Stream Life Below Industrial Outfalls

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The following brief review of present knowledge of the biological effects of industrial wastes in water is offered in anticipation of publication of a detailed book on this subject. The text will cover methods of presenting biological data (touched on here) and sampling equipment indicated for stream surveys. It will carry a full bibliography. Only a few outstanding references are cited in this article.

THAT DAY is dead when it seemed only natural and logical for Americans to discharge raw industrial wastes to the most convenient stream. The recognized need to protect the Nation's basic and essential water resource has brought all artificial additions to the stream under critical scrutiny. The present task is to establish reasonable appraisals of the various effects of specified industrial effluents. Conversely, we seek to learn how certain biological effects may serve as indicators of forms or degrees of industrial pollution in a stream.

What are the outstanding detrimental effects of industrial wastes on aquatic life? How do certain nutrient wastes contribute to the growth of biological nuisances? Comments on these questions are offered with confidence that they will be viewed in the large perspective that embraces all forms of stream pollution, including those provoked by improvident abuses of the land, excessive use of water, and failure to regulate streamflow. The contribution of domestic sewage and the scouring effects of peak flows also are assumed as being understood in the general context of these remarks.

The major emphasis here falls on four factors in industrial wastes that are responsible for the most subtle environmental effects: elevated temperature; particulate matter, contributing to turbidity and the formation of settleable solids; nutrients, favoring blooms of aquatic weeds and pests; and radioactive elements. These conditions in turn produce forces damaging to the productive use of the water resources.

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Elevated Temperatures

The effect of a mild heating of natural waters, its influence on the metabolic processes of biota as reflected in measurements of oxygen demand, oxidation, and reaeration, has long been recognized, if not fully understood. As temperature of water rises, oxygen becomes less soluble. Under a pressure of 760 mm. in fresh water, the concentration of dissolved oxygen at 0° C., is 14.62 ppm; at 20° C., 9.17 ppm; at 39° C., 7.63 ppm. The mere heating of a stream can deny stream life its normal supply of oxygen. Coupled with putrescible pollution, which increases the total demand for oxygen, a rise in temperature may deplete the oxygen level to a stage of asphyxiation for aquatic organisms, which cannot survive in such competition.

Another subtle effect of a rise in temperature is reflected, on occasion, in the increased toxicity of certain chemicals. For example, exposed to 0.4 ppm rotenone, brown trout die in 15 minutes at 21.11° C., in 70 minutes at

12.78° C. With dosage of 0.2 ppm, they die in about 22 minutes at 21.11° C. and in 100 minutes at 12.78° C. (*1*). But this gain in toxicity with heat is not the rule for all chemicals or species. At 10° C. and 25° C., there is no observed change in the toxicity of ammonia to chubs. Further, it has been demonstrated that toxicities of potassium dichromate and naphthenic acid were similar at 18° C. and 30° C.

For students of the effects of temperature on fish, laboratory studies offer a wealth of data which cannot be summarized here, but several such summaries are in the literature (*2,3*). J. R. Brett's "Some Principles in the Thermal Requirements of Fishes" is an especially useful and comprehensive review of this subject (*2*).

In industrial waste field surveys of large streams, it may be difficult to relate detrimental effects of temperature (heat pollution) to specific aquatic organisms. In bodies of water, such as the Mahoning River in Ohio, where temperatures become high enough to be lethal to most aquatic organisms in outfall areas, deleterious conditions arise also from other factors, such as low dissolved oxygen, high turbidities and settleable and floating solids, and pH and chemical toxicity.

Hot industrial discharges can be disastrous to fish. Also, high temperatures may alter the entire biosphere. By eliminating many organisms, heat may allow a few, such as the heat-resistant blue-green alga, *Phormidium*, to become dominant. Ranges in which algae are known to grow best in general are from 18° C. to 30° C. for diatoms, 30° C. to 35° C. for greens, and 35° C. to 40° C. for blue-greens. Some species grow at even higher temperatures (*4*). Gross limits of temperature (*5*) that most warm-water fish experience in natural bodies of water are somewhere between 0° C. and 35° C. (32° F. to 95° F.). If water of 30° C. is available, warm-water fish may seek it, leaving 32° C. water. Among warm-water fish are sunfish, catfish, carp, and many minnows. Cold-water fish, such as the salmonoids, salmon and trout, normally live in natural waters that range between 0° C. and near 18.34° C. (summer temperature). They usually do not tolerate temperatures above 27.23° C. Certain trout have been reported as surviving temperatures of 27.78° C. to 28.34° C. for very short periods in natural water (*5,6*). The Aquatic Life Advisory Committee of the Ohio River Valley Water Sanitation Commission, referring to waste discharges, recommended that temperatures not be raised above 34° C. (93° F.) "at any place at any time," and stated that temperatures during December through April should not exceed 23° C. (73° F.) "at any place or at any time" (*7*). The report emphasizes that natural temperatures must be maintained in streams suitable for trout propagation.

No one knows precisely how varying temperatures affect all the biota of a stream. However, in general, it appears that in most temperate zone streams of low gradient, large reaches should not exceed 30° C. for prolonged periods, and that headwater streams ought not be warmer than the top range of 22° C. to 25° C. for extended periods. Further research is more likely to reduce than raise these limits (*8*).

As examples on record of streams affected by high industrial heat discharges, one can mention the Mahoning River in the Warren-Youngstown, Ohio, reach; the Kentucky Lake site of the New Johnsonville steam plant, Martins Creek, Pa., site of the steam-electric generating plant on the Delaware River west bank several miles downstream from Belvidere, N.J.; and the waters near the Front Street power station at Erie, Pa.

Temperatures in the Mahoning River have exceeded those tolerated by fish and other aquatic organisms. The "Ohio River Pollution Control" document prepared by the Public Health Service states, "During periods of low streamflow the water temperature below Youngstown has risen often to over 43.34° C." (*9*). It is reported in "Water Resources of the Mahoning River Basin" that, when the last of four reservoirs went into operation, flows have been such that the maximum daily temperatures have only occasionally been above 37.78° C., and that monthly mean temperatures have been below 36.66° C. (*10*). During a survey in July and September 1952 of the Mahoning (Pricetown to Lowellville reach) in which Ingram participated, maximum temperatures for 12 stations occurred in September and were 35.1° C. at Struthers and 34.5° C. at Lowellville. Seines and various dip nets in the reach of the Mahoning from below Warren through Lowellville in September 1952 failed to take fish when industry was discharging wastes, including hot water, in addition to raw municipal sewage. At this time, several chemical and physical factors, in addition to heat, could have been considered equally lethal or detrimental to fish, for example, pH as low as 2.4, dissolved oxygen as low as 0.2 ppm, and various high concentrations of industrial and municipal sewage solids.

In July during the extended steel strike, when pollution was largely produced by raw domestic sewage, although there were also residual industrial effects, fish were taken at Girard and above Indian Run Creek in Youngstown. At Girard temperatures varied from 23.5° C. to 29.5° C.; dissolved oxygen varied from 5.0 to 5.6 ppm; and pH from 6.9 to 7.4. Northern creek chub and goldfish were taken at Girard. Fish taken at the Indian Run Creek station under comparable temperatures and pH and dissolved oxygen ranges were the large-mouth black bass and the common shiner. At upstream control stations above Leavittsburg in July and September, with stream temperatures varying from 24° C. to 31° C., the dissolved oxygen from 5.7 to 6.9 ppm, and the pH from 7.0 to 7.6, sampling obtained a variety of fish: white crappie, small-mouth black bass, northern creek chub, green sunfish, northern black bullhead, bluntnose minnow, and golden shiner.

A field survey of the fisheries related to heat discharged by the New Johnsonville steam plant on Kentucky Lake indicates that a localized warming effect, over that of contiguous waters in the impoundment, served to attract fish and help them survive during cold-water periods (*11*). Warm water from the steam plant may serve as a winter refuge for threadfin shad. These fish abounded in the steam plant discharge harbor, warmed by condenser water discharges to 12.78° C., when other water of Kentucky Lake was 7.22° C.

Information on the effects of hot condenser water discharged from a steam-electric generating plant to Martins Creek, Pa. (which, in turn, feeds heat to the Delaware River), so far has been inconclusive (*12*). These studies are continuing. An example of temperature dissipation in the area of the Delaware illustrates how rapidly temperature can be dissipated in a flowing stream, although the situations described are never exactly repeated. At a railroad bridge 1,500 feet below the heat source, the maximum temperature was 32.22° C., at 2,000 feet 30° C., at 2,750 feet 22.78° C., at 3,600 feet 21.66° C., and at 4,500 feet 20° C. The initial temperature of discharge water is not available.

Particulate Matter

Turbidity, which is considered to be an expression of the optical property of water which causes light rays to be scattered and absorbed rather than transmitted in straight lines, is increased by various forms of particulate matter in suspension (fig. 1). Such matter may include phytoplankton or zooplankton cells, such as algae and protozoans, or silt or other fine materials. Particulate matter in any form that settles to form organic or inorganic sludge is described here as "settleable solids." These solids include matter which increases turbidity.

Many industrial operations contribute settleable solids to water. Apart from the chemical activity that may be provoked in water by such particulate matter, the physical effects on aquatic life are often severe. Some industrial discharges of particulate matter are coal and other mineral products, including washery byproducts; glass sand; lumber; aluminum, steel, and other metals; pulp and paper; wastes from slaughterhouses, canneries, tanneries, and dairies; and oil.

Since such wastes in suspension limit the penetration of sunlight, they impede the growth of aquatic plants attached to the bottom as well as floating or weakly swimming algal forms. Being photosynthetic, these organisms depend on light for existence. Solids also floc planktonic algae and even surface animals and carry them to the bottom to die. By limiting growths of aquatic plant meadows, the wastes starve organisms which feed there. The food chains are interrupted, and aquatic life in general becomes sparse.

As particulate matter settles, the deposits can blanket the substrate. Such a physical en-

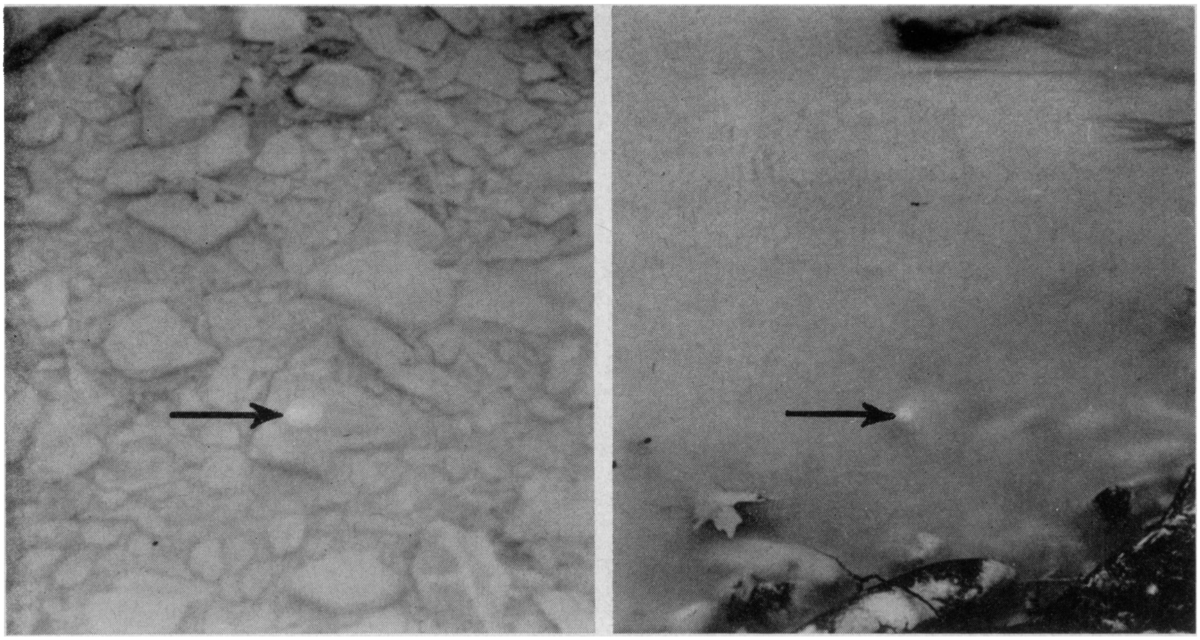


Figure 1. Stream turbidity

(Left) Arrow points to a dime in clear water of Potomac River with low turbidity. (Right) Dime is obscured by high turbidity resulting from inert particulate matter discharged from an industrial operation.

vironment is unacceptable to organisms that would normally occupy such a habitat. Not only industrial wastes but also silt produced by soil erosion is said to alter aquatic environments, chiefly by screening out light, by changing heat radiation, by blanketing the stream bottom, and by retaining organic material and other substances which create unfavorable conditions at the bottom. Also, it has been stated that the developing eggs of fish, as well as fish food organisms, may be smothered by deposits of silt (*13*). Direct injury to fully developed fish apparently by nontoxic suspended matter has been demonstrated only in tests with concentrations which are uncommon (*3*).

Quite different physical effects on stream life result if the bottom blanketing deposits are dominantly organic rather than inorganic. If they are not highly toxic and if the supply of dissolved oxygen is satisfactory, soft organic sludges will give rise to organisms adapted to that environment. On the other hand, inert solids, such as glass sand and other mineral wastes, destroy bottom life. Fewer organisms can live among compacted, heavy abrasives characteristic of such wastes. These wastes may actually simulate "ball-mills," grinding and crushing life that is contacted on a stream bottom, as they are resuspended and moved downstream by periodic surges of high water.

The physical effects of organic sludges of industrial origin are partially illustrated in figure 2, describing a hypothetical situation based upon specific data gleaned from field investigations. It is assumed, for this discussion, that the deposits are not appreciably toxic and that the dissolved oxygen resources are adequate for aquatic life. Settleable solids enter the stream at mile 0 and organic sludge deposits of maximum thickness are formed in the zone of active decomposition between miles 12 and 48. Turbidities are highest between miles 0 and 12. Sludge deposits are not significant elsewhere, and turbidities elsewhere are also unimportant.

In the clean water zones, the bottom is composed of small and large stones. Here a multitude of different species of bottom organisms, plankton, and fish abound. Typical of the species on this bottom are caddisfly larvae, stoneflies, mayflies, hellgramites, gill-breathing snails, and unionid clams. There are many spots where fish may nest. Small-mouth black bass, sunfish, and various minnows flourish on a rich diet of insects which, in turn, enjoy numerous algal species. The main observation is that there is a great variety of species represented by a few individuals of each form.

In the zone of degradation, floating solids blanket out the light penetration. Moving into the zone of active decomposition, as these solids settle, sludge blankets the entire bottom. Turbidity makes the water almost opaque. Only a few species can survive in the soft, shifting sludge. Being isolated from most competitors and predators, a few species here form huge populations. The few animal forms that thrive in a sludge substrate are bloodworms, *Tubifex* and *Limnodrilus*; water sow-bug crustaceans, *Asellus*; certain left-handed snails; and various leeches. Fish are absent or scarce. They prefer to nest elsewhere. Aquatic plants are not able to root. Species of algae are extremely limited: blue-greens, such as *Phormidium* and *Oscillatoria*, form gelatinous slimy blankets over the sludge in shallow marginal water. Only an occasional plankter moves through the water in the zone of active decomposition; most have been dragged out of the upstream water in the zone of degradation to suffocate in the clinging wastes.

A detailed description of a bottom covered with inert inorganic solids suggests an aqueous desert rather than the jungle of bloodworms found in organic sludge. Data collected in September 1952 (fig. 3) and again in September 1958 portray the physical effect on aquatic life of waste from a glass-sand operation on a small creek feeding the Potomac River. Below this creek reaches a submarine Sahara, dotted with a few rare oases. In 1958, above the point of confluence, the Potomac was sparkling clear, bedded by a bottom of rocky ledges, rocks, coarse gravel, and some natural clean sand, lush with beds of higher aquatic plants, such as *Elodea* and *Potamogeton*. Gill-breathing snails and mayflies dominate invertebrate life everywhere on the substrate. Large unionid, pearl-button clams dot the margin. Minnows swarm in the sunlight. The filamentous alga, *Clado-*

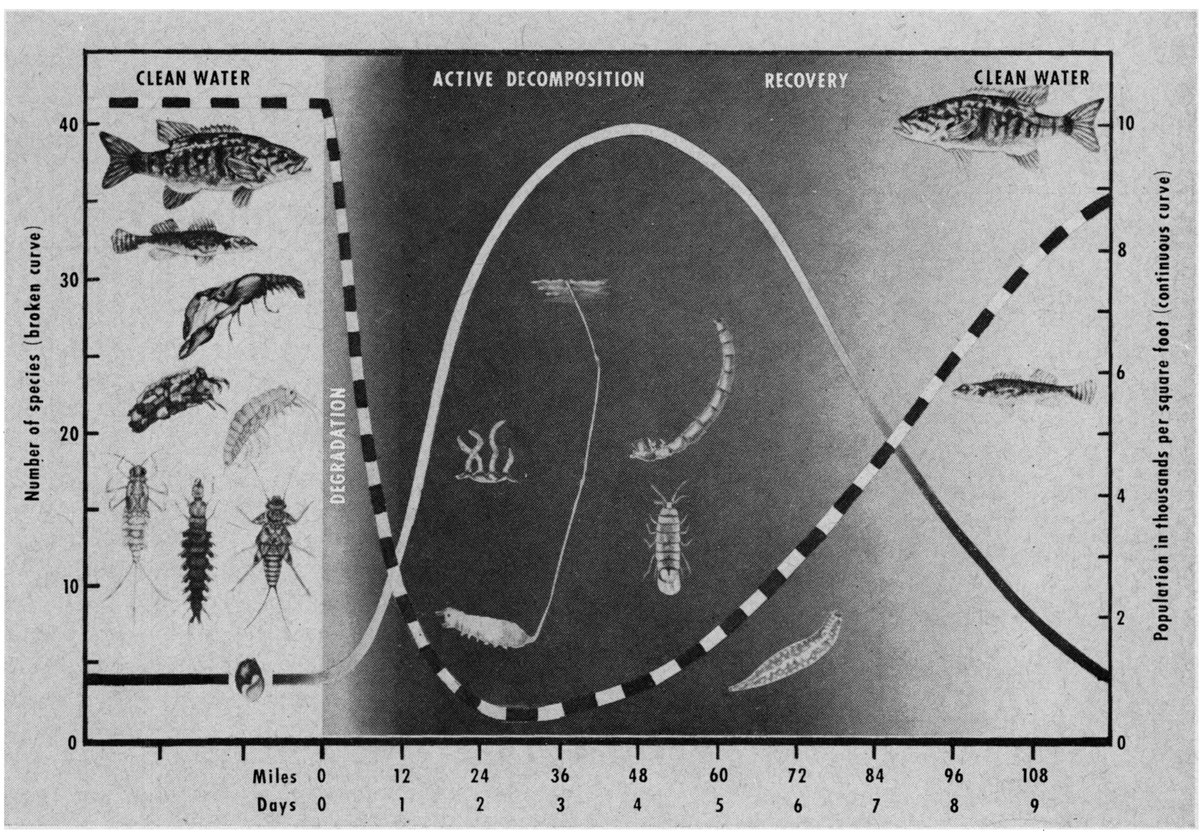


Figure 2. Biological effects of organic sludge

phora, covers much of the rocky area. Eleven genera of planktonic and filamentous algae and eight genera of animals are represented in our collections from this station.

At a station 600 yards below the confluence of the small creek (receiving glass-sand wastes) with the left bank of the Potomac, the bottom of the river was devoid of life in 1958, as it was in 1952. Blue-green algae grew marginally on the wave-wash area of the bank. This paucity of organisms extended to midstream, where 3 genera of snails and 10 genera of planktonic algae were collected. From the left bank (looking upstream) to the midstream rocky ledges, the rocks, gravel, and sand of the original Potomac River bottom were covered completely up to 2 feet deep by waste glass-sand fines. During the period when samples were collected in 1958, the sand fines desert was spectacular in clear water. Turbidities attributable to this operation were found to vary tremendously in 1958 with waste discharges, from 130 turbidity units to 50,000 turbidity units. The effects of such discharges in 1958 were observed to suppress bottom life as far as 10 miles downstream.

Excess of Nutrients

Overproduction of any plant or animal is a sign of an unbalanced ecology. The degree of disequilibrium may be a portent of disaster as when a rise in human population taxes a land's limited natural resources. Likewise overpopulation of a lake with shad may present a sudden and unwelcome abundance of protein at the shore.

Wastes with substrates of nitrogen, phosphorus, carbohydrates, and fats may have the potential of forming through hydrolysis in enzymatic systems, readily available end products of organic foodstuffs such as amino acids, simple sugars, fatty acids, and glycerol. These feed animals or stimulate aquatic plant growth. Such wastes may build up such a plant or animal nuisance growth that water uses are impaired. Organisms that flourish typically with certain of such nutrients are the sewage bacterium, devil grass (*Sphaerotilus*), and certain planktonic and sessile algae.

Algal and *Sphaerotilus* blooms that interfere with multiple uses of water result from a nutritional process that is not immediately relevant. However, the damage they do is likely to continue, and other nuisances may ensue. If streams, lakes, and manmade impoundments continue to be enriched with wastes of industrial, municipal, and agricultural origin, biological nuisances will be intensified and new unspoiled areas will suffer.

Sphaerotilus, the filamentous-plumose floc-forming bacterium, is not now susceptible to control. Research has not revealed treatment methods that have been productively put into operation on a plant-scale basis, either to prevent or eliminate the growth, despite the best efforts of the pulp and paper industry to foil this gelatinous pest (*14, 15*).

Sphaerotilus abounds in certain reaches of the Columbia River in Washington and Oregon; Altamaha River, Ga.; Hiawasee River, Tenn.; New River, Va.; Penobscot River, Maine; Clearwater River, Idaho; Fox and Menominee Rivers, Wis.; and Bear River, Utah.

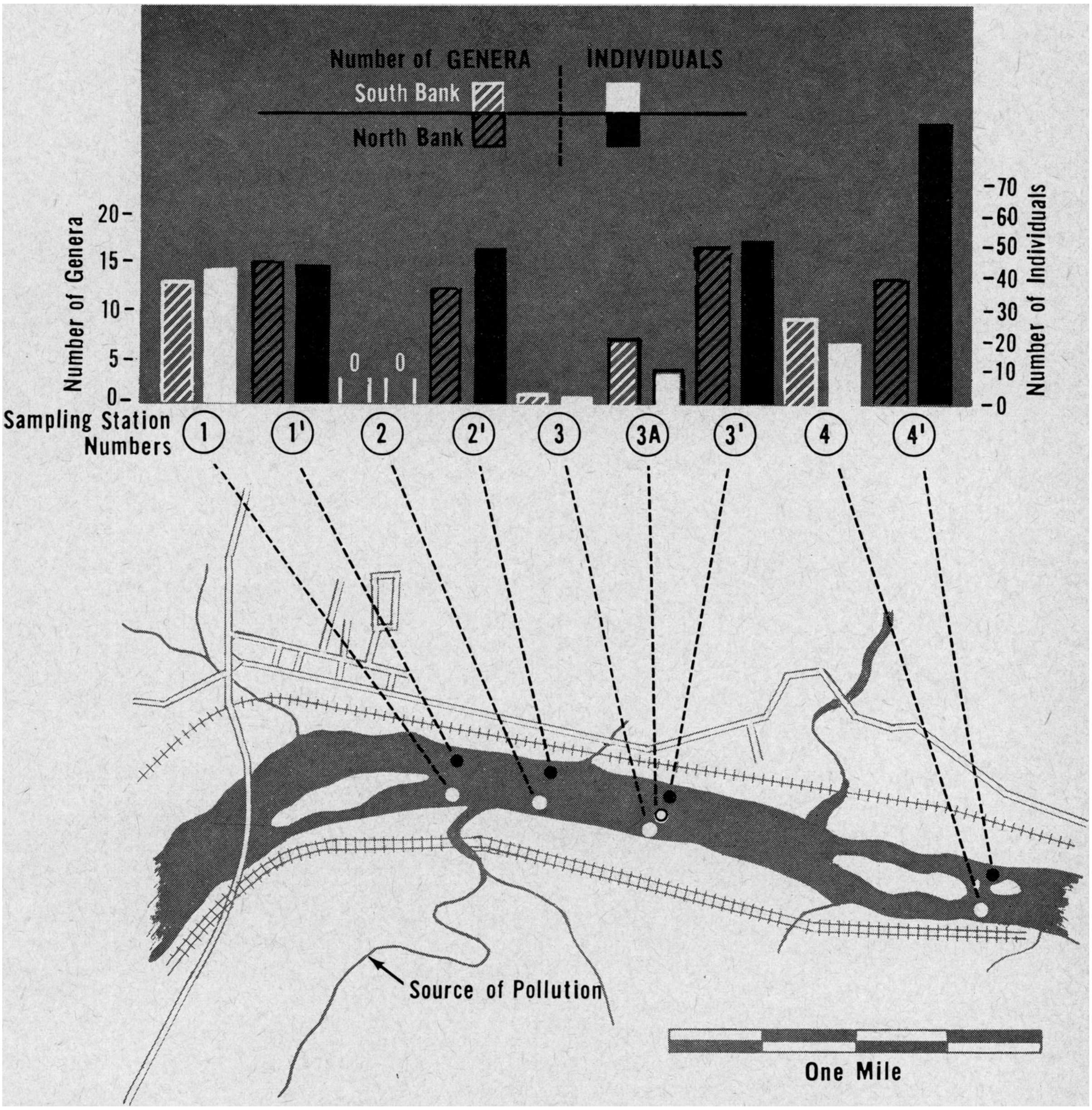
It occurs in restricted patches in the Connecticut River, Mass.; Ohio River, downstream from Cincinnati, Ohio; Grass River, N.Y.; Potomac River drainage in Maryland; South Holston River, Tenn.; as well as in smaller streams throughout the country.

Without an inventory to indicate the current abundance of *Sphaerotilus* in waterways of the United States, there can be no valid assessment of its distribution and the magnitude of its nuisance value. Too, only such an inventory can relate the subtlety of its development to bloom proportions to nutritional substrates from various types and combinations of waste and runoff.

Sphaerotilus has become recognized as a pest in recent years principally because of its interference with both commercial and sport fishing. Its effect on the gill-net commercial fisheries of the Columbia River is notorious. Specific complaints have been voiced also by fishermen on the Altamaha River in Georgia and the New River in Virginia. The major realistic objection is that *Sphaerotilus* flocs, entangled in fishing gear, hinder the catch and add to the work (*16*).

Sphaerotilus, in forming blooms, especially

Figure 3. Physical effects of glass-sand operations, Potomac River, September 1952



NOTE: This pictorial map combined with vertical bar graphs showing variations in bottom animals per square foot in a section of the Potomac River illustrates use of a graph to demonstrate the impact of pollution on aquatic life, replacing a long list of names of animals and plants found in an affected stream. The presentation shows sampling stations in relation to roads, railroads, and towns. The effects of inert, inorganic solids in limiting the number of animal genera and individuals (stations 2–4 on the south side of the river) are compared with their abundance at stations in unaffected stream areas (1 on south side and 1′–4″ on the north side). Stations 1 and 1′ are used as controls. Solids are carried into the main river from the tributary at the confluence between stations 1 and 2. Bottom animals are absent at downstream station 2. Only 1 genus was collected at station 3 on the south half of the bottom, while 7 genera were taken in the center of the river (3A) and 16 genera on the bottom of the northern half of the stream (3′).

in riffle areas with other associated bacterial slimes, may blanket the bottom, "crowding out" fish food organisms and spoiling potential fish nesting areas.

Prospective difficulties from *Sphaerotilus* are: (*a*) clogging of rapid sand filters of municipal and industrial water treatment installations, (*b*) tastes and odors in water produced by decay, (*c*) mucilaginous nuisances in pumping stations and in irrigation canals, and (*d*) contact nuisance to swimming, water skiing, and boating.

The process by which excess nutrients are released to create algal and rooted aquatic plant nuisance growths can be diverted rather than inhibited. In modern waste treatment practices, dissolved inorganic or mineral constituents of municipal sewage and industrial wastes are removed only incidentally by sedimentation and oxidation. Also certain organic materials are broken down, with treatment, to liberate inorganic nitrogen and phosphorus. Treatment plant effluents may actually contain more readily available nutritional substrates than are found in raw sewage effluents. In order to limit the fertilizing effect of sewage and of certain nontoxic industrial wastes, such wastes ideally should be excluded from natural lakes and impoundments. Despite exclusion of nutrient-bearing wastes, agricultural drainage, carrying nitrogenous and phosphorous compounds, will especially provide nutrients that may encourage green aquatic plant nuisances.

It has been shown that, if assets of inorganic nitrogen and phosphorus exceeded 0.30 and 0.01 ppm, respectively, at the start of the active growing season (the time of spring turnover in northern climates), a season with nuisance algal blooms could follow (*17*). This suggestion was made following 2 years of study on 17 lakes in southeastern Wisconsin. While it does not apply to all lakes, it has stimulated other investigations.

The facts today indicate that, with continual nutrient enrichment of waters, algal nuisances have only begun to demonstrate what they may become in future years. Domestic sewage alone may vary in its nitrogen content from 15 to 35 ppm and in phosphorus from 2 to 4 ppm (*18*). In relation to these nutrients, it has been stated: "A large percentage of these fertilizing elements exists in a readily available condition or becomes so during biological treatment or while undergoing stabilization by microorganisms in the receiving body of water. Consequently, it can be reasoned that sewage contains nitrogen and phosphorus in a ratio of about 8 to 1" (*18*). Data on increments of nitrogen and phosphorus from various industrial operations are not at hand but the total contribution of industrially produced chemicals offers many complications to the biochemistry of the water resource.

Specific contributions by agriculture of nitrogen and phosphorus to bodies of water by runoff are not known. However, data provided by the U.S. Bureau of Reclamation points to increments of nutrients in the soil. A 1955 estimate of an average use of fertilizer per irrigated acre in California is 382 pounds, of which 42 pounds per acre are nitrogen and 26 pounds per acre are P_2O_5.

The effects of algal nuisances have long been known to the waterworks field. Algal blooms cause tastes and odors in water, clog rapid sand filters, and form unsightly scums on basins in water treatment installations. In future years, those charged with management of water projects, such as the many multiple purpose reservoirs that are being constructed in this country, are likely to encounter a variety of biological nuisances, especially algal blooms nurtured by nutrients introduced by man. In summarizing information on European lakes, the data suggest the potential biological nuisance that can arise, with time, in our reservoirs (*19*). But little has been published on lake fertilization (eutrophication) to show systematically the effects of nutrients on the lake ecology and on the uses of lake water.

Lake Zurich, Switzerland, composed of two arms connected by a narrow channel, less than 100 years ago is stated to have been clear and clean, supporting trout and whitefish. Since the turn of this century, urban drainage from small communities totaling about 110,000 persons has been discharged to one arm of this lake. Beginning in 1896, algal scums formed that were malodorous as well as unattractive. The lake ceased to be enjoyed for bathing, boating, and general recreation. The cities and industries that used lake water had to install expensive "filtering and purifying systems" to remove the organic matter and overcome obnoxious tastes and odors. Oxygen in the deeper water declined so that trout and one species of whitefish disappeared, and two other species of whitefish became scarce. Other species, largely coarse, replaced the sought-after game fish. The shallower basin, Obersee, which received no urban drainage, is reported to have retained its "virgin-lake" characteristics and has changed but little. Unwitting fertilization not only causes nuisances, but hastens the extinction of a lake by accelerated sedimentation, according to records for 37 lakes in the United States, Austria, England, Finland, Germany, Italy, and Sweden. In these lakes, eutrophication within several decades has entailed disagreeable consequences similar for the most part to the events in Lake Zurich (*19*).

Effects on lakeside dwellers have been well documented for algal blooms on certain lakes near Madison, Wis. Especially during hot summer periods, lakes assume the appearance and consistency of thick green pea soup. At such times, the reaction of bathers, sailors, and fishermen may be imagined. The unsightly masses of green as they decompose, also produce vile odors that make life in the area hardly tolerable (*20*).

Algal blooms have been responsible for massive fish kills by reducing the resources of dissolved oxygen. During daylight hours, algae and submersed aquatic plants give off oxygen by photosynthesis, commonly raising the dissolved oxygen resources to supersaturation levels. But photosynthesis does not proceed during hours of total darkness although respiration continues. In streams with huge algal blooms, dissolved oxygen in these circumstances may be reduced below survival points. In Lytle Creek, Wilmington, Ohio, dissolved oxygen fluctuated over 24 hours from 19.4 ppm in the afternoon to 0.7 ppm before dawn. A fish kill in this creek was attributed to oxygen depletion, largely by algal respiration (*6*). Fish kills under similar conditions have been reported for East Okoboji Lake and Storm Lake, Iowa (*21*), and other such disasters have occurred in the Ohio River Basin (*22*).

Radioactive Wastes

Recommendations as to maximum levels of radioactivity in water or aquatic organisms are outside our province, except for the general acceptance of the principle that any addition to the prevailing burden of radiation should be judiciously considered, and that unnecessary additions be eschewed. Rather than evaluate the effects of given quantities of radioactivity, this discussion is confined to the quality or character of the process by which certain nuclides, through biological adsorption and absorption, are cycled into human food chains, as shown in figure 4 (*23*). By such processes, radioactive atoms are concentrated to relatively high orders of magnitude by organisms living in blooms in natural waters.

Concentration of radionuclides in edible fish and their subsequent lodging in human tissue is readily visualized. Less obvious is the potential transport of radionuclides into human tissues after algal blooms have increased the concentration in raw-water sources. Even though such blooms are caught on rapid sand filters and backwashed to carry them out of the drinking water supply, there remain opportunities for radionuclides to pass through the filters into finished water. As algal cells fragment on filters, they may release atoms in solution in the drinking water. Also, water supplies without treatment other than chlorination can carry algal cells with adsorbed and absorbed radionuclides directly into the drinking water supply.

Davis and Foster have cautioned that the recommended maximum concentrations of radioactivity in water do not in themselves limit the degree of biological concentration: "With an increasing number of atomic energy installations and their associated problems of disposal of liquid wastes, we recognize that more and more aquatic environments are going to be exposed to at least low concentrations of radioactive materials. For the safety of human populations who may be drinking water which contains such radioactive materials, a set of maximum permissible concentrations has been recommended (International Commission on Radiological Protection, 1955). By themselves, however, such recommendations are in-

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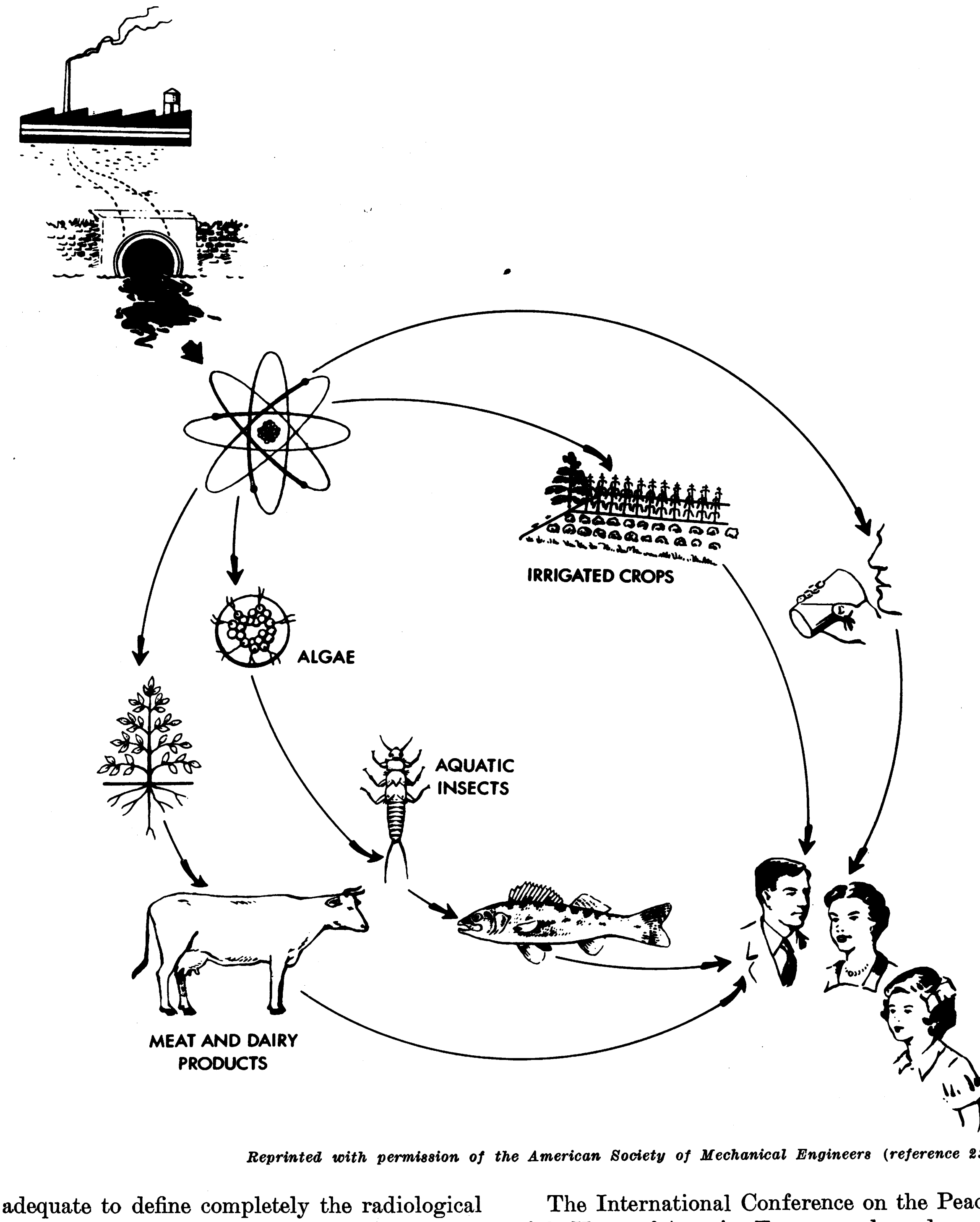
Figure 4. Radioactive wastes from water to man



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adequate to define completely the radiological hazard which may develop through aquatic food chains. Where biological systems are involved, the organisms may accumulate certain isotopes to many times the initial concentrations in the water" (*24*).

The International Conference on the Peaceful Uses of Atomic Energy enlarged upon information pertinent to this discussion (*25*): "Extensive studies have been made of the radioactivity in river organisms below the Hanford reactors, since the radiation levels could not accurately be predicted. Results indicate that concentration of very short-lived isotopes is of limited consequence in higher organisms such as fish. Radiophosphorus, on the other hand, is concentrated more than 100,000 times. Although the P^{32} is highly concentrated, existing amounts in the Columbia River are well below dangerous levels. Even in the most radioactive section, the young fish receive only about 0.1 rad per day from beta emitters—far less than the amount which would produce discernible damage. Both laboratory and field studies of river forms have shown no injurious effects from the presence of the reactor effluent. It is questionable that widespread decimation of aquatic populations will occur from radiation damage in situations where contamination levels in fish must remain below maximum permissible levels for human food. The difference in the activity density of Columbia River fish over that of the water, owing to the tremendous power of aquatic forms to concentrate some radioisotopes, illustrates the need for careful consideration of potential hazards prior to disposal of liquid wastes to public waters. If radiophosphorus were allowed to reach the maximum level permitted for drinking water, organisms living in the water would suffer radiation damage and the fish would be unsafe for human food. The seriousness of radioactive contaminations in an aquatic environment depends not only upon the quantities of individual isotopes which may be released but also upon the physical, chemical, and biological properties of the water. Where contamination of a river or lake may be significant, careful investigation of each particular case is essential since complex biological processes may introduce hazards not included in such conventional limits as permissible concentrations for drinking water."

For the immediate future, increased radioactivity in streams is likely to cause little apparent damage to aquatic life or human welfare. The long-range prospect, however, even on the basis of present burdens of radiation, offers no grounds for complacence or assurance.

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New Index Medicus

The indexing activities of the National Library of Medicine, Public Health Service, and the American Medical Association will be coordinated, according to plans approved by the Board of Regents of the library and the House of Delegates of the American Medical Association. The cooperative arrangement will go into effect in 1960.

Beginning with the January issue of that year, the National Library of Medicine will publish monthly issues only of a new medical index to be called the *Index Medicus.* The American Medical Association will issue annual cumulations of the index, to be known as the *Cumulated Index Medicus.*

Each monthly issue of the *Index Medicus* will contain entirely new material. The coverage of this index will be substantially increased over the present 110,000 to 120,000 articles in the *Current List of Medical Literature.*

After completion of the December 1960 issue, the library will rearrange and realphabetize by machine the contents of the year's 12 issues of the *Index Medicus.* The rearranged material will then be photographed by a high-speed step camera, and the film copy will then be transferred to the American Medical Association for direct use in the preparation of printing plates.

In 1879, publication of a monthly index to the periodical literature of medicine, the *Index Medicus,* began at the National Library of Medicine. In 1916 the American Medical Association commenced publication of a quarterly index to medical periodical literature under the title *Quarterly Cumulative Index.* In 1927 the two publications were combined under the joint sponsorship of the library and the medical association to form the *Quarterly Cumulative Index Medicus.* Since 1932 the medical association has been solely responsible for publishing the quarterly index. With volume 60, covering the period July–December 1956, publication of the quarterly will cease.

Subscriptions for the *Index Medicus* will be handled by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.; the *Cumulated Index Medicus* will be distributed separately by the American Medical Association.