INDUSTRIAL WASTES[1]

Water Pollution

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In one state the pollution load due to industrial wastes is two thirds of that due to sewage. Difficult conditions exist in all industrial regions, and much study has been given to the problem in various countries. Important has been the work of the U. S. Public Health Service, and before the depression the movement towards cleaner streams was well under way. With the depression, progress was retarded but interest is being revived. Streams must be used but not abused. This may require the classification of streams for various uses.

While the study of waste treatment is important and each waste presents an individual problem, the first consideration is the load that the stream can carry—that is, its capacity for self-purification. Treatment must then follow to enable it to meet this load and must be carried far enough to maintain about 4 p. p. m. of dissolved oxygen in streams used for water supply and 2 p. p. m. in others.

Certain wastes, because of their effects upon odor, taste, or aquatic life, require special treatment, but in any event the necessities of the stream should receive first consideration.

With the concentration of industries on both navigable and unnavigable waters, there necessarily follows the use of water for processes and the discharge of waste into these waters. The result is one of the problems of civilization and one absent from the concept of the hunter and the trapper.

That the problem is attracting public attention is shown by the criticisms of conditions on such rivers as the Merrimac, the Connecticut, the Blackstone, the Naugatuck, the Passaic, the Delaware, the Illinois, the Ohio, and many others, and by conditions in New York, Boston, and other harbors. Similar conditions exist in Europe, notably in England, France, Belgium, and Germany.

As early as 1872, the Massachusetts Legislature sent William Ripley Nichols to Europe to study the matters of stream pollution and methods of water analysis. Later he assisted in the studies of the pollution of the Merrimac at Lowell and of the Blackstone at Worcester.

In succeeding years the Massachusetts Board of Health extended the investigation to cover most of the polluted rivers of the state and studied methods for the treatment of many wastes, as described by Clark in 1909 (*7*).

Other valuable studies have been made by various state boards and commissions—for example, those in Rhode Island (*16*), Connecticut (*31*), New Jersey (*14*, *18*), Pennsylvania (*20*, *21*), Michigan (*12*), Wisconsin (*30*), Minnesota (*4*), and Illinois (*32*).

In the last decade and prior to the industrial depression, the widespread studies of the United States Public Health Service, particularly at the experiment station on the Ohio at Cincinnati, described by Streeter, Theriault, Hoskins, and others; the problems of the Sanitary District of Chicago with its large load of industrial waste; the studies of the international waters of the Great Lakes; the work of the Pennsylvania Sanitary Water Board, led by W. L. Stevenson; the work on the Emscher and the Ruhr Rivers in Germany; and in England the work of the Water Pollution Research Board and of the administrative boards controlling the West Riding, Mersey, Irwell, and other drainage areas—all have indicated the strong movement toward the cleaning of rivers and harbors.

[1] The group of papers on pages 1311 to 1380 were presented before the Division of Industrial and Engineering Chemistry at the 98th Meeting of the American Chemical Society, Boston, Mass.

But with the financial depression and the concurrent disabilities of industry, the pressure applied by the sanitary authorities was greatly lessened, and progress towards improvement was retarded in spite of an increasing demand for cleaner streams by the general public and by such organizations as the Izaak Walton League.

But curtailed production was accompanied by curtailed discharge of waste. Now, because industry is reviving, the insistence upon action is becoming more urgent, not only by the recreationists and nature lovers but also by the sanitary authorities. Clean rivers are being classed more and more with beautiful public buildings and parks as goals for municipal striving. The problem is not easy, since it involves the use of streams, on the one hand, and the avoidance of the abuse of them, on the other.

Twenty-one years ago, the writer expressed his idea of the problem as follows (*28*):

> Rivers attract population and population demands disposal of sewage, as well as water supply. On some industrial rivers the prohibition of pollution would so hamper industry that manufacturers would be forced to go out of business or move away; consequently, many rivers must necessarily be used for manufacturing, drainage and water supply. Others may become unfit for water supply and be relegated to drainage and manufacturing uses only. Each stream, in other words, must be used for the best interests of all riparian owners and with due regard for the right and convenience of all.

On handing down the opinion of the United States Supreme Court on the Delaware River Case (New Jersey *v.* New York), Justice Oliver Wendell Holmes stated that "a river is more than an amenity, it is a treasure. It offers necessities of life that must be rationed among those who have power over it."

In no place has the principle of designating streams for particular uses been applied better than in Pennsylvania, where three classes of streams were recognized. In brief, they were:

> I. Those preserved in nearly their natural condition and reserved for water supply.
> II. Those used for sewage disposal after treatment of the sewage, and for water supply after purification of the water.
> III. Those used for sewage disposal after such treatment of sewage and industrial wastes as is necessary to prevent nuisance.

The upper Delaware River is in class I, the middle Delaware in class II, and the lower Delaware in class III.

However, on June 22, 1937, the Commonwealth of Pennsylvania enacted a new law which forbade the discharge of any industrial waste into stream or sewer which "is or may prove injurious to public health or to animal or aquatic life or prevent the use of the waters for domestic, industrial or recreational purposes". Acid mine drainage and silt from coal mines were exempted from the requirements of this law until "in the opinion of the Sanitary Water Board practical means for the removal of the polluting properties of such drainage shall become known".

Obviously this law would go far beyond preventing the abuse of streams and would destroy their use for many. It seems unenforceable because, if taken literally, treatment of a reservoir water with copper sulfate to kill algae would be "injurious to aquatic life" and incidentally might kill a few perch or pickerel and therefore be "injurious to animal life".

Therefore, great need exists for care and judgment, for study by state and federal departments for the control of interstate drainage areas by interstate compacts (which is a better method than control by a federal commission), and for constructive programs not too burdensome for industry.

The United States National Resources Committee has well stated the situation as follows (*27*):

> The essential approach to the problem of ridding stream waters of undesirable industrial wastes lies in the active cooperation of the industries involved, always assuming, however, flexible and reasonably administered water pollution legislation. The problem cannot be settled by abstract studies on the part of government nor by inflexible and arbitrary state or federal legislation. Waste materials are so diverse and so complex that each industry, and possibly each plant, presents a special problem.

Instead of "industries involved", one might well substitute "all parties involved".

Other papers in this symposium are emphasizing the diversity of the problem, the need for research, the importance of recovery of by-products and utilization of waste, and the fact that each case presents a new problem requiring preliminary study before design and involving modifications in standard sewage devices to fit the various wastes. But in any case the necessities of the body of water or the sewerage system receiving industrial wastes are controlling factors.

From a practical standpoint, the questions to be asked regarding a stream are: What pollution load can it carry? What is its capacity for self-purification? Then, and not before, may follow the consideration of wastes to be disposed of and the methods of treating them prior to disposal.

Pollution Load

Here is presented a problem widely different from that of the disposal of domestic sewage because of the high biochemical oxygen demand of some industrial wastes and the character of their ingredients.

Wisely and Klassen (*32*) showed that in the Peoria-Pekin metropolitan area of Illinois the combined human population contributing sewage is 130,000, whereas the industries contribute a pollution load equivalent to more than 1,000,000 people, largely in the form of distillery wastes.

Calvert and Parks (*5*) compared the industrial wastes of Indianapolis; Table I is taken from their figures.

Table I. Population Equivalents of Wastes

Waste	Volume of Work Done	Total Population Equivalent
Laundry	2,800 lb. dirty clothing	668
Creamery	8,000 lb. butter made	736
Dairy	155,000 lb. raw milk received	11,782
Canning	309,700 lb. pork and beans	8,429
Starch	21,574 bu. corn	90,965
Five meatpackers	20,280 equivalent hogs	267,728
Paperboard	102.1 tons produced	5,978
Garbage	72.9 tons green garbage	12,271

The ordinary oxygen demand (B. O. D.) of sewage from American residential communities will average less than 150 parts per million, or 57 grams per capita, whereas the oxygen demand of the industrial waste in an American manufacturing city with separate sewers will usually exceed that of the sewage. The oxygen demand as well as the suspended residue and the oxygen consumed of certain wastes are given in Table II.

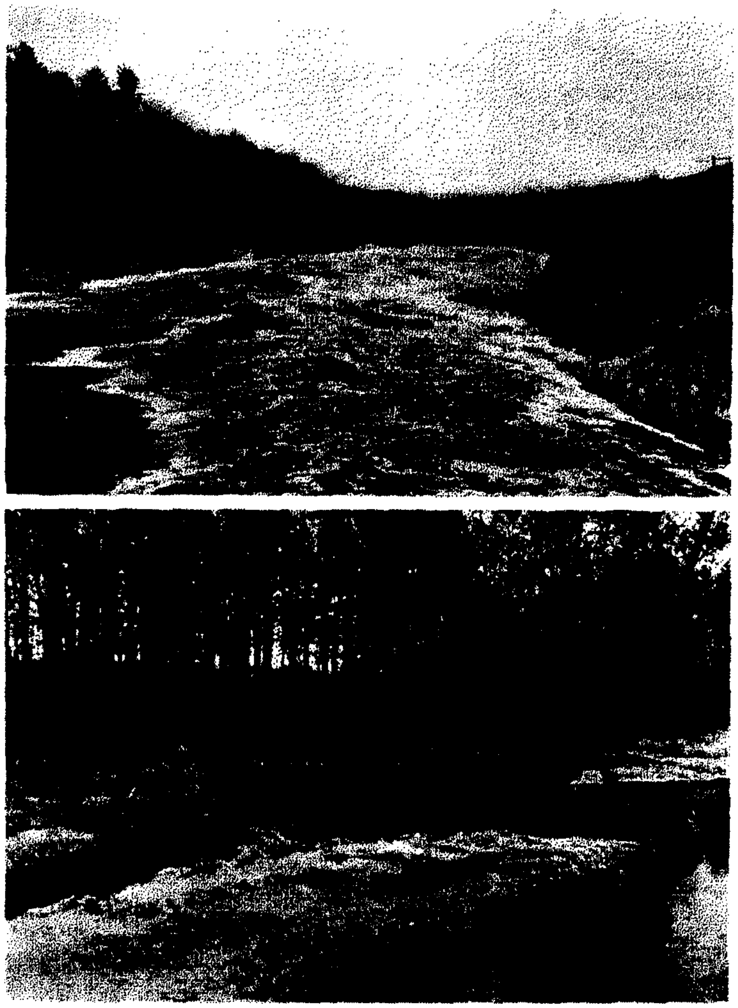
Table II. Oxygen Demand of Wastes

Kind of Waste	B. O. D. (5-day)	Suspended Residue	Oxygen Consumed
	Parts per million		
Mixed caustic and peroxide kier liquor	1241	1,685	2,842
Wool scouring waste, plant A	4464	15,000	7,900
Wool scouring waste, plant C	216	700	230
Tannery waste	5000	5,150	2,000
Paper sizing waste	610	120	236
Sulfite pulp liquor	9000	600	60,000
Paper machine waste	70	1,160	250
Slaughterhouse	600	3,600	356
Creamery waste	1200	....	500

While the biochemical oxygen demand of the waste, the suspended matter in it, and the oxygen consumed by it are all

Right. How Pollution Begins
Below. Floating Scum

Above. Sludge Bank Formation
Left. Befouled Bank



Above. UNPOLLUTED STREAM
Below. DEPOSITS OF PAPER WASTE

important, certain wastes demand consideration because of their individual characteristics:

LIGNEOUS AND RESINOUS WASTES. These wastes, both alkaline and acid, from the digestion of wood, paper stock, cotton cloth, and vegetable fibers, are often low in settleable solids; but they are usually highly concentrated and antiseptic, and therefore resist the natural biological purification of stream waters. Kier and sulfite liquors are among the most difficult of these wastes.

GREASY WASTES. Wool-scouring, cloth-washing, tanning, and meat packing wastes, with their high solids, fats, and organic contents, are potent for pollution and befoul many streams.

HIGHLY NITROGENOUS WASTES from the animal industries include tanning wastes, high in suspended matter and oxygen demand, and slaughterhouse and packinghouse wastes.

HIGHLY CARBONACEOUS WASTES. Industries such as starch, sugar, and glucose factories, breweries, and distilleries discharge wastes which undergo acid fermentation; when concentrated, they halt self-purification and consequently place a great burden upon waters receiving them.

SOAPY WASTES from laundries and textile mills are objectionable to sight and oxidize with difficulty.

ACID WASTES. When acid wastes from mines and metal works are discharged into streams, they may act as coagulants and not only acidify but precipitate the suspended matter from the waters into which they are discharged. Rivers in western Pennsylvania and in West Virginia illustrate this effect.

WASTES FROM GAS AND COKE WORKS may contain ammonia and tar derivatives; even when largely diluted they may impart tastes and odors difficult to remove and thus affect the animal life of the stream. They are particularly poisonous to fish life (*3*, *13*) and the biological units in its food chain.

WASTES HIGH IN SUSPENDED MATTER. These may vary in their effect, as a comparison of sand or silt, on the one hand, with parts of hides or beet sugar factory wastes, on the other, will show.

OILY WASTES are unsightly, sometimes poisonous.

MISCELLANEOUS WASTES may contain arsenic or cyanide. Then there are the highly colored dyehouse wastes which are unsightly although frequently low in oxygen demand.

Many objectionable conditions are due to batch discharges, as from wool-scouring bowls or from dyehouse or tannery vats. In many cases these discharges would be innocuous if they were distributed throughout the twenty-four hours.

Fish are sensitive to alkali and often succumb when exposed to the discharges of calcium hydroxide from tanneries, ammonia liquors, or laundry wastes. Species of fish vary greatly in their resistance to pollution. The introduction of silt into a nonsilt-bearing stream is often disastrous to fish life. This discharge, however, is rarely prohibited by statute, for law makers evidently assume that what a Mississippi catfish can stand a state-of-Maine trout ought to. Suspended matter, like paper fiber (*8*), is not only injurious to fish but may affect oysters also (*10*).

Self-Purification

From the classic studies of Adeney (*1*) in Great Britain and Phelps (*15*) in this country, followed by those of Theriault (*26*), Frost (*9*), Streeter (*22–25*), and others, the laws regarding the oxygen demand factor, the reaeration factor, and the oxygen balance (the main factors of self-purification in rivers and harbors) have been not only elucidated but mathematically expressed.

The progressive changes in the biochemical oxygen demand of polluted stream waters are becoming well known. They are modified, however, by additional pollution, inflow or dilution, sedimentation and absorption, channel scouring, and the presence of an "immediate" or "enzymic" oxygen demand. They are modified by the characters of polluting discharges.

Because self-purification is a combined biological, chemical, and physical process, it is evident that discharges of hot akaline antiseptic wastes, like kier liquor, or those high in suspended matter, like wool-scouring waste, may delay self-purification, first, by inhibitng or destroying the growth of stream-purifying bacteria, and secondly, by forming sludge banks and introducing resistant fats. This delay may last until the dilution of the waste is large.

The significance of sludge beds was suggested by Rudolfs (*17*) in the case of Connecticut *v.* Massachusetts (Connecticut River Case); their purification requirements have been estimated by several investigators, notably by the Public Health Service group, and their requirements under aerobic conditions have been calculated by the experiments of Baity (*2*).

Standards for Polluted Waters

In establishing standards for waters polluted by industrial wastes, it is generally customary to use certain values, such as minimal dissolved oxygen, freedom from accumulating sludge deposits, or limiting bacterial content, all dependent upon the uses of the stream.

These standards range from those of freedom from nuisance to those of suitability for the supply of water purification plants. When industrial wastes are discharged, the physical and chemical loading is more important than the bacterial contents. In the case of domestic sewage, the opposite is often the case.

The oxygen demand of normal sewage in a residential town is about 55 grams per capita, in large individual cities, as high as 150 grams per capita. This means that the discharge of sewage by 1000 people would be equivalent to from 55 to 150 kg. a day.

In 24 hours a fair sized woolen mill will discharge about 70,000 gallons of waste having a B. O. D. of about 9000 p. p. m. This is 2363 kg. daily or the equivalent of the sewage of an ordinary city having a population of twenty-one thousand people.

In some wastes the settleable solids are excessive and may amount to 20 per cent of the volume of waste. Furthermore, the diluting power of streams receiving wastes with high amounts of settleable solids is less than that of those receiving wastes with low amounts. The effect of sludge deposits on fish life is often disastrous, as Hubbs pointed out (*11*).

Because few industrial wastes are of human origin, although some are of animal origin, and because some of the most troublesome ones are sterile when discharged, the chemical criteria are generally more important than the bacterial. However, studies by the United States Public Health Service have indicated that the limit of tolerance for water purification plants employing chemical treatment and chlorination is about five thousand *B. coli* per milliliter.

That our analytical methods are not all-determining is well known. In studying the biology of stream pollution, Claassen (*6*) used schools of minnows for tests, but even these, valuable as they are, show the condition at the time of exposure only, just as chemical tests show the condition at the time of sampling only. This constitutes an argument for integrated rather than for catch chemical samples.

It naturally follows that a study of the plankton of a stream, which is a perfectly integrated index, is of great assistance in the study of pollution and self-purification. For example, the finding of the larvae of caddis flies is an index of tolerable condition, while the presence of blood worms (Chiromonidae) or a fungus such as Leptomitus indicates the opposite.

The amount of self-purification performed by the plants and animals in a stream is not generally recognized, although these factors are substantial. Studies by the M. I. T. Sanitary Research Laboratory (*29*) of the Coweeset River receiving treated Brockton, Mass., sewage showed that the river receiving the effluent lays down a "pollution carpet" containing an abnormal number of organisms, beginning with the lowest forms and ending with the highest; each group appears along with a definite food material.

When the Coweeset River was discharging less than 5,000,000 and was receiving about 2,000,000 gallons per day of sand bed effluent, the most important changes occurred in the first mile of flow. However, the return of this stream to its normal chemical condition was not so rapid as its return to its normal biological condition. Here, as in Europe (*19*), where fish ponds are used for the treatment of sewage, the value of shallow storage in the course of the stream was shown.

In many polluted streams the dissolved oxygen tends to decrease until the excessive growth of animal life which is favored by pollution ceases. The rate of this decrease is usually higher than the normal rate of reaeration of the stream by absorption from the atmosphere, by plant growth, or by both.

Conclusion

The foregoing may serve to introduce the problem of industrial waste disposal. Again we must emphasize the capacity for self-purification of the stream or other body of water and the volumes and characteristics (chemical and biological) of the wastes contributed. Then follows in logical order the treatment necessary to preserve the stream or other body of water for its most useful purpose, whether that be for sewage or waste disposal, angling, shellfish culture, recreation, or water supply. In every case the capacity of the diluting water is the most important factor.

EDITOR'S NOTE. In the discussion which followed the presentation of this paper, reference was made to a recent publication of Mohlman (*12A*).

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