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A RATIONAL EXAMINATION OF STREAM POLLUTION ABATEMENT

By RICHARD D. HOAK

MELLON INSTITUTE OF INDUSTRIAL RESEARCH, PITTSBURGH, PA.

STREAM pollution, from all sources combined, is an extremely complex problem which has expanded gradually, largely through non-recognition of its effects or indifference to them. If it is borne in mind that the amount of pollutive substances discharged to streams has increased almost imperceptibly, in general, over many years, it is not difficult to understand how such pollution has become widespread before there has been a realization of its significance. As pollution abatement involves many conflicting factors it is desirable, from time to time, to re-examine the subject and consider its fundamentals. Numerous technical reports, treatises and results of surveys are in existence, couched in the language of the biologist, the chemist and the engineer. In this article an attempt will be made to discuss some pertinent considerations in the familiar words of the layman.

STREAM FUNCTION

The geological plan of the earth offered streams to carry away the waste products of natural processes. In conducting excess water from the land to the oceans, streams transport such a quantity of mineral and organic wastes that many watercourses support but little aquatic life and their waters are unsuitable for domestic or manufacturing uses without extensive treatment. Streams vary widely from basin to basin in their normal burden of silt, dissolved substances, organic matter and microorganisms, and the restoration of streams to their natural state by the elimination of man-made waste products would, in some areas, result in little practical improvement.

As the country was settled, towns and industries grew on the banks of rivers, for here were highways on which merchants, farmers and artisans alike depended for the transfer of products. The convenient streams also served to carry away many of the wastes of communities. The development of public sewerage systems began in the United States in 1855, and by 1860 17 per cent. of the urban population was served by sewers. This proportion increased to 35 per cent. in 1900, and by 1942 about 87 per cent. of the population living in communities of more than 100 persons was connected to sewers. This development was accompanied by an increase in the volume of industrial wastes discharged to streams. At first the dilution of the wastes was usually so large that nuisances rarely occurred; but as the population became larger and the volume of wastes increased, there gradually developed a conflict over the relative importance of different stream functions.

The important functions of streams have been classified in one large basin as (1) public health, (2) drainage, (3) navigation, (4) industry and (5) recreation. It will generally be agreed that the highest use of a stream is for domestic water supply, but the importance of other uses will depend upon the area in which the stream lies and the relative value of one use over another may change from section to section of the stream. In fact, differences of opinion as to superior use will occur along relatively short stream lengths because each stream user will have a tendency to think that his benefit is the most important. Priority of stream utility can be established only by an impartial engineering, economic and societal survey which will give proper weight to all the factors involved.

Any survey which seeks to establish a basis for the abatement of stream pollution in a given area must take cognizance of existing legal decisions. The courts generally have based their rulings upon an interpretation of the principle of reasonableness, *i.e.,* a riparian proprietor may pollute a stream to a reasonable extent. It has been held that there is no public policy in favor of industrial development which will justify, for the sake of a factory or mill, destruction of the rights of other riparian owners by pollution of a stream. But it has also been decided that a long-continued uniform custom of mill owners and manufacturers along a particular stream may make it a reasonable use for them to discharge their waste and refuse into the stream. In a stream pollution suit a defendant can not escape liability by showing that his business is of great benefit to the public or that the contaminating matter can not be disposed of without great expense; but the courts recognize the importance of business enterprises and they do not overlook the needs of important manufacturing interests nor hamper them for trifling causes. Substantial injury to lower riparian property, however, will not be permitted for the purpose of enabling a new and great industry to flourish. The tendency of the courts to rule upon the reasonableness of a discharge must be kept in mind when waste-treatment plants are planned, because what may be considered reasonable in one jurisdiction may not be so regarded in another.

Natural Purification in Streams

A stream should be looked upon as a natural biological and chemical treatment plant which operates efficiently as long as its capacity is not exceeded. Full advantage of the ability of a stream to purify itself should be taken in evaluating the possible effect of pollution. Many individuals view the discharge of any pollutant whatever as harmful, but moderate organic pollution frequently improves stream ecology (the mutual relations between organisms and their environment) by providing a food supply for the development of aquatic life which would otherwise be absent. On the other hand, there are persons who believe that the capacity of a stream for self-purification is relatively unlimited. These misconceptions have often led to dispute. When a stream is subjected to excessive pollution for a brief period, a much longer time will be required to restore its normal biochemical balance.

Two constituents of natural waters most important in self-purification of streams are alkalinity and dissolved oxygen. The former is introduced mainly by the dissolution of rocks as the water percolates through or flows over the earth, the latter is obtained from the air and from aquatic plants in the stream bed. There are many other natural agencies which affect stream economy, but all are more or less dependent on these two.

Most streams contain natural alkalinity which consists principally of the bicarbonates of lime and magnesia. Stream alkalinity varies widely over the country, from the soft waters of the middle south to the very hard waters of the Midwest. Alkalinity is important because it reacts with acidic contaminants, *e.g.,* acid mine water, and helps to maintain the stream in proper condition to support the growth of the variety of plant and animal life necessary to stream balance. Where the alkalinity of a stream is destroyed by pollutants many beneficial flora and fauna die quickly if the water remains more than slightly acid.

The water in a clean stream is generally saturated with oxygen. Organic wastes, such as domestic sewage, are chemically unstable and have a strong tendency to decompose into simpler substances. If an adequate supply of oxygen is present, the decomposition occurs without creating a nuisance, and, if the waste is discharged to a stream, the stream water must supply the required oxygen. To preserve the normal functions of a stream, however, the organic load must not be allowed to increase beyond a point which would reduce the dissolved oxygen below about 50 per cent. of saturation.

Bacteria which thrive in the presence of air play a prominent role in stream purification, because they feed on unstable organic material, reducing it finally to gases, water and other compounds. The bacterial population of a stream varies directly with the food supply and where the concentration of organic substance increases in the water the bacteria multiply very rapidly. But the bacteria which reduce organic matter inoffensively also require oxygen to live, and as the waste increases and the oxygen reserve is depleted, these organisms gradually die. Finally, where the oxygen demand of the wastes continuously exceeds the oxygen available in the stream, other species of bacteria appear to which oxygen is a poison, and "anaerobic" decomposition begins. Under conditions of putrefaction a stream becomes septic and devoid of all higher forms of life; to restore a stream from this state to normal biological balance requires a long time.

Present Extent of Water Pollution

Somewhat more than half of the country's population is served by sewers, but of the sewage so collected only about 60 per cent. is treated before its discharge into streams, rivers and lakes. The sewered communities produce nearly 6,000 million gallons of waste daily. This large volume of waste corresponds to less than one half of 1 per cent. of the average daily stream flow in the United States; and if it could be equitably proportioned among these streams, it would probably be assimilated without difficulty, but, originating in selected communities, it may be an excessive local burden.

The flow of domestic sewage follows a well-defined pattern and, although its composition will vary somewhat in different localities, depending on mass habits, its contribution to the whole pollution problem can be accurately assessed and its effect can be confidently projected a reasonable distance into the future. The intensity of the pollution arising from the discharge of industrial wastes can not be evaluated in simple terms for the country at large, because such wastes vary widely in quantity and kind not only from industry to industry but from day to day in the same industry. Industrial wastes may consist of organic, inorganic, toxic, acid, alkaline or inert substances or of a combination of several of them.

Although there is no simple standard by which the intensities of industrial wastes can be compared with each other or with domestic sewage, the term "population equivalent" is ordinarily used as the most satisfactory index available. A large number of measurements has shown that the average daily volume of waste produced by one person requires 0.168 pound of oxygen for its stabilization. A determination of the oxygen demand of an industrial waste then yields a measure of its intensity in terms of an equivalent number of persons. Because organic wastes generally cause the most serious stream damage, this index is very useful for appraising the effects of such wastes and for establishing the kind and degree of treatment necessary.

The Ohio River Pollution Survey, recently completed by the U. S. Public Health Service, is the most extensive study of pollution and its effects ever undertaken for a large area in this country. The Ohio River drains 204,000 square miles, an area which has a population of more than 19 million. In this highly industrialized region about eight and one half million persons are served by sewers, but of the sewage so collected only 34 per cent. is treated before discharge. The industries in the basin produce wastes equivalent to a population of almost 10 million, and about 12 per cent. of this waste is treated along with domestic sewage at municipal plants. Measures have been taken to reduce the industrial waste originating in 808 or 50 per cent. of the 1,604 plants in the basin (exclusive of Cincinnati, where individual plant surveys were not made) which do not discharge wastes to municipal treatment works. In other words, some effort is made to reduce pollution intensity at more than 62 per cent. of the industrial plants in the Ohio River basin.

The continuous discharge of acid water from active and abandoned coal mines is an industrial waste problem of great importance. It has been estimated that the daily discharge of acid mine water in the Ohio River valley alone carries free and combined sulfuric acid equivalent to 4,900 tons of 100 per cent. acid, of which about 50 per cent. flows from abandoned mines and most of the remainder from worked-out sections of active mines. The Federal coal-mine sealing project (1935–1938) brought about a reduction of approximately 25 per cent. of the acid originally present in mine water, but it is reported that lack of a maintenance force has resulted in many of the seals becoming ineffective. Waste pickle liquor, the spent acid which is produced in removing scale from steel prior to further processing, is an industrial waste to which objections have been made from time to time. In the Ohio River basin, which contains a heavy concentration of steel mills, the average daily discharge of free acid from this source amounts to about 168 tons. Decomposition of the iron salts dissolved in this liquor slowly produces more free acid upon discharge to streams, but the total acid so introduced is small compared with that from acid mine drainage.

Acid mine water occupies the anomalous position of being an inorganic pollutant and, at the same time, of reducing the immediate effects of organic pollution. Acid water exerts a germicidal effect which inhibits the decomposition of organic matter, and the salts of iron and aluminum it contains coagulate and precipitate organic substances in watercourses. The situation at Pittsburgh, where all the sewage of the community is discharged untreated into the Allegheny and Monongahela Rivers, exemplifies this condition. Here, were it not for the presence of acid mine water and other acidic wastes in the rivers, sewage pollution would create an offensive odor nuisance at Pittsburgh and would seriously overburden downstream water-purification plants. That this situation is against the public interest, however, is evidenced by the fact that during drought periods intestinal disorders have developed in communities below Pittsburgh which depend on the Ohio River as a source of public water supply. Reduction in the intensity of mine acids by flow augmentation reservoirs coupled with effective mine sealing, and treatment of the sewage discharged by Pittsburgh, would be a long step toward the restoration of the Ohio to a healthy condition.

The volume of acid mine water is steadily increasing, and, unless or until the concentration of acid in streams can be appreciably reduced there appears to be no reasonable justification for requiring the elimination of minor sources of stream pollution. Operators of water purification plants, however, can not depend upon the bacteriostatic effect of acid water because during a freshet the acidity may be neutralized and its germicidal action eliminated. A rapid increase in the rate of river flow also flushes out accumulated sludge banks, thereby imposing a still heavier burden on water-treatment facilities.

THE PROBLEM OF WASTE TREATMENT

Waste treatment is a problem alike to municipality and industry. It is expensive and usually yields no by-products of substantial value. Delay in the installation of waste treatment is notable in the case of communities, where the taxpayer appears to receive no immediate benefit from sewage treatment. Federal financial aid acts as a stimulus to municipalities faced with problems in stream sanitation, as demonstrated by the fact that from 1932 to 1938 more progress was made in municipal sanitation than in the previous 25 years.

The treatment of domestic sewage is so well standardized by practice that plants can be installed, if the expense can be borne, for any degree of purification demanded by circumstances. Industrial waste treatment is a particularly difficult problem because standardized processes do not exist for more than a few wastes. The characteristics, volume and concentration of industrial wastes may change, even in the same plant, from day to day, and the variety of wastes is so great that almost every appropriate method of disposal constitutes an individual problem.

Research has been and is now in progress in many industries with the object of developing satisfactory waste-treatment processes. Typical of this kind of research is the current program of the American Iron and Steel Institute, established at Mellon Institute in 1938 for the investigation and development of feasible procedures for eliminating that part of stream pollution attributed to the discharge of steel mill wastes. The paper and pulp industry has initiated a comprehensive research program to develop new methods for processing its wastes and to coordinate the efforts of individual companies in dealing with their particular disposal problems. The leather tanning industry has made a survey of methods being employed to treat its wastes and is promoting the study of improved treatment processes. The food and beverage industries, probably the largest producers of organic wastes, are constantly alert to recognize and adapt new procedures for the disposal of their wastes, which are among the most difficult to treat successfully. In similar fashion other industries plan investigations in disposing of their waste waters. Only infrequently does industrial waste treatment become a profitable enterprise, although in some cases by-products can be recovered which will bear a portion of the cost of processing. Other things being equal, it is obvious that a manufacturer who is required to expend considerable sums for the installation and operation of a treatment plant is at a disadvantage over one who escapes this responsibility.

For some industrial wastes no completely satisfactory treatment process is yet known; others can be handled only at considerable expense. The cost of waste treatment has an important effect on industrial economy, particularly in highly competitive fields, and the operation of acceptable works might result in some manufacturers actually producing goods at a loss. It is clear that where a substantial segment of a community depends upon an industry operating on a small profit margin and that industry is required to install a costly waste-treatment plant the domestic economy of many workers may be seriously affected. This does not mean that the discharge of the pollutants should be universally tolerated, but it does suggest that every major pollution-abatement program be examined scientifically in the light of the net effect on the welfare of the community as a whole. Admittedly it is frequently difficult to balance the value of such an intangible as recreation against family income, but generally a competent and complete survey will enable a just decision to be reached.

The expansion of industry to fill quickly the colossal demands of war has resulted in an unavoidable increase in the discharge of waste waters to streams, just as it has added to air contamination by smoke. This temporary augmentation of pollution by industrial waste has served to emphasize the desirability of treatment as a means of reducing the effects of all forms of contamination.

Public Attitude toward Treatment

The unquestionably plain importance of prosecuting the war with all speed and with all available resources had made it practically impossible to consider the erection of new, or the extension of existing, treatment works. Allocation of materials of construction has been denied except in those apparently rare situations where the wastes could be shown to have a direct effect on public health. Further, the engineering staffs of state departments of health have been much reduced by the requirements of the Armed Forces for qualified sanitary engineers. The consequence of this depletion of public health engineers has been a relaxation in the supervision of existing works and a diminution of opportunities for industries and municipalities to receive advice on their problems.

State sanitary engineers have indicated their intention of adopting an aggressive policy toward industrial waste pollution of surface waters as soon as equipment and personnel again become available for the construction and operation of waste-treatment works. The demands made upon industry by state departments of health are normally reasonable because such agencies weigh the advantages to be obtained against the feasibility and cost of treatment and its economic effect on the industry involved. Primarily, they are influenced by the principle of the greatest good to the greatest number.

In the movement to purify the streams of the country, the desires and wishes of the sportsmen are quite positive. Few persons are unsympathetic with the general objectives of that group, within the limits of feasibility. But it must be remembered that the discharge of wastes is often not the only cause for the disappearance of aquatic life from our inland waters. Due attention must be given to other factors. For example, the temperature of stream water is raised by deforestation and the increase may be great enough to create an unfavorable environment for some species of fish. Clearing hillsides of trees and undergrowth increases the rate at which rainfall runs off the land and this condition results in scouring stream bottoms and the deposition of sand bars, thereby destroying the feeding and breeding grounds of fish. Aquatic fauna are modified as a result of soil erosion which changes the chemical and physical characteristics of streams. Conditions are adversely affected by canalization of rivers, construction of navigation and flood control dams, straightening and rip-rapping of river banks and curtailment of marshy, lateral areas along streams by drainage and channel improvements. Finally, it should not be forgotten that overfishing, even in uncontaminated waters, has been an important factor in the depletion of our aquatic resources.

The average person believes, in a broad way, that pollution abatement is desirable provided it is accomplished at no immediate cost to him. Accounts of pollution damage, particularly fish-killings, are much more newsworthy than stories of pollution eliminated, and the public has little appreciation of the complexity or the cost of a general pollution abatement program. It has been estimated that two and one quarter billion dollars worth of treatment plants, about half municipal and half industrial, would have to be built to correct the major but not all sources of pollution in the United States. If these plants were built, there would be an annual operating and financing cost of about 116 million dollars over a thirty-year period. A program even of this magnitude would not result in the complete elimination of pollution, but, applied wholly or in part, it might merit consideration in evaluating postwar unemployment.

Administration of Pollution Abatement

It is inevitable that a subject as broad as stream pollution should have its political aspects. Various authorities are interested, and pertinent rules and regulations have been promulgated by state and federal agencies. Legislation has been on the scene for a long time, more legislation is being advocated annually. Under certain conditions, loans or grants-in-aid have been available to municipalities faced with serious problems in sewage treatment. While it is not the purpose of this article to deal comprehensively with the many-sided political and jurisdictional questions involved, there is one observation, based upon history, which seems fitting at this time, namely, that legislation alone can hardly be wise enough to provide for an adequate, economically feasible and rational remedy and at the same time preserve the principle of the greatest good to the greatest number of people. Research, education and finance are at least as important as legislation in the abatement of stream pollution. Research and education must point the way, and finance furnish the wherewithal. Without them, attempts to apply mandatory corrective measures are apt to be abortive. Once the many answers as to proper methods of treatment are known and appropriate standards are set to govern the condition of streams in various localities, it may make little difference from whence the authority of administration flows, provided the administration is practicable and equitable.

The Future of Pollution Abatement

There is no gainsaying the fact that the discharge of waste waters into streams imposes a burden upon them which, under certain circumstances, may be undesirable. To hope, however, for the restoration of all streams to a state of pristine purity in thickly settled and highly industrialized sections of the country is probably beyond the realm of practical attainment. In some districts there are sources of contamination, resulting in part from past activities, which have been long established and may not be susceptible to engineering and chemical treatment. They will be factors even though wastes currently produced are rendered harmless.

It has been proposed by some students of the subject that streams be divided into several classes according to superior overall function. Into the first group would fall those streams which have been preserved in nearly their natural condition and to serve as sources of public water supply or for recreation. The purity of such streams is already so jealously guarded by various associations and by state health departments that they are unlikely ever to become contaminated. The second group would include those streams which serve for the disposal of sewage and industrial waste after treatment and for public water supply after purification. This class would comprise most of the streams in industrial areas except those carrying a heavy burden of acid mine water. Long reaches of such streams would provide recreational areas and wildlife refuges because waste treatment would be adequate to preserve a natural stream balance. Many watercourses in this group will have the benefit of additional waste treatment facilities, which are being installed as acceptable treatment processes are developed and money to finance them becomes available. A third group would consist of those streams now heavily polluted and unsuited for public water supply into which wastes might be discharged after treatment adequate to prevent nuisances. Actual stream mileage in this class is relatively small.

The network of streams with which industrial districts are endowed played an important role in our national development and can not be considered apart from their collective function in the overall economy. Over a period of years, contamination increased. Over a period of years, with the finding of feasible methods for the treatment of wastes, contamination should decrease. Chemistry and engineering, through research, have evolved many valuable by-products from former wastes. They have marked a course for industry to follow. With the continuation of research work supported by many branches of industry, there is the hope that reasonably economical processes may be developed whereby industrial wastes may be handled satisfactorily.

OBITUARY

THOMAS FRANKLIN HOLGATE

Dean Thomas F. Holgate, who had long held a distinguished place in American science and education, died on April 10 at the age of eighty-six years. He had been associated with Northwestern University for fifty-two years—as professor of mathematics, as dean of the college, as acting president of the university and as professor and dean emeritus. After retirement from teaching at the age of seventy-five, he continued to live in his home near the campus, maintaining his scholarly interests and participating in religious and civic affairs to the end of his long and fruitful life.

Born in Hastings County, Ontario, on April 8, 1859, he received a bachelor's degree from the University of Toronto in 1884, and a master's degree in 1889. He entered Clark University for advanced study in mathematics in 1890, receiving his doctorate three years later. He accepted a position as instructor in mathematics at Northwestern University in the summer of 1893, and was promoted to a professorship in applied mathematics the following year.

When he came to the Midwest in 1893, the Chicago World's Fair was in progress, and the new University of Chicago had recently been opened. Working with an enthusiastic and brilliant group of young mathematicians—including such men as White, Moore, Bolza, Maschke, Miller and Van Vleck—he took part in major scientific developments. He attended the first International Congress of Mathematicians (held in Chicago in connection with the Fair) and a famous series of Colloquium Lectures by Felix Klein (held in Evanston following the Congress). He was active in the formation of the Chicago Section of the Ameri-