission is authorized to have jurisdiction by the New Jersey State Legislature. The river winds through the Meadowlands, which for the most part is a flat, salt marsh, covered with extensive tidal flats which are only a few inches above the banks of the River. Where the ground is slightly higher and can support major structures urban areas have been developed. The River is used by these communities to discharge liquid wastes, both treated and untreated; industrial cooling waters; and for barge traffic and other navigation purposes.

The Meadowlands District has an annual water temperature of 51° F. The average low is about 29° F. The prevailing winds in the Meadowlands blow from a southerly direction during the summer months, which is the period of heaviest rainfall and maximum storm tides. Tidal movements over a 24-hour period has shown a diurnal tidal period of about 12.4 hours with a mean tide range of just over 5 feet. Spring tides are generally 120% of mean tide range, and hurricane tides have reached levels of 8.3 feet above mean sea level. Storm surge tide, reached a height of 9 feet above mean sea level. High tides have remained at a level greater than 6 feet above mean sea level for extended periods of time.

The lower Hackensack River and its watershed is a unique tidal estuary. Tidal circulation and advective freshwater dispersion found in typical freshwater streams which rapidly discharge to the ocean, is not found here since it has a very restricted freshwater addition. The seaward movement of surges of freshwater, which might be expected within this tidal estuary as a series of pulsations, do not wholly materialize. As the tide rises the freshwater inflow is held back and as the tide falls, the freshwater advection is insufficient to push itself and the tidal waters back through Newark Bay and outward to the hills.

The consequence of the absence of sufficient freshwater inflow into the upstream portion of the tidal estuary is far-reaching. In short, the Hackensack River has become a "dead-ended" tube in which the tidal water surges and retreats in rhythmic fashion, but from which is little flushing of accumulated pollutants and contaminants. The tidal cycles, pushing in and out of Newark Bay, which serves as a mixing basin for all of the pollutants in the river, causes a 'smoothing out' of peaks and dispersion within the estuary of localized sources of wastes. Since the flow of freshwater into the estuary is negligible, there is no net motion seaward of the masses of pollutants introduced into the River. Therefore, any attempt to analyze the Hackensack River and its tributaries as a stream separate from its larger complex, the New York Harbor, could lead to false conclusions.

Table No. 2 contains those treatment plants which were studied and their relation to the Meadowlands District can be seen in Figure 21.

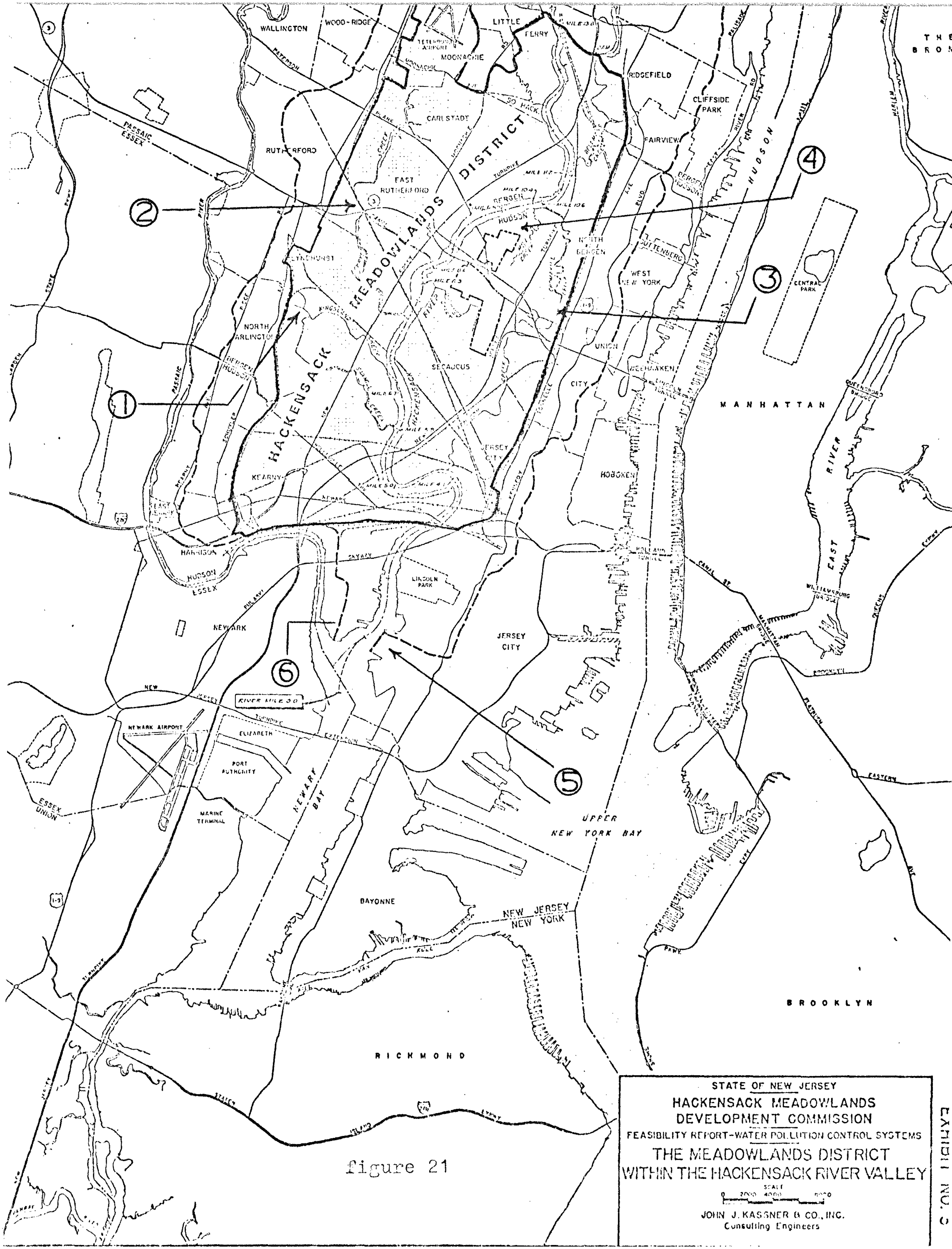
STATE OF NEW JERSEY
HACKENSACK MEADOWLANDS
DEVELOPMENT COMMISSION
FEASIBILITY REPORT-WATER POLLUTION CONTROL SYSTEMS
THE MEADOWLANDS DISTRICT
WITHIN THE HACKENSACK RIVER VALLEY
SCALE
0 2000 4000 8000
JOHN J. KASSNER & CO., INC.
Consulting Engineers
EXHIBIT NO. 3
HACKENSACK MEADOWLANDS DISTRICT
WALLINGTON
WOOD-RIDGE
LITTLE FERRY
TETERBORO AIRPORT
MOONACHIE
RIDGEFIELD
CLIFFSIDE PARK
CARLSTADT
RUTHERFORD
EAST RUTHERFORD
FAIRVIEW
NORTH BERGEN
GUTTENBERG
WEST NEW YORK
LYNDHURST
NORTH ARLINGTON
SECAUCUS
UNION CITY
WEEHAWKEN
JERSEY CITY
HOBOKEN
KEARNY
HARRISON
NEWARK
LINCOLN PARK
NEWARK AIRPORT
ELIZABETH
PORT AUTHORITY
MARINE TERMINAL
NEWARK BAY
BAYONNE
UPPER NEW YORK BAY
RICHMOND
BROOKLYN
MANHATTAN
CENTRAL PARK
EAST RIVER
HUDSON
THE BRONX
HOLLAND TUNNEL
LINCOLN TUNNEL
QUEENSBORO BRIDGE
WILLIAMSBURG BRIDGE
RIVER MILE 3.0
PASSAIC
ESSEX
BERGEN
HUDSON
UNION
NEW JERSEY
NEW YORK
1
2
3
4
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figure 21

TABLE NO. 2 - TREATMENT PLANTS WITHIN THE HACKENSACK MEADOWLANDS DISTRICT

Treatment Plant	Location or Municipality	River or Tributary Mile	Outfall or Discharge Point	Waste Treatment
(1.) No. Arlington-Lyndhurst Joint Meeting Plant	No. Arlington (Bergen County)	2.2 (6.7 HR)	Ditch to Kingsland Creek	Screening, Grit Removal & Primary Settling
(2.) Rutherford-East Rutherford-Carlstadt Joint Meeting Plant	Rutherford (Bergen County)	1.8 (8.6 HR)	Berrys Creek	Screening, Grit Removal, Primary Settling, Trickling Filters & Secondary Settling
(3.) No. Bergen Municipal, Central Plant	No. Bergen (Hudson County)	2.2 (10.6 HR)	Cromakill Creek	Grit Removal, Screening & Primary Settling

TABLE NO. 2 (CONT'D) - TREATMENT PLANTS WITHIN THE HACKENSACK MEADOWLANDS DISTRICT

Treatment Plant	Sludge Treatment	Disposal Method	Reported Flow in MGD Average Daily Flow				Chlorination Treatment	
			Plant Cap.	Max. Flow	1970	1974	Pre-	Post-
(1.) No. Arlington-Lyndhurst Joint Meeting Plant	Digestion & Air Drying	Landfilling	1.7	8	1.5	1.78	-----	Yes
(2.) Rutherford-East Rutherford-Carlstadt Joint Meeting Plant	Digestion & Wet Lagooning	Landfilling	4.0	11	3^+	3.1	Yes	Yes
(3.) No. Bergen Municipal, Central Plant	None	Scavenger Service	2.0	2.5	2.0	1.7	-----	Yes

TABLE NO. 2 (CONT'D) - TREATMENT PLANTS WITHIN THE HACKENSACK MEADOWLANDS DISTRICT

Treatment Plant	Location or Municipality	River or Tributary Mile	Outfall or Discharge Point	Waste Treatment
(4.) Secaucus Municipal Plant	Secaucus (Hudson County)	1.0 (10.4 HR)	Mill Creek	Screening, Grit Removal, Primary Sedimentation, Trickling Filters & Secondary Sedimentation
(5.) Jersey City Sewerage Authority, West Side Plant	Jersey City (Hudson County)	1.1	Hackensack River	Screening, Grit Removal & Primary Settling
(6.) Kearny Municipal Plant	Kearny (Hudson County)	0.7	Hackensack River	Primary Sedimentation, Chlorination

TABLE NO. 2 (CONT'D) - TREATMENT PLANTS WITHIN THE HACKENSACK MEADOWLANDS DISTRICT

Treatment Plant	Sludge Treatment	Disposal Method	Reported Flow in MGD Average Daily Flow				Chlorination Treatment	
			Plant Cap.	Max. Flow	1970	1974	Pre-	Post-
(4.) Secaucus Municipal Plant	Digestion Elutriation and Air Drying	Landfilling	2.25	3	1.25	1.20	Yes	Yes
(5.) Jersey City Sewerage Authority, West Side Plant	Sludge Thickening and Vacuum Filtration	Incineration	36	75	16	20	Yes	Yes (From May 15 to Sept. 15)
(6.) Kearny Municipal Plant	Digestion & Drying	Scavenger Service	4.0	4.25	2.75	2.6	Yes	Yes

THE NORTH ARLINGTON-LYNDHURST JOINT MEETING PLANT

The North Arlington-Lyndhurst Joint Meeting Plant is located east of the Erie-Lackawanna Railroad Kingsland Line, south of Canterbury Avenue and east of Schuyler Avenue in the Borough of No. Arlingtin. This facility is owned and operated by the No. Arlington- Lyndhurst Joint Meeting, an independent agency established by the two municipalities in 1954 for the purpose of treating the sewage generated by the easterly portion of both municipalities. The sewage emanating from the areas of each community lying to the east of Ridge Road is independently collected by each municipality and is independently conducted to the Joint Meeting Plant for treatment.

Neither the Joint Meeting nor the municipalities have ordinances or formal regulations to control the character and strength of discharged waste to their systems.

The sewers in each municipality's system are of varying age, the oldest portions of each were installed about 1917. Each municipality maintains a collection system of separate sanitary sewers in which infiltration is reported to be excessive, the probable cause being that older sewers have developed opened joints, and the presence of a fluctuating and sometimes extremely high water table. The existence of many suspected illegal foof drain connections and the admitted general inadequacy of the local storm drains also probably intensifies peak flows.

No. Arlington's sewage is conducted to the plant through an 18-inch diameter sewer which crosses the Erie-Lackawanna Railroad near Cary Road. This sewer runs to Schuyler Avenue via Verhoff Place and Canterbury Avenue where it branches into two 18-inch sewers, one entering from the Borough line to the north and one entering from a point just south of Noel Drive to the south. South of this point, the sewers continue as a 15-inch diameter pipe through a cemetery, along a line approximately 600-900 feet west of and parallel to the line of Schuyler Avenue, to the intersection of Park Avenue and Devon Street. South of this point the sewer extends as a 12-inch diameter to Devon Street to the Borough line at the Belleville Turnpike.

The Lyndhurst sewage is conducted to the Joint Meeting Plant through a 16-inch diameter cast iron sewer installed at the time that the Plant was constructed. It intercepts the flow from a 16-inch diameter sewer at Swane Avenue, just north of the Erie-Lackawanna Railroad. This flow had previously been conducted to the former Lyndhurst Municipal Plant which was abandoned at the time the Joint Meeting Plant became operational.

The sewage system's tributary to the Joint Meeting Plant operate by gravity with the exception of the newly developed meadowland area in the town of Lyndhurst near Polito Avenue. The sewage emanating from this area is pumped by a station located near the intersectio of Polito Avenue and Valley Brook Avenue across the Erie-Lackawanna Railroad to a gravity sewer in Orient Way.

Following the formation of the Joint Meeting Plant, the No. Arlington Municipal Plant was converted for use as a primary treatment facility. Construction of the Joint Meeting Plant was begun in 1955 and the plant was placed in service in August, 1957.

The present population served by the Joint Meeting Plant is approximately 14,300 people and is projected to be about 16,000 in 1985 which would produce a flow of 2.5 mgd and include development of approximately 400 acres of presently vacant, industrially zoned meadowland. Present average daily flow is 1.5 mgd with a peak dry-weather flow of 2.0 mgd. Peak storm-weather flows of 8 mgd are bypassed around the plant in order to avoid overflooding.

Although composition of the wastes is primarily domestic at this time, industrially zoned meadowlands lying within the two municipalities of the Joint Meeting Plant are estimated to be 1,300 acres presenting a potential for significant additional waste contribution to the system. Ultimate flow from the two municipalities has been estimated at 4.3 mgd.

Description of the Plant

In Fig. 22, the sewage flow, which is carried to the plant through a comminutor, a grit chamber, a grease removal chamber, two primary settling tanks and a chlorine contact tank and, finally, discharged into Kingsland Creek which goes to the Hackensack River. Primary sludge removed from the settling tanks is digested and dried on open beds prior to disposal as landfill in the Meadowlands. A plant by-pass is provided at the effluent end of the grit chamber which permits discharge directly into the ditch which normally receives the treated plant effluent.

There is one comminutor, which is the type with submerged, revolving drum and a special U-shaped outfall channel. The grit removal facilities include two channels, one of which contains a mechanical grit removal mechanism. Grease removal prior to the primary settling tanks is presently a manual operation, which at present is inadequate. Two primary settling tanks with mechanical sludge and scum collection equipment provide about 4,000 sq.ft. of surface area. The scum and sludge are pumped to the primary digester from the primary settling tanks. One chlorine contact tank provides a total contact volume of approximately 5,500 cu.ft.. Chlorination equipment consists of one vacuum-type gas chlorinator with a capacity of 50-500 lbs/day of chlorine.

Sludge digestion is presently a two-stage process, the primary digester being 50 feet in diameter by 21 feet high and the secondary digester being 28 feet in diameter and 23 feet high. The primary digester is heated and equipped with a Pearth gas recirculation unit on a floating cover. The existing open sludge beds provide a total area of about 30,000 square feet.

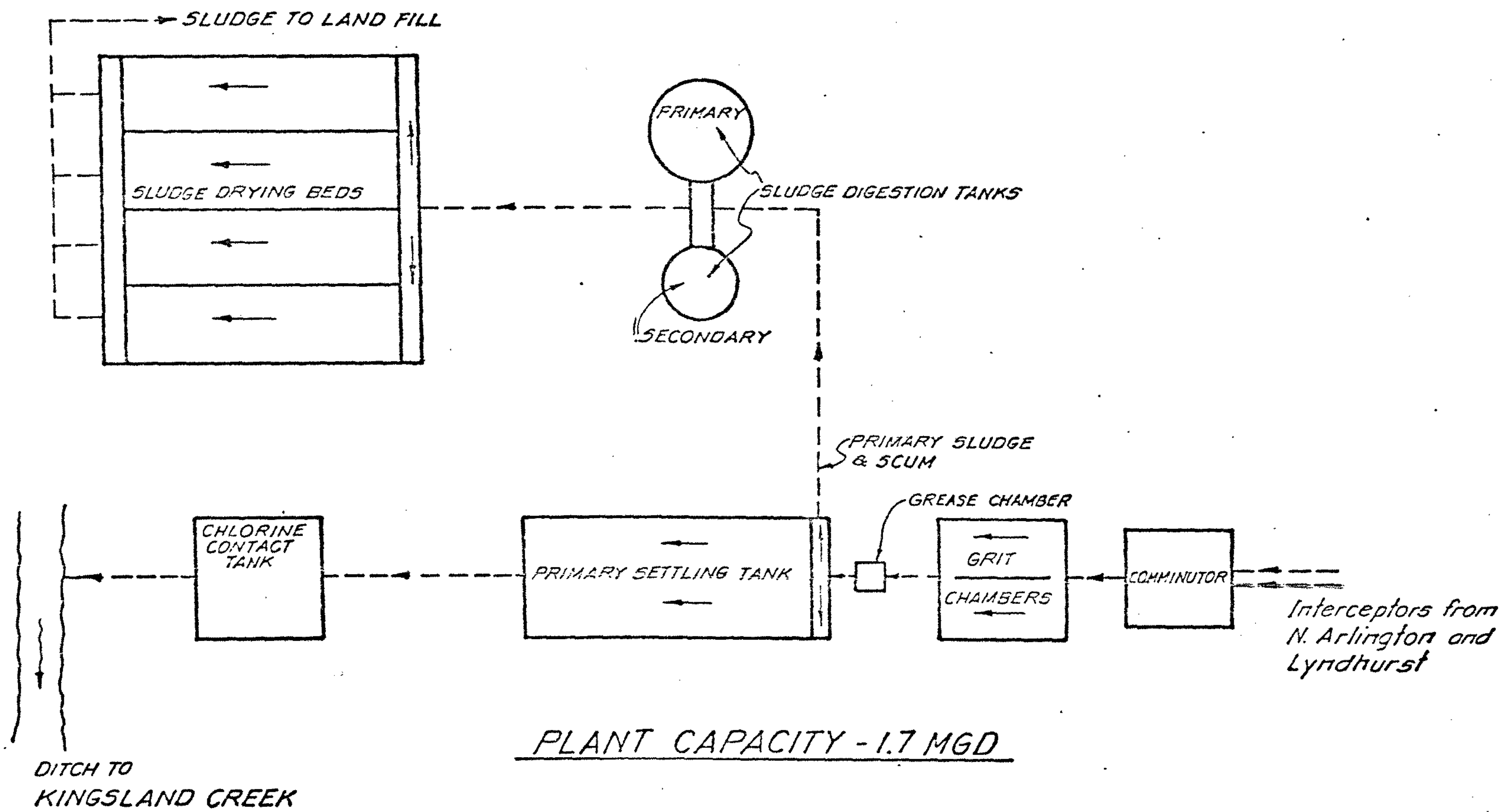


FIGURE 22

STATE OF NEW JERSEY
HACKENSACK MEADOWLANDS
DEVELOPMENT COMMISSION
FEASIBILITY REPORT-WATER POLLUTION CONTROL SYSTEMS

SCHEMATIC FLOW DIAGRAM
NORTH ARLINGTON - LYNDHURST
JOINT MEETING PLANT
JANUARY 1970

RUTHERFORD-EAST RUTHERFORD-CARLSTADT JOINT MEETING PLANT

The Rutherford-East Rutherford-Carlstadt Joint Meeting Plant, otherwise known as Tri-Boro, is an independent agency established by the Boroughs of Rutherford, E. Rutherford and Carlstadt in 1938 for the purpose of providing interceptor sewers and sewerage treatment facilities for approximately 1,040 tributary acres, with a population of about 39,000, which lie in these three communities, generally to the west of N.J. Route 17. The Tri-Boro Joint Meeting Plant is located east of N.J. Route 17 at the foot of Borough Street in the Borough of Rutherford near the westerly right-of-way of the Erie-Lackawanna Railroad.

The area of these three communities lying on the westly slope of the Hackensack River valley to the west of N.J. Route 17 has been developed to almost complete saturation with mixed residential, commercial and industrial development. For the most part, this upland area can be characterized as being essentially residential of low to medium density. The area to the east of Route 17 and west of Berry's Creek is low lying meadowland which has been intensely developed for industrial use with some being heavy industrial in nature. The Meadowlands to the east of Berry's Creek is zoned for industry and is mostly vacant but has been developed for industrial use along existing roads.

The individual municipal sewage collection systems located in the present Joint Meeting Service Area are owned and operated by the individual municipalities and are of the separate sanitary type. These collection systems drain to the Joint Meeting trunk by gravity. The Joint Meeting trunk sewers are separate gravity sewers owned and maintained by the Joint Meeting. Sewage from the north and east enters the plant through a 36-inch diameter sewer from Borough Street in Rutherford. This sewer extends along the southerly right-of-way of the Erie-Lackawanna Railroad, crossing it at apoint almost 250 feet east of N.J. Route 17. The sewer then continues along the northerly line of the Railroad to Route 17 where it proceeds in a northerly direction along the east side of Route 17 to the Union Avenue in East Rutherford. From here a 24 and 18 inch diameter spur extends westerly on Union Avenue to Hackensack Street. The main trunk continues northerly some 150feet to the east of Route 17 along William Street to the Carlstadt boundary at Paterson Plank Road. The line continues in Carlstadt in Twelfth Street to Broad Street where two 18-inch diameter lines join, one from the east from Fourteenth Street and the other from the west from Route 17. At Route 17, a 10-inch spur enters from the west on Broad Street from Eighth Street. The trunk extends as a 12-inch diameter sewer along Route 17 to the north terminating at Berry Avenue. These trunk sewers were constructed by the Joint Meeting in1938 together with some eight inch diameter sewers in Hackensack Street from Monroe Avenue to Mozart Street, in Union Avenue from Broad Street to Hackensack Street, and in Hackensack Street from just west of Union Street to Poplar Street and Paterson Avenue in East Rutherford.

The present Tri-Boro Joint Meeting Plant was placed in service in 1941 as a modern secondary treatment facility having a designed capacity of 4.0 mgd. It replaced the existing Borough of Rutherford Municipal Plant which was an obsolete, primary facility using Imhoff tanks.

Present flows to the Tri-Boro Plant have been variously estimated in excess of 3 mgd average daily, with estimated peak flows of 11 mgd due to combined storm and industrial peak flows. Peak flows presently imposed excessive hydraulic loadings on various plant units, which in turn contribute to the inability of the present plant to meet New Jersey State Dept. of Health requirements. Not only is the existing plant hydraulically overloaded but organic overloading also occurs due to the poisoning effect that strong plating, dye and industrial wastes have on the biological filter media.

Description of the Plant

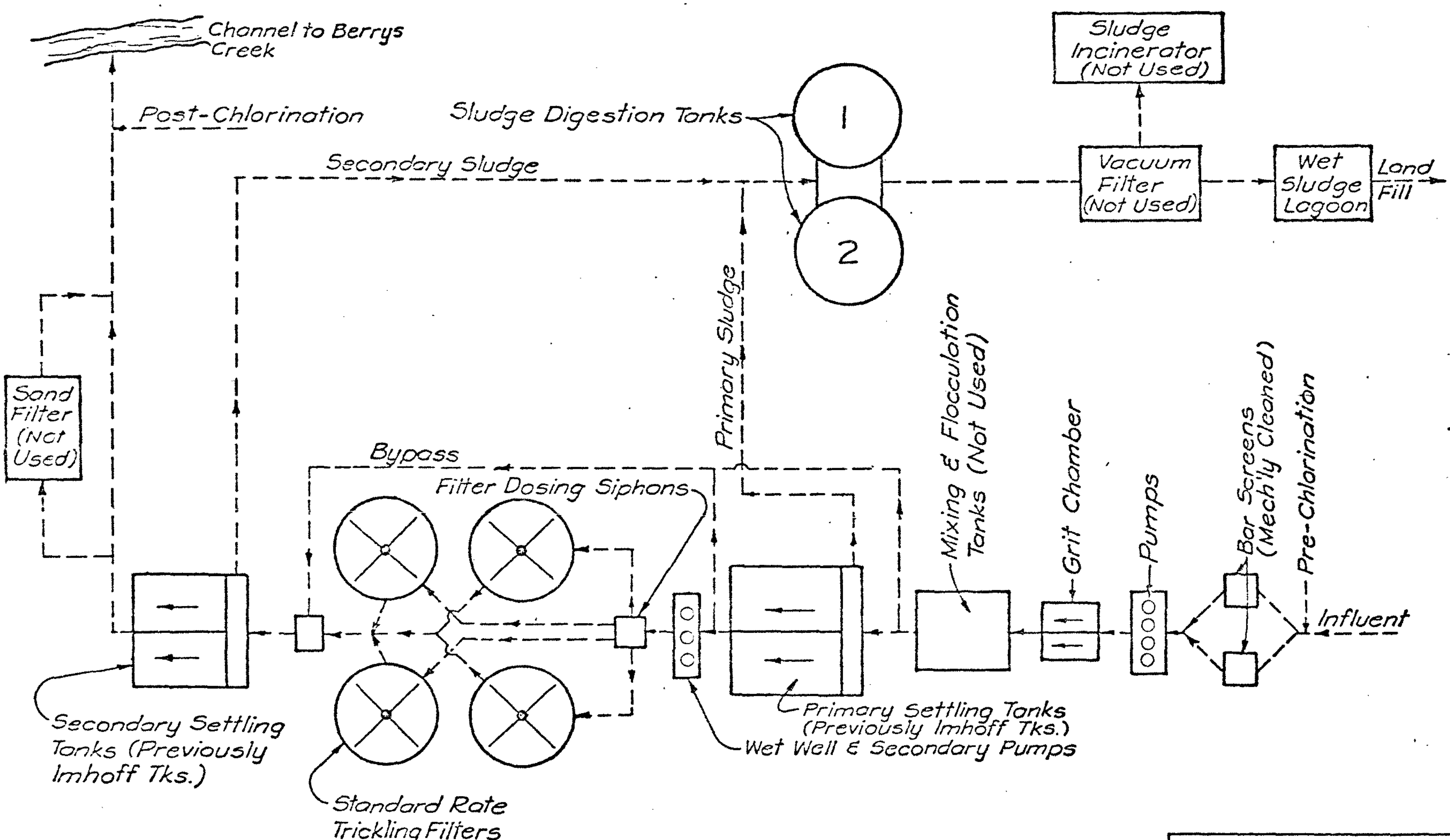
Figure 23 illustrates the Tri-Boro Joint Meeting Plant. Sewage into the plant first passes through two mechanically-cleaned bar screens into a wet well and is then pumped into the grit chamber. There are four raw sewage lift pumps providing a total capacity of 11 mgd, however, stand by electric power facilities provide only 4 mgd of dependable pumping capacity. One of the grit channels is presently provided with mechanical grit removal equipment installed in 1966.

The sewage then passes through rapid mix and flocculation chambers which were initially provided for the addition of a flocculant chemical prior to primary sedimentation. This equipment has seriously deteriorated and chemicals are not presently being added, so that the units now contribute little to the treatment process. From the rapid mix and flocculation chambers, the flow enters two primary settling tanks, each of which is equipped with sludge collectors, but not equipped for grease and scum removal. These units were converted from their previous function as Imhoff tanks to their present usage as primary settling tanks. These tanks are the plant units which limit present plant hydraulic capacity to 2.9 mgd. During periods of peak flow, a by-pass from the influent channel of the tanks normally conducts flow around the tanks and the trickling filters to the secondary settling tanks.

Following the completion of primary treatment in the primary tanks, the flow then enters the secondary pumping station which has one 4 mgd unit and two 2 mgd units, unfortunately, there is no stand-by power available for the station. The flow is then fed to standard-rate trickling filters by a filter-dosing chamber with dosing siphons. There are 4 units, of which 3 are normally in service. Each filter is a 110 feet in diameter and has an 8 foot deep crush stone bed. From the trickling filters, the flow enters into two secondary settling tanks which were also converted from Imhoff tanks.

Chlorination facilities include an evaporator and three chlorinators. Chlorine is presently applied to the plant influent and to the effluent from the secondary settling tanks. There is, however, no chlorine contact tank to provide required contact time before the plant effluent is discharged into Berry's Creek.

Sludge removed from the primary and secondary settling tanks is pumped into two digesters. The plant, as originally designed, provided for two-stage digestion with sludge-heating and utilization of gas produced during digestion. At present, only the sludge pumps are operable. Digester No. 1 was initially equipped with a floatingcover and Digester No. 2 with a fixed cover, both of which are reported to be in a seriously deteriorated condition. Facilities for the chemical conditioning of sludge, vacuum-filtration and incineration of sludge cake were installed with the initial plant. From the digesters, sludge is discharged into wet lagoons at the plant site for drying and ultimate disposition in the Meadowlands as landfill.



PLANT CAPACITY - 2.9 MGD

FIGURE 23

STATE OF NEW JERSEY
HACKENSACK MEADOWLANDS DEVELOPMENT COMMISSION
FEASIBILITY REPORT-WATER POLLUTION CONTROL SYSTEMS

SCHEMATIC FLOW DIAGRAM
RUTHERFORD-EAST RUTHERFORD
CARLSTADT JOINT MEETING PLANT
FEBRUARY 1970

NORTH BERGEN MUNICIPAL, CENTRAL PLANT

The Township of No. Bergen owns and operates three sewage treatment plants which treat the wastewater generated from within its corporate limits, as well as from the entire town of Guttenberg and a small portion of Union City. This report, however, will concern itself only with the Central Plant.

The No. Bergen Central Plant is located on the north side of 43rd Street and its site is bounded by 43rd Street on the south, West Side Avenue on the west, the projection of 45th Street on the north and the right-of-way of the New York-Susquehanna Railroad on the east. It serves the sewered area of the Township of No. Bergen lying east of the Erie-Lackawanna Railroad and generally south and west of a district boundary line which extends south-easterly from the Railroad at 80th Street to Tonnelle Avenue at 75th Street, easterly to the intersection of J.F. Kennedy Memorial Blvd. to the Township boundary at the Guttenberg Town line just north of 70th Street and includes that portion of Union City lying to the west of J.F. Kennedy Memorial Blvd..

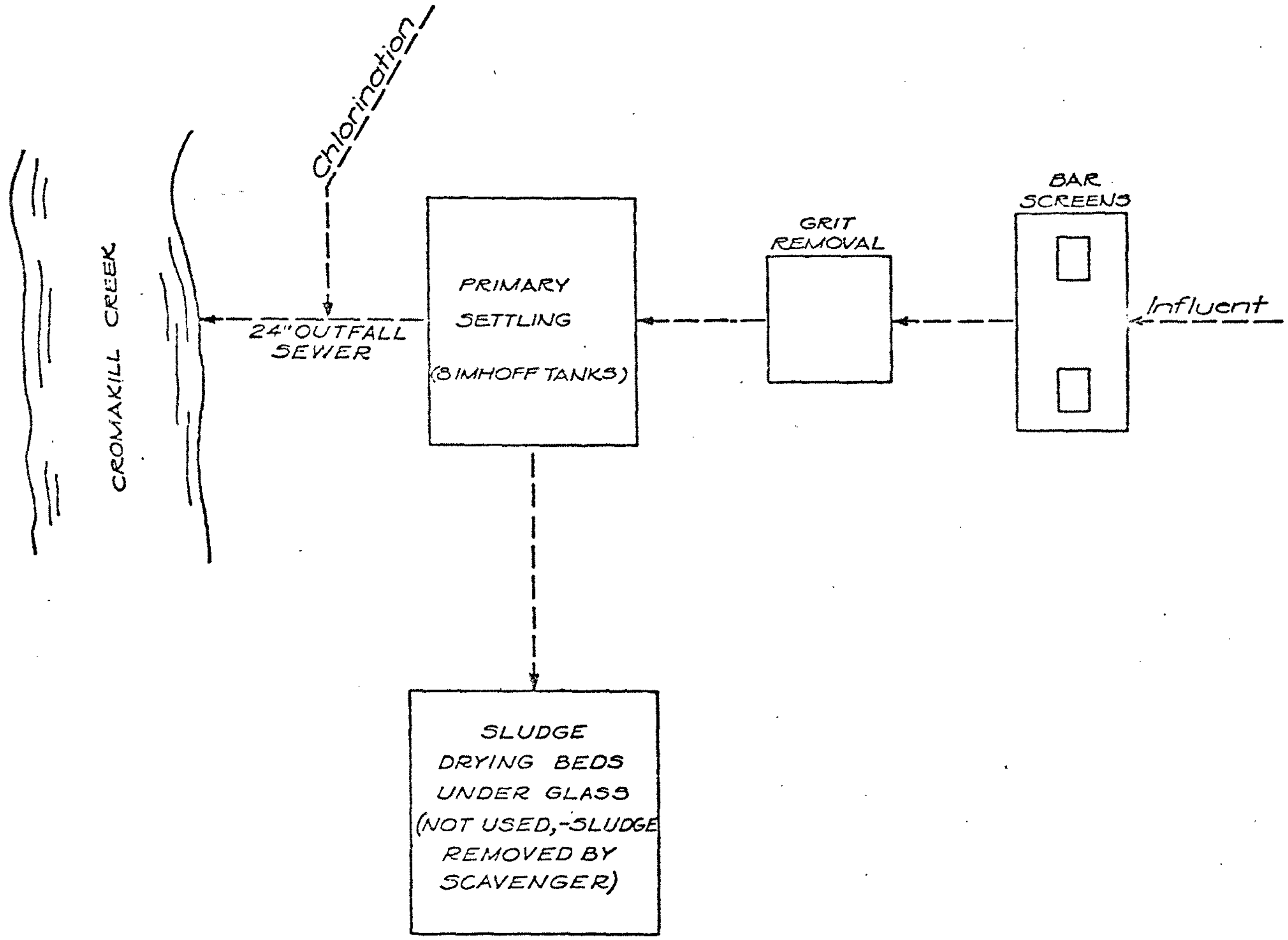
According to the Division of Economic Development of the New Jersey Dept. of Conservation and Economic Development, the populations of No. Bergen and Guttenberg are estimated to be 44,000 and 5,500, respectively and it was estimated that of this population only 30,000 were serviced by the No. Bergen Central Plant. As determined by observation, the more elevated portions of the Township appears to have been developed to near saturation, mostly with mixed residential, commercial and light industrial development. The entire lying to the west of Tonnelle Avenue has been zoned for heavy industrial use, but this type of development has occured principally to the east of the Erie-Lackawanna Railroad. The area lying to the west of the Railroad can be characterized as generally vacant and underdeveloped marshland.

Information obtained from the municipal officials indicates that the Township of No. Bergen does not have a separate ordinance or code to control the character and strength of sewage that may be discharged into their sewerage systems except for a regulation which prohibits the dumping of explosives and noxious substances. However, the agreement with the Town of Guttenberg contains restrictions on the composition and strength of sewage which Guttenberg may discharge into the No. Bergen sewerage system.

No. Bergen officials report that a portion of the sewerage system is composed of separate sanitary sewers but contains some combined sanitary-strom sewers. Of the total municipal area of 3,500 acres, 2030 acres are served by separate sanitary sewers and 270 acres are served by combined sewers. In addition, No. Bergen maintains four pumping stations. One pumping station is located on 8th Street between Dell Avenue and Tonnelle Avenue, and pumps sewage collected from an approximate one square mile area in the southern end of the municipality to a discharge point at the intersection of Grand Avenue and Paterson Plank Road, from there it flows via gravity sewers to the Central Plant. Another pumping station is located on 60th Street. The other pumping stations are a lift station at 43rd Street which pumps sewage into the Central Plant and a lift station at 91st Street which pumps sewage into the Northern Plant. The remainder of the sewerage system is operated by gravity.

Description of the Plant

A schematic diagram of the Central Plant is illustrated in Fig. 24. Sewage enters the Plant from a lift station which also handles storm water flow. The sewage flow then passes successively through hand-cleaned bar screens, a grit removal chamber and Imhoff tanks having a capacity of 4.0 mgd based on a retention time of 2.5 hours and a surface settling rate of 600 gallons/sq.ft./day. The plant effluent is discharged into Cromakill Creek through a 24-inch diameter cast iron pipe approximately 300 feet long. A recently installed vacuum-type solution feed chlorinator having an adjustable capacity of 1,000 lbs./day, diffusers chlorine at at the plant outfall sewer. The sludge, which is gathered, is serviced by sludge scavengers on an "as needed basis." In addition, the plant does not have any reliable flow-measuring equipment.



PLANT CAPACITY - 4.0 MGD

FIGURE 24

STATE OF NEW JERSEY
HACKENSACK MEADOWLANDS DEVELOPMENT COMMISSION
FEASIBILITY REPORT-WATER POLLUTION CONTROL SYSTEMS

SCHEMATIC FLOW DIAGRAM
NORTH BERGEN CENTRAL MUNICIPAL PLANT
MARCH 1970

SECAUCUS MUNICIPAL PLANT

The Secaucus Sewage Treatment Plant, located in Secaucus, N.J., serves both a residential and industrial town with an estimated population of 12,405 and an estimated 14,550 in jobs. Most of the jobs are in warehousing and distribution.

Located in the northwestern section of Hudson County, it is a part of the New Jersey - New York Metropolitan Area. In addition, it is bordered to the west and south of the Hackensack River and lies to the north and east of Cromakill and Penhorn Creeks, respectively. The total area of the Secaucus Town is 3,662 acres.

Because of its proximity to New York, it is the site of major rail and vehicular routes. For instance, Route 3 crosses the northern part of Secaucus which provides entry to New York via the Lincoln Tunnel and access to Bergen County across the Hackensack River. Also, there is the New Jersey Turnpike which runs the entire length of Secaucus before crossing the Hackensack River into Kearny to the south. One of the major principal local roads in Secaucus is Paterson Plank Road which connects the business section of Secaucus with other Hudson County communities. In addition, there is County Avenue, an arterial road which parallels the N.J. Turnpike, provides access to Jersey City. Finally, Secaucus Road allows direct entry into the town's Hartz Mountain Industrial Park from Union City and Hoboken.

Pollution Sources and Waste Loads

Secaucus is currently being serviced by a town sewerage system which has individually operated septic tanks and a private treatment facility system. The municipal system contains 18 sewered areas which combine to form 9 discharge areas. Seven of these discharge directly into the Hackensack River. One empties into a drainage ditch which finally empties into Penhorn Creek. The last, after being treated form the treatment plant, discharges into Mill Creek. The treatment plant provides secondary sewage treatment while the other 8 point sources discharge raw sewage.

Municipal Waste Loads

Secaucus presently has a total municipal waste load of approximately 1.9 mgd with the existing municipal system carry- about 40% of this load. However, approximately one-third of this flow conveyed by the public system is discharged from public septic tanks rather than the municipal treatment plant. Unfortunately, more than 1.10 mgd (about 60%) of the municipal waste load does NOT enter municipal sewers. More than half of this flow is industrial sewage from the town's three major concerns. The remaining flow is primarily domestic sewage from warehousing and distribution operations, hotels and motels, etc..

Characteristics of the town's sewage is provided by routine analysis determined at the treatment plant.

Industrial Waste Loads

Within the last decade, commercial and industrial operations have become increasingly important. For this thesis, the industrial category has been broadly defined to include all of the town's major employers, including institutions and transportation-related facilities. At present, there are 139 establishments employing some 11,500 people.

The three major concerns of Secaucus which discharge their wastes are Union Textile Printers, Charles Haag, Inc. and Meadowview Hospital. Union Textile and Charles Haag have been cited by the Hackensack Meadowlands Development Commission for discharging unsatisfactory or insufficiently treated sewage into the natural waters. As a result, they must provide their own treatment facilities and obtain individual discharge permits.

Meadowview Hospital, on the other hand, presently provides adequate secondary treatment facilities and its effluent has been approved by both state and federal officials.

Secaucus Treatment Plant

The Secaucus Municipal Treatment Plant began operation in Dec., 1963. It was originally designed for a average daily flow of 2.25 mgd but it has a maximum capacity of 3.00 mgd. The sewer system which leads to the plant does not provide for any by-passes or overflow structures, therefore, all of the sewage in the system terminates at the plant.

In order to facilitate the reader's snese of perception Fig. 25, which shows a schematic diagram of the plant, is included. As each unit of the plant is described, each unit will be numbered and enclosed either in a circle or a box.

At the beginning, sewage enters the plant from a junction chamber which is the end of 2-30 inch interceptors, one from the north and the other from the south. From the junction chamber, the flow enters the grit chambers via a 30-inch pipe.

The grit chamber (2) unit contains 2-2 feet wide grit chambers with mechanical heavy duty bar screens (1). Each screen discharges to a tray at grade where the screenings are mixed with water, passed through a grinder and then returned to the flow. Metals, sticks, rags and the such, are then collected off the bar screens and disposed of at a small onsite landfill. The unit is also equipped with a series of buckets and rakes. The rakes keep organic materials in suspension and the buckets carry the grit to the grit channel operating floor where it is collected in a receptacle for landfill disposal. At the end of the channel, the flow passes through a barminutor (3) which reduces the size of the coarse materials even more. Just beyond the barminutor is a proportioned weir which controls the velocity of the flow from the grit channels.

From the grit chambers, the flow goes to either of two wet wells (4) where a magnetic flow meter with a maximum capacity of 4.5 mgd measures the rate of flow from the grit chamber. Each wet well has its own float control system which activates one or two of the raw sewage pumps, depending on the rate of flow. The design for the system allows for the operation of two pumps with two other pumps as stand-by units.

From the wet well, sewage is pumped through a 14-inch manifold header to the primary clarifiers (5). In the header is the main plant by-pass valve, which when opened, causes flow to by-pass the remainder of the plant. This is used only in emergencies in order to avoid flooding conditions.

The primary clarifier unit is comprised of 3 independent, single pass primary sedimentation tanks grouped together to take advantage of common walls. The sewage flow enters, aerated, via a 6-inch inlet where it goes through a series of ports which convert the flow from a turbulent to a laminar phase. In addition, the primary clarifiers are also equipped with flight collectors for scum and sludge removal. The flight collectors gathers the sludge from the tank bottom and delivers it to a hopper at the inlet portion on the tank. From there, the sludge is removed by pumping. Also, the flight collectors skims the surface moving floatables to a tipping trough at the outlet end of the tank. The floating solids are then transferred to a scum header which then goes to a scum sump at the foot of the sedimentation tank. Collectively, the primary sludge and floating solids are then pumped to the primary digester (10) for processing and digestion. Finally, the flow is discharged over weirs to a distribution box (6) which feeds the trickling filters (7).

The effluent from the primary clarifier flows by gravity to a distribution box where it proportions the sewage to one of the two trickling filters. After passage through the trickling filters, the effluent flows to the secondary clarifiers (8).

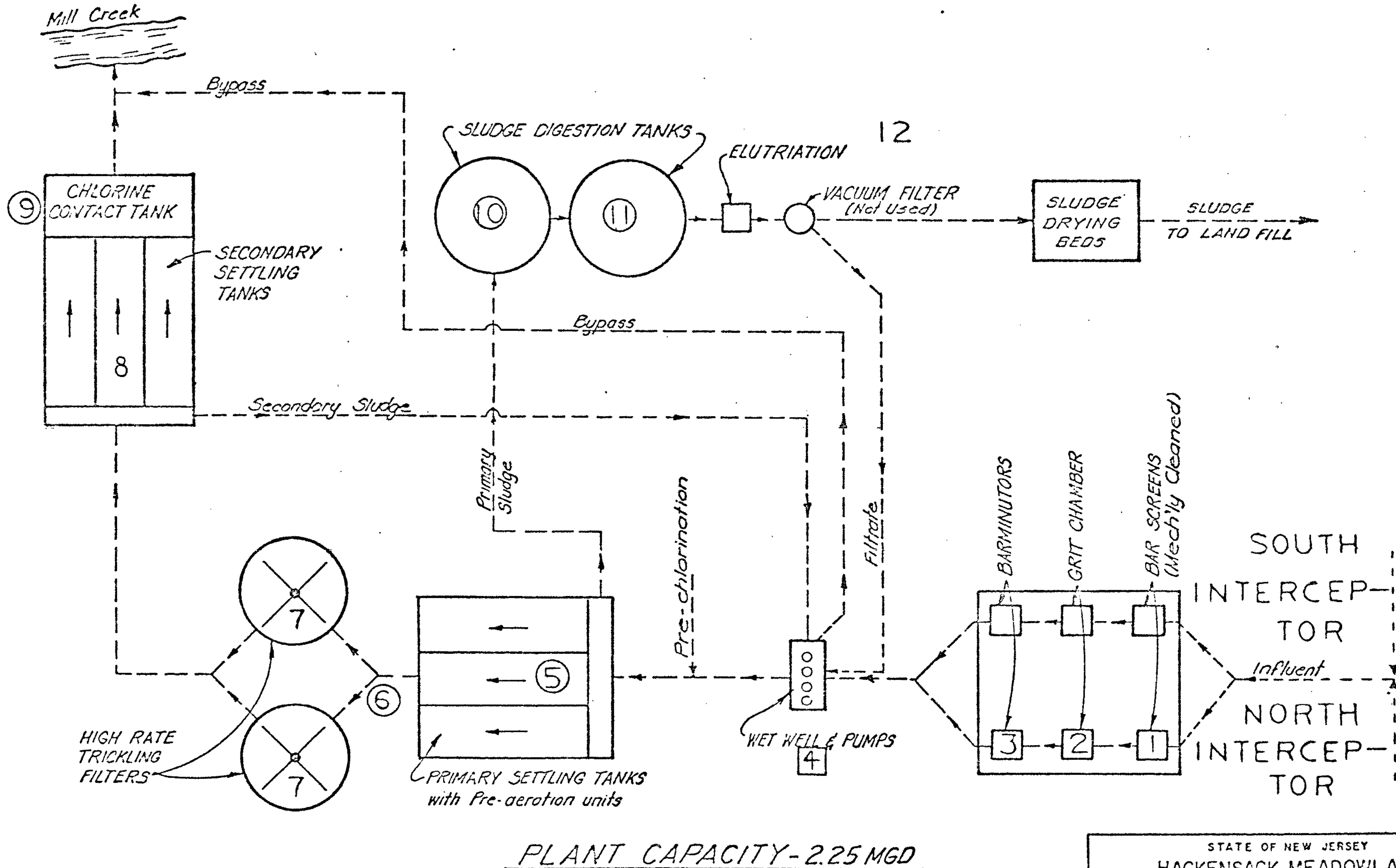
The secondary clarifiers are similar in construction to their primary counterparts, with one small exception: The sludge is returned to the wet well for collection in the primary sedimentation tanks. The sewage then flows on to a chlorine contact tank (9). Here, the sewage is mixed with chlorine chemicals in a three-channel chlorine contact tank before discharge to Mill Creek.

Sludge withdrawn from the primary clarifier to the sludge digestion facilities (10 & 11) by one of two sludge pumps located in the pump gallery. Each pump has a maximum capacity of 100 gpm. In the sludge digestion facilities, the sludge is digested in 2-45 foot wide by 35 foot high tanks. One is a heated high-rate primary digestion tank (10). The other is an unheated secondary digester (11). Each tank is equipped with gas mixing equipment and mixing pumps. Also, each tank has a floating cover. Finally, after digestion, the sludge is withdrawn to an elutriation tank (12) where it is washed prior to filtering. The wash water is then recycled back to the head of the plant and the sludge is treated chemically to improve filtering. The sludge is finally vacuum filtered and ultimately disposed at the onsite landfill.

The following are miscellaneous in terms of the function of the treatment plant, but, essential in the actual operation. For instance, there are 4-40 hp vertical centrifugal pumps (2 for service, 2 for stand-by). Each has a capacity of 2.8 mgd. In addition, the pumps have an 8-inch section and a 6-inch discharge opening. As the average flow increases, the pump impellers and motors can be replaced and with minor modifications to the discharging pipes, each pump's capacity can be increased to 3.9 mgd.

Also, there is a diesel engine serving as an emergency power in case of a power failure. This unit is rated at 165 KW for continuous stand-by service which is also sized to provide power for the raw sewage pumps and other miscellaneous equipment.

Finally, the plant effluent is withdrawn prior to entry into the chlorine contact tank and stored in a 4,000 gallon hydro-pneumatic tank located in the dry well area. Pumps used with this system are rated at 220 gpm and supply the recycled effluent water for use in the chlorinating facilities and for general flushing purposes.



STATE OF NEW JERSEY
HACKENSACK MEADOWLANDS DEVELOPMENT COMMISSION
FEASIBILITY REPORT-WATER POLLUTION CONTROL SYSTEMS

SCHEMATIC FLOW DIAGRAM
SECAUCUS MUNICIPAL PLANT
FEBRUARY 1970

FIGURE 25

JERSEY CITY SEWERAGE AUTHORITY
WEST SIDE PLANT

The Jersey City Sewerage Plant is located just north of Roosevelt Stadium at Droyers Point on the westerly side of N.J. Route 440 opposite Carbon Place in Jersey City. This plant is one of two existing water pollution control facilities located in Jersey City which treat wastewater generated from within its corporate limits as well as from portions of the municipalities of Union City and Bayonne.

The two plants and the interceptor sewers tributary to them are operated and maintained by the Jersey City Sewerage Authority, a separate and autonomous agency entirely independent from the Corporate Civil City. This Authority was established by the municipality of Jersey City in 1949 and the water pollution control plants and intercepting sewers were placed in service in 1957. Prior to this construction, raw sewage had been discharged from the City's collection system directly into the Hudson and Hackensack Rivers.

The West Side Plant serves the City's westerly slope, the portion of the municipality of Union City and a small area containing about 250 homes within the City of Bayonne. Approximately 4.1 square miles or 38% of the area of Jersey City and 0.4 sq.mi. or 46% of the area of Union City presently contribute sewage to this plant. Included in the westerly portion of Jersey City are about 1.1 sq. mi. of presently unsewered meadowlands. According to the municipal officials, the developed portion of the west side service area consists of medium and high density residential development, but also contains a significant amount of commercial and industrial development.

The individual collection system tributing to the West Side Plant are owned and maintained by their respective municipalities. With the possible exception of the small portion of Bayonne served, the collection systems are 50 or more years old and almost entirely of the combined type. The old combined sewers in Jersey City present many problems, among them being surcharging during periods of even moderate rainfall, with attendant surface ponding and backwash in many low lying areas.

The sanitary wastes and stormwater run-offs from these combined sewers on the City's westerly slope is intercepted by the Jersey City Sewerage Authority. West Side Interceptor Sewer and conducted to the plant. The southerly portion of this interceptor is a 48-inch diameter pipe which starts south of the Penn-Central Railroad tracks and runs northerly via N.J. Route 440 to the plant. The northerly portion of the interceptor starts at the No. Bergen Township line as a 48-inch diameter pipe and runs south along Tonnelle and

Carroll Avenues to a crossing of the Erie and Lackawanna Railroad as a 54-inch pipe. There it changes direction several times in the Pulaski Skyway area where it becomes a 72-inch pipe and continues to the south along U.S. Route 1 and N.J. Route 440 to the plant. The interceptor enters the plant as an 84-inch diameter sewer pipe. The entire sewerage system which includes both collecting and intercepting facilities is of the gravity type.

Description of the Plant

As indicating in Fig. 26, sewage enters the plant through the 48 and 84-inch West Side Interceptors, then passes through mechanically cleaned bar screens for removal of large debris. After the screening, the sewage continues into the grit collectors and comminutors from which it is pumped to the primary settling tanks. The comminuting system consists of 3 Chicago Pump "Comminutors" installed in the outlet end of the 3 grit collection chambers. The raw sewage pumping capacity is provided by 3 pumps with a total capacity of 90 mgd.

The sewage then passes through the primary settling tanks and the chlorine contact tanks before discharging in to the Hackensack River through a 54-inch diameter outfall sewer. There are no plant by-pass structures. Howver, high peak storm flows have caused flooding and flow-through of the plant with accompanying disruption of the treatment processes.

There are5 sedimentation tanks, each providing a surface area of approximately 10,000 sq.ft.. The chlorine contact tanks are reported to provide approximately 20 minutes of detention time at the plant design flow of 36 mgd. The 54-inch outfall sewer extends approximately 100 feet into the Hackensack River from the pierhead line, and from this point reduces in successive steps over an additional 140 feet to a 30-inch diameter at the open end of the pipe. A total of 64 outlets, 6-inches in diameter, spaced along the last 140 feet of the pipe provides for dispersal of the effluent for a better mixing.

The West Side Treatment Plant was designed for a 36 mgd. capacity, but provides only primary treatment of wastes. The wastes received at the plant have been characterized as predominantly domestic in nature, the heavier industrial contributions being treated at the East Side Plant. However, the Sewerage Authority officials have reported that a blue dye received at the West Side Plant from a nearby industry has been a recurring problem over a considerable period of time. It was reported that construction of pre-treatment facilities at the industrial source of the dye has begun in 1969.

Sludge from the West Side Plant primary sedimentation tanks and primary raw sludge from the East Side Plant pumped across town is collected in 2 sludge concentration tanks contration tanks, where concentration takes place over a 2 day period to a 6-9% solids condition. The concentration tanks are 45 feet in diameter and 35 feet deep. The sludge is then pumped from these thickeners to the 4 vacuum filters and about 700,000 gallons/day of supernatant are returned to the primary tanks. Following vacuum filtration, employing sludge conditioning by the addition of a special polymer, sludge cakes are transported by conveyor belt to the municipal incinerator. The incineration capacity is 6,150 lbs./hour of dry solids with a moisture content of not less than 30%. In addition, the unit is also capable of burning ground screenings and grit; unfortunately, at present the grit is disposed of by onsite burial.

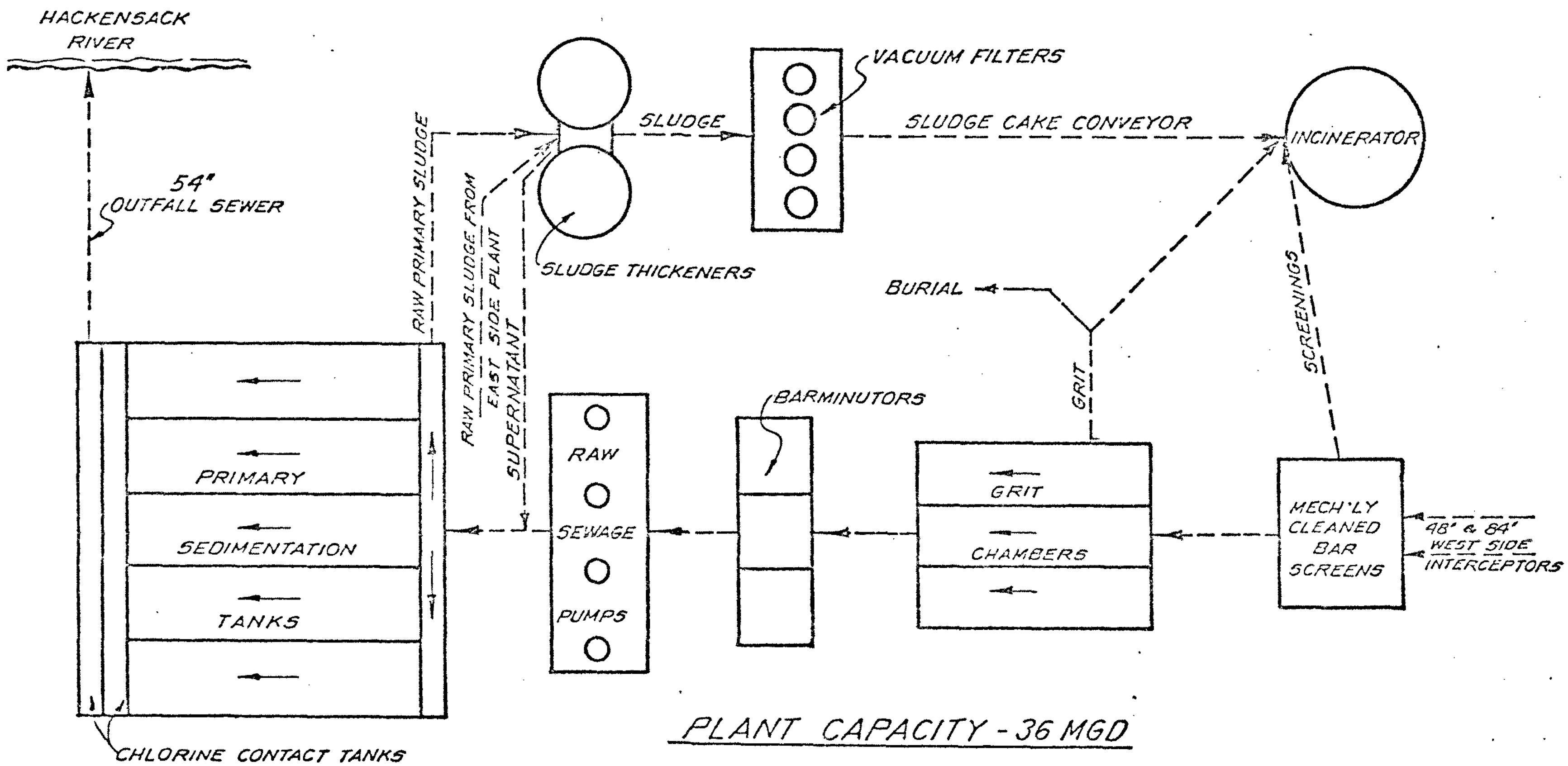


FIGURE 26

STATE OF NEW JERSEY
HACKENSACK MEADOWLANDS DEVELOPMENT COMMISSION
FEASIBILITY REPORT-WATER POLLUTION CONTROL SYSTEMS

SCHEMATIC FLOW DIAGRAM
JERSEY CITY SEWERAGE AUTHORITY
WEST SIDE PLANT
JANUARY 1970

JOHN J. KASSNER & CO., INC.
Consulting Engineers

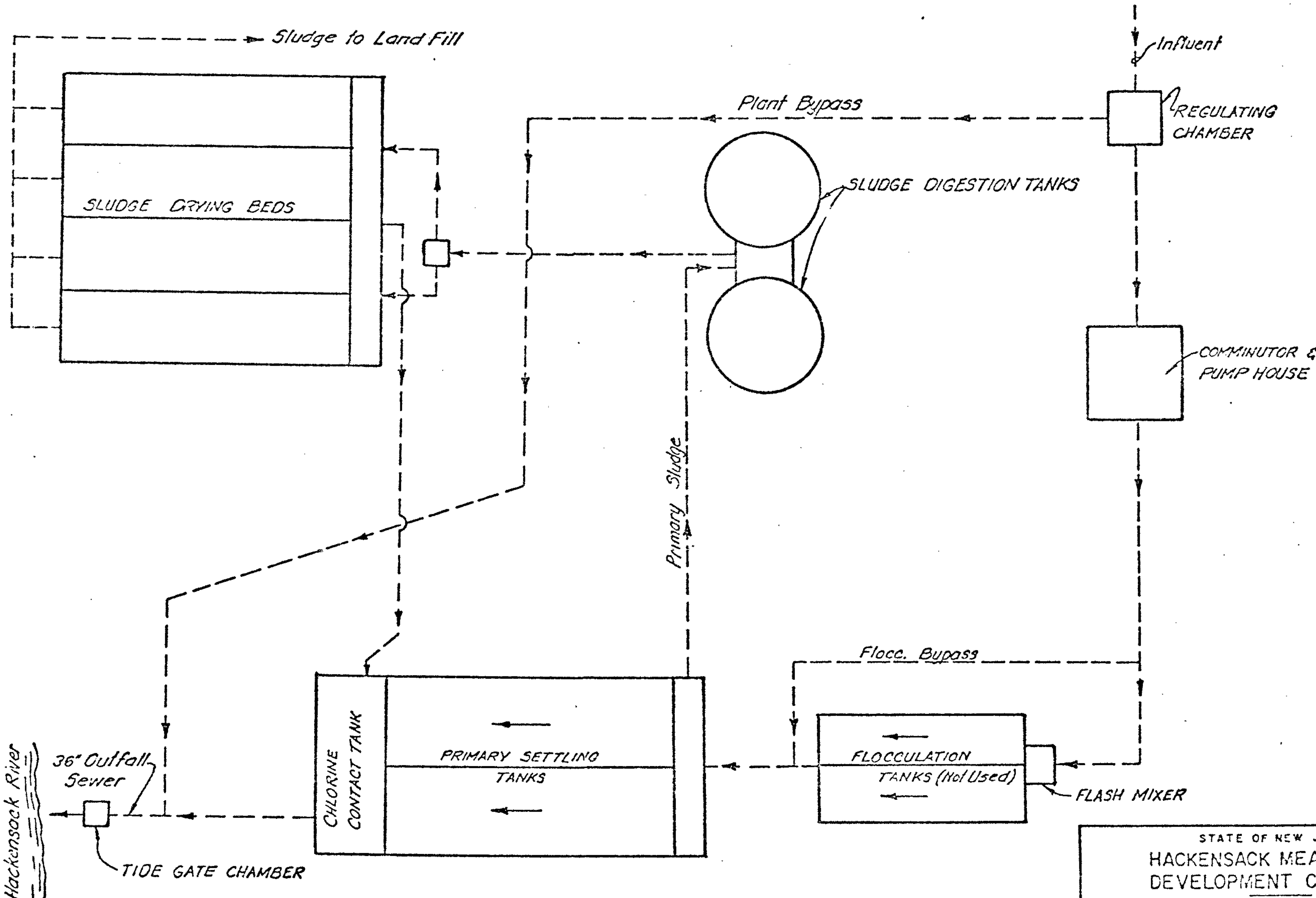
KEARNY MUNICIPAL PLANT

The Kearny South Side Plant is located at the southerly tip of Kearny Point immediately east of Central Avenue and south of the tracks of the New Jersey Central Railroad. Drawings, available at the Town Hall of Records, furnished for the municipality indicate that the plant was designed in 1948, but that the plant was constructed in 1955 for the purpose of treating the waste of approximately 6.6 sq.mi. of industrially zoned meadowland within the Town's corporate limits. The Kearny Plant area presently served by this plant has been intensely developed with heavy industries. Although this area has no resident population, it has been estimated that approximately 60,000 people are employed by these industries.

Sewage enters the plant through a 48-inch diameter sewer extending northerly to Second Street which is fed by sewers in Hackensack Street on the east and Jacobus Avenue on the west. It is further fed by east and west branches from Pennsylvania Avenue. A pumping station maintained by the municipality pumps the discharge from the Monsanto Chemical Co. into the westerly Pennsylvania Avenue branch. According to municipal officials, the sewers are generally 30-40 years old and of the combined type which causes problems of high flows at the plant during periods of rain. The existence of overflow regulating devices is not used at this plant.

Description of the Plant

Figure 27 illustrates the construction of the plant schematically. The Kearny was designed and constructed on an average daily flow of 4 mgd and with a peak flow of 8 mgd and it was constructed to provide only primary treatment and disposal of industrial wastes. However, some of the domestic sewage produced by the non-residential population working in the area is also received at the plant. The industrial wastes received at the plant contains paints, dyes, petrochemical wastes and other diverse elements. Sewage flow to the plant first passes through a regulating chamber which by-passes an underternined amount of the influent flow directly into the Hackensack River. Initial plant design provided for a regulator setting in the chamber which would by-pass all flow in excess of 4 mgd.



PLANT CAPACITY - 4.0 MGD

STATE OF NEW JERSEY
HACKENSACK MEADOWLANDS DEVELOPMENT COMMISSION
FEASIBILITY REPORT-WATER POLLUTION CONTROL SYSTEMS

SCHEMATIC FLOW DIAGRAM
KEARNY MUNICIPAL PLANT
FEBRUARY 1970

FIGURE 27

RESULTS AND DISCUSSION

Many parameters are determined in a laboratory analysis of samples from a municipal and/or industrial wastewater discharge. Depending on the degree of treatment and the degree of purity desired, the number of parameters examined will vary from treatment plant to treatment plant. However, for the purpose of brevity and because most plants in the Hackensack Meadowlands District are of the primary treatment type, the following parameters were used to evaluate the effectiveness of the treatment plants previously discussed - these are: Total Nitrogen (T.N.), Nitrate-Nitrate Compounds (NOx), Orthophosphate-P, Total Organic Carbon (TOC), Total Oxygen Demand (TOD), 5-day Biochemical Oxygen Demand (BOD), Suspended Solids (S.S.) and Fecal Coliform.

Because of the very nature of primary treatment facilities- that is, their function of screening and settling of suspended and coarse particles- they are providing to be outdated with our social and industrial development and the consequent increases of the municipal and industrial wastewaters generated. This section of the thesis will present a series of tables showing influent and effluent wastewater parameters with percent removals for each of the treatment plants. Because of the detention time of each of the plants, it was not possible to measure the effluent with respect to its influent counterpart. Therefore, the sample results were averaged so as to collectively represent wet and dry weather conditions for the sampling period.

Most plants estimate their efficiencies on the basis of the percent removal of the BOD and the suspended solids. The amount of the suspended solids removed from a treatment system largely depends on the detention time of the various units in any particular plant. In addition, when the suspended solids are removed, the BOD is also removed or reduced - providing that it is a primary plant and the suspended solids removed contain some organic materials. However, BOD removal is observed mostly in biological-physical treatment plants where the filter media change the nature of the organic loadings so that there is less oxygen demand from the effluent when discharged into a receiving stream.

Also, the degree of oxidation of nitrogen is indicative of the degree of treatment obtained. For instance, increasing nitrate concentrations indicate a high degree of treatment and possibly that air is being wasted and increasing ammonia concentrations indicate that insufficient treatment is being obtained or that too little oxygen is being used. Phosphate-P is a nutrient used in biological systems by bacteria in conjunction with nitrogen to reduce the organic loadings found in sewage. Finally, the TOD and TOC are removed, to a certain degree, by the treatment plants only because

LYNDHURST-NORTH ARLINGTON JOINT MEETING PLANT

TABLE NO. 3 - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
June 15	1.58	27.5	18.0					384	115	
17	1.70	22.0	20.0		0.650			483	173	
22	1.70	[illegible]	21.0		0.490				176	
24	1.65	[illegible]	[illegible]		0.550				213	
July 1	1.75	32.0	19.0		0.369		82.6		112	
7	1.70	28.5	24.0		0.270	5.05	70.9	558		182
9	1.80	30.5	26.5		0.500	4.50		390	140	291
13	1.45	20.5	22.5		0.230	2.58		168	133	142
15	2.90	20.5	21.0		0.360	5.63	158.0	700	209	274
20	1.50	26.5	23.0			5.00	188.0	540	269	190
23	1.40	21.0	22.0				427.0		292	204
Aug. 5	1.50	27.0	27.0				115.0		195	135
Oct. 5	1.45	18.0	21.0	15.2	0.320		77.8		105	86.0
12	1.60	15.5	19.0		0.570	8.55	179.0			122
19	1.55	12.0	19.0	22.7	0.515	3.03	92.0		112	108
26	1.90	4.0	17.0	21.9	0.640	3.66			457	943

LYNDHURST-NORTH ARLINGTON JOINT MEETING PLANT

TABLE NO. 3 (CONT'D) - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
Nov. 9	1.60	11.5	17.5	34.7	0.730	2.42		345	216	188
16	1.75	10.0	17.0		0.235	2.45		320		147
30	1.55	-1.0	13.0		0.575	1.72		380	213	94.0
1977										
Feb. 23	1.65	1.0	12.0	27.9	0.551	2.61			258	211
Mar. 2	1.60	4.0	12.0	23.8	0.958	0.855			303	313
9	2.20	15.0	13.0	26.5	0.910	1.72		525	609	275
30	2.90	24.0	16.5	26.2	1.33	1.42			228	193
Apr. 13	3.25	29.5	16.5	14.2	1.38	1.53			262	352
27	1.95	11.5	15.0	35.4	0.334	1.99			318	193
Ave.	1.82	19.0	19.0	24.9	0.593	3.22	154.0	383	232	240

LYNDHURST-NORTH ARLINGTON JOINT MEETING PLANT

TABLE NO. 4 - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1976										
June 15	23.5	17.0					231	52.0		0
17	25.5	19.0		1.10			222	71.4		0
22	28.0	19.0		0.560				94.7		0
24	40.0	24.0		0.290				69.8		
July 1	32.0	18.0		0.330		77.8		80.1		
7	28.5	22.5		0.340	4.00	54.6	252		75.7	
9	30.5	23.5		0.330	2.90		283	90.2	63.0	
13	20.5	21.5		0.410	2.76		270	77.1	59.8	
15	20.5	25.0		0.500	3.75	63.1	330	113	85.4	
20	27.0	22.0			2.30	49.0	150	45.4	40.3	0
23	21.0	22.0				53.0		80.7	59.3	0
Aug. 5	27.0	21.5				57.1		74.3	50.8	13,000
Oct. 5	18.0	21.0	20.4	0.620		58.0		17.7	85.4	200
12	15.5	20.0		1.01	6.00	52.0			48.7	300
19	12.0	19.0	31.0	0.075	3.12	70.0		64.7	38.6	0
26	11.5	17.0	17.9	0.740	2.94			90.0	76.1	400

LYNDHURST-NORTH ARLINGTON JOINT MEETING PLANT

TABLE NO. 4 (CONT'D) - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1976										
Nov. 9	4.0	16.0	36.8	0.890	3.55		370	108	59.0	0
16	10.0	15.0		0.260	2.65		200		70.0	0
30	-1.0	12.0		0.655	1.62		300	107	43.1	
1977										
Feb. 23	1.0	12.0	32.7	0.616	1.86			93.8	109	
Mar. 2	4.0	10.0	34.7	1.12	1.48			82.8	176	0
9	15.0	13.0	30.8	0.910	1.62		252	153	121	0
30	24.0	14.5	[illegible]	1.44	1.17		57.0	112	230	0
Apr. 13	29.5	15.0	25.7	1.42	0.320		44.0	72.8	251	
27	11.5	13.0	32.3	0.242	1.27			16.4	184	
Ave.	18.0	18.5	29.2	0.688	2.58	59.5	234	80.3	96.3	

LYNDHURST-NORTH ARLINGTON JOINT MEETING PLANT

TABLE NO. 5 - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1976						
June 15	1.58	115	1520	52.0	685	835
17	1.70	178	2520	71.4	1010	1510
22	1.70	176	2500	94.7	1340	1160
24	1.65	213	2930	69.8	960	1970
July 1	1,75	112	1630	80.1	1170	460
9	1.80	140	2100	90.2	1350	750
13	1.45	133	1610	77.4	936	674
15	2.90	209	5050	113	2730	2320
20	1.50	209	2610	45.4	568	2040
23	1.40	292	3410	80.7	942	2470
Aug. 5	1.50	195	3650	74.3	929	2720
Oct. 5	1.45	105	1270	17.7	214	1060
19	1.55	112	1450	63.5	821	629
26	1.90	457	7240	90.0	1430	5810

LYNDHURST-NORTH ARLINGTON JOINT MEETING PLANT

TABLE NO. 5 (CONT'D) - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1976						
Nov. 9	1.60	216	2880	108	1440	1440
30	1.55	213	2750	107	1380	1370
1977						
Feb. 23	1.65	258	3550	93.8	1290	2260
Mar. 2	1.60	303	4040	82.8	1100	2940
9	2.20	609	11200	153	2810	8360
30	2.90	228	5510	112	2710	2800
Apr. 13	3.25	262	7100	72.8	1970	5130
27	1.95	318	5170	16.4	266	4900

these processes are capable of removing or altering the BOD content and suspended solids within each unit.

Lyndhurst-North Arlington Plant

The results of the analyses of the influent and effluent wastewaters are outlined in Tables 3,4 and 5 with Table 6 showing averages and percent removals.

Table 6

Averages and Percent Removal

	Influent mg/liter	Effluent mg/liter	Percent Removal
T.N.	24.9	29.2	-
NOx	0.593	0.688	-
Phos.	3.22	2.58	19.9
TOC	154	59.5	61.4
TOD	383	234	38.9
BOD	232	80.3	65.3
S.S.	240	96.3	59.8

From Table 6 it can be seen that removal of the T.N., NOx and Phos.-P is nearly impossible with the available primary treatment at this plant. One excuse or explanation for the Phos. reduction may be that some of the phosphate may have been in precipitate form which settled out with the suspended solids. Being a primary treatment process (whose sole function is the removal of coarse materials from sewage prior to final discharge) the plant is not designed to remove those pollutants in soluble form unless additional units, such as biochemical-physical treatment units, are added.

The BOD and S.S. removals are acceptable for a primary treatment facility although they should be much greater so as not to exert any oxygen demands on the receiving stream. However, the TOD, which is similar to the Chemical Oxygen Demand (COD), shows a high effluent concentration or lower percentage removal in contrast to the other parameters. This high value is an indication of both organic and inorganic substances in the wastewater. Since most of the organic pollutants are removed from the plant, it is obvious that the TOD would show mostly inorganic substances exerting an oxygen demand. Therefore, it is necessary that the plant be upgraded so as to remove those inorganic substances in order to reduce the oxygen demand.

Finally, although the amount of BOD removal is sufficient for a primary treatment facility, it should be further increased. Calculated into lbs./day, the BOD discharge (1,270 lbs./day for this plant) may not be high considering the volume of the receiving water; but, if one were to calculate this figure over a one year period (463,550 lbs./year) this value may be surprising and quite frightening.

"Triboro" Joint Meeting Plant

Influent and effluent data are outlined in Tables 7,8 and

RUTHERFORD-EAST RUTHERFORD-CARLSTADT JOINT MEETING PLANT

TABLE NO. 7 - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
June 15	3.50	24.0	22.5					840	281	
17	3.60	30.0	25.0		2.15			964	229	
22	3.40	33.0	24.5		10.8				371	
24	3.20	34.0	29.0		0.975				283	
July 1	3.90	32.0	21.0		1.00		163		264	
7	4.50	28.5	26.5		3.24	14.0	110	480		196
9	4.50	31.5	28.0		3.24	2.35		625	216	150
13	2.90	21.5	21.5		3.25	2.60		564	71.0	193
15	2.95	25.0	27.0		1.18	3.15	146	720	261	142
20	2.00	25.5	25.0			5.75	234	380	245	195
23	3.50	21.5	24.5				86.9		241	146
Aug. 5	3.60	30.0	27.5				155		162	162
Oct. 5										
12	2.90	15.5	24.5			14.5	316			87.5
19	3.50	11.0	22.0	39.4	3.57	2.13	232		252	159
26	3.60	16.5	20.0	38.0	1.65	2.88			233	307

RUTHERFORD-EAST RUTHERFORD-CARLSTADT JOINT MEETING PLANT

TABLE NO. 7 (CONT'D) - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
Nov. 9	3.95	6.0	17.0	97.8		1.55	3.01		135	198
16	3.60	13.0	20.0		4.70	3.65		680		164
30	3.60	-2.0	10.0		5.70	1.01		1240	257	147
1977										
Feb. 23	3.40	15.0	15.5	92.0	0.786	1.31			169	191
Mar. 2	3.30	5.5	14.5	31.0	1.61	1.20			492	228
9	3.10	15.0	17.0	25.0	2.24	1.01			432	242
30	3.70	27.0	15.0	25.0	1.41	2.09		175	391	193
Apr. 13	4.90	32.0	23.0	35.4	2.90	0.350	-	219	243	150
27	3.40	12.5	17.0	33.9	0.421	2.15			92.3	213
Ave.	3.50	21.0	22.0	46.7	2.24	3.68	161	622	254	182

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RUTHERFORD-EAST RUTHERFORD-CARLSTADT JOINT MEETING PLANT

TABLE NO. 8 - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1976										
June 15	25.5	22.5					558	72.3		0
17	27.5	25.0		2.70			763	188		0
22	33.0	24.0		2.17				141		100
24	37.0	2[illegible].0		1.11				267		
July 1	32.0	21.5		0.800		90.7		130		
7	2[illegible].5	26.0		0.990	4.96	87.4	288		109	
9	31.5	28.0		1.96	3.15		615	23.3	115	
13	21.5	25.5		1.12	4.26		638	20.8	106	
15	25.0	26.0		1.25	4.50	154	845	128	175	
20	25.5	25.0			3.05	76.4	230	104	68.2	0
23	21.5	24.5				86.9		101	44.6	0
Aug. 5	30.0	27.5				155		169	56.5	0
Oct. 5										
12	15.5	22.0			5.15	124			91.7	0

RUTHERFORD EAST RUTHERFORD CARLSTADT JOINT MEETING PLANT

TABLE NO. 8 (CONT'D) - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1976										
Oct. 19	11.0	20.0	35.3	1.58	4.17	186		85.9	62.0	0
26	16.5	19.0	23.8	1.50	3.30	3.3		100	151	33,600
Nov. 9	6.0	19.0	32.1		3.49	6.9	735	108	121	2,700
16	13.0	18.0		0.550	6.10		250		96.4	0
30	-2.0	14.0		3.23	1.70		670	144	96.1	
1977										
Feb. 23	15.0	15.0	36.9	0.708	1.01			145	145	
Mar. 2	5.5	13.0	42.5	2.21	2.27			265	250	600
9	15.0	15.0	34.5	1.65	1.70		735	225	151	0
30	27.0	21.5	43.0	1.78	9.08		144	274	93.0	5,600
Apr. 13	32.0	22.0	34.9	1.61	1.75		80.0	238	106	
27	12.5	16.0	53.7	1.32	1.31			83.9	142	
Ave.	21.0	21.5	43.0	1.57	3.67	97.1	558	144	116	

RUTHERFORD-EAST RUTHERFORD-CARLSTADT JOINT MEETING PLANT

TABLE NO. 9 - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1976						
June 15	3.50	284	8290	72.8	2130	6160
17	3.60	229	6880	188	5640	1240
22	3.40	371	10500	141	4000	6500
24	3.20	283	7550	267	7130	420
July 1	3.20	264	7050	130	3470	3560
9	4.50	216	8110	23.3	874	7240
13	2.90	71.0	1720	20.8	503	1220
15	2.95	261	6420	128	3150	3270
20	2.00	245	4090	104	1730	2320
23	3.50	241	7030	101	2950	4080
Aug. 5	3.60	162	4860	169	5070	- -
Oct. 19	3.50	252	7360	85.9	2510	4850
26	3.60	233	7000	100	3000	4000
Nov. 9	3.95	135	4450	108	3560	890
30	3.60	257	7720	144	4320	3400

RUTHERFORD-EAST RUTHERFORD- CARLSTADT JOINT MEETING PLANT
TABLE NO. 9 (CONT'D) - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1977						
Feb. 23	3.40	189	5360	145	4110	1250
Mar. 2	3.30	492	13500	265	7290	6210
9	3.70	391	12300	274	8460	3840
30	3.40	432	12200	225	6380	5820
Apr. 13	4.90	243	9930	238	9730	200
27	3.40	92.3	2620	83.9	2380	240

9 with Table 10 showing percent removals.

Table 10

Averages and Percent Removal

	Influent mg/liter	Effluent mg/liter	Percent Removal
T.N.	46.7	43.0	7.9
NOx	2.24	1.57	29.9
Phos.	3.68	3.67	0.30
TOC	161	97.1	39.7
TOD	622	558	10.3
BOD	254	144	43.3
S.S.	182	116	36.2

"Triboro", as previously explained, is a secondary treatment plant utilizing trickling filters as the biological oxidation method for the removal and reduction of organic loadings in municipal and industrial wastewaters. Surprisingly enough, upon observing the percent removals one might wonder whether this plant were a primary or secondary treatment process. It is quite obvious that this plant, designed to operate as a secondary treatment facility, has degenerated to a point where the effective removal rates are below those required of a primary treatment plant.

Most secondary treatment facilities which utilize trickling filters have an overall plant efficiency ranging from 85-96% BOD removal.[1] Even if we used the BOD percent removal, we can see that this is still far short than required for plant efficiency determination and must, therefore, be given serious consideration if this plant is to continue operating as a secondary treatment facility.

It is obvious that with small decreases in the NOx and T.N., the trickling filters are not operating as effectively as they are designed to do so. One might assume that these minute deceases could indicate that either clogging of the filters (otherwise known as ponding) has occured or that the secondary treatment units of the plant are being completely by-passed. Removal of phosphates may be accomplished either by the nutrient demand of the bacteria in the trickling filter or by the settling out of precipitate phosphates.

Since the plant is also handling large flows from various industries, it is not surprising to note a high TOD value for the effluent which would indicate large loads of both organic and inorganic substances. The TOC, BOD and S.S. need not be explained as they are similarly removed by the plant in much the same fashion as the Lyndhurst-North Arlington Plant.

North Bergen Central Plant

Results of the influent and effluent waters of the plant are outlined in Tables 11, 12 and 13 with Table 14 illustrating percent removals.

NORTH BERGEN CENTRAL PLANT

TABLE NO. 11 - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
June 15	1.65	26.0	21.0					597	208	
17										
22	1.31	36.0	30.0		1.68				198	
24	1.53	35.5	28.0		0.320				101	
July 1	1.42	27.5	23.5		0.940		13.7		138	
7	1.26	26.5	27.0		0.160	2.20	30.2			121
9	1.60	30.5	26.5		0.410	2.80		315	95.4	115
13	1.43	16.0	24.0		0.060	2.16		225	81.0	112
15	1.48	25.5	27.5		0.040	2.60	63.9	355	123	115
20	1.53	27.5	30.0			3.65	288	770	274	167
23	2.05	21.5	26.5				117		147	146
Aug. 5	1.60	28.5	30.0						163	165
Oct. 5	1.34	16.0	22.0	13.6	0.690		120		132	152
12	1.57	15.0	23.5		1.31	2.85	103			79.5
19	1.32	12.0	22.0	14.5	1.90	2.58	98.9		136	64.4
26	2.22	14.0	18.0	10.5	2.16	1.62			112	70.6

NORTH BERGEN CENTRAL PLANT

TABLE NO. 11 (CONT'D) - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
Nov. 9	1.51	7.0	18.0	22.5	1.16	2.58		345	144	81.3
16	0.950	11.0	21.0		0.275	4.00		810		138
30	1.10	-1.0	18.0		1.41	0.500		670	277	175
1977										
Feb. 23	0.600			21.1	0.221	1.06			127	151
Mar. 2	1.48	8.5	13.5	16.8	1.79	0.725			155	220
9	1.60	12.5	16.0	14.1	1.80	0.500		120	182	254
30	2.04	30.0	17.0	19.6	1.94	0.942		75.0	151	123
Apr. 13	1.60	26.0	20.0	20.3	1.71	0.730		78.0	146	174
27	1.14	15.0	19.0	30.1	2.58	1.30			70.7	115
Avg.	1.51	20.5	22.5	18.2	1.80	1.93	112	399	151	140

NORTH BERGEN CENTRAL PLANT

TABLE NO. 12 - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES / 100 ml
1976										
June 15	28.0	26.0					630	68.9		
17										
22	35.0	28.0		0.700				155		7,200
24	38.0	29.0		0.210				50.1		
July 1	23.0	24.0		0.680		50.4		72.7		
7	20.5	25.5		0.040	2.00	66.8	144		55.0	
9	30.5	26.5		0.080	1.65		175	42.4	46.4	
13	16.0	26.5		0.090	2.58		169	62.7	43.8	
15	25.5	28.0		Trace	2.10	52.6	195	21.9	44.0	
20	27.5	28.0			3.51	96.0	285	89.6	47.1	100
23	21.5	28.0				112		77.4	49.6	0
Aug. 5	28.5	30.0						39.6	77.2	
Oct. 5	16.5	22.0	12.1	0.695		95.5		40.5	91.9	100
12	15.0	23.5		0.615	4.60		102		39.8	300
19	12.0	23.0	16.7	0.710	2.70	95.0		77.7	40.4	20,000
26	11.0	11.0	15.[illegible]	1.2[illegible]	1.26			3.1	63.0	

NORTH BERGEN CENTRAL PLANT

TABLE NO. 12 (CONT'D) - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1976										
Nov. 9	7.0	16.0	23.5	0.478	3.07		355	73.4	49.4	0
16	11.0	18.0		0.950	2.80		440		49.7	270000
30	-1.0	15.0		1.11	0.750		380	107	63.3	
1977										
Feb. 23			15.2	0.512	1.26			26.5	80.0	
Mar. 2	8.5	14.0	13.9	0.644	0.761			35.5	161	
9	12.5	11.5	17.6	0,606	0.750		260	53.2	151	0
30	30.0	20.0	22.5	1.66	0.580		73.0	55.3	91.0	136800
Apr. 13	26.0	22.0	19.7	1.77	0.940		69.0	69.7	118	
27	15.0	10.0	23.1	0.566	0.930			13.9	74.0	
Ave.	20.5	23.0	17.3	0.689	1.90	81.2	252	92.1	71.6	

NORTH BERGEN CENTRAL PLANT

TABLE NO. 13 - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1976						
June 15	1.66	208	2880	68.9	954	1930
22	1.31	198	2160	155	1720	440
24	1.53	101	1290	50.3	639	651
July 1	1.42	138	1630	72.7	861	769
9	1.88	95.4	1500	42.4	665	835
13	1.43	84.4	1010	62.7	748	262
15	1.48	123	1520	21.9	270	1250
20	1.53	274	3500	89.6	1140	2360
23	2.05	147	2510	77.4	1320	1190
Aug. 5	1.60	163	2180	36.9	492	1690
Oct. 5	1.34	132	1480	40.5	453	1030
19	1.32	136	1500	77.7	855	645
26	2.22	112	2070	3.1	57	2010
Nov. 9	1.51	144	1810	73.4	924	886
30	1.10	277	2540	107	981	1560

NORTH BERGEN CENTRAL PLANT

TABLE NO. 13 (CONT'D) - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1977						
Feb. 23	0.60	127	635	26.5	133	502
Mar. 2	1.48	155	1910	35.5	438	1470
9	1.60	182	2430	53.2	710	1720
30	2.04	151	2570	53.3	907	1660
Apr. 13	1.60	146	1950	69.7	930	1120
27	1.14	70.7	672	13.9	116	556

Table 14

Averages and Percent Removals

	Influent mg/liter	Effluent mg/liter	Percent Removal
T.N.	18.2	17.8	2.2
NOx	1.20	0.69	42.6
Phos.	1.93	1.90	1.6
TOC	112	81.2	27.5
TOD	399	252	36.8
BOD	151	92.1	39.0
S.S.	140	71.6	48.9

On the basis of the above percentage removals, it can be seen that, as a primary treatment facility employing Imhoff tanks as sedimentation basins, this plant is barely removing those pollutants found in sewage. For instance, Imhoff tanks are capable of removing at least 60% of the suspended solids and at least 30% of the BOD.

However, although the BOD removal is within the plants efficiency removal rate, the suspended solids are not. One probable reason for the low removal rate is that the rate of flow through the Imhoff tanks has not been reduced sufficiently to provide the proper settling rate for the suspended solids. However, this can be partially accomplished by introducing weirs at the inlet channels to the plant; thereby, reducing flow prior to entry into the Imhoff tanks for treatment.

NOx removals may have occured under anaerobic conditions, where facultative heterotrophic bacteria will utilize the

NOx as a hydrogen acceptor for the degradation of organic matter which will also contribute to a lower BOD value. If most of the T.N. is in the form of ammonia-N, it is possible that this low percentage removal may have resulted also from anaerobic conditions where anaerobic bacteria, using the available NOx as an energy source, may have oxidized the ammonia-N.

Although TOD removals are within the efficiency range of the plant, the effluent concentration is still much too high to allow it to be discharged into the receiving waters. As indicated in Table 1, the discharge point of the effluent is in Cromakill Creek. On-site inspection of this Creek has revealed that it is now a stale, septic, odiferous stream with no aquatic life. This has occured due to the daily discharge of the plant's effluent concentrations. Had the plant been operating efficiently, Cromakill Creek may have been instead a clear, odor-free body of water supporting aquatic life.

Secaucus Municipal Plant

Tables 15, 16 and 17 illustrate the results of the influent and effluent wastewaters of this plant with Table 18 containing percent removals.

SECAUCUS MUNICIPAL PLANT

TABLE NO. 15 - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
June 15										
17	1.26	26.0	21.0		0.250			498	237	
21										
24	1.32	[illegible]	[illegible]		0.170				226	
July 1	[illegible]	30.5	20.0		0.070		61.4		173	
7	1.14	27.0	23.5		0.050	[illegible]	145	246		162
9	1.55	29.5	26.0		0.040	15.5		204	246	614
13	1.17	19.0	22.0		0.040	3.00		231	116	155
15	1.50	27.0	25.0		0.100		171	649	209	343
20	1.20	25.5	24.5		0.095		209		207	218
23	1.11	21.5	25.0				99.7		190	116
Aug. 5	1.14	27.0	24.5		0.14				107	97.5
Oct. 5	1.64	14.0	20.0	13.0	0.067		47.2		116	108
12	1.03	20.0	22.0		0.220	5.65	64.8			110
19	1.26	12.5	20.0	27.4	0.110	3.81	10[illegible]		154	151
26	1.20	10.5	17.0	13.3	0.390	2.82			95.9	124

SECAUCUS MUNICIPAL PLANT

TABLE NO. 15 (CONT'D) - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
Nov. 9	1.40	[illegible].0	15.0	36.1		3.93		375	160	166
16	1.35	11.5	17.0		0.055	3.60		320		229
30	1.35	-2.0	14.0		0.285	0.340		320	230	275
1977										
Feb. 23	1.50			21.5	0.364	1.46			241	186
Mar. 2	1.45	10.0	10.0	13.7	0.810	0.809			139	170
9	2.05	11.5	13.0	15.9	0.401	0.910		217	182	195
30	1.70	26.0	17.0	28.5	0.756	0.830		35.0	360	236
Apr. 13	1.42	24.0	20.0		0.220	1.59		43.0	172	191
27	0.50	13.0	15.0	25.2	0.200	1.47	-		92.5	154
Ave.	1.36	19.5	24.5	21.7	0.275	3.41	113	240	186	200

SECAUCUS MUNICIPAL PLANT

TABLE NO. 16 - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES / 100 ml
1976										
June 15										
17	28.0	22.0		12.0			264	25.6		0
22										
21	39.0	25.0		8.82				13.7		
July 1	30.5	19.0		5.00		21.9		3.3		
7	27.0	24.0		3.41	4.50		78.0		16.6	
9	28.5	24.0		9.44	6.50		60.0	16.6		
13	19.0	21.5		5.10	5.76		81.0	17.8	9.73	
15	27.[illegible]	24.5		6.15		19.2	47.0	15.0	14.7	
20	26.0	21.0				21.9		9.90	6.80	0
23	21.0	23.0				21.4		29.4	8.70	TNTC
Aug. 5	27.0	20.5		7.20		21.4		6.70	9.42	100
Oct. 5	14.0	26.0	4.70	2.23		8.50		34.1	14.5	100
12	20.0	21.0		0.83	7.40	11.2			5.30	0
19	12.5	17.5	13.2	7.86	5.64	31.0		26.1	2.30	0
26	10.5	14.0	3.50	5.76	4.38			13.6	19.8	-

SECAUCUS MUNICIPAL PLANT

TABLE NO. 16 (CONT'D) - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1976										
Nov. 9	8.0	10.0	12.5	8.01	5.49			24.3	26.1	0
16	11.5	15.0		4.55	4.40		34.0		19.7	0
30	-2.0	10.5		5.31	1.72		58.0	17.9	15.4	
1977										
Feb. 22			13.2	1.79	1.91			26.3	61.8	
Mar. 2	10.1	10.0	15.0	3.29	1.59			11.3	109	0
9	11.5	11.5	14.9	1.94	1.72			103	38.5	0
30	26.0	19.5	20.6	9.20	1.84			13.0	16.8	0
Apr. 17	24.0	17.5		1.30	1.85		39.0	45.8	51.7	
27	13.0	14.5	23.6	1.39	1.55			34.2	37.7	
Ave.	19.5	14.5	13.9	5.56	2.50	19.2	83.0	25.3	27.4	

SECAUCUS MUNICIPAL PLANT

TABLE NO. 17 - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1976						
June 17	1.26	237	2490	25.6	269	2220
24	1.32	226	2490	13.7	151	2340
July 1	1.44	173	2130	3.3	39	2090
9	1.65	246	3390	16.6	228	3160
13	1.17	116	1130	17.8	173	957
15	1.50	229	2860	15.0	188	2670
20	1.20	267	2670	9.9	99	2570
23	1.14	190	1810	29.4	280	1530
Aug. 5	1.14	107	1020	6.7	64	956
Oct. 5	1.64	116	1590	34.1	466	1120
19	1.26	154	1620	26.1	274	1350
26	1.80	85.9	1290	13.6	204	1090
Nov. 9	1.40	160	1870	24.3	283	1590
30	1.35	230	2590	17.9	201	2390

SECAUCUS MUNICIPAL PLANT

TABLE NO. 17 (CONT'D) - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1977						
Feb. 23	1.50	241	3010	26.3	329	2680
Mar. 2	1.45	139	1680	11.3	137	1540
9	2.05	182	3110	103	1760	1350
30	1.70	360	5100	13.0	184	4920
Apr. 13	1.42	172	2040	45.8	542	1500
27	0.50	92.5	385	34.2	143	242

Table 18

Averages and Percent Removals

	Influent mg/liter	Effluent mg/liter	Percent Removals
T.N.	21.7	13.9	35.9
NOx	0.275	5.36	-
Phos.	3.41	2.50	26.7
TOC	113	19.2	83.0
TOD	240	83.0	65.4
BOD	186	25.3	86.4
S.S.	200	27.4	86.3

The Secaucus Plant, as originally designed, is operating within the acceptable range of 84-96% removal for those secondary treatment facilities employing trickling filters. In the trickling filter there are two highly specialized bacteria responsible for the conversion of ammomia-N to nitrate, these are the Nitrosomonas, which converts the ammonia-N to nitrite, and the Nitrobacter, which converts the nitrite to nitrate. As evident in Table 18, the T.N. percent removal indicates the application of a high degree of treatment followed by the subsequent increase of NOx. The resulting T.N. in the effluent must, therefore, contain organic forms of nitrogen in addition to the nitrites and nitrates. Phosphate removal is as expected in this system due to the nutrient demand of the bacteria in helping to reduce the biological loadings.

Next, the BOD and TOC are significantly reduced. Both parameters are used to indicate the "strength" of the sewage.

While the TOC indicates the amount of organic carbon present in the sewage, the BOD indicates the amount of oxygen required to biologically oxidize the organic portion of the sewage. Of lesser importance is the TOD; while it does indicate the amount of oxygen required to oxidize both organic and inorganic substances, it is mainly used in the determination of industrial wastes, such as paints, dyes, etc., and does not represent an overall picture of the loadings in the sewage. The resulting effluent must, therefore, contain contaminants which are not removable by the biological oxidation of the trickling filters.

Finally, suspended solids removal is as expected for a plant of this size. It is evident that both the primary and secondary sedimentation tanks are being used and are operating as efficiently as possible. However, it may still be possible to reduce the suspended solids content even more by altering the flow rates through the sedimentation basins, by adding extra tanks or by recirculating some of the final effluent into the inlet channel at the entrance of the plant.

Jersey City WestSide Plant

Data for the influent and effluent wastewaters are outlined in Tables 19, 20 and 21 with Table 22 illustrating the percent removals.

JERSEY CITY SEWERAGE AUTHORITY, WEST SIDE PLANT

TABLE NO. 19 - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
June 15										
17	30.0	27.5	23.5		0.150			1690	530	
22										
24	22.0	30.5	21.0		0.130				60.4	
July 1	20.0	22.0	13.0		0.133		36.4		90.0	
7	25.5	23.5			0.230	2.60	138	492	121	
9	25.0	29.5	24.5		0.080	3.80		340	182	110
13	16.0	15.0	21.0		0.020	2.28		156	108	83.2
15	15.0	22.0	24.5		Trace		67.2	270	146	97.9
20	18.0	30.0	25.0				97.6		197	113
23	19.0	23.5	25.0				—		284	126
Aug. 5	20.0	29.0	27.0						415	159
Oct. 5	36.0	17.0	19.0		0.210		32.1		131	56.8
12	26.0	21.0	22.0		0.430	7.40	149			67.2
19	16.0	11.5	22.0	20.3	2.68	3.01	116		214	126
26	29.0	12.0	16.0	11.8	0.530	1.92			69.3	86.5

JERSEY CITY SEWERAGE AUTHORITY, WEST SIDE PLANT

TABLE NO. 19 (CONT'D) - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
Nov. 9	21.0	6.0	18.0	21.1	0.404	3.49		330	160	128
16	20.0	15.0	18.0		0.160	5.05		530		196
30	12.0	3.0	15.0		0.545	0.900		950	305	184
1977										
Feb. 23	20.0			10.4	0.432	2.86			270	267
Mar. 2	17.0	13.0	13.0	20.2	0.651	1.25			409	320
9	22.0	20.0	14.5	17.9	0.600	0.900		770	277	294
30	12.0	24.5	19.0	25.0	0.676	1.079		90.0	31.5	315
Ave.	21.5	20.0	20.0	19.4	0.479	2.94	90.9	552	226	158

JERSEY CITY SEWERAGE AUTHORITY, WEST SIDE PLANT

TABLE NO. 20 - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
197[illegible]										
June 15										
17	25.0	12.0		0.350			276	96.0		TNTC
22										
24	31.0	24.0		0.500				49.5		
July 1	21.5	19.0		0.130		31.9		50.7		
7	26.5	24.0		0.160	1.30	52.[illegible]	114	59.8		
9	29.5	25.0		0.050	1.15		65.0	38.0	36.5	
13	15.0	21.5		0.040	1.62		104	21.4	50.1	
15	25.5	24.5		trace		45.0	100	47.9	37.3	
20	28.5	25.0				54.7		101	44.5	TNTC
27	23.5	24.0						139	75.0	0
Aug. 5	29.0	24.5						132	66.5	
Oct. 5	17.0	19.0		0.100		36.7		120	61.0	400
12	20.0	21.5		0.380		110			55.6	100
19	20.0	22.0	24.2	0.150	5.53	237		205	79.5	48,600
26	12.0	15.0	21.[illegible]	0.610	2.22			131	61.1	400

JERSEY CITY SEWERAGE AUTHORITY, WEST SIDE PLANT

TABLE NO. 20 (CONT'D) - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1976										
Nov. 9	6.0	11.0	[illegible]	0.450	3.12		315	109	98.3	0
16	13.0	17.0		0.120	3.30		400		68.1	50,000
30	3.0	15.0		0.410	0.990		660	261	57.6	
1977										
Feb. 25			20.5	0.381	1.56			72.7	157	
Mar. 2	13.0	13.0	20.9	0.392	0.332			55.4	137	0
9	20.0	14.0	23.9	0.606	0.990		725		173	16,200
30	24.5	18.5	26.0	0.649	0.880		74.0	331	161	20,000
Ave.	21.5	20.0	22.4	0.339	2.02	81.5	295	124	82.2	

JERSEY CITY SEWERAGE AUTHORITY, WEST SIDE PLANT

TABLE NO. 21 - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1976						
June 17	30.0	530	133,000	96.0	24,000	109,000
24	22.0	68.4	12,600	49.5	9,080	3,520
July 1	20.0	80.0	13,300	58.7	9,790	3,510
7	25.5	121	25,700	59.8	12,700	13,000
9	25.0	182	37,900	38.0	7,920	29,980
13	16.0	108	14,400	21.4	2,860	11,540
15	15.0	146	18,300	47.9	5,990	12,310
20	18.0	197	29,600	101	15,200	14,400
23	19.0	284	45,000	139	22,000	23,000
Aug. 5	20.0	415	69,200	132	22,000	47,200
Oct. 5	36.0	131	39,300	120	36,000	3,300
19	16.0	214	28,600	285	38,000	- -
26	29.0	69.3	16,700	131	31,700	- -
Nov. 9	21.0	166	29,100	169	29,600	- -
30	18.0	395	59,300	261	39,200	20,100

JERSEY CITY SEWERAGE AUTHORITY, WEST SIDE PLANT

TABLE NO. 21 (CONT'D) - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	$BOD_i - BOD_e$
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1977						
Feb. 23	20.0	270	45,000	72.7	12,100	32,900
Mar. 2	17.0	489	69,300	65.9	9,340	59,960
9	22.0	287	52,700	210	38,500	14,200
30	18.0	31.5	4,730	331	49,700	- -

Table 22

Averages and Percent Removals

	Influent mg/liter	Effluent mg/liter	Percent Removals
T.N.	19.4	22.4	-
NOx	0.479	0.339	29.2
Phos.	2.94	2.02	31.3
TOC	90.9	81.3	10.6
TOD	552	295	46.6
BOD	226	124	45.1
S.S.	158	82.2	47.9

For a plant of this size, it is depressing to find that as a large primary treatment facility it is removing less than half of the pollution loads encountered in the sewage. This plant is subjected to heavy industrial loads (65% of flow) in which colloidal matter, dyes, grease and oils are abundantly present resulting in ineffective treatment.

The T.N. has increased - another indication that a low degree of treatment is being applied to the sewage. The decrease in the NOx level is a result of anaerobic bacteria using the NOx as a nutrient and energy source in the anaerobic degradation of organic loadings. The same applies to the phosphate reduction.

The low TOC removal indicates that heavy concentrations of organic carbon are being discharged into the sewage system - that is, grease and oils are not removed due to the absence of grease traps in the primary process. TOD removals

KEARNY MUNICIPAL PLANT

TABLE NO. 23 - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1976										
June 24	3.00	32.0	23.5		0.025				233	
July 1	7.70	28.0	21.5		0.150		60.2		255	
7	2.90	25.5	24.5		0.060	27.0	569	305		339
9	2.90	28.5	25.0		0.040	14.4		374	182	542
13	1.17	11.0	19.5		0.000	33.1		190	108	228
15	2.90	20.5	21.0		0.040		355	410	266	13.6
20	2.80	30.5	25.0				504		545	221
23	2.70	23.0	24.0						420	81.5
Aug. 5	3.20	30.0	28.5						338	140
Oct. 5	4.40	15.5	22.0	1.00	0.490		30.1		227	208
12	4.30	18.5	24.0				183			111
26	4.90	11.0	18.0	4.00	0.350	0.600			310	271
Nov. 16	4.10	12.5	18.0			9.65	890			298

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KEARNY MUNICIPAL PLANT

TABLE NO. 23 (CONT'D) - INFLUENT DATA

DATE	FLOW	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.
	MGD	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM
1977										
Feb. 23	4.10			6.70	0.460	0.465			131	2,700
Mar. 2	4.40	7.5	12.0	5.30	0.498	0.900			266	523
9	1.90	20.0	15.0	7.0	0.375	9.65		560	237	417
30	5.00	24.0	19.0	11.0	0.514	0.069		190	356	324
Ave.	3.85	21.0	21.5	5.87	0.253	10.6	375	433	277	433

KEARNY MUNICIPAL PLANT

TABLE NO. 24 - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1976										
June 24	32.0	23.5		0.285				114		
July 1	22.0	20.0		0.130		116		130		
7	25.5	24.5		0.060	21.4	640	507		217	
9	22.5	23.0		0.060	23.5		100	37.9	59.9	
13	11.0	20.5		0.090	30.0		432	132	114	
15	20.5	25.0		Trace		285	385	133	55.3	
20	30.5	25.0				259		345	104	TNTC
23	23.5	23.0						209	65.9	0
Aug. 5	30.0	28.0						143	47.5	
Oct. 5	15.5	23.0	1.50	0.025		85.5		263	217	0
12	18.5	24.0		0.226		145			38.6	100
26	11.0	17.0	5.00	0.340	1.68			268	62.8	50,400
Nov. 16	12.5	18.0			10.2		940		128	

KEARNY MUNICIPAL PLANT

TABLE NO. 24 (CONT'D) - EFFLUENT DATA

DATE	AMBIENT	WATER	T.N.	NOx	PHOS.	TOC	TOD	BOD	S.S.	FECALS
	°C	°C	PPM	PPM	PPM	PPM	PPM	PPM	PPM	COLONIES/100 ml
1977										
Feb. 23			9.10	0.390	1.96	-		172	2035	
Mar. 2	7.5	12.0	6.10	0.566	0.725			269	513	8,900
9	30.0	14.0	5.7[illegible]	0.091	10.2		625		221	0
30	24.0	16.0	15.4	0.394	1.04		186		217	0
Avg.	21.0	21.5	7.07	0.210	11.4	261	454	190	319	

KEARNY MUNICIPAL PLANT

TABLE NO. 25 - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	BOD_i-BOD_e
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1976						
June 24	3.00	233	5820	114	2850	2970
July 1	7.70	255	16400	130	8350	8050
9	2.90	182	4400	37.9	917	3480
13	1.17	108	1050	132	1290	- -
15	2.90	266	6430	133	3220	3210
20	2.80	545	12730	345	8060	4670
23	2.70	420	9460	289	6510	2950
Aug. 5	3.20	338	9020	143	3820	5200
Oct. 5	4.40	227	8330	263	9650	- -
26	4.90	310	12670	268	10950	1720

KEARNY MUNICIPAL PLANT

TABLE NO. 25 (CONT'D) - B.O.D. DATA

DATE	FLOW	BOD (INFL)	BOD (INFL)	BOD (EFFL)	BOD (EFFL)	BODi-BODe
	MGD	mg/liter	lbs./day	mg/liter	lbs./day	lbs./day
1977						
Feb. 23	4.10	131	4480	172	5880	- -
Mar. 2	4.40	266	9760	269	9870	- -
9	4.90	237	9680	186	7600	2080
30	5.00	356	14840	210	8760	6080

indicate a high concentration of inorganics which are discharged by the industries in the immediate area.

Primary sedimentation tanks should remove at least 60% of the suspended solids and at least 50-55% of the BOD. As in Table 22, this does not occur in this plant. Flow rate experienced at this plant are high; thereby, lowering the detention time for a particle of slug or grit to properly settle out. With the subsequent low removal of the suspended solids content, the BOD content is also affected.

Kearny Municipal Plant

Tables 23, 24 and 25 outline the influent and effluent sewage results with Table 26 illustrating their respective percent removals.

Table 26

Averages and Percent Removal

	Influent mg/liter	Effluent mg/liter	Percent Removal
T.N.	5.87	7.07	-
NOx	0.253	0.216	14.6
Phos.	10.6	11.4	-
TOC	375	261	30.4
TOD	433	454	-
BOD	277	199	31.4
S.S.	433	310	26.3

Obviously, this plant is incapable of handling the industrial loads (approx 93% of flow) which are constantly being discharged into the sewage system. If it were not for the BOD and S.S. removals, the treatability of this plant on the influent sewage would be near non-existant in terms of operation.

Removal of the BOD and S.S. also reduces the TOC since many of the suspended solids are organic. The TOD clearly shows that industry is discharging their wastes without any apparent pre-treatment. Since this plant is using primary sedimentation basins as the only treatment, it is evident that it cannot cope with the adverse chemicals and other pollutants and must, therefore, be up-graded in order to provide satisfactory treatment.

Sampling Procedures

Samples were taken from the inlet and outlet channels at each treatment plant and stored in separate 200-ml ground glass-stoppered bottles. Each sample bottle was then taken and its contents were transferred into small test tubes for the analyses of the various parameters. BOD was set up upon arrival at the laboratory from the sampling sites during the same day. S.S. samples were stored in a freezer until determined.

Flow readings were obtained from the flow-measuring devices at each plant - with the exception of the North Bergen Central

Plant, which does not have any reliable flow-measuring equipment. Flow data for the No. Bergen Central Plant was calculated using the cross-sectional area of one of the inlet channels, depth of the sewage wastewater and by measuring the time for a particle of slug to travel through the cross-sectional area. Fecal Coliform samples were taken at each site in a Millipore Coli-Count Sampler and incubated at 44.5° C.

Sample Preservation

Hydrochloric acid was used as a preservative for the analysis of the T.N., TOD and TOC parameters and stored in a refrigerator. No preservatives were added to the test tubes containing samples for the analysis of the orthophosphate-P and NOx as these tests were accomplished within 24 hours of the sampling period.

Analytical Procedures

Total Organic Carbon

The TOC was measured by the use of the Dohrmann Envirotech DC - 52D Carbon Analyzer. Potassium hydrogen phthalate ($C_6H_5O_4K$), also known as KHP, was used as a standard for calibrating the instrument.

Total Oxygen Demand

An automated method of analysis for the determination of the TOD was accomplished with the use of the Ionics, Incorporated Model 225 Total Oxygen Demand Analyzer. Again, KHP was used with this instrument as a standard ranging from 100-800 ppm in order to set up a linear scale. The TOD method was used over the conventional Chemical Oxygen Demand method because results can be obtained within minutes with the TOD while it requires several hours for the COD and, most importantly, chlorine ion interferences are eliminated with the TOD method.

Orthophosphate-P

The orthophosphate-P analysis was accomplished with the use of the Technicon AutoAnalyzer II Industrial System Manifold No. 116-D221-01 Cartridge. Potassium dihydrogen phosphate (KH_2PO_4) was used as a standard in the range of 0.04-2.00 ppm PO_4-P to set up linearity.

Nitrite-Nitrate (NOx)

The NOx analysis was accomplished with the Technicon AutoAnalyzer II Industrial Manifold No. 116-D049-01 Cartridge. Potassium nitrate (KNO_3) was used as the standard ranging from 0.04-2.00 ppm NOx.

Total Nitrogen

The T.N. was measured with the use of the Dohrmann Envirotech C-300 Microcoulometer and the S-300 Furnace.

Fecal Coliform

Fecal Coliforms were measured using the Millipore Coli-Count^{tm} Sampler Cat. No. MC 00 000 00 and incubating at 44.5^{o} C. for 12-18 hours.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demands were analyzed using the Yellow Springs Instrument Co. YSI Model 5720 BOD Bottle Probe with the YSI Model 57 Oxygen Meter.

Suspended Solids

Suspended solids were measured as outlined in Standard Methods, 13th Edition, Section 148B. Determination was based on 100-ml samples.

CONCLUSIONS AND RECOMMENDATIONS

The general situation found in the Hackensack Meadowlands is that an insufficient degree of treatment of sewage is being practiced by the treatment plants discussed in this thesis with the possible exception of the Secaucus plant. As previously mentioned, the Hackensack River has become a "dead-ended" tube from which there is little or no flushing of pollutants. Being aware of this, the New Jersey State Dept. of Health has issued orders to most of these plants to conform, at least, to present State effluent limitations. Conformance to these orders would require that plants which presently provide primary treatment be up-graded to include secondary treatment facilities which will biologically treat the, otherwise, untreated organic loads.

As the effluents from the existing treatment plants are of inferior quality and the volumes of such wastes large, other sources of pollution remain hidden. Among them are small industries, combined sewer overflows, treatment plant by-passes and other unconnected discharges, such as run-off, which are not presently treated. It must be realized that while industrial wastes generally contain chemical and physical contaminants which may be harmful to the aquatic environment; this harm may be an unwantedcolored water, which is unappealing aesthetically, or a film over the water which reduces the oxygen-liquid transfer ratio, thus lowering the dissolved oxygen content in the water.

Therefore, it is necessary that the degree of treatment and the quality of the effluent discharged into the Hackensack River must be at such a level so as to permit the intended use of the area to be developed. In order to aid in maintaining adequate and reliable operation of the treatment facilities, there must be rigid enforcement of sewer regulations in controlling the raw wastes entering the system. In addition, these regulations should be specific with respect to the maximum allowable concentrations of the materials permitted to be discharged to the sewerage system.

The remainder of this section shall be devoted to discussing and illustrating the alternate methods of upgrading those treatment plants previously discussed. No attempt shall be made to include a cost analysis since it is beyond the scope of this thesis.

Lyndhurst-No. Arlington Plant

One of the problems experienced in the operation of this plant is the fact that head losses through the comminutor during peak flows create a back-up condition into the Parshall flumes, thus interfering with accurate flow measuring. In addition, excessive maintenance is required on the cutting assemblies on the comminutor, as grit is not removed from the sewage prior to flow through the comminutor. Also, grease and oil removal is accomplished manually with little results.

Among the first steps in up-grading a primary treatment facility is to determine at what rate of efficiency the plant is operating. From there, it should be a simple matter of deciding which units should be replaced or added to the system in order to increase the operation efficiently.

Obviously, it is necessary to reduce the head losses through the comminutor so that back-up pressures will not occur, even during peak flow conditions. One solution would be to provide a wet well unit before the comminutor so that the flow rate to the comminutor can be maintained at a constant rate through the use of sewage pumps. In addition, it will be necessary to remove the coarser materials prior to flow through the comminutor. Therefore, coarse bar screens should be set up before the wet well, allowing removal of materials to be used as landfill. This procedure should save considerably on the wear of flow pumps and other units in the treatment plant.

Next, since the average flow of sewage is above the designed capacity of the plant, it is necessary to provide settling basins capable of handling the increased flow. Perhaps the simplest solution would be to provide additional settling basins. With three tanks in service, the detention time will be increased allowing more suspended solids to settle out. From the primary settling tanks, the primary sludge may be pumped into a larger primary sludge digester than the one now in service.

After the primary treatment, it is necessary to install a secondary treatment system which will further reduce the organic loading. Trickling filters should be used at this point - parallel to one another - with proper recirculation for effective treatment. From the trickling filters, the effluent should then flow into secondary settling basins which will further remove any suspended particles which may have washed through the trickling filters. Part of the effluent from the secondary settling basins should be recycled to the influent channel leading into the plant for further treatment. Secondary sludge may be pumped into the primary digester. The remaining effluent may proceed to the chlorine contact tank now used for disinfection with chlorine or chlorine compounds.

Because grease and oil cause scum on sedimentation tanks and interfere with the biological filtration, grease traps or skimming tanks should be provided to remove them from the sewage prior to the primary settling tanks. Figure 28 illustrates such a plan.

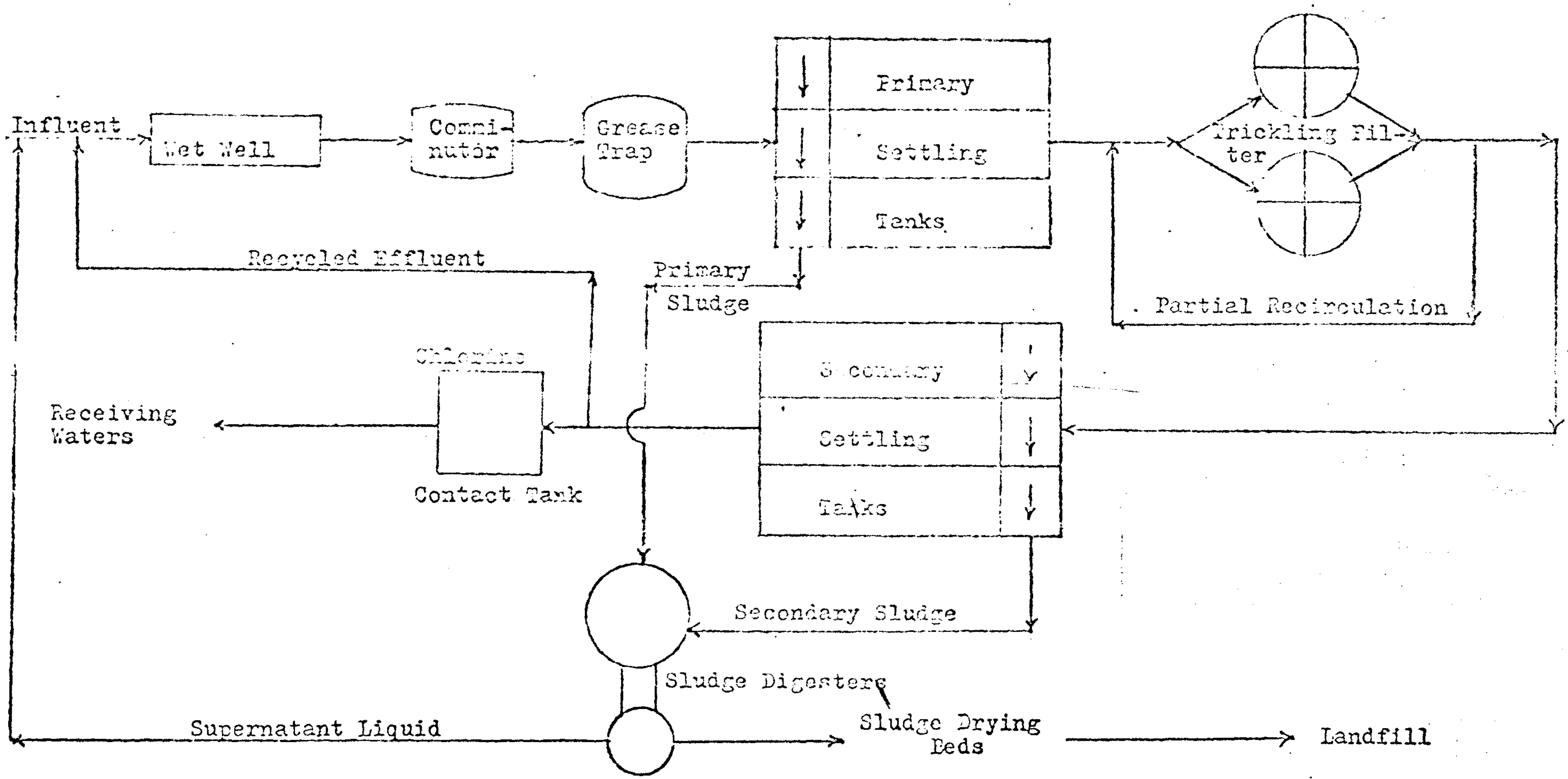

FIGURE NO. 28

UP-GRADED LYNDHURST - NORTH ARLINGTON JOINT MEETING PLANT

"Triboro" Meeting Plant

The problems being experienced in this plant are many; among them are the lack of grease and scum collection equipment. This allows floating materials to pass to the trickling filters with resultant clogging and inefficient performance of the filters. Plant pumping facilities, both raw and secondary sewage, are unreliable and experience considerable downtime. In addition, the mode of operation of the secondary pumps is not proper for uniform dosing of the trickling filters and contributes to poor filter efficiency.

The industrial components of the flow are apparently of considerable strength. The inadequate treatment presently applied to the wastes from this plant has been the subject of attention from the New Jersey State Dept. of Health resulting in various citations for excessive BOD's and suspended solids, by-passing of plant units, coliform bacteria, color, odor and for insufficient chlorine residual.

Obviously, from the problems encountered within the plant that it is mandatory that effective treatment be added in order to reduce those pollutants and contaminants which are causing poor performance. Therefore, the treatment plant should be reconstructed or up-graded in such a manner so as to cut costs to a minimum.

To begin with, pre-chlorination of the sewage is ineffective due to the possible chlorine demands of the various industrial pollutants. Chlorination at this point should be discontinued and saved for final disinfection where there will be little chlorine demand from the treated effluent. Next, mixing and flocculation should be introduced to create large floc particles which can then be easily removed. Following this syste, will be chemical coagulation; here various precipitates may be formed, thus, lowering the TOD level.

The primary settling tanks should be expanded in order to handle more sewage. Presently, the plant has a designed capacity of 4.0 mgd with an average daily flow rate of 3.4 mgd. If we assume that the communities will expand socially and industrially, then the treatment plant should be ready to handle this increase. From the primary settling tanks, the sewage should flow into the four available trickling filters which will be in parallel and series. This is to create a high degree of treatment by allowing the sewage to flow through two filters rather than individually. Recirculation will not be necessary for this type of set-up.

Trickling filter effluent should then proceed to secondary settling. Some of the secondary effluent should be recycled to the inlet channel leading into the plant for further treatment. The remaining effluent should go to a carbon adsorption column for color reduction. From here, the final effluent is chlorinated and ultimately diposed.

Suspended solids - raw and secondary sewage - are pumped into the primary sludge digester and then into the secondary digester where the supernatant liquid is recycled into the plant at the inlet channel. Treated sludge from the secondary digester should be elutriated so as to reduce the concentration of bicarbonates and, finally, vaccum-filtered prior to ultimate discharge as landfill. Figure 29 illustrates the up-graded plant.

North Bergen Central Plant

The New Jersey State Dept. of Health has evaluated the treatment facility maintenance at the plant to be marginal. It has been reported that the flow through this plant is either by-passed or afforded little or no treatment. In addition, there are no sludge digestion tanks and the sludge drying beds are not being used. In addition, sludge is removed by scavenger service on an "as needed" basis.

Obviously, this plant must be converted into primary sedimentation basins with grit chambers to remove most of the suspended solids. In addition, due to low flow rate into the plant only two trickling filters may be required to oxidize the organic loadings, with three sedimentation basins supplying recirculation to the trickling filters for further treatment. Figure 30 illustrates what this plant should appear as.

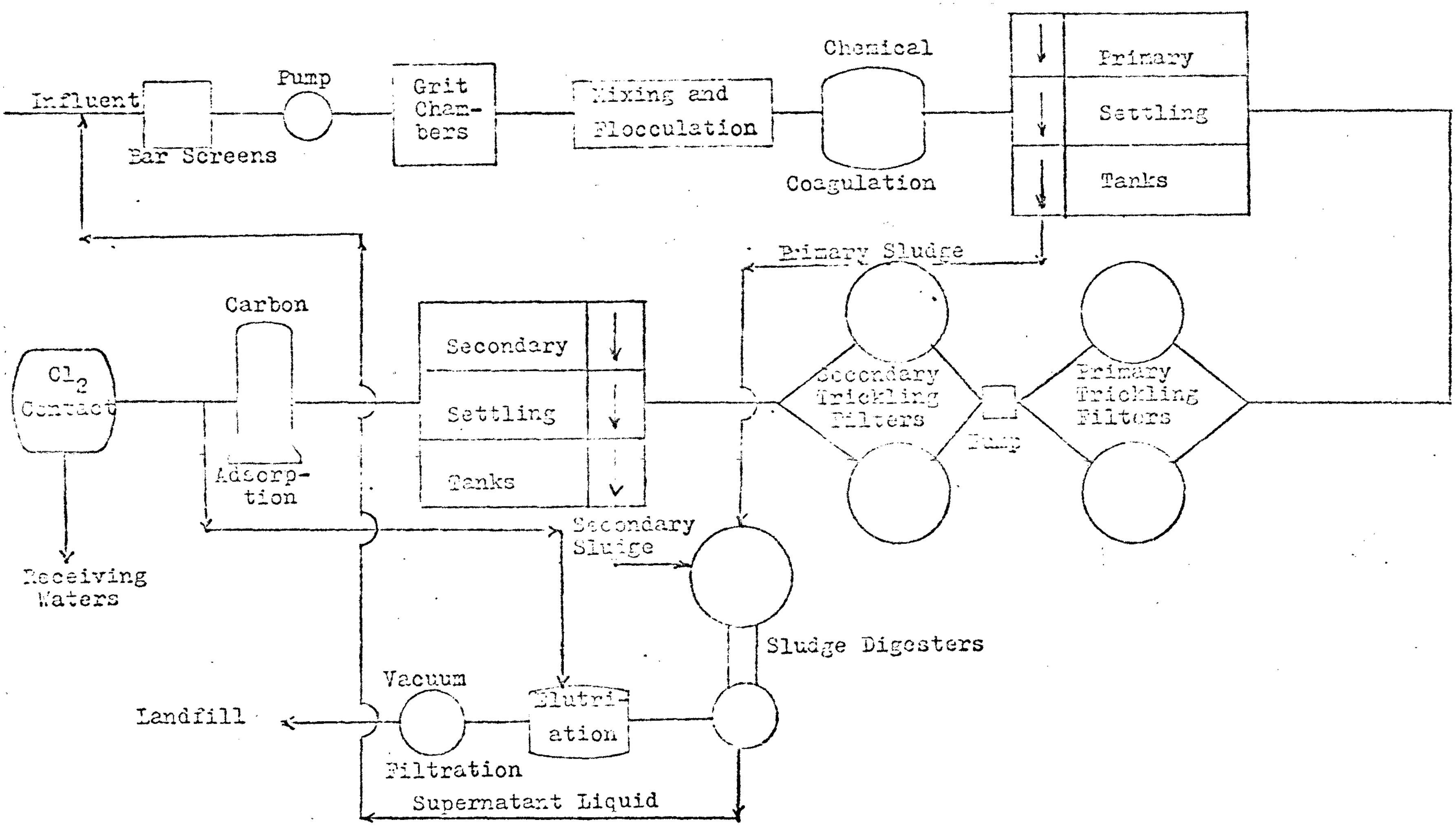

FIGURE NO. 29

UP-GRADED RUTHERFORD - EAST RUTHERFORD - CARLSTADT JOINT MEETING PLANT

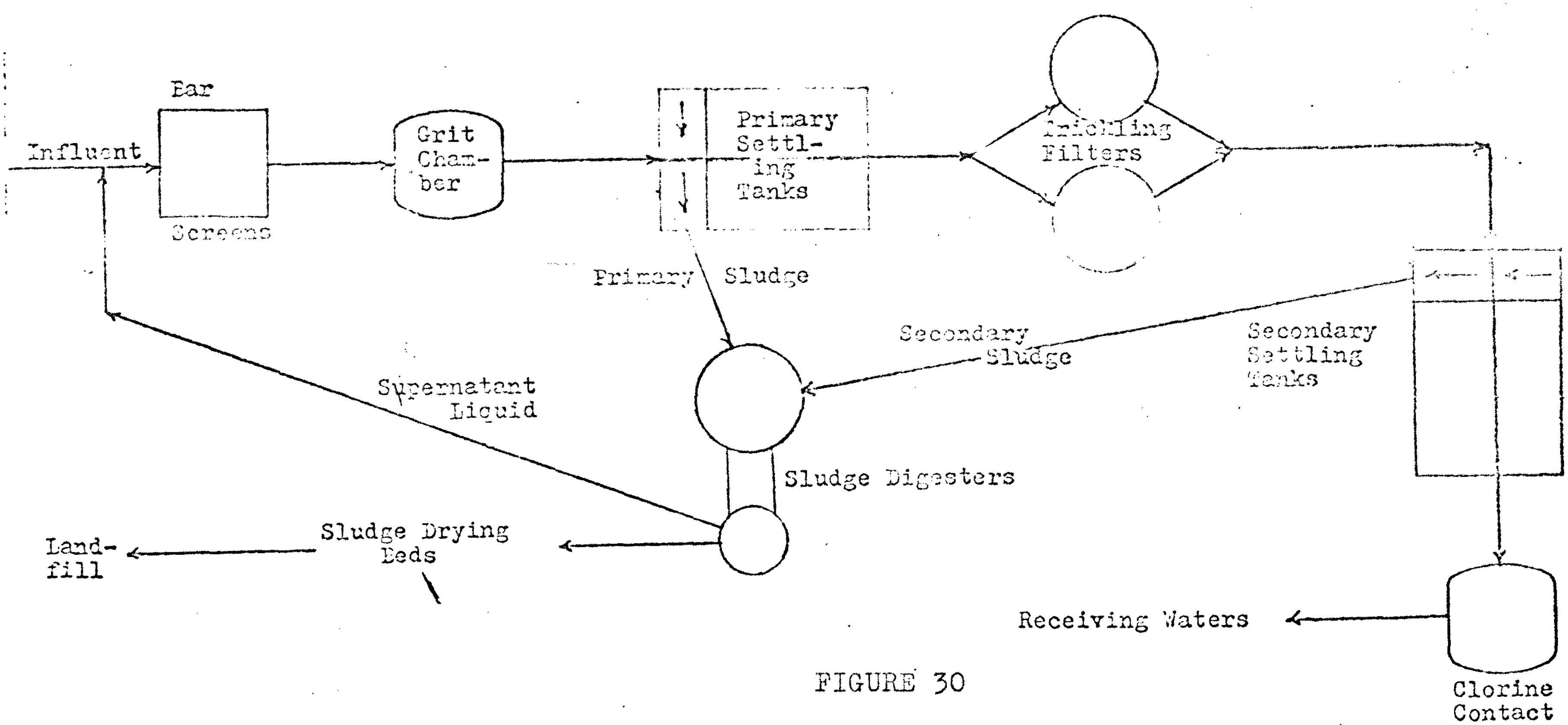

FIGURE 30

UP-GRADED NORTH BERGEN TREATMENT PLANT

Secaucus Municipal Plant

Because the present flow rate is only 60% in comparison to the designed capacity, the plant operates with two of the three primary settling tanks, one of the high-rate trickling filters and two of the three secondary settling tanks. Although the plant is generally applying treatment, due to the low flow rate, it is possible to improve the system by the correction of filtration presently received in the system. In addition, since a significant portion of the Town is zoned for heavy industry, the nature of the sewage may change as these areas are developed and tied into the municipal sewer system. Therefore, due to the acceptable treatment available at this plant, it is not necessary to up-grade the plant's treatment facilities.

Jersey City West Side Plant

There are a number of problems which plague this plant. Among them, the previously mentioned recurring dye component of the influent sewage is a definite color pollutant of the Hackensack River. In addition, a high grease and oil content of the East Side Plant sludge, which is pumped to the West Side Plant for treatment, is creating problems in sludge handling and disposal facilities.

Obviously, the first step is to remove all grease and oil contaminants in the sewage and sludge influents. In addition, the color contaminants from the dyes must also be removed. Trickling filters should be used instead of an activated-sludge process the regeneration of bacteria would take less time than for the activated-sludge process should the bacteria be destroyed by toxic materials which are frequently found in industrial wastes. The basic design for this plant is similar to that of "Triboro" with the exclusion of sand filter beds and the addition of separate sludge- grease removal equipment. See Figure 31 for illustration.

Kearny Municipal Plant

The problems associated with this plant are obvious and need not be discussed. Therefore, the modified design of this plant will be similar to that of "Triboro" as illustrated in Figure 32.

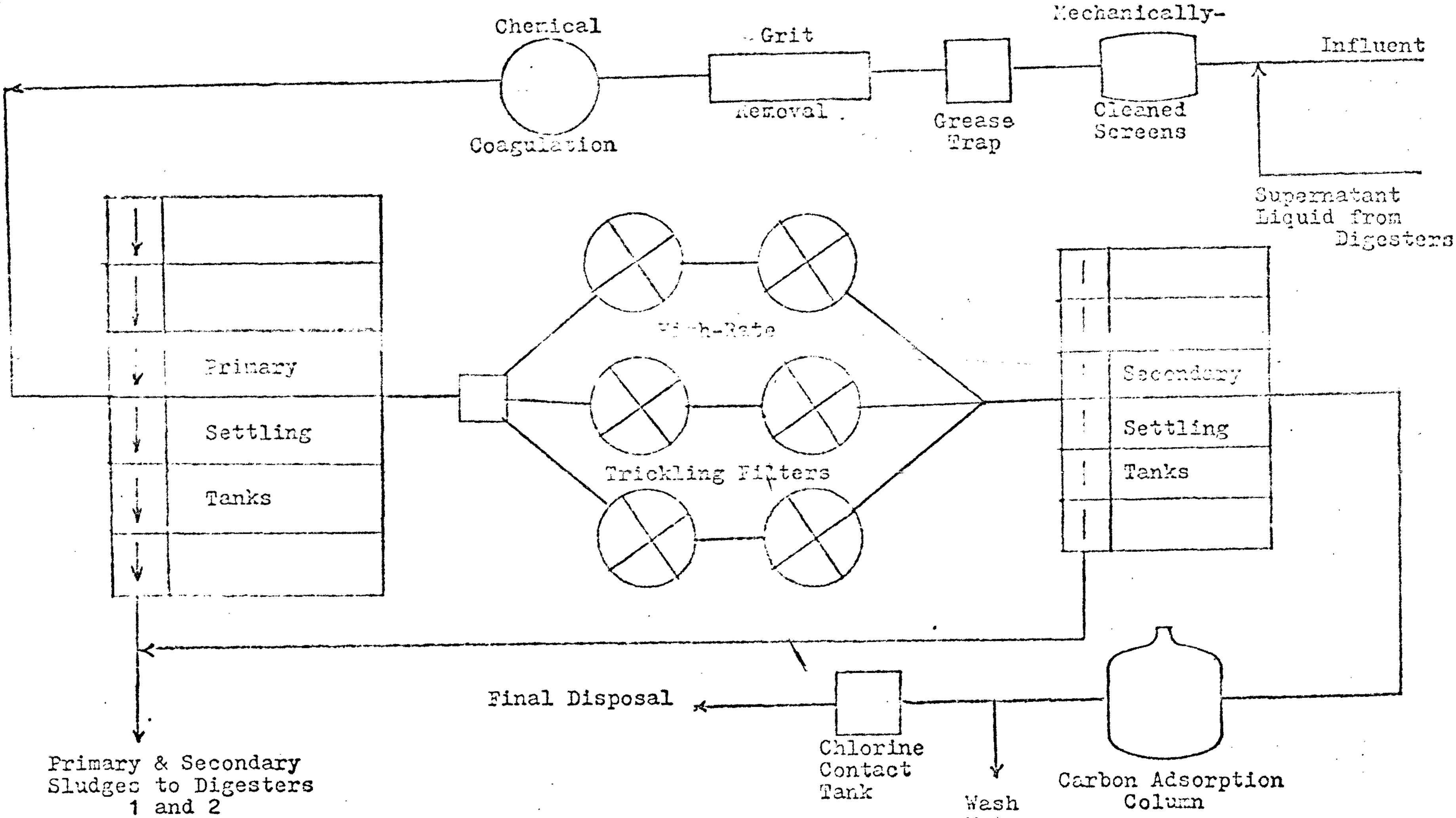

FIGURE NO. 31

UP-GRADED JERSEY CITY SEWERAGE AUTHORITY

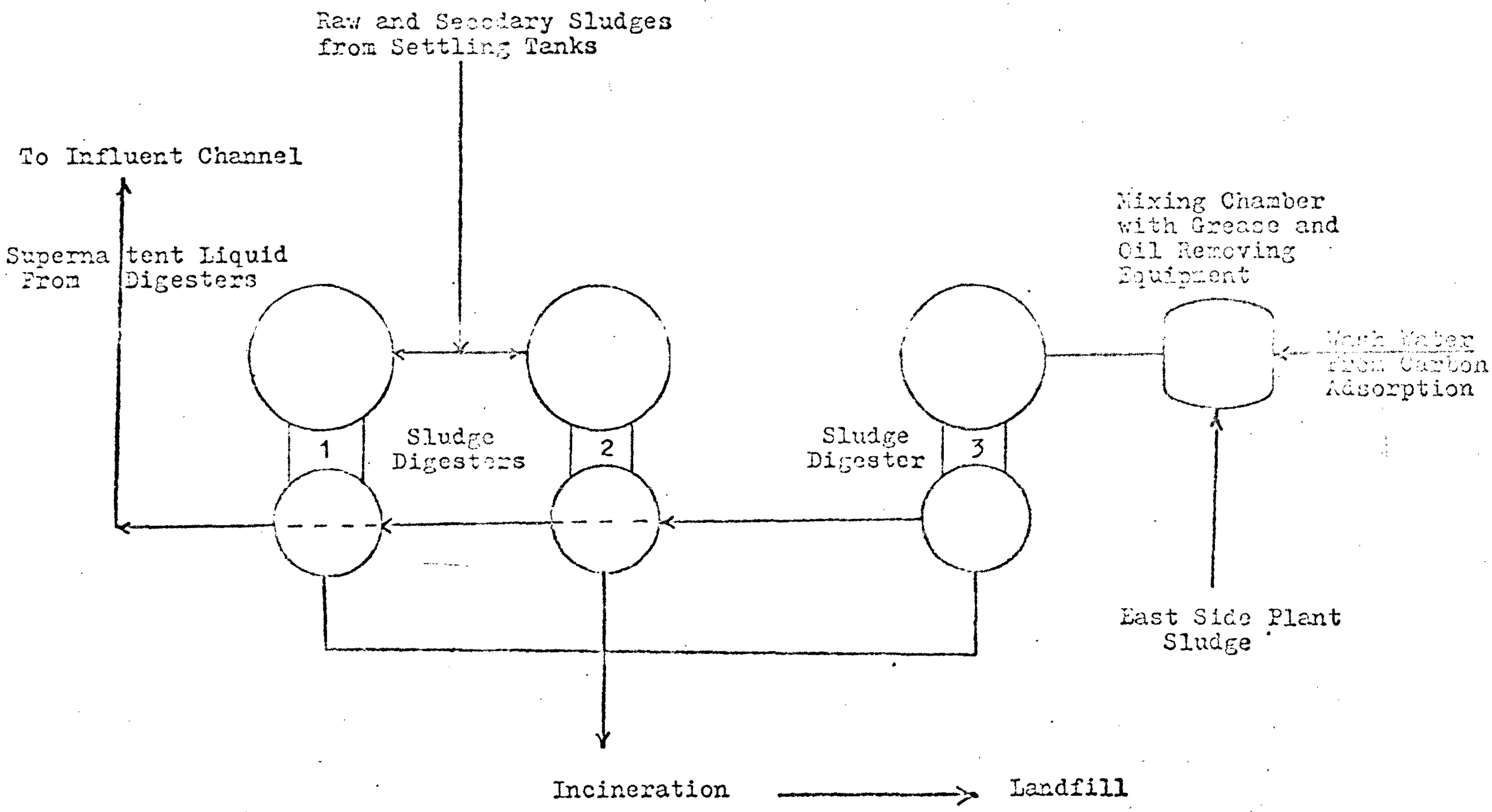

FIGURE NO. 31 (CONT'D)

UP-GRADED JERSEY CITY SEWERAGE AUTHORITY

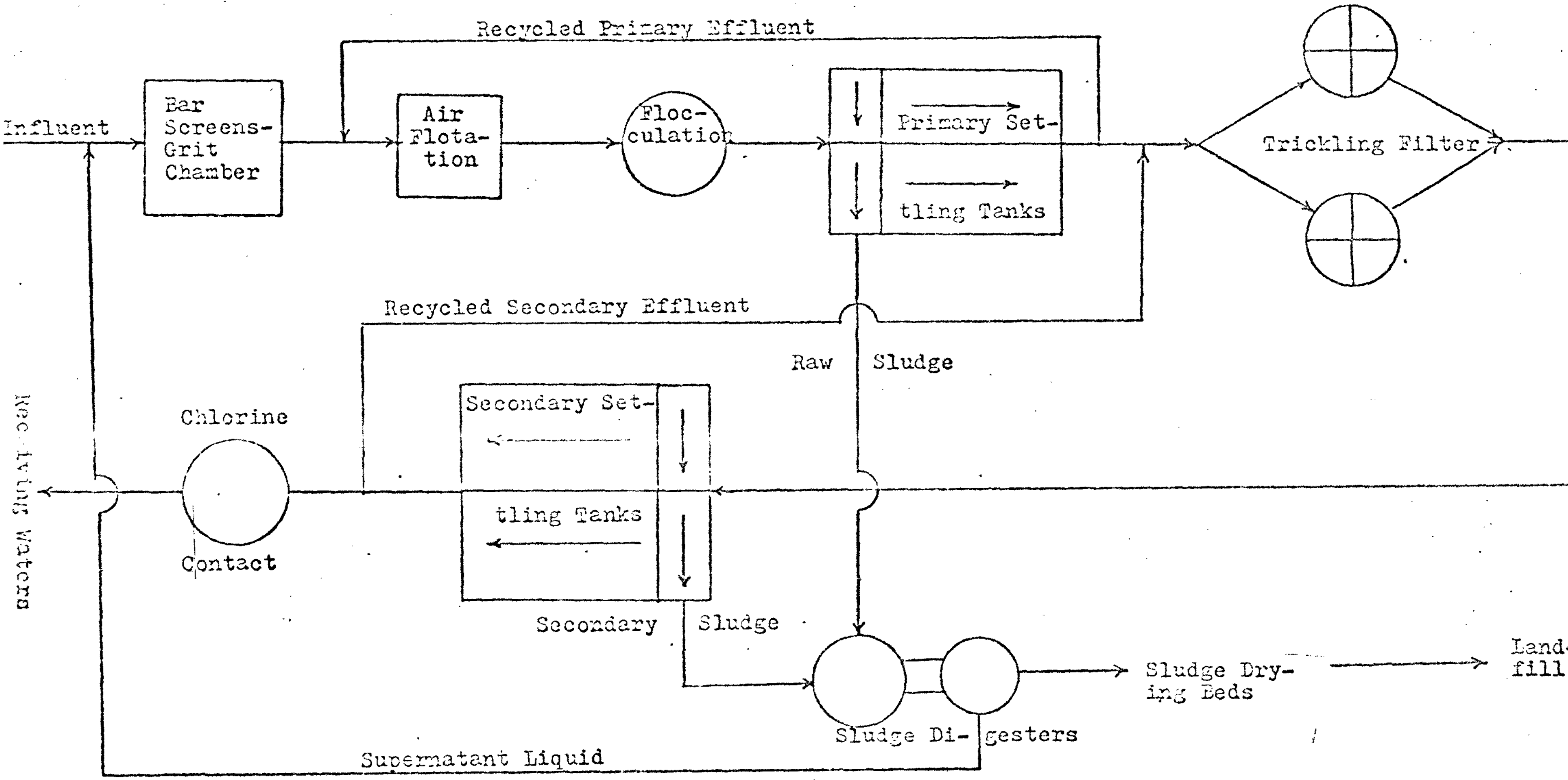

FIGURE NO. 32

UP-GRADED KEARNY TREATMENT PLANT

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