WATER POLLUTION - SOURCES AND REMEDIAL MEASURES

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Introduction

Pollution can be defined as the introduction into a body of water of substances whose characteristics and quantity alter or impair its usefulness or render it offensive to the senses of sight, taste, or smell. It may involve either a surface or underground supply. By definition, the process involves an intermediary whose function is to introduce the pollutant into the body of water. This intermediary is normally man. Pollution may therefore be considered a direct function of population. Historically, population growth and increased pollution have occurred simultaneously.

Since the colonization period, quantities of waste have grown until at present it is not at all uncommon to find that a once sparkling stream has turned into a turbid sewer. Such impairment of water quality has resulted in extensive loss of aquatic life and in the loss of the lives of other creatures using the stream as a habitat or for drinking purposes. In addition, and of utmost importance, pollution has effected a real loss of part of our country's water resources. If the water is so foul that its treatment for public consumption or industrial use is not economically feasible, then other sources of supply must be sought and the polluted body of water can be considered as much of a loss as if it were physically removed from the area.

Today considerable emphasis is placed on the quality of our water resources. This comes in the face of increasing population, accelerated industrial activity, and large scale pollution. Waste abatement operations range from simple technical adjustments to the consideration of exceedingly complex social-political-ecological-psychological problems. A complicating factor is that each pollution abatement problem is different. In addition, the motivations for abatement programs are shifting from the pure health hazard base to an inclusion of aesthetic valuations. As ably stated by Renn (1961), we undoubtedly have more common interests in pleasant living and are less moved by moralistic views. If we don't like dirty water for any reason, we simply don't like it, and we don't argue that it must necessarily be toxic or bad for health. There is profit in offering a more pleasant future and we know it. We take it for granted that we have a right

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to some minutes of leisure, irresponsibility, and beauty without reproach. In fact, a very large fraction of our economy rests on this presumption.

Water Quality

The usefulness of the maximum water supply available to man is determined in large part by its quality. As precipitation, this water is usually quite pure. By the time it has penetrated the soil with its various minerals and rocks and flowed in streams contaminated by municipalities and industries, its quality may be seriously degraded by bacteria, organic matter, dissolved salts, acids, and possibly even radioisotopes.

The drinking water standards set forth by the United States Public Health Service recommend that the total dissolved solids content for human consumption should not exceed 1,000 ppm. The United States Geological Survey states that waters containing more than about 2,000 ppm dissolved solids are generally unfit for long term irrigation under average conditions. This value will depend however, on the elements present, soil type, and tolerance of the crop and may thus vary considerably from the average allowable concentration. Sodium and boron for example, are particularly undesirable in agricultural waters.

a. Ground Water

The quality of ground water is a direct function of the quality of its source. Changes in source waters or degraded quality of normal supplies may seriously impair the quality of the ground water supply. Sewage and industrial wastes entering an aquifer are major sources of pollution. Because it is difficult to introduce large quantities of wastes underground, gross organic pollution of ground waters rarely occurs. Inorganic solutions, however, pass readily through the soil and once introduced, are removed only with great difficulty. In addition, the effects of such pollution may continue for indefinite periods since natural dilution is slow, artificial flushing is expensive, and treatment is generally impractical. Thus, great care should be taken to insure that ground water storage capacity is not irreparably harmed by the disposal of waste materials.

The percolation of water through 6 or 7 feet of fine grained soil is generally considered sufficient to reduce the presence of most harmful enteric organisms below a tolerable level (Hirshleifer 1960). However, as the water passes through the soil, a significant increase in the amounts of dissolved salts may occur. These salts are added by soluble products of soil weathering and of erosion by rainfall and flowing water. Locations downstream from heavily irrigated areas may thus find that the water they are receiving is too saline for satisfactory crop production. These saline contaminants which are introduced by nature (primarily a problem in western parts of the country) are difficult to control because removal methods are exceedingly expensive. A possible solution is to dilute with waters of lower salt concentration (possibly sewage treatment plant effluent) so that the average water produced by mixing will be suitable for use.

b. Surface Water

The primary causes of deterioration of surface water quality are municipal and domestic sewage, industrial wastes (organic, mineral, cooling water), and solid and semi-solid refuse. A municipality obtaining its water supply from a surface body may find upstream users discharging untreated sewage and toxic chemicals in such quantities as to render the stream unsuitable or too costly to treat for use as a water supply. It is significant however, that the waste products discharged by cities and industry can be controlled at the point of initiation. This has been borne out by recent successes in cleaning up such watersheds as the Delaware and Susquehanna in the eastern United States. Effluent treatment is assuming increased importance and today thousands of industrial plants treat their wastes. Chemical and Engineering News in 1956, suggested that the chemical industry alone is spending 50 million dollars a year in new water pollution control facilities.

Some Modern and Future Pollution Problems

While industry and municipalities are accelerating programs to cope with waste abatement problems, the nature and dimension of these problems is also rapidly expanding. MacKichan in 1957, indicated that industrial water use increased 43 percent from 77 billion gallons to 110 billion gallons a day from 1950 to 1955. Total waste volumes discharged by the chemical industry very likely rose even more strikingly during this period. New products such as synthetic detergents, insecticides (DDT), herbicides (2,4D), and numerous others, are contaminating surface and ground waters with the wastes associated with their manufacture. Some of these contaminants are exceedingly difficult to remove from waste waters and many technical problems concerning them are yet to be solved. Thus, although pollution control practices have improved and their application has spread, industrial vitality has produced a whole new spectrum of waste disposal needs. The remainder of this paper will be concerned with a brief discussion of four of these modern and future waste pollution problems.

a. Saline Brine Wastes

Pollution of ground and surface waters by inland desalination plant wastes is destined to become an exceedingly serious consideration as economic desalination becomes a reality. Consider the following excerpt from "Desalination Research and the Water Problem," published by the National Academy of Sciences - National Research Council, 1962.

> "In the long run when man's desalination of sea water approaches the magnitude of natural events, brine disposal will become a worldwide problem. Probably the oceans are now more saline than is optimum for sea life, and most marine organisms are more vigorous in sea water diluted as much as 50 percent. Thus man may wish some day to dispose of his brines in such a fashion as to isolate them from the sea."

Regarding inland conversion processes, the publication further states:

> "The problem of brine disposal from the processing of inland saline waters is much more difficult. If useful by-products are present, the brines can be employed for this. Otherwise, it is probably undesirable merely to return them to the channel or to the original stratum from which the parent water was derived without a careful hydrologic investigation."

In July of 1962, construction of the world's largest brackish water distillation plant was begun at Roswell, New Mexico. The completed plant will deliver one million gallons of pure water to the city of Roswell each day. It will also burden the city with the disposal of about one-third million gallons per day of waste effluent having a dissolved solids concentration of about 100,000 ppm. This amounts to 139 tons of solids per day. Present plans (1962) are for the disposal of the brine waste by solar evaporation in five, forty acre ponds.

Even on such a relatively small scale of water production, the disposal problem is of immense proportions. Of equal significance is the potential pollution hazard by pond seepage which will menace the quality of already saline or borderline ground waters in the area. It is significant that the ponded waste will have no self-purification properties since its constituents are the simplest of inorganic compounds. This, combined with the prospect that the operation may be continuous for many years, indicates the seriousness of the problem. The pollutional aspect of ponded brine wastes relates directly to the possible impairment in quality of agricultural waters and thus to the amount and kind of salts in the water. A measure of potential sodium hazard may be had by computing the sodium-adsorption-ratio (SAR) defined below,

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{\mathrm{Ca}^{++} + \mathrm{Mg}^{++}}{2}}}$$

where ion concentrations are expressed in milliequivalents per liter. The higher the SAR, the greater the potential Sodium hazard from using the water. An indication of how the SAR can be used as a pollution index is presented below using Roswell as an example.

The United States Geological Survey (USGS) indicates four classes of waters with respect to sodium hazard. These are low, medium, high, and very high depending upon the specific conductance and SAR. Using this classification and values of specific conductance reported by Dregne (1954) for several Roswell waters, a value of about 7 is determined as the SAR separation point between medium and high harzard waters. Designating this as a desirable upper limit (the pollution index), a determination can be had of the effect of brine seepage on waters in the disposal area.

From data reported by Hantush (1957), it is estimated that the rate of water movement in the area of the proposed site is 303 gallons per day per foot of aquifer. Seepage from the ponds will be assumed at a rate of 0.03 cubic feet per square foot per day (a minimum value reported by Koenig (1958) for seepage from sealed canals). Using the data and average values of calcium, magnesium, and sodium concentrations reported by Dregne (1954) for Roswell, New Mexico, well waters, and Office of Saline Water figures for the plant feed water, SAR values before and after the advent of seepage can be estimated. These estimated values are as follows:

a. SAR (before seepage) = 6.8

b. SAR (original ground water mixed with seepage) = 7.2

This prototype problem illustrates how an increase of 6 percent in SAR would result from seepage. It also shows how the SAR is increased to a value above the designated pollution index. Thus, it can be seen that even for seepage rates which are currently considered low for canal losses, brine pollution might easily result.

Since the pollution problem stems from the potential increases in salinity of a ground water or surface water source through seepage from brine ponds, it is imperative that seepage rates be significantly less than the best figures currently indicated for satisfactory seepage losses from irrigation canals. A careful study of seepage losses from brine ponds is thus necessary and may indicate that chemical sealants, liner materials or means of collecting the irreducible minimum of seeped liquor will be required if pollution is to be prevented.

b. Heat

Many of our country's surface water courses are experiencing rising temperatures due to the increasing use of water for cooling purposes. This is a direct result of the necessity for disposal of waste heat by industrial operations such as steel mills, steam electric power plants, petroleum refineries, and paper mills. Unfortunately, the effect of heat discharge on stream temperature is generally most severe during summer periods when river flows are often low and demands for cooling waters high.

Increased temperatures can make water sources less desirable for municipal, industrial, and recreational uses and can have fatal effects on various forms of aquatic life. The Aquatic Life Advisory Commission of the Ohio River Sanitary Commission (1956) states that fish kills may result from sudden temperature increases, from short periods of lethal temperature, or from prolonged periods of sublethal temperature. This stems from the fact that the amount of dissolved oxygen in a stream decreases significantly as temperature rises while at the same time oxygen requirements increase. In addition, it has been shown by Klein (1957) and others that biochemical reactions using oxygen proceed at an accelerated rate at higher temperatures. Harmful effects of compounds toxic to fish also increase with rise in temperatures.

Although Sanders and others (1962) have shown there are records of extreme thermal loads in a few streams, heat discharges are only now beginning to emerge as significant problems. The Federal Government has no guides for regulating heat discharges and only a few States have tried to legislate the problem by setting maximum allowable temperatures. In addition, there is as yet little uniformity or agreement on what the temperature limits for receiving bodies of water ought to be.

Increased heat loadings which are expected to develop through future industrial expansion can cause a serious deterioration in the usefulness of many water supplies.

Estimates prepared for the Senate Select Committee on Natural Water Resources indicate a sixfold increase in cooling demands by the year 2000. Although the effect of heat discharges on the temperature of receiving waters may be somewhat mitigated by low flow augmentation projects during critical summer months and through increased use of cooling towers and spray ponds, substantial increases in temperature of surface bodies of water may be expected in the future. Extensive State and Federal regulatory activity is also certain to follow. Regulations limiting the temperature rise of a stream may become a controlling factor for industries selecting plant sites, deciding on expansion of existing facilities, setting production schedules, and estimating the need for evaporation facilities.

c. Synthetic Detergents

The increasing use of synthetic detergents in household and industry is creating problems in maintaining potable water supplies. Because detergents are not successfully removed by most sewage treatment operations, their concentration is steadily increasing in many of our water courses. Babbitt (1962) and numerous others have shown that synthetic detergents cause foaming; affect the taste and odor of water; make coagulation, settling and filtration more difficult; increase the difficulty of iron and manganese removal; increase the difficulty of regeneration of base exchange materials; may produce physiological reactions such as nausea; are toxic to tropical fish; cause increased corrosivity; and deteriorate the quality of water in distribution systems. They also possess the ability to destroy bacteria and other living organisms some of which are important to biological treatment operations.

Indications are that detergents persist in stream waters for considerable periods and may thus adversely affect coagulation processes in water treatment plants far downstream. There are also indications that detergents may affect results of tests such as the test for biochemical oxygen demand. Solutions to many of the problems created by synthetic detergents are not yet available and a great need exists for the development of procedures for the removal of these substances from our waters.

d. Radioactive Materials

Although radioactive wastes from nuclear power plants, hospitals, research laboratories, and chemical plants processing reactor fuels are not at present a major problem in the United States, nuclear operations may some day become common enough to make radioactive waste pollution a primary source of concern. Numerous major cities are currently monitoring their water supplies to make certain that radioactive contamination does not exceed safe or tolerable levels. This is important since only minute quantities of radioactive wastes can be discharged into surface or ground waters without danger of creating a health hazard.

There are several important differences between radioactive wastes and other common municipal and industrial wastes. Ackerman (1959) states that these differences appear in the degree of toxicity of the contaminants, the rate at which they can be naturally purified in streams, the methods for removal of wastes from plant effluents, and the final disposition of the removed waste materials. In all of these respects, radioactive pollutants are a substantially more serious and difficult problem than wastes previously or presently discharged into receiving waters.

Partial removal of radioactive materials may be had by the common operations of coagulation, sedimentation, and filtration. Straub (1951) also lists the following methods: evaporation, ion exchange (including natural clays), electrodialysis, metallic displacement, solvent extraction, electrolytic separation, biological processes, and crystallization. Removals up to 80 to 90 percent can be expected but these may have little significance from the health point of view because residual radioactivity may still exceed tolerable levels. In addition, the removed radioactive materials are still retained in the treatment plant or discharged in increased concentration in the plant waste effluent.

Without doubt, considerable future effort must be directed towards public control of radioactivity in streams and ground waters. An increasing need for knowledge related to measurement, physiological effects, and methods for reduction of radioactivity in waters is thus of utmost importance.

Conclusions

Waste abatement problems are increasing daily in number and complexity. Pollutants such as synthetic detergents, brines, heat, insecticides, herbicides, and radioactive substances are assuming increased importance. Solutions to many of the modern pollution problems are yet to be obtained and can be developed only through concentrated research efforts. An additional problem results from the fact that even when abatement methods are available, it is not always easy to institute them. As stated by McKee (1960) "There's no great technical or engineering block to building more waste treatment plants. The trouble is getting people to vote bonds. Water issues pass, but sewerage bonds are tough; particularly when it takes a two-thirds vote." Nevertheless, progress is being made and today, without question, man is becoming more aware than ever before of the importance of achieving and maintaining a satisfactory quality in his water resources.

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