Biological Effects of Industrial Pollution

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Industry in the aggregate is a very big polluter of water, and water in the aggregate is one of this Nation's most valuable resources. The wastewater discharges from food, textile, paper and chemical products, petroleum and coal, rubber, primary metals, machinery and transportation equipment exceed 13 trillion gallons annually. By comparison, the wastewater volume of domestic sewage from the sewered population of the United States is slightly more than five trillion gallons. Wastewater volumes from two industries only, chemical and allied products and primary metals, which include blast furnaces and steel mills, exceed that of domestic sewage by a substantial margin.

Perhaps more significant than the gross quantity of industrial waste is its quality or concentration of constituents. A few industries such as paper and allied products, the chemical group, petroleum refining, sugar refining, and primary metals, which are typically composed of a relatively few, relatively large plants, use most of the Nation's industrial water and produce most of the Nation's wastes. Because industries tend to be concentrated at points of demand or of raw material availability, and because industrial concentrations create or are attracted to concentrations of population, the environmental effects from such industries are magnified beyond the level that their gross production of pollutants might suggest.

The tendency to industrial concentration has a tremendous impact on the regional prevalence of industrial water pollution. The great preponderance of American industrial water use, as measured by wastewater discharges, occurs in the northeast, the north Atlantic, Great Lakes, and Ohio River drainage areas.

Of the more than 13 trillion gallons of wastewater, some indeterminate part may be considered to require treatment because of its pollutional characteristics. Included are 3,700 billion gallons of process water, all of which might be expected to require treatment prior to discharge, and 960 billion gallons of water for miscellaneous uses, of which at least the component used for sanitary services would require waste treatment. The largest category of water use, cooling water, accounts for 9,385 billion gallons. Under many circumstances, cooling water might require only temperature stabilization. Where recycling involves the mixing of process and cooling waters or the diversion of used cooling waters to process application, then waters brought into a plant primarily for cooling would be expected to require treatment in addition to temperature stabilization prior to discharge.

Waste controls and wastewater cooling facilities having a current replacement value of from $5 billion to $6 billion must be utilized by 1973 to achieve the level of industrial waste reduction and temperature control assumed necessary to provide adequate protection against water pollution. Roughly half of the value of the necessary investment is presently provided by industrial waste treatment and cooling plants in place, or by municipal facilities that treat industrial wastes. But an investment in excess of $2 billion to almost $3.5 billion will be required to overcome the accumulated deficiency in industrial waste treatment and cooling facilities that now exists; another $.5 billion to $1 billion, exclusive of depreciation will be needed by 1973.

Economic growth and acceptable environmental quality must go together, because ultimately, economic growth and for that matter, life itself, depends on environmental quality. And of what use is economic growth if, in promoting it, an environment is created in which it is hazardous to live?

Some of the specific pollutional problems associated with this country's industrial complex of which we are aware, and that we have taken actions to prevent and control include:

1. underground, surface and off-shore mining
2. acid and alkali mine drainage from underground and surface mines and from strip mines
3. oil field wastes from well drilling, brine disposal and oil pipelines
4. organic materials that remove dissolved oxygen in decomposition and supply nutrients that stimulate undesirable aquatic growths
5. suspended solids that settle to destroy aquatic life and interfere with other water uses
6. materials that are toxic to aquatic life or cause harm when present in sublethal concentrations
7. materials, including complex organic compounds, that impart an odor to a domestic water supply or to fish or shellfish flesh.
8. In essence, anything that interferes with a designated water use.

What are the biological effects of industrial pollution? Upstream from the waste source, limiting factors such as food and intense competition among organisms and among organism groups, predation, and available habitat for a particular species will restrict organism populations to those that can be sustained by the particular environment. Most often the limiting factor will be available food. Within this population, however, there will exist a great number of organism species. Thus, the old biological axiom for an environment unaffected by pollution is one that supports a great number of species with the total population delimited largely by food supply.

Following the introduction of organic wastes, conditions of existence for many organisms become substantially degraded. Increased turbidity in the water will reduce light penetration that in turn will reduce the volume of water capable of supporting photosynthesizing plants. Particulate matter in settling will flocculate small floating animals and plants from the water. As the material settles, sludge blankets are formed on the stream bed and many of the areas that formerly could have been inhabited by bottom associated organisms become covered and uninhabitable except by worms and sludge loving organisms.

The breakdown of organic products by bacteria may consume available dissolved oxygen. Fish spawning areas are eliminated, but perhaps fish already are no longer present because of diminished dissolved oxygen and substantially reduced available food. Here, aquatic plants will not be found in large numbers because they cannot survive on the soft shifting blanket of sludge. Turbidity may be high and floating plants and animals destroyed. Water color may be substantially affected. When organic materials are decomposed a seemingly inexhaustible food supply is liberated for those particular organisms that are adapted to use this food source. Thus, bacterial and certain protozoan populations may increase to extremely high levels. Those bottom associated organisms such as sludgeworms, bloodworms, and other worm-like animals may also increase to tremendous numbers because they are adapted to burrowing within the sludge, deriving their food therefrom, and existing on sources and amounts of oxygen that may be essentially nondetectable by conventional field investigative methods.

Within this zone of active decomposition the organism species that can tolerate the environment are reduced to extremely low levels. Under some conditions those bottom associated animals that are visible to the unaided eye may be completely eliminated. Because of the tremendous quantity of food that is available to those organisms that are adapted to use it, the numbers of individuals of the surviving species may, indeed, be great. For example, it may be possible to find 50,000 sludgeworms or more living within each square foot of bottom area with the above-described conditions. Such a population is comparable to one pound of living "hamburger" for each square foot of surface.

The zone of recovery is essentially the downstream transition zone between the zone of active decomposition and an environment that is unaffected by pollution. This zone features a gradual, natural cleaning up of the environment, a reduction in those features that form adverse conditions for aquatic life, an increase in organism species, and a gradual decrease in organism populations because of decreased food supply and the presence of some of the predators that are less sensitive individually to pollutional effects. Pollutional effects from a single source of organic waste may extend for many stream miles or days of stream flow.

The general effects on the aquatic environment of inorganic silts is to reduce severly both the kinds of organisms present and their populations. As particulate matter settles to the bottom, it can blanket the substrate and form undesirable physical environments for organisms that would normally occupy such a habitat. Erosion silts alter aquatic environments chiefly by screening out light, by changing heat radiation, by blanketing the stream bottom and destroying living spaces, and by retaining organic materials and other substances that can create unfavorable conditions. Developing eggs of fish and other organisms may be smothered by deposits of silt; fish feeding may be hampered. Direct injury to fully developed fish, however, by nontoxic suspended matter occurs only when concentrations are higher than those commonly found in natural water or usually associated with pollution.

Wastes containing concentrations of heavy metals, either individually or in combination, may be toxic to aquatic organisms and, thus, have a severe impact on the water community. A severely toxic substance will eliminate aquatic biota until dilution, dissipation, or volatilization reduces the concentration below the toxic threshold. Less generally toxic materials will reduce the aquatic biota, except those species that are able to tolerate the observed concentration of the toxicant. Because toxic materials offer no increased food supply, such as has been discussed for organic wastes, there is no sharp increase in the population of those organisms that may tolerate a specific concentration. The bioassay is an important tool in the investigation of these wastes, because the results from such a study indicate the degree of hazard to aquatic life of particular discharges; interpretations and recommendations can be made from these studies concerning the level of discharge that will not be hazardous to the receiving aquatic community.

Waste discharges that impart an off flavor to fish or shellfish flesh are prohibited by water quality standards. Such a flavor is imparted to the receiving organism generally through absorption from the water, but it may be imparted through the food chain. A relatively new biological testing procedure has been devised to determine the degree of off flavor that is derived from waste sources in a particular stream reach.

Wastes that contribute nutrients in the form of nitrogen or phosphorus are especially hazardous to the receiving waters because these nutrients become incorporated into the biodynamic cycle and their effects remain and persist long after other evidence of a particular waste source may be dissipated. These wastes give rise to obnoxious growths of slimes or troublesome blooms of algae or interfering growths of other aquatic plants. The problems associated with cultural eutrophication are unfortunately common for many lakes, streams and reservoirs.

Specific effects from industrial wastes on aquatic life can be determined with a field investigation of the lake or stream reach involved. Techniques are available to determine these effects and predictions can be made regarding changes in water quality that will result from recommended remedial actions. The objectives of such a field study may be satisfied with a single field endeavor involving one or two weeks of field effort or repeated studies may be required that will depict conditions of existence for aquatic life during each of the prevailing seasons in a given year. Usually the biological laboratory and office effort will be equal to or exceed in slight degree that effort expended in the field investigation for a study to solve a particular problem.

Pursuant to the Federal Water Pollution Control Act, water quality standards have been established as State-Federal standards on all interstate streams. In addition, most of the States have adopted water quality standards on intrastate streams as well. These standards establish a minimum quality that all waters must meet. In addition, numerical criteria have been established for many particular constituents and the number of constituents depends in some measure on the designated use for a particular stream reach. The Act recognizes the primary responsibility of the individual States to enforce water quality standards within their boundaries.

There are a number of avenues of approach that the Federal Water Quality Administration can take to control pollution. One approach is through enforcement proceedings to abate pollution and to enforce water quality standards. And this approach has been taken on several occasions. Another is to investigate a particular problem at the request of a State water pollution control agency, and make recommendations to alleviate the condition. Yet another is to consult, and to make available the knowledge and expertise that the Administration has gained through many studies in many areas and climates of the country.

The study of an industrial waste problem involves a focusing of many disciplines — engineering, hydrology, biology, chemistry, and perhaps microbiology — on the particular situation. Through this effort it is possible to assess the prevailing water quality and the effects of a discharge or discharges on the receiving waters. The biological effects of pollution are important indeed because through this avenue is found the life in the receiving water and its state of health. Most water uses depend to a great extent on the life in water, either directly, or indirectly when this life is a measure of the water's quality and usefulness.