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ABSTRACT

This information pamphlet is for teachers, students, or the general public concerned with the types of waste water treatment systems, the need for further treatment, and advanced methods of treating wastes. Present day pollution control methods utilizing primary and secondary waste treatment plants, lagoons, and septic tanks are described, illustrated, and evaluated. Eight categories of pollutants affecting our waters are given accompanied by the effect each has on man and the environment. Water renovation techniques involving coagulation-sedimentation, absorption, electrodialysis, and the blending of treated water are discussed. In addition, new challenges for waste treatment including reverse osmosis, methods of chemical oxidation, and the use of polymers are investigated. Throughout, problems of water pollution control and waste disposal are presented to illustrate the need for planning, financing, and buidling facilities to meet governmental water quality standards. A glossary of common sewage treatment terms is included. (BL)

a primer on waste water treatment

U. S. DEPARTMENT OF THE INTERIOR • FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

INTRODUCTION

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Thousands of waste treatment plants will be constructed or expanded across the Nation during the years ahead to control or prevent water pollution.

This increased construction activity is the result of the passage of the Water Quality Act of 1965 which called for the establishment of water quality standards for all the interstate streams, coastal waters, and lakes, and the Clean Water Restoration Act of 1966 which increased Federal financial aid to cities to help build these needed plants.

Communities across the land will be planning, financing, and building the facilities to meet the water quality standards. Some cities will be constructing plants where none existed before. Others will be expanding inadequate facilities while some communities will be adding more advanced methods to handle new types of wastes.

It won't happen overnight. From drawing board to operation takes time. In some cases, projects will be built in stages. Consequently, more and more people will be watching this developing progress toward cleaner water. They will need to know more about waste treatment.

In this primer, the methods used now and processes being developed for the future to treat wastes are explained.

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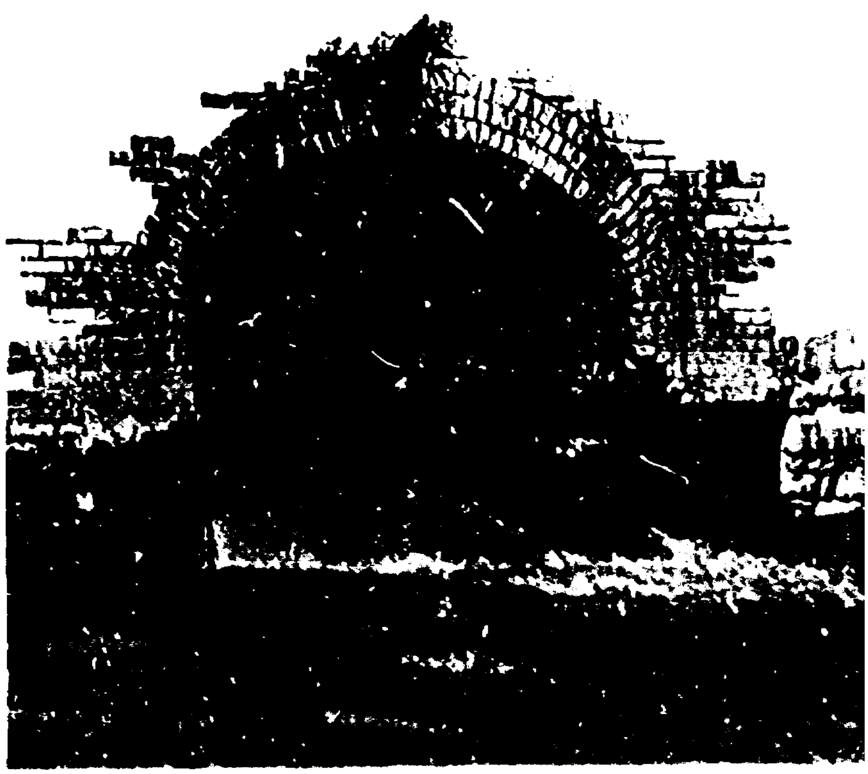

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a primer on waste water treatment

COLLECTING AND TREATING WASTES

The most common form of pollution control in the United States consists of a system of sewers and waste treatment plants. The sewers collect the waste water from homes, businesses, and many industries and deliver it to the plants for treatment to make it fit for discharge into streams or for reuse.

There are two kinds of sewer systems—combined and separate. Combined sewers carry away both water polluted by human use and water polluted as it drains off homes, streets, or land during a storm.

In a separated system, one system of sewers, usually called sanitary, carries only sewage. Another system of storm sewers takes care of the large volumes of water from rain or melting snow.

Each home has a sewer or pipe which connects to the common or lateral sewer beneath a nearby street. Lateral sewers connect with larger sewers called trunk or main sewers. In a combined sewer system, these trunk or main sewers discharge into a larger sewer called an interceptor. The interceptor is designed to carry several times the dry-weather flow of the system feeding into it.

During dry weather when the sewers are handling only the normal amount of waste water, all of it is carried to the waste treatment plant. During a storm when the amount of water in the sewer system is much greater, part of the water, including varying amounts of raw sewage, is allowed to bypass directly into the receiving streams. The rest of the wastes are sent to the treatment plant. If part of the increased load of water were not diverted, the waste treatment plant would be overloaded and the purifying processes would not function properly. (A special research program is under way on the problem of storm and combined sewers.)

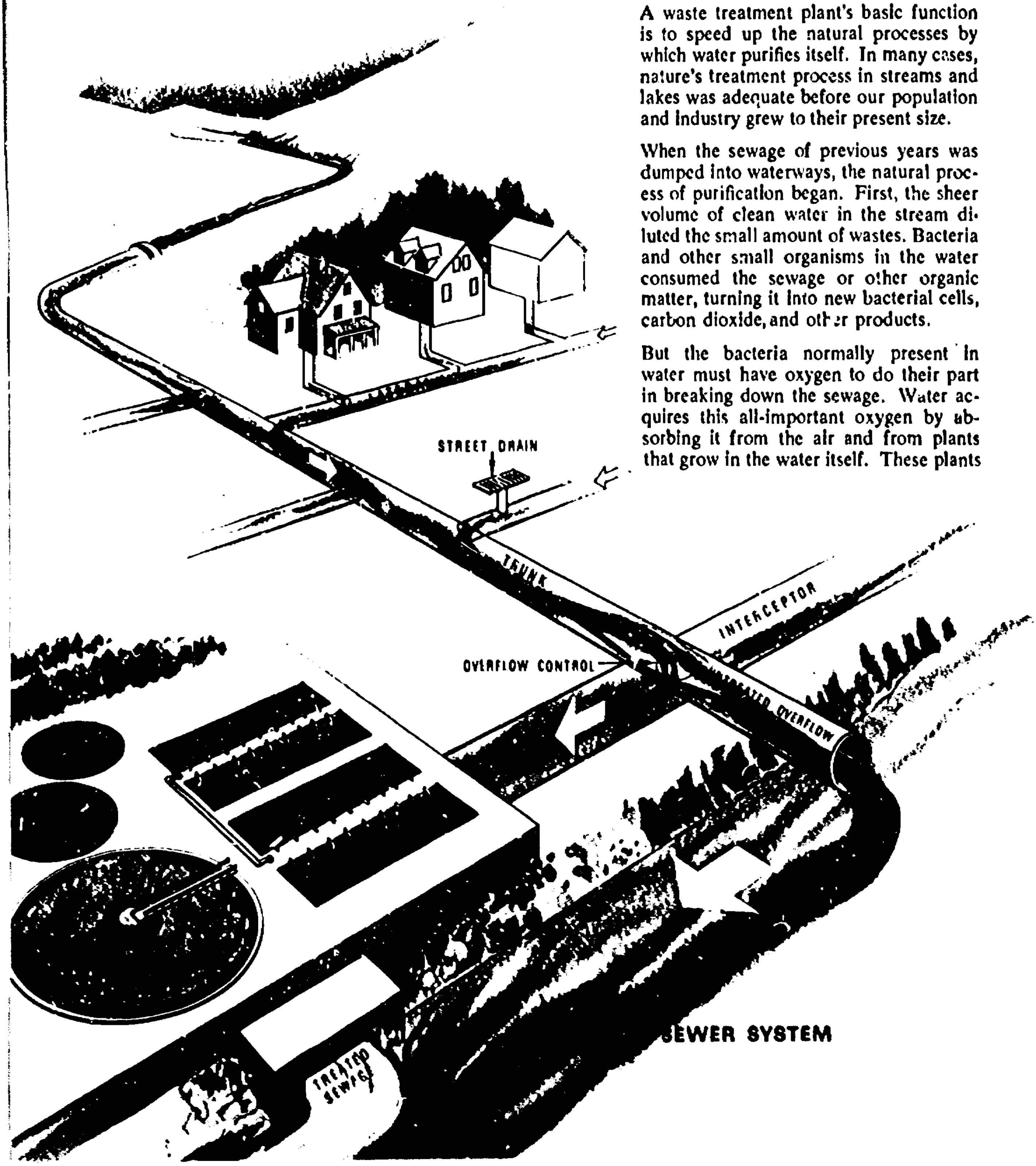
Interceptor sewers are also used in sanitary sewer systems as collectors of flow from main sewers and trunks, but do not normally include provisions for bypassing.

Untreated sewage pours into stream from combined storm-sanitary sewer.

A waste treatment plant's basic function is to speed up the natural processes by which water purifies itself. In many cases, nature's treatment process in streams and lakes was adequate before our population and industry grew to their present size.

When the sewage of previous years was dumped into waterways, the natural process of purification began. First, the sheer volume of clean water in the stream diluted the small amount of wastes. Bacteria and other small organisms in the water consumed the sewage or other organic matter, turning it into new bacterial cells, carbon dioxide, and other products.

But the bacteria normally present in water must have oxygen to do their part in breaking down the sewage. Water acquires this all-important oxygen by absorbing it from the air and from plants that grow in the water itself. These plants



use sunlight to turn the carbon dioxide present in water into oxygen.

The life and death of any body of water depends mainly upon its ability to maintain a certain amount of dissolved oxygen. This dissolved oxygen—or DO—is what fish breathe. Without it they suffocate. If only a small amount of sewage is dumped into a stream, fish are not affected and the bacteria can do their work and the stream can quickly restore its oxygen loss from the atmosphere and from plants. Trouble begins when the sewage load is excessive. The sewage will decay and the water will begin to give off odors. If carried to the extreme, the water could lose all of its oxygen, resulting in the death of fish and beneficial plant life.

Since dissolved oxygen is the key element in the life of water, the demands on it are used as a measure in telling how well a sewage treatment plant is working. This measuring device is called biochemical oxygen demand, or BOD. If the effluent or the end-product from a treatment plant has a high content of organic pollutants, the effluent will have a high BOD. In other words, it will demand more oxygen from the water to break down the sewage and consequently will leave the water with less oxygen (and also dirtier).

With the growth of the Nation, the problems of pollution have become more complex. The increased amounts of wastes and the larger demands for water have reduced the capacity of running water to purify itself. Consequently, cities and industry have had to begin thinking about removing as much as possible of the oxygen-demanding pollutants from their sewage.

Adequate treatment of wastes along with providing a sufficient supply of clean water has become a major concern.

PRIMARY TREATMENT

At present, there are two basic ways of treating wastes. They are called primary and secondary. In primary treatment, solids are allowed to settle and are removed from the water. Secondary treatment, a further step in purifying waste water, uses biological processes.

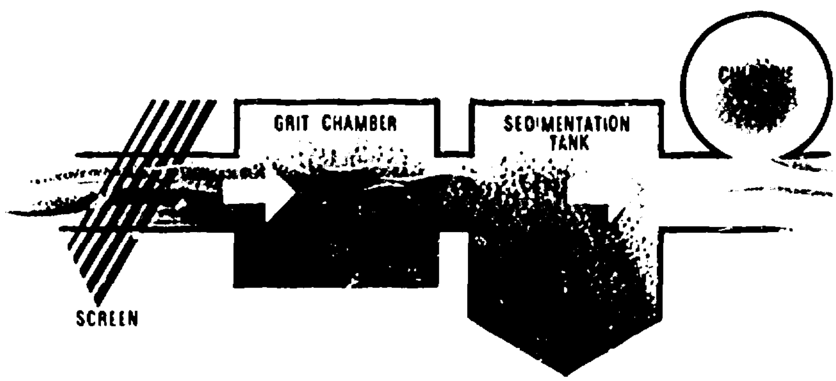
As sewage enters a plant for primary treatment, it flows through a screen. The screen removes large floating objects such as rags and sticks that may clog pumps and small pipes. The screens vary from coarse to fine—from those with parallel steel or iron bars with openings of about half an inch or more to screens with much smaller openings.

Screens are generally placed in a chamber or channel in an inclined position to the flow of the sewage to make cleaning easier. The debris caught on the upstream surface of the screen can be raked off manually or mechanically.

Some plants use a device known as a comminutor which combines the functions of a screen and a grinder. These devices catch and then cut or shred the heavy solid material. In the process, the pulverized matter remains in the sewage flow to be removed later in a settling tank.

After the sewage has been screened, it passes into what is called a grit chamber where sand, grit, cinders, and small stones are allowed to settle to the bottom. A grit chamber is highly important for cities with combined sewer systems because it will remove the grit or gravel that washes off streets or land during a storm and ends up at treatment plants.

The unwanted grit or gravel from this process is usually disposed of by filling land near a treatment plant.



In some plants, another screen is placed after the grit chamber to remove any further material that might damage equipment or interfere with later processes.

With the screening completed and the grit removed, the sewage still contains suspended solids. These are minute particles of matter that can be removed from the sewage by treatment in a sedimentation tank. When the speed of the flow of sewage through one of these tanks is reduced, the suspended solids will gradually sink to the bottom. This mass of solids is called raw sludge.

Various methods have been devised for removing sludge from the tanks.

In older plants, sludge removal was done by hand. After a tank had been in service for several days or weeks, the sewage flow was diverted to another tank. The sludge in the bottom of the out-of-service tank was pushed or flushed with water to a pit near the tank, and then removed, usually by pumping, for further treatment or disposal.

Almost all plants built within the past 30 years have had a mechanical means for removing the sludge from sedimentation tanks. Some plants remove it continuously while others remove it at intervals. To complete the primary treatment, the effluent with the sludge removed leaves the sedimentation tank for chlorination before being discharged into a stream or river. Chlorine gas is fed into the water to kill disease-causing bacteria. It also helps to reduce odors.

Although 30 percent of the municipalities in the United States give only primary treatment to their sewage, this process by itself is considered entirely inadequate for most needs.

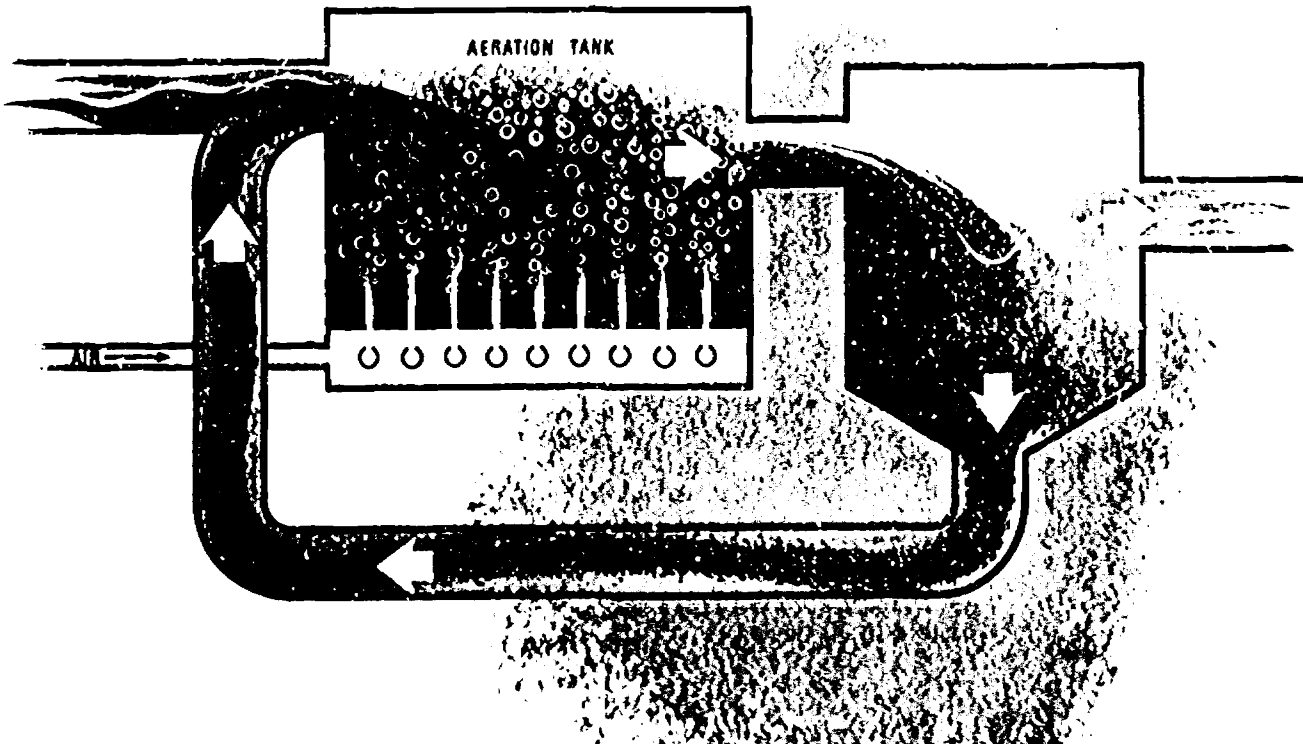
Today's cities and industry, faced with increased amounts of wastes and wastes that are more difficult to remove from water, have turned to secondary and even advanced waste treatment.

SECONDARY TREATMENT

Secondary treatment removes up to 90 percent of the organic matter in sewage by making use of the bacteria in it. The two principal types of secondary treatment are trickling filters and the activated-sludge process.

After the effluent leaves the sedimentation tank in the primary stage of treatment, it flows or is pumped to a facility using one or the other of these processes. A trickling filter is simply a bed of stones from three to ten feet deep through which the sewage passes. Bacteria gather and multiply on these stones until they can consume most of the organic matter in the sewage. The cleaner water trickles out through pipes in the bottom of the filter for further treatment.

The sewage is applied to the bed of stones in two principal ways. One method consists of distributing the effluent intermittently through a network of pipes laid on or beneath the surface of the stones.



Attached to these pipes are smaller, vertical pipes which spray the sewage over the stones.

Another much-used method consists of a vertical pipe in the center of the filter connected to rotating horizontal pipes which spray the sewage continuously upon the stones.

The trend today is toward the use of the activated sludge process instead of trickling filters. This process speeds up the work of the bacteria by bringing air and sludge heavily laden with bacteria into close contact with the sewage.

After the sewage leaves the settling tank in primary treatment, it is pumped to an aeration tank where it is mixed with air and sludge loaded with bacteria and allowed to remain for several hours. During this time, the bacteria break down the organic matter.

From the aeration tank, the sewage, now called mixed liquor, flows to another sedimentation tank to remove the solids. Chlorination of the effluent completes the basic secondary treatment.

The sludge, now activated with additional millions of bacteria and other tiny organisms, can be used again by returning it to an aeration tank for mixing with new sewage and ample amounts of air.

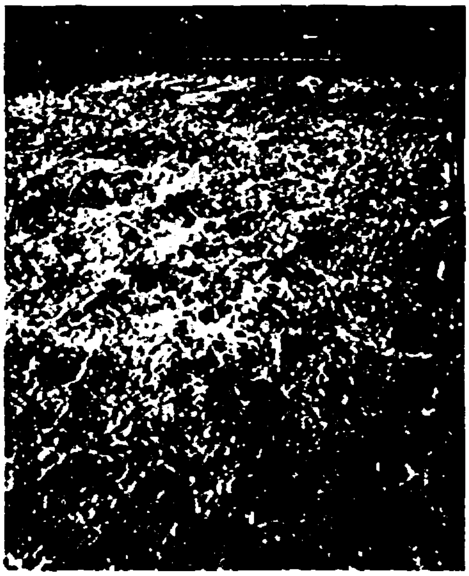
The activated sludge process, like most other techniques, has advantages and limitations. The size of the units necessary for this treatment is small, thereby requiring less land space and the process is free of flies and odors. But it is more costly to operate than the trickling filter, and the activated sludge process sometimes loses its effectiveness when faced with difficult industrial wastes.

An adequate supply of oxygen is necessary for the activated sludge process to be effective. Air is mixed with sewage and biologically active sludge in the aeration tanks by three different methods.

The first, mechanical aeration, is accomplished by drawing the sewage from the bottom of the tank and spraying it over the surface, thus causing the sewage to absorb large amounts of oxygen from the atmosphere.

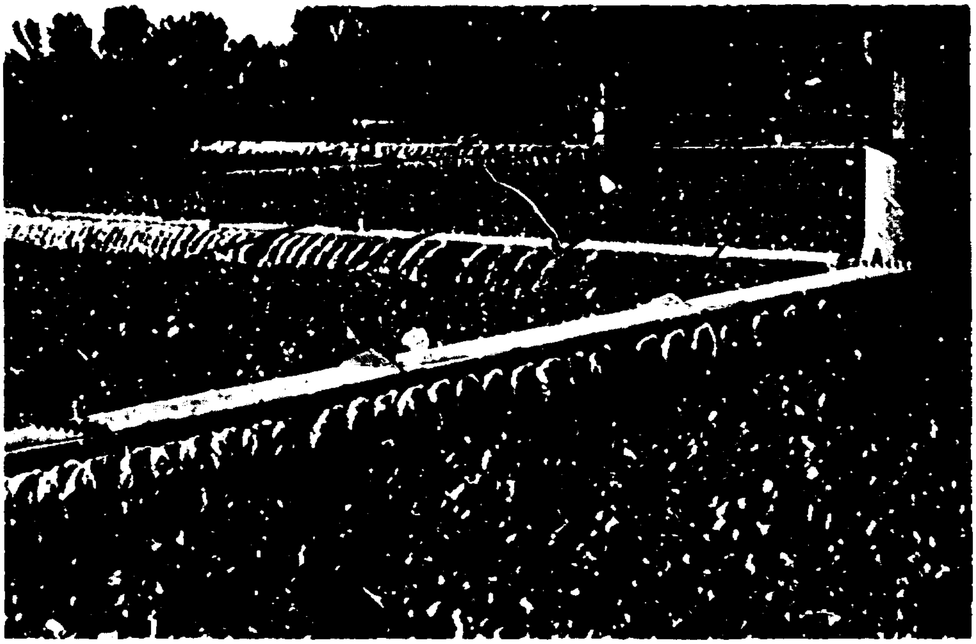
In the second method, large amounts of air under pressure are piped down into the sewage and forced out through openings in the pipe. The third method is a combination of mechanical aeration and the forced air method.

The final phase of the secondary treatment consists of the addition of chlorine to the effluent coming from the trickling filter or the activated sludge process. Chlorine is usually purchased in liquid form, converted to a gas, and injected into the effluent 15 to 30 minutes before the treated water is discharged into a watercourse. If done properly, chlorination will kill more than 99 percent of the harmful bacteria in an effluent.



Aeration unit in sewage treatment plant mixes oxygen from the air with waste water to help bacteria break down organic compounds.

Slowly revolving pipes in trickling filter spray waste water over beds of stones where bacteria consume organic matter.



LAGOONS AND SEPTIC TANKS

There are many well-populated areas in the United States that are not served by any sewer systems or waste treatment plants. Lagoons and septic tanks are the usual alternatives in such situations.

A septic tank is simply a tank buried in the ground to treat the sewage from an individual home. Waste water from the home flows into the tank where bacteria in the sewage break down the organic matter and the cleaner water flows out of the tank into the ground through sub-surface drains. Periodically the sludge or solid matter in the bottom of the tank must be removed and disposed of.

In a rural setting, with the right kind of soil and the proper location, the septic tank is a safe and effective means of disposing of strictly domestic wastes. Septic tanks should always be located so that none of the effluent can seep into wells used for drinking.

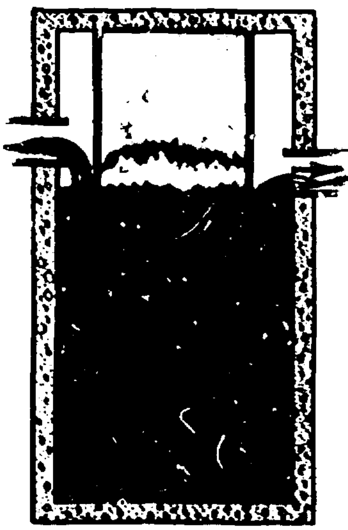


DIAGRAM OF A SEPTIC TANK

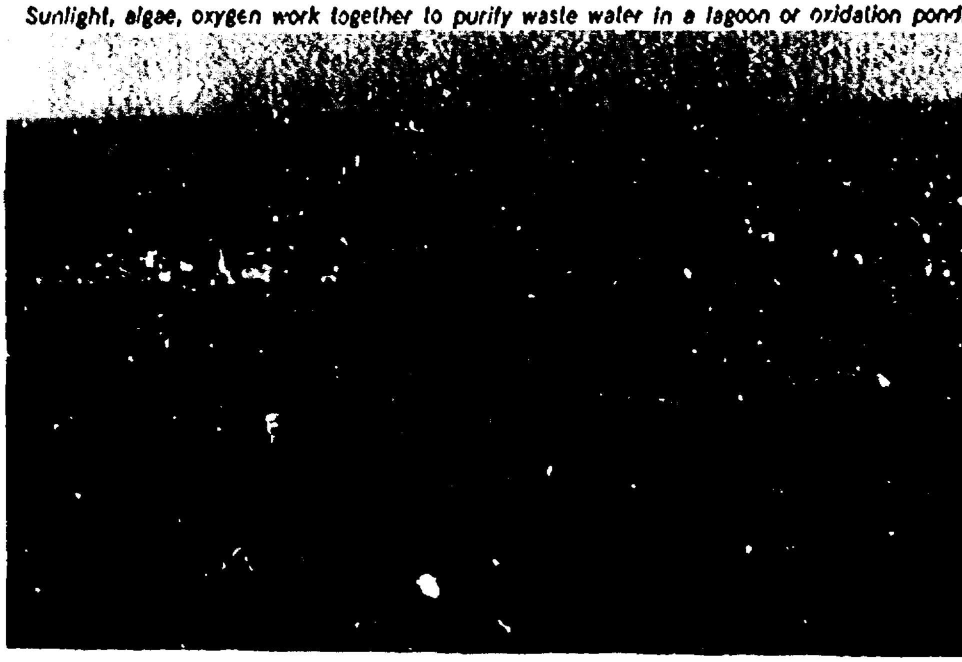
Lagoons or, as they are sometimes called, stabilization or oxidation ponds also have several advantages when used correctly.

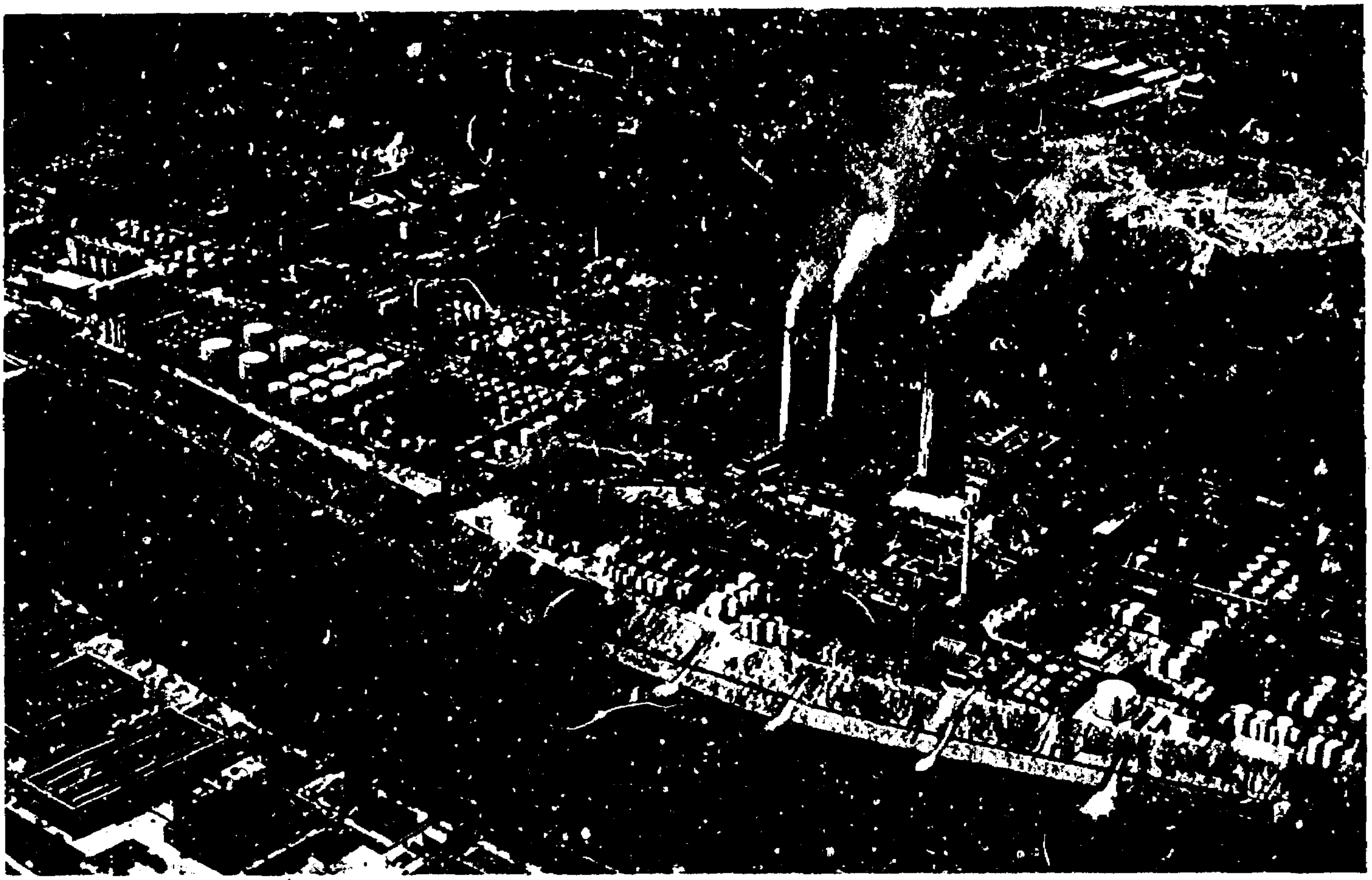
They can give sewage primary and secondary treatment or they can be used to supplement other processes.

A lagoon is a scientifically constructed pond, usually three to five feet deep, in which sunlight, algae, and oxygen interact to restore water to a quality equal to or better than effluent from secondary treatment. Changes in the weather affect how well a lagoon will break down the sewage.

When used with other waste treatment processes, lagoons can be very effective. A good example of this is the Santee, California, water reclamation project. After conventional primary and secondary treatment by activated sludge, the town's waste water is kept in a lagoon for 30 days. Then the effluent, after chlorination, is pumped to land immediately above a series of lakes and allowed to trickle down through sandy soil into the lakes. The resulting water is of such good quality, the residents of the area can swim, boat, and fish in the lake water.

Sunlight, algae, oxygen work together to purify waste water in a lagoon or oxidation pond.





Industrial concentrations can cause gross pollution without adequate treatment. Note sewers dumping wastes.

Activated carbon is tested in tanks as an improved method of removing organic matter by adsorption. Organic compounds cling to carbon and settle out.

THE NEED FOR FURTHER TREATMENT OF WASTES

In the past, pollution control was concerned primarily with problems caused by domestic and the simpler wastes of industry. Control was aimed principally towards protecting downstream public water supplies and stopping or preventing nuisance conditions.

Pollution problems were principally local in extent and their control a local matter.

This is no longer true. National growth and change have altered this picture. Progress in abating pollution has been outdistanced by population growth, the speed of industrial progress and technological developments, changing land practices, and many other factors.

The increased production of goods has greatly increased the amounts of common industrial wastes. New processes in manufacturing are producing new, complex wastes that sometimes defy present pollution control technology. The increased application of commercial fertilizers and the development and widespread use of a vast array of new pesticides are resulting in a host of new pollution problems from water draining off land.

The growth of the nuclear energy field and the use of radioactive materials foreshadow still another complicating and potentially serious water pollution situation.

Long stretches of both interstate and intrastate streams are subjected to pollution which ruins or reduces the use of the water for many purposes. Conventional biological waste treatment processes are hard-pressed to hold the pollution line, and for a growing number of our larger cities, these processes are no longer adequate.

Our growing population not only is packing our central cities but spreading out farther and farther into suburbia and exurbia. Across the country, new satellite communities are being born almost daily. The construction or extension of sewer lines has not matched either the growth rate or its movements. Sea water intrusion is a growing problem in coastal areas. It is usually caused by the excessive pumping of fresh water from the ground which lowers the water level, allowing salt water to flow into the ground water area.

THE TYPES OF POLLUTANTS

Present-day problems that must be met by sewage treatment plants can be summed up in the eight types of pollutants affecting our waters.

The eight general categories are: common sewage and other oxygen-demanding wastes; disease-causing agents; plant nutrients; synthetic organic chemicals; inorganic chemicals and other mineral substances; sediment; radioactive substances; and heat.

Oxygen-demanding wastes— These are the traditional organic wastes contributed by domestic sewage and industrial wastes of plant and animal origin. Besides human sewage, such wastes result from food processing, paper mill production, tanning, and other manufacturing processes. These wastes are usually destroyed by bacteria if there is sufficient oxygen present in the water. Since fish and other aquatic life depend on oxygen for life, the oxygen-demanding wastes must be controlled, or the fish die.

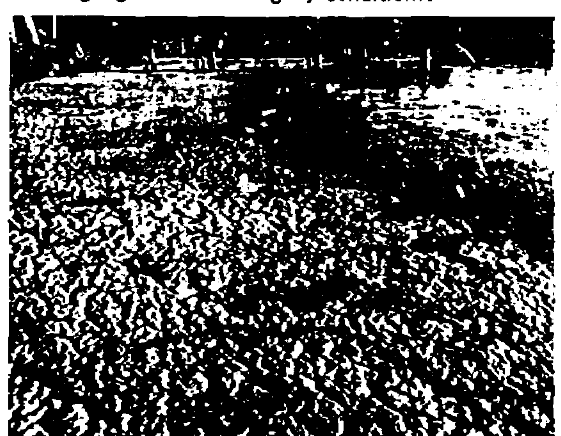
Disease-causing agents—This category includes infectious organisms which are carried into surface and ground water by sewage from cities and institutions, and by certain kinds of industrial wastes, such as tanning and meat packing plants. Man or animals come in contact with these microbes either by drinking the water or through swimming, fishing, or other activities. Although modern disinfection techniques have greatly reduced the danger of this type of pollutant, the problem must be watched constantly.

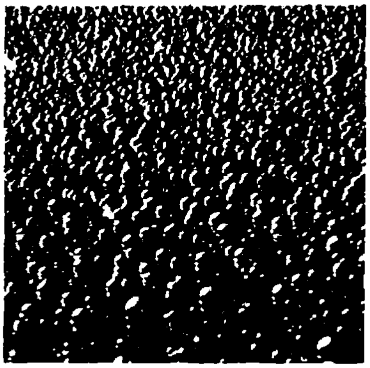
Plant nutrients—These are the substances in the food chain of aquatic life, such as algae and water weeds, which support and stimulate their growth. Nitrogen and phosphorus are the two chief nutrients present in small amounts in natural water, but much larger amounts are contributed

Common sewage from homes, businesses depletes oxygen supply in the water.

Blood and grease turn water brown at drain from meat packing plant.

Floating algae create unsightly conditions.





Chemicals in water from factory turn stream into bubbling mess and are difficult to remove.

by sewage, certain industrial wastes, and drainage from fertilized lands. Biological waste treatment processes do not remove the nutrients—in fact, they convert the organic forms of these substances into mineral form, making them more usable by plant life. The problem starts when an excess of these nutrients over-stimulates the growth of water plants which cause unsightly conditions, interfere with treatment processes, and cause unpleasant and disagreeable tastes and odors in the water.

Synthetic organic chemicals—Included in this category are detergents and other household aids, all the new synthetic organic pesticides, synthetic industrial chemicals, and the wastes from their manufacture. Many of these substances are toxic to fish and aquatic life and possibly harmful to humans. They cause taste and odor problems, and resist conventional waste treatment. Some are known to be highly poisonous at very low concentrations. What the long-term effects of small doses of toxic substances may be is not yet known.

Inorganic chemicals and mineral substances—A vast array of metal salts, acids, solid matter, and many other chemical compounds are included in this group. They reach our waters from mining and manufacturing processes, oil field operations, agricultural practices, and natural sources. Water used in irrigation picks up large amounts of minerals as it filters down through the soil on its way to the nearest stream. Acids of a wide variety are discharged as wastes by industry, but the largest single source of acid in our water comes from mining operations and mines that have been abandoned.

Acid forms in water draining from abandoned mine.

Dirt from soil erosion pollutes water, reduces stream bed.

Many of these types of chemicals are being created each year. They interfere with natural stream purification; destroy fish and other aquatic life; cause excessive hardness of water supplies; corrode expensive water treatment equipment; increase commercial and recreational boat maintenance costs, and boost the cost of waste treatment.

Thousands of fish are killed each year by wastes in water that reduce oxygen supplies.

Sediments—These are the particles of soils, sands, and minerals washed from the land and paved areas of communities into the water. Construction projects are often large sediment producers. While not as insidious as some other types of pollution, sediments are a major problem because of the sheer magnitude of the amount reaching our waterways. Sediments fill stream channels and harbors, requiring expensive dredging, and they fill reservoirs, reducing their capacities and useful life. They erode power turbines and pumping equipment, and reduce fish and shellfish populations by blanketing fish nests and food supplies.

Steaming hot water pollutes river.

More importantly, sediments reduce the amount of sunlight penetrating the water. The sunlight is required by green aquatic plants which produce the oxygen necessary to normal stream balance. Sediments greatly increase the treatment costs for municipal and industrial water supply and for sewage treatment where combined sewers are in use.

Radioactive substances—Radioactive pollution results from the mining and processing of radioactive ores; from the use of refined radioactive materials in power reactors and for industrial, medical, and research purposes; and from fallout following nuclear weapons testing. Increased use of these substances poses a potential public health problem. Since radiation accumulates in humans, control of this type of pollution must take into consideration total exposure in the human environment—water, air, food, occupation, and medical treatment.

Heat—Heat reduces the capacity of water to absorb oxygen. Tremendous volumes of water are used by power plants and industry for cooling. Most of the water, with the added heat, is returned to streams, raising their temperatures. With less oxygen, the water is not as efficient in assimilating oxygen-consuming wastes and in supporting fish and aquatic life.

Water in lakes or stored in impoundments can be greatly affected by heat. Summer temperatures heat up the surfaces, causing the water to form into layers, with the cooler water forming the deeper layers. Decomposing vegetative matter from natural and man-made pollutants deplete the oxygen from these cooler lower layers with harmful effects on the aquatic life. When the oxygen-deficient water is discharged from the lower gates of a dam, it may have serious effects on downstream fish life and reduce the ability of the stream to assimilate downstream pollution.

To complicate matters, most of our wastes are a mixture of the eight types of pollution, making the problems of treatment and control that much more difficult.

Municipal wastes usually contain oxygen-consuming pollutants, synthetic organic chemicals such as detergents, sediments, and other types of pollutants. The same is true of many industrial wastes which may contain, in addition, substantial amounts of heat from cooling processes. Water that drains off the land usually contains great amounts of organic matter in addition to sediment. Also, land drainage may contain radioactive substances and pollutants washed from the sky, vegetation, buildings, and streets during rainfall.

ADVANCED METHODS OF TREATING WASTES

These new problems of a modern society have placed additional burdens upon our waste treatment systems. Today's pollutants are more difficult to remove from the water. And increased demands upon our water supply aggravate the problem. During the dry season, the flow of rivers decreases to such an extent that they have difficulty in assimilating the effluent from waste treatment plants.

In the future, these problems will be met through better and more complete methods of removing pollutants from water and better means for preventing some wastes from even reaching our streams in the first place.

The best immediate answer to these problems is the widespread application of existing waste treatment methods. Many cities that have only primary treatment need secondary treatment. Many other cities need enlarged or modernized primary and secondary systems.

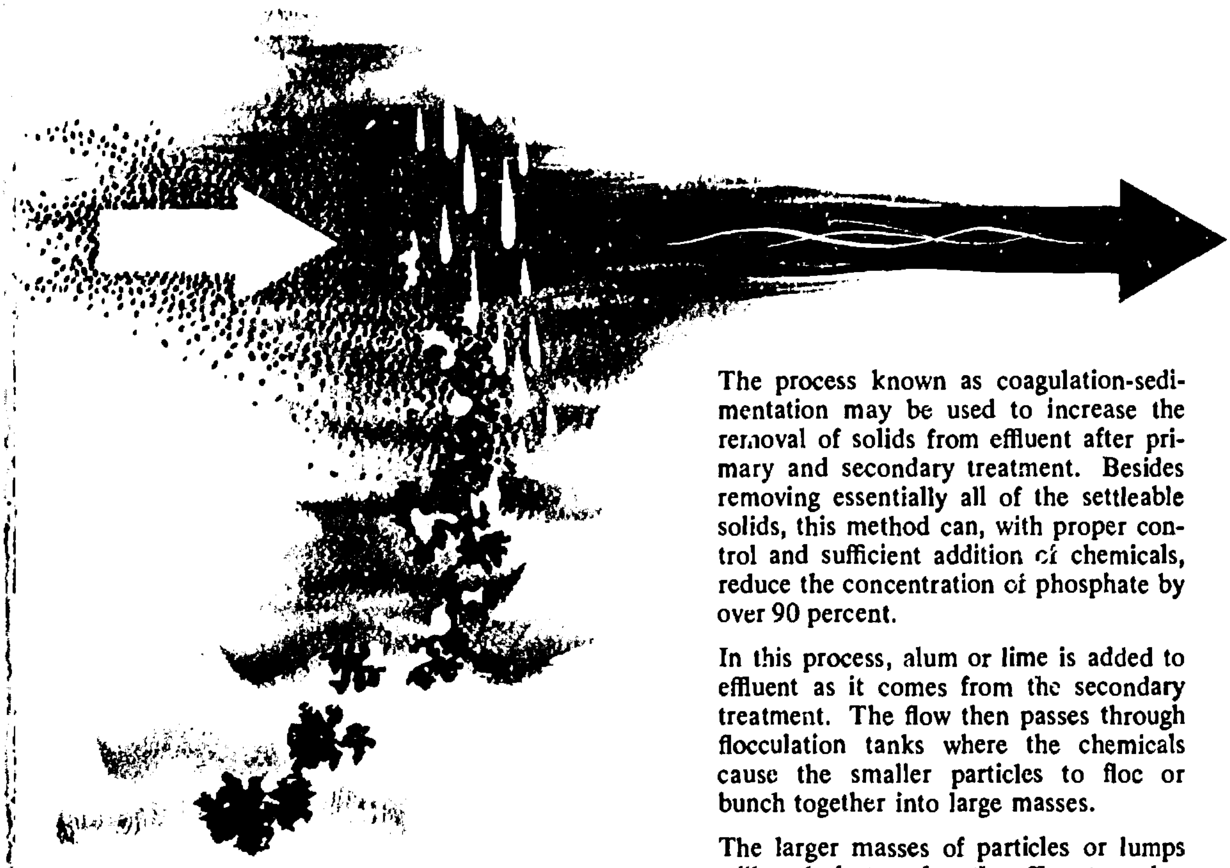
But this is only a temporary solution. The discharge of oxygen-consuming wastes will increase despite the universal application of the most efficient waste treatment processes now available. And these are the simplest wastes to dispose of. Conventional treatment processes are already losing the battle against the modern-day, tougher wastes.

The increasing need to reuse water now calls for better and better waste treatment. Every use of water—whether in home, in the factory, or on the farm—results in some change in its quality.

To return water of more usable quality to receiving lakes and streams, new methods for removing pollutants are being developed. The advanced waste treatment techniques under investigation range from extensions of biological treatment capable of removing nitrogen and phosphorus nutrients to physical-chemical separation techniques such as adsorption, distillation, and reverse osmosis.

These new processes can achieve any degree of pollution control desired and, as waste effluents are purified to higher and higher degrees by such treatment, the point is reached where effluents become "too good to throw away."

Such water can be deliberately and directly reused for agricultural, industrial, recreational, or even drinking water supplies. This complete water renovation will mean complete pollution control and at the same time more water for the Nation.



The process known as coagulation-sedimentation may be used to increase the removal of solids from effluent after primary and secondary treatment. Besides removing essentially all of the settleable solids, this method can, with proper control and sufficient addition of chemicals, reduce the concentration of phosphate by over 90 percent.

In this process, alum or lime is added to effluent as it comes from the secondary treatment. The flow then passes through flocculation tanks where the chemicals cause the smaller particles to floc or bunch together into large masses.

The larger masses of particles or lumps will settle faster when the effluent reaches the next step—the sedimentation tank.

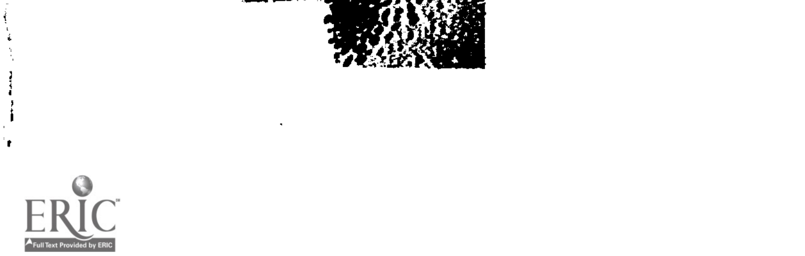
COAGULATION—SEDIMENTATION

The application of advanced techniques for waste treatment, at least in the next several years, will most likely take up where primary and secondary treatment leave off. Ultimately, entirely new systems will no doubt replace the modern facilities of today.

Although used for years in the treatment of industrial wastes and in water treatment, coagulation-sedimentation is classified as an advanced process because it is not usually applied to the treatment of municipal wastes. In many cases, the process is a necessary pre-treatment for some of the other advanced techniques.

ADSORPTION

After the removal of most of the solids, the next problem facing the advanced waste treatment system is to get rid of the dissolved refractory organics. As the word indicates, this is the stubborn organic matter which persists in water and resists normal biological treatment.



The effects of the organics are not too well understood, but taste and odor problems in water, tainting of fish flesh, foaming of water, and fish kills have been attributed to such materials.

Adsorption consists of passing the effluent through a bed of activated carbon granules which will remove more than 98 percent of the organics. To cut down the cost of the procedure, the carbon granules can be cleaned by heat and used again.

An improvement of the process through the use of powdered carbon is under study. Rather than pass the effluent through a bed of granules, the powdered carbon is put directly into the stream. The organics stick to the carbon and then the carbon is removed from the effluent by using coagulating chemicals and allowing the coagulated carbon particles to settle in a tank.

As would be expected, this finely ground carbon will take out even more of the refractory, or stubborn, organics. The potential widespread use of powdered carbon adsorption depends largely on the effectiveness of regenerating the carbon for use again.

Except for the salts added during the use of water, municipal waste water that has gone through the previous advanced processes will be restored to a chemical quality almost the same as before it was used.

When talking of salts in water, salt is not limited to the common kind that is used in the home for seasoning food. In waste treatment language, salts mean the many minerals dissolved by water as it passes through the air as rainfall, as it trickles through the soil and over rocks, and as it is used in the home and factory.

ELECTRODIALYSIS

Electrodialysis is a rather complicated process by which electricity and membranes are used to remove salts from an effluent. A membrane is usually made of chemically treated plastic. The salts are forced out of the water by the action of an electric field. When a mineral salt is placed in water it has a tendency to break down into ions. An ion is an atom or a small group of atoms having an electrical charge.

As an example, the two parts of common table salt are sodium and chlorine. When these two elements separate as salt dissolves in water, the sodium and chlorine particles are called ions. Sodium ions have a positive charge while chlorine ions have a negative charge.

When the effluent passes through the electrodialysis cell, the positive sodium ions are attracted through a membrane to a pole or electrode that is negatively charged. The negatively charged chlorine ions are pulled out of the water through another membrane toward an electrode with a positive charge.

With the salts removed by the action of the two electrodes, the clean water flows out of the electrodialysis cell for reuse or discharge into a river or stream.

When a typical city uses its water the amount of salts in the water doubles. Fortunately, electrodialysis can reduce the amount of salts by about one-half or more. In other words, this process returns the salt content of the water back to where it was or even better than when the city first received the water.

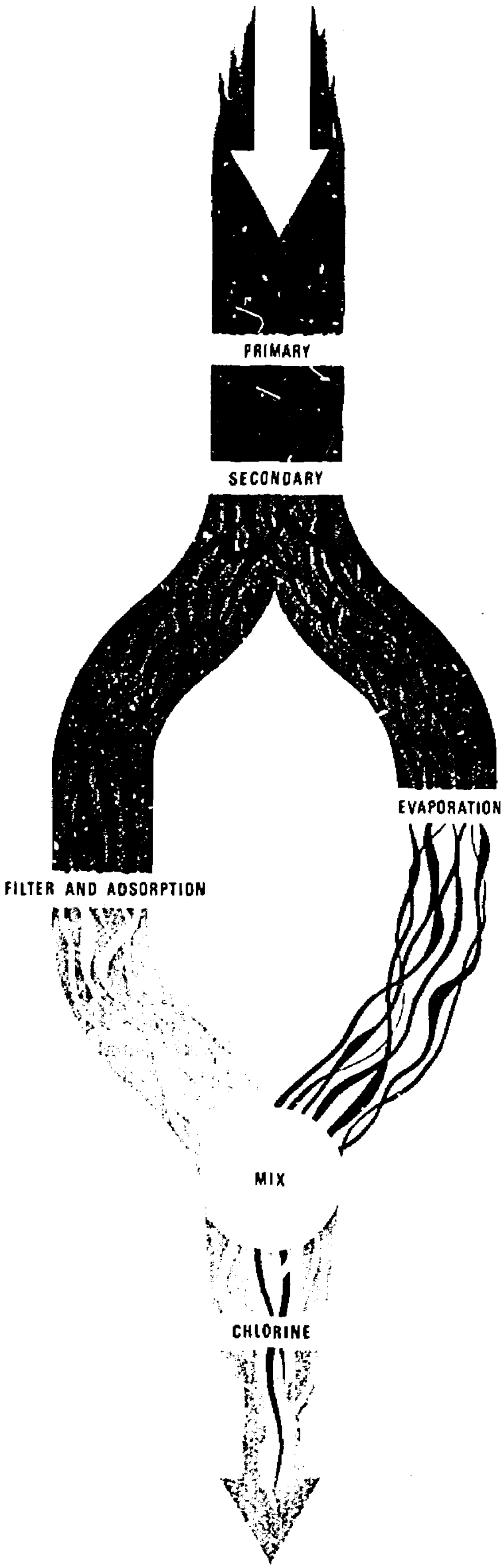
THE BLENDING OF TREATED WATER

Properly designed and applied, the methods that have been explained will be able to supply any quality of water for any reuse.

But none of these processes will stand alone. They must be used in a series or a parallel plan. In a series, all the sewage passes through all the processes, one after another, each process making a particular contribution toward improving the water. For example, the conventional primary treatment removes the material that will readily settle or float; the secondary biological step takes care of the decomposable impurities; coagulation-sedimentation, the third step, eliminates the suspended solids; carbon adsorption removes the remaining dissolved organic matter; electrodialysis returns the level of the salts to what it was before the water was used; and, finally, chlorination provides the health safety barrier against disease carriers.

Basically the same result can be achieved by separating the effluent into two streams. In this instance, all of the waste receives the primary and secondary treatment but then is divided. Part of the effluent passes through the coagulation-sedimentation and adsorption processes which remove the organic matter. The other half of the sewage is treated by evaporation and adsorption to remove all impurities including the minerals.

After going separate ways, the two



streams are mixed together, chlorinated, and then are ready for reuse or discharge into a stream. Splitting the effluent into two streams and then reblending helps reduce the cost of waste treatment for a more expensive process such as distillation.

Distillation or evaporation basically consists of bringing the effluent to the boiling point. The steam or vapor produced is piped to another chamber where it is cooled, changing it back to a liquid. The unwanted minerals and other impurities remain in the original chamber.

As most people have discovered, distilled water has a flat, disagreeable taste caused by the absence of minerals and air. But by blending this pure water with water that still contains some minerals, a clean, better tasting water results. And just as importantly, the more expensive distillation process is used on only part of the effluent, and the rest of the waste water is treated by the less costly procedures.

NEW CHALLENGES FOR WASTE TREATMENT

So far, the most readily available processes that will solve most current pollution problems have been covered. But the future holds many new challenges. Scientists are still looking for the ultimate system that will do the complete job of cleaning up water, simply and at a reasonable cost.

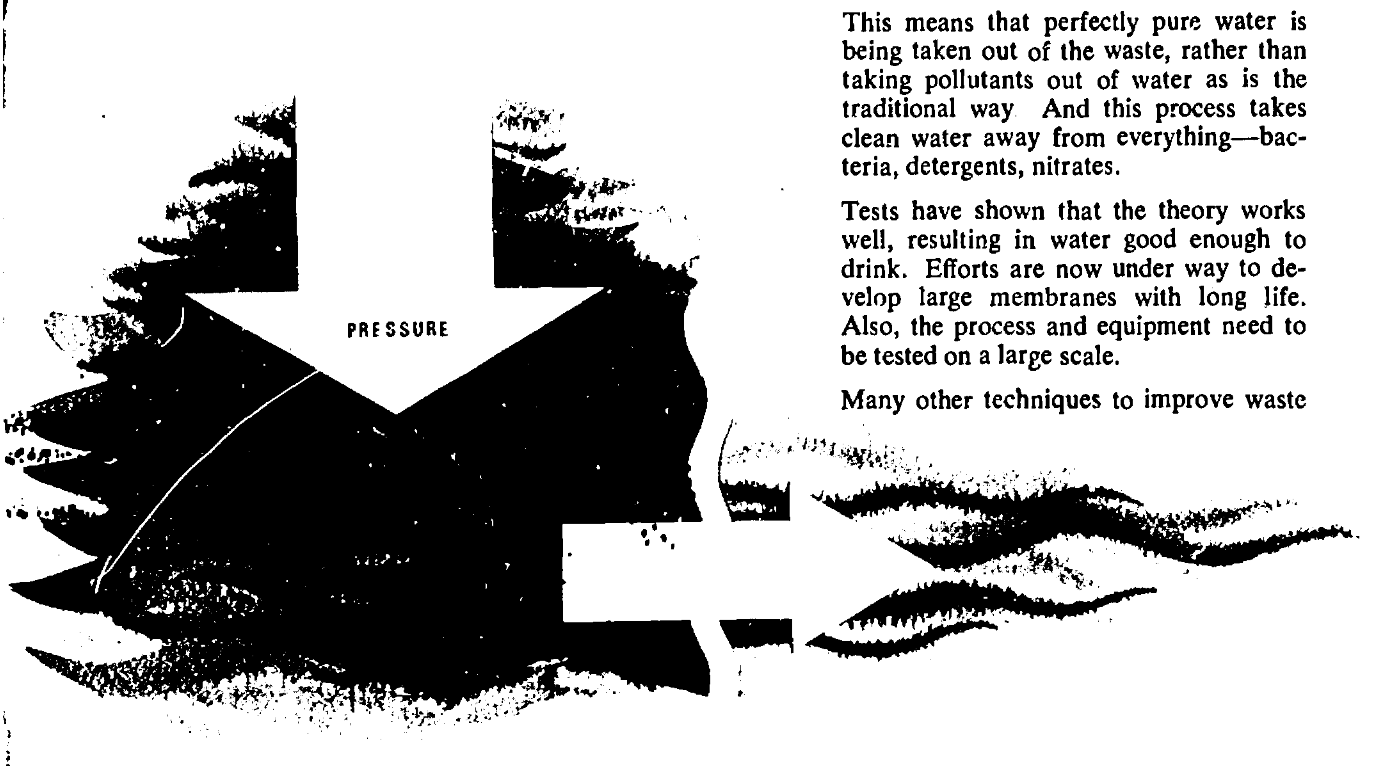
One such possible process under study is reverse osmosis. When liquids with different concentrations of mineral salts are separated by a membrane, molecules of pure water tend to pass by osmosis from the more concentrated to the less concentrated side until both liquids have the same mineral content.

Scientists are now exploring ways to take advantage of the natural phenomena of osmosis, but in reverse. When pressure is exerted on the side with the most minerals, this natural force reverses itself, causing the molecules of pure water to flow out of the compartment containing a high salt concentration.

This means that perfectly pure water is being taken out of the waste, rather than taking pollutants out of water as is the traditional way. And this process takes clean water away from everything—bacteria, detergents, nitrates.

Tests have shown that the theory works well, resulting in water good enough to drink. Efforts are now under way to develop large membranes with long life. Also, the process and equipment need to be tested on a large scale.

Many other techniques to improve waste



treatment are under development in laboratories and in the field.

For example, special microscopic organisms are being tested for removing nitrates from waste water by reducing the nitrates to elemental nitrogen.

CHEMICAL OXIDATION

Municipal waste waters contain many organic materials only partially removed by the conventional treatment methods. Detergents are a good example. Oxidants such as ozone and chlorine have been used for many years to improve the taste and odor qualities or to disinfect municipal drinking water. They improve the quality of the water by destroying or altering the structure of the chemicals in the water.

However, the concentration of the organic materials in drinking water supplies is much less than it is in the waste-bearing waters reaching treatment plants. Until recently, the cost of the oxidants has prevented the use of this process in the treating of wastes. Now, improvements in the production and application of ozone and pure oxygen may reduce costs sufficiently to make their use practicable. When operated in conjunction with other processes, oxidation could become an effective weapon in eliminating wastes resistant to other processes.

POLYMERS AND POLLUTION

In discussing the coagulation-sedimentation process, mention was made of the use of alum or lime to force suspended solids into larger masses. The clumping together helps speed up one of the key steps in waste treatment—the separation of solids and liquids.

During the past 10 to 15 years, the chemical industry has been working on synthetic organic chemicals, known as polyelectrolytes or polymers, to further improve the separation step.

Formerly, polymers have proved effective when used at a later stage of treatment—the sludge disposal time. Sludge must be dried so that it can be more easily disposed of. By introducing polymers into the sludge, the physical and chemical bonds between the solids are tightened. When this happens, the water can be extracted more rapidly.

Wider use of polymers is now being investigated. By putting polymers into streams or rivers, it may be possible to capture silt at specified locations so that it can be removed in quantity.

If polymers are put into raw sewage, waste treatment plants may be able to combine a chemical process with the standard primary and secondary stages. And this method of removing solids can be applied immediately without lengthy and expensive addition of buildings or new facilities.

The chemicals also hold promise as a means of speeding the flow of waste waters through sewer systems, thus, in effect, increasing the capacity of existing systems.

THE PROBLEM OF WASTE DISPOSAL

No matter how good the treatment of wastes, there is always something left over. It may be the rags and sticks that were caught on the screens at the very beginning of the primary treatment. It could be brine or it could be sludge—that part of the sewage that settles to the bottom in sedimentation tanks. Whatever it is, there is always something that must be burned, buried, or disposed of in some manner.

It is a twofold problem. The sludge or other matter must be disposed of to complete a city's or industry's waste treatment. And it must be disposed of in a manner not to add to or upset the rest of the environment.

If it is burned, it must be done in a way not to add to the pollution of the atmosphere. This would only create an additional burden for our already overburdened air to cope with. And air pollutants by the action of rain and wind have a habit of returning to the water, complicating the waste treatment problem rather than helping it.

There are many methods and processes for dealing with the disposal problem, which is sometimes referred to as the problem of ultimate disposal. The most common method for disposing of sludge and other waste concentrates consists of digestion followed by filtration and incineration.

The digestion of sludge takes place in heated tanks where the material can decompose naturally and the odors can be controlled. As digested sludge consists of 90 to 95 percent water, the next step in disposal must be the removal of as much of the water as possible.

Water can be removed from sludge by use of a rotating filter drum and suction. As

Sludge, solid matter left after treatment, is spread over the land to dry.

the drum rotates in the sludge, the water is pulled through the filter and the residues are peeled off for disposal. For more effective dewatering, the sludge can be first treated with a coagulant chemical such as lime or ferric chloride to produce larger solids before the sludge reaches the filter.

Drying beds which are usually made of layers of sand and gravel can be used to remove water from sludge. The sludge is spread over the bed and allowed to dry. After a week or two of drying, the residue will be reduced in volume and, consequently, will be easier to dispose of on land or in water.

Incineration consists of burning the dried sludge to reduce the residues to a safe, non-burnable ash. The ash can be disposed of by filling unused land or by dumping it well out into the ocean. Since most of the pollutants have been removed by the burning, the ash will cause very little change in the quality of the water.

A very promising new method of sludge disposal gets rid of the unwanted sludge and helps restore a ravaged countryside. In many areas of the country, tops of hills and mountains were sliced away to get at the coal beneath. This strip mining left ugly gashes and scars in otherwise beautiful valleys of many States. It would take nature many years to restore the denuded areas.

With the new disposal idea, digested sludge in semi-liquid form is piped to the spoiled areas. The slurry, containing many nutrients from the wastes, is spread over the land to give nature a hand in returning grass, trees, and flowers to the barren hilltops.

Restoration of the countryside will also help in the control of acids that drain from mines into streams and rivers, endangering the fish and other aquatic life and adding to the difficulty in reusing the

Countryside restored after strip mining by using sludge as fertilizer for plants.

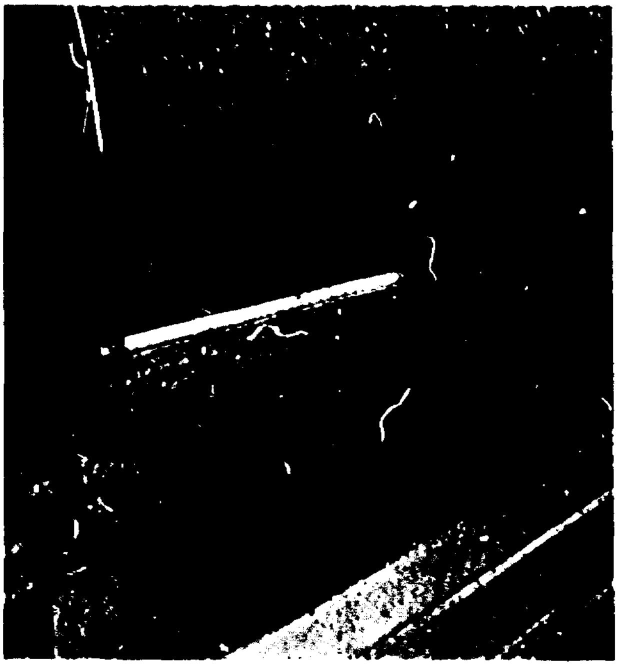
water. Acids are formed when pyrite containing iron and sulfur is exposed to the air.

Sludge or other waste concentrates are not always costly burdens. By drying and other processes, some cities have produced fertilizers that are sold to help pay for part of the cost of treating wastes. If not sold to the public, some municipalities use the soil enrichers on parks, road parkways, and other public areas.

Some industries have found they can reclaim certain chemicals during waste treatment and reuse them in manufacturing or refining processes. Other firms have developed saleable by-products from residues in waste treatment.

More studies are going on to find greater use for sludge to help solve the disposal problem and to help offset the cost of waste treatment.

Sludge from paper mill removed from waste stream and dried to prevent pollution of nearby river.



Revolving drum filters water from sludge so residues can be disposed of more easily.

Common sewage treatment terminology

Activated Sludge process removes organic matter from sewage by saturating it with air and biologically active sludge.

Adsorption is an advanced way of treating wastes in which carbon removes organic matter not responsive to clarification or biological treatment.

Aeration Tank serves as a chamber for injecting air into water.

Algae are plants which grow in sunlit waters. They are a food for fish and small aquatic animals and, like all plants, put oxygen in the water.

Bacteria are the smallest living organisms which literally eat the organic parts of sewage.

BOD, or biochemical oxygen demand, is the amount of oxygen necessary in the water for bacteria who consume the organic sewage. It is used as a measure in telling how well a sewage treatment plant is working.

Chlorinator is a device for adding chlorine gas to sewage to kill infectious germs.

Coagulation is the clumping together of solids to make them settle out of the sewage faster. Coagulation of solids is brought about with the use of certain chemicals such as lime, alum, or polyelectrolytes.

Combined Sewer carries both sewage and storm water run-off.

Comminutor is a device for the catching and shredding of heavy solid matter in the primary stage of waste treatment.

Diffused Air is a technique by which air under pressure is forced into sewage in an aeration tank. The air is pumped down into the sewage through a pipe and escapes out through holes in the side of the pipe.

Digestion of sludge takes place in heated tanks where the material can decompose naturally and the odors can be controlled.

Distillation in waste treatment consists of heating the effluent and then removing the vapor or steam. When the steam is returned to a liquid it is almost pure water. The pollutants remain in the concentrated residue.

Effluent is the liquid that comes out of a treatment plant after completion of the treatment process.

Electrodialysis is a process by which electricity attracts or draws the mineral salts from sewage.

Floc is a clump of solids formed in sewage when certain chemicals are added.

Flocculation is the process by which certain chemicals form clumps of solids in sewage.

Incineration consists of burning the sludge to remove the water and reduce the remaining residues to a safe, non-burnable ash. The ash can then be disposed of safely on land, in some waters, or into caves or other underground locations.

Interceptor sewers in a combined system control the flow of the sewage to the treatment plant. In a storm, they allow some of the sewage to flow directly into a receiving stream. This protects the treatment plant from being overloaded in case of a sudden surge of water into the sewers. Interceptors are also used in separate sanitation systems to collect the flows from main and trunk sewers and carry them to the points of treatment.

Ion is an electrically charged atom or group of atoms which can be drawn from waste water during the electrodialysis process.

Lateral sewers are the pipes that run under the streets of a city and into which empty the sewers from homes or businesses.

Lagoons are scientifically constructed ponds in which sunlight, algae, and oxygen interact to restore water to a quality equal to effluent from a secondary treatment plant.

Mechanical Aeration begins by forcing the sewage up through a pipe in a tank. Then it is sprayed over the surface of tank, causing the waste stream to absorb oxygen from the atmosphere.

Microbes are minute living things, either plant or animal. In sewage, microbes may be germs that cause disease.

Mixed Liquor is the name given the effluent that comes from the aeration tank after the sewage has been mixed with activated sludge and air.

Molecule is the smallest particle of an element or compound that can remain in a free state and still keep the characteristics of the element or compound.

Organic Matter is the waste from homes or industry of plant or animal origin.

Oxidation is the consuming or breaking down of organic wastes or chemicals in sewage by bacteria and chemical oxidants.

Oxidation Pond is a man-made lake or body of water in which wastes are consumed by bacteria. It is used most frequently with other waste treatment processes. An oxidation pond is basically the same as a sewage lagoon.

Primary Treatment removes the material that floats or will settle in sewage. It is accomplished by using screens to catch the floating objects and tanks for the heavy matter to settle in.

Pollution results when something—animal, vegetable, or mineral—reaches water, making it more difficult or dangerous to use for drinking, recreation, agriculture, industry, or wildlife.

Polyelectrolytes are synthetic chemicals used to speed the removal of solids from sewage. The chemicals cause the solids to coagulate or clump together more rapidly than chemicals like alum or lime.

Receiving Waters are rivers, lakes, oceans, or other water courses that receive treated or untreated waste waters.

Salts are the minerals that water picks up as it passes through the air, over and under the ground, and through household and industrial uses.

Sand Filter removes the organic wastes from sewage. The waste water is trickled over the bed of sand. Air and bacteria decompose the wastes filtering through the sand. The clean water flows out through drains in the bottom of the bed.

The sludge accumulating at the surface must be removed from the bed periodically.

Sanitary Sewers, in a separate system, are pipes in a city that carry only domestic waste water. The storm water runoff is taken care of by a separate system of pipes.

Secondary Treatment is the second step in most waste treatment systems in which bacteria consume the organic parts of the wastes. It is accomplished by bringing the sewage and bacteria together in trickling filters or in the activated sludge process.

Sedimentation Tanks help remove solids from sewage. The waste water is pumped to the tanks where the solids settle to the bottom or float on top as scum. The scum is skimmed off the top, and solids on the bottom are pumped out to sludge digestion tanks.

Septic Tanks are used to treat domestic wastes. The underground tanks receive the waste water directly from the home. The bacteria in the sewage decomposes the organic waste and the sludge settles on the bottom of the tank. The effluent flows out of the tank into the ground through drains. The sludge is pumped out of the tanks, usually by commercial firms, at regular intervals.

Sewers are a system of pipes that collect and deliver waste water to treatment plants or receiving streams.

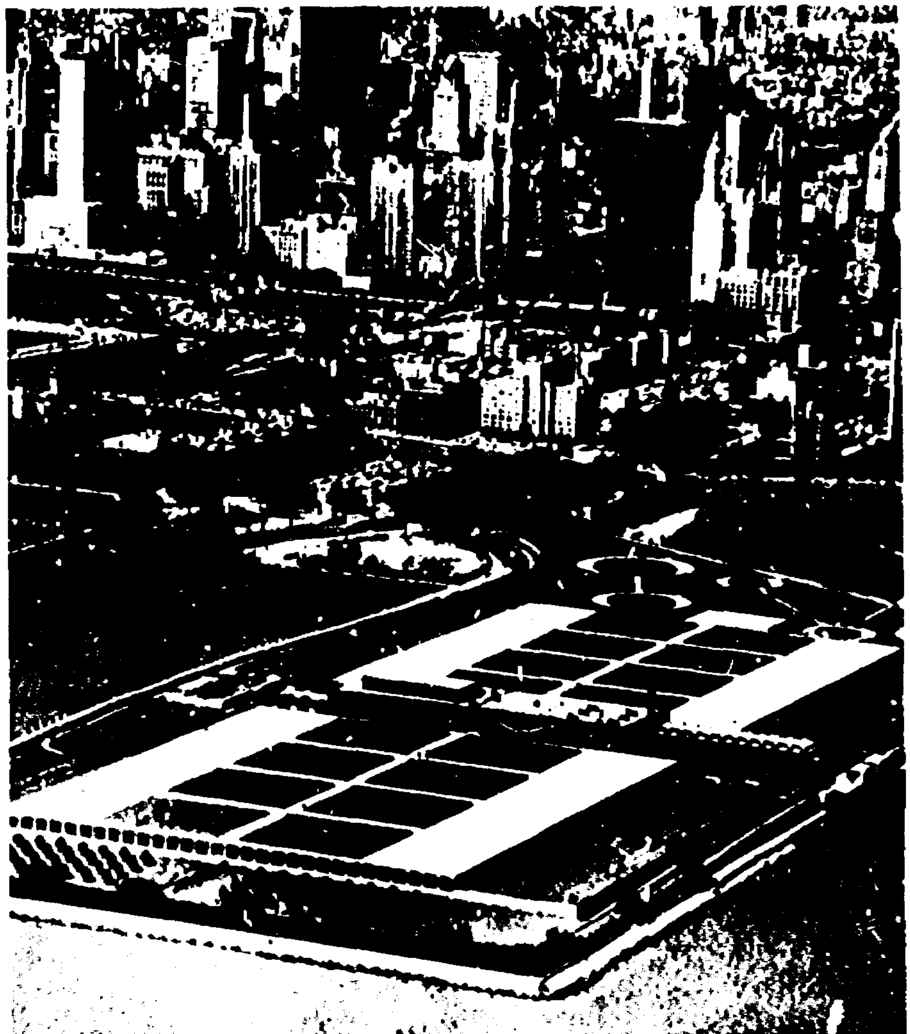
Sludge is the solid matter that settles to the bottom of sedimentation tanks and must be disposed of by digestion or other methods to complete waste treatment.

Storm Sewers are a separate system of pipes that carry only runoffs from buildings and land during a storm.

Suspended Solids are the wastes that will not sink or settle in sewage.

Trickling Filter is a bed of rocks or stones. The sewage is trickled over the bed so the bacteria can break down the organic wastes. The bacteria collect on the stones through repeated use of the filter.

Waste Treatment Plant is a series of tanks, screens, filters, and other processes by which pollutants are removed from water.



Sprawling waste treatment plant that serves part of Chicago.

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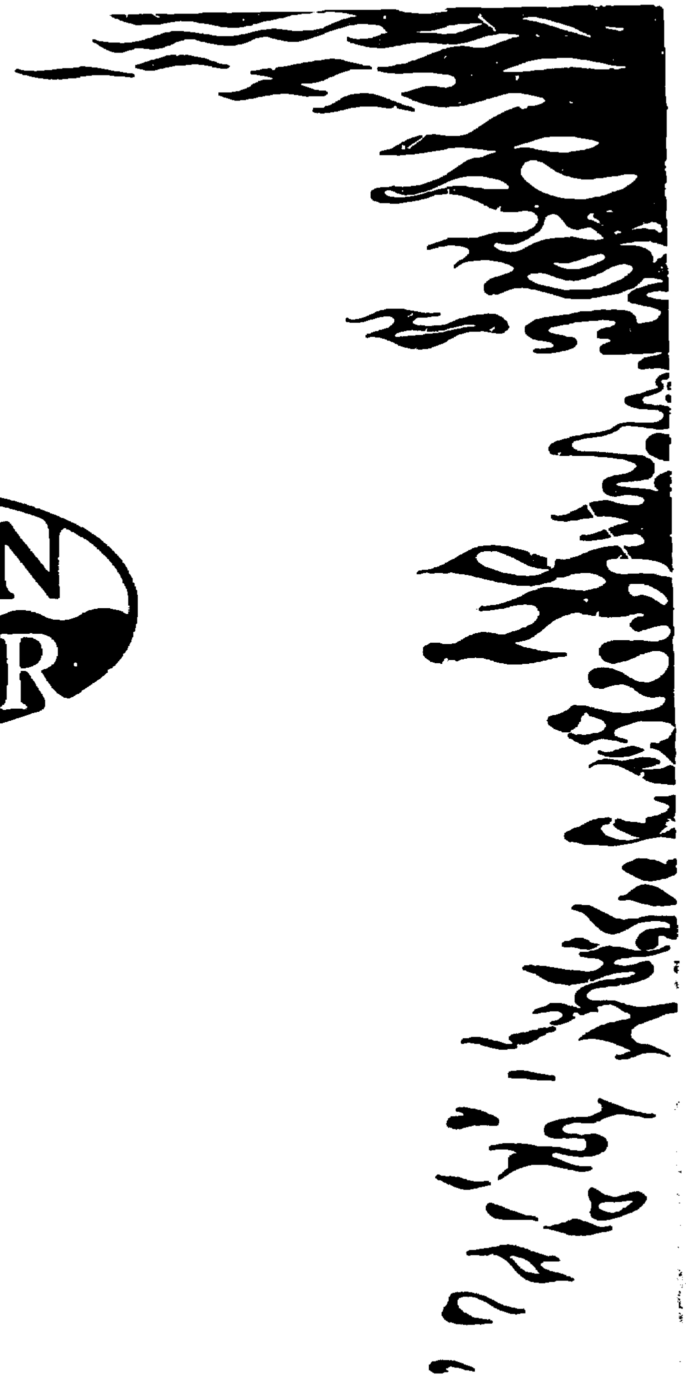

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