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ABSTRACT

This general information pamphlet is concerned with the types of wastewater treatment systems, the need for further treatment, and advanced methods of treating waste. Current methods are described, illustrated and evaluated. Pollution problems from oxygen-demanding wastes, disease-causing agents, plant nutrients, synthetic chemicals, inorganic chemicals, sediments, radioactivity and heat are discussed. Throughout, problems of water pollution control and waste disposal are presented to illustrate the need for planning, financing and building treatment facilities to meet water quality standards. A glossary of common sewage treatment terms is included. (CS)

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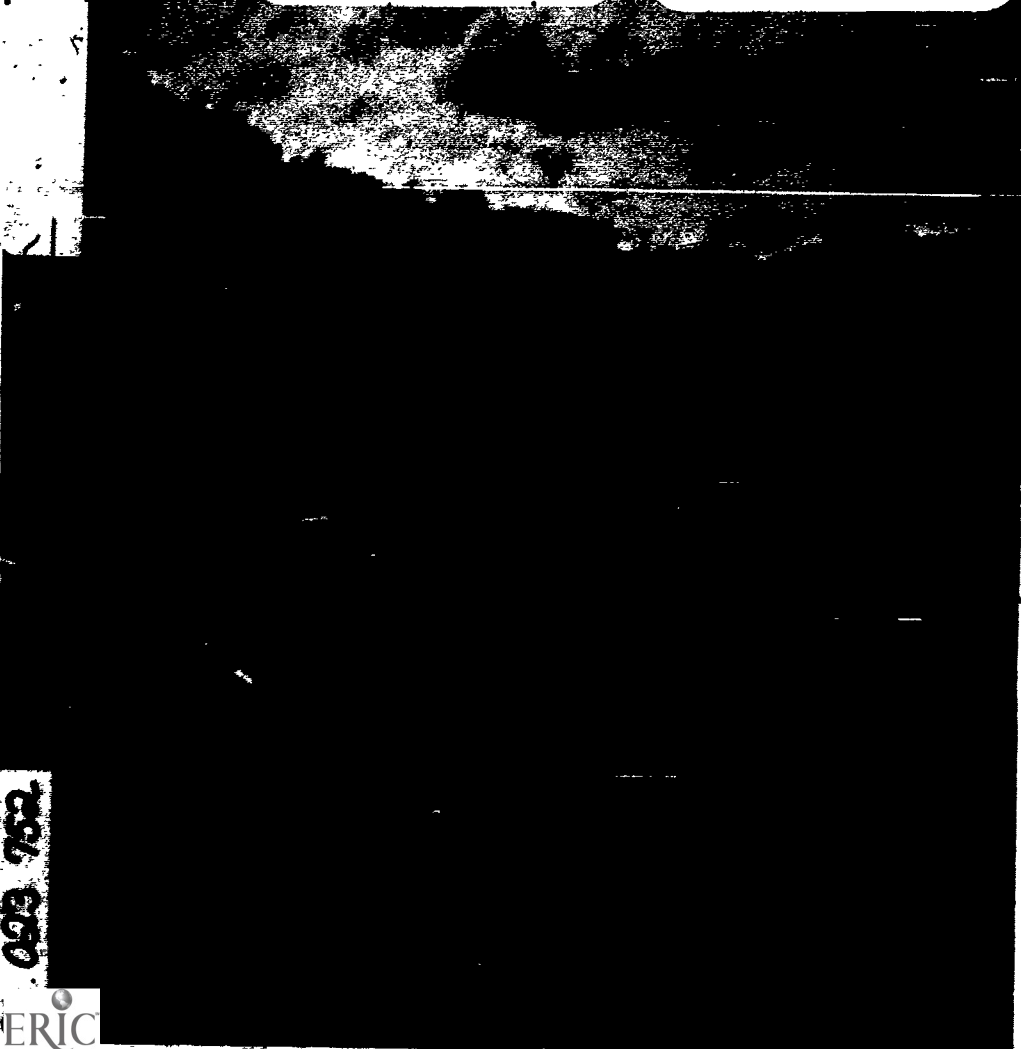
A Primer on Wastewater Treatment



A Primer on Wastewater Treatment

Contents

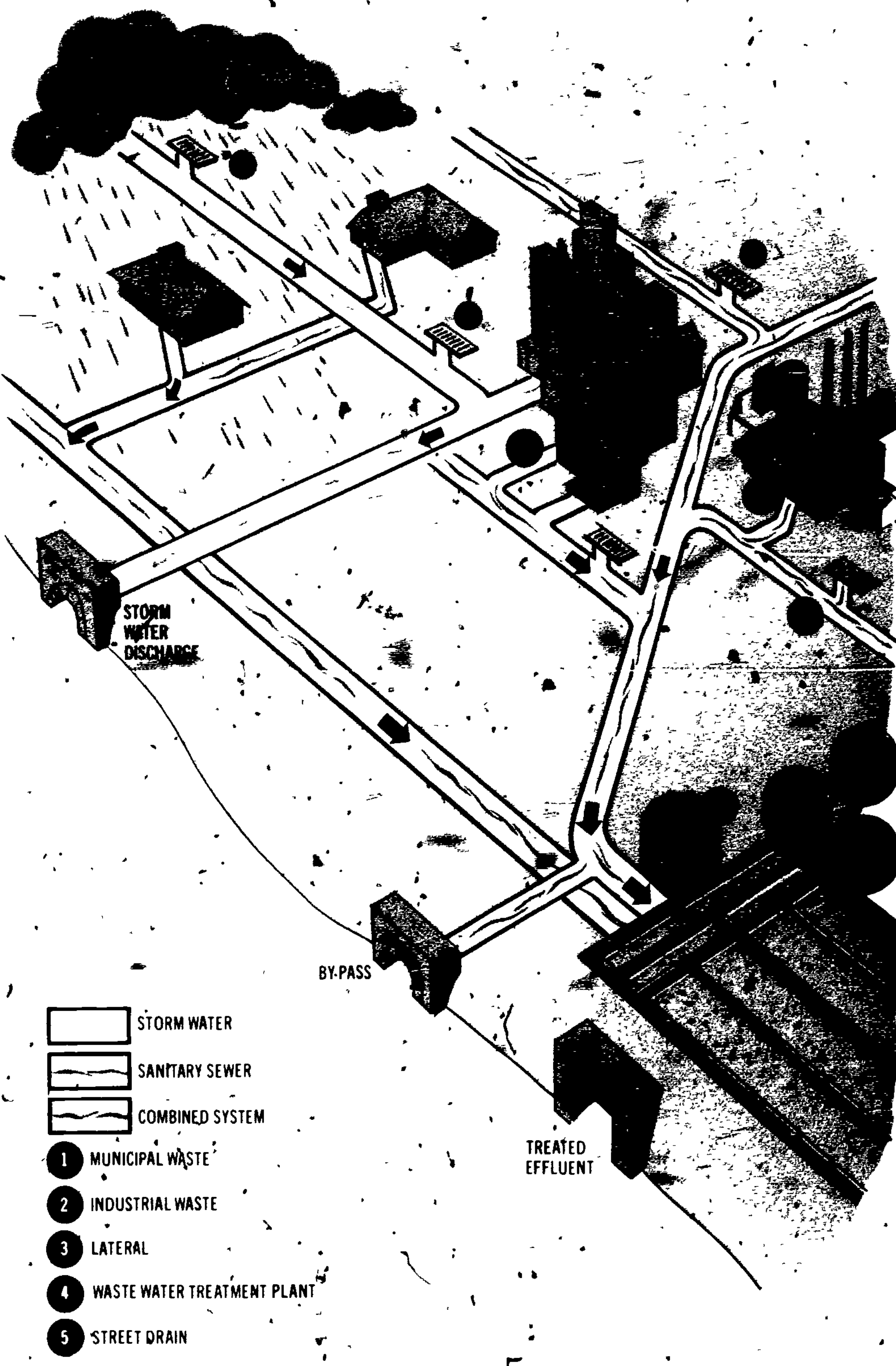
Under the 1972 amendments to the Federal Water Pollution Control Act (Public Law 92-500), thousands of municipal waste treatment plants are being constructed or expanded across the Nation to control or prevent water pollution.

The 1972 law authorizes grants totalling $18 billion to help towns and cities construct waste treatment facilities. The grants, which cover 75 percent of the cost of the facilities, were to be awarded by September, 1977.

The law also established the National Pollution Discharge Elimination System which calls for limitations on the amount and quality of effluents and requires all municipal and industrial dischargers to obtain permits. The permits include effluent clean-up dates which are enforceable by State or Federal Government. Further, the new law sets this goal: water clean enough for swimming, boating, and protection of fish, shellfish, and wildlife by 1983.

Construction of the needed municipal treatment plants won't happen overnight. From drawing board to operation takes time. But progress is being made, and more and more people are watching this progress. And they want to know more about wastewater treatment.

This primer explains the methods used now and processes being developed for the future to treat waste water discharges and to give the Nation clean water.


STORM WATER DISCHARGE
BY-PASS
TREATED EFFLUENT
STORM WATER
SANITARY SEWER
COMBINED SYSTEM
1 MUNICIPAL WASTE
2 INDUSTRIAL WASTE
3 LATERAL
4 WASTE WATER TREATMENT PLANT
5 STREET DRAIN

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 separate 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, it may be necessary to allow part of the water—including varying amounts of raw sewage—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. (Technology has been developed that will, when applied, control and treat the storm water discharges and the general runoff of rainwater polluted by dirt and other contaminants.)

Separate system . . . storm sewer outfall

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.

A waste treatment works' 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.

However, these natural processes, even though accelerated in a waste treatment plant, are not sufficient to remove other contaminants such as disease-causing germs, excessive nutrients such as phosphates and nitrates, and chemicals and trace elements.

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 depend 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; 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 absorb waste water and purify itself. Consequently, cities and industries have had to begin to remove as much as possible of the oxygen-demanding and other pollutants from their sewage.

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

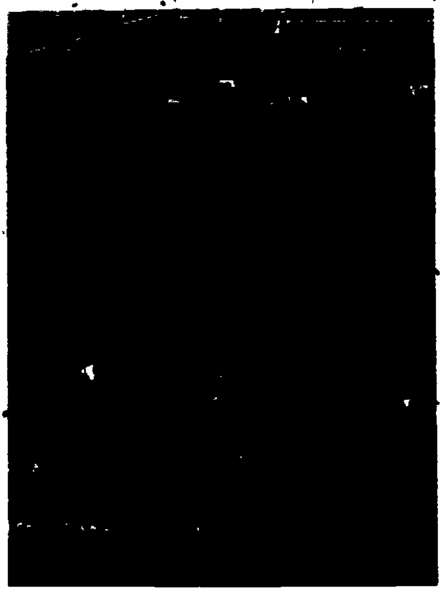
At present there are two basic stages in the treatment of wastes. They are called primary and secondary. In the primary stage of treatment, solids are allowed to settle and are removed from the water. The secondary stage uses biological processes to purify the waste water even further. In some cases, the two stages may be combined into one basic operation.

Primary Stage

As sewage enters a plant for 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.

Sedimentation tank



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 dissolved organic and inorganic matter along with suspended solids. The latter consist of 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.

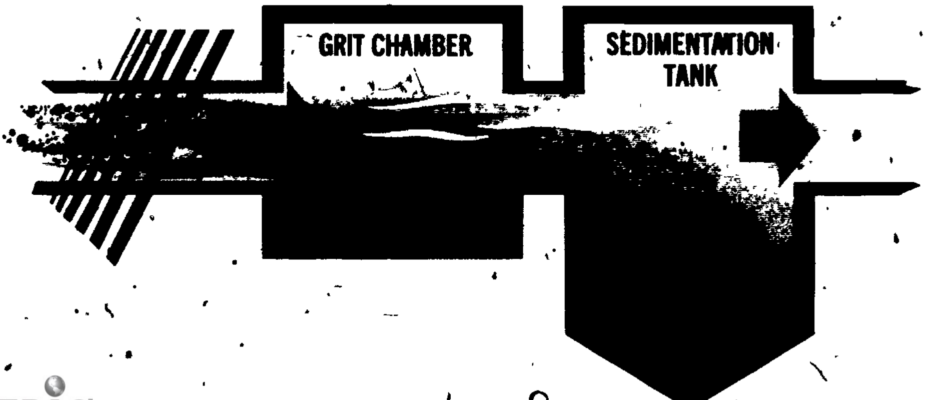
Various methods have been devised for removing sludge from the tanks.

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 from the sedimentation tank is chlorinated before being discharged into a stream or river. Chlorine gas is fed into the water to kill and reduce the number of disease-causing bacteria. Chlorination also helps to reduce objectionable odors.

Basic treatment . . . primary stage



In the past, 30 percent of the municipalities in the United States did not treat their sewage beyond the primary stage. This amount of treatment alone was inadequate to meet today's water quality requirements. To meet these requirements, cities and industries will have to remove even more contaminants at the secondary stage, and in some cases, use advanced treatment.

Secondary Stage

The secondary stage of treatment removes up to 90 percent of the organic matter in sewage by making use of the bacteria in it. The two principal techniques used in the secondary stage 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 six 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.

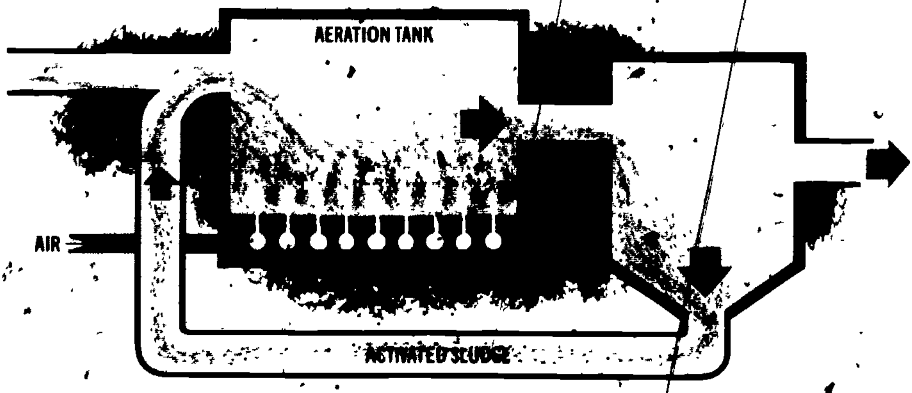
Another much-used method consists of a vertical pipe in the center of the filter connected to rotating horizontal pipes which spray the sewage continuously upon the stones.

From the trickling filter, the sewage flows to another sedimentation tank to remove the bacteria. Chlorination of the effluent completes the secondary stage of basic treatment.

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 the primary stage, 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.

The sludge, now activated with additional millions of bacteria and



Secondary stage . . . activated sludge process 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 complex industrial wastes.

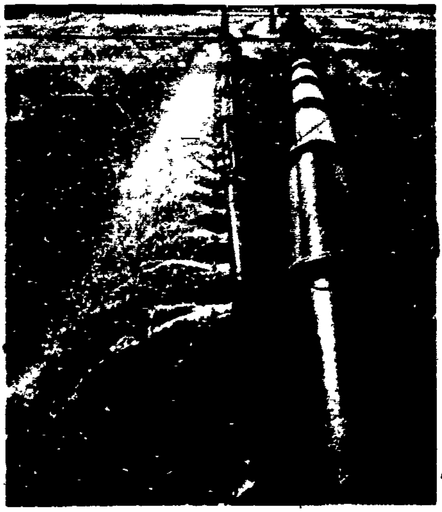
An adequate supply of oxygen is necessary for the activated sludge process to be effective. Air is mixed with sewage and biologically active sludge in the aeration tanks by three different methods.

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.

From the aeration tank, the sewage flows to another sedimentation tank to remove the bacteria.

The final step again consists of the addition of chlorine—the most



Trickling filter

Aeration tank

common method of disinfection—to the effluent coming from the trickling filter or 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 water course. If done properly, chlorination will kill more than 99 percent of the harmful bacteria in an effluent.

Lagoons

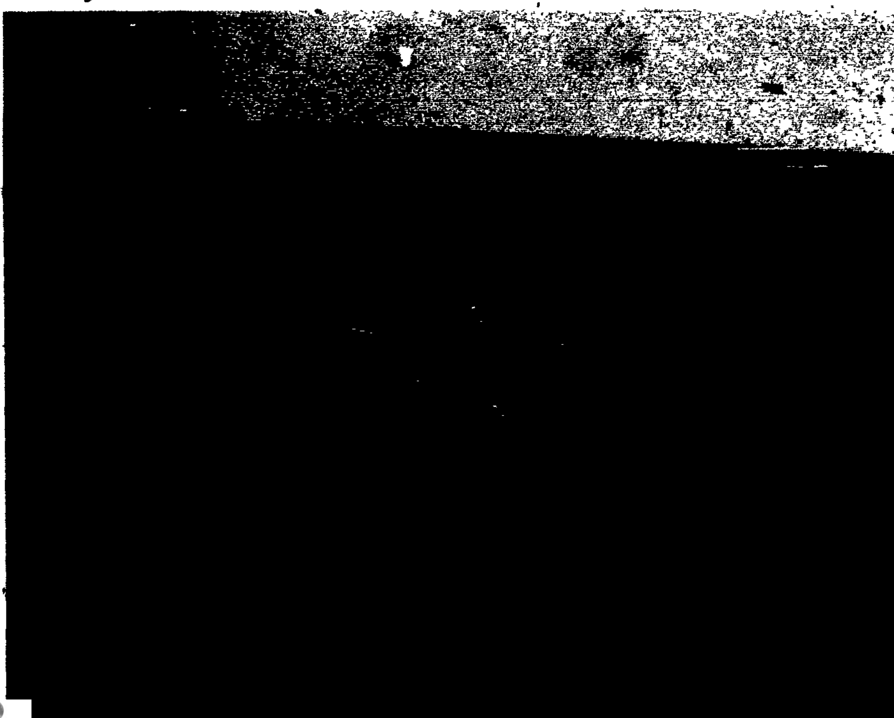
Lagoons, or as they are sometimes called, stabilization or oxidation ponds also have several advantages when used correctly.

They can be used to treat sewage to the secondary stage of 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 that is often equal to effluent from the secondary treatment stage. Changes in the weather may change the effectiveness of lagoons.

When used with other basic waste treatment processes, lagoons can be very effective. A good example of this is the Santee, California, water reclamation project. After conventional basic 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.

Sewage treatment lagoons



Septic Tanks

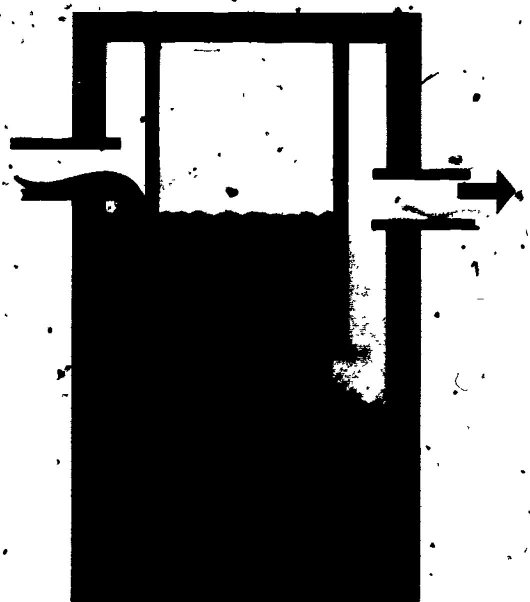
A septic tank is simply a tank buried in the ground to treat the sewage from an individual home. Waste water from the home flows into the tank where bacteria in the sewage may break down the organic matter and the cleaner water flows out of the tank into the ground through sub-surface drains. Periodically, 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 may be a reasonable and temporary means of disposing of strictly domestic wastes. Septic tanks should always be located so that none of the effluent can seep into sources used for drinking.

Operation and Maintenance

Wastewater treatment plants can clean the Nation's waters and prevent pollution. But to accomplish this purpose, they must be maintained and operated efficiently.

EPA studies have shown that many wastewater treatment plants are not meeting water quality requirements. The most common reason for this failure is poor operation and maintenance. A sufficient number of well-trained operators and maintenance people and a well-equipped water-testing laboratory will assure an efficient operation and a satisfactory reduction of pollutants.



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 sometimes not matched either the growth rate or changes in growth patterns. 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 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; sediments; radioactive substances; and heat.

Oxygen-demanding wastes—These are the traditional organic wastes and ammonia contributed by domestic sewage and industrial wastes of plant and animal orgin. 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.

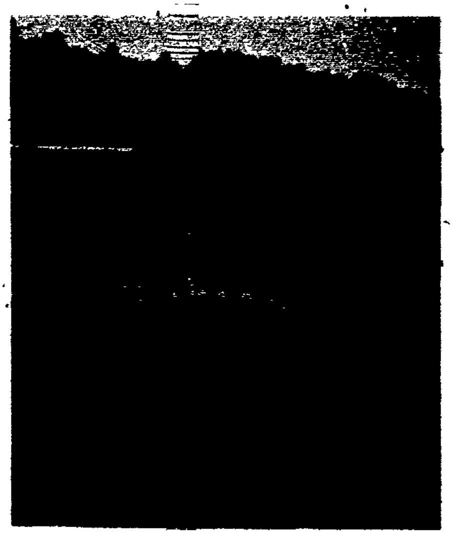
Disease-causing agents—This category includes infectious organisms which are carried into surface and ground water by sewage from cities and institutions, and by certain kinds of industrial wastes, such as tanning and meat packing plants. Man or animals come in contact with these microbes either by drinking 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

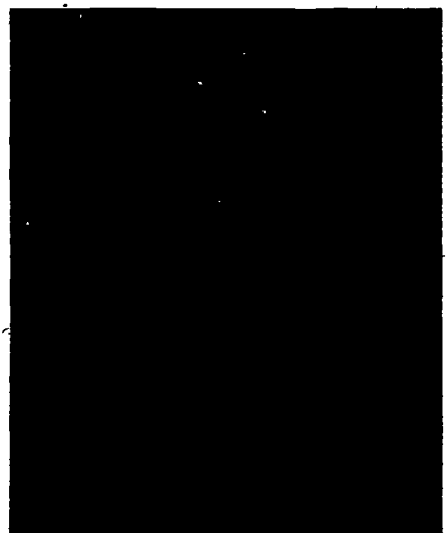
Industrial wastes

Domestic sewage

Algae



Chemicals



drainage

Sediment

life, such as algae and water weeds, which support and stimulate their growth. Carbon, nitrogen and phosphorus are the three chief nutrients present in natural water. Large amounts of these nutrients are produced by sewage, certain industrial wastes, and drainage from fertilized lands. Biological waste treatment processes do not remove the phosphorus and nitrogen to any substantial extent—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.

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.

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.

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. Unchecked waste heat discharges can seriously alter the ecology of a lake, a stream, or even part of the sea.

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.

Thermal pollution

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 still do not treat their sewage beyond the primary treatment stage. Many other cities need enlarged or modernized systems to treat waste water at the secondary stage. But this only a temporary solution. The discharge of oxygen consuming wastes will increase despite the nationwide addition of the secondary stage of wastewater treatment. 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 at 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."

Advanced wastewater treatment plant

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.

Land Application

Land application is one method of advanced wastewater treatment that can remove pollutants not removed in basic treatment, and in some cases, reuse or renovate the waste water.

Municipal waste water has been used to irrigate crops around the country, but primarily in the arid western states. Land application of industrial waste water has also been tried but mainly in a few eastern states. In land application three techniques are used: crop irrigation, rapid infiltration, overland flow, or a combination of the three.

Irrigation

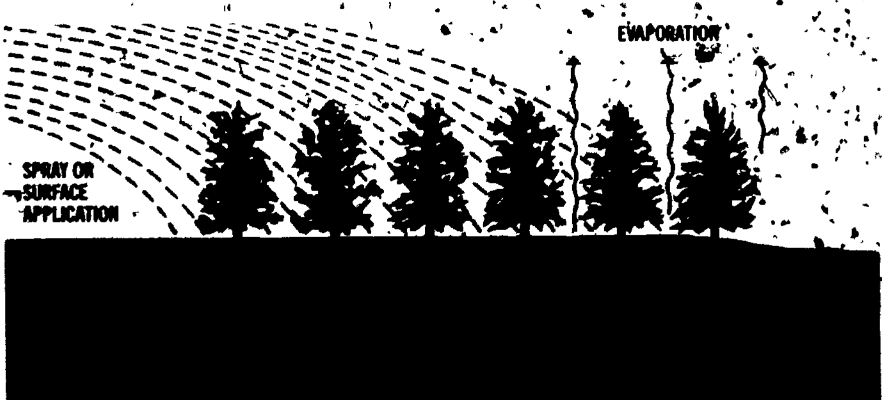
In the case of crop irrigation (or slow rate infiltration) the wastewater penetrates into the ground where the natural filtering and straining action of the soil removes most of the pollutants. The water eventually percolates to the groundwater, evaporates, or is absorbed by plants.

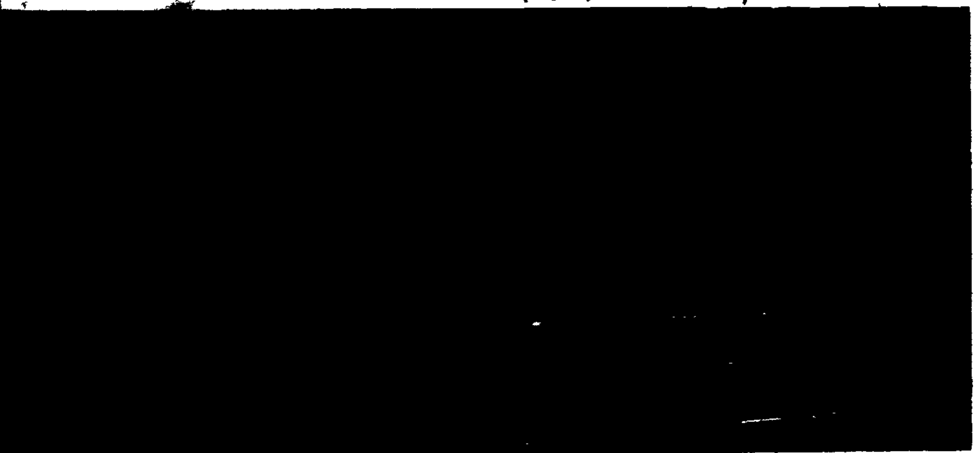
Crop irrigation is one land application method that reuses the water, and the minerals and nutrients in it. It is the most commonly used land application technique. The waste water is sometimes disinfected before being used for crop irrigation, depending on the end use of the crop. The waste water is applied to the land by spraying, flooding, or ridge and furrow irrigation, to supply water and nutrients to the crops. The irrigation method selected depends on cost considerations, terrain, and the crops grown. Much of the water and most of the nitrogen are absorbed by the plants. The remaining water evaporates or percolates to the groundwater. Phosphorous and trace elements are removed to the soil by adsorption.

Rapid Infiltration

Unlike slow rate systems, the rapid infiltration process is used mainly to treat and recover waste water for reuse. Since the rapid infiltration process is the simplest land application technique, and is effective in cold or wet weather, it has been used frequently in the northeastern states.

Large amounts of waste water are applied to a limited land area and allowed to infiltrate the ground's surface and percolate through the soil below. If the water is to be reused, it





Flood irrigation

Spray irrigation

can be recovered by drilling wells to draw it to the surface. Normally, however, the water will seep downward to the goundwater. Because this process depends on the soil's ability to absorb a large amount of water quickly and efficiently, good soil drainage is important. Impervious soils may be better suited to the overland flow process.

Overland Flow

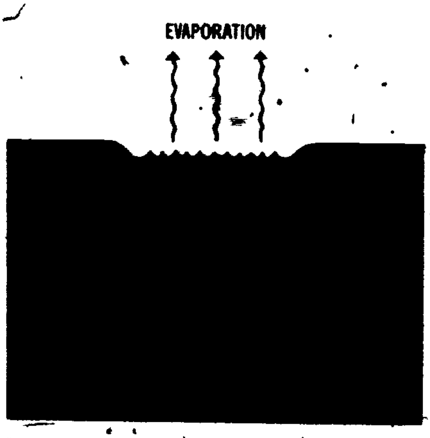
This method has been used successfully in the food processing industries to remove bacteria and nutrients from waste water. And it has been used to a limited extent in treating municipal waste water for many years.

The waste water is allowed to flow down a sloped surface that is planted with vegetation to control runoff and erosion. As the water runs down the slope, the soil and its micro-organisms remove the bacteria and nutrients. Most of the water is recovered at the bottom of the slope for reuse. The remainder evaporates. This process is well suited to clay or clay-type soils with little or no absorption capacity.

Ridge and furrow irrigation

Whatever method is used, land application may be an economic alternative to more costly advanced treatment plants. Further study is underway to evaluate the costs more accurately. Research is also being conducted to determine what levels of nutrients and trace elements can be allowed to build up in the soil without harming agricultural plants, or posing health hazards where the crops may enter the human food chain.

Overland flow



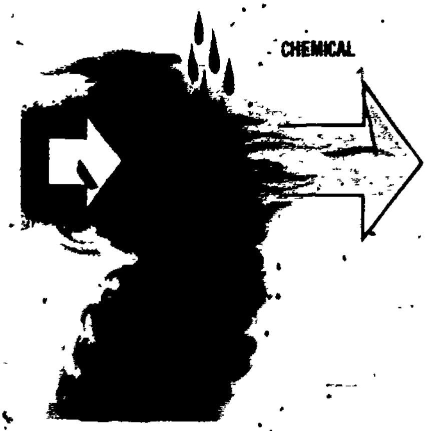
Rapid infiltration

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.

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 95 percent.

In this process, alum, lime, or iron salts are added to effluent as it comes from the secondary treatment. The flow then passes through flocculation



Coagulation-Sedimentation

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.

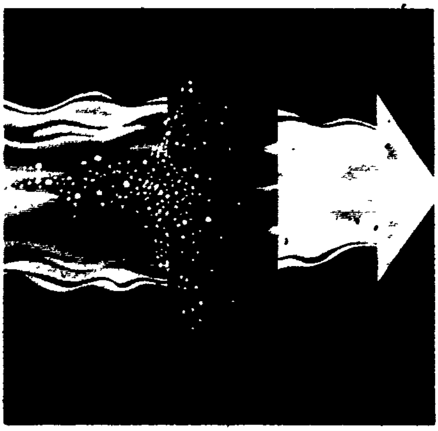
Although used for years in the treatment of industrial wastes and in water treatment, coagulation-sedimentation is classified as an advanced process because it is not usually applied to the treatment of municipal wastes. In many cases, the process is a necessary pre-treatment for some of the other advanced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

Adsorption

Technology has also been developed to effect the removal of refractory organic materials. These materials are the stubborn organic matter which persists in water and resists normal biological treatment.

The effects of the organics are not completely 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.



Adsorption

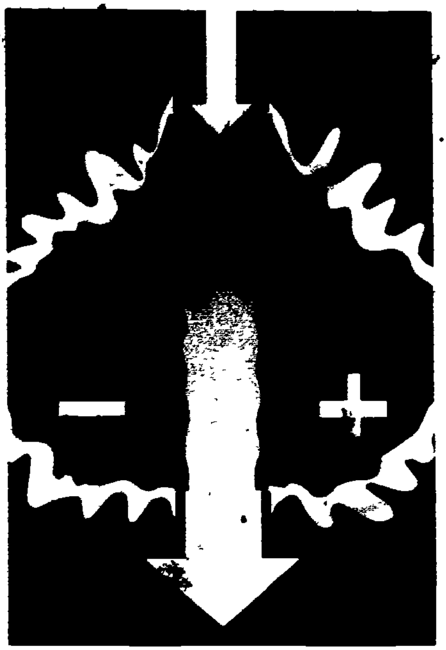
Except for the salts added during the use of water, municipal waste water that has gone through the previous advanced processes will be restored to a chemical quality almost the same as before it was used.

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.

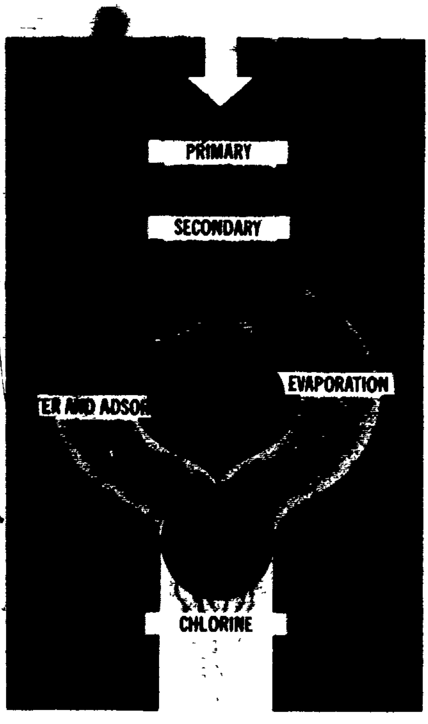
Electrodialysis

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 a city uses its water, the amount of salts in the water increases by 300-400 milligrams per liter. Fortunately, electrodialysis can remove this buildup of salts.



Electrodialysis



Blending water

In other words, this process returns the salt content of the water 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 stage of 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.

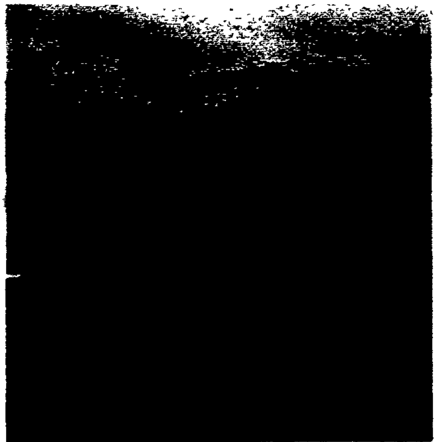
Basically the same result can be achieved by separating the effluent into two streams. In this instance, all of the waste receives the basic treatment and then passes through the coagulation-sedimentation and adsorption processes which remove the organic matter. Half of the sewage is then treated by evaporation and adsorption to remove all impurities including the minerals. This effluent, when blended with the other half, can provide water with the desired level of minerals. After chlorination, the water can be reused for industrial purposes.

Almost any degree of water quality can be achieved by varying the flow of the two streams. This technique reduces the treatment cost, since only a fraction of the flow requires treatment with the more expensive unit processes, 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. Most of the unwanted polluting impurities remain in the original chamber. However, some volatile substances may distill along with the water and carry along foreign materials that contribute objectionable taste.

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.

Denitrification plants can remove excess nitrogen in advanced treatment



Wastewater filtration unit in the coagulation-sedimentation process

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

verse osmosis

Chemical Oxidation

Municipal waste waters contain many organic materials only partially removed by the conventional treatment methods. 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 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 water reaching treatment plants. Until recently, the cost of the oxidants has prevented the use of this process in the treating of wastes. 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 chemicals 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 step. Sludge must be dewatered 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 Use or Disposal of Wastewater Treatment Residues

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 reused, burned, buried, or disposed of in some manner.

The management of these wastewater treatment residuals is a twofold problem. The sludge or other matter must be disposed of to complete a city's or industry's waste treatment efforts. And it must be done in a manner not to 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 over-burdened air to cope with. And air pollutants by the action of rain and wind have a habit of returning to the water, further complicating the waste treatment problem.

The requirements of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) emphasize the need to employ environmentally sound sludge management techniques. At the same time, the national requirements for improved wastewater treatment will result in the production of a greater quantity of residuals. And possibly more concentrated forms of contaminants will be present in these residuals than ever before. As much as 40 percent of the construction grant funds for individual treatment plants provided under PL 92-500 may be required to build adequate sludge management facilities. In addition, the permits required for effluent discharge from sewage treatment plants can in some cases be affected by the sludge management techniques employed by the facilities.

There are many methods and processes for dealing with the "ultimate disposal" of wastewater treatment residuals. In general, the various techniques involve either direct resource recovery from or beneficial uses of the residuals.

One of the most common disposal methods consists of digestion followed by filtration and incineration. The

Sludge drying beds

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.

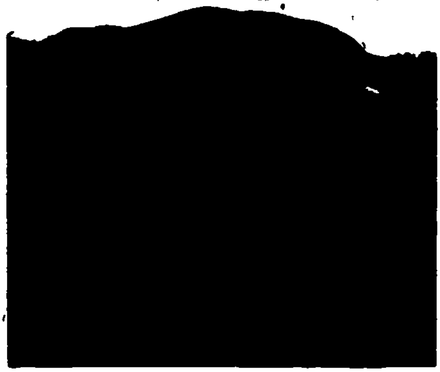
Water can be removed from sludge by use of a rotating filter drum and suction. As the drum rotates, the water is filtered out of the sludge and the residues are peeled off for disposal. For more effective dewatering, the sludge can be first treated with a coagulant chemical such as lime or ferric chloride 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.

Incineration consists of burning the dried sludge to reduce the residues to a non-burnable ash. The ash can be disposed of by filling unused land. Since most of the pollutants have been removed by the burning, the ash should cause very little nuisance.

In 1974, 5,676,000 tons of sewage sludge were disposed in the oceans. The Marine Protection, Research, and Sanctuaries Act of 1972 authorized EPA to regulate this kind of ocean disposal. Accordingly, EPA implemented a permit program in late 1973 to limit the amounts and kinds of wastes that can be dumped at sea.

A very promising new approach to sludge management gets rid of the unwanted sludge and helps restore ravaged countrysides, where 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 areas of some



Municipal sludge may be composted for use as a soil enricher

Rotating drum filter

Treated sludge may be used as fertilizer for some agricultural crops

States. It would take nature many years to repair the damage.

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

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

Sludge or other waste concentrates are not always costly burdens. By drying and other processes, some cities have produced fertilizers from sludge which are sold to help pay part of the cost of treating wastes. 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 processes and reuse them. Other firms have developed saleable by-products from residues of waste treatment.

More studies are underway to find other beneficial uses for sludge and to help solve the problem of what to do with increasing volumes of wastewater treatment residuals—and to help offset the cost of waste treatment.

Common Waste Treatment Terminology

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

Adsorption is an advanced way of treating wastes in which activated carbon removes organic matter from waste water.

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 small living organisms which often consume the organic constituents of sewage.

BOD, or biochemical oxygen demand, is the dissolved oxygen required by organisms for the aerobic decomposition of organic matter present in water. It is used as a measure in determining the efficiency of a sewage treatment plant or to determine the potential of an effluent to degrade a stream.

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 and iron salts.

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 ...les in the side of the pipe.

Digestion of sludge takes place in tanks when the materials decompose, resulting in partial gasification, liquefaction, and mineralization of pollutants.

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.

Eutrophication: The normally slow aging process by which a lake evolves into a bog or marsh and ultimately assumes a completely terrestrial state and disappears. During eutrophication the lake becomes so rich in nutritive compounds, especially nitrogen and phosphorus, that algae and other microscopic plant life become super-abundant, thereby "choking" the lake, and causing it eventually to dry up. Eutrophication may be accelerated by many human activities.

Floc is a clump of solids formed in sewage by biological or chemical action.

Flocculation is the process by which clumps of solids in sewage are made to increase in size by chemical, physical, or biological action.

Fungi are small, non-chlorophyll-bearing plants which may play a useful role in trickling filter treatment operations.

Groundwater is the body of water beneath the surface of the ground. It is made up primarily of the water that has seeped down from the surface.

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

Infiltration is the penetration of water through the ground's surface into sub-surface soil.

Infiltration/Percolation is a land application technique where large volumes of waste water are applied to land, allowed to penetrate the surface and percolate through the underlying soil.

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.

Irrigation is a land application technique where waste water is applied to the land to supply the water and nutrient needs of plants.

Land Application – the discharge of waste water onto the ground for treatment or reuse.

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

Mechanical Aeration uses mechanical energy to inject air into water, causing the waste stream to absorb oxygen from the atmosphere.

Microbes are minute plant or animal life. Some microbes which may cause disease exist in sewage.

Mixed Liquor is a mixture of activated sludge and waters containing organic matter undergoing activated sludge treatment in the aeration tank.

Nitrogenous wastes: Wastes of animal or plant origin that contain a significant concentration of nitrogen.

Nutrients: Elements or compounds essential as raw materials for organism growth and development, for example, carbon, oxygen, nitrogen and phosphorus.

Organic Matter is the carbonaceous waste contained in plant or animal matter and originating from domestic or industrial sources

Overland Flow is a land application technique that cleanses waste water by allowing it to flow over a sloped surface. As the water flows over the surface, the contaminants are removed and the water is collected at the bottom of the slope for reuse

Oxidation is the addition of oxygen which breaks down organic wastes or chemicals in sewage by bacterial and chemical means.

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

Percolation is the movement of water through sub-surface soil layers, usually continuing downward to the groundwater

Phosphorus: An element that while essential to life, contributes to the eutrophication of lakes and other bodies of water

Pollution results when animal, vegetable, mineral or heat wastes or discharges reach water, making it less desirable for domestic, recreation, industry, or wildlife uses

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

Primary treatment is the stage in basic treatment that 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

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 Filters remove some suspended solids from sewage Air and bacteria decompose additional wastes filtering through the sand Cleaner water drains from 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 the top as scum The scum is skimmed off the top, and solids on the bottom are pumped to incineration, digestion, filtration or other means of final disposal.

Septic Tanks are used for domestic wastes when a sewer line is not available to carry them to a treatment plant. The wastes are piped to underground tanks directly from the home or homes The bacteria in the wastes decompose 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, floats, or becomes suspended in the sedimentation tanks and must be disposed of by filtration and incineration or by transport to appropriate disposal sites

Sterilization is the destruction of all living organisms. In contrast, disinfection is the destruction of most of the living organisms

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

Suspended Solids are the small particles of solid pollutants which are present in sewage and which resist separation from the water by conventional means

Trickling Filter is a support media for bacterial growth, usually 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.

Virus is the smallest form of microorganism capable of causing disease.

Expansion of Blue Plains waste treatment plant