AUGMENTATION OF WATER RESOURCES THROUGH POLLUTION ABATEMENT

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Few of us in the eastern part of our country, where water resources are fairly abundant, stop to consider the real value of a safe, potable, water supply. Because we have safe water at the turn of a tap, we do not realize the problems faced in some other areas of the world or the consternation that would result if our water supply were disrupted. Water has been so abundant that we have not realized its intrinsic value. Along with soil, air, and sunlight, it is one of our basic resources. All living things contain a high percentage of water and require a constant supply; water is basic to all life. Potable water, therefore, is worth whatever we have to pay to get it. If we continue our present practice of discharging untreated or partially treated wastes to the same streams which we take our drinking water the cost in the future will be high.

In the past our water resources were considered by many to be inexhaustible. Water shortages in New York City, Texas, Kansas, and other portions of the country have clearly demonstrated, however that the supply is not inexhaustible and shortages can and do occur. The increase in population and the accompanying increase in industry are adding an ever-increasing flood of wastes to our streams and lakes. These wastes tend to reduce the available supply of usable water just at the time when more is needed. Thus, we have the double-barrelled action of the need for a greatly increased water supply and a concomitant destruction of our usable water by pollution. The gross pollution of a water may virtually

destroy the value of that water for other uses. We have had great success in making our water safe bacteriologically, but viruses and dissolved materials present problems that have not yet been solved. Synthetic organic materials and those producing tastes and odors in water also cause problems that need solution.

THE PROBLEM

Our problem is to provide enough usable water to maintain our way of life. Recently there has been a great awakening of interest in our water resources. Only a few years ago, the conservationists stood almost alone in the campaign for the preservation and restoration of our aquatic resources. For many years they stressed the value of grass cover and forests to prevent run-off and erosion and to augment seepage water. It is well known that the various federal and state conservation agencies have been very active in the control of fire, erosion and grazing, the protection and planting of forests, and the promotion of good agricultural practices. Unwise agricultural practices and over-grazing have been outstanding causes of soil erosion, increased run-off, and decreased stream values.

There is a much greater and wider appreciation of the value of water resources now than formerly. Recently many committees, groups, commissions, and agencies have been created to work on plans for water conservation and the management of water resources. Consideration is being given to the sociological, the economic, and the political implications of the problem. As scientists, we need to devise means to maintain an adequate and suitable supply of water for each of the constantly growing, necessary or desired, uses.

Because it is dependent upon rainfall, our supply of fresh water is relatively fixed. As yet, there are no economically practical methods of increasing it. We have heard a great deal about the conversion of sea water to fresh water by various methods. Many people feel there is no need to worry about our water supplies as there is an unlimited supply in the oceans and that it will be only a matter of time until we devise methods for producing fresh water from sea water at a cost comparable to that of fresh water. Such methods probably will be developed in the future. However, the amount of water needed and the transportation of this water to the areas in which it is needed are important considerations. Purified sea waters may be used in the future to supply coastal areas but its use is entirely impractical, at present for supplying inland areas. During low water stages in many areas we are using *total* stream flow at least once. To supply inland areas with a sufficient quantity of purified sea water, the direction of flow of our streams would have to be reversed; this, of course, is impractical. If this approach is to be used, it is more practical to develop methods for converting sewage and other waste waters to usable water at the point where it is to be used.

At present the best method of increasing our water supply is to reuse our fresh water over and over again. Under our present system, this is often impractical because of the great and unknown assemblage of materials that have been added to the water by those who use it for a variety of purposes. Serious pollution is tantamount to the destruction of a water supply. Thus, for the effective use and reuse of our water supplies pollution must be controlled. Effective reuse requires each user to return his waste water to its source in such condition that it is suitable for other desired uses.

The effective and efficient treatment of waste waters is dependent upon a knowledge of the water quality required for each use. Without such knowledge the objectives of pollution abatement or waste treatment are unknown. We must know the water quality required for each of the desired uses before we can detect and evaluate pollution, define for the general public the need for pollution abatement, furnish the basis for uniform pollution regulations, and define requirements for pollution abatement that will be upheld in the courts of law. Some research is now underway but an expanded and continuous program is essential to determine water quality requirements for all the various desired uses.

CURRENT RESEARCH

State Sponsored Research

Efforts to abate sewage pollution, especially as it is related to human health, began in the last century. Since the turn of the century, better organized and more effective programs for the abatement of pollution have been carried on by a variety of governmental agencies. State health and conservation departments entered the field at an early date and have been assisted and supplemented by state water pollution control boards. State conservation and fish and game departments have carried on investigations and research directed toward the prevention of kills of fish and other aquatic organisms.

The Ohio Department of Natural Resources has a very vital interest in the protection and restoration of water resources. The Division of Water carries out the inventory of water supplies and the investigation of water quality. This Division has collected data on acid mine wastes and has made an inventory of the problem. The U. S. Geological Survey works through this Division in its water quality studies. The Ohio Division of Wildlife has investigated fish kills and is the agency most interested in the protection of aquatic life. This Division has carried out surveys in several areas, including the Raccoon Creek acid mine waste survey. (Clifford and Snavely, 1954; Moulton, 1957). Life history and management studies routinely carried out by the Ohio Division of Wildlife furnish information on the habitat, distribution, and abundance of fish which is of value in determining the environmental requirements of fish and other aquatic organisms. The Division now has a cooperative agreement with the State Water Pollution Control Board under which it lends a man to the Board to cooperate in pollution work and coordinate activities. This man works with the Division of Sanitary Engineering of the State Department of Health, which carries on routine activities in water supply, waste treatment and water pollution abatement. They have made stream surveys on the Cuyahoga, Scioto, Miami, Maumee, Muskingum, and Mahoning rivers.

ORSANCO Studies

During the past 15 years several interstate compacts have been formed for the abatement of water pollution. Prominent among these is the Ohio River Valley Water Sanitation Compact commonly known as ORSANCO. This eight-state group has been very active in the abatement of pollution in the Ohio River. In addition to making surveys, ORSANCO has sponsored several investigative projects in educational institutions that have been financed with grants received under terms of Public Law 660 (Ohio River Valley Water Sanitation Commission, 1960). Among these are the following:

1. The Acid Mine-Drainage Study carried out by the Engineering Experiment Station of The Ohio State University. The purpose of this study was to assemble and evaluate findings and data available from mine drainage research projects, to determine gaps in knowledge, and to indicate where future research might prove fruitful.

2. The Aquatic Life Resources Survey of the Ohio River carried out by the Biology Department of the University of Louisville. This group has studied fish populations to determine the species present and their relative abundance. They have made some limnological studies that will be valuable for indicating conditions in the river before the construction of larger dams, and have studied also the local effects of certain pollutants and the tainting of fish flesh by various materials. In addition the Biology Department of the University of Louisville is conducting studies on the uptake and accumulation of radionuclides in the biota.

3. A continuing surveillance of aquatic life in the Ohio River by the Potamological Institute of the University of Louisville. This is a unique organization

in that it is the only one of its kind in the country studying the biology of a large river. It is hoped that this organization will grow and will receive the backing needed for effectively accomplishing its mission. At present, phytoplankton determinations are being made in the river at Louisville, and these have demonstrated considerable variations in the plankton in a cross section of the river. Year-round studies of environmental conditions in the river also are being made.

Public Health Service Research Grant Program

Studies are being carried out at seven Ohio colleges and universities with research grants from the U. S. Public Health Service's National Institutes of Health. At the Case Institute of Technology two projects are under way. One deals with "Growth Stimulation of the Methane Bacteria" and another with "Growth Factors in Biological Treatment of Wastes." Kenyon College has a study to determine the ions in wastes and water. The Ohio Agricultural Experiment Station at Wooster is investigating treatment of farm pond waters to make them suitable for domestic use. Two projects are being carried on at The Ohio State University; one deals with the physiology of those aquatic bacteria which are important in acid mine waste problems, and the other with the microbiological aspects of farm pond water supplies. The University of Cincinnati has a project to study foam fractionation with reflux and another project on continuous measurement and recording of BOD data. The total funds granted for these projects are about $89,000.

The research grant programs of the U. S. Public Health Service are nationwide, and considerable amounts are awarded for specific research projects. In 1960, 130 awards, totaling $1,668,776 (U. S. Public Health Service Research Grants in Water Pollution, 1960), were made mostly to colleges and universities to promote research in water pollution control. The National Science Foundation also has a research grant program and has supported studies on water pollution.

Federal Investigations

Several federal agencies are conducting investigations and research that are of practical value in the abatement of pollution. The Geological Survey has for many years measured and recorded stream flows. Gauging stations have been set up on all principal streams and many tributaries. Stream flow data provided by these studies are of great value in meeting pollution problems. The Geological Survey also carries out extensive ground water investigations and studies on water supply and water quality that furnish much needed data. The U. S. Army Engineers, in connection with their regular activities, conduct survey-type studies and other detailed studies of water supply, stream flow, and the effects of impoundment.

For many years the U. S. Fish and Wildlife Service and its predecessor, the Bureau of Fisheries, has carried out studies on the life history, habitat requirements, ecology, population, and management of aquatic organisms. Much of this data has direct application in the evaluation and solution of pollution problems. The Service also has conducted studies on the environmental requirements of aquatic life that have direct use in the establishment of water quality criteria. The outstanding work of Dr. Ellis in this field is widely known. The Service is continuing life history and ecological studies and, in addition, is carrying out studies for the discovery of specific fish toxicants for population management. The Denver Laboratory of the Service is studying the effects of pesticides on aquatic life (Bureau of Sport Fisheries and Wildlife, Pesticide–Wildlife Review, 1959), including the toxicity of these materials to wildlife, their concentration in the bodies of fish and game, their long term effects on reproduction, and the effects of various modes of application in the field. Studies have been made on the effects of oil pollution in estuaries and coastal waters with special reference to fish, shellfish, and aquatic birds.

The U. S. Public Health Service has been a leader in water sanitation for many years and became directly concerned with stream pollution in 1912. Early investigations, which began in 1914 at the old Third and Kilgour Laboratory in Cincinnati, are now classic. Pioneer studies by Purdy, Butterfield, and Ruchhoft are internationally known and furnish the basis for much of the work now carried on throughout the country. In 1948, with the passage of the first national water pollution law, the activities of the Public Health Service in this field were broadened and made more intensive. At the present time, the legal responsibilities of the Service in water pollution are carried out by the Division of Water Supply and Pollution Control. Research in water supply and pollution control is being carried out at the Robert A. Taft Sanitary Engineering Center by the Division's Research Branch. A wide variety of problems are under investigation through a diversified research program. These studies are described under two main headings.

Water supply studies.—Many and varied water supply studies are under way at the Taft Center. Studies of domestic and municipal water supplies are being directed toward the development of improved procedures for the recovery, measurement, and evaluation of organic contaminants in finished water supplies. Studies also are being made of the persistence and toxicity of chemicals in surface and ground water supplies with special reference to detergents, pesticides and other synthetic organic chemicals. Special efforts are being made for the improvement of water treatment methods. Equipment has been devised and tested to provide small water supplies for individual homes. Investigations directed toward the reduction of evaporation from open water surfaces have been carried on for a number of years. Pathological studies have received special consideration, and a number of investigations are in progress bearing on the role of water supplies in the transmission of viral diseases. Efforts have been made to develop rapid methods for the counting of bacterial indicators of contamination. Studies also are under way for determining the significance of protozoal and metazoal organisms in water.

With the increase in human populations and the resulting increase in organic materials in our streams, the problem of nuisance organisms, i.e., those causing taste and odor, filter clogging, growths and infestations in distribution systems, is assuming ever increasing importance. It is expected that problems due to nuisance organisms will become more widespread and serious in the future. Studies therefore are being undertaken to identify, enumerate, and control nuisance organisms. Algae have been grown in pure culture to determine whether they produce taste and odor, and studies have been carried out to identify the odoriferous material. If these studies are successful it may be possible to remove such materials in the coagulation chamber of water treatment plants. Screening studies have been carried out that have as their objectives the discovery of specific algicides, the reduction of treatment costs, and the protection of important fish food organisms. Physiological studies have been made to determine the effects of various environmental conditions on algae and their photosynthetic activity. The problem of infestations in finished water supplies and in distribution systems is under investigation also.

Extensive studies in waste treatment are being continued. Investigation is under way to determine the behavior of specific organic chemicals in biological treatment processes such as activated sludge plants and trickling filters. For a number of years studies have been conducted to determine the effects of heavy metals on sewage treatment processes and their accumulation in sludge. Extensive investigations have been made of the role and value of sewage stabilization ponds to evaluate the fundamental factor in such waste treatment methods. The use of fungi in waste treatment is receiving continuous attention. A special research project has been set up for the determination of methods for adapting or obtaining

microorganisms to degrade specific organic wastes. Studies also have been made to convert waste organic materials into useful products by means of microorganisms.

Present sewage treatment methods are not adequate to meet future problems. In several areas the effluent from so-called complete-treatment plants has caused serious trouble in receiving waters. Tremendous algal blooms have resulted and it is evident that the mere breaking down of organic wastes and the release of nutrient salts, CO_2, and other materials to receiving streams is not the answer. When broken down to nitrates, phosphates, CO_2, and other materials, these wastes serve as fertilizers for the rapid development of algal populations. Advanced or tertiary waste treatment therefore is needed for the removal of these materials.

Water pollution investigations.—At the Robert A. Taft Sanitary Engineering Center a wide variety of research projects are directed toward the solution of water pollution problems. Extensive studies are being made of land drainage as a factor in stream pollution. The studies include the effects of fertilizing elements, silt, pesticides, and other materials that are washed into the stream from the land areas. These pollutants differ markedly from such conventional pollutants as sewage or industrial wastes, which enter the stream from a point source, in that they enter the stream from the whole watershed; thus any effective control must be applied either through control of erosion on the watershed or through control of the kinds and amounts of materials, such as pesticides, that are applied to the watershed. Chemists at the Center are actively engaged in the classification of wastes and the development of methods for forecasting the pollutional effects of various groups of chemicals.

The toxicity of industrial and other wastes has long been an important problem. Bioassay methods for the determination of acute toxicity of wastes to fish have been developed and tested and are now contained in the Eleventh Edition of "Standard Methods for the Examination of Water and Wastewater." Extensive bioassay studies have been made on a large variety of wastes and long term studies are under way to determine concentrations of wastes that are not harmful under conditions of continuous exposure. Recently, investigations were completed on the toxicity of ten chlorinated hydrocarbons and thirteen organic phosphorous pesticides to four species of fish. Physiological, histological, and histochemical studies are under way to determine the effects of sublethal concentrations of various industrial wastes and certain other materials on fishes and other aquatic organisms. The purpose of these studies is to discover the maximum concentrations of important waste materials that can be present in our waters without causing damage to aquatic biota under conditions of continuous exposure. They also are directed toward the development of application factors that can be used with the results of short term bioassays to indicate safe levels of toxicants in a specific section of a stream. Studies also have been made of biological indicators of pollution and their role and value in indicating the severity and extent of stream pollution and the degree of stream recovery.

In the field of aquatic biology, the greatest effort is directed toward the determination of environmental requirements of aquatic life. Such data are essential for the establishment of water quality criteria for the protection of aquatic life. Studies are under way on oxygen requirements of fish and aquatic insects and the effects of temperature, pH, CO_2, and other environmental factors on oxygen requirements. The effects of different oxygen concentrations on feeding, growth, activity, and the development of fish eggs and fry are being studied also. Artificial and experimental stream studies are being made to determine various levels of productivity and the effects of organic materials on slime growth and stream productivity. Special studies are under way to develop methods for determining HCN in water and waste water containing complex cyanides and for determining the toxicity of the undissociated HCN molecule to fishes. Extensive studies are in progress to determine the toxic constituents of paper-mill wastes and their effects on stream-

bottom growths. Investigations have been made in the laboratory and in the field on the tainting of fish flesh; recently, special studies under controlled conditions have been made on the tainting effects of outboard motor exhaust materials.

DISCUSSION

Water quality criteria are essential for the protection of the aquatic biota, both marine and fresh-water. Without these criteria, there can be no effective pollution control. Such criteria will indicate the environmental conditions that must be maintained in receiving waters if the aquatic life resource is to be protected. These conditions are attained by developing and maintaining standards for the quality and quantity of effluents.

When determining water quality criteria, the only consideration should be the needs that must be met. The criteria must define clearly the quality of water required for the use in question. Economic considerations will be met by water pollution control boards and other agencies through determining what use or uses will be given precedence in a particular stream or stream section. Water quality criteria, if carefully developed and backed up by adequate data, will probably be accepted by the various states and uniform regulations may be developed. Under such uniform regulations special groups would no longer be able to obtain from a state or other organization concessions in waste treatment at the expense of the resource simply because of their desire to obtain an industrial payroll. Uniform regulations would be of benefit to industry in that they would indicate, in advance, the requirements for treatment of wastes. Such criteria would inform the public of the true needs in pollution control and thus enable public opinion to be a more effective force for pollution abatement. A clear definition of what constitutes pollution would permit more effective enforcement of pollution control regulations in courts of law. Such criteria, even though some of them must at present be set on a tentative basis and new ones established as our studies progress because we cannot determine beforehand the toxicity of new wastes, would enable us to utilize knowledge as it is acquired for the preservation of the aquatic resource. Our aquatic resources are of great value as food supplies and as a source of recreation. They are well worth our best efforts for their maintenance and restoration.

SUMMARY

Our basic need is an adequate supply of usable water. Since the supply is controlled by rainfall which is not subject to significant augmentation, our approach must be the reuse of existing supplies. This requires that water used for various purposes shall be returned to the receiving water in a condition suitable for other uses. In order to do this we must know the quality required for each use. Therefore, the key to effective and efficient reuse of water is the establishment of adequate water quality criteria. Without such criteria the objectives of pollution control or waste treatment are unknown. The establishment of water quality criteria is a direct, logical, and effective approach to the problem and should be the first consideration in a pollution control program. Without clear-cut objectives, we cannot effectively and efficiently detect, evaluate, and abate pollution. In the past, there have been surveys and resurveys but the results of many have been only partially used or not used at all. The study of treatment methods is valuable and necessary, but to be really effective we must first establish water quality criteria.

As the result of surveys, resurveys, and research not directly applicable to the solution of the problem, or research directed along lines not having first priority, conservationists have tended to turn away from research. Many have come to regard suggested further research as an excuse for doing nothing or for delaying the actual meeting of the problem.

Actually, however, there is a great dearth of information on the environmental

requirements of aquatic organisms. Without the information we cannot establish water quality criteria to protect our aquatic life. Our present efforts in this field of research are inadequate to meet the problem. An adequate well-directed research program is essential.

LITERATURE CITED

Bureau of Sport Fisheries and Wildlife, Pesticide—Wildlife Review, 1959. 1960. United States Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Circular 84.

Clifford, J. E., and **C. A. Snavely.** 1954. Studies of acid mine waters with particular reference to the Raccoon Creek watershed. Battelle Memorial Institute, Columbus, Ohio.

Moulton, E. Q. 1957. Acid mine drainage problems in Ohio. Engineering Experimental Station, The Ohio State University, Columbus, Ohio.

Ohio River Valley Water Sanitation Commission. 1960. Chronicle of the Twelfth Year—1960.

United States Public Health Service Research Grants in Water Pollution, Complete list of grants awarded in Fiscal Year 1960. Mimeographed Report.