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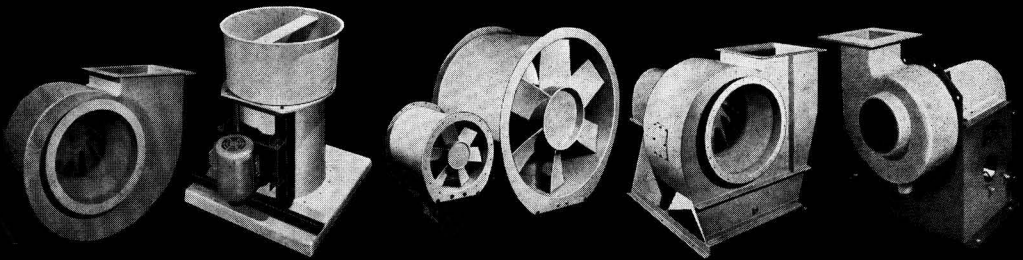
AUGUST 1968

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becoming ever more
dependent on the suc-
cessful management of
the quality of our
environment**

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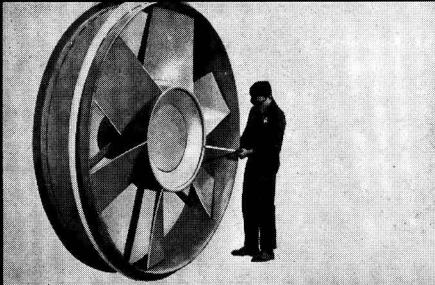
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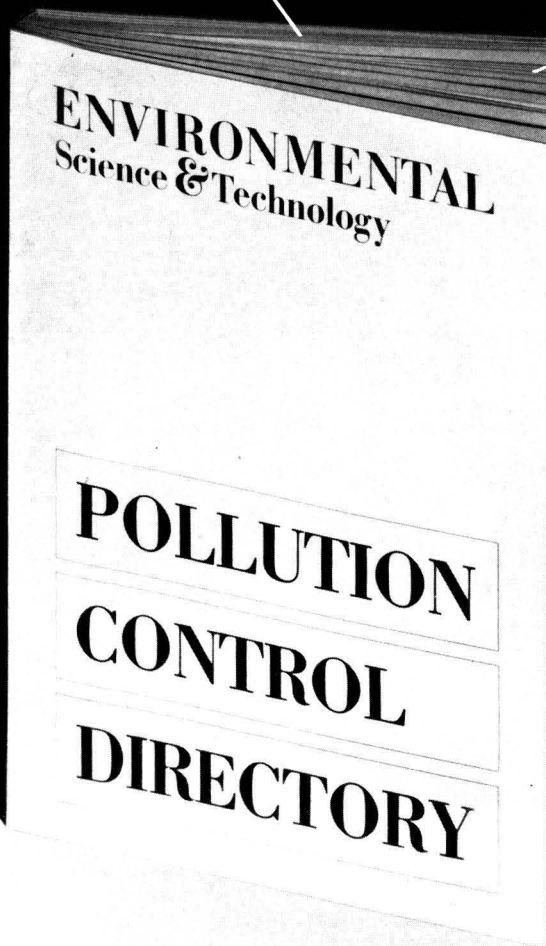
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Volume 2, Number 8

August 1968

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P. Urone, H. Lutsep, C. M. Noyes, and J. F. Parcher

In the presence of metal oxides, sulfur dioxide in air at concentrations between 8 and 27 p.p.m. reacts with other airborne pollutants such as saturated and unsaturated hydrocarbons, nitrogen dioxide, and others within minutes, both in the presence and absence of sunlight.

In the presence of water vapor, the rate of photochemical reaction of sulfur dioxide in the air under UV is 0.1% per hour. When hydrocarbons and nitrogen dioxide are present, the rate of the reaction is of the order of a few per cent per hour.

Effect of macroscopic properties of manganese oxides on absorption of sulfur dioxide 619

K. Li, R. R. Rothfus, and A. H. Adey

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N. T. Thomas and K. Nobe

The pellet size of the catalyst $CuO-Al_2O_3$ affects the combustion of methane, ethane, and propane. Porous diffusion effects in the combustion of these gases are influenced by pellets of size 3.0 mm. \times 2.5 mm., but are not by half-sized pellets. Good agreement between the calculated and experimental data of the larger size pellets was obtained by considering both surface diffusion and gas phase pore diffusion.

Effects of radiation on corn starch sols 628

B. S. Tyler, F. J. Munno, and T. W. Cadman

Total doses of gamma radiation between 10^3 and 10^4 rad do not enhance the sedimentation of corn starch sols. Doses to 10^4 rad have no appreciable effect on the sols, but doses larger than 10^4 rad decrease sedimentation. A dose of approximately 10^5 rad appears sufficient to degrade the predominant chain length of amylose to nearly five D-glucose units.

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Variable speed pump drive 633

R. E. Leonard

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LETTERS

Milorganite lives on

DEAR SIR:

The comments by Dr. Abel Wolman about Milorganite in a recent issue of ES&T (April 1968, page 254) may have created some confusion about the product and its measure of success. Therefore, we wish to call your attention to the following:

1. Milorganite has been produced and sold since 1926—not the "fifties" as stated in the article.

2. We have no intention of discontinuing production at our Jones Island Plant. The decision to start a primary treatment plant on the South Side relates to the nature of the sewage it will receive. It will be primarily urban wastes of low fertilizer value.

3. We continue to sell everything we produce, and, at a substantial savings to our taxpayers. In calendar 1967, we sold 94,005 tons. It is shipped to every state in the Union, Canada, and other foreign countries as well.

4. Although not "money making" in the sense that industry would look at the picture as based on production costs, the sale of Milorganite has paid for the original capital investment and continues to pay for much of the plant operation. It has been estimated that to dispose of our solids by any other known method would cost the taxpayers in excess of \$2,000,000.00 per year. This is due to the tremendous load of solids contributed by our breweries and packing house industry. It is industry's contributions that also give Milorganite the highest nitrogen analysis of any known activated sewage sludge.

5. By inference to San Diego's problems, the article implies that any activated sewage sludge isn't "really good fertilizer." Nothing could be farther from the truth with our Milorganite. Florida and Georgia report less nematode injury on turf grass plots where Milorganite has been compared with other nitrogen sources. New Jersey, Iowa, and Rhode Island have found less turf grass diseases in similar nitrogen studies. Wisconsin

proved many years ago that Milorganite was an excellent source of available secondary and minor nutrient elements. All of this is in addition to its superior nitrogen release and non-burning qualities.

Charles G. Wilson
Head Agronomist
Turf Service Bureau
Sewerage Commission of the
City of Milwaukee, Wis.

Phosphate removal costs are low

DEAR SIR:

I would like to point out a few considerations overlooked by W. D. Hatfield in his letter appearing in your June issue.

Dr. Hatfield expresses concern about the extra sludge handling costs which might be anticipated when the Dow Process is applied for phosphate removal. We certainly do expect to remove more dry sludge solids when we remove phosphate as precipitated mineral matter; however, we also expect reduced volumes of wet sludge to be sent to the digester.

All of the pertinent data that Dow has collected indicate that the treatment of raw wastes with combinations of metals and polymeric flocculants results in the production of additional primary sludge. The same data show that there is also a concurrent reduction in the quantity of excess secondary sludge.

Primary sludges are ordinarily put into the digester at solids concentrations of about 5%. Excess secondary sludge carries much more water, and, regardless of the route it takes to the digester, it puts more water into the digester. One to one-and-a-half per cent solids concentration for settled, activated sludge is a good figure.

To cite an example: Moving the sludge load forward in the plant at Grand Rapids, Michigan, resulted in a reduction in the total volume of sludge sent to the digester. This, in turn, increased digester detention time to 32 days from 19 days, yielded a more

filterable digested sludge, and produced a digester supernatant with a lower solids content.

Dow's work in phosphate removal will be discussed by Dr. R. F. Wukasch at the Workshop on Phosphorus Removal sponsored by the FWPCA. He will show that substantial removal of phosphates in primary treatment process (through inclusion of phosphate in the modest amounts of excess secondary sludge) is perhaps the best performance package attainable with only minor modification of existing secondary treatment plants.

We do not wish to claim that phosphate removal can be attained without cost; however, substantial phosphate removal need not cost \$100 per million gallons, and it need not be accompanied by problems related to sludge handling and digestion.

Morris B. Ettinger
Dow Chemical Co.
Midland, Mich.

Dynamic approaches solicited

DEAR SIR:

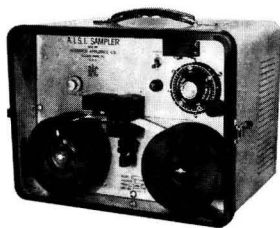
There is a growing awareness that improved instrumentation and control of water and waste treatment processes should achieve significant reductions in the pollution load to the environment. Unfortunately, some of the investigators in this area are not skilled in basic systems engineering. A common error is to use steady-state concepts and relationships when simulating dynamic conditions. There also appears to be a lack of appreciation of distance-velocity lag, blending, and other fundamentals of signal theory and dynamic analysis. Although static or steady-state models have been widely used for design purposes, they have severe limitations for dealing with transients that are the *raison d'être* for control.

We hope that this will warn investigators of these pitfalls and alert granting agencies to view with disfavor proposals for dynamic analysis by stagnant approaches.

**John F. Andrews and
Henry R. Bungay, III**
Department of Environmental
Systems Engineering
Clemson University, Clemson, S. C.

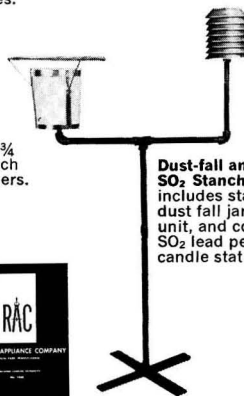
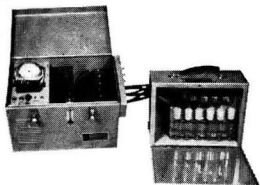
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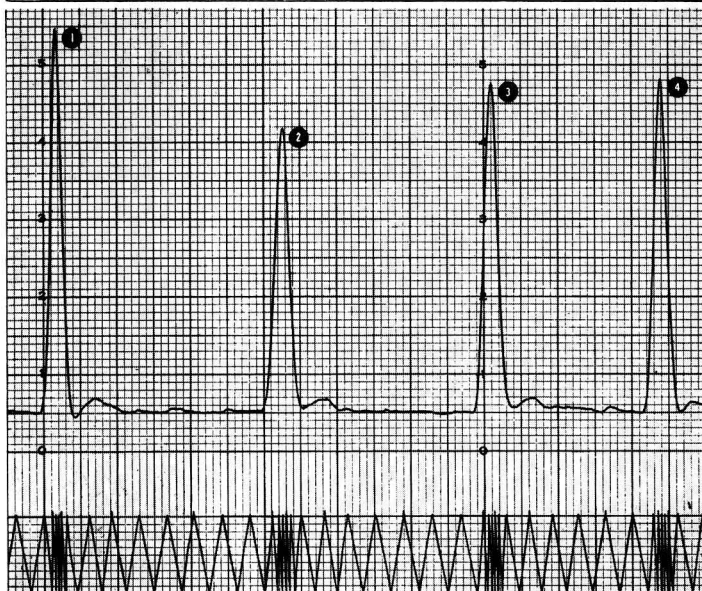


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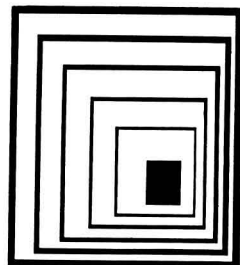
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Alan S. Michaels, President of Amicon Corp. and symposium chairman, contributed the introductory "Chemical Engineer's Assessment". Chapter titles and the roster of authors appear below.

Energetics of Nucleation . . . D. R. Uhlmann, M.I.T.
B. Chalmers, Harvard

Homogeneous Nucleation from the Vapor Phase . . . R. P. Andres, Princeton

Nucleation in the Atmosphere . . . Horace R. Byers, Texas A & M

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Ford Foundation Grants \$4 Million for Environmental Studies

Ecology is the key word in \$4 million worth of grants that the Ford Foundation has made for training and research in resource management. Of the eight grants, six are for new or expanded graduate programs aimed at encouraging ecological training for those directly concerned with problems of managing resources, and two are to bring ecological principles and techniques directly to bear on real resource problems. The grants are part of Ford's enlarged program of natural resource preservation and management. Prior to 1964, the foundation confined such activities to support of Resources for the Future. The \$4 million worth of grants break down as follows: \$909,655 to the Yale School of Forestry and \$587,695 to the University of Washington School of Fisheries for new graduate programs that emphasize the importance of mathematical training; \$858,000 to Johns Hopkins University for a new graduate program in geography and environmental management; \$483,200 to the University of British Columbia for a new interdisciplinary program of graduate education in resource science; \$470,000 to Stanford University for a new graduate program in the biology of human populations; and \$420,000 to the Missouri Botanical Garden for an expanded graduate program in biophysical ecology. In addition, a grant of \$174,000 goes to the University of California at Davis for a case study of the social costs of increasing population growth in California, and \$62,000 goes to Colorado State University for a case study of the potential ecological impact of weather modifications.

Data Available on Separating Combined Sewers

The cost of separating the combined storm and sanitary sewers in the U.S., which now service 36 million people, approximates \$48 billion, according to a recent report prepared by the American Public Works Association for the Federal Water Pollution Control Administration. The report, a national inventory of the effects and means of correcting combined sewer overflows and separate storm and sanitary sewer discharges in the U. S., contains 13 recommendations for solving the problem. Commenting on the report, Secretary of Interior Stewart L. Udall said, "The report shows that separation of sewers is not the whole solution to this problem of preventing overflows from these sewers reaching our streams. While in some instances it is going to take complete separation of sewers, in others new or improved methods of control or treatment will be necessary."

Meanwhile, working on a \$500,000 pilot project of FWPCA, Underwater Storage, Inc. (Washington, D. C.), will construct two giant rubberized tanks in the Anacostia River in the nation's capital to store overflow during heavy rainfall. Each tank has a capacity of 100,000 gallons and will be anchored in the river bed under 17 feet of water. During the period of overflow, sewage will be diverted into an on-shore pump house where it will be crushed before being pumped into the tanks. After the storm water recedes, the contents of the tanks will be pumped back into the sewer lines and then to the treatment plant. At the site on the Anacostia River, 10 tanks, each of 100,000 gallons capacity are needed, according to Dr. Harold Quase of Underwater Storage, Inc.

New Guidelines for Construction Seek to Minimize Pollution

Department of Agriculture contracts for new construction contain 11 guidelines which, according to D. A. Williams, administrator of the Soil Conservation Service, will minimize soil erosion and water and air pollution during construction. These guidelines are recommended for use in all construction involving the movement of earth, and apply to watershed projects and similar construction which are carried out with SCS technical and financial assistance.

Coal Investigations Take on New Life

Previously unpublished information on the conversion of coal to liquid oils and fuels by hydrogenation is available for public inspection (Room 4558, Interior Building, Washington, D. C.). The information contains data gathered by teams of technical specialists that visited German coal-to-oil plants following World War II. Available for inspection are details of the Bergius-I. G. Farben hydrogenation process, operations at the Ludwigshafen-Heidelberg hydrogenation plant, and others.

Synthesis of gas and gasoline from coal is technically feasible but not yet economically competitive with natural gas and petroleum products. Recent U. S. Patent No. 3,357,896 describes a process for treating coal so that it will cake or agglomerate when heated at high temperature. The cake or agglomerate can then be converted to other products such as pipeline gas, gasoline, or chemicals. In the process, crushed coal is preheated to its softening point of close to 360° F., and then allowed to fall through an updraft of hot, inert gas containing a small percentage of oxygen. In a few seconds of free fall, the coal is further heated through its plastic temperature range, emerging as a noncaking char suitable for conversion to other more desirable final products.

Both the economic and social effects of air pollution controls on the economy of a coal mining area are being assessed under a Bureau of Mines contract to the University of West Virginia (Morgantown). The study centers on the economics of the mining community at Monongalia County, W. Va., whose economy depends heavily on the production of high sulfur content coal. Headed by Dr. Frederick A. Zeller, the study will determine specific and measurable effects of coal production shifts on income and employment in all local industries, including those that are related only indirectly to coal mining.

Fish Kills for 1967 Up 21 % from 1966

In 1967, water pollution killed 11,591,000 fish in 40 states, according to the Federal Water Pollution Control Administration's eighth annual fish kill census. According to FWPC's report, "Pollution Caused Fish Kills—1967," industrial pollution killed 71% (8,217,000) of the total fish killed in a reported 139 cases. Since the annual census began in 1960, a total of 88,144,000 fish have been reported killed in 2451 cases.

Environmental Quality Lacks Status of Being a National Goal

The elements for a national policy for the environment were aired last month at a joint House-Senate colloquium. Cochaired by Rep. George P. Miller (D.-Calif.) and Sen. Henry M. Jackson (D.-Wash.) the colloquium was attended by members of Congress, key officials of the executive agencies, and invited guests from the scientific and industrial communities. "Soon, some President and some Congress must face the inevitable task of deciding whether or not the objective of a quality environment for all Americans is a top-priority national goal which takes precedence over a number of other, often competing, objectives in natural resource management and the use of the environment," said Sen. Jackson. Laurance S. Rockefeller suggested a Commission on Environmental Policy and Organization. The commission would have 18 members and equal representation from Congress, executive agencies, and private citizens. "We need more of a task force approach than the long-term study effort," according to Rockefeller. The alternative organizational solution appears to be sweeping reorganizations in both the executive branch and the congressional committee system. Another colloquium on the subject is planned for early next year.

Contracts Are Awarded for the Cleanup of Dead Alewives

The alewife program for Lake Michigan (ES&T, June, page 397) calls for the leasing of 16 fishing boats to net dead alewives in the lake before they pollute beach waters. To date, 10 contracts for 12 boats have been awarded, and contracts for the remaining four boats are awaiting final approval. Under this program the Department of Interior will pay up to \$250,000 as its share, and each of the states—Indiana, Michigan, Illinois, and Wisconsin—will contribute \$62,500 to the cleanup operation. The program's daily skimming operation will protect 20 miles of shoreline in each state (a total of 80 miles).

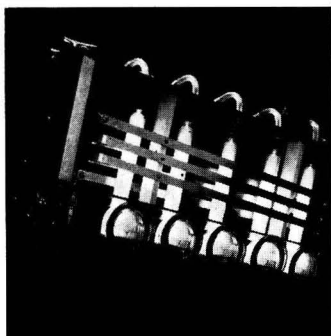
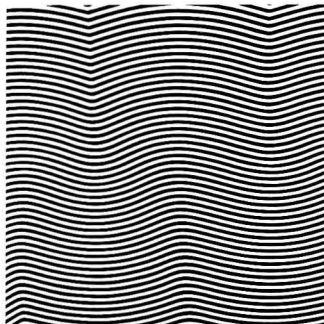
Economies Predicted for Flash Evaporation Desalting Plant

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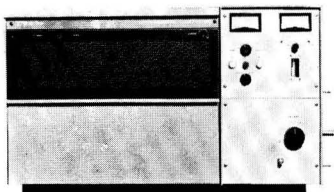
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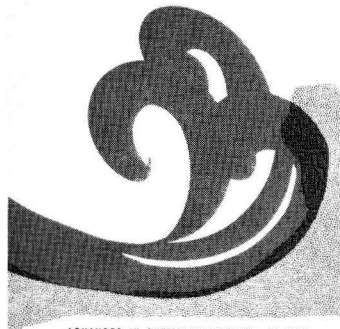
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The Environmental Studies Board of the National Academy of Sciences and the National Academy of Engineering provides a national focus for broad interdisciplinary efforts toward reducing or controlling pollution and other environmental problems, according to its chairman, Dr. Harold Gershinowitz. The board will coordinate all scientific and engineering activities of the two organizations in this area, work directly with the legislative and executive branches of the government in attacking related problems, and initiate broad new studies when necessary. Last month, Gershinowitz told the Senate Subcommittee on Air and Water Pollution that more than 200 NAS scientists and NAE engineers have already worked on a diversity of subjects relating to environmental protection such as population, resources, urban technology, environmental physiology, and pesticides. Also serving are ESB's four engineering-oriented committees, in the Division of Engineering of the National Research Council, and other committees, which are being organized.

- The Committee on Solid Wastes Management advises Public Health Service on the PHS continuing solid waste program. The committee also advises on R&D efforts in this field.
- The Committee on Water Quality Management recently established a panel to advise and counsel with the Appalachian Regional Commission on the control and abatement of mine drainage pollution.
- The Committee on Air Quality Management provides advisory services to the National Air Pollution Control Administration. This committee will assist NAPCA in the development of the administration's large contract program for control technology for air pollution abatement and the development of computer simulation models for air pollution and alternate abatement strategies. The air quality management committee will assist NAPCA in the review of work statements, selection of contractors, and periodic evaluation of progress.
- The Committee on Noise proposes an initial study on the subject by defining many of the known technical facts about noise and noise control and determining the attitudes and costs that play important roles in successful noise control programs.
- The Committee on the Effects of Atmospheric Contaminants on Human Health and Welfare will examine the data being generated under the programs of the Coordination Research Council (ES&T, February, page 87). The committee will review and make recommendations to AEC on the agency's long-range waste management plans for an expanding nuclear energy industry.

FAA Measures Noise Exposure at Airports

Total aircraft noise exposure has been measured for 29 U. S. airports by the Federal Aviation Administration (Department of Transportation). Under an FAA contract to Bolt, Beranek, and Newman, Inc. (Cambridge, Mass.), the data will be used to develop computerized methods for predicting noise exposures at all U. S. airports. The data will also assist planning officials to develop compatible land use around airports. The 29 U. S. airports which handle general aviation and commercial air traffic represent U. S. airports where remedial action, preventative action, or a combination of the two can be taken to alleviate noise.

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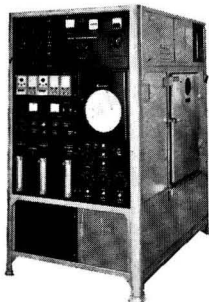
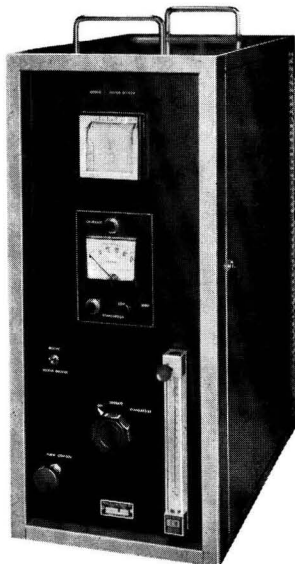
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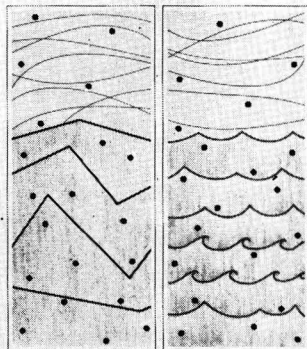
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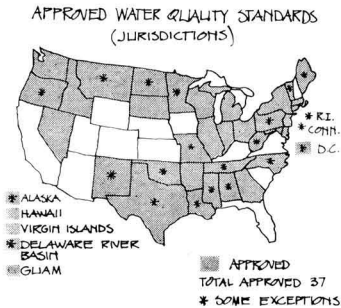
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Interior Seeks Information on Industrial Wastes

A national inventory of industrial wastes is essential for water pollution control and abatement, according to a recent report of the House Committee on Government Operations. Based on a study of its Subcommittee on Natural Resources and Power, the report states that the inventory should be prepared by the Department of Interior in a questionnaire. In the past four years, Interior's questionnaire has been held up by the Bureau of the Budget. But now Interior should be allowed to establish and annually review and revise the inventory of industrial wastes. The inventory would provide definitive information on source, composition, points of discharge, and quantity of industrial effluent.

Approval of Water Quality Standards Nears Completion

By the end of this month, Joe G. Moore, Jr., Commissioner of the Federal Water Pollution Control Administration, expects to have the remaining 15 water quality standards at the preliminary approval stage. To date, 41 of the potential 56 standards have been approved. And by the end of this year, Moore believes that FWPCA will be making final approvals. In a special interview with ES&T's sister publication, *Chemical and Engineering News*, (C&EN, July 23, page 24), Moore said that the number of problems related to the concept of nondegradation of water could be separated into four categories and that all four are being discussed with the appropriate government officials. The categories are: • Interior's commitment to the concept of preserving high quality water. • Interior's plan to require application of the best practicable degree of treatment. • Interior's determination that if there is to be degradation, it is a result of a development that is both socially and economically necessary. • Interior's pursuit of how FWPCA or Interior itself can be assured that the agreed on criteria will be met.



New Vehicle Readied for Gulf Stream Study

Sometime this month Grumman Aircraft expects to rechristen its PX-15 research submersible as the **Ben Franklin** and launch the craft from its West Palm Beach, Fla., facility. After final outfitting and testing, the 30-ton, 50-foot undersea vehicle will be readied for its first sustained underwater cruise, the 30-day Gulf Stream drift mission, slated for early next year. For this cruise, the vehicle will submerge into the Gulf Stream a few miles from Florida and drift at depths of 300 to 2000 feet, propelled only by the underwater current, to a point off the coast of Massachusetts. Periodically, the ship will draw on its ability to hover within the stream to make acoustical, biological, temperature, current, and salinity observations, including an intensive study of the deep scattering layer. The six-man crew for the cruise will include the recently selected skipper, Donald J. Kazimir, a former U. S. Navy submarine officer, Dr. Jacques Piccard, the Swiss ocean engineer who consulted for Grumman on the design and construction of the vessel, and a three-man team from the Naval Oceanographic Office. NOO will also furnish support ships for the mission.

Air Quality Criteria: A Preliminary Round

At a recent meeting sponsored by five separate organizations, medical experts pointed out the lack of evidence for health effects of air pollutants

The recent symposium on air quality criteria (New York City) summed up existing data on the health effects of air pollutants and found that many cause-and-effects relationships are lacking. Sponsored by the Air Pollution Control Association, the American Industrial Hygiene Association, the American Petroleum Institute, and the Industrial Medical Association and its educational affiliate, the Occupational Health Institute, the symposium considered the published evidence on the health effects of carbon monoxide, sulfur dioxide, lead, oxidants, and inert particulates. Where data exist, the evidence for the effect of the contaminants on vegetation was also weighed.

The criteria would describe what is known of the predictable effects of exposures on man to various concentrations of pollutants for various lengths of time.

Carbon monoxide

The health effects of carbon monoxide are not fully known and, thus, still leave many unanswered questions. It is difficult to perceive that a burden of 5%—or possibly 10%—COHb (carbon monoxide-hemoglobin in the blood) in general imposes an undue risk of health impairment, Dr. Bertram D. Dinman, Professor of Industrial Health, School of Public Health, University of Michigan, told the symposium attendees. Unfortunately, there is a gap in our knowledge of the rates of transfer and of buildup curves for carbon monoxide at concentrations greater than the physiologic (more than 1.0% COHb) and less than 100 p.p.m., he continued.

The preponderance of published pa-



Well being. *Despite heavy, obvious, and increasing air pollution particularly in the large cities, the public's health appears to be generally good*

pers dealing with carbon monoxide does not discuss the effects of carbon monoxide—or the rates of carbon monoxide buildup—at levels of concern in community air, according to Dinman. Estimation of effects at 15 or 30 p.p.m., based on extrapolations from studies performed at much higher concentrations, is ill advised and, in some cases, very misleading, he warns.

Dinman and the other two medical experts who spoke on the subject of health effects of carbon monoxide agreed that probably the carbon monoxide level in a community should not be allowed to exceed 20 to 30 p.p.m.

Sulfur dioxide

All attempts to find conclusive evidence of health damage caused by sulfur dioxide at levels normally present in city air have failed, according to Dr. Mario C. Batigelli, Associate Professor of Occupational Health Public Health Service, University of North Carolina. Battigelli directed some of his comments to the role of sulfur dioxide in the recorded major air pollution episodes—Meuse Valley, London, and Donora. "In all of these episodes, the concentration of pollutants studied has remained within toxicologically negligible levels," Batigelli said. The

fact that only insignificant amounts of sulfur dioxide have been measured in the air—even during pollution incidents—is an obvious discrepancy in claims that gas is harmful to health, Batigelli noted.

The search for an acceptable rationale, or for reasonable evidence documenting a toxicological relevance for SO₂ levels, as these are measured and encountered in urban air pollution, has thus far failed, Batigelli said. If urban pollution has a measurable adverse effect on health and a growing incidence of disease in exposed populations, as it appears to have, this phenomenon probably does involve sulfur dioxide in its mechanism, he added.

Furthermore, Batigelli explained, when he examined three alternative hypotheses that seek to explain why sulfur oxides might be more toxic in smogs than by themselves, he concluded that none seemed clearly to explain why sulfur dioxide in smog is toxic enough to dominate the toxicity picture.

Inert particles

We have come to an impasse in trying to define ambient air quality criteria in terms of particulates, said W. L. Faith, consulting chemical engineer, San Marino, Calif. The main trouble is that we try to oversimplify by relating gross values such as mass of particulates, color of particulates, 24-hr. averages, annual geometric means, and the like, to specific effects to which the gross value is really not applicable, he continued. We do this because the available instrumentation is inexpensive both in original cost and operation. We have equipment that provides for quick discrimination of particulates by size and concentration. But such equipment is unduly expensive, Faith said. So we are stuck with high-volume samplers, tape samplers, and dustfall jars as means of quantifying the nuisance of atmospheric particulate matter, according to Faith. The soundest bases for setting ambient air quality standards for a long time to come will be the desires of the local community, tempered by technological

capability, and the effect on the local economy, Faith concluded.

In commenting on Faith's presentation, Austin N. Heller, Commissioner of Air Pollution Control, New York City, said that the readily documented problem of nuisance effects must serve as both justification and basis for ambient air quality criteria. Nevertheless, more needs to be done about the problems that might persist after the nuisance effects have been abated, Heller said. Knowledge of particle size is critical in the study of the effects of particles as a health matter or simply as a nuisance. In general, large particles, which are readily evident by their soiling effects or their accumulation on window sills, do not present serious health hazards. But the finer particles, particularly those smaller than 10 microns, create a much different situation, Heller cautioned.

In principle, it is prudent to expend our efforts on the elimination of particulates, not primarily because of their nuisance effects, but because they may present a very real health hazard, Heller said. We must mount guard against ever developing a false sense of security as a result of eliminating a nuisance whose most important function might have been to serve as an index of a coexisting health hazard, Heller concluded.

Lead

There is no evidence that the present body burden of lead in the general population is causing any deleterious effect on human health, according to Dr. Gordon J. Stoops, Haskell Laboratory for Toxicology and Industrial Medicine, for Du Pont. Furthermore, there is no convincing evidence that the present levels of lead in the air exert a significant effect on this body burden, he observed. If an air quality standard for lead were to be set today, it would be based on inadequate and fragmentary data, according to Stopps. However, a conservative air quality standard for lead could be set: 10 µg. per cubic meter, based on a 30-day average. This 30-day average figure is based solely on health criteria which

embody a considerable safety margin. But, he cautioned, the 10-µg. figure is not to be construed as a sharp line between health and disease. This figure would not lead to any significant, detectable, adverse effect on the population at present or within the next few years, he volunteered.

Nevertheless, Stopps proposed that several worthwhile studies on the subject of lead effects should be pursued:

- Biological monitoring of representative population groups should be continued to measure the actual level of lead absorption rather than merely relying on the level of lead in the air.

- Studies should be undertaken to measure the δ-aminolevulinic acid levels of populations in areas of light and heavy lead exposure since this is one of the most sensitive tests of the effect of lead in humans.

Oxidants

Concentrations of oxidants known to be harmful to man when exposure is continuous have been exceeded for many hours during peak periods on many days in Los Angeles. However, except for eye irritation, there is little evidence of serious or sustained impairment in man, according to Dr. Irving R. Habershaw, Professor of Occupational Medicine and Head of Environmental Health and Safety, University of California (Berkeley campus).

The criteria for control of oxidants should be based at least in part on the fact that short oxidant peaks followed by time for recovery may not be harmful. For example, nitrogen dioxide has never attained a degree of contamination in smog which would be deemed harmful, Habershaw noted. Certainly, physical effects such as the well documented limitations in visibility, do occur. Nonetheless, their control provides an ample safety factor.

Current combustion technology is inadequate, according to Habershaw. He advises that the intense study of the fundamental sciences of converting organic material to energy without polluting the atmosphere must become the prime goal of long-term air pollution control.

The Right Man for the Job

As the national environmental control program grows, it creates thousands of new jobs that require a wide range of training. Many of these jobs will be with state and local regulatory agencies. Such agencies have frequently had trouble recruiting professionals because of non-competitive salary levels. The agencies also have another problem: out-of-date merit system requirements that often do not reflect today's needs—let alone tomorrow's.

This merit system problem is particularly apparent in the case of technicians, the graduates of technical vocational schools or junior colleges. The concept hardly existed when many of the merit systems were set up. Currently, the regulatory agencies throughout the U. S. employ about 20,000 technicians in the environmental protection area. However, only comparatively few of these were actually trained as technicians.

The environmental control program will also create many new jobs in industry. These jobs will be at all levels—professional, technician, and aide. Following present utilization patterns, as many as a quarter million technicians and aides may be required by government and industry within 10 years, according to estimates of the Public Health Service's Bureau of Health Manpower. And these patterns should be changed to use even more technicians and aides in the opinion of Frederick K. Erickson, Deputy Director of the bureau's Division of Allied Health Manpower. Employers should also allow for more upward mobility. An employee starting out as an aide should be able to rise through technician ranks to the professional levels.

But changing these patterns will take time, one reason being that no

one really knows what tasks are involved and what training is required to do them.

The Bureau of Health Manpower—along with PHS's Consumer Protection and Environmental Health Service—has just awarded a contract to the Pennsylvania Hospital and Educational Research Foundation (Harrisburg, Pa.) to start such a study. The Harrisburg organization, long active in the health manpower field, is now branching into the environmental area.

Initially, the contract will be used to develop classification schemes and other tools to describe the tasks. Additional funds may become available in the current fiscal year to extend the study to the specific tasks involved in such jobs as air pollution monitoring and incinerator operation. The Federal Water Pollution Control Administration is taking a similar approach in its area (ES&T, May 1968).

"Very little is known about what is really involved in some of these jobs," Ralph C. Graber, of the Consumer Protection and Environmental Health Service, points out. "A lot of time and motion studies have been done, but they don't really apply in this field, where something is not being made, but, rather, a service is being delivered."

Erickson and Graber feel that results from the current study will stimulate the regulatory agencies and industry to reexamine their personnel requirements. Indeed, there are signs that such reexaminations are already beginning to take place. For example, when the Baltimore Health Department set up its rat control program last year, the department instituted a four-step promotion ladder for what it terms "health aides." Without a high school diploma, an aide can hire on at

an annual salary of \$3750. By continuing his education, or substituting experience for some of the educational requirements, he can qualify to take the examination required for promotion to the next classification. In this manner, he can progress through the technician level and climb to a salary as high as \$8400, or about what the beginning professional commands. Once he achieves the equivalent of the beginning professional level he may take the qualifying exam. If he passes it he can then progress up the professional ladder.

"Personnel policies are going to have to change," Erickson maintains. "When they were set up, the feeling was that you had to have a bachelor's degree to be able to do the work and to command a good salary. Employers must find ways to make better use of the abilities of all employees. For example, a professional, bored with a routine job, often doesn't do it as well as a technician or aide with motivation. The changes we're talking about will permit tapping new sources of manpower to staff the environmental controls efforts; at the same time, they will provide new opportunities for some of our disadvantaged citizens."

Inadequate training facilities

Meeting this new demand for more technicians will require a considerable expansion of training opportunities. Only a handful of junior and community colleges now offer such training programs; most have been set up in the past 10 years.

The curriculum is generally labeled "environmental health technology," and equips the graduate to enter a variety of fields, including air pollution control, water pollution control, solid waste disposal, radiological health, in-

The burgeoning efforts to protect the environment face serious manpower problems. In large part, solving the problems will require identifying the specific tasks to be done and assigning them to properly trained individuals

dustrial hygiene, milk and food sanitation, and housing.

The first year of the environmental health technology curriculum is devoted largely to basic sciences, the second year to applications in environmental and sanitary sciences. However, the specialized requirements of radiological health have led to development of special curricula in this area. The same type of evolution may well occur in air pollution.

But Erickson and Graber tend to favor the more general approach. "At such an early stage in his career, a stu-

dent frequently isn't ready to commit himself to specialization. With general training, he has a wider range of job opportunities. On-the-job training, or short courses, can later add to his competence in specialized areas. Also, the general approach lends upward mobility, since credits can be transferred more readily should the student continue work toward a bachelor's degree," they maintain.

They look for more such curricula to be set up as local needs for technicians develop. "The junior college graduate tends to be provincial, so one

of the functions of these schools is to provide training that permits the graduate to find employment in the general area in which he resides."

Or technicians might be trained at vocational schools patterned after the Missouri Water and Sewerage Technical School at Neosho, Mo. The school has been very successful in providing intensive, practical courses in operation of water and waste treatment facilities. Originally, it offered a one-year course. Now it also offers a two-year, work-study program. One reason given for Neosho's success is that it has

Environmental programs in two-year colleges

Agricultural and Technical College, Morrisville, N. Y.	Water and waste water technology
Milwaukee Technical College, Milwaukee, Wis.	Water and waste water technology
James Connally Technical Institute, Waco, Texas	Water and waste water technology
San Diego Junior College, San Diego, Calif.	Water and waste water technology
Chicago City College (Southeast campus), Chicago, Ill.	Water and waste water technology
Monroe County Community College, Monroe, Mich.	Water and waste water technology
Broome Technical Community College, Binghamton, N. Y.	Environmental control technology
Ferris State College, Big Rapids, Mich.	Environmental control technology
Hudson Valley Community College, Troy, N. Y.	Environmental control technology
Brevard Junior College, Cocoa, Fla.	Environmental control technology
Fayetteville Technical Institute, Fayetteville, N.C.	Sanitary engineering technology
Contra Costa College, San Pablo, Calif.	Water technology
Sumter Area Technical, ^a Sumter, S. C.	Environmental engineering technology
Charles County Community College, La Plata, Md.	Solid wastes and waste water technology
Essex Community College, Essex, Md.	Air pollution technology
Santa Fe Junior College, ^a Gainesville, Fla.	Air pollution technology

^a Starting Fall 1968



Graber (left) and Erickson

Changing technician training patterns

received direct and indirect financial support from many sources—federal, state, and local agencies, consulting engineers, and suppliers of chemicals and equipment.

Federal grant programs

Various agencies in PHS, however, are funding extramural programs to develop curricula to meet specialized needs. In addition, the staffs conduct comprehensive short courses for employees of government agencies and industry.

Since 1966, the National Air Pollution Control Administration has supported a course at Pennsylvania State University (University Park, Pa.). The course is given to students from the state's junior colleges and requires them to spend an extra term in school. Students are selected mainly from associate degree majors in three curricula: electrical and electronics technology, chemical technology, and drafting and design technology.

NAPCA has just made its first grant to develop a two-year program for

training air pollution technicians. The \$24,000 grant went to Santa Fe College in Florida. It may be renewed for three more years. Funds may be available in fiscal year 1969 for additional grants.

NAPCA feels that lack of qualified teachers will deter the effort to train more technicians. Therefore, in the summer of 1969, NAPCA will give a three- or four-week course called the Air Pollution University Faculty Training Institute. The course will be given at Durham, N. C., where NAPCA training activities are centered.

NAPCA is also developing a kit for training monitoring personnel. Although designed for state and local agencies, it will also be available to others such as junior colleges and industries who can use it.

Solid wastes

A training program for solid waste technicians is also being developed. With a \$33,433 grant from the National Center for Urban and Industrial Health, Charles County Community College, La Plata, Md., is developing a curriculum. The grant, made in 1968, will be renewed for three years, depending on availability of funds.

PHS's solid waste program has contracted with the American Public Works Association to develop and conduct a series of courses for operators of incinerators and sanitary landfills. The contract is for \$76,685 to be spent during the next year and a half.

Radiological health

Since 1963, programs for development of curricula for radiological health technicians have been supported by grants from the National Center for Radiological Health. Two-year, full-time programs are being developed by Central Florida Junior College, Ocala, Fla.; Hudson Valley Community College, Troy, N. Y.; Montgomery Junior College, Takoma Park, Md.; Murrell Dobbins Technical School, Philadelphia, Pa.; and Oklahoma State Univer-

sity Technical Institute, Stillwater, Okla. Part-time evening study programs are supported at Lowell Technological Institute, Lowell, Mass., and Manhattan College, Bronx, N. Y., as well as at Hudson Valley Community College and Montgomery Junior College.

These developmental grants, which may run as long as five years, range from \$20,000 to \$50,000 each annually. The total program is budgeted at a yearly \$250,000. About 150 students are enrolled, with approximately 50 associate degrees being awarded each year.

The technician training effort is getting an assist from a nongovernmental quarter. The National Sanitation Foundation (Ann Arbor, Mich.), which for 20 years has provided a meeting ground for industry and governmental regulatory agencies, also sees a need to provide more teachers for the technician training programs.

Almost invariably, the foundation finds, teachers lack experience in the practical aspects of environmental protection. Furthermore, regulatory agency personnel often don't know how to teach. The foundation is granting about 10 fellowships (from funds made available by the W. K. Kellogg Foundation and the Statler Foundation) to such individuals to round out their backgrounds. The teachers will work with governmental agencies to get experience in regulatory operations. Some of the agency people will probably attend the University of Michigan School of Public Health. Others might spend the year getting experience at junior colleges which would like to hire them later as teachers.

These combined efforts, in the opinion of Erickson and Graber, are laying the groundwork. "It might be difficult now for a junior college to set up an effective training program. But as curricula are developed and trained teachers become available, we should begin to see a lot more training opportunities open up," they conclude.

Sewage Sludge and Refuse Composting Test Begins

Despite the spotty history of success of composting ventures, the possibility of making a marketable material from a waste problem keeps luring investigators to keep trying

What is perhaps the most comprehensive study yet of composting as a waste disposal technique is moving into high gear at Johnson City, Tenn. A 60-ton-per-day refuse composting plant—a cooperative venture of the Public Health Service, the Tennessee Valley Authority, and Johnson City—was formally dedicated on June 28, and plant personnel are settling into the fulfillment of the plant's primary objective. That mission: to prove whether refuse and sewage sludge composting is a feasible alternative to conventional disposal methods for these wastes.

Part of the project's goal will be the evaluation of equipment and techniques for windrow composting. But just as important, the project will draw on TVA's extensive facilities for agricultural product development to determine what present and potential markets exist for refuse compost as a soil amendment. For marketing problems—specifically, the inability of the originating jurisdiction to dispose of large quantities of compost at a favorable price—have been a major stumbling block for the 16 or more composting facilities that have been built in the U. S.

The very nearly 20-year history of composting ventures in the U. S. has been something less than an unqualified success. The first plant, in Altoona, Pa., was built in 1951. In the subsequent 15 years, eight more plants were built, but six of these have since been shut down or forced into intermittent operation. Several reasons have been cited for the shutdowns, but the most common one has been a lack of ready markets for the product.

Most of these plants were commercial ventures and as such depended on

the sale of compost for their primary income, with only nominal assessments on the municipalities for disposal of refuse and sewage. Although compost contains some plant nutrients and trace elements, and can be fortified with additional nutrients to form an organic base fertilizer, its principal value is as humus for soil building and conditioning.

Since there is now no large-scale demand for compost, some of the plants have relied on a few bulk outlets for their product. Loss of a single market has proved crucial for at least one plant. Other plants have had to extend their marketing areas as much as 600 miles from the plant site; such high transportation costs weaken what is probably, at best, nothing more than a shaky marketing situation.

However, a major premise of the Johnson City project and of the several recently built plants is that new markets and uses can be developed. For, to be sure, interest in composting is increasing. The past few years have seen new plants built at Boulder, Col., St. Petersburg, Fla., Gainesville, Fla., Mobile, Ala., and a 300-ton-per-day plant, the largest in the U. S. to date, at Houston, Tex.

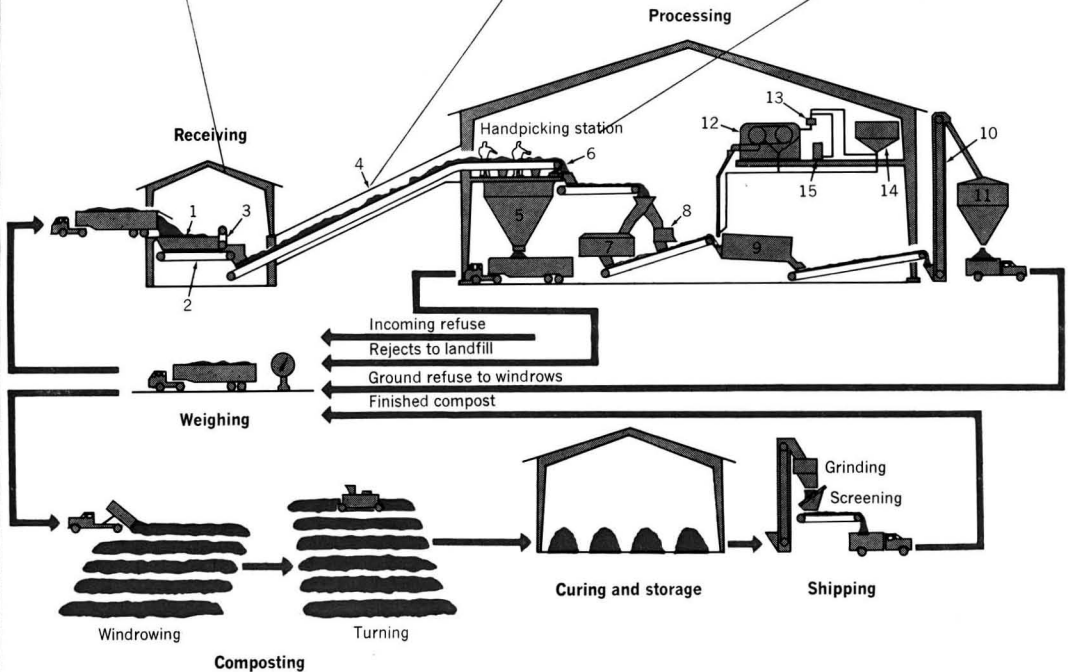
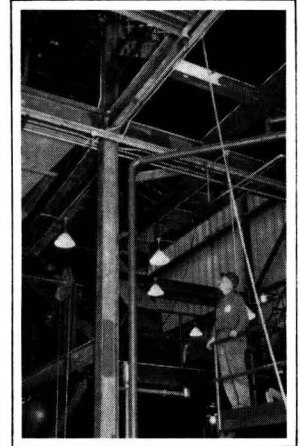
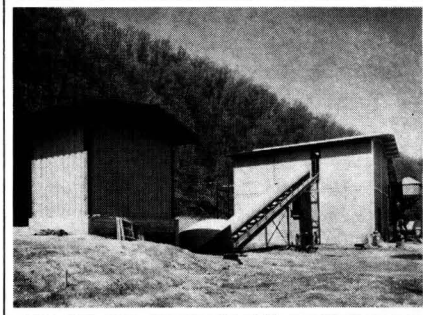
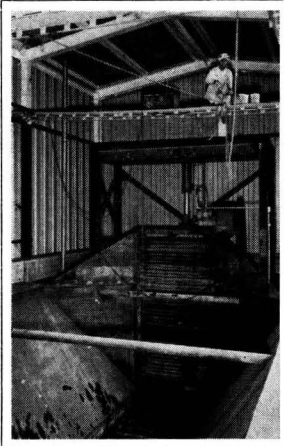
The apparent paradox between past performance and the optimistic outlook for composting in some quarters was underscored by Richard D. Vaughn, Chief of the Department of Health, Education, and Welfare Solid Wastes Program, in describing the PHS-TVA project earlier this year: "There seem to be few neutral parties concerned with learning the whole story about this controversial method of solid waste disposal. We hope to shed much light on this important matter."

The TVA-PHS collaboration which culminated in the Johnson City project had its origins in laboratory studies on composting conducted during the mid-1950's at the PHS communicable disease center in Atlanta, Ga. These studies, and subsequent pilot plant work at Chandler, Ariz., indicated that composting of municipal refuse, with or without sewage sludge, presented a satisfactory method of waste disposal. Windrow composting decomposed 35-40% of the volatile solids, and the resulting product could be used as a soil amendment. However, a number of unanswered questions remained. Adequate cost figures for windrow composting were not available from the few existing plants, and no comprehensive market development work had been done. Furthermore, the question of pathogen survival and the public health aspects were not fully explored for windrow composting.

Accordingly, a full-scale demonstration plant was proposed, and after preliminary discussions between TVA and PHS, agreement on a program was reached in 1964. In the next phase of the project's evolution, engineers of TVA and PHS, together with state and local health department, surveyed refuse and sewage disposal at cities in the Tennessee Valley area. Johnson City was selected as the preferred site because it best fulfilled the three prime requirements for the project: it had a modern sewage treatment facility, a well developed and organized refuse collection system, and a surrounding area that was a good test market.

The final agreement on the construction of the plant was signed in February 1966. Under the agreement, TVA designed and built the plant. TVA operates it with technical guidance

Process flow diagram of the USPHS-TVA composting project



1. Receiving hopper
2. Receiving hopper conveyor
3. Leveling and metering gate
4. Elevating belt conveyor
5. Rejects hopper

6. Magnetic separator
7. Rasper
8. Grinder
9. Mixer
10. Bucket elevator

11. Ground refuse storage bin
12. Sludge thickener
13. Sludge coagulating tank
14. Sludge holding tank
15. Chemicals mixing tank

from PHS. PHS funded the design and construction with funds made available under Solid Waste Disposal Act. PHS also will reimburse the city for services and expenses over and above normal as a result of the operation of the plant. The city, on its part, furnished the 7-acre plant site adjacent to its sewage treatment plant and will deliver its refuse to the compost plant. The city will continue to maintain its sanitary landfill for auxiliary use and the disposal of noncompostable rejects from the compost plant.

In windrow type composting, as at Johnson City, the composting, or biological decomposition, is accomplished by spreading the refuse-sewage sludge mixture in long banked rows, about seven feet wide and five feet high. Though cheaper than the alternative method where composting is partially or completely accomplished in digestion tanks or troughs, windrow composting requires more time to complete the composting process. Windrow composting takes about six to seven weeks, where mechanical digestion requires as little as five to seven days. Thus, the windrow method requires more land area for spreading the windrows. Mechanical digesters are being studied at a compost plant in Gainesville, Fla. This facility also was built with a demonstration grant from the solid waste program.

Operation of the Johnson City plant will be completely coordinated with the municipal refuse collection and disposal and sewage treatment facilities. All the mixed refuse from the city of about 34,000 population, which averages about 60 tons per day, will be delivered to the plant in two compaction trailers.

Processing

After preliminary sorting of large items, the material is dumped into a receiving hopper, from which the refuse is transported by conveyor to hand-picking stations in the processing building. Noncompostable items such as bulk paper, rags, metal, glass, rubber, and plastic will be removed by hand sorting and magnetic separation and hauled to the sanitary landfill for

disposal. Such material accounts for about 25% of the incoming refuse.

After hand sorting, the next step is particle size reduction, and for this purpose the plant has installed two types of grinders—a rasping machine and a hammermill. Each has a design capacity of 8 tons per hour and will be operated alternatively for comparison of efficiency and operation and maintenance cost. After sorting and grinding, the refuse contains about 35% moisture, and is mixed with thickened sewage sludge and water as needed to increase the moisture to between 50 and 60%.

Sewage sludge for the compost plant is pumped from the treatment plant adjacent to the processing building. After mixing with chemical flocculants, the sludge is thickened in a solids concentrator to about 85% water content. Filtrate from the sludge thickener along with waste water from the compost plant is returned to the sewage treatment plant. The thickened sludge is then mixed with the refuse and carted to the windrow field. The windrows are turned periodically to assure adequate composting, with water added as needed to maintain 50-60% moisture. After composting, at least two weeks of curing time is provided during which the moisture content drops to about 25%.

Windrows

Time-temperature factors are important in windrow composting for the destruction of disease-causing pathogens. As part of the Johnson City plant operation, microbiological studies will be conducted by PHS to correct any health or safety hazards that may occur. Another program will attempt to determine whether any antimicrobial substances are produced during composting, as has been suggested by previous studies. Some of this work will be performed under contract at East Tennessee State University's College of Health at Johnson City.

In addition, PHS personnel attached to the project will make routine analysis on samples of raw wastes and compost for in-plant control and performance studies. Periodic chemical tests

will be made to assess the nutrient value of the compost, and the effect of adding chemicals directly to the refuse to accelerate the composting process and increase the nutrient value of the product.

PHS says that research for the project has cost about \$400,000 to date, and that capital costs for the plant total about \$900,000. But this plant cost is not typical of what a municipal facility of comparable capacity would cost. Included in the figure are certain items required by the experimental nature of the plant: laboratories, duplication of equipment and processes for evaluation, and market research facilities.

Market development work is under the direction of TVA's division of agricultural development which is headquartered in Muscle Shoals, Ala. James C. Duggan, TVA agriculturalist assigned to the Johnson City project, points out, "In order to make this project a success, we've got to develop a wide variety of uses. The potential markets haven't really been explored."

Market development

The main thrust of market development will concentrate on large-scale agricultural or land reclamation uses. Commercial agricultural uses would include fruit orchards, truck gardens, specialty crop growers, and to a lesser extent, crop farmers. Other possible uses are in reclaiming strip mine acreage, and maintaining recreational lands such as parks and golf courses. An attractive possibility is a market in reseeding highway road cuts.

Several firms are already developing means of applying the compost to road embankments, either by compacting it into the surface or by spraying a water suspension of compost, fertilizer, and grass and shrub seed. Some markets may exist for small quantities packaged for retail sale through home gardening shops, but that market potential is tiny. Preliminary surveys have shown that a typical community presents a market for only one seventh of the total amount of compost that the community would produce from its refuse.

Making a State into a Sanitary District

Maryland's proposed waste acceptance service casts the state in the role of wholesaler who would accept all liquid wastes generated in the state, then dispose of them in the most efficient and economical manner

In common with the other 49 states, Maryland in recent years has found itself with a water pollution control program growing by leaps and bounds. A number of different state agencies were involved; expenditures were rising sharply. To get a better grip on the overall situation, the Maryland General Assembly in 1966 adopted a resolution calling for appointment of a Study Commission to Investigate the Problems of Water Pollution Control.

From its investigations, the commission summed up the situation this way: 99 municipal and close to 225 industrial waste treatment plants discharge into the state's waterways. There are 264 sewage treatment plants in the state for such things as schools and trailer parks.

The state's waterways are largely self-contained, so Maryland is in the enviable position of being able to select the measures it feels most desirable to manage the quality of its waters. The commission's conclusion: the state should establish a waste acceptance service (WAS)—what amounts to a state-operated sanitary district. WAS would accept all municipal and industrial wastes generated in the state and handle them in such a manner that the state's water quality standards are met. The legislation setting up such an agency is now being drafted and may be considered by the legislature in January 1969.

Under WAS, communities would continue to control such things as land use, sewer extensions, and service charges. But neither they nor industries could treat or discharge liquid wastes into a state waterway. WAS would become essentially a wholesaler;

it would be obligated to accept all liquid wastes, regardless of location or nature of the wastes, except that it could require pretreatment of wastes harmful to physical structures or treatment processes.

WAS would own and operate all major treatment, transmission, and outfall facilities. It would acquire existing facilities by gift, negotiation, or condemnation, assuming any outstanding debt on the facilities. It could construct new treatment facilities, with the right to condemn any land needed.

A wide range of options on how to treat wastes would be open to WAS. It could treat wastes on the spot. It could consolidate wastes from several locations to achieve economy of scale in the treatment plant. Or, in a rapidly developing area, it could use interim measures, then provide permanent measures when the area has stabilized.

But treatment is not the only means of protecting water quality, James B. Coulter, of the Maryland State De-

partment of Health, points out. Coulter was a member of the study commission, which was chaired by Andrew Heubeck, Jr., of the State Board of Public Works. The state could make full use of all these means in ways rarely available to individual communities. The state could:

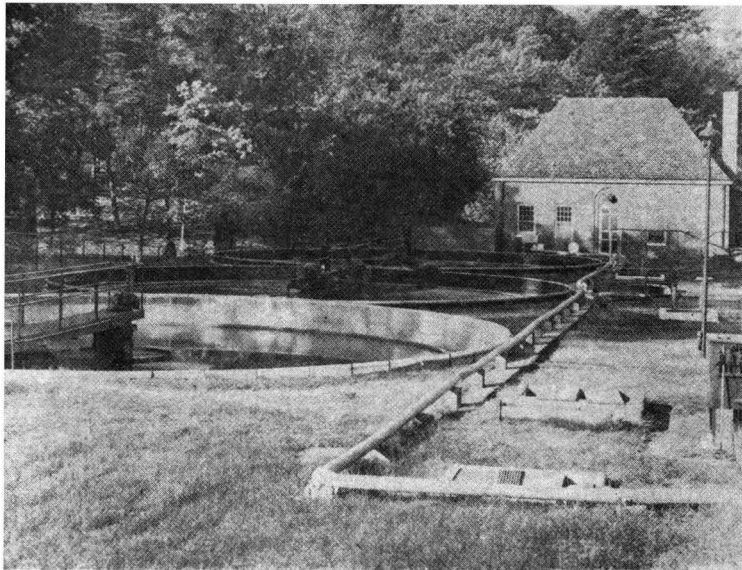
- Hold and control release of wastes.
- Alter stream flow or other waste assimilative features of streams.
- Reduce or eliminate wastes at the source.
- Salvage and reuse wastes.

But WAS's advantages go beyond day-to-day operations, the commission feels. The lengthy litigation required now to clean up individual cases of water pollution would be eliminated. New technology could be introduced more quickly than in a system of several hundred different treatment plants.

WAS could take a longer and broader view of water quality than is possible under the existing system.



Odor. Sewage treatment operators control odor at this new Havre de Grace, Md., plant by completely enclosing treatment tanks



Idyllic. *In a sylvan setting, a sewage treatment plant serves Maryland's capital city, Annapolis*

Coulter cites as an example the threatened buildup of phosphates in Chesapeake Bay, an important economic and recreational asset to the state. "Elected officials and plant managers would be reluctant to agree to the higher costs involved in coping with damage that may not be apparent until 30 years from now. WAS can look beyond the immediate pocket-book benefits."

Regional problems could be dealt with far more effectively than is possible under the existing system. The commission found numerous examples where localities refused—despite the obvious need—to get together on a common sewage collection and treatment system. Under WAS, the state would find it easier to enter into regional and watershed programs with other states and the Federal Govern-

ment. It could make commitments knowing it has the power to produce without having to depend on several hundred independent waste dischargers. It could also coordinate state activities to make the best use of funds available under various federal laws. The commission points out that state and federal governments are assuming the major costs of water pollution control, but many vital decisions are being left in the hands of independent dischargers.

Local gains, too

Localities stand to gain from WAS, too, in the commission's opinion. Elected officials would be relieved of the most bothersome aspects of water pollution control. Municipalities could depend on a stable, annual service charge—usually less than what they

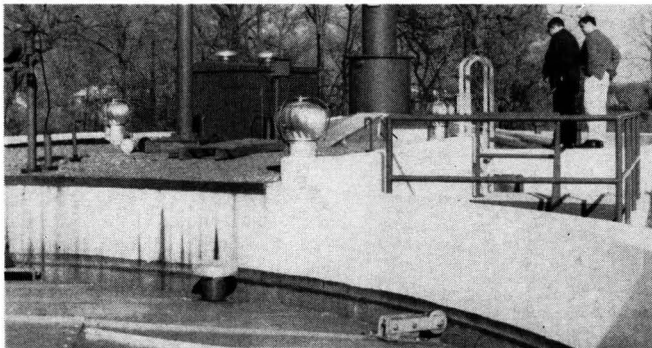
had been paying. Charges would be based on volume, strength, and treatability of the wastes discharged. They would be used to cover maintenance, operating, and replacement costs of the system. Capital improvements would be financed through grants and contributions from local, state, and federal organizations.

Industry would reap these same advantages, plus a couple more. It would avoid direct capital investment in treatment facilities. If industrial waste treatment facilities had to be built or enlarged, as part of a public system they could receive the same state and federal construction grants that municipalities now receive. These combined grants could cover as much as 80% of a project's cost. Industry would contribute to capital costs through a substantial hook-up fee, or some other arrangement.

Secondly, WAS would offer an incentive to industry to reduce its waste load. According to the commission, the service charge would be levied on a formula similar to that adopted by Cincinnati, Ohio. The quantity of industrial waste was reduced there by almost 40% when a service charge system went into effect.

Support from another quarter

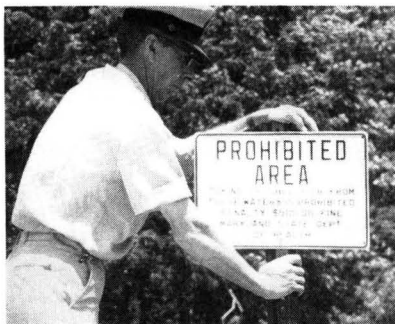
The type of program Maryland is trying to set up is highly touted in "Incentives to Industry for Water Pollution Control: Policy Considerations," prepared by ABT Associates, Inc., (Cambridge, Mass.) for the Federal Water Pollution Control Administration. Pointing to the complexity of effective pollution control, the re-



Cover. *As sewage level in treatment tanks changes, the floating cover rises or falls. Included is equipment for gas circulation and burning*



Shellfish. Sanitarians keep constant check (top) of the water quality in the shellfish growing areas of Chesapeake Bay. Shoreline septic tanks and badly operated sewage disposal plants are the main cause of pollution, which, when it is noted by the State Department of Health, leads to posting by officers of the Department of Chesapeake Bay Affairs (right)



port concludes: "The answer to this complexity then is regional or river basin treatment authorities of various forms. Only this change in orientation and focus in the nation's pollution control efforts will produce abatement in an efficient and equitable manner."

ABT advocates a single authority for each river basin. Where a basin includes several states, and an interstate compact would be difficult to create, a reasonable alternative would be a separate agency for that part of the basin in each state. A given state might go further and combine all its agencies in a single statewide structure; this is what Maryland—with only three major water systems, the Chesapeake Bay, Potomac River, and Atlantic shore—is proposing.

River basin treatment authorities exist already in Germany and England, as well as in the U. S. In addition, the idea is being applied in the metropolitan area sewage agencies in Boston, Chicago, Seattle, and Washington (D. C.). This approach, says ABT, "offers such tremendous possible savings to all concerned that it is worth pursuing with energy and imagination."

The basic difficulty with the current approach, as ABT sees it, is that the cost of waste treatment varies so widely. The quantity of waste, availability of land, and the chemical nature of the waste—all play a part. "In light of this wide variation," ABT points out, "any rule that requires all plants to cut back their pollution load by a specified percentage, or to provide a specified level of treatment, will be very inefficient. Under this type of system, which is more or less like the current one, some plants will be asked to spend relatively large sums for small or even negligible increases in the usefulness of the stream, while others will not be asked to treat to the economically efficient degree."

Prospects for passage

With these obvious advantages, what then is the outlook for WAS? Pretty good, in Coulter's opinion. "The Maryland General Assembly is very conscious of our pollution problems. This spring, it appropriated—without a dissenting vote—\$129 million for water pollution control. Of course, it's going to take a little time for the municipali-

Official U.S. Navy photo



Navy. This modern installation serves the U.S. Naval Training Center at Bainbridge, Md., and includes, among other treatment equipment, primary sedimentation units, trickling filters, and prechlorination devices

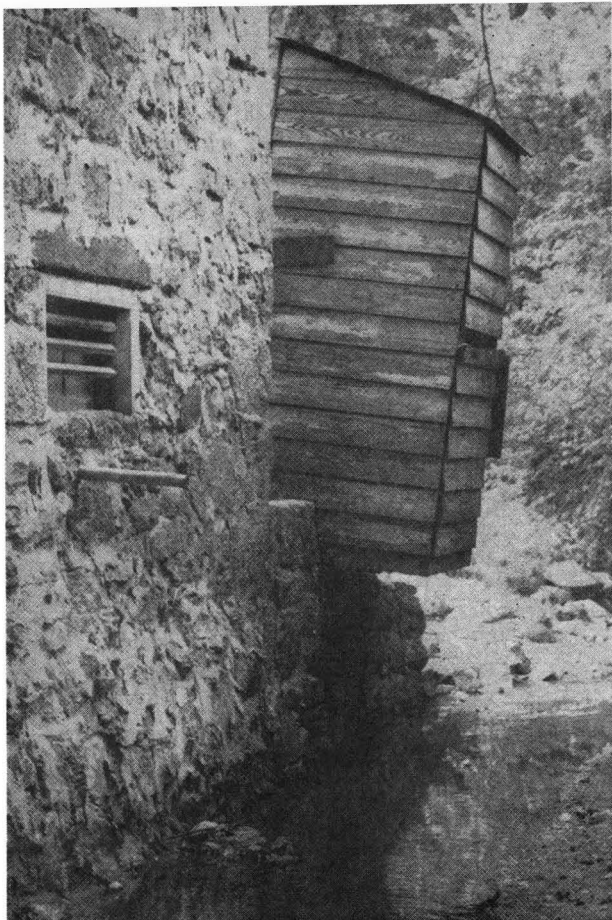
ties to digest the concept. But Maryland is a small state with a fairly simple system of waterways. We have been able—and I think we will continue to be able—to move rapidly.”

The WAS proposal is just one part of Maryland's recent push on water pollution control. In 1966, the state passed a law requiring that, by 1970, its 23 counties and Baltimore City prepare comprehensive plans for water supplies and sewage systems. In 1966, only Baltimore and two counties in the metropolitan Washington (D. C.) area had plans of any kind. The law also requires such plans to conform to existing land use plans, although it does not call for setting up land use plans. “There are still two or three counties with no land use plans or zoning regulations; in other counties, regulations are inadequate. The overall effect of the sewage planning law, however, has been to encourage more statewide planning in general,” according to Coulter.

Another element of the state's program is grants to municipalities to construct sewage treatment plants. Since 1957, the state has made grants totaling \$76 million. The \$129 million appropriated this spring includes \$100 million for construction grants in the period 1969-71. A large portion is expected to be recovered through federal grants in the next few years.

This same appropriation includes \$25 million to set up a revolving fund for loans to smaller municipalities. They can get grants from the state and the Federal Government to cover 75% of the costs of constructing the treatment plant, pumping stations, and interceptor sewers. But such communities still have trouble financing collecting sewers and other elements of the sewage system for which federal and state grants are not provided. The revolving fund will provide for low interest long-term loans for these parts of the system. The remaining \$4 million of the \$129 million appropriation is to permit participation in river basin planning.

And in 1967, the state passed a law requiring certification of operators of water supply and waste water treatment facilities, both municipal and industrial. It also appropriated \$50,000 to set up training courses in four state junior or community colleges, and to



Primitive. *Although such sights as these are hardly commonplace today, it has been such primitive contributors to the sanitation problem that caused sanitarians much concern. Relics, such as this outhouse hung directly over the stream and the drainpipe discharging waste from the building into the stream, fortunately will soon disappear*

train 200 operators. This year's bill provides for payment of tuition for all operators taking the courses.

“These recent actions are laying the groundwork for an effective statewide program,” Coulter declares. “They'll make it possible for us to meet our water quality standard calling for plants built or under construction by 1971 to provide secondary treatment for all our wastes. From then on, our efforts will be geared to meeting population growth.

“WAS is a bold new proposal. We can't look for help from the experience of other states. But we on the commission believe it offers the most efficient and economic way of administering the state's water pollution control program and of maintaining the quality of its waters.”



Maryland's Coulter

Many ways to protect water quality

Environmental Management Needs Long-range Program

Today's problems of environmental management may well be served by reorganizational realignments of various federal agencies; but tomorrow's solutions call for development of a long-range strategy

Today, the Federal Government has no long-range strategy for the active management of our natural environment. What is needed is a strategy for ecological research and environmental engineering. And such a strategy must be organized and carried out by the leadership of this nation, both public and private. These statements, at least in part, are the message of a recent report, "Managing and Environment."

The strategy referred to in the report by the House Subcommittee on Science, Research, and Development would weigh pollution abatement needs against other national needs and would also involve other threats to environmental quality. In the development of this strategy, both scientific knowledge and technical economics would be emphasized. With this kind of program the number of future mistakes in the management would probably be reduced.

The report is a summary of current information on the general subjects of pollution control, ecology, and environmental quality. The report is based on testimony of witnesses from no less than 39 organizations at hearings held earlier this year.

Congress recognizes the problem of environmental management. A glance at the number of newly introduced bills testifies to the fact. But the long range strategy is lacking, as pointed out by the report.

The report also notes that the problem which remains with us today is the translation of information into action. And even when the translation has occurred, concepts have been lost or

modified and the translation has not been smooth.

The subcommittee, whose chairman is Rep. Emilio P. Daddario (D.-Conn.), recommends the following:

- The development of a national policy for environmental management.
- The continuing emphasis on science and technology.
- The careful preparation and execution of organizational realignments.

Policy

The national policy for environmental management should also consider the worldwide effects of environmental management, mismanagement, and planning. The report is quick to point out that management progress will probably be delayed if the hazards to environmental health from environmental degradation are the sole basis for national policy. Legally useful cause-and-effect data are difficult to obtain.

In addition to its specific recommendations, the subcommittee called attention to the following suggestions:

- Allocations and priorities for federal R&D activities should be coordinated by the Office of Science and Technology.
- Activities of OST's Committee on Environmental Quality should be summarized in an annual report to the Congress.
- Adequate funding should be provided for the International Biological Program and the environmental sciences and biology programs of the National Science Foundation. Both promise baseline ecological data.

• Social science information should be developed under the leadership of NSF. This information would reduce the need for subjective choice between environmental values.

Organization

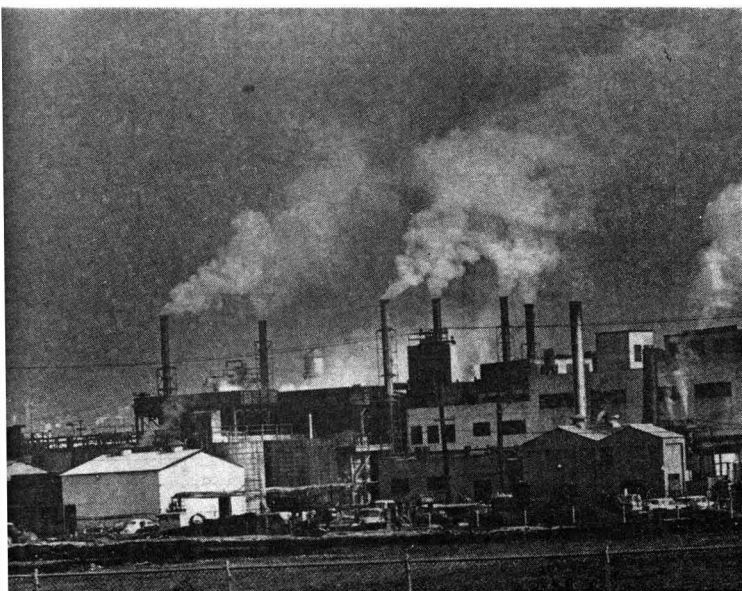
As the lead organization, the Department of the Interior would coordinate all environmental engineering operations of all federal agencies and departments—with the exception of the activities of the Department of Agriculture.

The principal transfers to Interior proposed in the report are the following:

- Corps of Engineers (from Department of Defense).
- Engineering aspects of air pollution (from HEW).
- Solid waste programs (from HEW).

A study of the effect of these transfers and of the reorganization in general should be undertaken by appropriate committees of the Congress, according to the report.

An Environmental Cabinet, under the leadership of the Secretary of the Interior, would, says the report, assure conformity of all federal operations with the national policy for environment management and control. High level officials from each agency would participate in the activities of the environmental cabinet. Were the new cabinet to fail to achieve coordination, then the cabinet would be succeeded by a special council that would be created through the legislative actions of Congress.



Climate. *Current industrial technology continues to belch forth pollution control indicators which serve to call for improved federal-industrial relationships*

Stage of development

Each environmental quality issue may be at one of 12 different stages of activity, according to the report. Starting with apathy, coursing through the stages of episodes, monitoring, human health effects, abatement goals and needs, and others, and ending with today's status, each environmental quality issue is a subject for public opinion and ultimately a subject for public policy.

In the past five decades, billions of dollars have been spent for waste treatment, the report notes. Despite this fact, the average citizen is not aware of the extent of the effort. During the same period, life expectancy has risen continuously; mortality rates have reached their lowest point in history; and the public health must be consid-

ered as good. Therefore, the current, rather sophisticated, concern with environmental hazards does not always gain immediate attention.

But as the climate for discussion becomes less emotional, less polarized, and based more on greater knowledge, society begins to accept commonsense tradeoffs. Then environmental quality values can be considered rationally in terms of benefits of resource use in the standard of living.

Criteria for consideration of wastes

Historically, waste management was accomplished with minimum cost; and free and available disposal sinks of air and water resources were used as much as possible. But no longer can waste management costs be exchanged for environmental degradation. Thus, the

expenditures for maintaining a satisfactory environmental quality have become a mandatory cost of doing business in today's world.

Accordingly, in the future the recycle concept of continual renewal and reuse must surely become the dominating theme of resource utilization, in contrast to the old patterns of use and discard.

Contrast

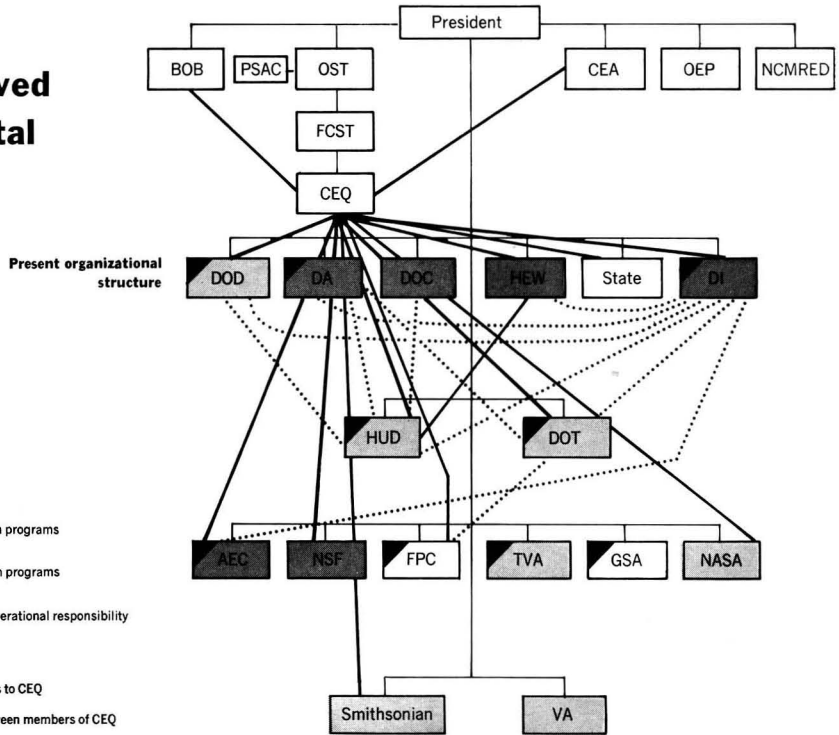
In the western world today, environmental quality management is a political issue, primarily because of the western world's general affluence. The plethora of things which money can buy serves only to accentuate the values in the landscape which cannot be purchased but must be planned for, the report notes.

In the world as a whole, including the emerging nations, environmental quality management is essential to adequate food supply and rapid economic development. Environmental management and control will lead to a systematic ecology and provide environmental managers with a sound basis for evaluating alternative actions.

One such program is the International Biological Program which, if successfully funded and executed, would provide from its various field investigations considerable data for environmental managers to build upon (ES&T, June 1968, page 411).

Management of environmental quality is a matter of international need and concern. An international program in ecological management would be a substitute for war, suggests Aldous

Major federal agencies involved in environmental quality



Huxley, the report observed somewhat wistfully.

Basis for policy

A threat to health from a contaminant arouses much more intense public interest than does a threat to any esthetic, economic, or social event. But today, in the U. S. and elsewhere in the world, excellent human health is no longer considered to be merely the absence of disease or infirmity.

The definition of human health has been extended to include a state of complete physical, mental, and social well-being, according to the World Health Organization of the United Nations. The new definition says that not only may the concept of health extend beyond consideration of disease, but that it now extends in time over the whole life of an individual and even to the genetic effects which may appear only in the offspring of persons exposed to an environment that has been degraded. Not only is the new definition difficult to comprehend, but the

use of the new definition in new legislation is almost impossible.

Cause and effect

Some departure from the strict cause-and-effect relationship usually accepted in consideration of environmental problems has already occurred, according to the report. For example, in sanitary engineering practice the specification of coliform count for public bathing waters is not based on the danger to human health per se of the coliform bacteria. Rather, the micro-organism is used as an indicator that other (less easily identified) pathogenic organisms may be present.

Criteria and standards

Both lack of factual information and the presence of an emotional atmosphere of conflicting interests combine to make difficult the administration of current protective legislation and the development of public policy. The scientific work needed to remedy the critical environmental situation

is not being carried on at an adequate pace, the report continued.

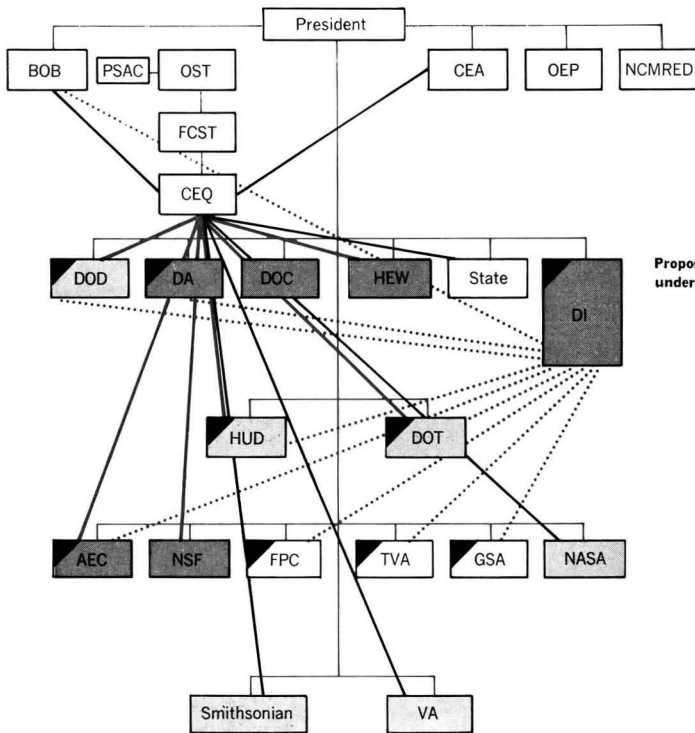
Establishment of criteria should be an extension of good scientific practice. All competent scientists, both in and out of federal agencies, should participate openly and freely in the establishment of these criteria.

Congress placed the responsibility for developing and publishing air and water quality criteria in proper federal agencies. But there was no Congressional intent to restrict the usable expertise to that found among federal employees.

Many congressional committees deal with environmental quality, as a public policy issue. But the underlying research and development activities are quite diffuse, and are widespread within government and the private sector, according to the report.

Coordination and funding

Science and technology are adequately served by the Committee on Environmental Quality within the Fed-



Proposed realignment under Interior

- AEC Atomic Energy Commission
- BOB Bureau of the Budget
- CEA Council of Economic Advisers (EOP)
- CEQ Committee on Environmental Quality (FCST)
- DA Department of Agriculture
- DOC Department of Commerce
- DOD Department of Defense
- DI Department of the Interior
- DOT Department of Transportation
- FCST Federal Council for Science and Technology
- FPC Federal Power Commission
- GSA General Services Administration
- HEW Department of Health, Education, and Welfare
- HUD Department of Housing and Urban Development
- NASA National Aeronautics and Space Administration
- NCMRED National Council on Marine Resources and Engineering Development
- NSF National Science Foundation
- OEP Office of Emergency Planning
- OST Office of Science and Technology
- PSAC President's Science Advisory Committee
- TVA Tennessee Valley Authority
- VA Veterans' Administration

eral Council on Science and Technology, according to Dr. Horning's testimony before the subcommittee. However, other aspects of environmental management are lacking.

To counter this deficiency, the Committee on Environmental Quality plans to work with the Environmental Studies Board of the National Academy of Engineering. Together they will coordinate a national technical program that can be applied to both the public and private sectors.

In part, the necessary research will be funded by federal agencies as part of their programs in pursuit of their assigned missions and, in part, by special programs such as the International Biological Program and those of the National Science Foundation that are directed to environmental biology.

Water quality standards

The report notes that water quality standards apply to receiving water and not to effluent streams, as the law

implies. The Secretary of the Interior has taken the position, however, of requiring secondary treatment to be included in all states' water quality standards. This position replaces engineering calculations with bureaucratic judgment, the report decries. Just because secondary treatment is technically feasible does not mean that it should be applied universally. To do so would require the U. S. taxpayer to spend money which might be used more advantageously for other abatement actions, the report admonishes.

Air quality criteria

After publication of the preliminary criteria for sulfur dioxide (March 1967), the document was immediately rejected by scientists and medical experts in federal agencies, universities, and industry. The criticism was that no free and open exchange of views took place prior to publication of the document.

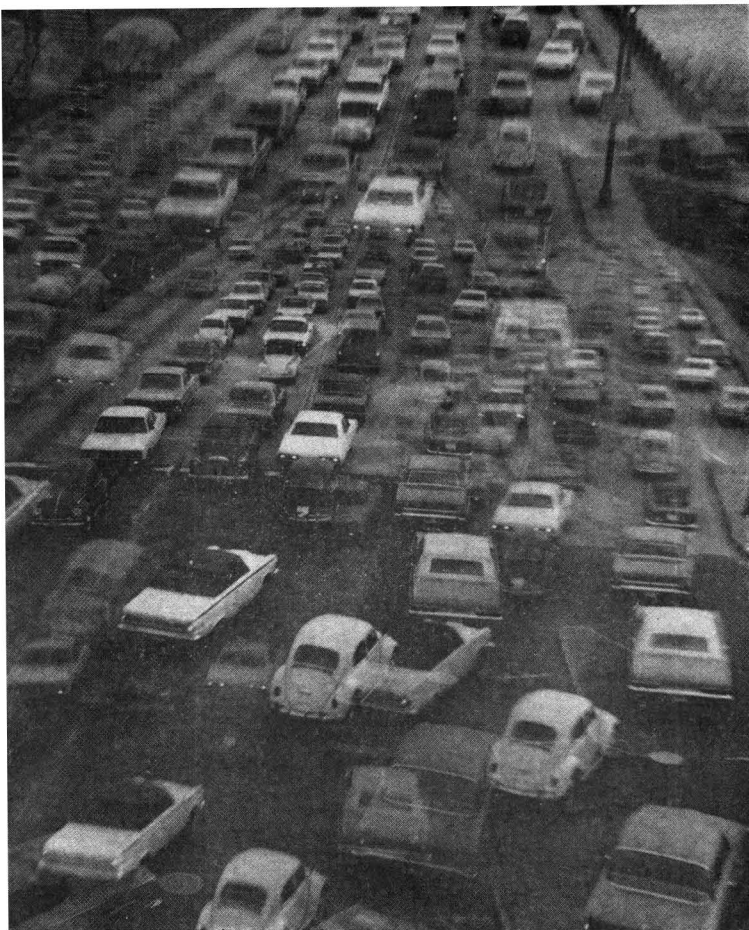
At present, scientists continue to differ about the health effects of air

pollutants. Witness not only the differences in the interpretation of existing data but the deficiency of cause-and-effect data, at least as noted by medical experts at a recent symposium on air quality criteria (New York City).

If the sequence leading to management and control of air as a resource breaks down at the criteria establishment stage, then the Air Quality Act of 1967 will not operate, the report notes. Furthermore, any leapfrogging of the criteria to abatement actions may result in unwarranted expense and unnecessary social and economic disruption, the report adds.

Potentialities

Currently, the Weather Bureau predicts the occurrence of air mass stagnation. Announcement of the existence of such conditions, that could prevent ventilation of an area and allow pollutant concentrations to increase, could also unduly alarm the public, the report cautions. Yet, the meteor-



Conundrum. Cars cause more than 50% of all air pollution, yet stopping cars to lessen pollution may lead to chaos in transportation

ological situation is only one factor in an air pollution episode.

Where automobile traffic is singled out as the major contributor to pollution hazard, health authorities have considered placing restrictions on automobile driving. The legality of such an action against a whole class such as motor vehicle operators is in question. In an area such as Los Angeles, the restriction of driving could result in chaos, according to both the testimony and the report.

Tradeoffs

Ultimately, the tradeoff of environmental quality must be weighed against other national considerations. The choices between alternatives simply cannot be made if no single coordinating group views the total problem.

For example, according to testimony received at last year's abatement conference for the metropolitan Washington, D. C. area, 40% of the air pollution caused by sulfur dioxide could be

reduced by requiring Washington to burn fuel with a sulfur content less than 1%. But, at an estimated cost of \$6 million, the problem of control then becomes the problem of deciding if the added economic burden on the community or local government is worth the cost.

As another example, the report considers surface water for bathing. Inadequate sewage treatment may cause lakes and estuaries to exhibit coliform counts that exceed the standard for water contact sports. However, a public health official, knowing the statistical incidence of waterborne disease, and weighing this against the recreational needs of a densely populated society in midsummer, may decide to permit bathing, the report says.

Information base

The best means of gaining a long-term, rational approach to environmental management is to generate an information base and provide a policy

for all operational programs. With such a base, individual decision makers will be able to act in harmony with the entire system. The desired results must ultimately come from education and voluntary compliance, the report comments.

The management of the environment should be a joint public-private effort, the report notes. Nonetheless, the report notes that Federal Government programs have a dominant and leading role. Existing institutions can do the job, the report observes, if they cooperate:

- Under a coherent national policy for the environment.
- With an expanded understanding of ecological facts and processes.

In large measure, decisions in environmental management depend on scientific and technical information. Yet, current R&D programs of mission-oriented federal agencies may leave serious gaps in information needed for effective environmental quality management programs. These research gaps could be filled by special programs within the Federal Government on the private sector.

The report endorses the establishment of a continuing panel on environment within the President's Science Advisory Council. Such a panel would direct research in controversial areas such as worldwide climate change and synergism between environmental contaminants.

Limitations

The Committee on Environmental Quality and the NAS/NAE Environmental Studies Board cannot coordinate the operational action programs of the agencies using existing technology, according to the report. Because they cannot, the subcommittee proposes that all environmental related programs be placed in the Department of the Interior. Although interagency cooperation has improved in recent years, many examples of coordinating difficulties were sounded during this year's hearings. For example, the subcommittee learned from the Office of Science and Technology that in the field of environmental management four federal councils, 12 interagency committees under the Federal Council for Science and Technology, and 14 interagency agreements were in operation.

At present, the coordination is a hodgepodge of interconnected alliances, according to the report. Although all agencies that are involved in major research activities do receive the coordinating activities of the Committee on Environmental Quality, the operational environmental engineering programs are not coordinated through any one single group. At best, they are handled through individual interagency liaisons.

According to the opinion of the subcommittee, the Department of the Interior could assume effective coordination of all nonresearch environmental programs in the Federal Government. At present, Interior has major research and operational activities in all aspects of environmental quality.

The Committee on Environmental Quality would still have the responsibility for coordination of research. And all aspects of engineering programs would be controlled through Interior.

In the realignment, Interior would be charged with the responsibility of developing a systematic management approach in which engineering would be a dominant factor.

In its report the subcommittee admits that, at present, Interior has conflicting and competing projects in the field of environment. But the subcommittee's recommendations are designed to introduce an environmental policy into existing federal organiza-

Daddario

Mounting concern for the environment



Udall

Pressing for controlling role

tions which will decrease further conflict without undue interference with mission objectives.

One serious criticism of the current alignment is that the engineering aspects of present programs in air pollution and solid waste in the Department of Health, Education, and Welfare are subjugated to health relationships, according to the report.

Environmental cabinet

According to the report, environmental officials from each federal agency plus the chairman of the Committee on Environmental Quality of the Federal Council for Science and Technology should be recognized as a Cabinet for the Environment. If the national policy is well defined and interpreted by the President, then a formal organization may not be necessary.

Another organizational and management proposal involves a technical assessment capability for the Congress. This capability is under active consideration by committees in both houses of Congress, according to the report.

The nation should have an institution that transcends any political administration to continuously assess environmental quality. The institution would provide an early warning of consequences and respond quickly and objectively to questions from a public policy standpoint. Furthermore, states

the report, Congress is the place for such an institution.

A climate of government-industry cooperation must be created. In this way, the commercial section is not automatically the villain in the field of environmental quality. Industry can make many contributions, according to the subcommittee.

For example, industry has accumulated experience related to the effects of carbon monoxide exposure. This experience shows that workers can be exposed to 50 p.p.m. for an 8-hour day, 5 days per week, for their entire working life without adverse effects.

Measurement along city streets and in traffic, which were presented to the subcommittee, indicated that 50 p.p.m. carbon monoxide is rarely exceeded for long periods. Also, people do not spend 8 hours in such an atmosphere.

Therefore, the report points out, industrial hygiene data should ease the concern of the public about carbon monoxide as an air pollutant.

Enlightened management is the key to environmental quality; and management by the private sector should be employed whenever possible, the subcommittee urges. For example, an entire watershed or airshed could be managed by a government-chartered corporation. In such a fashion, the imaginative use of private management talent could address itself to environmental problems.

Priorities for abatement action become important because money, manpower, facilities, and management attention are always limited. Often the lack of a comprehensive systematic abatement scheme allows emotions and vocal advocates to distort the order of corrective action.

Coordination by Congress

Congress was mentioned in the report as perhaps the only organization with a broad enough charter to bring together coordination of both information and action programs. The possibilities for a technology assessment board created by the legislative branch and responsive to it, are under consideration by the subcommittee. A technology assessment capability for Congress would provide a planning and coordinating function responsive to the electorate and, thus, the subcommittee hopes, relatively free of the pressures of agency missions.

Harry P. Kramer

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THE FIRST THIRD OF THE 20TH CENTURY WITNESSED IMPORTANT EFFORTS IN ENVIRONMENTAL RESEARCH.

- ☞ Establishment of the Lawrence Experiment Station
- ☞ Creation of a federal water program
- ☞ Elucidation of stream purification phenomena
- ☞ Discovery and development of biological waste treatment
- ☞ Introduction of rapid sand filtration and chlorination
- ☞ Development of drinking water standards
- ☞ Extensive expansion of municipal sanitation facilities
- ☞ Control of coal-burning in large buildings
- ☞ Establishment of state and local environmental programs
- ☞ Standardization of laboratory methods for identification of pollutants

A preliminary report by the Organization for Economic Cooperation and Development is extremely respectful of American accomplishments in science and technology. It states that our success is unchallengeable. However, it suggests that the policy-making machinery that has helped our country attain its lead in this field may not be adequate to serve the needs of the future. This doubtful situation is expressed in the first of the two major themes that run throughout the critique:

• Instead of a single coherent science policy, the U. S. has a number of policies that have evolved from attacks on specific problems, such as the atom bomb and the Soviet space challenge. While the results have been fruitful, the work often has been disorganized and wasteful.

• American science policy has engaged the support of the country's citizens. In contrast, public indifference or even hostility is encountered in Europe.

In the U. S. the system succeeded not because of its built-in strengths, "but in spite of defects which are no doubt tolerable and even profitable in a society of plenty, but which would be unacceptable in a European society with limited resources."

Examiner C. D. Waddington, professor at Edinburgh's Institute of Animal Genetics, points out that urban problems, environmental pollution, and competing pressures for funds have combined to confront the U. S. with a need for a grand strategy for research. He sees little indication, however, that U. S. scientists concerned with grand strategy have been thinking about "how we can ever develop a really sci-

entific approach to creating an environment and social organization in which human living will be at the best level of physical well-being of which it is capable.

"If Europe can take the lead in the technology of insuring that life is biologically enjoyable," writes Waddington, "it may be under less necessity to keep up with the Joneses in the advance of existing technology, such as supersonic travel, which has no obvious merit except that of being more of what we have already."

These remarks speak forcefully of the growing concern with which we view our relationship with our environment—our ecosystem. Our cities have become the habitat of the vast majority of our population. The trend continues. Within our human ecosystem we witness a breakdown in our cultural values. Major crime has tripled in 30 years and is still growing rapidly. Our health picture, as revealed by the President, is shocking, and its worst aspect is the continual rise in the incidence of chronic disease.

Without hard facts capable of revealing immediate and direct cause-effect relationships, we increasingly realize that we are immersed in an overwhelmingly complex system; we sense that our health and well-being are becoming ever more dependent on the successful management of the quality of our environment.

Such success depends, among other factors, on *how* we use and manipulate our natural resources. The *how*, in turn, brings fresh awareness of the magnitude and dynamic nature of these problems. At present, we find concern for and involvement with solutions to environmental quality-management

ENVIRONMENT

Past, Present, Future

A century survey of environment

problems almost universally in our institutions, with public agencies at all levels playing a central role.

However, what we seem not yet fully to realize is that effective protection of our environment calls for a new kind of partnership, one that will join public agencies in a dynamic relationship with industry and universities.

The onward rush of technology brings not only social change but concomitant changes in our social and individual values, for example: mobility due to jet, automobile, and expressways; instant communication by radio, television, and satellite; immediate problem analysis by computer; unused labor due to automation; leisure derived from cheap energy.

But what of change in our political capabilities? Here we lag in recognition and acceptance of change, and in accommodation to change. We can achieve real benefits from our new technology only by reshaping our political attitudes as well as our social and economic habits.

Early developments

The 20th century is a century of change. At no time in history has the rate of change been as great. At no place in the world is change taking place as rapidly as in the U. S. And the effects on our environment are climactic. To illustrate this change I shall briefly summarize the accomplishments in environmental technology achieved thus far in this century and the events that produced them. Then I shall offer a view of probable eventualities that may occur during the last three decades.

I have divided the century into three

approximately equal segments. Our American era of environmental control actually began in 1886 when the Massachusetts State Board of Health created the Lawrence Experiment Station. The board's report of 1890 on the purification of water and sewage stands as an outstanding contribution to the art of sewage treatment. The general principles established at Lawrence underlie all later processes of sewage treatment developed in the first part of this century, and dominate conventional practices even to this day.

Studies on the longevity of typhoid, cholera, and dysentery bacteria in polluted waters by Jordan, Russell, Zeit and Frost in 1904 revealed the bacterial phenomena involved in stream self-purification.

In 1910, Black and Phelps studied the tidal waters in the vicinity of New York City. This study led to development of a procedure for estimating the oxygen requirements of polluted waters, and provided a foundation for accurate evaluation of self-purification.

In 1912, Congress extended the functions of the Public Health Service to include investigation of "the diseases of man and conditions influencing the propagation and spread thereof, including sanitation and sewage, and the pollution, either directly or indirectly, of the navigable streams and lakes of the U. S." In 1913, PHS established a field station for this purpose in Cincinnati. The field station was used to make comprehensive studies of pollution and self-purification in the Ohio River.

Much progress ensued during the two decades, 1920-39, in development and application of biological wastes treatment, in understanding of related

THE SECOND THIRD OF THE CENTURY BROUGHT NEW PROBLEMS AND EXPANDED EFFORTS IN RESEARCH, PROTECTION, AND CONTROL.

- ☞ Expansion of municipal and industrial wastes treatment
 - ☞ Introduction of radiological health programs
 - ☞ Extension of food protection research
 - ☞ Passage of the Federal Water Pollution Control Act
 - ☞ Construction of the Robert A. Taft Sanitary Engineering Center
 - ☞ Progress in advanced waste treatment methods
 - ☞ Passage of federal acts to control air pollution and for solid wastes
 - ☞ Establishment of water and air quality standards
 - ☞ Availability of demonstration and construction grants
 - ☞ Development of research and training programs in universities
 - ☞ Transfer of the federal water pollution control program from the Public Health Service to the Department of the Interior
 - ☞ Publication of the Gross, PSAC, NRC, and DHEW Reports
-

THE LAST THIRD OF THE CENTURY WILL BRING SUBSTANTIAL PROGRESS IN MEANINGFUL ENVIRONMENTAL QUALITY MANAGEMENT.

- ☐ A unified approach to environmental quality standards
- ☐ Institutional arrangements
- ☐ Development of an environmental epidemiology
- ☐ Advances in urban ecology and planning resulting from closer interrelationships among air, water, land, and people
- ☐ Improved waste collection and transport systems and better designed commercial products for ultimate disposal
- ☐ Use of fast breeder reactors for nuclear power
- ☐ University centers for interdisciplinary research and training
- ☐ Development of automatic surveillance and intelligence systems
- ☐ Practical payoffs derived from experimental cities
- ☐ A concerted program of public information
- ☐ An alerted citizenry that will demand political action

biological phenomena in lakes and streams, and in development of university research and training programs.

As early as 1931, Thorndike Seville expressed this prophetic warning: "The complexity of the problems of water pollution is well indicated by the fact that, with all the advance in the sciences related to industry and government, with the notable increase in stream pollution everywhere consequent upon industrial development and growth of urban populations, no country has yet worked out any scheme satisfactorily reconciling the conflicting interests of public water supply versus waste disposal; of industrial interests versus those of the sportsman; of public welfare as opposed to private or corporate gain; or, in short, the true conservation of water resources by maximum judicious use for the greatest public benefit."

The complexity of the problem so ably expressed by Seville nearly 37 years ago continues to challenge us today, but with mounting intensity. It finds expression, for instance, in the competitive manner in which environmental quality standards are established. In large measure, they are set by contest. To correct this wholly unscientific procedure, to the advantage of overall environmental improvement, requires a heavy research investment. Hopefully, such research will develop a rational, scientific basis for establishment of effective quality standards.

Mid-century developments

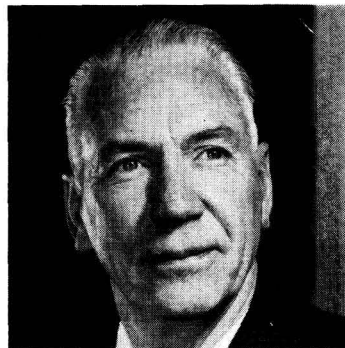
During the middle third of the century—a period that spawned the careers of most present-day environmentalists—urban problems intensified tremendously. These problems have deep interrelationships with environmental quality. In response to these chal-

lenges, Congress passed a number of acts dealing with water and air pollution and with the menace of solid wastes. The reports of a number of distinguished committees voiced national concern. The Federal Government started to support university-based research and training in environmental protection. Federal and state governments, often in cooperation with universities, made specialized short-term training widely available to practicing professional personnel in both public and private agencies.

Two young activities, though at different stages of development, deserve special mention. Air pollution control has made remarkable progress in a short span of years. Solid wastes control is off to a vigorous, renewed start. Both activities represent critical aspects of our urban problems. And it is the urban problems for whose management the stage has been set for the action that will occur during the crucial last third of the century.

Looking ahead

As we enter the final third of the century, we believe that we comprehend the nature and scope of the environmental quality-management problem in a new perspective and can identify the correlative social, behavioral, economic, political, technological, and scientific aspects as never before. But we also see the difficult struggle ahead if we are to make significant advances in solution of this management problem. Rene Dubos has given us sharp insight into an important aspect of the problem: "The delayed effects of air pollutants constitute a tragic model for the kind of medical problems likely to arise in the future from the various forms of environmental pollution. The course of events can unfortunately be



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predicted with a measure of confidence.

"Whenever it is convenient, chemical pollution of air, water, and food soon will be sufficiently controlled to prevent the disabling toxic effects that are *immediate* and *obvious*. Human beings will then tolerate without complaint concentrations of environmental pollutants that do not constitute an *obvious* nuisance and do not interfere seriously with social and economic life.

"But it is probable that continued exposure to low levels of toxic agents will eventually result in a great variety of delayed pathological manifestations, creating much physiological misery and greatly increasing the medical load. The point of importance here is that the worst pathological effects of environmental pollutants will not be detected at the time of exposure."

This statement indicates that many chronically ill people today may be suffering from long-term exposure to environmental insults received during previous decades of this century.

Though we now see the problem in the totality of its complex interrelationships, we may well ask if we have sufficient knowledge, talent, resources, and capability to change our environmental pattern. Do we—that is, does the public—have the will to make the change? Can we make realistic decisions with respect to environmental quality? How can we accurately quantify social values?

A broader view

Can we extend the century's tremendous developments in chemical measurements into truly effective monitoring systems? If environmental management is to be based upon fact, we need to know not just what is present, where it is present, and how much is

present, but in what chemical form it is present as it is taken into the body. Is it a molecule, a free-radical, an ion, a complex, or what?

I believe that we must take a more inclusive view of environmental protection:

- We must learn to regard as a complex interrelated system such environmental components as the air we breathe, the food we eat, and the water we drink.

- We must develop practical, economical methods for effective protection of these components against contamination. Such protection must become an inherent aspect of original design, whether it be for an urban community, a private vehicle or transportation, a new plastic, a new highway, or a new industry.

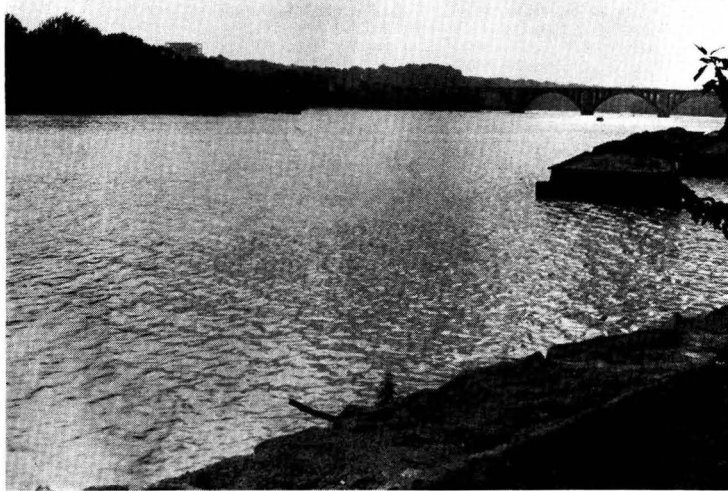
- We must provide the mass public with clearer, more comprehensive understanding of environment and its relation to themselves. Such education will have to begin in the primary grades and continue through all educational levels.

Ways must be discovered to create a new partnership with industry, public agency, and university. This concept of partnership is not limited to the development of environmental quality standards. It must be pervasive. It is a call for change.

Perhaps universities can spark this enormously important partnership. These institutions are becoming aware that their traditional product—the narrowly trained specialist—is of limited value in dealing effectively with problems of elaborate inherent complexity. Increasingly, universities recognize that they must provide an educational framework to bridge the gaps among specialists and equip them for intensive collaboration on environmental

problems. Some are taking interdisciplinary approaches addressed to real problems in real places.

Leaders in science and technology are making statements regarding the need for and the justification of mission-oriented applied research in universities. These incidents give promise of a future outlook that will carry the intricate problems of environmental quality management to unique levels of interest and challenge.



Automated Water Quality Monitoring

In many situations, significant changes in water quality occur often and abruptly. Flow changes due to storms, unpredictable industrial discharges or spills, and flow changes from impoundments—all may alter the concentration of many substances of interest to the water user.

In some cases, these changes may occur within a few hours, as, for example, the diurnal fluctuations in dissolved oxygen and the salinity changes in tidal estuaries. Thus, considerable advantage is gained by continuous monitoring of water quality (McCallum and Stierli, 1964).

The use of manual sampling and standard laboratory analyses to record these changes is impractical; therefore, a wide variety of automated instruments has been developed. Since the basic purpose is control of water pollution, rather than measurement, the use of monitoring equipment to sound an alarm or even to automatically initiate action by control mechanisms should be an essential part of the monitoring concept.

In the strict sense, continuous measurement of a single water quality characteristic is automatic monitoring. Thus, a simple thermograph, a recording pH meter, or a recording conductivity meter, may be considered an automatic monitoring instrument.

However, because of the interreaction between waste components and the multiple effect of a single compo-

nent on several water quality characteristics, the investigator is seldom satisfied with the measurement of a single parameter. In fact, such a single measurement may be misleading.

Therefore, this discussion is confined to integrated (multiparameter) instruments for monitoring of water quality. With current designs, up to eight separate parameters can be measured simultaneously within the same instrument package.

Consideration of the current status of automatic monitoring instruments should involve the following questions:

- How many units are now in use?
- Where and how are they used?
- How are they designed?
- How well do they work?
- How much of the total monitoring need do they fill?
- What are the problems encountered in their use?

Answers to these six questions should provide a summary of the current state of the art.

Application of automatic monitors

An estimated 250 automatic water quality monitors are presently in use. The principal suppliers to date have been Schneider Instrument Co., Cincinnati, Ohio; Honeywell, Inc., Fort Washington, Pa.; and Fairchild Space and Defense Systems, Woodbury, N. Y. (successors to Pro-Tech, Inc.). A majority of the instruments are involved in stream monitoring, princi-

pally at fixed stations on the major river systems of the U. S.

However, mobile monitors are attracting more attention since they can sample at a number of sites within a river basin. Several units are now housed in small trailers or in patrol boats, and in the future more instruments will be used in mobile applications. Using an automatic monitor as a portable system requires no significant change in design. But, the portable power supplies needed pose a new problem.

The U. S. Army Corps of Engineers is presently developing a three-unit system to explore control of impoundments to augment flow as the values reported by the monitors indicate need for downstream dilution.

Current use of automatic instruments for direct monitoring of waste effluents is limited. Usefulness of these devices is obvious, and the potential for a "closed-loop" is particularly attractive. The use of the monitor as part of the waste control process will be expanded in waste treatment facilities.

Basic design of automatic monitors

Most automatic monitors involve sensor system, analyzer phase, and output phase. The sensing element—the part of the system in contact with the sample—may be immersed in the stream or set in flow cells through which the sample is pumped. Both methods have benefits and limitations.

Yet, despite the effective and widespread use of automated water monitoring systems, there is much need for careful maintenance, thoughtful application and location of equipment, and for broadening the scope of the equipment

When the sensor is in the stream, the sample is not affected by pumping, temperature changes, or time of travel through the instrument. Such installation, however, presents certain problems. The sensing elements must be protected from floating debris and must be mounted so as to remain in a fixed position in spite of changes in velocity or direction of current.

In bodies of water which fluctuate in surface level, such as impoundments or estuaries, the relative depth of the sensor may change. In addition, the sensing elements must be inspected frequently for attached growths or physical damage—a difficult job that is apt to be neglected. Because of these difficulties, *in situ* monitors are primarily used for short-term studies.

Shore-based systems, where the stream sample is pumped through flow cells within the instrument housing, are free from some of the difficulties mentioned. Inspection, cleaning, and replacement of sensing elements are readily accomplished. However, the precautions required for satisfactory mounting and protection of sensor units in the stream apply equally well to the pump intake. Further, the sample being tested in the flow cell must be representative of the stream water.

If dissolved oxygen is to be measured, a submersible pump is required to avoid cavitation and removal of dissolved gases. The intake screen must be carefully designed; a fine screen will quickly clog, a coarse screen may permit floating material to enter the system. Because of the advantages in de-

sign and maintenance, most systems use the flow cell principle.

Use of flow cells in a multiparameter instrument requires a manifold system designed to provide uniform velocity to each cell without cross contamination between sensing elements. The pumping system normally provides a flow of 5–20 g.p.m. at a pressure of 20 pounds per square inch.

Flow cells constructed of transparent material facilitate inspection of the sensors in use. The design of the pumping and flow cell system is critical to satisfactory operation of the monitoring instrument.

Sensors presently employed are of the electrical type and are primarily adaptations of electrode systems used in laboratory instruments. For use in continuous monitoring instruments, electrodes must be rugged in construction, unaffected by vibration, employ larger electrolyte reservoirs to provide long-time usage, be equipped with temperature compensation where required, and have effective shielding of the electrode leads. The electrode approach to water quality sensing is a valid one, but there are limitations.

Another approach is based on colorimetric measurements (Bryson and Vasuki, 1964). Such procedures would greatly expand the number of parameters which could be measured automatically. Automated colorimetric systems have been seriously considered, and the manufacturers of such instruments strongly advocate their use.

Laboratory experience has indicated, however, that certain problems

arise. Color or turbidity of the sample strongly influences colorimetric systems, consequently, double-beam operation is usually required to compensate for the variables.

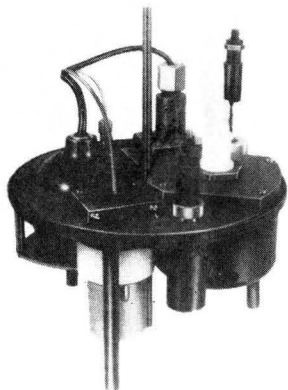
Foolproof manifolds capable of operating for extended periods of time without leakage or change in reagent flow must be provided. In addition, these instruments may exhibit baseline drift, requiring a circuitry to compensate on a continual basis.

Finally, the colored complex builds up in the measurement cell in a number of colorimetric procedures. The operator in the laboratory can readily correct these difficulties, but in unattended operation they would severely limit reliability of the data.

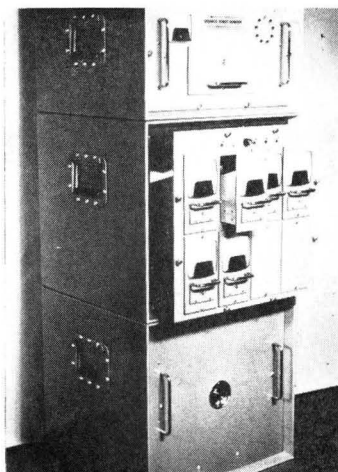
I hope that both independent investigators and the manufacturers of these automated systems will try to develop capability for long-time unattended operation.

Analyzer phase

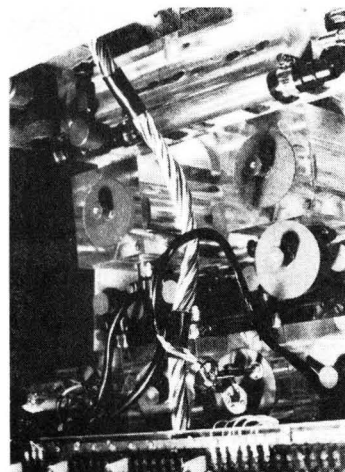
The analyzer phase of the monitoring instrument is designed to convert the signal from the sensor into a satisfactory voltage to apply to the output phase. Present analyzers employ solid-state circuitry and are usually modular in design, facilitating servicing and replacement of defective units. The analyzer may be independent, that is, modulate a signal from a single sensor, or may be shared, providing signal conditioning for several of the sensing elements. Recent design of solid-state amplifiers has greatly increased the efficiency of these devices.



Submersible probe assembly, Honeywell



ORSANCO robot monitor



Flow cell compartment

Output phase

The output phase of the instrument presents the measured value in the necessary units—pH units, milligrams per liter, micromhos, for example—and records it permanently. This component normally has a panel meter on the face of the instrument to indicate output to the recording devices. The panel meter must indicate the final output signal to the recording device, since in some designs this is the only readout at the instrument site. Final

data may be presented in the form of multichannel strip chart, digital paper or magnetic tape, or a telemetry system to provide remote handling of the data.

The multichannel analog recorder is perhaps the least desirable way to present the data because of the difficulties involved in the final statistical analysis of the information derived. Even at relatively slow chart speeds, the chart for 10- to 14-day periods of measurement is long. At speeds capable of indicating rapid changes in a given

parameter, the chart becomes completely unusable. Further, handling data from a strip chart requires significant manual transposition of the data into some type of computer input.

A preferable system is the multichannel tape which can be transferred directly to a computer for analysis of the data. Where a number of monitoring devices are connected to provide a simultaneous evaluation of water quality in a river system, telemetry is a distinct advantage, in fact, almost a requirement. Sophisticated telemetering and data logging systems are in use in a number of river basins.

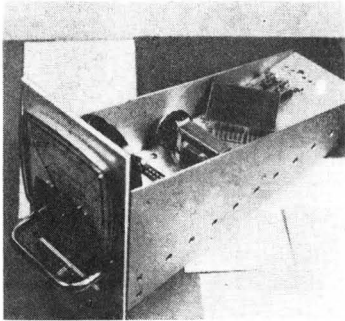
Table I. Performance requirements for FWPCA automatic monitors

Parameter	Sensor	Range	Accuracy (full scale)	Auto-temp. comp.	Stability
pH	Glass-Ag/AgCl	2-12	1%	Yes	4 weeks
Conductance	Platinized or Induction, or Potentiometric	0-6000 0-60,000 manual 0-6000, six intermediate, automatically	1%	...	4 weeks
Chloride	Ag-Ag/AgCl	0-240 0-2400 (automatically)	5%	Yes	4 weeks
Dissolved oxygen	Polarographic	0-24	1%	Yes	2 weeks
Temperature	Thermistor or Thermocouple	0-120° F.	1°F.	...	4 weeks
Turbidity	Optical (automatic cleaning)	0-120 JCU 0-240 JCU 0-1200 JCU 0-2400 JCU	2%	Yes	2 weeks

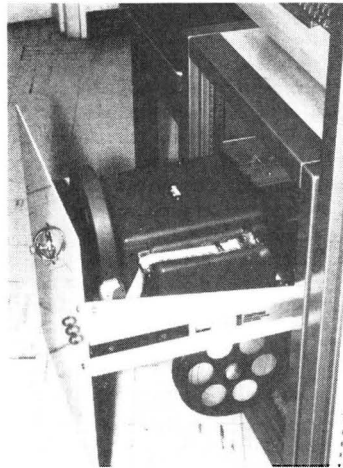
Shortcomings of present parameters

At present, the parameters measured include a standard package of pH, conductivity, chlorides, dissolved oxygen, temperature, and turbidity. Occasionally, ORP and solar radiation are also determined. These parameters are primarily water quality characteristics, rather than specific pollutants. Candidly, they represent parameters for which electrode systems are readily available; they do not include many measurements vital to adequate characterization of water quality.

The Federal Water Pollution Control Administration has set up design



Modular plug-in analyzer



Paper-tape recorder



Central logging facility, Potomac System

requirements for automatic monitors. In addition to these requirements, the parametric systems must provide a two-minute response and stability in the presence of a wide range of environmental conditions of temperature and humidity.

Performance

The reliability of data from automatic water quality monitoring instruments is an important consideration. Therefore, every effort should be made in design, installation, and maintenance of the equipment to provide the best accuracy possible.

All instrument systems acquired by FWPCA are subjected to extensive preliminary testing in the instrument laboratory and in a field test station. Experience indicates that the present generation of automatic monitors is capable of excellent *precision* (repeatability).

The *accuracy* of the measurement is primarily defined by the performance specifications. These specifications are essentially equivalent to the accuracy provided by laboratory instruments in routine use.

The quality of day-to-day performance of the automatic monitors can only be determined by a calibration check at the end of a measurement

period and by split-sample techniques, where the instrument value is compared to a value obtained by standard laboratory analysis. In this regard, performance is satisfactory, and there are indications that operational problems, rather than design faults, produce unsatisfactory results.

Capability

The next question which arises is the capability of present automatic monitors to provide the necessary information on water quality. FWPCA's computerized storage and retrieval system (STORET) for water quality data can list 425 water quality parameters. Obviously, only a limited number

would be required at a single sampling site. However, the number of different measurements that might be required is large and includes both water quality characteristics and specific pollutants (Ballinger, 1967).

The present monitoring capability is for only six to eight individual parameters. These are primarily basic water quality characteristics, and there is an immediate need to expand the number of parameters measured. Both public and private laboratories are intensively studying new sensor systems. Chemical and physical parameters require study; but a breakthrough is needed in the capability of automatically monitoring bacterial densities in water.

Table II. Data lost by FWPCA in 629 days

Parameter	Data lost due to sensor (%)	Data lost due to recorder (%)	Data lost due to pump (%)	Data lost due to power (%)	Total data lost (%)
Dissolved oxygen	5	7	8	1	21
pH	21	7	8	1	37
Turbidity	0	7	8	1	16
Conductivity	0	7	8	1	16
Temperature	0	7	8	1	16
Solar radiation intensity	2	7	0	1	10

Problems encountered

Ten years of use of automatic monitoring instruments have served to identify certain recurring operational problems. FWPCA has recorded information on continuous operation at an automatic monitor for 629 days.

The data indicated that the sensors have performed relatively well except for dissolved oxygen and pH; in these cases the data lost could have been severely reduced if replacement parts had been readily available. The data lost due to the recorder (recorder down time) demonstrates one of the difficulties with remote sensing; the failure of the recorder was not detected until a routine maintenance visit. The ready availability of a replacement pump would have reduced the down time due to pump failure. The down time due to power failure resulted from modification of the power lines into the sampling station.

In general, it appears that the lost data could have been readily minimized by improvement in maintenance, including the availability of replacement units, and immediate knowledge of malfunction in the recorder.

While the total per cent of data lost appears to be excessive, the reasons have been identified and necessary corrections made in program plans. (Assuming adequate maintenance, the performance would have been quite acceptable.)

An additional problem is the effect of particulates and biological growths on the flow cells and sensor systems. While all the electrodes are susceptible to this kind of fouling, the dissolved oxygen electrode and the turbidity measurement system are particularly vulnerable.

To alleviate these difficulties, adequate velocity through the flow cells is maintained, mechanical cleaning is routinely required in the turbidimetric system, and—when necessary—the dissolved oxygen electrode is automatically cleaned. Experience indicates that an adequate maintenance program, designed to alleviate operational problems encountered, is of paramount importance in securing accurate and reliable data from automatic monitoring instruments.

The need for—and the value of—continuous monitoring of water quality is readily apparent to those familiar with the problems of water pollution.

These instruments are in use in a variety of situations and locations; their application should be expanded in the future.

Current design concepts provide for reliable performance within the limitations of the parameters presently available. There is a great need to expand the number of parameters which can be continuously measured.

Operational experience emphasizes the need for strict and careful maintenance of the continuous monitors, and preplanning of the location and application of the monitoring instrument.

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Static Studies of Sulfur Dioxide Reactions in Air

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Reactions of sulfur dioxide in parts per million concentrations and in the presence of saturated and unsaturated hydrocarbons, nitrogen dioxide, moisture, particulates, and ultraviolet irradiation were studied by a combination of colorimetric and radio-tracer techniques. Gaseous mixtures kept in the dark for days did not react, whereas sulfur dioxide in the presence of powdered oxides of aluminum, calcium, chromium, iron, lead, and vanadium reacted within minutes without sunlight or ultraviolet irradiation. Reactions in the presence of powdered sodium chloride and calcium carbonate were very slow compared to reactions in the presence of the metal oxides studied. The photochemical reaction rate of sulfur dioxide in air in the presence of water vapor up to 100% relative humidity was of the order of 0.1% per hour in ultraviolet irradiation equivalent to noonday sunlight intensities. When hydrocarbon and nitrogen dioxide were present, the photochemical reaction in the gas phase was noticeably faster and of the order of a few per cent per hour. Under these conditions, a photochemical product not involving sulfur dioxide was formed, adhered to the walls of the flask, and slowly reacted with sulfur dioxide after it had been collected with the West-Gaeke sampling solution.

Sulfur dioxide is one of the more common and widespread air pollutants. It has been the object of many studies of its reactions, its effects, and the magnitude of its existence in the atmosphere. Yet, because of the complexity of polluted atmospheres, there are many unknown areas in which sulfur dioxide or its reaction products may or may not play an important roll. At least two extensive literature surveys, brought on by recent efforts to establish air quality criteria, have high-lighted the need for more detailed studies of the mechanisms of sulfur oxide reactions in the atmosphere (Negherbon, 1966; U. S. Public Health Service, 1967).

The studies reported here were undertaken to characterize more definitely some possible reactions of sulfur dioxide at low concentrations in air. The method of attack was designed to be simple and direct. Known amounts of radiochemically tagged sulfur dioxide in air were prepared in calibrated 2-liter flasks and exposed to controlled amounts of nitrogen dioxide, saturated and unsaturated, hydrocarbons, water vapor, particulates, and sunlight or 3500-A. ultraviolet irradiation. Analysis of the sulfur dioxide and its reaction products was designed to account for the total amount of sulfur dioxide taken. The unreacted sulfur dioxide was measured colorimetrically, and a scintillation method was used to account for all of the sulfur dioxide taken (Urone, Evans, *et al.*, 1965).

Apparatus and Procedure

Mixtures of sulfur dioxide tagged with $S^{35}O_2$ and clean, dry air were prepared in 20-liter Mylar bags using an apparatus described previously (Figure 1). The air was cleaned by passing through a series of anhydrous calcium sulfate (Drierite), indicating silica gel, molecular sieve, activated charcoal, and glass wool filters. Hydrocarbons were introduced into the air stream filling the Mylar bag through an injection port by means of a microliter syringe. After filling, the bag was kneaded vigorously to mix the contents. One or more calibrated, 2-liter flasks, evacuated to 10^{-3} torr or better, were immediately filled from the bag. An all-quartz and seven borosilicate flasks were used. Calculated volumes of triple-distilled water were injected into the flasks with a 50- μ l. syringe to obtain the desired per cent relative humidity. The water vapor was allowed to diffuse overnight, while the flasks were kept in the dark. Nitrogen dioxide was added to the flask with a microliter syringe just before irradiation or just before the flask was replaced in the dark.

Aliquots of the gaseous contents of the flasks were taken by a calibrated sampling bulb which had been previously evacuated (Figure 2). The bulb was cooled with liquid nitrogen and 15.00 ml. of the West-Gaeke tetrachloromercurate (TCM) scrubbing solution were admitted with a pipet. After shaking, the sample solution was passed into a 50-ml. stoppered flask. Of this solution, 10.00 ml. were transferred to a 25-ml. volumetric flask for colorimetric analysis, and 1.00 ml. was transferred to a vial for scintillation counting (Urone,

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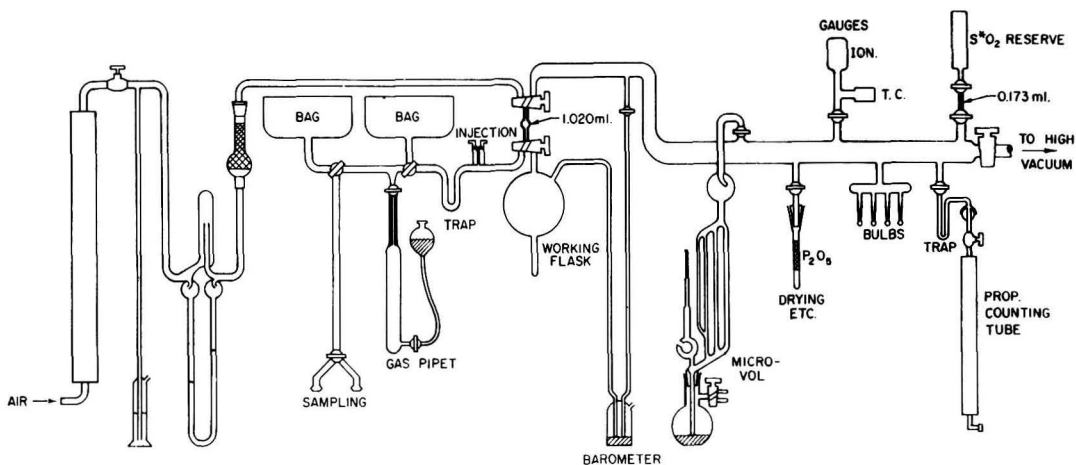


Figure 1. Apparatus for making $S^{32}O_2$ -air mixtures

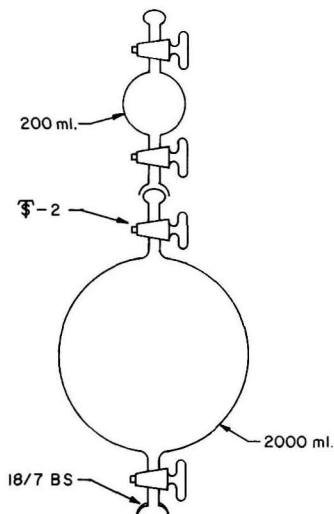


Figure 2. Static testing apparatus

Evans, *et al.*, 1965). At the conclusion of the experiment, 30.00 ml. of TCM solution were admitted to the 2-liter reaction flask. The flask was shaken vigorously, so that the remaining SO_2 , the gaseous reactants, and any substances adhering to the interior walls were scrubbed and/or absorbed. Aliquots of the rinsing solution were analyzed as described above.

A Beckman Model B spectrophotometer was used for the colorimetric measurements, and a Packard Tri-Carb Model 3003 instrument was used for the scintillation counting.

The nonirradiated reaction mixtures were kept in complete darkness by covering the flasks with black crepe paper and aluminum foil. Most of the other mixtures were irradiated with ultraviolet light for controlled periods of time in a Srinivasan-Rayonet-Griffin photochemical chamber reactor (Southern N.S. Ultra Violet Co., Middletown, Conn.), which

contained a bank of sixteen 30×1.5 cm. intermediate pressure ultraviolet lamps coated to give a spectral distribution from 3100 to 4200 Å. with about 90% of the radiation near 3500 Å. The manufacturer's power rating of the lamps was 24 watts each. The photon flux was measured by chemical actinometry using potassium ferrioxalate (Calvert and Pitts, 1966) and found to be 5.39×10^{15} photons per second per sq. cm., about seven times the intensity of noonday sunlight in the same wavelength region (Leighton, 1961).

In the experiments where particulates were used, the finely ground powder was weighed and placed on the inside walls of a freshly cleaned and dried flask. The stopcocks were greased and a plug of glass wool was pushed into the ball joint to be connected to the vacuum system for evacuation. After evacuation, the glass wool plug was removed and the reaction flask was filled from the bag. The turbulent flow of the entering gas helped give intimate contact within the first few seconds. At the conclusion of the experiment an extra 15.00 ml. of TCM solution were used to rinse the flask a second time. The combined rinsings were filtered through a Whatman No. 42 filter paper to remove the metal oxide particles. In the reaction flasks which contained calcium oxide, acidified TCM (3 drops of concentrated HCl per 45 ml.) was used to clear up the resulting solution. In the filtrates from the Fe_2O_3 and Cr_2O_3 systems, 1.00 ml. of 0.009M disodium EDTA solution was added to 9.00 ml. of the TCM solution. The samples for scintillation counting were prepared in the usual manner.

In general, a concentration of 20 p.p.m. of sulfur dioxide was used to assure a reasonable amount of sulfur dioxide in each aliquot taken. The individual analyses were accurate to $\pm 0.1 \mu g$. However, a variation of ± 3 to 5% in aliquot sizes, trace metal, surface, and other extraneous effects was observed between replicate experiments even with utmost care in the analytical techniques.

Colorimetric Analysis

The 25-ml. volumetric flasks, each containing 10.00 ml. of the sample, were placed in a thermostated water bath and kept at $25.0^\circ C$. One milliliter of an equal mixture of the sulfamic acid and formaldehyde solutions and 1 ml. of the pararosanili-

line (all equilibrated at 25.0° C.) were added to each sample, mixed, and allowed to develop color for exactly 30 minutes. The absorbance was read at 560 m μ with a Beckman Model B spectrophotometer, and compared to a standard curve prepared weekly from gaseous SO₂ solutions. Reagent blanks were run with every batch of samples.

Scintillation Counting

To the 1.00 ml. of sample solution in a glass vial, 9.00 ml. of the scintillation solution were added and mixed. The samples were counted in a Packard Tri-Carb Model 3003 spectrometer at 2° C. One milliliter of the TCM solution mixed with 9.00 ml. of the scintillation liquid was used to determine background counts. Standard solutions of tagged sulfur dioxide in TCM were counted along with a series of samples, obviating the need to make radioactive decay corrections.

Reagents

Sulfur dioxide was obtained from a lecture bottle (Matheson, Coleman and Bell), and purified by passing through P₂O₅ and alternate pumping at liquid nitrogen and dry ice temperatures, respectively. Enough radioactive sulfur dioxide (Nuclear-Chicago, 10 to 20 mc. per mmole) was passed into the working flask to give the desired specific activity (Dainton and Ivin, 1950).

Nitrogen dioxide, lecture bottle (Matheson Coleman and Bell).

n-Hexane, research grade (Phillips, 99.6%).

1-Hexene, reagent grade (Matheson, Coleman and Bell, 99 + %).

Absorbing solution, 0.1M sodium tetrachloromercurate in triply distilled water. Reagent grade HgCl₂ (54.4 grams) and reagent grade NaCl (23.4 grams) were taken to 2000 ml.

Pararosaniline solution, pararosaniline hydrochloride, recrystallized from 4 to 1 benzene-butanol. In a dry 1000-ml. volumetric flask 0.4 gram was treated with 60.0 ml. of concentrated HCl for about 10 minutes. Small increments of triply distilled water were added with mixing until all was in solution, and diluted to the mark. The solution was equilibrated for 3 to 4 days before use and color reaction checked once a week.

Formaldehyde solution, 1 ml. of 40% diluted to 100 ml., prepared fresh daily.

Sulfamic acid solution, 1.2 ml. diluted to 100 ml.

Scintillation solution, 0.30 gram of dimethyl POPOP [1,4-bis-2-(4-methyl-5-phenyl-oxazolyl)benzene] 7.0 grams of PPO (2,5-diphenyloxazole) and 75 grams of naphthalene to 1000 ml. in 1,4-dioxane, all reagent grade. The 1,4-dioxane was further purified by passing through activated alumina before use.

Metal oxides, CaCO₃, and NaCl were reagent grade or better. They were ground, dried at 250° C., and stored in a desiccator, except that NaCl and CaCO₃ were dried at 110° C., and the chromatographic quality Al₂O₃ was used as received. The "alkaline" aluminum oxide was prepared by mixing equimolar amounts of Al₂O₃ and CaO, drying them for a day at 450° C., and heating at 900° C. for 5 hours. The Fe₂O₃ was obtained from precipitated hydrous ferric oxide.

All water used was triply distilled. Laboratory-distilled water was redistilled from permanganate solution and distilled again from an all-glass apparatus. High purity water was essential in all these studies.

Table I. Reaction of Sulfur Dioxide in Air

Aliquot No.	Time from Filling the Reaction Flask	SO ₂ Found, μ g.		
		Counts	Color	Calcd.
Mixture 12				
SO ₂ , 19 p.p.m. H ₂ O, 50% relative humidity				
1	30 min.	7.9	7.8	7.9
2	6 hr. 10 min., after 10-min. irradiation	6.9	6.8	7.2
Remainder	6 hr. 10 min.	71.2	71.4	71.3
Total SO ₂		86.0	86.0	86.4
SO ₂ conversion, 0.5% S ³⁵ recovery calculated as SO ₂ , 99.5%				

Homogeneous Reactions

The gaseous reactions of sulfur dioxide in mixtures with *n*-hexane, 1-hexene, water, and nitrogen dioxide in the presence or absence of sunlight or ultraviolet irradiation are illustrated by Tables I through VII. Table V summarizes the reactions involving *n*-hexane and sulfur dioxide.

Sulfur dioxide at 19 p.p.m. and 50% relative humidity reacts little if any when stored for more than 6 hours and exposed to 10 minutes, irradiation in the ultraviolet exposure chamber or an equivalent of more than an hour of noonday sunlight (Table I). The first aliquot was taken 30 minutes after the flask was filled and before the irradiation period. The colorimetric and scintillation analyses (expressed in micrograms) were essentially the same as those calculated from the known concentration of SO₂ in the original Mylar bag mixture. Six hours later the flask was irradiated for 10 minutes and the second aliquot was taken; some of the sulfur dioxide may have been adsorbed on the flask walls—i.e., 6.9 μ g. calculated by scintillation counting *vs.* 7.2 μ g. calculated. Although within experimental error, the slightly lower amount found by colorimetric analysis of the same aliquot (6.8 μ g.) shows that some of the sulfur dioxide may have reacted to form a compound which remained in the gaseous phase but did not give the color reaction for sulfur dioxide. The remainder of the contents of the flask was analyzed immediately after taking the second aliquot. The totals of all the analyses showed very little sulfur dioxide reacted (0.5%), and the high recovery of the S³⁵ tracer (99.5%) showed that practically all of the sulfur was accounted for. In all cases, however, the amount of reaction was calculated by comparing the amount of sulfur dioxide found in the colorimetric analyses to the amount taken.

Table II shows the results of irradiating a similar mixture for 30 continuous hours. Approximately 0.6% of the sulfur dioxide reacted for each hour of irradiation, slightly less than 0.1% per hour of equivalent noonday sunlight. Another experiment for 20 hours gave a reaction rate of 0.57% per hour, or approximately 0.1% per hour of noonday sunlight.

Table III illustrates the analysis of a more complicated experiment. Sulfur dioxide at 16 p.p.m. was mixed with 12 p.p.m. of *n*-hexane, 15 p.p.m. of NO₂, and water at 50% relative humidity. The first aliquot, taken immediately after filling the flask, verified the sulfur dioxide content. The second aliquot

Table II. Thirty-Hour Irradiation Experiment

Aliquot No.	Time from Filling Reaction Flask	SO ₂ Found, μg.		
		Counts	Color	Calcd.
1	40 hr. after 30-hr. irradiation	3.7	3.7	4.7
Remainder	40 hr.	46.2	37.9	46.0
Total SO ₂		49.9	41.6	50.7

SO₂ conversion, 17.9% (or 0.6% per hour)
S³⁵ recovery, 98%

Table III. Reaction of Sulfur Dioxide with *n*-Hexane and NO₂ in Air

Dark Mixture 5
SO₂, 16 p.p.m.
H₂O, 50% relative humidity
n-Hexane, 12 p.p.m.
NO₂, 15 p.p.m.
Purified air

Aliquot No.	Time from Filling Reaction Flask	SO ₂ Found, μg.		
		Counts	Color	Calcd.
1	0 min.	6.5	6.5	6.5
2	21 hr.	5.1	5.4	5.9
Remainder	21 hr.	58.8	54.5	58.7
Total SO ₂		70.4	66.4	71.1

SO₂ conversion, 7.3%
S³⁵ recovery calculated as SO₂, 99.0%

Table IV. Effect of Ultraviolet Irradiation on SO₂, *n*-Hexane, and NO₂ in Air

Mixture 6
SO₂, 21 p.p.m.
H₂O, 50% relative humidity
n-Hexane, 16 p.p.m.
NO₂, 15 p.p.m.
Purified air

Aliquot No.	Time from Filling Reaction Flask	SO ₂ Found, μg.		
		Counts	Color	Calcd.
1	0 min.	8.1	8.1	8.1
2	8 hr. 45 min., after 1-hr. irradiation	6.6	6.4	7.3
Remainder	8 hr. 50 min.	75.1	(33.8) ^a	73.3
Total SO ₂		89.8	(48.3)	88.7

SO₂ conversion, 12% (47%)
S³⁵ recovery calculated as SO₂, 101%

^a Excess reaction in rinsing solution.

was taken after the flask was kept dark for 21 hours. The scintillation count showed some loss of sulfur (5.1 *vs.* 5.9 μg. calculated), but the colorimetric analysis showed that the scintillation counting may have been low (5.4 *vs.* 5.1 μg.). (Except for experimental error, the colorimetric analysis should not be higher than the corresponding scintillation analysis.) Analysis of the remainder of the flask's contents and addition of the totals showed that approximately 7% (±3%) of the sulfur dioxide reacted during the 21-hour period. The higher scintillation *vs.* color analysis of the remainder which included wall rinsings (58.8 *vs.* 54.5 μg.) indicated that some or all of the reaction products may have resulted from the surface-catalyzed reaction of SO₂ to H₂SO₄ in the presence of NO₂ and H₂O. Recovery of 99% of the tracer showed that the cumulative of the various analyses was essentially correct.

Secondary Reaction. Table IV illustrates results obtained when a mixture similar to that shown in Table III was irradiated with ultraviolet light. The first aliquot gave the flask contents. The second aliquot was taken after the flask was stored for 7 hours and 45 minutes and then irradiated in the ultraviolet reaction chamber for 1 hour; analysis showed that approximately 12% of the sulfur dioxide had reacted (6.4 of a calculated 7.3 μg.). The scintillation analysis (6.6 μg.), showed that most of the reacted sulfur dioxide had gone to the flask wall but approximately 0.2 μg. had remained in the gas phase.

The remaining contents of the flask were sampled immediately after the second aliquot, analyzed under identical conditions, and should have given approximately the same results. The amount of sulfur dioxide expected was 6.4/7.3 × 73.3 or 65 μg. Yet only 33.8 μg., roughly 50% of the amount expected, were actually found (Table IV). Analyses of similar mixtures not irradiated by ultraviolet light showed that the analyses of the flask contents were consistent with the analysis of the preceding aliquot (Tables II and III). Whereas approximately the same amount of excess reaction was obtained in every experiment involving irradiation of sulfur dioxide in the presence of both NO₂ and *n*-hexane, the presence of 410 p.p.m. of NO₂ (mixture 25, Table V) did not increase the amount of the excess reaction.

Experiments repeated under identical conditions but in flasks cleaned with acetone rather than chromic acid cleaning solution showed the same gas-phase results but no excess reaction in the rinsing solution. It is possible that traces of chromium catalyzed the excess reaction of the photochemical products with sulfur dioxide in the rinsing solution or that traces of acetone interfered with the reaction (Schroeter, 1966).

The most logical explanation for this excess reaction at this point is that NO₂ and *n*-hexane react in the presence of ultraviolet irradiation to give a product which, possibly with the prior formation of an aerosol (Schuck and Doyle, 1959), condenses on the flask wall. The sulfur dioxide does not react with this product while it remains on the wall of the flask. However, when the flask is rinsed with the TCM scrubbing solution, the product in the presence of a catalyst reacts with the residual sulfur dioxide. The consistency of the half-reaction value in all

Table V. Summary of Sulfur Dioxide, Hexane, and NO₂ Reaction Rates in Air

Mix No.	SO ₂ , P.P.M.	n-C ₆ H ₁₄ , P.P.M.	NO ₂ , P.P.M.	UV, Min.	Rate of SO ₂ Reaction, Min. ⁻¹ × 10 ³				
					% Relative Humidity				
					0	30	50	70	100
12	19 ^a	10	0.01 [385]	0.00 [375]	0.01 [370]	0.01 [475]	0.00 [460]
7	22	116	...	30	...	0.2	0.5	0.2	...
32	8	...	15	10	1 [120]	...	1 [120]	2 [120]	2 [135]
6	21	16	15	60	0.06(53) [230]	0.1(52) [640]	0.3(47) [530]	0.00(55) [700]	0.3(52) [645]
8	21	16	15	30	0.1(52) [785]	0.00(52) [1030]	0.1(53) [940]	0.2(50) [1060]	0.2(52) [1170]
25	15	11	410	10	0.2(59) [2880]	1(51) [2820]	2(45) [2790]	1(63) [2830]	4(54) [2845]
5	16	12	15	dk ^b	0.00 [1190]	0.00 [1260]	0.06 [1260]	0.00 [1280]	0.1 [1245]

^a Recovery of the S³⁵ tracer in all experiments averaged 99.6 ± 1.8%.

^b Rates based on total time in flask.

[], Total time in flask, minutes.

(), % reaction of residual SO₂ in flask rinsings.

experiments conducted under the same conditions suggests the formation of a new sulfur compound or a coincidence in the timing of a slowly preceding reaction. The flask rinsings as well as the immediately preceding aliquot were routinely analyzed the morning after sampling.

In reporting the data for the experiments showing excess reaction, the amount of the gas-phase reaction of sulfur dioxide was calculated from the gaseous aliquot taken immediately before the remainder of the flask contents was analyzed. The amount of excess reaction in the rinsing solution is shown in parentheses next to the reported gas-phase reaction (Tables IV and V).

Table V summarizes the gas-phase, or homogeneous, reaction rates of a number of representative series of increasing relative humidity for sulfur dioxide with n-hexane and nitrogen dioxide (data obtained from tables similar to Tables I through IV). A first-order, or pseudo-first-order, reaction rate per minute of irradiation equivalent to noontday sunlight was assumed in order to make reasonable comparisons, where $k = -(dt/dc)/[SO_2]$. Multiplication of the rate data (Table V) by 100 gives the per cent SO₂ reaction per minute. In most cases less than 10% of the sulfur dioxide reacted even over extended periods of irradiation and contact time. A few isolated cases of high results could have been caused by surface conditions or traces of chromium left from the chromic acid cleaning procedure. The rates were independent of the amount of moisture present. Higher rates were observed for mixtures having a large excess of nitrogen dioxide or nitrogen dioxide in the absence of hexane (mixtures 25 and 32, Table V). The consistency of the approximately 50% excess reaction figures in the parentheses is remarkable and is observed only for the

Table VI. Reaction of SO₂ with 1-Hexene in Air

Mixture 6-4
SO₂, 15.2 p.p.m.
1-Hexene, 14.7 p.p.m.
H₂O, 50% relative humidity
Exposed only to room light

Aliquot No.	Time, Days	SO ₂ Found, μg.		
		Counts	Color	Calcd.
1	3	1.9	1.8	2.3
2	6	1.9	1.8	2.1
3	7	1.0	1.0	2.0
Remainder	20	29.1	30.8	27.3
Total SO ₂		33.9	35.4	33.7

irradiated mixtures containing both nitrogen dioxide and hexane.

Reaction with Olefins. Tables VI and VII, taken from earlier work (Noyes, 1966) with 1-liter flasks, again show that the gas-phase reaction of sulfur dioxide is very slow even in the presence of an unsaturated hydrocarbon. Table VI shows complete recovery of sulfur dioxide in the presence of 1-hexene and water at 50% relative humidity in a 1-liter flask exposed for 20 days to laboratory room light. However, there is a definite indication that 20 to 50% of the sulfur dioxide was adsorbed on the flask walls, possibly as a sulfinic compound (Dainton and Ivin, 1950).

Table VII. Twin-Flask Studies of Reaction of SO₂ with 1-Hexene and NO₂ in Air

Mixture 2-7
 SO₂, 24.6 p.p.m.
 1-Hexene, 17 p.p.m.
 NO₂, 25 p.p.m.
 H₂O, 50% relative humidity

Aliquot No.	Time, Days	SO ₂ Found, µg.					
		Dark			Irradiated ^a		
		Counts	Color	Calcd.	Counts	Color	Calcd.
1	6	10.0	6.6	10.0	9.7	6.9	10.0
2	6	8.1	6.0	9.1	7.7	6.0	9.1
Remainder	14	91.6	100.2	90.0	91.5	78.7	90.0
Total SO ₂		109.7	112.8	109.1	108.9	91.6	109.1

^aGas chromatographic analysis before and after irradiation showed a loss of from 2/3 to 4/5 of the 1-hexene in irradiated flask and no loss in dark flask. No new peaks appeared.

Table VIII. Reaction of SO₂ in Presence of NaCl

Mixture 24
 SO₂, 13 p.p.m.
 H₂O, 50% relative humidity
 NaCl particles, 38.2 mg.

Aliquot No.	Time from Filling Reaction Flask	SO ₂ Found, µg.		
		Counts	Color	Calcd.
1	1 hr. 15 min.	5.2	5.1	5.2
2	5 hr. 50 min., after 10-min. irradiation	4.7	4.7	4.7
3	6 hr. 20 min., after 2nd 10-min. irradiation	4.3	4.2	4.3
Remainder	6 hr. 25 min.	39.8	38.9	43.3
Total SO ₂		54.0	52.9	57.5

SO₂ conversion, 8.0%
 S³⁵ recovery calculated as SO₃, 93.9%

Table IX. Reaction of SO₂ in Presence of Fe₂O₃

Dark Mixture 26
 SO₂ in dry air, 18 p.p.m.
 Fe₂O₃, precipitated as hydrous oxide, dried, and exposed to room air for 3 days. 20.0 mg.

Aliquot No.	Time from Filling Reaction Flask, Min.	SO ₂ Found, µg.		
		Counts	Color	Calcd.
1	5	0.1	0.1	8.3
2	14	0.1	0.2	6.8
3	22	0.0	0.2	6.1
Remainder	22	83.2	0.0	62.3
Total SO ₂		83.4	0.5	83.5

SO₂ conversion, 99.3%
 S³⁵ recovery calculated as SO₃, 99.9%

Table VII gives the results for a twin-flask experiment involving sulfur dioxide, 1-hexene, nitrogen dioxide, and water at 50% relative humidity. One flask, kept dark for 14 days, showed no sulfur dioxide reaction, but an indication of adsorption on the flask walls. The other flask, kept exposed to room light for the 14 days, including 3 hours in direct midday sunlight, showed an over-all reaction of approximately 16% of the sulfur dioxide. Gas chromatographic analysis of both flasks before and after sunlight irradiation showed a loss of approximately 70% of the 1-hexene in the gas phase of the irradiated flask and no loss in the dark flask.

Heterogeneous Reactions

The reaction of sulfur dioxide with particulates is illustrated by Tables VIII and IX and summarized in Table X. In the presence of sodium chloride particles at 50% relative humidity, after 20 minutes' irradiation, and a total contact time of 6 hours and 25 minutes, approximately 8% of the sulfur dioxide reacted (Table VIII). This is above the reaction rate for sulfur dioxide alone or in the presence of sodium chloride under dry conditions (Tables V and X), but it does not indicate a greatly increased reaction rate when one considers that the 6% not recovered from the experiment was included in the amount reacted.

The reaction of sulfur dioxide with hydrous ferric oxide was virtually complete within minutes, even though the ferric oxide had been exposed to the laboratory air for 3 days (Table IX). The reaction with carefully dried hydrous ferric oxide (data not shown) was complete within seconds after the air-sulfur dioxide mixture was admitted to the flask. The reaction with the magnetic oxide of iron (Fe₃O₄) was approximately 17% in 4 minutes (experiment 13, Table X), but the slower rate may have been largely due to the smaller specific surface area of the Fe₃O₄ particles.

Table X summarizes the results from a number of representative heterogeneous experiments, most of them run dry and without ultraviolet irradiation. Some of the reaction mixtures were irradiated with ultraviolet light, and a few, with NaCl and V₂O₅ present, were conducted at 50% relative humidity. However, within the experimental error of the limited

Table X. Summary of SO₂ Reactions in the Presence of Various Particulates

Expt. No.	Present	UV, Min.	Total Time in Flasks, Min.	%S ³⁵ Recovered	% SO ₂ Reacted
7	SO ₂ 14 p.p.m. NaCl 21.0 mg.	0	1000	99	-1.8
5	SO ₂ 13 p.p.m. NaCl 38.2 mg.	20	385	94	8.0
8	H ₂ O 50% RH SO ₂ 14 p.p.m. CaCO ₃ 30.3 mg.	0	1100	99	4.2
9	SO ₂ 13 p.p.m. CaCO ₃ 36.1 mg.	20	140	98	10
12	SO ₂ 18 p.p.m.	0	22	100	99
13	Fe ₂ O ₃ 20.0 mg. SO ₂ 8 p.p.m.	0	4	102	17
15	Fe ₃ O ₄ 14.0 mg. SO ₂ 14 p.p.m.	0	1030	99	9.0
16	Cr ₂ O ₃ 11.0 mg. SO ₂ 17 p.p.m.	0	15	101	(26)
17	PbO 11.0 mg. SO ₂ 18 p.p.m.	0	9	103	(53)
20	PbO ₂ 12 mg. SO ₂ 8 p.p.m.	0	800	97	9.3 (12.2)
21	V ₂ O ₅ 17.2 mg. SO ₂ 8 p.p.m.	180	810	98	-0.9 (5.6)
23	V ₂ O ₅ 16.2 mg. SO ₂ 8 p.p.m.	180	815	88	12 (25)
24	H ₂ O 50% RH SO ₂ 12 p.p.m.	0	30	92	53
25	CaO 19.7 mg. SO ₂ 12 p.p.m.	10	20	98	61
28	CaO 22.7 mg. SO ₂ 14 p.p.m.	0	1145	93	46
37	Al ₂ O ₃ 33.1 mg. SO ₂ 10 p.p.m.	0	30	32	79
38	Al ₂ O ₃ 19.8 mg. CaO 16.6 mg. SO ₂ 10 p.p.m.	10	30	35	73
	Al ₂ O ₃ 17.7 mg. CaO 17.7 mg.				

() % SO₂ removed from gas phase before flasks were rinsed.

number of experiments performed, neither moisture nor irradiation greatly increased the rate of reaction of sulfur dioxide.

Oxidation of sulfur dioxide was not promoted by dry, powdered sodium chloride. Calcium carbonate, chromium trioxide, and vanadium pentoxide in the dry and nonirradiated experiments gave reaction rates of approximately 0.2, 0.5, and 0.7% per hour, respectively. These rates were surprisingly low, especially for chromium trioxide and vanadium pentoxide, which are known to catalyze the oxidation of sulfur dioxide at higher temperatures. The additional effects of moisture and ultraviolet irradiation caused slightly greater reaction rates, the results exhibiting some experimental difficulties. The 12% reaction indicated for vanadium pentoxide in experiment 23, Table X, was entirely due to the 12% irreversibly absorbed by the vanadium pentoxide. Gaseous aliquots taken from the

flasks containing vanadium pentoxide showed that a significant amount of the sulfur dioxide was absorbed and later released partially or wholly unreacted to the rinsing solution. The figures for the amount of loss of sulfur dioxide from the gas phase before the rinsings were analyzed are shown in parentheses next to the figures for the over-all reaction (experiments 16, 17, 20, 21, and 23, Table X).

Lead monoxide and lead dioxide gave much higher reaction rates of 1.7 and 6.0% per minute, respectively. This was not surprising, since lead dioxide is used in the lead candle method of determining sulfur oxides in air. The reaction rates for calcium oxide and mixtures of calcium oxide and aluminum oxide varied between 2 and 3% per minute. The reaction rate for aluminum oxide alone was much smaller—of the order of 2.4% per hour, or 0.04% per minute. The reaction rates of

calcium oxide (Table X) may have reflected the effect of some moisture picked up under the experimental conditions.

Discussion

The experimental techniques used had a number of limitations. A small amount of reaction was measured by the difference in the total amounts of sulfur dioxide found before and after each experiment. The use of a radioactive isotope limited the use of large air volumes, and the colorimetric method was capricious and had to be carefully controlled and checked. However, mass balances of all of the sulfur dioxide taken were routinely possible. The colorimetric method gave a positive measure of the amount of sulfur dioxide present, and the scintillation method accounted for the sulfur dioxide that had reacted. The gas-phase products were separated from those adhering to the flask walls, and there were no limitations on residence or irradiation times.

Within experimental error, no reaction or adsorption of sulfur dioxide on the flask walls was detected when the flasks were kept in the dark. The photochemical reaction of sulfur dioxide in clean air with ultraviolet radiation having a cutoff point at 3000 Å. and with 90% of its intensity centered at 3500 Å. was found to be of the order of 0.1% per hour of equivalent noonday sunlight—verifying the results obtained by Gerhard and Johnstone (1955). No differences in reaction rates could be detected when the all-quartz flask was used. Consequently, most experiments were conducted in borosilicate glass flasks.

In the presence of saturated and unsaturated hydrocarbons, nitrogen dioxide, and water vapor, the photochemical reaction rates were somewhat faster and a maximum rate of 1 to 3% per hour of equivalent noonday sunlight was observed. Water vapor had no effect on the reaction rates except at 100% relative humidity, where reaction was slightly greater. At such humidity levels the formation of water films and droplets was possible and the occurrence of heterogeneous reactions could not be ruled out.

In general, analysis of the aliquots of the gas phase showed the presence of only sulfur dioxide. The reaction products, if any, either migrated to the flask walls or were formed and retained there. Some gaseous sulfur-bearing compounds may have been formed which in the TCM rinsing solution gave the sulfur dioxide color reaction. Such substances would be difficult to detect by the methods used. Gas chromatographic, mass spectroscopic, or far-ultraviolet spectrophotometric techniques could furnish important supplementary information.

With *n*-hexane and in the presence of nitrogen dioxide a number of irradiated experiments showed excess reaction of the sulfur dioxide in the rinsing solution. It is assumed that this reaction was caused by non-sulfur-bearing photochemical products adhering to the flask walls and possibly catalyzed by traces of chromium. When the flasks were washed with acetone rather than chromic acid cleaning solution, no excess reaction of sulfur dioxide was found.

There was some evidence that sulfur dioxide reacted with 1-hexene in the dark to condense on the flask walls. The reaction products gave the usual sulfur dioxide colorimetric reaction, indicating the possible formation of a sulfinic compound (Dainton and Ivin, 1950). When irradiated with sunlight, the presence of both a sulfinic compound and an oxidized sulfur compound was indicated (Table VII).

The heterogeneous reaction rate of sulfur dioxide on inert solids, such as sodium chloride and calcium carbonate, was small, indicating little, if any, surface effects from such substances. The heterogeneous reaction rate with iron oxide at room temperature, for example, was several orders of magnitude greater than any of the photochemical homogeneous reaction rates observed. The heterogeneous reactions were complicated to some extent by the tendency of the sulfur dioxide to be adsorbed by particles with high specific surface area in addition to reacting in their presence.

The weights of the particulates used in the heterogeneous experiments were from 100 to 200 times the weight of the sulfur dioxide taken. In a polluted atmosphere the total weight of particulates suspended in air is much smaller relative to sulfur dioxide and other gaseous pollutants (Cadle, 1965; Schuck, Stephens, *et al.*, 1966), and heterogeneous reactions, although much more rapid, could be limited in this respect.

The low rate of the homogeneous photochemical reaction of sulfur dioxide in the presence of nitrogen dioxide and saturated and unsaturated hydrocarbons, coupled with the relatively small amounts of particulates available for heterogeneous reactions, in all probability accounts for the common observation that sulfur dioxide comprises 60 to 90% of the sulfur-bearing compounds found in polluted atmospheres (Thomas, 1964). Under such conditions there is ample opportunity for sulfur dioxide to enter into secondary reactions with other photochemical reaction products or to form loose adducts with olefins, carbonyls, or other substances known to react with sulfur dioxide (Schroeter, 1966).

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Effect of Macroscopic Properties of Manganese Oxides on Absorption of Sulfur Dioxide

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Several macroscopic properties of manganese oxides have been studied to establish their effects on the removal of SO₂ from gases. Bulk density, specific gravity, porosity, and surface area were examined in six samples of MnO₂ and γ -Mn₂O₃. Absorption tests were made by passing dry gas containing 0.4% SO₂ and 99.6% N₂ by volume through a packed bed of oxide at 300°C. and atmospheric pressure. Runs were also made with 3.4 volume % moisture in the gas. Surface area, specific gravity, and humidity had an important influence on the absorptive capacities of the manganese oxides. The capacity increased with increasing surface area and decreasing specific gravity.

An attractive method of removing SO₂ from flue gases is sorption on metallic oxides with subsequent regeneration (Bienstock, Field, *et al.*, 1961; Uno, Yamada, *et al.*, 1967). Manganese oxides are especially promising, even though regeneration of MnSO₄ is difficult. However, samples prepared by different methods show varying capacities for SO₂ absorption (Bienstock, Field, *et al.*, 1961). That suggests that the manganese oxides may exhibit differences in macroscopic properties, depending on the method of preparation. The present work seeks to relate macroscopic properties such as surface area, bulk density, specific gravity, and porosity of the manganese oxide to its ability to absorb SO₂.

Experimental Methods

Six samples of manganese oxides were tested. Complete or partial chemical analyses were obtained from the suppliers. Compositions with respect to some of the more important elements are shown in Table I along with the other macro-

scopic properties measured in the present work. While no chemical analysis was made of the MnO₂ prepared in this laboratory, it is estimated that it should contain about 94% MnO_{1.88} by weight based on U. S. Bureau of Mines analysis of material prepared in exactly the same manner. The specific gravity and bulk density were measured by volumetric displacement and the porosity was calculated from these results. Surface area was measured with a Numinco Orr surface area-pore volume analyzer, Model MIC-101 (Orr and DallaValle, 1959).

The effectiveness of each sample as an absorbent was determined by removing SO₂ from a mixture containing 0.4% SO₂ and 99.6% N₂ by volume, specially prepared by the United States Bureau of Mines and closely approximating the concentration of SO₂ found in ordinary flue gases. A measured, constant flow of the gas was maintained through the reactor, which was a vertical, borosilicate glass tube 19 mm. in inside diameter and 750 mm. long, enclosed by cylindrical heaters to control the temperature. The bed of absorbent, about 1.2 or 2.5 cm. in height, was preceded by an 8-cm. preheating zone of 4-mm. glass beads and followed by another zone of glass beads. SO₂ was determined by passing the off-gas through I₂ and Na₂S₂O₃ solutions in series, combining the solutions, and titrating with S₂O₃²⁻ or I₂ solution with a starch indicator. Each analysis was made on 0.020 standard cu. foot of the gas.

Both dry and wet gases were used. The moisture-free gas flow for all runs was constant at 0.15 SCFH (20°C. and 760 mm. of Hg). In the tests with wet gas, the gas was saturated ahead of the reactor by bubbling it through water previously saturated with SO₂. The moisture content of the gas was measured by removal by Drierite, which picks up almost no SO₂. The average amount of moisture in the gas mixture for all runs was 3.38 ± 0.10% by volume.

Results and Discussion

The results of the absorption tests are shown in Table I in terms of gram moles of SO₂ absorbed per gram atom of manganese in the sample. On this basis, a value of unity indicates 100% utilization of manganese oxide for SO₂ absorption. The absorption shown in Table I represents the

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Table I. Properties and SO₂-Absorption Capacities of Manganese Oxides

Source	Natural MnO ₂	Chem. G. MnO ₂	Chem. G. MnO ₂	Lab. Prep. MnO ₂ ^a	γ-Mn ₂ O ₃	Regenerated γ-Mn ₂ O ₃ ^b
	Manganese Chemicals Co.	Manganese Chemicals Co.	Fisher Scientific Co.	Present work	Manganese Chemicals Co.	U. S. Bureau of Mines
Form used in tests	Pellets (8-16 mesh) and powder	Powder	Powder	Powder	Powder	Loose pellets (8-24-mesh)
Approx. atoms O per atom Mn	1.92	1.88	2.00	1.88	1.50	1.50
Chemical analysis, approx. % by Wt.						
Mn	53.5	57.2	63.1	60.9	68.5	65.5
MnO ₂	77.8	79.4	99.9	84.8	54.4	51.8
Fe	2.7	0.05			0.25	0.1
Si	0.87				0.075	0.5
Al	2.78					0.05
S	0.01	0.86	0.0057			
Specific gravity, 20°/20°C.	3.58	2.82	4.23	3.04	4.24	3.46
Bulk density, g./cc.	Powder 2.05 Pellet 1.35	1.31	2.26	0.32	1.28	0.56
Porosity	Powder 0.43 Pellet 0.62	0.53	0.66	0.89	0.70	0.84
Surface area, sq. m./g.	Powder 12.2 Pellet 14.9	60.8	1.68	51.2	3.9	27.5
Absorption Data. G. Moles SO ₂ Absorbed/G. Atom Mn ^c						
Dry gas	0.0175	0.511	0.000955	0.268	0.00138	0.0428
Wet gas	0.0177	0.515	0.00122	0.540	0.00163	0.0793

^a Preparation. $(\text{NH}_4)_2\text{S}_2\text{O}_8 + \text{MnSO}_4 + 2\text{H}_2\text{O} \xrightarrow{\text{heat}} 2\text{H}_2\text{SO}_4 + (\text{NH}_4)_2\text{SO}_4 + \text{MnO}_2 \downarrow$
Sample dried at 300°C. for 12 hours.

^b Preparation. $\text{MnSO}_4 \xrightarrow[\text{air}]{\text{NaOH}} \gamma\text{-Mn}_2\text{O}_3 \downarrow + \text{Na}_2\text{SO}_4$; ppt. washed, dried, and heated with air at 300°C. and in vacuum at 300-340°C. for 20 hours.

^c Up to time of 90% removal of SO₂ from gas under following experimental conditions: temperature, 300°C.; space velocity, dry gas 600 hr.⁻¹, wet gas 1250 hr.⁻¹.

amount of SO₂ absorbed up to the time when 90% of the SO₂ in the inlet gas stream had been removed by the manganese oxide.

Capacity to absorb SO₂ does not show a consistent trend with bulk density or porosity. On the other hand (Figure 1), absorption of dry SO₂ by MnO₂ decreases with increase in specific gravity in a manner essentially linear on semilogarithmic coordinates. The data for γ-Mn₂O₃ lie almost on the same line. Figure 2 shows that absorption of dry SO₂ by MnO₂ increases with increase in surface area. Even though data on capacities do not in themselves contribute to uncovering the mechanism involved, the results indicate that specific surface area must be a pertinent factor in studies of mechanism. For the samples studied, there is a definite relationship between surface area and specific gravity. It is possible that

the absorption is not influenced by surface area and specific gravity independently and that surface area is the more fundamental factor. Under the conditions of the present experiments, no differences were found between the powder and pellet forms of natural MnO₂ with respect to SO₂ absorption.

Experiments with and without moisture in the gas were run at different space velocities, making it difficult to arrive at a quantitative comparison. Since the residence time was shorter for the wet runs, any increase in capacity shown by the present data can be interpreted as a true increase under conditions of equal space velocities. In general, moisture enhances the absorption, but the effect depends on the particular material under examination. The role of moisture on SO₂ absorption is probably not a simple one.

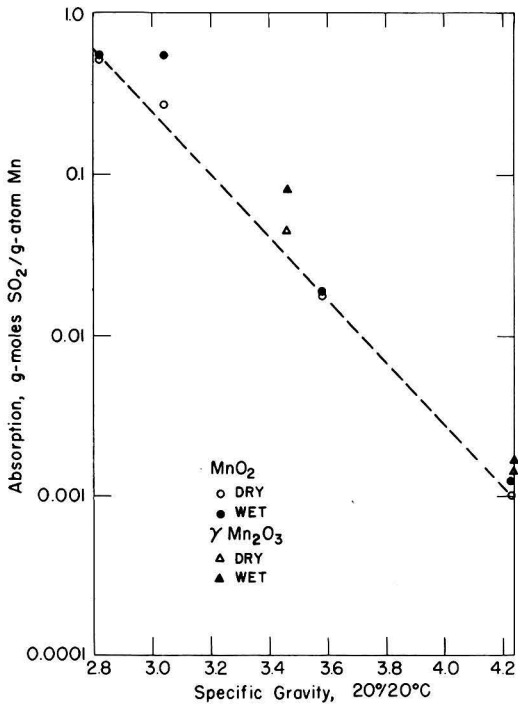


Figure 1. Effect of specific gravity on capacity to absorb SO₂

Using a simulated flue gas containing 6.0% O₂ and 6.7% moisture, Bienstock, Field, *et al.* reported absorption capacities (up to 90% removal of SO₂) of 0.467 gram mole of SO₂ per gram atom of Mn at 130°C. and 0.863 at 330°C. for prepared MnO_{1.88}; 0.244 at 130°C. and 0.745 at 330°C. for regenerated γ-Mn₂O₃. While the capacity for prepared MnO_{1.88} (with wet gas) from the present work falls within their range, the value for regenerated γ-Mn₂O₃ is several times smaller. This suggests that free oxygen is involved in the absorption of SO₂ to a degree probably depending on the oxygen deficiency in the solid to form manganese sulfate.

The effects of both moisture and oxygen are being studied in a continuing investigation on the kinetics of SO₂ absorption by manganese oxides.

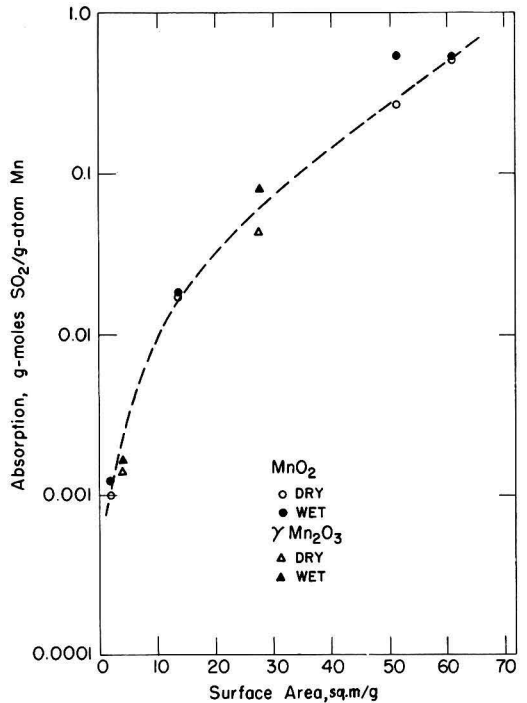


Figure 2. Effect of surface area on capacity to absorb SO₂

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Intraparticle Diffusion in the Catalytic Combustion of Methane, Ethane, and Propane

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■ The effects of pore diffusion in the catalytic combustion of methane, ethane, and propane have been investigated with CuO-Al₂O₃ catalyst pellets of two different sizes. Analysis of the experimental data indicates that pore diffusion effects were negligible for the smaller pellets, but not for the larger pellets. Good agreement between the calculated and experimental data of the larger pellets was obtained by considering both surface diffusion and gas-phase pore diffusion.

In a continuation of investigations on the catalytic elimination of air pollutants from hydrocarbon-consuming combustion processes, the catalytic oxidation reactions of methane, ethane, and propane on CuO-Al₂O₃ reported previously (Accomazzo and Nobe, 1965) were re-examined to determine the extent of pore diffusion effects. In the correlations of his experimental data, Accomazzo attributed the deviations between experiment and the calculations to external and internal diffusion. The effects of external diffusion were easily determined by calculations and shown to be of relatively minor importance. The discrepancy between the experimental and calculated (including the effects of external diffusion) data was surmised to be due to intraparticle diffusion. The purpose of this work was to investigate in detail the role of pore diffusion in the combustion of methane, ethane, and propane on CuO-Al₂O₃. The CuO-Al₂O₃ catalysts prepared by Accomazzo (1965) and aged in air for over 3 years were used. The full-sized cylindrical pellets were 0.3 × 0.25 cm.; half-sized pellets were the full-sized ones cut in half. In theory, pore diffusion effects decrease with decrease in the catalyst size.

Thiele (1939) treated the diffusion of reactants in an ideal catalyst pore mathematically. He introduced the concept of the effectiveness factor, which is defined as the ratio of actual reaction rate to the rate that would be observed if all of the catalyst surface were at the same conditions as the external surface. The major part of the surface area of a highly porous catalyst is, of course, in its interior.

Reviews on pore diffusion effects and equations for the effectiveness factors of different geometries are given by Satterfield and Sherwood (1963), Weisz and Prater (1954), and Wheeler (1951).

The effectiveness factor, η , of first-order reactions on cylindrical pellets has been determined by Aris (1957) as

$$\eta = 1 - \frac{32}{\pi^2} \sum_{m=1}^{\infty} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2 j_m^2} \times \frac{\lambda^2 R_c^2}{\lambda^2 R_c^2 + j_m^2 + \frac{\pi^2 R_c^2}{L_c^2} (2n+1)^2} \quad (1)$$

where $\lambda^2 = \frac{k_v}{D_e} = \frac{k_p RT}{V_p D_e}$.

The effective diffusivity, D_e , can be determined experimentally. However, calculation methods approximate this parameter. The effective diffusivity can be determined from the diffusivity ratio, ratio of the effective diffusivity of the gas per unit volume of the catalyst to the diffusivity (diffusion coefficient) of the gas per unit volume of the free space. For the latter, the ordinary bulk diffusion coefficient can be used if the pore size is greater than 10,000 Å. or the Knudsen coefficient if it is less than 1000 Å. under normal conditions of temperature and pressure. For intermediate pore sizes, there is a transition from Knudsen to bulk diffusion and the diffusion coefficient can be estimated by the Bosanquet interpolation formula (Pollard and Present, 1948),

$$\frac{1}{D} = \frac{1}{D_{bd}} + \frac{1}{D_k} \quad (2)$$

Weisz and Schwartz (1962) give an empirical equation for the diffusivity ratio, $\frac{D_e}{D} = \frac{\epsilon^2}{\sqrt{3}}$, which provides a method of approximating D_e .

However, the effective diffusivity calculated by this method assumes that diffusion in the pores proceeds only by gas-phase diffusion. Smith and his coworkers (Krasuk and Smith, 1965; Rivarola and Smith, 1964) have shown that surface diffusion may also contribute to the mass transfer in the pores.

Experimental

The CuO-Al₂O₃ catalyst prepared by Accomazzo (1965) was aged in air for over 3 years. Cupric nitrate and alumina were mixed in distilled water and the mixture was heated. Then, copper hydroxide was precipitated from the solution by the addition of potassium hydroxide. The precipitate was

filtered, washed, pressed into molds, and then heated in an oven to decompose the copper hydroxide to cupric oxide.

BET surface areas of the catalysts were measured by adsorption of nitrogen gas at liquid nitrogen temperatures. Pore volume was determined by the water injection method. The physical properties of the catalyst are listed in Table I.

A schematic diagram of the equipment and apparatus is shown in Figure 1. The reactor was constructed of Vycor tubing, 19-mm. i.d., with a thermocouple well placed along the axis of the reactor tube. The annulus of the reactor was packed with ceramic beads to a depth of 50 cm. with 16 grams of the catalyst placed on top of the beads. The reactor was enclosed in an electric furnace consisting of two sections with two variable-resistance controls.

Laboratory air freed of carbon dioxide and water vapor by passage through a molecular sieve bed was metered by a calibrated flowmeter. Methane, ethane, and propane of Matheson C.P. grade (minimum purity, 99.5%) were used. The flow rate of hydrocarbons was controlled by a pressure regulator and precision needle valve and determined with a 10-ml. soap bubble buret. The initial concentration was determined by the ratio of the flow rates of hydrocarbon to air. The hydrocarbon and air were completely mixed in the mixing chamber.

In order to attain as nearly as possible isothermal conditions within the reactor, the axial temperature gradient across the catalyst bed was minimized by carefully controlling the variable resistances. The temperature profile in the bed was determined by seven iron-constantan thermocouples and continuously monitored with a Brown 0° to 1200° F. multipoint recorder. The maximum temperature difference of 10° C. across the bed (bed temperatures ~500° C.) was observed at the higher concentration and at high per cent conversion during methane oxidation. However, for all hydrocarbons at intermediate and low per cent conversion, the temperature gradient was 2° C. or less.

After the oxidation of methane, ethane, and propane with the full-size pellets, the catalyst was removed from the reactor and the pellets were cut in half with a razor. The catalyst was then placed in the reactor again. Some borosilicate glass distillation helices were placed over the catalyst bed to minimize fluidization.

The hydrocarbon-air mixture was sampled at the entrance and the exit of the catalyst bed with the hydrocarbon concentration in the exit stream continuously analyzed until steady state was attained. Then, the concentration of the hydrocarbon in outlet stream was recorded, and the inlet concentration determined. The hydrocarbon concentrations in the experiments with the full-size pellets were measured with a Carad flame ionization analyzer and detector, and in the case of half-size pellets, with a Beckman flame ionization detector, Model 108. The instruments were zeroed with nitrogen and calibrated every day with a known concentration of the hydrocarbon used. The output of the analyzer was connected to a Leeds and Northrup recorder to indicate when steady-state condition was achieved.

Table I. Physical Properties of $\text{CuO-Al}_2\text{O}_3$ Catalyst

Diameter, mm.	3.0
Length, mm.	2.5
Weight per pellet, g.	0.028
Surface area, sq. m./g.	.96
Pore volume, ml./g.	0.415
Mean pore radius, A.	86

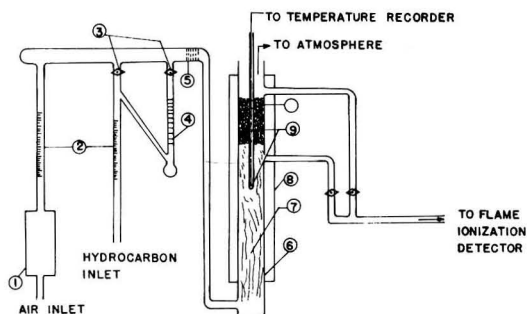


Figure 1. Apparatus

1. Molecular sieve trap
2. Rotameters
3. Teflon stopcocks
4. Soap bubble buret
5. Mixing disks
6. Vycor tubing
7. Ceramic packing
8. Furnace
9. Thermocouple well
10. Catalyst bed

The catalyst was activated before the experiment by passing air at 600° C. for 48 hours through the bed. This procedure was repeated with the half-size pellets.

Results and Discussion

Total gas flow rates of 525 and 275 liters per hour at normal temperatures and pressures were used for each hydrocarbon. Typical experimental data on methane, ethane, and propane combustion with full-size pellets are shown in Figure 2. Conversion of hydrocarbons increased with increase in temperature and with decrease in the flow rate. Methane was the most difficult to oxidize of the three hydrocarbons. Typical data for the combustion of hydrocarbons with half-size pellets of the catalyst are given in Table II. Conversion of hydrocarbons with half-size pellets was always greater than with full-size, as expected. The temperatures required for 50% conversion with full-size pellets at a flow rate of 275 liters per hour were 442°, 377°, and 340° C. for methane, ethane, and propane, respectively; with half-size pellets, 404°, 349°, and 326° C. for methane, ethane, and propane, respectively.

The rate expression $r = k_p p_H^n$ was used to correlate all the data, where p_H is the partial pressure of the hydrocarbon. The experimental data on methane, ethane, and propane combustion with full-size and half-size pellets of copper oxide

were initially examined neglecting diffusion effects in order to obtain a first approximation of the apparent reaction order and other kinetic parameters.

The reduction of the data for the combustion of methane, ethane, and propane with full-size and half-size pellets assuming a first-order reaction with respect to the hydrocarbon concentration is shown in the Arrhenius plots in Figures 3 and 4. The Arrhenius curves were linear for the half-size and

nonlinear for the full-size pellets. Comparison of the difference between the degree of oxidation on the full-size and half-size pellets at a specific temperature shows that this difference decreases as the temperature decreases and in the following order: methane > ethane > propane. In addition, the half-size pellets were more active than the full-size pellets. These results indicate that pore diffusion effects were negligible for the half-size pellets, but significant for the full-size pellets.

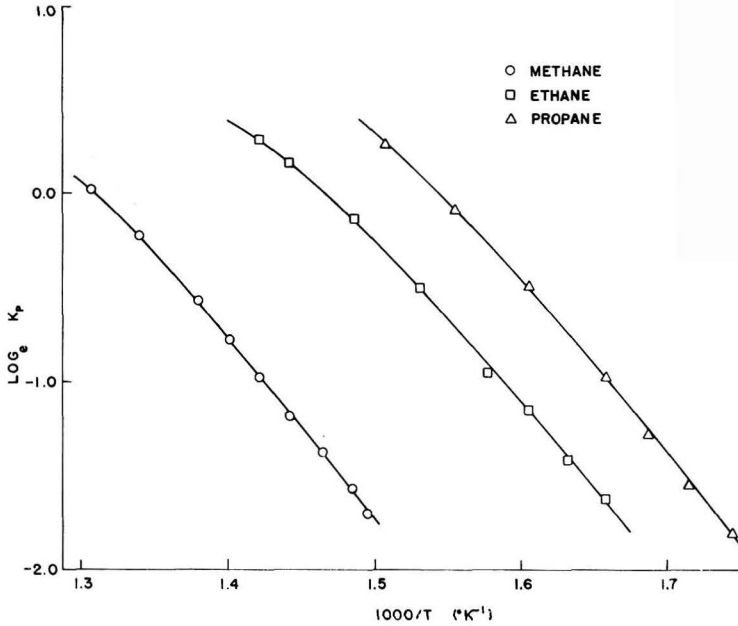


Figure 3. Arrhenius plots for full-size pellets

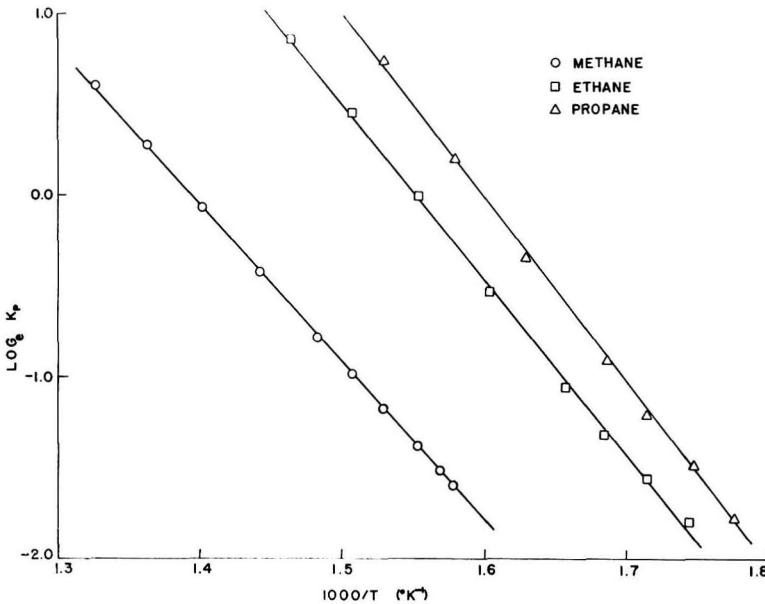


Figure 4. Arrhenius plots for half-size pellets

The rate equations for the combustion of the hydrocarbons with half-size pellets are

$$r_{\text{CH}_4} = 2.99 \times 10^5 e^{-\frac{17820}{RT}} p_{\text{CH}_4} \quad (3)$$

$$r_{\text{C}_2\text{H}_6} = 8.29 \times 10^6 e^{-\frac{19193}{RT}} p_{\text{C}_2\text{H}_6} \quad (4)$$

$$r_{\text{C}_3\text{H}_8} = 1.73 \times 10^2 e^{-\frac{20682}{RT}} p_{\text{C}_3\text{H}_8} \quad (5)$$

where p is hydrocarbon partial pressure in atmospheres and r is the rate in gram moles/hour-atmosphere-gram of catalyst. With the above kinetic parameters obtained with the half-size pellets, the effects of pore diffusion with the full-size pellets were determined.

The effective diffusivity was calculated using the relation

$$\frac{1}{D_e} = \frac{\sqrt{3}}{\epsilon^2} \left(\frac{1}{D_H} + \frac{1}{D_{KH}} \right) \quad (6)$$

where ϵ is the porosity of the pellets, D_{KH} is the Knudsen diffusion coefficient of the hydrocarbon, and D_H is the ordinary diffusion coefficient of the hydrocarbon in air. The diffusivity ratio, D_e/D , was determined to be 0.26. To take into account the temperature gradient along the bed and the external diffusion effects, the bed was divided into small increments and

the design equation in difference form was used, $\frac{\Delta W}{F} = \frac{\Delta X}{r}$.

The temperatures at each end of the increment were measured with thermocouples placed along the bed. The conversion across the increment was calculated by a trial and error method (Caretto, 1965). Computer calculations taking into account the temperature gradient along the bed determined the conversions at the exit of the reactor by considering pore and external diffusion effects, the effect of external diffusion alone, and finally no diffusion effects.

The results showed that the effects of external diffusion were negligible. The detailed calculations of exit conversion considering both pore and external diffusion showed that the experimental conversions were always greater than the calculated values. This observed higher conversion has been attributed to surface diffusion (Krasuk and Smith, 1965).

Krasuk and Smith (1965) considered the calculation of effectiveness factors for cases where surface diffusion was significant. They calculated effectiveness factors from Miller and Kirk's (1962) catalytic dehydration data of ethanol, 1-propanol, and 1-butanol by replacing the normal diffusion modulus, λL , by $\lambda L \sqrt{\frac{1}{1 + \phi}}$, where ϕ is the ratio of the sur-

face-to-gas-phase pore diffusion. Calculations showed that ϕ increased with increase in temperature and increase in chain length of the alcohol. Rivarola and Smith (1964) measured the surface diffusion rate of carbon dioxide on alumina and observed that surface diffusion was as substantial as gas-phase pore diffusion for pellets with large surface areas.

Caretto (1966), investigating the catalytic combustion of cyclohexane, cyclohexene, and benzene with a $\text{CuO-Al}_2\text{O}_3$

catalyst, also showed that surface diffusion may contribute to intraparticle diffusion. With Krasuk and Smith's method (1965), Caretto calculated ϕ values of 1.7, 3.2, and 5.1 for benzene, cyclohexene, and cyclohexane, respectively.

Good correlation between experimental and calculated data of this investigation can be obtained by using larger diffusivity ratios than those determined with Equation 6. The diffusivity ratio required for propane (2.3) was larger than those required for methane and ethane, and was independent of temperature between 296° and 406° C. The diffusivity ratios of methane varied from 0.26 to 1.0 from 379° to 511° C., and of ethane varied from 0.26 to 1.1 from 328° to 431° C.

Following Krasuk and Smith (1965), the ratio of surface-to-gas-phase pore diffusion, ϕ , with the diffusivity ratios of methane, ethane, and propane can be determined by the equation

$$\phi = \frac{\sqrt{3} D_e}{D \epsilon^2} - 1 \quad (7)$$

The ϕ for methane varied from 0 to 2.8 in the temperature range of the experiments. For ethane, ϕ varied from 0 to 3.2, and for propane, ϕ was 7.8 with no variation with temperature observed. The required diffusivity ratios, the corresponding surface diffusion ratios, ϕ , and the effective factors, η , for methane, ethane, and propane combustion at various temperatures are given in Table III.

Figure 2 shows the results of the calculations considering gas-phase pore diffusion and surface diffusion effects for full-

Table III. Pore Diffusion Parameters in the Catalytic Combustion of Hydrocarbons on Full-Sized Pellets

Hydrocarbon	T , °C.	D_e/D	ϕ	η
Methane	397	0.26	0	0.557
	423	0.30	0.15	0.489
	462	0.60	1.30	0.488
	496	1.00	2.83	0.473
	511	1.00	2.83	0.432
Ethane	328	0.26	0	0.540
	356	0.35	0.34	0.462
	361	0.35	0.34	0.441
	364	0.35	0.34	0.428
	394	0.75	1.88	0.432
	431	1.10	3.22	0.367
Propane	296	2.3	7.8	0.917
	327	2.3	7.8	0.817
	343	2.3	7.8	0.747
	354	2.3	7.8	0.695
	385	2.3	7.8	0.506
	406	2.3	7.8	0.463

size pellets. The linearity of the Arrhenius curves in Figure 4 indicated that for the half-size pellets the pore diffusion effects were negligible. According to theory, the effect of pore diffusion should diminish with decrease in pellet size (the internal characteristics of the catalyst being identical). In other words, if pore diffusion effects are significant, decreasing the pellet size of the catalyst should increase the activity per unit mass of catalyst. Experimental results are thus in qualitative agreement with theory. Comparison of the experimental data for the combustion of methane, ethane, and propane on half-size pellets (Table II and Figure 4) and full-size pellets (Figures 2 and 3) indicates that the effect of pore diffusion for the full-size pellets was significant.

Satterfield and Sherwood (1963) show that catalytic activity increases with decrease in the size of the catalyst. Weisz and Prater (1954) reported that the activity of a silica-alumina catalyst for the cracking of cumene increased with decrease in the catalyst size. Caretto (1965) showed the importance of pore diffusion in the combustion of ethylene with copper oxide-alumina catalysts and indicated that the effects of pore diffusion decrease with decrease in the catalyst size, as expected.

Conclusions

Surface diffusion may play a significant role in the pore diffusion effects of methane, ethane, and propane combustion on $\text{CuO-Al}_2\text{O}_3$. Since the surface diffusion ratio, ϕ , is a measure of the effects of surface diffusion, the results given in Table III show that surface diffusion relative to gas-phase pore diffusion increased with increase in temperature and with the chain length of the hydrocarbon. These results are in accord with the analysis of Miller and Kirk's data (1962) by Krasuk and Smith (1965).

Nomenclature

- D = gas phase diffusivity, sq. cm./sec.
 D_H = ordinary diffusion coefficient of hydrocarbon in air, sq. cm./sec.
 D_e = effective diffusivity in catalyst particle, sq. cm./sec.
 D_e/D = diffusivity ratio
 D_K = Knudsen diffusion coefficient, sq. cm./sec.
 F = initial feed rate of hydrocarbons, moles/sec.

- J_0 = zeroth order Bessel function of the first kind
 j_m = roots of equation $J_0(j_m) = 0$
 k_p = rate constant, moles/sec.-g.cat.-atm.ⁿ
 k_v = rate constant, moles/sec.-ml.cat.-(moles/ml.)
 L_c = length of pore
 n = reaction order
 p_H = partial pressure of hydrocarbon, atm.
 p_0 = initial partial pressure of hydrocarbon, atm.
 Q = flow rate, liters/sec.
 r = reaction rate, moles/sec.-g.cat.
 R = gas constant
 R_c = cylinder radius
 T = temperature, ° K.
 V_p = pellet volume, ml./g.
 W = weight of catalyst, g.
 X = conversion of hydrocarbon
 ϵ = porosity of catalyst pellet
 η = effectiveness factor
 λ = diffusion modulus, cm.⁻¹
 ϕ = ratio of surface diffusion to gas-phase pore diffusion

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Effects of Radiation on Corn Starch Sols

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■ The effect of gamma radiation on the sedimentation and degradation of corn starch sols has been investigated for doses between 10^2 and 10^6 rad. No enhancement of the sedimentation during a 1-hour period has resulted from the irradiation. For the higher doses, radiation has decreased the degree of sedimentation although a progressive decrease in turbidity resulted as the dose increased. The observed reduction of turbidity has been attributed to progressive degradation of the starch with increased doses. The steps and the degree of degradation have been investigated spectrophotometrically using an iodine indicator and are analogous to those noted in chemical degradation studies.

In recent years, considerable emphasis has been placed on the development of improved methods for sewage treatment. Of particular interest to several investigators has been the possibility of using ionizing radiation to aid in coagulation and sedimentation of colloidal particles. Reported results have, however, indicated considerable variation and strongly suggest that additional research is required to establish the full potential of radiation treatment of sewage waters for the purpose of enhancing coagulation and sedimentation.

Because of the complex and varied composition of sewage waters and the equally complex and varied sedimentation effects which radiation may induce, many investigators have chosen to work with clearly defined, often rather simple, systems in an attempt to isolate the significance of individual effects. This study is of such a nature and deals with the effects of gamma radiation on a common colloid, the corn starch sol.

The study was initiated to confirm and expand upon the sparse experimental sedimentation data reported in the literature for this system (Unidynamics, 1960, 1961a,b, 1962a,b, 1963, 1964). However, the results obtained were at considerable variance with those in the literature. A closer examination of available information led to the establishment of two goals for this research study: the determination of the effect of gamma radiation on the sedimentation rate over a wide range of total dose, and the investigation of the degree of starch degradation resulting from irradiation.

Literature Survey

The effects of ionizing radiation on colloids have been studied for a variety of systems. In several cases, little or no perceptible effects on settling and precipitation were noted. These included studies of stannic oxide, bacterial and river suspensions, and ferric and aluminum oxide sols (Burrows, Corbett, *et al.*, 1963). Investigations of ferric hydrate sols, arsenic sulfide sols, and mastic resin using radon also indicated no change for negative sols but did indicate faster flocculation of positive sols (Boutaric and Roy, 1933). In contrast, irradiation with x-rays enhances precipitation of both positively and negatively charged sols (Nanobashnili and Bakh, 1955), and gold sols flocculate after irradiation (Crowther Liebman *et al.*, 1938, 1939). Accelerated sedimentation of synthetic sewage colloids after suitable doses of ionizing radiation has also been reported (Unidynamics, 1960, 1961a,b, 1962a,b, 1963, 1964).

Included in the latter reports were studies of corn starch sols. Samples (0.12% starch solution) irradiated with a total dose of 71,040 rad settled a maximum of 28% of the total solids after a 60-minute settling time while only 8% of the total solids settled for the controls. On the other hand, samples which received a total dose of 275,280 rad indicated no significant change in the sedimentation pattern. These results were obtained gravimetrically using the Andreason sedimentation pipet and chemically using the starch iodine test. Samples of an irradiated 1% solution were treated with iodine and analyzed for starch content by measuring the absorption at $420\text{ m}\mu$.

In apparent contrast to this marked increase in the sedimentation rate after suitable doses of ionizing radiation and marked dependence of this effect on total dose, other studies have indicated that the characteristic effect of irradiation on polysaccharides is degradation (Swallow, 1966). This phenomenon had been indicated by a decrease in viscosity and by a change in electrophoretic and ultracentrifuge pattern. Extensive irradiation of polysaccharides has also resulted in monosaccharides, oligosaccharides, monosaccharide oxidation products, and low-molecular weight fragments in the form of gases such as hydrogen and carbon oxides. Cleavage is reported to occur usually at the glucosidic bond constituting a hydrolysis-like split, and radiation studies of amylose have indicated that the action of radiation is both hydrolytic and oxidative (Weiss, Allen, *et al.*, 1956).

Khenokh (1947) suggests that irradiation of starch causes breaking of the principal bonds of the chain, accompanied by the release of aldehyde groups, and oxidation leading to the formation of acid. Swallow (1966) notes that free radicals from

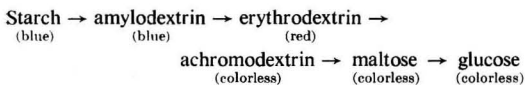
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irradiated water, predominately H and OH following gamma irradiation (Allen, 1956), are probably responsible for the degradation and observes that Fenton's reagent, another source of free radicals, also produces degradation. He further indicates that degradation of dextran can be at least partly attributed to attack at the ether linkage.

Theoretical Background

Although numerous mechanisms have been hypothesized for the changes in sedimentation characteristics of colloids following irradiation—alteration of surface charge, polymerization, modification of particle solvation degradation, denaturation (Unidynamics, 1960, 1961a,b, 1962a,b, 1963, 1964), alteration of the structure and potential of the electrical double layer, and the surface conductance of the sol particles (Burrows, Corbett, *et al.*, 1963), and agitation (Weiser, 1949)—current theories do not permit the a priori prediction of sedimentation characteristics. The sedimentation results obtained in this study are consequently presented without analysis of the mechanism of sedimentation.

Several steps in the degradation of starch following irradiation should, however, be conveniently followed by examining the visible spectra after addition of an iodine indicator. Corn starch is a glucopyranose polysaccharide mixture of amylose and amylopectin. Amylose, the unbranched-chain component, forms a deep blue complex with iodine; and amylopectin, the branched-chain component, forms a blue-violet or purple complex (Whistler and Paschall, 1965). As the molecular weight or chain length of amylose decreases, the color of the iodine complex changes toward the red and finally disappears at low molecular weight. With a chain length of 30 to 35 D-glucose units, the iodine complex is blue with a peak near 600 $m\mu$. As the chain is shortened to 8 to 12 units, the absorption peak shifts towards 520 $m\mu$. With additional shortening to 4 to 6 units, the characteristic color and absorption peak disappear (Whistler and Smart, 1953).



These characteristic color changes of the iodine complex should be observed if degradation of starch occurs as a result of irradiation and should permit the degree of degradation to be estimated while the higher molecular weight constituents are present.

Experimental Procedure

The irradiations required for this study were completed using a 3-kilocurie Co^{60} gamma source emitting energy primarily at 1.17 and 1.33 m.e.v. at the University of Maryland. Prior to use, the source was calibrated using the Fricke ferrous sulfate dosimeter (Choppin, 1961). Polyethylene bottles were chosen for sample containers since some irregular results have been observed using glass containers for related sedimentation studies (Unidynamics, 1964). Fifty-milliliter samples were ir-

radiated to total doses of 14,000 to 18,000 rad, and the absorbance at 305 $m\mu$ and 23.7° C. was used to compute the calibration curve shown in Figure 1. A Beckmann DB model spectrophotometer, equipped with a constant temperature bath, was used for all spectral measurements.

The corn starch sols used were prepared by stirring 1 gram of corn starch into 10 ml. of cold water, adding the slurry to 400 ml. of boiling distilled water, and then boiling the mixture for 20 minutes. This was immediately followed by dilution to 1 liter using cold distilled water.

Sixty-milliliter samples of the starch sols in polyethylene bottles were subsequently irradiated to obtain specified total doses. The samples were thoroughly mixed before being irradiated but were quiescent during irradiation. Following another thorough mixing, a 50-ml. portion of each sample was allowed to settle for 1 hour in a cylindrical glass tube with a 5 $\frac{1}{2}$ -inch settling depth, and the remaining 10-ml. portion was used to provide the analysis before settling. After the 1-hour settling time, a 3-ml. sample was removed from a depth of 1 inch for analysis. The spectrum of the samples, before and after settling, was recorded in the 320- to 800- $m\mu$ range against a distilled water blank at a constant temperature of 25° C.

The same procedure was followed for the studies incorporating an iodine indicator with the exception that 0.5 ml. of the indicator was added to each sample after the irradiation. The indicator was prepared by stirring 3.2 grams of iodine into 20 ml. of distilled water containing 5.5 grams of potassium iodine until the iodine was completely dissolved, followed by dilution to 250 ml. with distilled water. The more dilute (~0.006N) solution used as an indicator was prepared from this solution by diluting 10 ml. of stock solution to 180 ml. In Figure 2, the transmittance spectra obtained for distilled water and the iodine indicator are presented to place subsequently presented results on a quantitative basis.

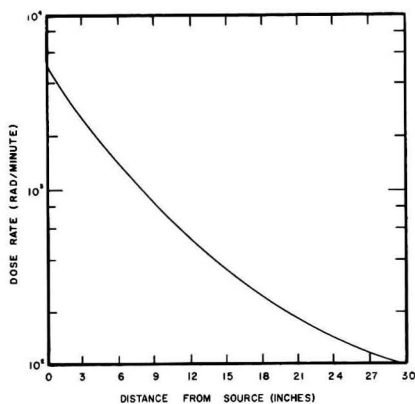


Figure 1. Gamma source calibration curve

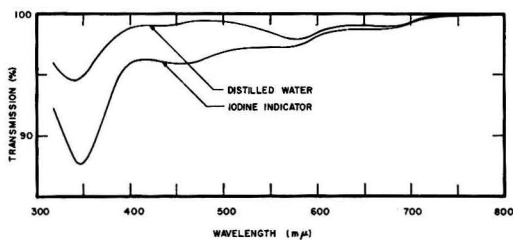


Figure 2. Visible spectra for distilled water and iodine indicator

Results and Discussion

The observed effects of gamma radiation on the sedimentation of corn starch sols are summarized in Figures 3-6. In Figure 3, the per cent transmittance at 440 mμ for the sol samples before settling and after a 1-hour settling period are compared as a function of the total dose. Each point represents the average of at least five duplicates and the limits given are the 85% confidence limits on each set of duplicates. Noting that the difference between the per cent transmittance after settling and that before settling is a measure of the sedimentation, the data show that radiation has not enhanced sedi-

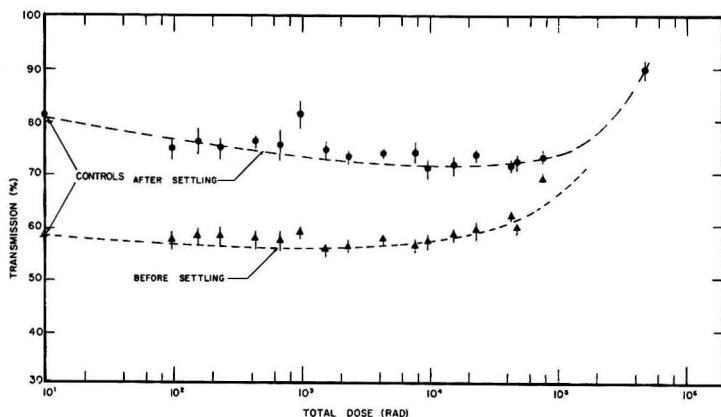


Figure 3. Effect of radiation on sedimentation of starch sol measured by transmittance at 440 mμ

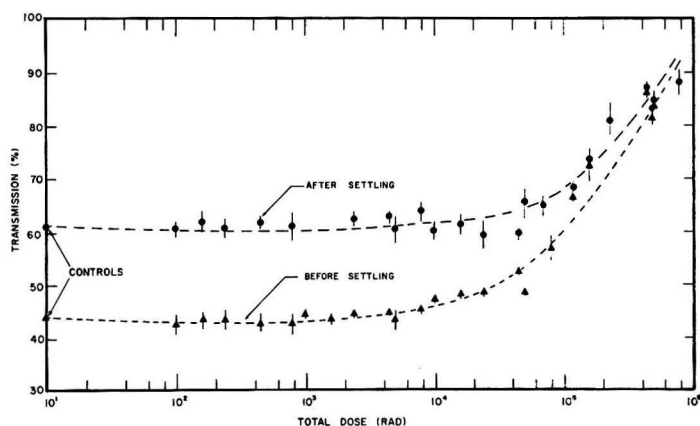


Figure 4. Effect of radiation on sedimentation of starch sol measured by transmittance at 440 mμ using iodine indicator

mentation. Particularly at the higher doses, radiation has actually decreased sedimentation. Preliminary investigations not presented here indicated that the results were not dose-rate dependent.

Figure 4 presents analogous results, leading to the same conclusions, for the cases in which the iodine indicator was added to each sample.

Since the data in Figures 3 and 4 are at $440\text{ m}\mu$, the possibility exists that different conclusions might be drawn if another wavelength were chosen to make the comparison. Evidence to the contrary is presented in Figure 5 where the per cent transmission for typical samples is presented *vs.* wave-

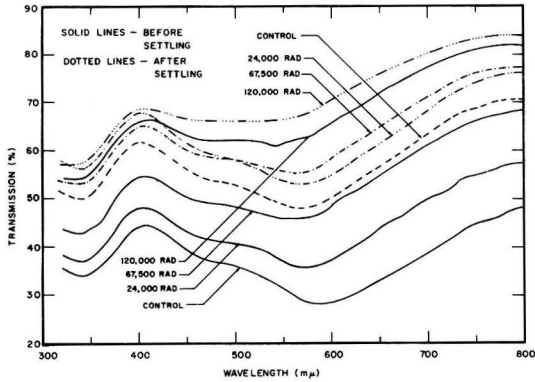


Figure 5. Visible spectra of starch sol before and after settling using iodine indicator

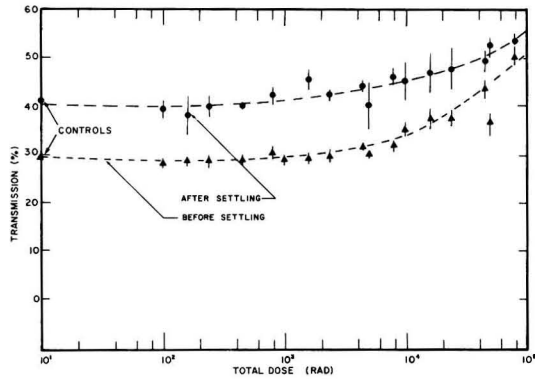


Figure 6. Effect of radiation on sedimentation of starch sol measured by transmittance at absorption peak using iodine indicator

length. The data indicate that the curve obtained before settling is directly comparable to that obtained after settling and the difference between the two does not vary appreciably with wavelength. Choosing the most obvious characteristic of the curves, namely the absorption peak in the 450 to $600\text{ m}\mu$ range, also leads to analogous conclusions as may be seen from Figure 6.

Particularly evident in Figures 3, 4, and 6 is the marked increase in the per cent transmittance over that of the control at doses greater than about 10^4 rad. An examination of this effect with wavelength is given in Figure 7 for the sol itself. Except for the marked change in the 300 to $400\text{ m}\mu$ range at the highest doses, the effect of radiation appears similar to that expected for decreased concentrations. Results obtained using the iodine indicator (Figure 8) indicate that degradation has taken place. For the control, an absorption peak near $600\text{ m}\mu$ is obtained as expected for the starch iodine complex. As increasing doses are applied, the peak is observed to occur at successively lower wavelengths down to a minimum of near $520\text{ m}\mu$ for over $120,000$ rad. By $166,000$ rad, the absorption peak has disappeared. This is in accordance with the characteristic color changes expected for the iodine complex during starch degradation (Whistler and Smart, 1953) and, as indicated by the comparison given in Figure 9, is similar to the observed spectra of amylose during the hydrolysis with HCl (Swanson, 1948).

For the particular starch sol studied, the examination of the color shift in the starch iodine complex indicates that radiation doses of less than about 10^4 rad result in little degradation of the amylose. From about 10^4 to over 10^5 rad, the characteristic chain length is apparently reduced from near 30 or 35 D-glucose units to near 8 or 12 units. By $166,000$ rad, the characteristic chain length is apparently reduced to near 5 units. At higher doses, further degradation takes place al-

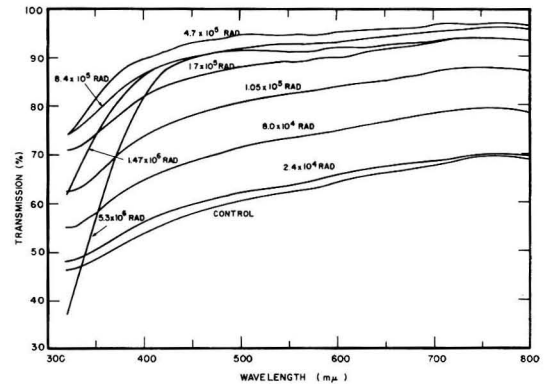


Figure 7. Effect of radiation on spectra of starch sol

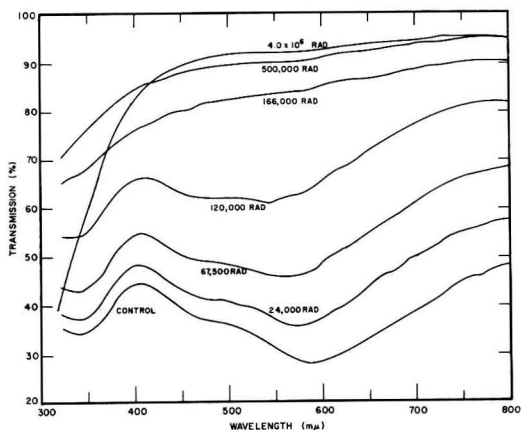


Figure 8. Effect of radiation on spectra of starch sol using iodine indicator

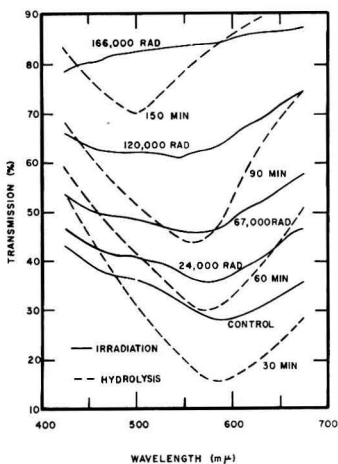


Figure 9. Comparison of hydrolysis of amylose and irradiation of starch sol

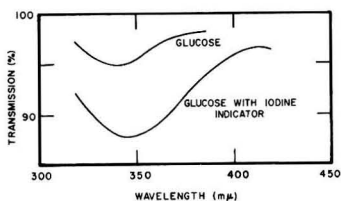


Figure 10. Visible spectra of glucose solutions

though the predominance of glucose can not be established as a comparison of Figures 2 and 10 shows. At doses over about 10^6 rad, progressive degradation to unidentified product(s) is evidenced by the marked drop in the per cent transmittance in the 300- to 400- μ range.

Conclusions

In sharp contrast to the reports of Unidynamics (1960, 1961a,b, 1962a,b, 1963, 1964), no enhancement of the sedi-

mentation of corn starch sols has been observed for total doses of gamma radiation between 10^2 and 10^6 rad. For doses up to about 10^4 rad, radiation has no appreciable effect on sedimentation, the visible spectra of the sol, or the visible spectra of the sol upon addition of an iodine indicator. However, for doses above 10^4 rad a progressive decrease in the turbidity and sedimentation are observed as the total dose increases.

Above 10^4 rad, progressive degradation of the starch with increasing dose has been observed by examining the visible spectra of the sol upon addition of an iodine indicator. The steps and degree of degradation have been noted to correspond to those reported in chemical degradation studies (Swanson, 1948; Whistler and Smart, 1953). Although the full extent of the degradation could not be determined, a dose of about 10^5 rad appears sufficient to degrade the predominant chain length of amylose to near 5 D-glucose units.

Acknowledgment

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COMMUNICATION

Variable-Speed Pump Drive

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■ A variable-speed drive for a syringe pump can be constructed using the stepping motor and pulse amplifier from a readily available multispeed chart drive. Use of the stepping motor and its associated electronic circuitry allows accurate selection of many drive speeds and is readily adapted to either proportional or programmed control. The system described has a range of 0.00019 to 0.275 ml. per minute in 21 steps.

A combination of a transistorized frequency dividing circuit and pulse amplifier, together with a stepping motor and a glass syringe, provides a very versatile and inexpensive low flow rate pump. A drive using this circuit can cover a wider range of flow rates than are readily available using purely mechanical speed selection; and is readily adaptable to both proportional and programmed control. Because it uses components from an inexpensive chart drive, the cost is much less than controls designed specifically for control of metering pumps. Although the author's application was only to meter a few milliliters of solution accurately into a small atmospheric reactor, several other applications are evident. The unit can be used to meter small quantities of possible pollutants into a dilution stream, which after passing through a mixing chamber flows past the sensing device of a monitoring instrument under test. Then, assuming the diluent stream is constant, 21 additional concentrations covering a range of 1440 can be obtained by rotation of a selector knob. This dynamic mixing method of calibration minimizes problems of wall adsorption effects occurring in large premixed calibrating streams and, of course, has long been practiced.

Since the pump speed is proportional to the input pulse rate, the speed can be made proportional to a primary flow measured by any of several meters which provide an electrical switch closure or pulse as an indication of output and is readily adaptable to programmed rates from a magnetic tape.

The principal component is the Multispeed chart drive EUW20A, sold by Heath Co., Benton Harbor, Mich. This drive works as follows: Reference timing pulses, obtained either from the 60-Hz line frequency or an external source, are electrically divided by transistor binary dividers to produce 21 lower frequencies. The desired frequency is selected by a switch and is applied through a power amplifier to a stepping motor. Using a 60-Hz reference frequency, the maximum motor output speed is 3 r.p.m. (7200 steps per minute), and the lowest is 0.00208 r.p.m. (5 steps per minute).

Applications

Figure 1 shows a method of mounting a syringe and the necessary lead screw and gearing. For our application a 3 to 1 speed reduction was used. With the 20-ml. syringe used, the highest pumping speed was 0.275 ml. per minute, corresponding to $1/28$ inch of plunger travel per minute.

The maximum speed obtainable, using parts shown in Figure 1, is 0.275 ml. per minute. Lower rates are obtained by dividing by 2, 3, 4, 6, 10, 12, 20, 24, 40, 60, 100, 120, 180, 200, 240, 360, 600, 720, 1200, and 1440. By changes in drive gear and lead screw, flows up to about 10 times this rate should be obtainable. Beyond that point, the stepping motor will probably stall. If a multispeed chart drive is on hand and only a variable-speed pump is desired, the following modifications allow a quick interchange between the normal recorder

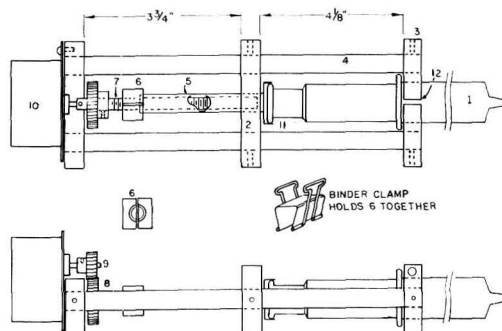


Figure 1. Syringe pump assembly

1. 20-ml. glass syringe, Yale 2303
2. PVDC body blocks, 3 each
3. Tap for setscrew
4. $1/2$ -inch aluminum rod
5. $5/16$ -inch o.d. \times $1/4$ -inch i.d. seamless brass or steel tube
6. Adjustable drive nut (split)
7. Drive screw $1/4$ inch \times 28
8. Boston gear H3248
9. Boston gear H3216
10. Stepping motor, Heathkit No. 420-37, Haydon Timer No. 36046
11. Attach wire yoke on plunger stem. Use spring or rubber bands to pull plunger toward drive end.
12. Slit body block to allow clamping of syringe

function and pump drive. Purchase an extra stepping motor for the pump unit. Then, by using three conductor plugs on this extra motor and the motor mounted in the recorder, either can be plugged into a socket at the amplifier output. We used a Cinch Jones S303AB mounted on the "input-output" control panel of the recorder and C-J P303 CCT plugs for the motors. Total costs were about \$30.00 for parts, plus approximately one man-day to make the pump assembly. If a recorder is not available, the multispeed drive unit can be purchased for \$95.00.

If an X-Y plot is desired—for example, volume added vs. pH—a Heath Multispeed recorder is used to measure the response and a signal from that chart drive used to synchronize the pump drive described in the first application. The Heath instruction manual shows the details. The time (y) axis is then directly proportional to volume pumped.

If the reference frequency is derived from the output of a positive displacement meter, the pumping rate can be made directly proportional to the reference flow. A common output for a displacement meter is one pulse per 0.1 gallon metered. The pump shown in Figure 1 displaces 3.83×10^{-3} ml. per pulse. Using the example of 1 pulse per 0.1 gallon of primary flow, with a feed solution containing 0.4 gram per ml. of solute, an average diluted concentration of 4 p.p.m. is obtained. It would, of course, be necessary to utilize a mixing volume of about 1 gallon to smooth out the pulses. The 20 ml. of feed solution in the pump will undergo a 1.7×10^{-3} ml. volume change with a 1° C. temperature change, which could introduce an appreciable error. To avoid this, a greater displacement per stroke could be obtained by selecting a different gear ratio when assembling the pump.

For repetitive testing, a programmed flow rate sequence can be put on magnetic tape, using a calibrated audio oscillator. Since for most purposes inputs of 72 to 7200 c.p.s. should provide adequate concentration ranges, a good quality Hi Fi type tape recorder would be adequate.

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BOOKSHELF

Air pollution monograph falls short . . .

Air Pollution. Monograph No. 22. Alan R. Smith. x + 203 pages. Pergamon Press, Long Island City, N.Y. 11101. 1966. \$10, hard cover. *Arthur C. Stern is assistant director, National Center for Air Pollution Control, Department of Health, Education, and Welfare, Washington, D.C. 20201*

By *Arthur C. Stern*

A series of monographs on how air pollution is institutionalized in each of the principal industrialized nations of the world would be a valuable addition to scientific literature. In such monographs, one could find out what institutions make and enforce control regulations, set air quality and emission standards, do the air quality monitoring and the air pollution research, handle the air pollution documentation, compile and publish the pertinent data and technical papers, train the air pollution scientists and technicians, and provide the financial support.

Such monographs would include some historical background on these matters to give the reader perspective and an understanding of why things are as they are today, and also assess the dimensions of the present and future problem, cite and interpret the pertinent present regulations and trends, and discuss technological problems unique to the nation. They would require frequent updating to keep them current.

Alan Smith's monograph comes close to doing this for Great Britain for the year 1965—even though it falls short of what is really needed on this score. Some measure of the book can be derived by noting that it contains no figures, no reference numbers or footnotes, and a 22-item list of "Main published sources of information consulted," five items of which

are the Annual Reports of the Chief Alkali Inspectors and of the Warren Spring Laboratory, and the Proceedings of the Institute of Fuel, the Royal Society of Medicine, and the Annual Conferences of the National Society for Clean Air.

The only table in the book occurs in a seven-page section, entitled "Air Pollution Control in the United States," which departs from the otherwise British cast of the book. The table is entitled "Air Pollution in Los Angeles," and lists the tons per day of major pollutants emitted and prevented from being emitted from the principal sources. The table has no date, so that presumably it represents 1965 data.

Pollution economics

When Mr. Smith started work on the book in 1964 and discussed it with the persons in the U.S. whom he so graciously acknowledges in his introduction, it was to be a book on the economics of air pollution control. This was before any of the more recent books on this subject appeared or were even in prospect. We, therefore, both encouraged him to fill this obvious gap with a definitive work on the subject and discouraged him by telling him how difficult the task seemed to be. What actually appears in his book, under the title "The Economic and Social Aspects of Air Pollution," confirms our forebodings. It represents less than 10% of the book, rather than its entirety, adds no new data on costs or cost/benefit ratios, and points no new directions.

As befits a monograph commissioned by the Society of Chemical Industry, the greater part of the book, and its greatest strength, lies in its discussion of the relationship between the British chemical, metals, fuels, ceramics, and allied industries and the Alkali

and Clean Air Acts. Certainly persons in other countries can benefit from the author's review of the interplay between regulator and regulated over the hundred-year history of the Alkali Inspectorate and the decade of history of the Clean Air Act.

The title on the spine of the book, "S.C.I. Monograph No. 22," is a more accurate description than that which appears on its cover—"Air Pollution." This is certainly not a general work on the subject of air pollution and can be used neither as a general reference work nor a teaching textbook.

The book admirably serves the needs of its sponsors, the British Chemical Industry, for a short (199 page) monograph to give insight into the air pollution problems with which their chemists and chemical engineers have been coping for several generations.

The book is on the smallish side—in fact will fit into the pocket of your jacket. It is well printed and bound, and has a five-page index in which reference to work in non-British countries is identified by country. There are 10 references to Europe, nine to Germany, five each to Belgium, France, and Italy, three each to Sweden and Switzerland, and one each to Argentina, Holland, and Ireland. Under the heading United States (21 references) the subheadings are: air quality standards in California; Clean Air Act; Department of Health, Education, and Welfare; Division of Air Pollution; Federal Government, role of; National Air Sampling Network; Senate Public Works Committee; solid waste; and State Governments, role of.

In these days of high cost environmental science and technology books, it isn't often that one comes down the pike priced as low as \$10. However, in my opinion, for the American reader this one is not a bargain at this price. ■

... Oceanography book proves inadequate. . .

Encyclopedia of Oceanography, Edited by Rhodes W. Fairbridge. xiii + 1021 pages. Reinhold Publishing Corp., New York, N.Y. 10022. 1966. \$25, hard cover. *Edward D. Goldberg is Professor of Chemistry, Scripps Institute of Oceanography, University of California, La Jolla, Calif. 92037*

By *Edward D. Goldberg*

Harvey Einbinder, in a devastating critique of the Encyclopaedia Britannica ("The Myth of the Britannica," Grove Press, New York, 390 pages, 1964), suggested the following: "Ideally an encyclopedia distills the information contained in a giant reference library." Such a concept had been preceded by the feeling of H. G. Wells, who thought, "It would not be a miscellany, but a concentration, a clarification, a synthesis." But "The Encyclopedia of Oceanography" has not attained these goals, as the reviews over the last year have indicated (see, for example, John Lyman in *Transactions of The American Geophysical Union* 48, 769-70, 1967). Its defects of format, indexing, and out-dated information, as well as its sins of omission and its descriptive nature, have been amply illustrated.

But, this book is going to be purchased by librarians and used by students and research workers. It will be cited as an authoritative volume. The reactions of the critics to this book will direct the editor, hopefully, to more rigorous treatments for a subsequent edition. This review evaluates the chemical information that might be sought by environmental scientists in the pursuit of problems involving the marine environment.

The general chemical characteristics of sea water are haphazardly distributed about four articles—chemical oceanography, nutrients in the sea, marine microbiology, and sea water chemistry. Two overlapping compositional tables are given (one of vintage 1957 with minor revisions, and the other from 1963, both neglecting the recent values for the rare earths first published in 1963). Titanium values in the two tables range over an order of

magnitude, yet only one analyst is responsible for the results.

The environmental parameters receive no better treatment. Two of the presentations contain sections on pH—but neither attempts a clear elaboration of the factors governing hydrogen ion concentrations, including the weathering reaction concepts of Sillén, first put forth by him at the International Oceanography Congress in New York in 1959. But more disturbing, the effect of depth upon pH seems to have escaped the attention of the contributors.

The information of oxidation potentials is trivial and frequently erroneous in the two sections that consider it. The only quantitative statement refers to measurements made with irreversible electrodes in aerobic waters with a neglect of references to the pH or temperatures of the system or even to the standard potential upon which the voltage is based. Redox potentials in anaerobic waters are passed over completely.

Confidence gap

Such inadequacies, coupled with a peppering of misprints and inadvertent omissions (Table 2 on page 793 lacks units, for example) destroy any confidence that these sections can be of any substantial help to a scientist seeking information about the compositional and chemical characteristics of the oceans.

On the other hand, several of the articles that bear on man's influence upon the marine environment possess all of the attributes put forth by Wells for an encyclopedic presentation. The carbon dioxide cycle in the seas and atmosphere is treated most lucidly and profoundly. Newly constructed tables and figures complement this refreshing review.

The input of carbon dioxide into the atmosphere from the combustion of fossil fuel and its effect upon natural processes may set the patterns or norms for the treatment of other contamination phenomena where the oceans can, in principle, act as a reservoir. This chapter provides a most appropriate background for such considerations. Further, the interested reader is provided with an excellent bibliography with which to probe more deeply into aspects of the geochemistry of carbon dioxide.

Similarly, authority and reliability pervade the articles on radionuclides in the oceans and in the sediments and the applications of unstable isotopes in oceanography. The tremendous efforts that have gone into the problems involved in radioactive waste disposal in the oceans are digested with skill. Such treatments can be readily updated in future editions.

Is the book worth having in the library of a practicing environmental scientist? In its present edition, I submit a negative reply. Although some of the essays are noteworthy, the inadequacies in the treatment of sea water chemistry from a utilitarian point of view are decisive. ■

... But water chemistry book hits the mark

Water Is Everybody's Business: The Chemistry of Water Purification. A. S. Behrman. viii + 229 pages. Doubleday & Co., Inc., New York, N.Y. 10017. 1968. \$4.50, hard cover; \$1.45, paper. *Robert C. Kroner is chief, Physical Sciences, Division of Pollution Surveillance, FWPCA, U.S. Department of the Interior, Cincinnati, Ohio 45202*

By *Robert C. Kroner*

A. S. Behrman's book is an excellent summary of the chemistry of water purification. He has tried very hard—and for the most part succeeded—in rendering a book that can be understood by the informed layman. The fact that the author depends heavily on technical formulation in two chapters, however, imposes a burden on the nontechnical reader. The reader will assuredly glean considerable information from the book, whether or not he takes the time to digest the formulas.

Not all of the book is semitechnical. Behrman's first four chapters on the commonalities of water—sources, impurities, and how impurities are measured—are well written, lucid, and highly informative. Readers will be intrigued by the author's easy familiarity with his subject. For example, Behrman discusses in simple terms some of the difficult material that usually haunts the sanitary chemist, such as

hypothetical combinations of ions in water and interpretations of general analyses.

Water treatment

After setting the background of reasons for variations in water quality, the author covers the subject that is his forte—water treatment. In three chapters that account for approximately half of the book, he discusses the fundamental operations of sedimentation, coagulation, filtration, and chlorination. In these basic operations he gives a wealth of information on more detailed operations, too numerous to list completely. Some of the more important suboperations are filter construction, use of coagulation aids, zeta potential, “slow” and “rapid” sand filters, operating costs.

He gives due consideration to softening procedures, under such headings as lime-soda process, recarbonation, removal of carbonate and noncarbonate hardness, cation exchange, zeolites, and comparative uses of the various processes. In his discussion of disinfection he includes the use and costs of chlorine, bromine, iodine, and silver, and the advantages or disadvantages of each material. The lay reader should be particularly interested in the eight-page section on disinfection of swimming pools.

Other topics Behrman discusses throughout the remainder of the book include fluoridation, desalination, and prognostications of future water use and needs. In view of Behrman's long career as a consultant in the field of water supply and treatment, his opinions are especially valuable. Finally, I wish to emphasize that the book is a particularly unbiased presentation of the story of water purification and all its ramifications.

This book is highly recommended to a broad spectrum of readers: college students, water treatment plant and other public works employees, members of civic clubs and, particularly, the well-informed layman. ■

Statistical Analysis of Ground Water Use and Replenishment. A thesis. J. D. Rockaway and R. B. Johnson. vii + 142 pages. Purdue University, Water Resources Research Center, Lafayette, Ind. 47907. 1967. No charge, paper.

A trend-surface analysis of hydrogeologic data for Bartholomew County, Ind., was carried out and trend-surface maps drawn and evaluated to establish a relationship between the water-level data and the hydrogeologic regimen. The analysis shows that a mathematically computed surface, sensitive to variations in recharge and discharge rates, approximates the water-table or piezometric surface. The addition of orthogonal flow lines to the contours of the trend-surface maps can provide additional information on the direction and relative amounts of ground water flow. The anomalous areas of the trend-surface or residual maps represent local effects superimposed on the regional base and may be explained by a particular set of geologic, hydrologic, or man-made conditions. Also, wells from a multiple aquifer system or from an aquifer not associated with the aquifer under study may be identified from the given set of wells. ■

Community Action for Natural Beauty. 36 pages. U.S. Government Printing Office, Washington, D.C. 20402. 1968. 40 cents, paper.

Prepared by the Citizens' Advisory Committee on Recreation and Natural Beauty, this booklet is a guide for citizens who want to participate in practical action to make communities better places to live in. It concentrates on the principal approaches, how each works, how they can work together, and what organizations and agencies one can go to for further help. ■

Air Pollution. R. S. Scorer. 168 pages. Pergamon Press, Long Island City, N.Y. 11101. 1968. \$7.50, hard cover; \$4.50, paper. ■

Agriculture and the Quality of Our Environment. AAAS Publication 85. A symposium. Edited by Nyle C. Brady. xv + 460 pages. American Association for the Advancement of Science, Washington, D.C. 20005. 1967. \$11.50, hard cover. ■

Environmental Effects on Polymeric Materials. Vol. 1: Environments. Edited by Dominick V. Rosato and Robert T. Schwartz. xvi + 1246 pages. John Wiley & Sons, Inc., 605 Third Ave., New York, N.Y. 10016. 1968. \$42, hard cover. ■

“Torrey Canyon” Pollution and Marine Life. A report by the Plymouth Laboratory of the Marine Biological Association of the United Kingdom. Edited by J. E. Smith. xiv + 196 pages. Cambridge University Press, New York, N.Y. 10022. 1968. \$9.50, hard cover. ■

CRC Handbook of Laboratory Safety. Edited by Norman V. Steere. 568 pages. Chemical Rubber Co., 18901 Cranwood Parkway, Cleveland, Ohio 44128. 1968. \$19. ■

Chemical Environment in the Aquatic Habitat. A symposium. Edited by H. L. Golterman and R. S. Clymo. 322 pages. North-Holland Publishing Co., P.O. Box 103, Amsterdam, Holland. 1967. \$8.40, paper. ■

Industrial Waste Disposal. Edited by Richard D. Ross. xii + 340 pages. Reinhold Book Corp., New York, N.Y. 10022. 1968. \$16, hard cover. ■

Air Pollution. Vol. 2: Analysis, Monitoring and Surveying. 2nd Edition. Edited by Arthur C. Stern. xix + 684 pages. Academic Press, Inc., 111 5th Ave., New York, N.Y. 10003. 1968. \$35, hard cover. ■

The Columbia River Treaty: The Economics of an International River Basin Development. John V. Krutilla. xv + 211 pages. The Johns Hopkins Press, Baltimore, Md. 21218. 1967. \$7.50, hard cover. ■

Scientific Method in Analysis of Sediments. John C. Griffiths. xiii + 508 pages. McGraw-Hill Book Co., 330 West 42nd St., New York, N.Y. 10036. 1967. \$17.50, hard cover. ■

Social Sciences and the Environment. Edited by Morris E. Garnsey and James R. Hibbs. iv + 249 pages. University of Colorado Press, Regent Hall, Boulder, Colo. 80302. 1968. \$6.00, hard cover. ■

The Economics of Water Utilization in the Beet Sugar Industry. George O. G. Lof and Allen V. Kneese. ix + 125 pages. Johns Hopkins Press, Baltimore, Md. 21218. 1968. \$4.00, paper. ■

NEW PRODUCTS DIGEST



Automated Device for Municipal Air Pollution Studies Delivered

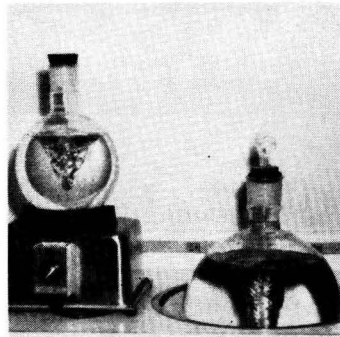
An automated atomic absorption spectrophotometer developed by Jarrell-Ash division of Fisher Scientific has twice the speed and 10 times the sensitivity of conventional instruments, according to the company. The prototype instrument, shown being demonstrated by Jarrell-Ash's research manager Dr. Frederick Brech, was delivered to the New York City Air Pollution Control Department last month. The city will use the instrument to correlate metallic airborne pollutants at 38 Manhattan locations with weather, industrial activity, and traffic conditions.

After preparation of the samples gathered from the collection stations, analysis is completely automated. Vials containing the dissolved samples are placed in electronically coded racks and loaded into the sample handler. Each rack advances to a station at which a measured aliquot is dispensed to a preconcentrator. At the preconcentrator the sample solution is converted to a stream of dry particles that is carried by gases through a transport tube to the flame. Twin monochromators allow for the analysis of two elements from each sample, and results are automatically converted to digital form. Data are displayed in tabular form on a teletypewriter readout, and simultaneously stored on punched tape for future computer analysis.

The New York City program calls for analysis for 12 elements per day from each station. The weekly load of 3192 determinations requires only about 15 hours of instrument time. Sensitivities range from 0.2 p.p.m. for vanadium down to 0.005 p.p.m. for beryllium and 0.002 p.p.m. for zinc. **61**

Biological Storage Cabinet

A new series of model RSA-714 Reliablab Sub-Arctic Biological storage cabinets has been introduced. Equipped with the "hermeti-cool" refrigeration system, these cabinets provide temperatures to -130° F., with a control accuracy of $\pm 1^{\circ}$ F. Standard design features include 7.4 cu. ft. storage capacity, a vapor sealed stainless steel liner for durability and cleanliness, and a counterbalanced lid with chromeplated latch assembly. Insulating foam sub-lids minimize frost accumulation and improve gradient work space to 3° F. Tenney Engineering, Inc. **62**



Stirring System

Stirmix is designed to mix large volumes of high viscosity liquids in round bottom flasks. Employing a curved stirring blade and curved drive magnet, the mixers feature solid-state speed control belt drive and mantle heating. Three basic models are available: power unit, power unit with housing for heating mantle, or built-in counter-top model with heater support. Will Scientific, Inc. **63**

Synthetic Sludge Conditioner

A liquid formulated for sludge conditioning in boilers that operate on the carbonate cycle, Dearborn Polycarb Sludge Conditioner Antifoam combines a synthetic polymer with a blend of antifoams and boiler water catalysts.

The manufacturer claims that the new conditioner will not char, is noncorrosive to chemical feed equipment, and aids in the removal of metallic oxides from boilers. The conditioner is available in 30- and 55-gallon drums. W. R. Grace & Co. **64**

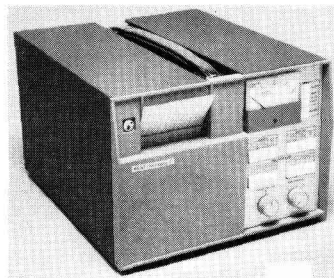


Talc for Oil Spills

A special ultra-fine ground talc is available for treating oil spills and harbor pollution from tanker flushings and accidents. Offered in two types. Mistron Vapor for beach cleanups and Mistron ZSC for floating spills, the talcs are said to be harmless to marine life. Cyprus Mines Corp. **65**

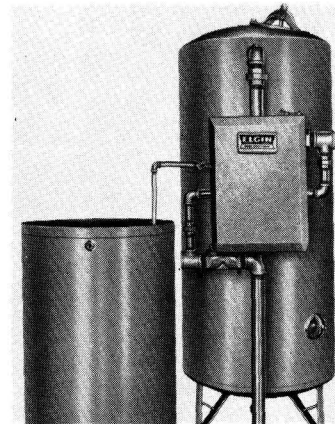
Sequential Air Sampler

An automatic, sequential air sampler runs continuously for two days without resetting, gathering 24 samples (24 ports) in 48 hours. The unit is compact and portable, according to the company. Gelman Instrument Co. **66**



Digital Integrator

Chromalog 2 is a fully automatic, digital electronic integrator for gas chromatography. The instrument, which connects directly to the chromatographic outlet, accurately integrates peaks of varied shapes and sizes from packed and capillary columns, operating isothermally and with temperature programming. Featuring built-in printer and solid state integrated circuits, the instrument can be programmed to change slope sensitivity automatically during a chromatogram. Chemicon Co. **67**

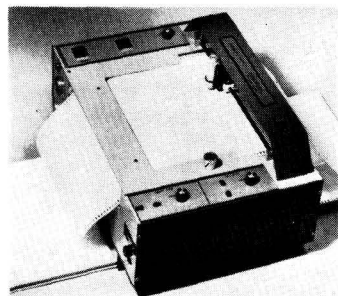


Automatic Water Softener

The Hyperflow 22 water softener provides continuous water flow rates from 40 to 150 g.p.m., with peak flow capacities from 65 to 200 g.p.m. Five models are available, all offering operation in the 30 to 100 p.s.i. range and 40° to 120° F. temperature range. The automatic packaged units are preassembled and pretested at the factory for a minimum startup time. Elgin Softener, Inc. **68**

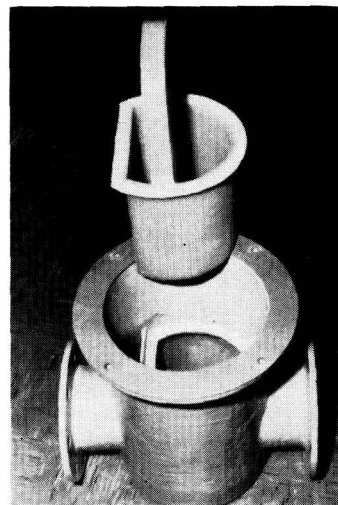
First Aid Cabinet

A first aid cabinet stocked with 37 items useful in treating accidental cuts, corrosive burns, poisons (both inhaled and swallowed), and other injuries encountered in the laboratory comes complete with all equipment necessary to carry out the treatments specified in the Fisher laboratory emergency chart, which is mounted on the cabinet door. A mouth-to-mouth resuscitator is included, along with instructions for its use. Fisher Scientific Co. **69**



Digital Plotter

Complot DP-1 digital plotter operates both on-line with digital computer or off-line from magnetic or paper tape, at 300 increments per second. The unit accepts both negative or positive going logic, and has connectors for either a.c. or d.c. input. Plots are made with either ballpoint or fiber tip pens, in a variety of colors, on Z-fold paper. Bausch & Lomb, Inc. **70**



Corrosion Resistant Strainer

A new basket type strainer for the removal of solids from liquid recirculation streams has excellent corrosion resistance to a wide range of chemicals and alkalis, according to the manufacturer. The polypropylene basket has 1/8" diameter holes; the strainer shell is made of reinforced polyester plastic (Rigidon). Fast delivery and simple servicing are offered. Heil Process Equipment Corp. **71**

NEW LITERATURE DIGEST

Carbon analyzer. An automated method for continually analyzing carbon content of waterways or plant effluents is described in a 4-page bulletin. Bulletin 4093 includes a section of general information on continuous water quality evaluation and explains the analyzer's combustion/infrared method of measuring dissolved carbon in water. Beckman Instruments, Inc. **91**

Chloride determination. Bulletin 68-2A discusses in detail the potentiometric determination of chlorides in water, sewage, and industrial wastes using the Titralyzer. Fisher Scientific Co. **92**

Labware catalog. Catalog 668S includes tubing clamps, Teflon stirring blades, glassware drying supports, aluminum mounting brackets and electrical accessories, plastic-coated wire products, miniframe rack systems, and like products. Penn-Chem Corp. **93**

New journal. Volume 1 No. 1 (Spring 1968) of *Limnos*, the quarterly publication of the Great Lakes Foundation, features articles on water pollution in the Great Lakes basin, the coho fish, and Great Lakes Water levels problems. Great Lakes Foundation. **94**

Marine current meters. A line of PISA current meters for subsurface and seabed current measurements, and an abyssal PISA for measurement of great depths, are described in Bulletin WAP-3667. The abyssal PISA utilizes a graduated, rolling inclinometer and a disc-compass for its measurements. The other devices use a brass screw-cap, gelatin-filled bottle with magnetic disc compass suspended in the gelatin. G. M. Manufacturing & Instrument Co. **95**

Miniature wire pins. A 2-page, color bulletin describes miniature cold-headed pins, fabricated from wire, for electronic, semiconductor, medical, appliance, business machine, electric con-

trol, and other applications. The welding, soldering, staking, glass-sealing, and plastic-molding capabilities of the minipins are discussed. General Electric Co. **96**

Fast recorder delivery. A 12-page brochure gives details on a new three-week delivery program for recorders and recorder-controllers. The illustrated brochure, P1211B, includes operating procedures, prices, and technical specifications of the various available instrument types, including electric, pneumatic, and solid-state recorder-controllers. Bristol Co. **97**

Nonwetted pumps. A 12-page catalog lists and describes a line of pumps designed for use wherever sterility must be maintained. The manufacturer says that these pumps are effective in protecting fluids from chemical effects of the atmosphere and moving them in accurately determined amounts at precisely controlled rates. Eleven models are offered for medical, chemical, and general scientific use. Extracorporeal Medical Specialties, Inc. **98**

Clean water. An 8-page brochure, "Clean Water . . . A Product We Help to Make," gives a brief description of the company's capabilities in waste treatment systems. The booklet—in three main sections: water treatment and distribution, sewage treatment, and industrial waste water treatment—concludes with a section listing the company's products in these areas, and a schematic showing where products are used in treatment plants. General Signal Corp. **99**

Noise abatement. An 8-page illustrated brochure describes the HP 8051A Loudness Analyzer, a new instrument for noise abatement studies. Also included are operational features and specifications of the unit, as well as a listing of available accessories. Hewlett Packard Co. **100**

Simplified colorimetric chemical analyses. A 24-page brochure describes the Lovibond 1000 Comparator and alphabetically lists the more than 300 analytical tests that can be performed with the instrument. The brochure lists the available test discs along with the code reference, working range, and related chemical method, and principal applications. Hayes G. Shimp, Inc. **101**

Deep wells. "A Management Guide to Deep Well Disposal of Industrial Wastes" is a full color 8-page brochure which discusses what must be considered in evaluating a deep well for use in special pollution problems. Topics discussed include subsurface geology, cost analysis, state regulations. Drawings and photographs illustrate subsurface composition and location of industrial waste disposal wells in the U.S. Deep Well Pollution Control Corp. **102**

Waste disposal systems. An 8-page brochure (Bulletin 132) describes various equipment and processes for the disposal of industrial wastes and the recovery of reusable materials. Methods of solid waste disposal, liquid waste control, and waste gas disposal are detailed. Information on available testing facilities is also included. Cosmodyne Corp. **103**

Air pollution. "Clearing the Air" is a 20-page brochure describing the Bureau of Mines programs in air pollution abatement, including research on automotive exhaust, urban, and industrial pollution. Emphasis is placed on the waste of resources that pollution entails, and on the need for improved technology to minimize such waste. Publication Distribution Section, Bureau of Mines, 4800 Forbes Ave., Pittsburgh, Pa. 15213. (Write direct.)

Water pollution. Water pollution, how each person is affected, the role of the individual in prevention, now and in the future, are some of the topics discussed in "Clean Water." The 48-page brochure also includes an appendix giving citizen action checklists, and an information directory of antipollution agencies and officials. Isaak Walton League of America, 1326 Waukegan Rd., Glenview, Ill. 60025. (Write direct.)

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**August 11-14
Water Conditioning Association
International**

23rd Annual Convention

San Francisco Hilton Hotel, San Francisco

This year's conference will include a trade show, joint seminars with the extension agriculture engineers, business and entertainment programs, and demonstrations of water conditioning equipment. In addition, a post-convention tour and meeting in Hawaii is planned beginning August 15.

**August 14
Water Conditioning Industry**

4th Annual International
Water Quality Symposium

San Francisco Hilton Hotel, San Francisco

A one-day session on agricultural water and waste management will examine the problems of water pollution by agriculture. Leaders from local and Federal Government agencies, and agricultural authorities will discuss the problems from their respective viewpoints. Topics include agricultural wastes in perspective; various needs and problems in agricultural wastes; federal law. For further information, contact: David X. Manners Co., Inc., 237 East Rocks Road, Norwalk, Conn. 06851.

**August 18-21
Soil Conservation Society of America**

23rd Annual Meeting

University of Georgia, Athens

This year's meeting, theme of which is "Creative Conservation for Life and Living," will feature discussions on natural resources and man's environment, economics of environmental modification, land, air, and water conservation, and recreational needs in land and resources.

**August 20-21
North Atlantic Regional Water
Resources Study**

Sheraton Belvedere Hotel, Baltimore
NAR's Coordinating committee, a 23-member panel of federal and state water resources officials, will hold a public meeting on NAR study of water and related land resources of Atlantic seaboard states. Additional meeting planned for Oct. 22-23 at Willard Hotel, Wash., D.C., will be relocated.

**MEETING
GUIDE**

**August 26-30
International Atomic Energy Agency**

Operating and Developmental
Experience in Treatment of Airborne
Radioactive Waste

United Nations Building, New York

Symposium will discuss recent R&D in treatment of nuclear energy wastes, with review of operating experience. Separate one-day session for U.S. papers will be designated "Tenth AEC Air Cleaning Conference." Further details: Mr. John Kane, Chief, International Conferences Program, Division of Technical Information, Atomic Energy Commission, Wash., D.C. 20545

**September 2-4
University of Alaska Institute of
Marine Science**

Symposium on Organic Matter in
Natural Waters

University of Alaska, College

Discussions and papers on chemical, biochemical, and geochemical effects of organic waste on aquatic environment are planned for sessions on organic matter and water quality, inorganic-organic associations in natural waters, and reports of recent research on the subject. Subsequent to the meeting, field trips will be available for symposium participants.

**September 3-7
American Institute of Biological
Sciences**

19th Annual Meeting

Ohio State University, Columbus

Meeting will include symposia, panel discussions, field trips, and workshops conducted by member societies. Features include symposium on biological effects of nuclear excavation of a sea level canal, round-table discussion of information problems in biological sciences, and an AIBS plenary session on the biologist's role in the world food crisis.

**September 8-13
American Chemical Society**

156th National Meeting

Atlantic City, N.J.

The Division of Water, Air, and Waste Chemistry will present, in joint session with other Divisions, symposia discussing: colloid and surface chemistry in air and water pollution; biochemical target systems of air pollutants; organic removal in advanced waste treatment; air quality standards; and pollution problems caused by sulfur in petroleum. In addition, general papers on air and water will be presented.

Meeting Guide continues on page 642

**September 17-18
Scientific Apparatus Makers
Association**

Conference on Measurement Technology
National Bureau of Standards Laboratories, Gaithersburg, Md.

The program, scheduled to be held during SAMA's 50th anniversary celebration, will feature discussions of key international developments relating to measurement technology; the international system of standards; precision measurement capabilities for application in water pollution abatement, oceanography, space, and other related areas of research; a government-industry reception; and tours of NBS. For program details and registration information, contact: W. Reeves Tilley, National Bureau of Standards, U. S. Department of Commerce, Washington, D.C. 20234.

**September 22-27
Water Pollution Control Federation**

Annual Conference

Conrad Hilton Hotel, Chicago

Technical program includes sessions on federal-state relationships, combined sewers, nutrient removal, water quality analysis, manpower and education crises, and water resources planning.

**September 22-25
AECHE, AICHe, and CSCHe
Tripartite Meeting**

Montreal, Canada

The meeting will feature presentation of papers from the United States, Canada, United Kingdom, and elsewhere. Topics discussed will include water and waste treatment processes, and the technology of their fundamental phenomena. For further information, write: Prof. P. L. Silverston, Department of Chemical Engineering, University of Waterloo, Ontario, Canada.

**September 25
Ground Water Resources Institute**

4th Ground Water Seminar

Shoreham Hotel, Washington, D.C.

In keeping with the theme of the seminar, "Communicating the Ground Water Story—The Role of Ground Water in Total Water Management," the program will feature papers on water resources for smaller cities, ground water hydrology for the layman, and trends in state water well legislation. (This seminar has been rescheduled from its original date, April 9, this year.)

**September 25-27
Association of Analytical Chemists**

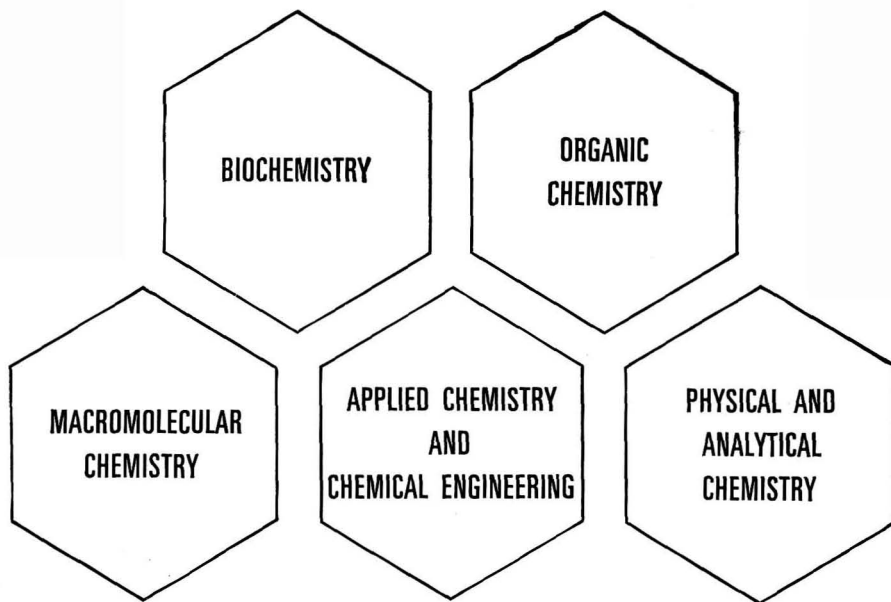
16th Detroit Anachem Conference

Statler Hilton Hotel, Detroit, Mich.

Program of invited and contributed papers will include separate session on environmental chemical analysis. Manufacturers' exhibit will feature latest developments in scientific instrumentation.

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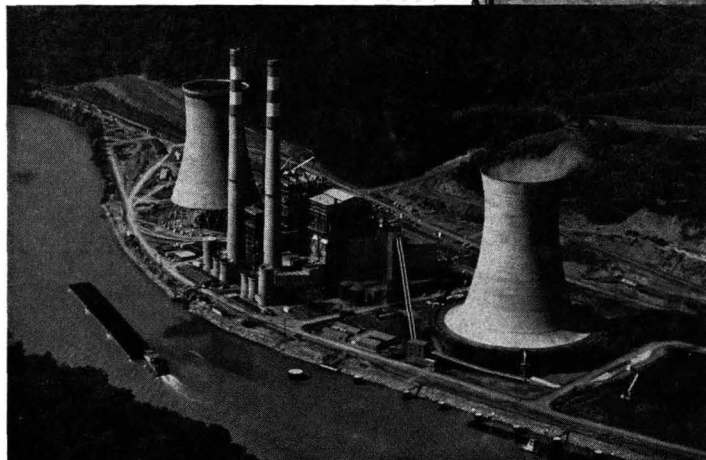
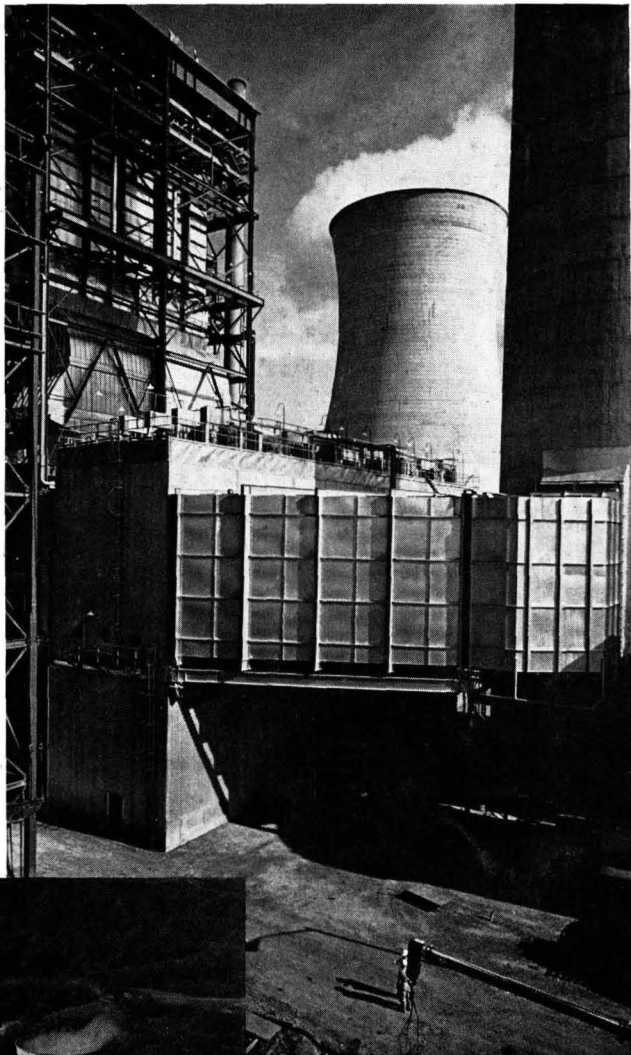
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