Water, Sewage, and Industrial Waste Research Trends and Needs

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ALTHOUGH the problems of sanitation are as old as man, scientific research in the water and sewage field is relatively new. It is a field in which the States have historically taken a leading part. The establishment of the Lawrence Experiment Station as a part of the Massachusetts Health Department in 1886 marked the beginning of the science of sewage disposal in the United States. Since those early days, similar experimental work has been undertaken by many of the other States.

It is appropriate that the States should continue to have a major role in this field. They have the knowledge of the factors in their own environments—climate, health, natural resources, economic conditions, industrial and other relationships—that is necessary for the most effective research on problems relating to their own individual concerns. In addition the States are the best laboratories for trying and testing new sanitation developments, prior to adoption on a broader or even national scale.

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This paper is based on material presented by Mr. Wieters before the Texas Water and Sewage Research Foundation at Austin on November 10, 1952.

Volume of Research

A complete listing of current research projects is not available. However, on the basis of information assembled from several sources (*1–3*), it appears that between 150 and 200 projects currently in progress in the States directly concern water supply, sewage treatment, and pollution control and about 100 additional projects deal specifically with industrial waste. Most of these are being conducted by college and university laboratories, and the rest by State organizations, technical associations, or private research institutions. Some of the projects are being supported in part by Federal grants, principally from the Public Health Service and the Atomic Energy Commission, with a few from the United States Bureau of Mines, United States Geological Survey, United States Army, and others. Many additional investigations on industrial wastes are, of course, being conducted by individual industries.

Even on the basis of admittedly incomplete information, it is apparent that in more than three-fourths of the States some research activity is under way in either the water and sewage or the industrial waste field. The extent of this activity ranges from 1 project to more than 25 separate studies in a single State.

The Federal Government has been an important factor in certain broad areas of research, either by conducting investigations in its own laboratories or by contributing largely to their support in the facilities of universities, States, industries, or private institutions. Such studies include those related to military developments and electronics; those concerned with the public domain, mineral resources, agriculture; a considerable part of health research; and other broadly based, long-term investigations in the purely theoretical area. The advances in fundamental knowledge stemming from basic research makes possible the applied and developmental progress in problem areas.

Public Health Research

In the public health field, systematic and continued scientific investigation as a recognized function of the Public Health Service began at the turn of the century, although some research was conducted as early as 1891 in the somewhat makeshift facilities of the Hygienic Laboratory. In 1901 Congress provided for the erection of a laboratory "for the investigation of infectious and contagious diseases and matters pertaining to the public health," and a division of scientific research was organized in the Service.

From the very beginning, attention was given to the relation of stream pollution to disease. It was not until 1910, however, that there was an organized, large-scale investigation in this field. At that time a study was made in the Great Lakes region of the relation of polluted water supplies to typhoid fever. This study was followed in 1912 by a pollution survey of the Missouri River. A short time later several temporary laboratories were established for field investigations, one of them at Cincinnati, and work on a plan for comprehensive stream pollution investigations was begun (*4*).

The Cincinnati laboratory, now the Environmental Health Center, has since been the focus for the Service's environmental research. Consistently, through the years, the investigations of the center have been those having general, rather than local, application, and those requiring the kind of continuous or extensive studies not likely to be undertaken by private agencies, or by State and municipal organizations.

Work currently in progress in water pollution and related areas includes development and evaluation of analytical techniques for both organic and inorganic materials; studies of persistence of particular organic compounds in water; application of biological oxidation processes to waste purification; studies of industrial waste sources, characteristics, and corrective measures; inventory surveys on pollution of water resources; development of biological methods for determining the severity and extent of pollution; studies of toxicity of water pollutants to aquatic life; development of bioassay methods and their application to pollution control; development of methods for control of organisms responsible for tastes and odors in water supplies; and studies of pollution and purification of shellfish in aquatic environments. Time and time again, these studies have resulted in significant developments that are now being widely used.

The Need for Basic Research

The importance of basic research to the Nation's security and continued prosperity was emphasized by experience during both World Wars. Since the turn of the century, the country has made rapid and continuous technological progress, advancing from an agricultural Nation to a highly industrialized world power. In many fields, however, technological developments were based principally on the basic and fundamental discoveries of the scientists of other nations, and our contribution was mainly applied and developmental. When the free flow of scientific information from Europe was cut off, we faced a serious deficiency in facilities and capacity for basic research.

Recognition of the inadequacy of this country's research programs led the President, in 1946, to appoint a Scientific Research Board to review the current national situation and recommend a course of action which would insure that the scientific personnel, training, and research facilities of the Nation would be used most effectively in the national interest.

The board's report in 1947 indicated that the Nation was then spending $1.1 billion annually for research. Only about 10 percent of that amount was for basic research. The board recommended that by 1957 the annual rate of total research expenditures be doubled, of health research, tripled, and of basic research, quadrupled. It further recommended the establishment of a National Science Foundation to establish research policy for the Nation and to administer Federal grants in support of basic research.

Such a foundation was established by the Congress on May 10, 1950. Subsequently, the foundation has reported that in 1951 the Nation spent an estimated $2.5 billion for research and development (*5*), and in 1952, about $3 billion (*6*). A preliminary report issued jointly by the Departments of Defense and Labor set the 1952 national outlay for scientific research and development at more than $3.5 billion (*7*). Thus the Scientific Research Board's 1957 goal for total research has already been reached and passed. The unexpectedly rapid acceleration was due in part, of course, to the great increase in projects having military significance, stimulated by the defense buildup. A contributing factor has also been industry's growing awareness of the important role of research in expanding productivity and markets. To an increasing degree, industries are devoting substantial portions of their budgets to research and product development, such expenditures amounting in 1951 to $1.2 billion. In view of the high returns now recognized as resulting from these outlays, the trend toward greater emphasis on industrial research is expected to continue (*8*). The cost of research conducted by the industries included in the Defense-Labor survey referred to above was reported as 2 percent of sales.

Health Research

Although the rate of increase in health research expenditures has been considerably less than that for total research expenditures, progress has been made toward the 1957 goal of $300 million recommended by the Scientific Research Board. The latest published estimates indicate a total of $181.2 million for 1951, an increase of about 60 percent over the $115 million reported by the board in 1947 (*9*). The national totals for health research expenditures have not been broken down into subcategories which would permit a similar determination of the increase in water and sewage research. A committee exploring research needs in the somewhat broader area of environmental health reported in 1952 that it roughly estimated 1951 expenditures for research in that field at less than 10 percent of total health research (*10*).

An analysis of Public Health Service research expenditures (slightly less than 20 percent of the national total for health research), while not entirely representative of the overall situation, is meaningful. In 1952, about 2 percent of the total funds expended under Public Health Service research grants, and something less than 5 percent of the funds expended for direct research by Public Health Service staff, were allotted to projects in the environmental health field. These included, in addition to projects related to water treatment, water quality control, and water pollution, those covering various aspects of occupational health, air pollution, milk and food sanitation, radiological health, and such. In the 5-year period from 1948 through 1952, the number of environmental health grants increased about 40 percent and the amount of expenditures for such projects about 30 percent, as compared with increases of about 85 percent and 90 percent, respectively, in total public health research grants.

The report of a recent survey limited to projects dealing with treatment and disposal of sewage and industrial wastes and water pollution indicates that in the decade 1943 to 1953 the number of such projects increased from 128 to 148, about 16 percent. However the 1953 survey covered only the member institutions of the Engineering College Research Council, leaving for a later survey the projects being conducted directly by State health departments, interstate and intrastate agencies, industries, equipment manufacturers, municipal plants, trade associations, and others (*3*). Undoubtedly inclusion of those projects would materially raise the percentage of increase for the 10-year period, although it must be assumed, from the report of the earlier survey, that it, too, was incomplete.

Industrial Wastes

With respect to the problem of pollution caused by industrial wastes, specific responsibility rests upon the particular industries and plants that create the wastes. The Water Pollution Control Act (*11*) does, however, authorize the Service to support and aid research to devise and perfect methods of treatment of industrial wastes, and otherwise to help in solving the problem.

Industry has undertaken a considerable amount of research, over the years, looking toward the solution of specific industrial waste problems. Recognizing the need for concerted action, several branches of industry volunteered early in 1950 to form a national committee as a means of appraising and coordinating the work under way, promoting further research and development, and stimulating the adoption of known practical pollution abatement methods by all segments of industry. The National Technical Task Committee on Industrial Wastes, representing 36 major industrial categories, was organized in May of that year at the invitation of the Surgeon General.

The Service works closely with the committee, providing technical and consultative assistance and serving as a clearing house for the interchange of technical information. As one phase of this cooperative work, the Service has compiled and maintains on punch cards an up-to-date inventory of industrial waste treatment methods, problems, and current and planned research projects. The initial information for this inventory was provided by the member industries of the committee, which supply additional items as they develop, and has been supplemented by abstracts of pertinent articles and reports appearing in technical journals. The assembled information is made available to the committee through distribution of sets of the punch cards to each member.

Obviously, the coordinated research and pooling of information available from this group, representing practically the entire industrial organization of the country, is of tremendous value.

Future Research Needs

The foregoing background is presented for the consideration of future research needs in the water, sewage, and industrial wastes fields. In determining specific research areas that most critically need attention, both now and in the future, special consideration must be given to the impact on water and sewage problems of such factors as: the expansion of industry; the development of new products; the depletion of our natural resources; the growth of population; increased urbanization; rising standards of living; increases in water requirements; increase in volume of wastes; the broadening concept of water resources development.

Industrial Developments

Perhaps the greatest number and variety of problems stem from expanding industry. Since 1900, production has increased more than seven times. Over half of that increase has taken place in the past decade. The President's Materials Policy Commission predicts that between 1950 and 1975 there will be another 100 percent increase (*12*). As the growing industrial machine has consumed raw materials at faster and faster rates, the threat of depletion of the less plentiful natural resources has furnished incentive for the development of many new materials from the abundant supplies of coal, air, and water—materials such as plastics, synthetic fibers, insecticides, and weedkillers. Production of these materials is adding quantities of wastes to our streams. As yet, there is no basis for even estimating what the volume of these wastes will be. The Materials Policy Commission reports that it is impossible to project production of those new materials as for established products, since these recent and continually growing industries have not yet found their stable place in the economy. Tentative estimates indicate that the production of synthetic fibers, such as nylon, orlon, and dacron, will increase from slightly more than 150 million pounds in 1950 to about 4 billion pounds in 1975; production of insecticides is expected to double and of weedkillers to triple in that period; 1975 production of plastics is estimated at 9 billion pounds as compared with 2.28 billion in 1950; detergents may increase from 1.66 million pounds to possibly 4 billion by 1975 (*13, 14*).

In addition to the problem of manufacturing wastes, there is, for some of these products, the question of the effects their use will have on the basic elements of our environment. What will they do to the air and to the water when they are washed into the streams? For example, we do not yet know the extent to which present public water supply treatment methods will be effective against the chemicals now being placed in our streams as a result of use of new insecticides and weedkillers. The recent rapid development of chemical-producing industries in concentrated areas, as for example, along the east coast of Texas, has created air pollution and other difficulties that must be speedily overcome if the benefits of such growth are to outweigh the penalties.

The chemical industry as a whole is progressive, forward-looking, and conscious of its responsibilities to the communities in which it operates. It has spent large sums of money on research and equipment for preventing pollution of both air and water and there is good reason to expect that, as new problems arise, answers will be found.

Other industries, too, are becoming increasingly aware of the need for conserving water quality in order to insure an adequate future supply for their needs. They are also becoming more conscious of their public responsibility for disposing of the wastes they create in such a way that they will not damage these resources.

Population Growth

This country's population has doubled during the past half century. Current estimates indicate that by 1975 it will approach the 200 million mark. Along with this growth, there has been a continued trend toward concentration of population in urban centers. Sixty-five percent of the population is now urban, 35 percent rural. This trend can be expected to continue and the problems are expected to intensify as the Nation's industrial machine expands.

The problem of disposal or utilization of the added volumes of both industrial and municipal wastes is in itself a staggering one. When the demands that will be made upon our water resources in the years immediately ahead are considered it is clear that the Nation cannot afford the inevitable reduction in usable water supplies that would result from discharge of these wastes, untreated, into the streams. The Nation's water requirements in 1975 are expected to be 90 percent greater than in 1950—almost double. Industry's needs alone may increase 170 percent, from 80 billion gallons per day to 215 billion gallons. Municipal and rural needs should increase 50 percent, partly due to increased population and partly to intensified use of modern appliances requiring water for operation—dishwashers, garbage disposals, automatic laundry equipment, and air conditioning.

These estimates are an indication of what the future will demand. The fact that there are many areas, even now, where the problem of adequate water supplies is becoming critical is forewarning that solutions must be found while there is yet time.

Most Needed Areas of Research

There are several areas of research that are obviously of major and primary importance.

New techniques must be developed for determining the amounts and kinds of pollution present in the streams, and the effects of such pollution on the receiving waters. With present analytical methods it is necessary to be satisfied with something less than the best determinations on the growing volume of wastes, many of which are the products of raw materials and processes that are outside our present experience.

Better yardsticks must be established for water quality objectives. Until more precise quality requirements are agreed upon for each of the various water uses—bathing water quality, irrigation, livestock, public water supply, industrial, and the others—we are restricted in our ability to determine which of those uses are attainable in each of the individual river basin areas and can thus be adopted as goals in developing comprehensive water pollution control programs.

Cheaper sewage treatment methods must be developed. There have been relatively few basic changes in sewage treatment methods over the years, although some attempts have been made to perfect and refine them. While the methods in use have been reasonably effective, there is an obligation to the public to reduce the cost of this public service if it is possible to do so. Scientific knowledge has made great advances since the present treatment methods were developed. Some of those advances should provide the basic principles from which could be developed better, quicker, and cheaper sewage treatment processes.

Methods for treating new types of industrial wastes must be developed. As stated earlier, this is basically the responsibility of industry itself. Those who develop the new manufacturing processes and products are the ones best fitted to solve the waste problems accompanying such development. For that task principal reliance must be placed on industry itself. Industry is best equipped also to look beyond the wastes and investigate the prospects of utilization, either by reclaiming raw materials or by developing byproducts.

Persons trained for this work are in short supply. The Nation is not producing enough technical personnel to satisfy its growing requirements. A solution to the problem of conserving and making full use not only of trained personnel but of laboratory facilities may be found in the more extensive use of regional, nonprofit, independent research organizations. Such agencies can provide corps of trained researchers who can give service to State governments, to industry, and to others interested in sponsoring investigations in various fields. They are able to undertake jointly sponsored research leading to the solution of many of the common problems that face industries and local governments in areas where rapid development is taking place. They can act as a clearing house for new scientific information in such areas.

A recent summary of 1950–53 growth of 7 independent research organizations (which together account for more than 1 percent of the Nation's total research outlay) gives evidence of the increasing use being made of this type of organization. Collectively these 7 regional centers have doubled their business volume in less than 4 years (*15*).

There is need for integration and coordination of research studies and findings. Research organizations and workers must be constantly aware of studies under way in other areas that might produce results affecting their own investigations. As an illustration, consider the work in progress on removal of salt from sea water in order to open up new water supply sources. Thus far, no economically feasible method has been perfected, but the project has progressed beyond the merely theoretical stage. In a law passed in 1952 (*16*), the Department of the Interior was directed to further pursue the investigations. Excessive processing cost is an important hurdle in attaining the objective. Closely allied studies are concerned with the extraction of usable minerals from the ocean. In the search for new sources of rare materials, attention has turned to sea water, sea life, and the ocean bottom. Practical methods have already been found for extracting some of the wealth that we now know the ocean holds. For example, bromine and magnesium are being economically recovered from sea water. The development of economical recovery techniques will add many others. All of these endeavors will move more rapidly if the researchers in each field keep informed of developments in the others. Every usable material that can be added to the list of those obtainable from the sea, every feasible combination of processes for their extraction, will lessen the cost for each and bring closer the possibility of economical operation.

Multiple-purpose use. We need to project our vision beyond its horizons, which perhaps have been too limited by our concentration over the years on the narrowly defined public health aspects of water and the relation of waste treatment to public health per se. We need to have a deeper appreciation of the multiple-purpose concept of water use, and to apply that concept to our work. From a long-term view, this is a relatively new concept. It has been an outgrowth of basic legislation developed over the past half century—the Reclamation Act of 1902; the Tennessee Valley Authority Act, adopted in 1933; the Flood Control Law of 1936; the Water Pollution Control Act of 1948.

This kind of development of our water resources was foreseen by Theodore Roosevelt when he wrote (*17*):

> Every stream should be used to its utmost. No stream can be so used unless such use is planned far in advance. When such plans are met, we shall find that, instead of interfering, one use can often be made to assist another. Each river system, from its headwaters in the forest to its mouth on the coast, is a single unit and should be treated as such.

Under this concept, the water problem takes on a new perspective. Programs encompass entire basins; all water uses—domestic, industrial, agricultural, recreational, fish and aquatic life, waste disposal—are factors in a total regional planning process rather than separate entities related only to a particular water or sewage plant. Under this concept our sights are raised past the boundaries of the communities which those plants serve.

In actual practice, the States are attaining this broadened perspective through the increasing use of regional councils and interstate compact groups for joint consideration and solution of their common water problems.

As plans are developed on broad basin areas, the water needs of industry, of the population, of agriculture, and of other users must be compared. The benefits from those uses must be weighed. The possible advantages of changing existing priorities—as between industrial, agricultural, and other uses—must be given careful consideration. If the full benefits of river basin development are to be realized, water quality must be conserved.

Adequate basic information is essential to meet the growing need for developing the Nation's water resources in a way that will best serve all the people. We need more rainfall and stream flow records, particularly low flow records; we need additional data on the physical, chemical, and bacteriological characteristics of the raw water in our streams. We need up-to-date facts on the economics behind the various water uses.

Development of better procedures for assuring that research findings are utilized is an urgency. Too often, the active interest of those who have completed a research study ends with their report of findings. There should be an additional step in the research process, a following-through by those actually producing the findings, to assure that new knowledge is channeled to those who need it. This requires the development of closer relationships between those engaged in research of a physical nature and those working in the social and political science fields. In the area of research dealing with water and sewage, for example, there should be cooperation with agencies such as the bureaus of governmental research in universities, and the organizations providing service to governmental agencies—the International Association of City Managers, the Council of State Governments, and the like. The use of periodicals in the political science, social science, and economic fields, in addition to those in the sanitary engineering and public health fields, as a means of communicating certain kinds of research findings might aid in the development of such relationships.

Careful interpretation of findings and their presentation in a way that will permit their most effective use at the operating levels are also important elements in this followup procedure. The important point is that in order to get the maximum value from research expenditures, we must not only take responsibility for actually doing research, but must also make certain that the knowledge provided by research reaches those who can make effective use of it.

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Dr. Meister Wins 1954 Chemistry Award

Dr. Alton Meister, head of the clinical biochemical research section, laboratory of biochemistry at the National Cancer Institute, was selected to receive the 1954 Paul-Lewis Laboratories award in enzyme chemistry. The award, consisting of a gold medal and $1,000, is given each year by the American Chemical Society to the outstanding American enzyme chemist under the age of 40.

Dr. Meister, who is 31, won the award for discovering the mechanisms by which normal tissues and cancer tissues cause the exchange of chemical groups between amino acids and the breakdown products of sugar and for discovering that vitamin B_6 is necessary in this exchange. Glutamine, an important compound present in almost all tissues, was found to be the key substance in many of these reactions. In the course of his experiments, a number of new compounds called "keto acids" were isolated in crystalline form for the first time, and the way in which the body converts them into amino acids was determined. These studies may be helpful in explaining the growth processes of cancer cells.

Previous Paul-Lewis awards were won in 1953, 1952, and 1951 by Drs. Earl R. Stadtman, Bernard L. Horecker, and Arthur Kornberg, all of the National Institutes of Health, Public Health Service, Bethesda, Md.