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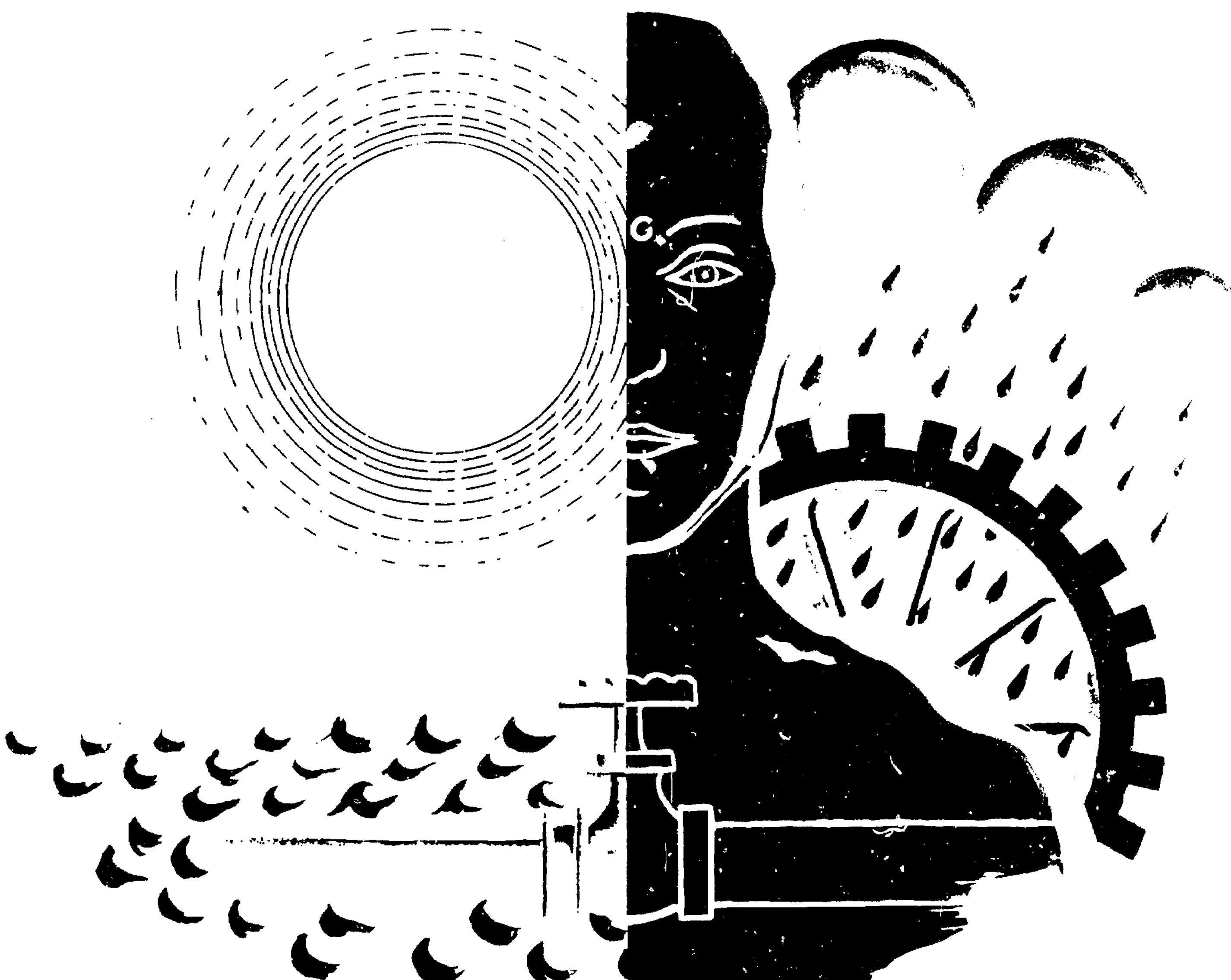
ABSTRACT

This commentary on sources of water pollution and water pollution treatment systems is accompanied by graphic illustrations. Sources of pollution such as lake bottom vegetation, synthetic organic pollutants, heat pollution, radioactive substance pollution, and human and industrial waste products are discussed. Several types of water purification treatments are presented with cut-away diagrams of the facilities and technical procedures. (JP)

water pollution

CAUSES & CURES



MANUFACTURING
CHEMISTS
ASSOCIATION

1825 CONNECTICUT AVENUE, N W WASHINGTON, D C 20009

Founded in 1872, the Manufacturing Chemists Association is the oldest chemical trade organization in the Western Hemisphere. Its member companies represent more than 90 percent of the production capacity of basic industrial chemicals within the United States and Canada.

Water Pollution —causes & cures

If man were still few in numbers and nomadic, he could move on once his habitat became defiled.

If man were still primitive, he would not need modern shelter, clothing, food, medicine, communication and transportation.

If the human body was environmentally perfect, it would not discharge wastes.

If the human body did not have certain needs or desire certain comforts and conveniences, manufacturing processes which give rise to potential pollutants would not exist.

In fact, if nature were ecologically perfect, pollutants would not be washed from the soil or leached from the subsoil.

The combination of these imperfections, however, make water a chemically complex commodity whose true identity is unknown to most laymen.

At home and at work, we flush a variety of materials down the drain; in recreation, we may toss them into streams or lakes, thoughtless as to how they insult our common, priceless resource—water.

Yet we are quick to complain when water is not usable for a particular purpose. We may even bridle at the rising cost of water and oppose expenditures essential to waste water conservation and treatment.

The purpose of this booklet is to explain the complexity of water pollution problems and to encourage their amelioration and prevention.

William J. Driver

William J. Driver
President
Manufacturing Chemists Association

Definition

Many people define a water pollutant as *anything put into water which was not there in its natural* state.

However, water's *natural state* varies with locale. So, they must mean pure water. In other words, 100 percent distilled water, which is fine for automobile batteries, steam irons and the like. But, what does it taste like? Peanuts' Lucy would have a word for it, "Bleah!"

Even delicious-tasting spring water is not pure in this sense. It has just the right combination of minerals—chemical impurities—put there by nature, to titillate our taste buds. Yet these same minerals, in sufficient amount, could eventually clog a steam iron or shorten the life of a car battery.

On the other hand, the right amount of chlorine added to swimming pool water purifies it by keeping it germ-free. Spray it on grass, however, and it may turn brown.

Or, consider plant nutrients, such as nitrogen and phosphorous. A farmer would welcome some in irrigation water. But, in ponds or lakes, too much nutrient may stimulate algal growth and use up the water's dissolved oxygen. If algae multiply to excess, other aquatic life—fish, plants and the like—cannot survive.

Therefore, any definition of water pollution must begin with, "It all depends . . ." Any substance can be a pollutant if too much of it is present and how much is *too much* depends on the water use which is involved.

Conversely, the presence or addition of some chemical substances in the right amount may be beneficial or, at least, not harmful to particular water uses. Under such circumstances they are not polluting.

cause

There are eight general categories of water pollutants:

Organic . . .

. . . or oxygen-demanding wastes. They come from human, animal and plant life; from food processing and certain other manufacturing procedures.

Nature breaks down such wastes in a manner very much like digestion of food in the human stomach. The metabolism of food in the human body requires oxygen, supplied through the lungs and blood stream.

In like manner, acquatic life requires a certain amount of organic "food" and oxygen. This "digestive" process is called biological degradation and the measure of oxygen required to sustain it is called Biochemical Oxygen Demand.

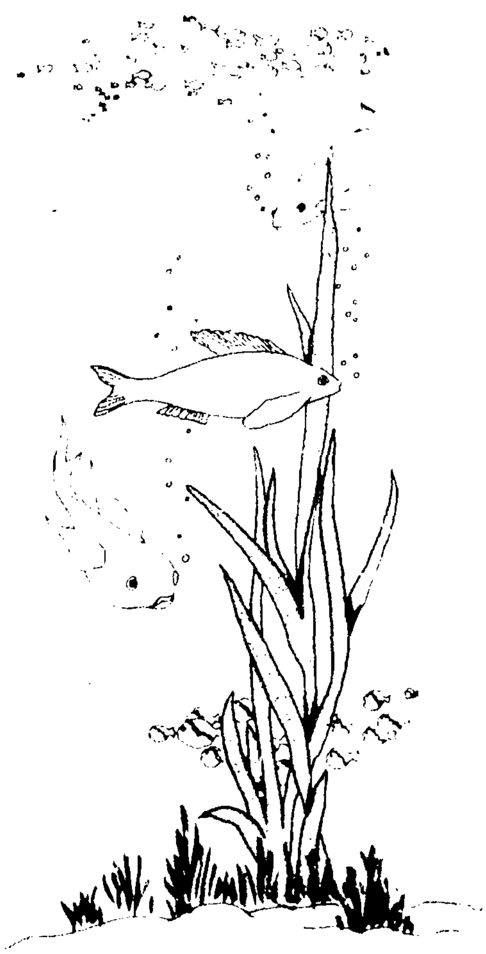
In a sense, water breathes to obtain oxygen just as we do and the amount of oxygen present in water is that which is dissolved in it. If we exert ourselves, we breathe harder to get more oxygen. If water is aerated—stirred up—it, too, tends to absorb all the oxygen it can hold.

Since fish and other aquatic life depend on both organic food and oxygen to survive, the amount of oxygen-demanding wastes and their rate of discharge into a given body of water must be controlled.

Disease-causing wastes . . .

. . . which also come from humans, animals and from some manufacturing processes—especially meat packing and tanning operations.

Although modern disinfectants minimize the danger from such pollutants, they must be carefully controlled and constantly watched. Some disease-causing microbes develop resistance to disinfection and new formulas must be created.



Plant nutrients . . .

. . . such as nitrogen and phosphorus compounds, which are essential to plant growth. Small amounts are present in natural waters. Large amounts are contributed by sewage, certain industrial wastes and land drainage. Biological degradation utilizes these substances in mineral form as fertilizers—the way nature intended it.

Pollution problems develop when excessive amounts get into water, especially lakes or ponds where the water has little flow, since algal and water plant growth may be over-stimulated.

Toxic substances . . .

. . . in the form of synthetic organic compounds such as solvents, cleaning agents and bug killers, and inorganic substances such as mineral salts and acids. Some of these cause taste or odor problems. Others are toxic even in low concentrations.

Persistent substances . . .

. . . which are not normally biodegradable. Certain organic compounds are in this category; and inorganic materials are not subject to biological breakdown, anyway. They get into water from natural sources due to rainfall run-off, seepage, and, to a considerable degree, from agricultural practices and various industrial operations.

Sediments . . .

. . . which are particles of soil, sand and minerals conveyed in water as silt from land run-off and high-

way and building construction.

These can be a major problem because of their magnitude. They settle to the bottom of rivers and harbors, requiring expensive dredging; get into reservoirs, reducing their capacities and useful life; erode power turbines and equipment and reduce fish and shellfish populations by covering their sources of food. If organic, they may decompose and exert additional oxygen demand.

Radioactive substances . . .

. . . which result from mining and processing radioactive ores and the use of refined radioactive materials for industrial, medical and research purposes. They also result from fallout following nuclear weapons testing in the atmosphere.

Heat . . .

. . . which speeds up the rate of biological degradation. Power and manufacturing plants using water for cooling purposes must, in some instances, cool the cooling water before releasing it.

Summer temperatures also contribute to thermal pollution problems. Warm water holds less oxygen and absorbs less from the air, disturbing the oxygen and biological balance.

PROBLEM

Population and industrial expansion during the last 50 years has vastly increased the volume of potential water pollutants so that, in some instances, nature's self-cleansing capabilities are overwhelmed. Where this is so, the problem is man-made and demands man-made solutions.

control

Sewers collect the wastewater from homes, buildings and many industries and deliver it to treatment plants which are supposed to make it fit for discharge into rivers or streams or for reuse. Some of these systems are efficient, others are not. Many are inadequate for today's pollution control requirements. This is not due to a lack of knowledge. Technically, most water pollution can be controlled. The deterrent has been planning, financing, building and operating facilities to meet rapidly-increasing needs.

There are two kinds of sewer systems—combined and separate.

Combined sewers carry water polluted by human wastes and storm water that drains off buildings, streets and land.

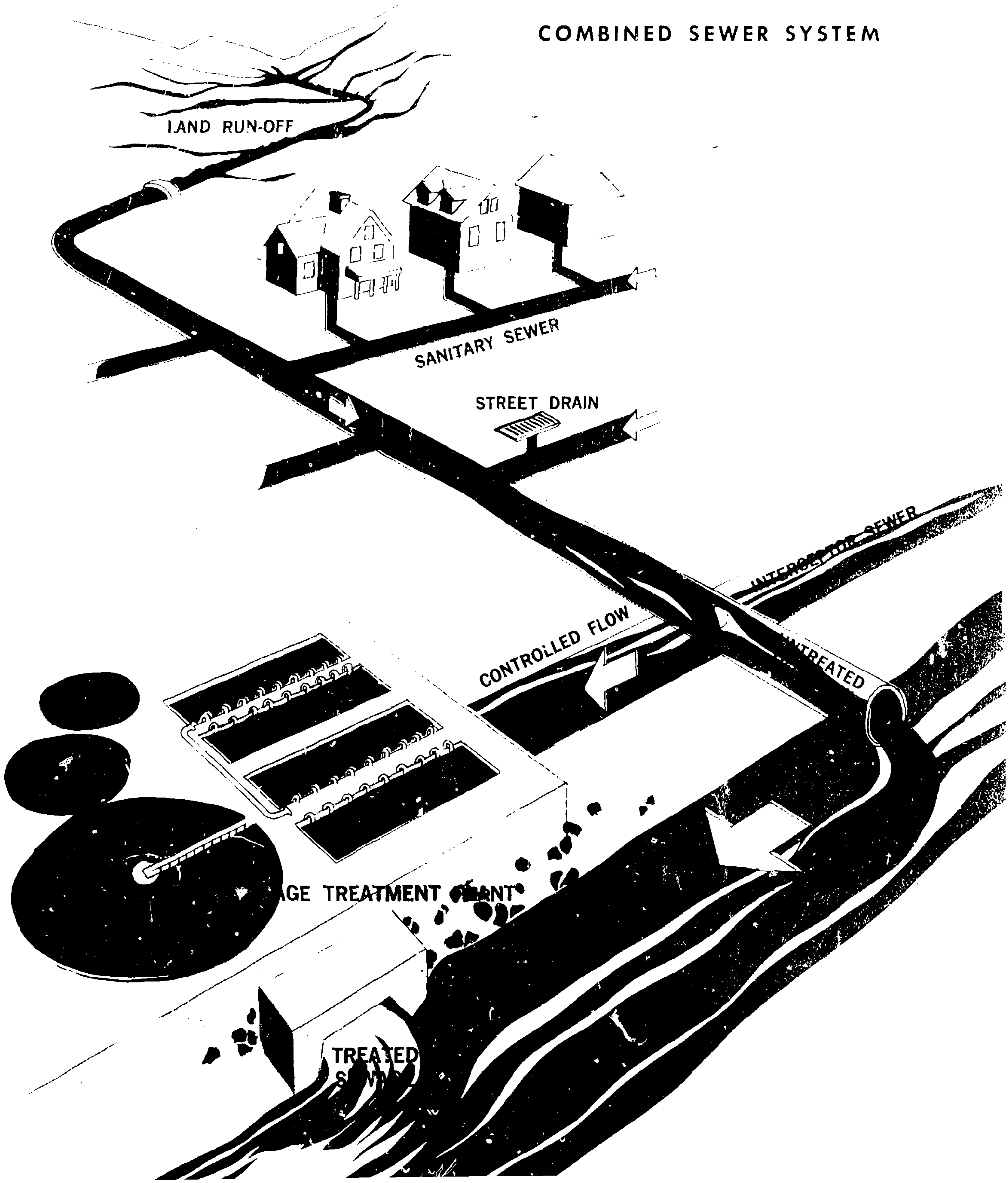
Separated sewers divide up those two sources. One—called a *sanitary sewer*—carries only the water polluted by human waste. The other—called a *storm sewer*—takes care of rainfall, melting snow and street washing.

Except in rural areas where there is no sewerage system, or in others where septic tanks are used, every home and building has a pipe which carries wastewater and sewage to a larger sewer beneath a nearby street. These are connected to trunk or main sewers. In a combined system, these flow into a still larger sewer called an interceptor which is designed to carry several times the normal dry-weather flow.

During dry periods, all the sewage goes from the interceptor to a waste treatment plant. However, during a storm, part of the water—including varying amounts of raw sewage—may bypass the plant and go directly into receiving streams. Only the amount the plant is equipped to handle is treated—obviously not an ideal situation. Much research is under way on methods of solving the problem of combined sewers.

In separate sewer systems, storm water carries sediment, oil, grease and other pollutants from lawns, sidewalks, driveways, streets, roofs and construction sites. As a result, urban storm water is becoming more recognized as a cause of water pollution.

COMBINED SEWER SYSTEM



cure

Sanitary wastes, and residual wastes from industrial operations remaining after other means are used to restrict and control them, may be treated to minimize adverse effects on water and the aquatic environment.

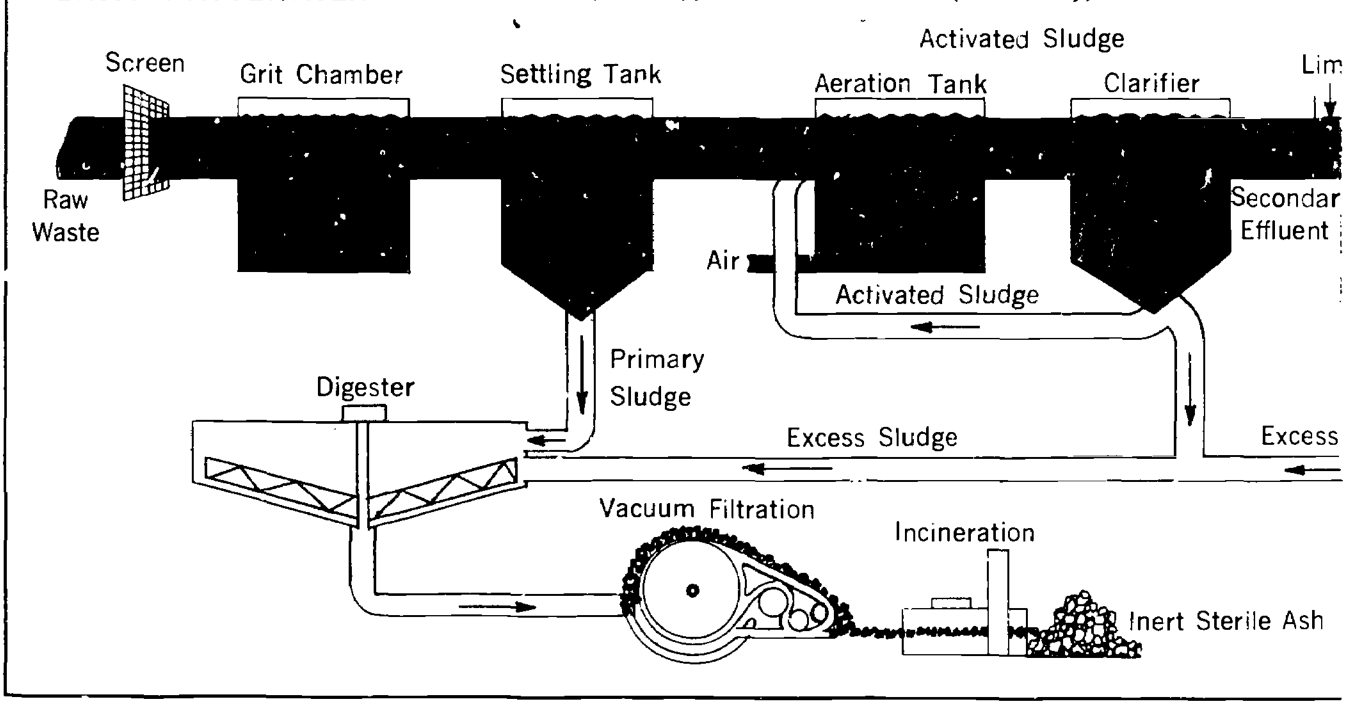
Primary—namely, first stage—treatment is a physical separation process to remove undissolved solid materials.

As the sewage enters the treatment plant, it may flow through screens to remove rags, sticks and other floating objects. The screens vary from coarse to fine and are usually slanted in a receptacle so that the debris can be scraped off and disposed of, generally as land fill.

Some plants grind these objects so they remain in the sewage flow to be removed later in a settling tank.

After the sewage has been screened or ground, it passes into a grit chamber where dense materials, such as sand, cinders and small stones settle to the

BASIC WASTEWATER TREATMENT (Primary) (Secondary)



bottom. This step is essential to combined sewer systems because run-off from streets and lawns ends up at the treatment plant. The settled material is normally washed and used as land fill.

Some plants use another screen after the grit chamber to remove any additional material which would damage equipment or otherwise interfere with subsequent processing.

At this point, sewage still contains undissolved suspended matter which can be removed in a settling tank or primary clarifier. There, it gradually sinks to the bottom, forming a mass called raw sludge. The sludge is drawn off into a digester, which concentrates it for use as land fill. In some instances, the concentrated sludge is burned and the ash used as land fill.

The remaining liquid from the settling tank is called primary effluent, and if only primary treatment is applied, it may be disinfected with chlorine to destroy disease-causing bacteria and reduce odors before being discharged.

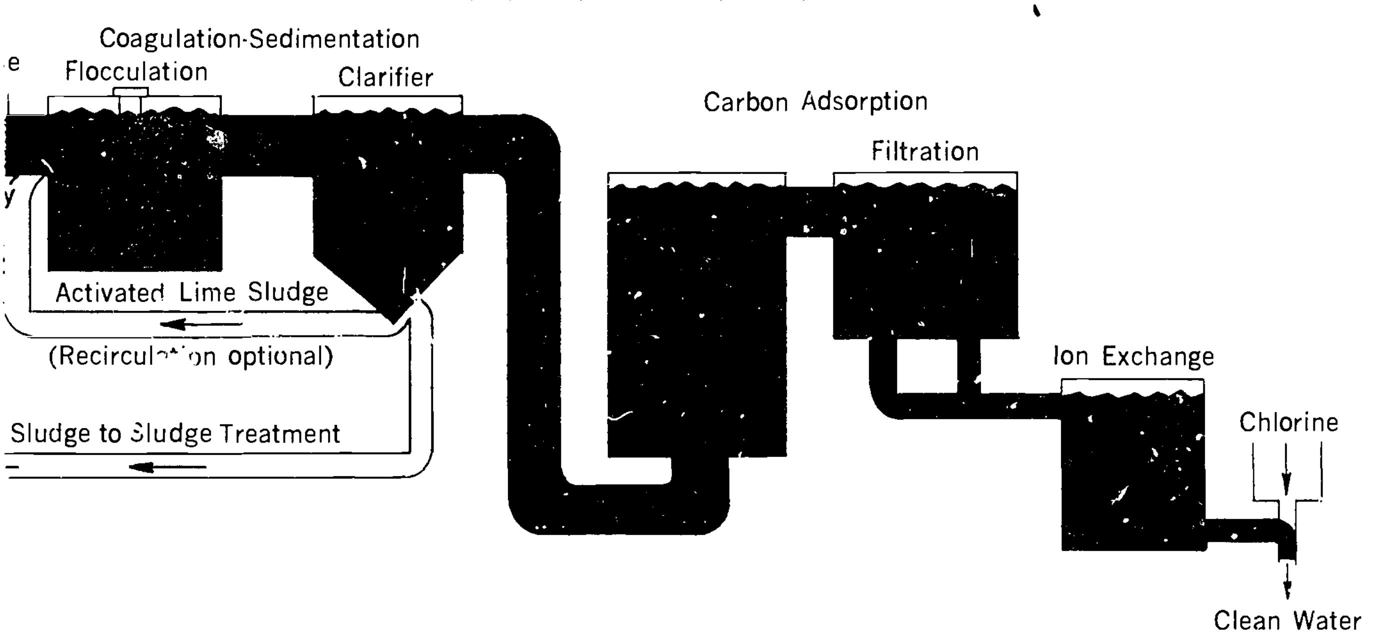
Secondary treatment, applied to sanitary sewage, can further remove organic matter—up to 90 percent—by making use of the bacteria in it. The biological oxidation effected is the same in the two principal types of processing units:

Trickling filters . . .

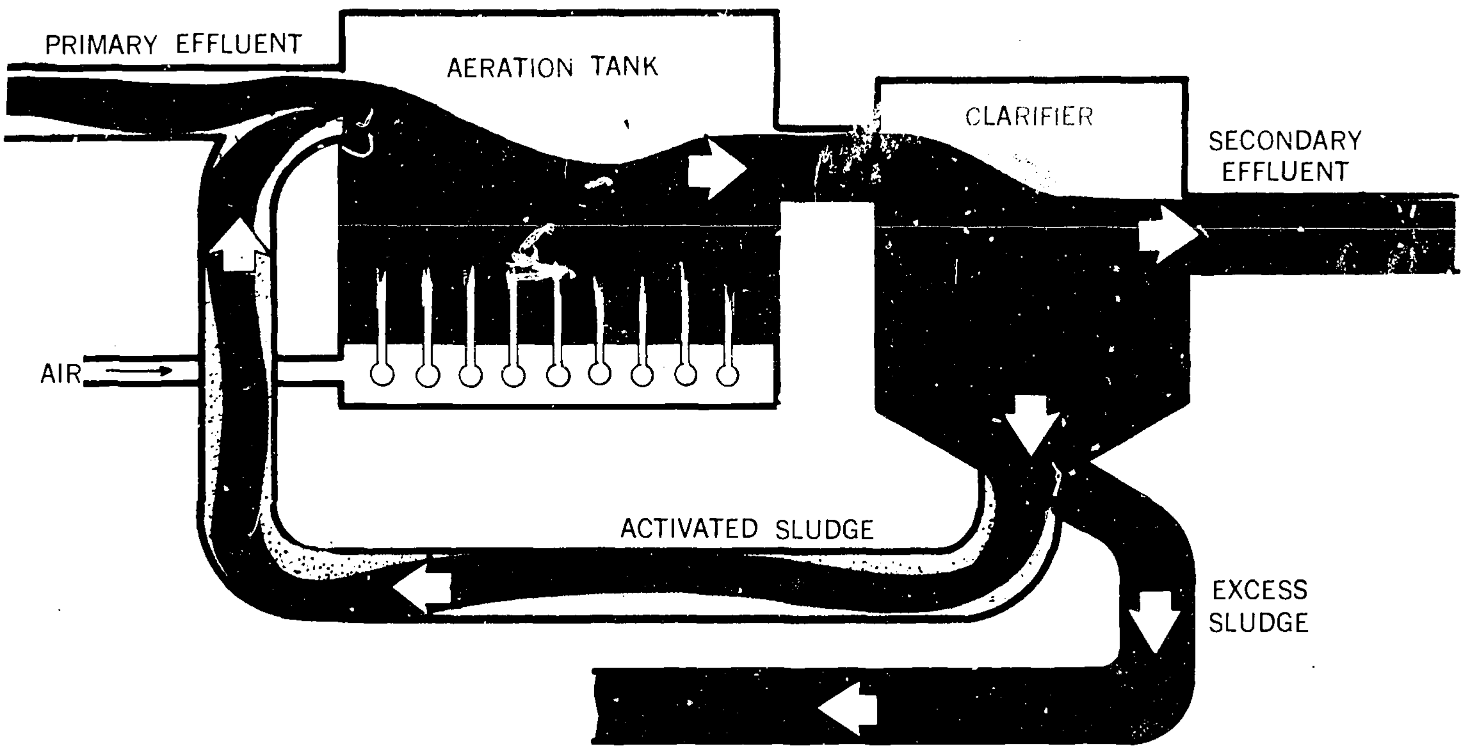
. . which are beds of stones several feet deep through which the wastewater trickles. Bacteria adhere to the stones and consume most of the organic matter. The treated water is led out through piping from the bottom of the filter. After suspended matter settles out, it may be disinfected with chlorine before being discharged.

However, the trend in secondary treatment is toward . . .

ADVANCED WASTEWATER TREATMENT (Tertiary or Physical-Chemical)



. . . ACTIVATED SLUDGE



In the activated sludge process, primary effluent is pumped to an aeration tank and combined with biological sludge to create "mixed liquor," which is aerated for several hours. The process must be carefully controlled since the quantity or organic matter varies constantly and the proper amounts of oxygen and biological sludge must be provided so the bacteria can do their job.

After aeration, the mixed liquor then flows to a sedimentation tank for removal of the biological sludge, part of which is recycled back to the aeration tank. The remainder goes to a digester where it is treated the same as raw sludge from primary treatment. The liquid effluent may be chlorinated before release.

TERTIARY TREATMENT . . .

. . . is what its name implies, a third step in water pollution control. There are several such "advanced treatment" techniques, ranging from extensions of biological treatment—which remove nitrogen, phosphorus and other nutrients—to physical/chemical separation. One or more may be used to meet specific needs. They include:

Chemical Oxidation . . .

. . . which utilizes oxidants such as ozone and chlorine. The process does not remove anything in the water but has been used for many years to improve the taste and odor qualities of municipal drinking water. It does so by destroying or altering organic constituents in drinking water which may be present in very small quantities. For special purposes chemical oxidants are also useful for treating wastewaters.

Coagulation-Sedimentation . . .

. . . wherein alum, lime or a selected organic polymer is added to the screened sewage or to the effluent as it comes from biological treatment. It then passes through flocculation tanks where the alum or lime causes the smaller suspended particles to bunch together (floc) into larger masses, making them settle faster and easier to remove.


COAGULATION—SEDIMENTATION

Adsorption . . .

. . . is another form of tertiary treatment which may be needed to remove organics that resist normal biological treatment.

The effect of such organics in water varies, depending on the particular substances involved. Some may cause taste and odor problems, foaming, tainting of fish and even fish kills.

Adsorption uses activated carbon and can be applied in either of two ways—by passing the wastewater through a bed of activated carbon granules or by putting powdered activated carbon directly into the wastewater.

Carbon granules can remove nearly all of the dissolved organic matter and the granules can be reused after regeneration by heat with due regard not to cause air pollution.

Powdered carbon is highly efficient but more difficult to handle, since the particles must be removed as sediment. Also, regeneration and reuse of ground carbon is more complicated.

Except for dissolved salts, municipal wastewater that has gone through the processes described thus far can be restored to quality comparable to that before it was used. In wastewater treatment language, dissolved salts mean any mineral dissolved by water—during rainfall, seepage through soil or trickling over rocks as well as those present in human and animal waste. Their removal requires a different kind of tertiary step . . .

ADSORPTION

. . . Desalination

Several methods are available. All are expensive. They include:

Ion exchange . . .

. . . which uses special types of synthetic resins characterized by either a positive or a negative electrical charge. In simple terms, this is how they work:

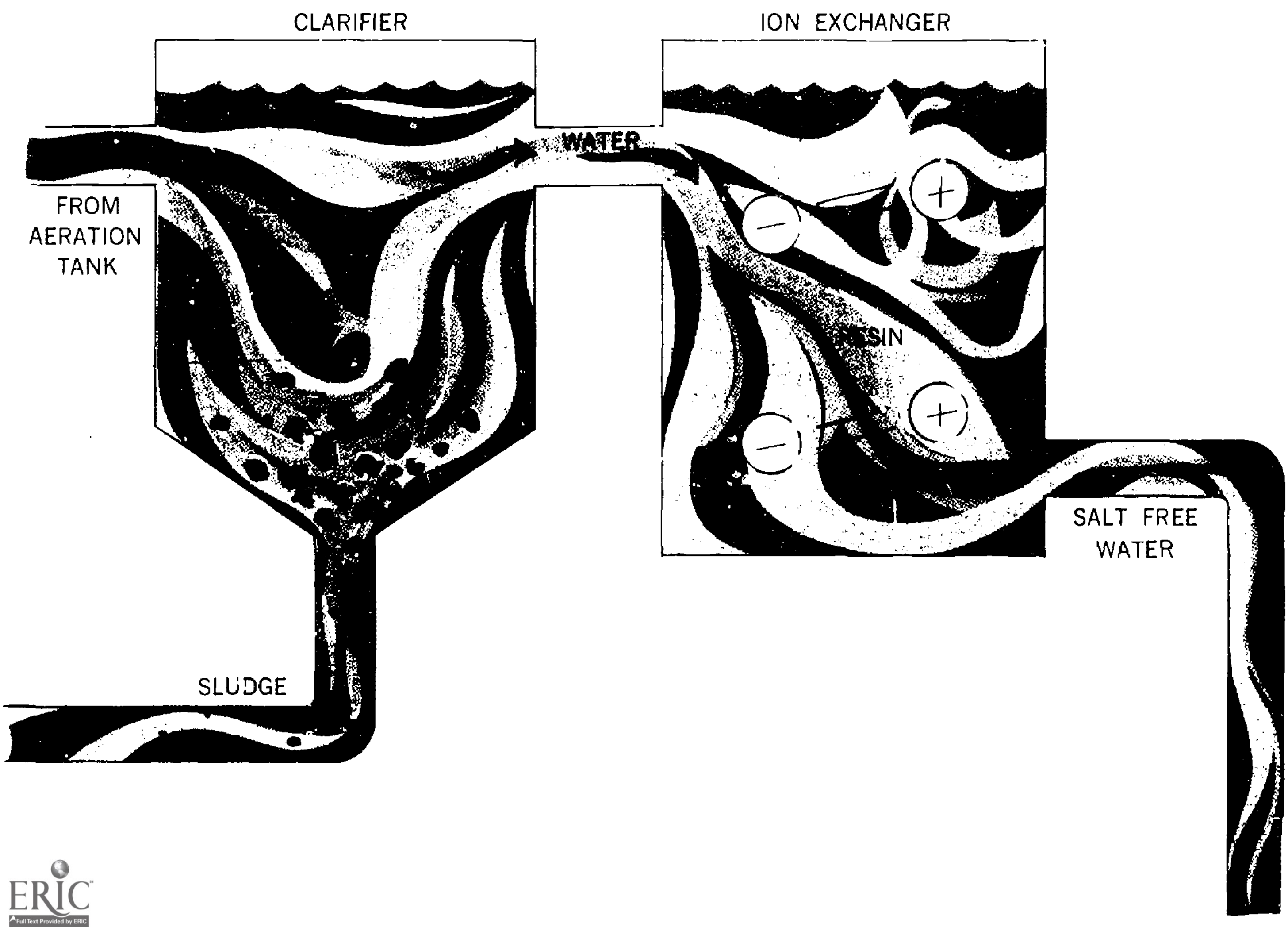
When dissolved in water, a mineral salt breaks down into ions. An ion is an atom or small group of atoms having an electrical charge, either positive or negative. Example: common table salt—a combination of sodium and chlorine which we see as white crystals. However, when dissolved in water, the sodium and chlorine occur as ions we cannot see. Sodium ions are positive, chlorine ions negative.

When poured into or through a container containing the right combination of electrically charged ion exchange resins in the form of small plastic beads, opposites attract. Positive beads attract and hold chlorine ions; negative beads, sodium. Salt-free water remains. Steam-iron water purifiers are a simple version of ion exchange.

When the plastic beads have attracted all the ions they can hold, they may be regenerated by putting them through a reverse process whereby they release the ions they have attracted. This produces a concentrated salt solution which may or may not be useful. If the latter, it must be disposed of; for instance—it may be pumped to a holding basin where the moisture evaporates, leaving the salts behind.

Electrodialysis . . .

. . . is a complicated and costly process using



electricity and membranes. The membrane is made of a chemically-treated plastic and the salts are drawn out of the water by negative and positive electrodes. The end result is similar to ion exchange. Disposal methods for the remaining salts vary considerably, depending on type and quantity.

Reverse Osmosis . . .

. . . is a process based on this natural phenomenon:

When liquids with different concentrations of mineral salts are separated by a porous membrane, molecules of pure water tend to pass by osmosis from the less concentrated to the more concentrated side until they are equal. When pressure is applied, the flow can be reversed.

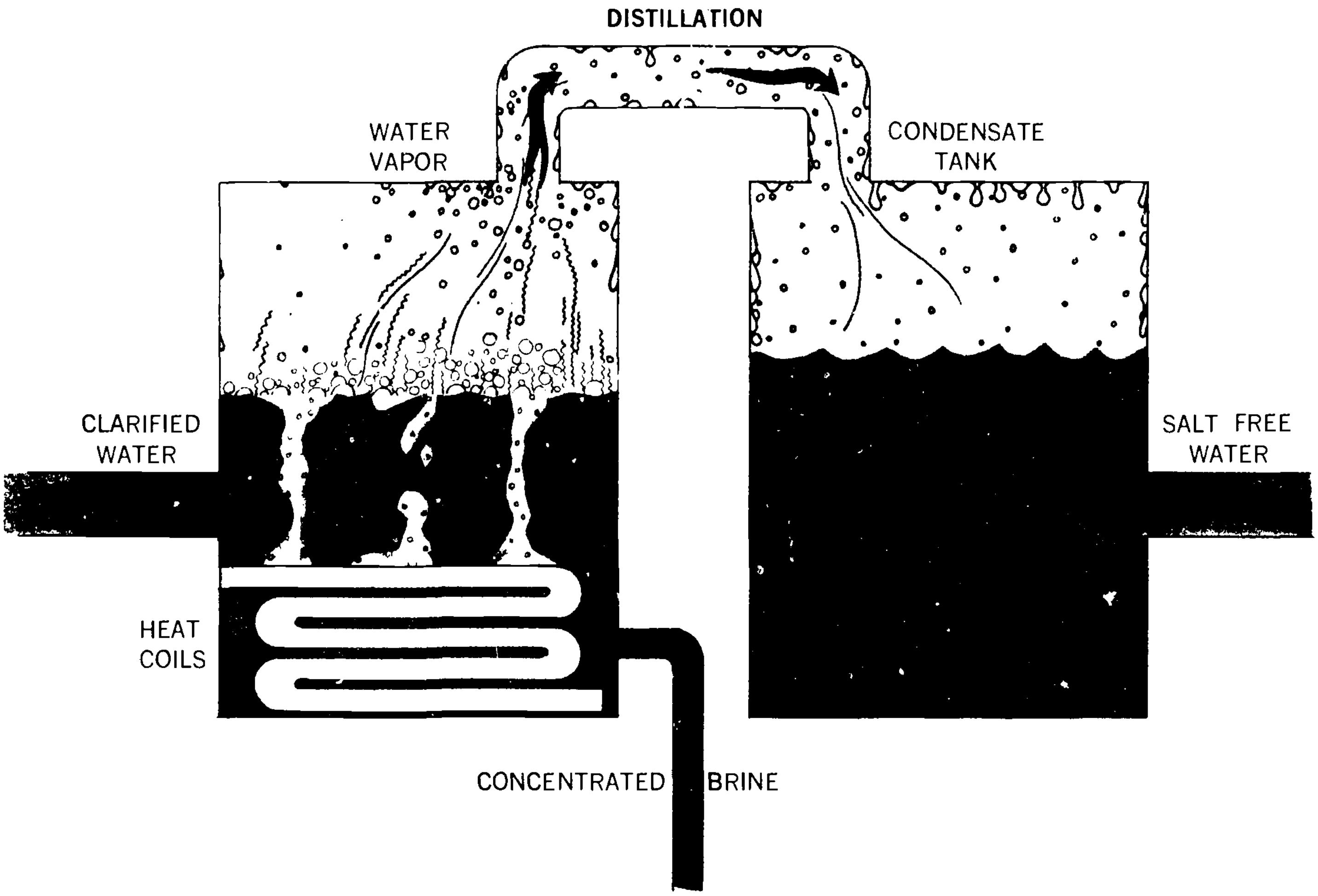
Scientists are taking advantage of this reverse process, which means taking good water out of wastewater rather than decomposing or otherwise removing the waste.

The practical application of reverse osmosis is relatively expensive, however, and is continuing to be developed.

Distillation . . .

. . . is the ultimate in producing pure water. An effluent, or any kind of water, is brought to a boil. The steam is collected and allowed to cool back into water. On a large scale, distillation can be expensive and is applied only to special purposes.

As mentioned at the beginning, 100 percent distilled water is excellent for steam irons and car batteries. It is essential to some manufacturing processes. Yet, for drinking, Lucy's "Bleah" is most descriptive.



conclusion

All wastewater treatment methods, even distillation, leave something behind that must be disposed of. The scale inside a tea kettle is an everyday example. Thus, keeping water in useful condition is a never-ending cycle.

Water pollution can be controlled, however, through the application of technology, none of which would be possible without the chemical industry. It has created and currently manufactures a majority of the essential materials described in this booklet—oxygen, chlorine, alum, lime, activated carbon, polymers, ion exchange resins, plastic membranes and filters.

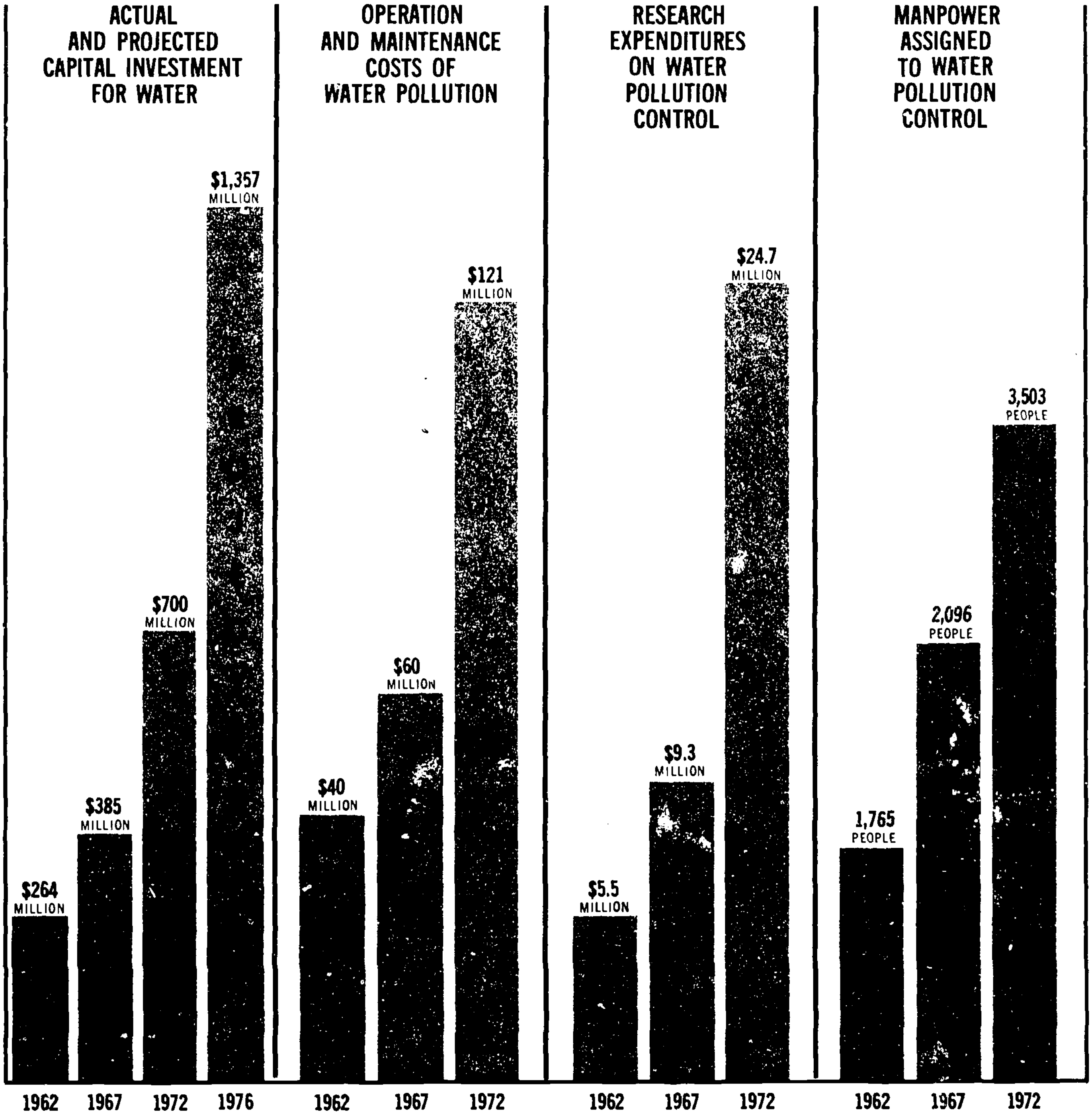
In addition, the basic chemical industry has invested millions of dollars to control water pollution from its manufacturing facilities. Many more millions are spent every year to operate wastewater treatment facilities, to provide surveillance and to conduct extensive research which improves present technology and develops new processes.

On March 20, 1972, the Manufacturing Chemists Association announced the results of a survey which is illustrated on the opposite page. It leaves no doubt as to the long-time dedication of the chemical industry in protecting the environment.

In revealing cost factors covering air pollution, water pollution and solid wastes disposal, the survey shows that up to 1972, 137 Association member companies had invested $700 million in capital equipment to control water pollution alone. This compares with $264 million a decade earlier and $385 million as of 1967. These companies predict their capital investment by 1976 will reach $1.3 billion.

For this same purpose, annual operating and maintenance expenditures by these companies also increased over the years: $40 million in 1962, $60 million in 1967 and $121 million in 1972. And, research expenditures in water pollution control more than quadrupled: $5.5 million in 1962, $9.3 million in 1967, $24.7 million in 1972.

Full-time personnel engaged in the operation and maintenance of water pollution control equipment in these companies has doubled in the last 10 years: 1,765 were involved in 1962; 2,096 in 1967, and more than 3,500 by 1972.



NUMBER OF REFORTING COMPANIES: 1962—125 1967—129 1972—137

SOURCE: Manufacturing Chemists Association

postscript

The expressed goal of the United States Government is to make the nation's water clean enough for swimming and for the propagation of aquatic life by 1981. The price of achieving that objective may be modest in rural areas or small communities.

However, the cost increases rapidly in urban areas where concentration of households and industries create overwhelming amounts of sewage and other pollutants. Just how fast it increases in each instance is a matter of conjecture and a dozen experts will come up with a dozen different answers. No one can be absolutely sure of the ultimate price until every facet of the local situation is evaluated, facilities constructed and a treatment plant put into operation. However, since this booklet was written in Washington, it is possible to cite this specific example:

As 1972 began, the Blue Plains treatment plant in the District of Columbia was handling 275 million gallons of sewage from nearly two million residents in a portion of the National Capital Area—the District itself and several adjacent counties in Maryland and Virginia. The plant is inadequate for the job. Its activated sludge installation provides only a 70-75 percent waste reduction and the receiving river, the Potomac, is unfit for swimming or fishing.

This is understandable. Blue Plains was built in 1938 as a primary treatment plant only. Expansion to an activated sludge process took place in the 1950's, with sporadic improvements since then. Although the cost of the plant in terms of today's dollars is nearly impossible to estimate, the 1972 budget to operate it was $4.5 million.

Now, a new Blue Plains combined sewer treatment facility is under construction. Due for completion by January 1975 it will:

- Cost $360 million to build.
- Require $22-$25 million-a-year to operate.
- Handle a normal load of 309 million gallons of sewage, with a peak capacity of 650 million gallons.
- Be capable of handling an additional 290 million gallons of storm water for primary treatment only.
- Remove 97 percent of organic (oxygen-demanding) wastes and phosphorous, and 85 percent of the nitrogen prior to discharging its effluent.

The new plant will not solve all the Potomac's problems. Silt from construction sites and pollutants washed from streets will continue to get into it. However, when in operation, the facility will be a giant step towards making the river suitable for swimming and the support of aquatic life.

In relating this example to situations in other parts of the nation, it must be borne in mind that the Greater Washington area is not highly industrialized. Many of the pollutants common to major manufacturing centers do not exist. It does mean, however, that—like chemical manufacturers—all communities and industries will be making huge investments in pollution control equipment and spending large sums every year to maintain it in order to restore and protect water for beneficial uses by mankind.

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