THE ADEQUACY OF TECHNOLOGY FOR POLLUTION ABATEMENT

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HEARINGS

BEFORE THE

SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS

U.S. HOUSE OF REPRESENTATIVES

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APPENDIX 1

RESPONSE BY WITNESSES TO QUESTIONS SUBSEQUENTLY SUBMITTED BY THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT

Responses to Questions of the Subcommittee on Science, Research, and Development by Department of Health, Education, and Welfare

Question 1: Please provide a listing of all contracts and grants concerning research and development in the area of pollution abatement within the jurisdiction of your agency for the last several years, up to the most current date for which statistics are available. Included in such listing should be a breakout by category of contract versus grant; university, industry, in-house effort, or other; basic research, applied research, and development; and general subject of research contract or grant. Also provide estimated amounts of funds to be obligated during fiscal year 1967, by type of research and by type of pollution research area.

Answer: The requested information, broken out by air pollution activities and those pertaining to solid waste pollution activities is contained in the following summary tables. Detailed listings of all in-house research projects, grants, and other activities for both areas are available in the committee files.

Table No. 1.—*Air pollution research and development by performer*

[In thousands of dollars]

Year	Federal operations	State and local agencies	Universities	Other nonprofits	Profit organizations	Other	Total
Fiscal year 1964	5, 266	118	4, 154	679	188	2	10, 407
Fiscal year 1965	5, 722	120	4, 655	959	397	------	11, 853
Fiscal year 1966	7, 041	64	4, 974	1, 224	607	------	13, 910
Subtotal	18, 029	302	13, 783	2, 862	1, 192	2	36, 170
Fiscal year 1967 [1]	------	------	------	------	------	------	17, 784
Total	------	------	------	------	------	------	53, 954

[1] Estimate.

Table No. 2.—*Air pollution research and development by type of research*

[In thousands of dollars]

Year	Basic	Applied	Development	Total
Fiscal year 1964	1, 449	7, 591	1, 367	10, 407
Fiscal year 1965	1, 517	8, 878	1, 458	11, 853
Fiscal year 1966	1, 922	9, 987	2, 001	13, 910
Subtotal	4, 888	26, 456	4, 826	36, 170
Fiscal year 1967 [1]	------	------	------	17, 784
Total	------	------	------	53, 954

[1] Estimate.

TABLE NO. 3.—*Air pollution research and development by research activity*

[In thousands of dollars]

Year	A	B	C	Total
Fiscal year 1964	5, 490	3, 156	1, 761	10, 407
Fiscal year 1965	6, 539	3, 483	1, 831	11, 853
Fiscal year 1966	7, 945	4, 137	1, 828	13, 910
Subtotal	19, 974	10, 776	5, 420	36, 170
Fiscal year 1967 [1]				17, 784
Total				53, 954

[1] Estimate.

NOTE.—Subcategory A equals identification, measurement, and control of air pollution. Subcategory B equals medical and biological studies. Subcategory C equals community and other field studies.

Office of Solid Wastes applied research contracts by performer for fiscal year 1966 to fiscal year 1967

[In thousands of dollars]

	Fiscal year 1966		Fiscal year 1967 [1]	
	Number	Amount	Number	Amount
University			8	300
Nonprofit organizations	1	10	2	50
Profitmaking organizations	3	271	5	300
Total	4	381	15	650

[1] Estimated.

Office of Solid Wastes project contracts by performer for fiscal year 1966 to fiscal year 1967

[In thousands of dollars]

	Fiscal year 1966		Fiscal year 1967 [1]	
	Number	Amount	Number	Amount
University			3	75
Nonprofit organizations	1	86	2	50
Profitmaking organizations			1	25
Federal agencies	1	370	1	395
Total	2	456	7	545

[1] Estimated.

Office of Solid Wastes demonstration grants by performer for fiscal year 1966 to fiscal year 1967

[In thousands of dollars]

	Fiscal year 1966		Fiscal year 1967 [1]	
	Number	Amount	Number	Amount
University	3	253	5	720
State government agency	1	134	4	440
Local government agency	14	1, 352	35	3, 340
Other nonprofit organizations	1	250	2	500
Total	19	1, 989	46	5, 000

[1] Estimated.

Office of Solid Wastes research grants for fiscal year 1966 to fiscal year 1967

[In thousands of dollars]

	Fiscal year 1966		Fiscal year 1967 [1]	
	Number	Amount	Number	Amount
Universities	18	699	36	1, 450
State government agencies	2	62	4	140
Local government agencies	4	92	5	179
Other nonprofit organizations				
Total	24	853	45	1, 769

[1] Estimated.

Office of Solid Wastes graduate training grants to universities for fiscal year 1966 to fiscal year 1967

[In thousands of dollars]

	Fiscal year 1966		Fiscal year 1967 [1]	
	Number	Amount	Number	Amount
Universities	4	150	8	350
Total	4	150	8	350

[1] Estimated.

Office of Solid Wastes State and interstate planning grants for fiscal year 1966 to fiscal year 1967

[In thousands of dollars]

	Fiscal year 1966		Fiscal year 1967 [1]	
	Number	Amount	Number	Amount
State	14	400	29	1,000
Interstate				
Total	14	400	29	1,000

[1] Estimated.

NOTE.—In accordance with the Solid Wastes Disposal Act of 1965 (Public Law 89-272) these grants are awarded only to State and/or interstate agencies.

Question 2. If all desirable research, in the view of your agency, were to be funded, what would be the estimated funds on an annual basis needed for what type of research and in what areas?

Answer. In his prepared statement to the subcommittee on July 21, Mr. Arthur C. Stern, Assistant Chief of the Division of Air Pollution, presented a detailed discussion of the present status of technology for the control of air pollution and needs for additional research and development in such areas as control of pollution from motor vehicles, fuel combustion, and various industrial operations. Mr. Stern also discussed needs for additional knowledge of the health hazards of air pollution. The accompanying report, entitled "Research in Air Pollution: Current Trends" (see p. 612) provides additional information from the Division of Air Pollution. The other reports enclosed in this section provide assessments of the current situation from the standpoint of publications which are widely circulated in science and industry.

Over the past several years, Federal expenditures for research in air pollution have increased steadily. The combined annual expenditure for in-house, grant-supported, and contract-supported research has grown approximately sevenfold since 1960, from slightly more than $2 million to some $14 million. A further increase of about $4 million is contemplated in the pending appropriations request for the air pollution program for fiscal 1967. In addition, Senate bill 3112, passed by the Senate on July 12, 1966, would authorize additional appropriations for fiscal 1967. Of the proposed additional amount, about $2.1 million would be devoted to research. Thus, the total research investment in fiscal 1967 may be in the area of $20 million.

That a still greater investment in research will be necessary in subsequent years is beyond question. The enactment of the Clean Air Act (Public Law 88-206) in 1963 and major amendments (Public Law 89-272) to it in 1965 have substantially expanded the research and development responsibilities assigned to the Federal air pollution program. In addition to a broad directive for Federal research on the causes, effects, extent, prevention, and control of air pollution, the Clean Air Act, as amended, calls for special attention to the development of improved, low-cost techniques for controlling sulfur-oxide pollution arising from fuel combustion, research on the control of air

pollution from gasoline-powered and diesel-powered motor vehicles, and the development of air quality criteria indicating the kind and degree of adverse effects on human health and welfare which may be expected from the presence in the air of specific pollutants or combinations of pollutants in various concentrations. To meet these responsibilities and to take advantage of new developments in technology, the Federal Government must clearly be prepared to increase its investment in air pollution research.

To provide a basis for estimating future needs for Federal activity in the air pollution field, goals have been established in a number of important categories. With respect to research and development efforts, the goals that are most germane are those relating to reduction of pollution from industrial and municipal sources, reduction of motor vehicle pollution, control of sulfur-oxide pollution arising from fuel combustion, and the development of air quality criteria.

For industrial and municipal sources of air pollution, the goal is a 25-percent reduction in emissions by 1975. Industrial operations, including manufacture of chemicals, cement, and pulp and paper, petroleum refining, mining, and metallurgical processes, and municipal activities, primarily refuse disposal, constitute major sources of air pollution in most parts of the country. Emissions from most such sources can be significantly reduced through the application of currently available technical knowledge and equipment; the fact that this technical capability is not being fully utilized is mainly a reflection of the inadequacy of State and local governmental air pollution control programs. Expansion of regulatory control programs is clearly the most important single step that must be taken to achieve the 1975 goal with respect to control of industrial and municipal sources of air pollution. But there can be no doubt that additional research and development will also be required; a need clearly exists for more effective and more economical control techniques. The estimated requirement for Federal spending for research in this area through fiscal year 1970 is $20 to $30 million.

For motor vehicle pollution, the goal is a 25-percent reduction in emissions by 1975, a 40-percent reduction by 1985, and the development of an essentially pollution-free automotive propulsion system by 1985. The reasons why increasingly stringent control of emissions from the present-type motor vehicles will be needed in the next 20 years and why other approaches to this problem may be needed in subsequent years were presented in detail in testimony by Under Secretary Cohen and Mr. Stern. Through fiscal 1970, the needed Federal expenditure for research and development in this area is estimated to be $20 million.

For sulfur-oxide pollution arising from combustion of fossil fuels, the goal is to establish by 1970 the technical and economic feasibility of various engineering control methods and, in the meantime, seek the application of available measures, e.g., greater use of low-sulfur fuels, for preventing further worsening of this problem in urban areas where it is already very serious. This problem was discussed in some detail in the prepared statements by Under Secretary Cohen and Mr. Stern. For the period 1966–70, the needed Federal expenditure is estimated to be $25 million.

The final goal is the development by 1970 of air quality criteria for all major classes of air pollutants known to be harmful to man, animals, plants, and materials. There is already a substantial body of scientific evidence relating to the adverse effects of air pollutants acting alone or in combination with one another. This evidence provides ample justification for strenuous efforts to reduce air pollution in all parts of the United States. But as control efforts are expanded and as knowledge of the impact of air pollution improves, guidelines indicating the degree of control needed to protect the public health and welfare against various adverse effects of air pollution will be increasingly useful. The development of such guidelines—in the form of air quality criteria—is already in progress. The additional activity directly involved in developing criteria and in seeking needed additional knowledge of the harmful effects of air pollution will require an estimated expenditure of $55 million at the Federal level during the next 4 years.

Thus, in the four areas discussed above, the requirement for research and development efforts at the Federal level in the next 4 years is estimated at $130 million. This figure does not include expenditures for research and development concerned with other aspects of air pollution or for such activities as Federal technical and financial assistance to State and local control agencies, abatement of interstate air pollution problems, administering regulations for the control of motor vehicle pollution, and the various other responsibilities assigned to the Federal program by the Clean Air Act, as amended. The need for continuing increases in Federal budgeting for air pollution activities is quite clear. Senate bill 3112, passed by the Senate on July 12, would authorize appropriations of $46 million for the current fiscal year, $70 million for fiscal 1968, and $80 million for fiscal 1969. These figures are in line with projections made by the Division of Air Pollution.

But the Federal Government should not—and cannot—be expected to bear the total responsibility for dealing with the modern air pollution problem. State and local governments must certainly be expanding their activities and increasing their budgets for air pollution control; moreover, industry is still not engaged in research and control efforts commensurate with its contribution to the air pollution problem and its proper share of the responsibility for bringing the problem under control. The total expenditure needed to deal effectively with air pollution in the next few years will inevitably be several times greater than present levels of spending by government and industry. The cost of a truly effective control effort will indeed be substantial, at least in terms of the dollars that must be spent for research and control programs and for control equipment. But to the Nation as a whole, the result will clearly be a net gain, for air pollution is already costing billions of dollars in economic losses every year—far more than it will cost to achieve better control; moreover, the benefits of better control will also include an immeasurable saving in terms of protection against the serious hazards which air pollution now poses to human life and health.

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Air pollution has been recognized as one of our major environmental health problems, but much about it requires investigation. A review of current research trends is presented in terms of two over-all categories: medical-biological and physical-engineering. As more is learned, the nature of the problems becomes clearer, and it becomes possible to approach further investigation and control of air pollution more rationally.

RESEARCH IN AIR POLLUTION: CURRENT TRENDS

John H. Ludwig, Sc.D., F.A.P.H.A., and B. J. Steigerwald, Ph.D.

IN 1963 there were approximately 500 air pollution projects totalling about $20 million under investigation in the United States. This presentation includes the following: (1) a very brief discussion of the classification of these projects into medical-biological and engineering-physical science categories, and of the types of organizations conducting and funding this research, and (2) a discussion of the more important research problems now under investigation in these two major categories. The discussion of the medical-biological field will be more limited than that of the engineering-physical sciences. We will attempt in both areas to extend our discussion of present research into areas of future need, at least as these needs are anticipated at the present time.

Current Air Pollution Research Projects

The total dollar effort in air pollution research in 1962 was divided roughly into 29 per cent for medical-biological-epidemiological studies, 31 per cent for survey and monitoring, and 40 per cent for engineering-physical sciences projects. Of the latter 40 per cent, 18 per cent was expended in chemistry and physics, 8 per cent for meteorology, and 14 per cent for engineering studies.

Roughly 37 per cent of the total research was conducted by universities, 31 per cent by federal agencies, 15 per cent by industry, 8 per cent by private research organizations, and 9 per cent by state and local governmental agencies. Sixty per cent of the support for these projects came from the federal government, 15 per cent from industry, and the remaining 25 per cent in about equal amounts from universities, state agencies, local agencies, and various private groups.

As might be expected, a large share (22 per cent) of this research was conducted in California; 19 per cent in Ohio, most of which reflects the work of the Robert A. Taft Sanitary Engineering Center; 10 per cent in New York; 10 per cent in the District of Columbia, again reflecting federal efforts; 7 per cent in Michigan, and the balance in other states.

The federal funding which represents, as previously indicated, 60 per cent of the total, was expended approximately as follows: 35 per cent in Public Health

Service facilities, 11 per cent in facilities of other federal agencies (Bureau of Mines, National Bureau of Standards, Weather Bureau), 18 per cent by contract research outside the government (universities, industries, etc.) and 36 per cent in research grants, the largest share of which went to universities.

Medical-Biological Research

Medical-biological research specifically related to air pollution has been carried on extensively only since the inauguration of the federal air pollution program in 1955. Extensive background data, a good deal of which are directly transferable to the air pollution field, are available from previous studies specifically related to other areas of interest, principally industrial hygiene or occupational health. Current medical-biological studies may be divided into two major areas: controlled biological experimentation and epidemiological investigations.

The former is confined mainly to the laboratory and uses as experimental subjects for measurement of effects the gamut of biological systems ranging from microorganisms, biochemical systems, such as enzymes and tissue cultures, to plants, animals and humans. Exposure studies also have been carried to the field to avail the researcher of actual polluted atmospheres rather than laboratory simulations. The extensive animal studies under way at several locations in Los Angeles and the citrus studies at Uplands, California, are examples of the latter.

Epidemiological investigations may be subdivided into two major areas. The first of these comprises field investigations, in which mortality, gross morbidity, or some indicator of health status, vegetation damage, corrosion, and the like, are measured and correlated with current air pollution levels. Since the main avenue of insult of air pollution to the human is through the respiratory system, these studies have stressed and continue to emphasize respiratory illnesses of many types or respiratory function testing. The second area of epidemiology encompasses studies of mortality and morbidity records and their correlation with existing demographic, socio-economic, meteorological, and air-quality information. As one might expect, such statistical studies tend to provide leads for further intensive field investigations rather than definitively indicating cause-effect relationships.

Today's areas of emphasis for medical effect research in air pollution are veering considerably from traditional investigations of the past. Because of the low-concentration, long-term nature of air pollution exposures, present investigations center on the evaluation of and search for functional changes in both epidemiological and laboratory studies in contrast to previous studies that used mortality, gross morbidity, gross lung damage, and the like, as indicators of biological stress.

In the epidemiological field, research now encompasses the more subtle technics, such as lung function testing or investigation of illnesses restricted to sensitive portions of the population, e.g., asthmatics, or to those considered to be of less serious clinical significance, e.g., the common cold. The emphasis is on uncovering biological indicators of resulting chronic diseases, particularly those involving or related to the respiratory system. Because of the low concentrations of the exposures, laboratory studies are being extended to investigations of the more subtle effects of exposure, such as reaction time, color perception, learning rates, spontaneous activity, fertility, mutations in the cells of exposed animals, and biochemical studies.

The second area of divergence of present-day medical research in air pollution from the traditional practices

stems from the complex nature of the pollution insult. Air pollution involves a complex and constantly changing mixture of gaseous, liquid, and solid chemical compounds resulting in an infinite number of dosage patterns. In addition, the physical association of these mixtures is a complex, confusing, and little understood phenomenon that is probably directly related to the insult on the biological system. There is still much to be learned concerning the physical nature of pollutant mixtures to help clarify the nature of the biological effect; this will be discussed in more detail later. Medical research cannot wait for this clarification, however, and studies are under way even though the exposure system is not clearly defined. The best examples are studies of the synergistic or potentiating effects of aerosol-gas systems, which to date have involved mainly sulfur dioxide as the gaseous component, and the use of realistic multicomponent exposure systems.

In addition to the complexity in composition of the pollutant, other non-air pollution factors may be of major contributing importance in chronic or infectious illness stemming from pollution of the air. Consequently, much emphasis is being given to studies involving pollutants plus infectious agents and the interaction of pollutants and weather factors. The effects of meteorology (biometeorology) and of socio-economic factors further complicate the exposure pattern of pollution insults.

Lastly, air pollution medical research will be hard put to keep up with the investigations of all the combinations of pollutant mixtures that may be significant in the development of chronic disease. Hence, it would be of significant benefit if adequate screening technics could be developed to point the way for more extensive medical investigations. A case in point is the present attempt to use microbiological systems (paramecia) as indicators of the potential carcinogenicity of fractions of organic material extracted from the suspended particulate of community atmospheres. This project is of particular interest, in that the chemical nature of the fractions is for the most part unknown. Information uncovered via the biological indicator-animal experimentation route can be used to point up the need for chemical identification of the specific compounds in the fraction, tracing them back to their sources in the community for possible control. Only a few per cent of the organic fraction of atmospheric pollution have been identified and quantified, so that any leads to candidate materials of suspected health significance are welcome.

Air Quality Criteria

The last item we will briefly discuss under the medical-biological areas of air pollution research is the development of air quality criteria. It is discussed here principally because man is the air pollution receptor of primary concern. The determination of air quality criteria will be greatly assisted by medical-biological investigations, both laboratory and epidemiological, directly related to man or in connection with systems that can be more or less extrapolated to man. This by no means signifies that the physical sciences, engineering investigations, and sociological studies in air pollution are not concerned with air quality criteria. Rather, the situation should be viewed as an ecological system with man's health as the principal focus of attention. The urgent need for cleaning the air sufficiently to assure only minimal effects on man's health can no longer be denied. This goal automatically demands a sequence of knowledge of what levels of pollutants are consonant with such minimal effects; what is the status of man's air environment; where these pollutants come from, and how these

sources may be controlled or eliminated. The quality and character of the air environment, the sources of pollutants, and their control are obvious arenas for engineering and physical sciences research.

Engineering and Physical Sciences Research

Space does not permit an area-by-area or project-by-project discussion of current research in the engineering and physical sciences. This discussion will be directed to the principal areas under study, focusing on those items that in our opinion are the most pressing for the immediate future. This approach will not allow the discussion to proceed in neatly tied packages representing professional disciplines, but this is the interdisciplinary nature of research in the environmental field, and particularly in air pollution. Engineering and physical sciences research in air pollution requires a multiplicity of talents: organic and inorganic analytical chemists; photochemists, physical chemists, meteorologists; physicists; sanitary, electronic, electrical, chemical, mechanical, and automotive engineers; statisticians, mathematicians, and data-handling specialists. Studies closely associated with these disciplines require others, such as economists, urban planners, sociologists, and information specialists. The field is broad, and the talents of many are needed.

Vehicle Emission Research

The most widely publicized area of air pollution research concerns the nature, effects, and control of vehicular emissions. The term "vehicle emissions" is used rather than "automobile exhaust" because it includes all moving transportation sources—both gasoline- and diesel-fueled automobiles, trucks, and buses; and all emissions—tailpipe exhaust, crankcase ventilation, and evaporative losses. There is also some concern over pollution from aircraft. Although considerable effort has gone into this area of research over the past 10 to 15 years, the results have mainly served to improve our understanding of the complex physical-chemical-engineering systems involved and to delineate areas of fruitful research for the immediate future. Gone is the hope for finding "the" chemical compound in the atmosphere responsible for all effects of California-type smog, from whence we could trace the "culprit" to its source and eliminate it. In lieu of this panacea has come some understanding of the complex nature of the problem of vehicle emission pollution and associated photochemical phenomena. This understanding is vital and points the way toward eventual solution of this particular problem through a series of complicated developments and innovations. The disconcerting aspect of what has been learned is the probability that additional significant photochemical systems, involving pollutants from sources other than the automobile, may be on the horizon.

The outlook for the vehicle emission pollution problem involves three phases: (1) control of vehicle emissions from the types of power plants used today. This will be an interim measure leading to (2) modification of the power plant to so improve its combustion efficiency that it will meet presently sought goals, e.g., the state of California standards: 80 per cent reduction in over-all hydrocarbon emissions and 40 per cent reduction in carbon monoxide emissions. This again will be an interim measure leading to (3) development of new-type power plants with essentially no emissions as we know them today.

The delineation of emissions into chemical species indicates a potpourri of organics, most of which are hydrocarbons, although this does not insure by

any means that hydrocarbons are our major headache for all types of emissions. Photochemical studies indicate that various classes of compounds, e.g., olefins and certain dimethyl and trimethyl substituted benzenes, are more reactive than other classes, and vary in reactivity within the class. Hence, there will always be a need to measure quantitatively the various chemical species by class or individually. This now requires and will continue to call upon the adaptation of the most sensitive advanced technics for chemical separation and identification, including sampling procedures that will insure determination of exhaust constituents rather than those resulting from the sampling method.

As more knowledge of the presence and reactivity of specific hydrocarbons is amassed, it is reflected in consideration of improved criteria for control devices, and sets in motion a whole new chain of events involving instrumentation development, inspection requirements, and the like. The concept of controlling only portions of the exhaust from vehicles, e.g., hydrocarbons and carbon monoxide, but not nitrogen oxides, poses questions as to the effects on the pollution picture after such controls are implemented.

The role of organics other than hydrocarbons has already been mentioned. This is precisely the problem in diesel exhaust pollution. In the diesel engine, combustion takes place in a large excess of air as compared to combustion in the spark-ignited engine, which operates at air-fuel ratios in such a way that all of the hydrocarbon cannot be completely combusted. The diesel engine is comparatively efficient, and diesel exhaust will meet the present California standards without need for control devices. However, the large excess of oxygen in diesel combustion results in the synthesis of oxygenated organic compounds, which are malodorous. They are very obnoxious and public complaints are numerous, even though diesel fuel usage in urban areas is small in comparison to gasoline consumption, e.g., in Los Angeles County it is only 1 to 2 per cent.

In the area of engine modifications, effort at the present time relates to effects of fuel composition, ignition, engine timing, combustion chamber design, and fuel carburetion and distribution. The Chrysler proposal for exhaust reduction, tested for certification by the state of California, utilizes the advantages of lean carburetion operation coupled with spark retardation at low speeds (idle), which increases the combustion time during low-load, low-speed conditions when hydrocarbon concentrations in the exhaust are normally high. The systems to be used by General Motors and Ford involve the injection of air into the exhaust manifold at the valve parts to combust unburned hydrocarbons and carbon monoxide in the exhaust.

In our own laboratories in Cincinnati we are working on the feasibility of an economical system of distributing fuel to each cylinder individually to overcome problems of unequal distribution inherent in the present system. Carburetor and manifold wetting, and unequal air-fuel mixture delivery, due to the tortuous channels in the present carburetor-intake manifold system, may be an important factor in emissions. It is obvious that tuning the engine to insure combustion in the "poorest" cylinder of present engines results in overrich mixtures in all others.

These are only a few engine modifications that should be explored. The need for such an interim program is twofold: (1) from an over-all point of view this approach is considered to be superior to the use of tailpipe devices as a method for control, in that control is built into the engine and the cost will be offset in part or in full by fuel savings, and (2) such modifications can be applied to the present engine and can be improved as the demand war-

rants, pending the long lead time required to develop, tool up, and produce new engine types to replace existing vehicle power plants. What these new engines will eventually be, is difficult to ascertain. Turbine and stratified-charge engines are in the testing stage; development of radically new engines, such as those incorporating fuel cells, is also under way.

Atmospheric Chemistry and Physics

There is a need to adapt existing methods and instrumentation to the quantification of chemical pollutants in the atmosphere, both gaseous and particulate, and to develop more specific and more sensitive technics. This need becomes greater as efforts are directed to specific effects of interest in the establishment of air quality criteria. During the past eight years or so, analytical methods, in particular those developed for industrial hygiene purposes, have been applied to air pollution problems, and fortunately these have proved adequate for many situations.

Previously we indicated that one phase of air pollution medical research —that dealing with laboratory animal studies—is going through a transition from studies of clinical effects utilizing exposures to single pollutants at high concentrations to those using multicomponents at concentrations more consonant with polluted atmospheres, so that threshold functional changes that may be precursors of chronic disease may be uncovered. These studies establish the need for the development of methods for the separation and quantitation of the host of chemical air pollutants that may be of health significance in relation to chronic diseases, such as cancer and cardiorespiratory ailments.

Efforts over the past ten years or so on a worldwide basis have stressed a group of hydrocarbon compounds commonly known as polynuclear aromatics or polycyclic hydrocarbons. Among these, benzo(a)pyrene is the best known because of the established relationship of this compound to production of skin tumors in animal experimentation. It is disconcerting to note, however, that known polycyclic hydrocarbons obtained from the organic fraction of air particulate constitute only about 1 to 2 per cent of the total organic particulate in air. The status of other organic materials of significance in cancer research, including cocarcinogens and anticarcinogens, is largely unexplored in the chemistry of community atmospheres. Information on the role of organic compounds containing oxygen, nitrogen, and other minor constituents is virtually nonexistent.

Recently national attention has been focused on the use of agricultural chemicals, particularly pesticides. The importance of these compounds, in relation to body insult through the respiratory route, is an air pollution responsibility which must be coordinated with the work of others in this field. Pesticide exposure by any route may well produce effects in individuals which are enhanced by exposure to other air pollutants. In other words, pesticide exposures may produce impaired individuals more susceptible as a result to community air pollution.

Another area of need concerns the low-molecular-weight organics. These exist in the atmosphere principally as vapors in contrast to the high boiling-point compounds previously discussed, which for the most part are adsorbed on atmospheric particulate. These low-molecular-weight reactive hydrocarbons were mentioned previously in connection with vehicle emissions, but it is obvious that vehicles are not the only source of organic vapors to the atmosphere.

Still another chemistry area that merits increased effort is the development of more specific and more sensi-

tive technics for quantitative analysis of inorganic air pollutants. Although chemical methods for nitrogen oxides and sulfur oxides, as two examples, may sound "old hat" to many analytical chemists, there is a particular need to establish more precise laboratory and field methods to distinguish nitric oxide from nitrogen dioxide at low concentrations and to understand more precisely the conversion of nitric oxide in the atmosphere. Renewed interest in sulfur oxides in the air pollution field stems from both epidemiological and laboratory investigations currently under way. One of these epidemiological studies indicates that asthmatics show increased reactions at very low levels of sulfur oxide, and another shows excellent correlation between respiratory infection rates and average sulfate pollution.

Laboratory studies indicate that the physiologic effects of sulfur dioxide are greatly enhanced by the simultaneous presence in the inhaled air of certain particles of size appropriate to deep penetration in the lung. This synergistic effect, it has been found, depends not only on the size of the aerosol—the effect generally increasing with decreasing size—but on the composition of the aerosol. Our abilities to quantify sulfates by size fraction of the particulate are presently quite limited; the solution to the problem involves improved fractionating samplers or improved microtechnics for sulfate analysis, or both.

The fact that pollutants, individually of only minor concern, react in the atmosphere to form new obnoxious compounds of physiologic, economic, and aesthetic interest, adds a new dimension to environmental health investigations. Although it was universally agreed that reactions between pollutants (such as oxidation reactions) did occur, the role of sunlight as an additional source of energy to activate complex chain reaction systems, which create new obnoxious end products, was a concept that emerged from investigations of the Los Angeles smog situation. This work resulted in the now commonly used term "photochemical smog," and established the need for applied investigations with a tool that previously had been more or less relegated to more exotic pursuits in the physical sciences.

Fifteen years of research in this area has indicated that solar irradiation indeed plays a significant role in air pollution chemistry, and even though our understanding has increased many-fold, the questions still requiring answers have increased directly with our knowledge. Deficiencies in our ability to develop practicable methods for the control of the precursors to photochemical smog have further sharpened the need for increased understanding of the detailed mechanisms of smog formation. This is not a simple field for investigation, and it offers a challenge as great as any in the physical sciences today.

Present interest in the application of analytical methods ranges from routine monitoring of community atmospheres to precise laboratory experimentation. Hence the need to adapt and package feasible micromethods into monitoring instruments, and to extend our capabilities for precise quantitation to laboratory studies or to exploratory field studies in order to establish pollutant levels in existing atmospheres, as they relate to the need for additional biological or physical research.

The subject of aerosols or particulates has been touched on in relation to medical research and the development of analytical methods. The field to date has been explored only in a gross fashion for its air pollution significance. Detailed investigations have concentrated on the general physical properties of aerosols, e.g., the effects of size, shape, density, and the like, on settling rates, deposition, agglomeration, optical properties, and so forth.

The suspended particulate fraction for

the most part has been chemically quantitated only in gross terms, such as total weight of particulate, weight of the benzene-extractable organic material, and the weight of a number of metals and anions such as sulfates, chlorides, and nitrates. This is not without reason, since the routine collection of masses of such data is not inexpensive and the work to date has utilized existing practical methods for both sampling and analysis.

Effects studies clearly indicate the need for aerosol studies to relate the physical and chemical properties of aerosols, as they exist in the atmosphere to biological and physical effects of atmospheric pollutants. Of immediate concern is the determination of chemical composition of particulates by size fractions, principally as these relate to biological systems. Specific examples are sulfuric acid, sulfate aerosols by gross sulfate levels, and specific chemical compounds, lead by total weight and by specific compounds, and organics by total weight and by specific compounds. Not only must sampling and analytical methods be developed to enable these studies to be done at realistic atmospheric pollution levels, but their application to field measurement is highly desirable.

Other areas of interest involve aerosols that are photochemically induced, e.g., typical Los Angeles haze, or those that occur naturally, and their relationships. Study is also needed in the broad area of gas-aerosol interactions, particularly as related to biological or physical effects. Not only is it important to know the chemical and physical bonds of pollutants in aerosols of various compositions, but it is equally important to understand how pollutants are eluted from inert particulates under various environments after they have been deposited, e.g., in the biological environment of the respiratory tract, or in the physical environment of material surfaces in relation to corrosion.

Meteorological Research

In our discussion of atmospheric chemistry, we indicated that the activation of chemical reactions by sunlight had introduced to environmental health problems the new dimension of photochemistry. The meteorological aspects of air pollution introduced the third space dimension to environmental problems, in that other environmental health disciplines are generally confined to areal distribution on the surface of man's living space. Even the areal problems of the earth-atmosphere interface are much more complex for the air environment, in that topography confuses the theoretical picture rather than dictating it in its entirety, as in stream pollution. In air pollution, we are dealing with multiple multicomponent pollution sources, injected into the base of a three-dimensional fluid. This fluid is mainly subject to the influences of the general worldwide atmospheric circulation, upon which are superimposed general and local diurnal influences, general and local topography, and the social habits of man and his works. We are interested in the interaction of air pollutants and meteorological factors, not merely in the significance of meteorological processes to air pollution.

Research to date has been primarily concerned with the interrelationship of meteorological parameters and measurements of air quality, the development of technics for forecasting stagnating air conditions conducive to the buildup of pollution (provided there are sources), and the development and field-checking of mathematical models to predict the dispersion and transport of pollution for a variety of source configurations and atmospheric conditions. Present emphasis is on the latter two areas.

Relative to air stagnation forecasting, there is a need to sharpen our abilities to superpose local diurnal and topographical effects on the general synoptic

picture. In the development of mathematical models for dispersion and transport, there are two areas of interest: (1) intraurban models for use in connection with local air pollution control programs or with long-range air resource management associated with urban planning; and (2) interurban models for the long-range transport of pollutants. The solid extensive urban complex referred to as "megalopolis" is, in terms of air pollution, a reality today on the northeastern seaboard. The area from the nation's capital to Boston is oriented somewhat parallel to the general circulation in the northern hemisphere, and the transport of pollution up the Atlantic seaboard poses a significant problem in the long-range development of this entire area.

The importance of this problem should be determined before it becomes acute, and consequently the Public Health Service is tooling up for a major study on the potential for intercity transport of pollution along the northeastern megalopolis. Development of models and practical means for checking their validity are under study. For the latter there is a need to produce several types of tracer materials, which must be nontoxic, chemically stable, nonexistent as pollutants in the atmosphere, and so distinctive in chemical structure that they may be monitored after thousands to millions of dilutions. Fluorescent particles look promising in the lower dilution range indicated, and new sensitive analytical technics, such as gas chromatography with electron capture detectors, make the prognosis promising for success in the higher range.

Other meteorologically oriented studies of importance concern the development of ground-based methods for measurement of atmospheric properties in situ, e.g., determination of temperature discontinuities (inversions) or pollution discontinuities, the latter usually being associated with inversions. Improved methods for visibility determination, or instrumentation for monitoring solar energy by wave-length distribution, are also of interest.

Control Methods Research

Research on methods for control of air pollution has been dictated to a large extent by the status of methods and equipment available when air pollution emerged as an important community problem after World War II. Practicable methods for particulate control are available to meet today's needs, albeit improvements that will increase collection efficiency and reduce equipment and operating costs are always desirable. In the future our increasing industrial base and mounting population will require ever-increasing efficiencies of collection even to maintain the status quo, let alone reduce present levels. The prognosis is toward atmospheric loadings with an over-all decrease in average particle size, and with consequent increase in the portion penetrable into the depths of the respiratory system. It is imperative, then, that we improve our basic understanding of removal processes and the engineering of these into more economical as well as more efficient control devices.

The control of automobile exhaust has already been discussed. A great deal of effort has gone into this area and will continue because of the economic promise of return on such control devices and their anticipated widespread mandatory use.

The control area of greatest need, affecting the nation as a whole, concerns sulfur oxide emissions from combustion equipment that uses fossil fuels containing appreciable quantities of sulfur. The association of sulfur oxides with health effects has already been discussed. The enormous quantities of fossil fuels consumed daily, and the future outlook for vast over-all increase in usage to

meet the nation's ever-mounting energy demands, further emphasizes the need to develop economically feasible methods for control. Two approaches are being pursued: (1) removal of sulfur from fuel, and (2) removal of the sulfur oxides formed during combustion from the stack effluent. Coal contains sulfur as inorganic pyrite and also as combined organic material; sulfur in oil is in the combined state.

Investigations are currently under way to reduce the sulfur content of both coal and residual fuel oils; the roadblocks involve the technology of the basic processes involved as well as economics of application. Investigations of removal of sulfur oxides from stack effluents are proceeding along several lines: use of packed or falling beds for sorption of sulfur dioxide and sulfur trioxide, with recovery of the sulfur as elemental sulfur or sulfuric acid and regeneration of the bed material; conversion of the sulfur trioxide to sulfate by chemical reaction with additives, and removal as particulate; and conversion of the sulfur dioxide to sulfur trioxide by catalytic conversion, and removal as sulfuric acid or as sulfates. Several of the processes are in the pilot stage of development; their ultimate acceptance will be based on their over-all economic feasibility. Here is an area where a technological breakthrough would be of major significance.

Control of nitrogen oxides also is being investigated in some depth. The search for more efficient vehicle power plants or the use of tailpipe converters theoretically postulates increased fixation of atmospheric nitrogen, a reaction that occurs in all types of combustion. Methods for reduction of nitrogen oxide production from all combustion processes, including vehicle power plants, are under study. Three avenues are being investigated: (1) the use of catalytic converters, (2) recirculation of combustion products to reduce the over-all concentration of oxygen available for combustion, and (3) the use of two-stage combustion to reduce the over-all temperatures involved, thereby inhibiting the rate of reaction for nitrogen fixation.

Associated Research Needs

The problems in research in the physical and biological sciences have their counterpart in the social sciences. Methods for assessing the economic impact of air pollution on our society need development and application. There is need for better methods of informing the public of existing and potential environmental health situations and, in turn, of proper interpretation of the public wishes by responsible officials. The social structure of our society plays an important role in economic problems, particularly in relation to the impact of control measures needed to meet minimum air quality criteria. The need to incorporate air resources management into urban planning is just now being recognized as another of the many problem areas of importance in urban resource development. With our burgeoning population and urban development, we can no longer logically hold to the concept of growth based on chance; space no longer is available to provide the factor of safety against severe air pollution situations that we have relied upon up to the present stage in our national development.

Summary

What, then, is the over-all status of current research in air pollution? Great strides have been made in the 15 years since World War II, which gave sufficient impetus to our industrial growth and urbanization so that in certain areas our air resources were overtaxed. This growth has continued, adding to the over-all problem. Assessment nation-

wide, and research on the physical-biological-engineering problems involved, have resulted in a clearer understanding of the nature and magnitude of the problem. It has made possible a more rational approach to both continued research and means for bringing pollution under control.

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A Fortune Proposition:

We Can Afford Clean Air

by Edmund K. Faltermayer

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Public Health Service

[November 1965]

A Fortune Proposition:

We Can Afford Clean Air

by Edmund K. Faltermayer

Polluted air is corroding metals, menacing health, and degrading the human spirit. For around $3 billion a year, equitably shared, we can erase the outrage.

An astounding 133 million tons of aerial garbage is now being dumped into the U.S. atmosphere each year. If it could be placed on a giant scale, it would outweigh the country's annual steel production. The charts on the opposite page, based on estimates by the U.S. Public Health Service, show which human activities are responsible for this rising torrent of contamination, and what each activity's ugly brew consists of. The charts show only the five pollutants that account for most of the over-all tonnage; not shown are scores of other gases and stinks that defile the nation's air.

These pollutants are eating away at fabrics and metals. They are defacing buildings and spoiling crops. The government estimates the property damage alone at $11 billion a year, and this does not include the decline in real-estate values in neighborhoods with air that is second class or worse. Air pollution also represents a prodigious waste of potentially valuable resources: the harmful sulfur dioxide that is vented to the atmosphere each year, for example, contains about $300 million worth of sulfur at today's prices. While medical researchers have not proved that any of these pollutants is injuring large numbers of people, this junk obviously is doing our systems no good. "There is no longer any doubt," Surgeon General Luther L. Terry declared nearly three years ago, "that air pollution is a hazard to health." In agreement, the American Medical Association recently called for "maximum feasible reduction of all forms of air pollution."

Besides damaging health and property and wasting resources, air pollution dejects and degrades the human spirit in ways that a civilized society should not tolerate. The acrid smog associated with automobile exhausts, once confined to Los Angeles but now turning up elsewhere, probably does not kill people. It merely envelops them in an ugly yellow haze that blots out the view and smarts the eyes. The pride of Denver—the prospect of the Rocky Mountains from downtown streets—is often obscured these days by a man-made cloud of pollution. New Yorkers, plagued with 12,000 soot-spewing apartment-house incinerators, literally inhale a portion of their own garbage. In St. Louis, a survey showed, 39 percent of the people are dogged by noisome odors. After poor schools and inadequate play space, air pollution is probably the most important single factor driving the middle class to the suburbs, and a portion of the country's commuting woes must be ascribed to it. Renascent cities are trying to lure these citizens back, but they recoil from air that is dirty, malodorous, and menacing.

The U.S. has both the technology and the wealth to reduce pollution drastically. Even though thousands of factories are still discharging their wastes into the public air, most of the devices for controlling emissions from industrial plants were invented years ago. "We can handle just about any pollution-control demand that is likely to be made," says John E. Schork, president of Research-Cottrell, Inc., a leading maker of pollution-abating devices. Cleaning up automobile emissions and the sulfur dioxide from electric power stations still presents engineering problems, but solutions will undoubtedly be found in the next few years.

Money is not a problem, either. The nationwide application of the best techniques either already or soon to be available would cost the country far less than is generally believed. An expenditure of less than one-half of 1 percent of the gross national product—probably about $3 billion a year—would reduce air pollution by at least two-thirds. By drastically reducing that $11 billion a year of property damage, the expenditure would easily pay for itself.

With the technical skills and the monetary means at hand, it is incredible that we put up with this needless outrage. With an awakened public, there would be no need to employ susbsidies and other economic gimmicks to hasten industry's cleanup, as some experts have proposed. Corporations can absorb many of these expenditures anyway, and consumers would not notice them in the prices of the things they buy. Indeed, households would probably feel the costs of a national rollback of air pollution only in the prices of two items, electricity and new cars. But these two items are so universal that price increases, rather than subsidies, would be a perfectly equitable way to distribute the burden. The role of the federal government, FORTUNE believes, can largely be confined to the setting of standards, and to aiding state and local governments in enforcement.

What's done is too little

A good deal is already being done about air pollution, to be sure. Thanks to the Clean Air Act of 1963, which for the first time made matching federal grants available for state and local enforcement efforts, dozens of localities have set up control programs. While many companies have waited until local authorities forced them to clean up, some enlightened managements have designed new factories more tightly controlled than local regulations require. Exact figures are not available, but industry is probably spending about $300 million a year on the installation and operation of special equipment, changes in materials and production processes, and on research designed to abate air pollution. Spending by government at all levels on enforcement and research now is running at $35 million annually, about three-fifths of it federal money. The national effort may grow larger now that Congress has passed a bill by Senator Edmund S. Muskie of Maine that, among other things, enables the Secretary of Health, Education, and Welfare to order the nationwide installation on new cars of devices to limit the pollution from tail pipes.

But all the present efforts, even combined with those under serious consideration, may not permit us to hold our own. During the next forty years the population of the country's urban areas is expected to double, and industrial output and automobile ownership in these same urban zones will grow even faster. The emissions from each factory chimney, automobile tail pipe, and other sources will have to be reduced more than 50 percent on the average, just to keep the urban air from becoming any fouler than it already is. If the air is to be *improved*, the clampdown on emissions will obviously have to be even tighter.

In the case of "stationary" sources of air pollution like factories, incinerators, and electric power stations, the present effort is far too small to bring about any significant advances. The only pollutants of this kind that have been reduced noticeably are the nongaseous, largely nontoxic dusts and fumes that come under the general heading of "particulate matter." Chicago's "dust fall" has declined since the 1930's, and Pittsburgh and St. Louis no longer experience darkness at noon. But this improvement was helped along by the switch from coal for heating, and the switching is nearly complete. As the rainfall of dust and soot on Manhattan's East Side (eighty tons a month per square mile) testifies, particulate matter is still an abominable nuisance in many areas. In fast-industrializing cities like Denver, it is on the increase.

Meanwhile, emissions of the far more dangerous gaseous pollutants are rising dramatically. If recent trends continue, the emission of sulfur dioxide from electric power stations—the largest single source—will increase sixfold by the year 2000. The control devices recently developed for autos, even if adopted across the nation, will bring no lasting rollback in carbon monoxide and hydrocarbon emissions, since these gains will be more than canceled out by rising automobile registrations, which are doubling every twenty-five years.

In the longer-range future, the increase in the airborne wastes thrown off by man's activities may require some drastic solutions. The tremendous rise in the worldwide use of fossil fuels, some authorities say, is putting carbon dioxide into the atmosphere faster than plants and the ocean can absorb it. This gas, which is the unavoidable result of all combustion, is not a "pollutant" in the ordinary sense of being harmful or annoying. But carbon dioxide produces a "greenhouse effect," and tends to block the radiation back to outer space of some of the heat energy that the earth absorbs from the sun. The carbon dioxide concentration in the atmosphere has increased about 8 percent since 1890, and may account for the slight warming up of the Northern Hemisphere since then. In a study two years ago, the Conservation Foundation found this carbon dioxide buildup "not yet alarming," but said it might eventually cause the polar ice caps to melt, submerging many of the world's cities. To this kind of threat, the only answer might be a large-scale switchover to nuclear power, which produces no carbon dioxide.

The dump has its limits

While the carbon dioxide buildup will bear close watching in the years ahead, the immediate task is to cleanse the air of those 133 million tons of dirt and poison that are annually pouring into it. The atmosphere's limitations as a dumping ground for this kind of junk have already become obvious. There are 90 trillion tons of air over the forty-eight contiguous states at any given time. Last year's load of pollutants, if released in an instant and evenly dispersed, would amount to only 1.5 parts per million in the air. Since the contamination actually is spread over a year and continually falls to the ground or is washed out by rains, the average concentration in the nation's total air supply is considerably less than that. But half of this pollution is emitted from less than 1 percent of the U.S. land area, where 50 percent of the population lives. When winds are slack, this far heavier outpouring can build up to thousands of times the national average.

Things can get even worse when there is also a temperature inversion, in which a warm layer of air aloft acts as a lid atop the contaminants in the cooler surface air. This phenomenon was once thought to be peculiar to Los Angeles, where the lid drops to 500 feet or less 40 percent of the time. Actually, it occurs commonly throughout most of the U.S. In New York and Philadelphia, for example, low-level inversions occur 25 percent of the time, and even more often in the fall. The only real difference is that Los Angeles' inversions tend to be lower, and are accompanied by below-average winds. But New York throws off much more non-automotive air pollution. The air above us is not a boundless ocean. Much of the time it is a shallow, stagnant pond, and we are the fish at the bottom.

In Los Angeles, compulsion brings results

The most rigid emission standards in the U.S. today are applied in the Los Angeles County Air Pollution Control District. Faced with acute smog conditions, Los Angeles authorities have forced the installation of pollution-limiting devices on California automobiles. They have also forced industry to reduce its emissions by nearly 80 percent since the late 1940's; an estimated 5,000 tons of pollutants a day from stationary sources are now being kept out of the sky. What would be the cost of a "Los Angeles treatment" for all manufacturing? We can get some indication by looking at a few of the major air polluters, such as steel and chemical plants and oil refineries.

The orange clouds of dust—mainly iron oxide—pouring out of smokestacks carry the major pollutants that the steel industry generates. Not long ago steel companies in Chicago, with a combined ingot capacity of about 13 million tons a year, agreed to eliminate all dust by 1971 at a reported capital cost of approximately $30 million. This suggests a cost of about $2.50 per ton of capacity. Since steel companies in several other cities are pushing ahead with controls or replacing open hearths with basic oxygen furnaces—all of which have controls—it appears that as much as two-thirds of the country's approximately 150 million tons of steelmaking capacity may be operating with "clean stacks" by the early 1970's. Generously assuming that it might cost as much as $5 per ton of capacity to equip the remaining third, or about $250 million, the industry would have approximately to double its spending on air-pollution equipment in the years ahead.

The chemical industry, turning out thousands of different products, emits a bewildering variety of gases and exotic odors. Lots of chemical plants, as one industry spokesman concedes, are "quite flavorsome" to human noses, which have a remarkable sensitivity to noisome odors. A lot of the effluent is potentially dangerous, too. The phosphate fertilizer plants in Polk and Hillsborough counties in Florida used to emit large quantities of fluorides that damaged citrus crops and caused the teeth of cattle to drop out. But in the last five years the plants have installed about $22 million worth of equipment and cut emissions by more than half, while increasing production 43 percent. One of them, faced with a shutdown by a court injunction, managed to reduce its daily fluoride emissions from 900 to 300 pounds in only sixty days. The members of the Manufacturing Chemists Association, which embraces most of the industry, have invested a total of $212 million in air-pollution control facilities to date, and expect to spend another $49 million in the next five years. This does not include additional operating costs or research, which together come to $26,600,000 a year. Rough estimates of what it would cost to bring all the country's chemical plants up to the level of the cleanest ones range up to $500 million just for equipment, not counting outlays already planned, but half that amount might do the job.

The cleanest petroleum refineries in the nation are to be found, not surprisingly, in the Los Angeles area. Standard Oil of California's refinery at El Segundo, partly screened by trees, emits little besides innocuous steam to the atmosphere and cannot be smelled more than half a block away. To comply with Los Angeles' strict rules, oilmen say, would probably add between 5 and 10 percent to the cost of a new refinery. While no recent figures are available, a 1961 survey showed that U.S. petroleum refineries were spending about $18 million a year on pollution-abatement equipment. But 44 percent of the money was being spent on the West Coast. Bringing all U.S. refineries up to Los Angeles standards, therefore, might require the expenditure of an additional $10 million a year on equipment. Some of this would pay for itself by recovering valuable substances. Indeed, it has been estimated that four-fifths of the sulfur dioxide which U.S. petroleum refineries might otherwise be venting to the atmosphere is now captured as sulfuric acid or elemental sulfur.

The particulars on particulate matter

The troublesome pollutants from electric power stations are particulate matter, in the form of fly ash, and sulfur dioxide. The first comes almost entirely from coal-burning generating plants, and the techniques for controlling it have been around for decades. In 1962, according to the Edison Electric Institute, private power companies kept nine million tons of fly ash from entering the sky, far more than the approximately two million tons that escaped. Electrostatic precipitators in the newest plants catch 99 percent of the stuff, and a still newer unit at a mine-mouth plant going up in western Pennsylvania will be the first in the U.S. to remove 99.5 percent. Unfortunately, new plants are still being built in some areas with mechanical collection systems that keep no more than 70 percent out of the air. To bring all the country's 130 million kilowatts of coal-burning generating capacity up to the 99.5 percent level might cost about $300 million.

The cost of collecting fly ash has only a negligible effect on the price of electricity—well under 1 percent by one estimate, counting the write-off of equipment. The control of sulfur dioxide, on the other hand, could have a sizable effect on consumers' monthly bills. Electric generating stations are the country's biggest single source of this gas, and capturing it before it goes out the stack is one of the really tough problems in cleaning up the air. Most of the gas comes from the burning of coal, which contains about 2.5 percent sulfur on the average, and which is used to generate 54 percent of the nation's electricity. Oil accounts for a much smaller share, but heavy residual fuel oil, which generally has about the same percentage of sulfur, is used extensively in places like New York City.

Sulfur dioxide is the most worrisome of the major pollutants, and 23 million tons of it are currently being discharged into the country's air. It has been implicated in most of the famous air-pollution disasters, such as the 1948 one at Donora, Pennsylvania (twenty dead), and the 400 "excess deaths" recorded during a fifteen-day smog episode in New York City early in 1963. While not toxic to man in the concentrations ordinarily found in the atmosphere, it can cause acute crop damage in relatively small concentrations. In industrial regions it causes nickel to corrode twenty-five times as fast as in rural air, and copper five times as fast. And under certain conditions it kills people. One of its derivatives, sulfuric acid mist, can get past the body's natural filtration system and penetrate deep into the lungs, causing severe damage. While the sulfur dioxide in New York City, which has the highest concentration, averages only 0.16 parts per million, it has flared up as high as 2.64 p.p.m.—enough to kill some persons already suffering from respiratory ailments.

Until now, no economically feasible way has been found to curb the emissions of this gas from coal- and oil-burning power stations. The only solution has been for the electric companies to build tall stacks so that the sulfur dioxide will not reach the ground until it is far away and greatly diluted. But electric-power consumption in the U.S. is doubling every twelve years, and the consumption of coal by utilities is expected to rise almost as rapidly in the years ahead. Some air-pollution men already question the efficacy of building ever higher stacks in the nation's fast-

spreading metropolitan complexes. Nor will atomic power or natural gas—which contains very little sulfur—be of much help in the years just ahead.

There appear to be only two ways out. In the case of residual fuel oil, local authorities could require power companies to switch to No. 2 oil, which is low in sulfur but costs 80 percent more. Or petroleum companies could take part of the sulfur out of residual oil, raising its price 20 to 30 percent. As for coal, the only answer is to trap the sulfur dioxide after the fuel is burned, and to convert it to marketable acid or elemental sulfur. The Department of Health, Education, and Welfare is planning to spend $7 million to build pilot models of some systems that show promise of being able to make such a conversion economically. Recently, officials of the Bureau of Mines estimated that any one of the three leading processes would impose an added cost, even when allowance was made for the sale of acid or sulfur, equivalent to an increase in fuel costs of 10 to 25 percent. The estimates, it should be noted, are based on the installation of these processes in a new, 800,000-kilowatt plant. The capital expense of fitting them into existing power stations, other studies show, would be much higher, perhaps doubling the augmented cost.

These figures are not quite so gloomy as they look. Fuel represents only about one-seventh of the total cost of generating and distributing electricity, or about 2.5 mills per kilowatt-hour. Even if the power companies were forced to burn low-sulfur fuel or were directed both to install sulfur dioxide recovery systems in new coal stations and to fit out similarly all the existing ones, the cost of the electricity generated by them—about 600 billion kilowatt-hours last year—would probably not rise by more than $600 million a year.

Traffic in carbon monoxide

In terms of sheer tonnage, the automobile is the country's No. 1 air polluter. According to Public Health Service estimates, it accounts for over four-fifths of the 85 million tons of contaminants emitted by all forms of transportation, including trucks, buses, railroads, and airlines. The three dangerous and obnoxious ingredients issuing from the nation's 72 million automobile tail pipes are carbon monoxide, unburned hydrocarbons, and oxides of nitrogen. While it can kill a man by depriving his blood of its oxygen-carrying capabilities, carbon monoxide is generally not dangerous in open places. Nevertheless, it can reach dangerous concentrations in heavily traveled city intersections and expressways. Biochemist A. J. Haagen-Smit of California Institute of Technology says the level frequently gets to 30 p.p.m. on the Los Angeles freeways—enough to deprive the blood of 5 percent of its oxygen capacity if inhaled for eight hours—and sometimes reaches 120 p.p.m. in traffic jams. More trouble per ton is caused by the unburned hydrocarbons, some of them highly reactive, that spew out of cars. Their partners in crime are the oxides of nitrogen. All forms of combustion, particularly in motor vehicles and electric power stations, give off nitric oxide. Most of this is quickly converted into nitrogen dioxide, a whiskey-brown gas that is five times as toxic. When the sun shines on a mixture of hydrocarbons and nitrogen dioxide on a warm day, the result is photochemical smog.

The automobile industry has opposed controls on automobile exhaust emissions outside Los Angeles on the unpersuasive ground that other cities do not yet have an acute smog problem. But Washington, D.C., where the number of cars per square mile is three times as great as in the Los Angeles metropolitan area, has already had some eye-watering days. Denver figures that 40 percent of its pollution comes from the automobile, and in New York City the car contributes a third. "We didn't have that haze until they built the expressways," says a Chicago air-pollution man, "but we sure have it now."

Most of the radical proposals for dealing with smog, even if adopted, would barely enable cities to hold their own. Turbine-powered vehicles, now being tested by the auto manufacturers, are low in pollution ("It would make your eyes bug out, it's that low," enthuses a Chrysler man), but have not yet proved out. Diesel engines are noisier and costlier than the gasoline engine and, while they emit less carbon monoxide and hydrocarbons, they produce just as much oxides of nitrogen.

The only solution, for the foreseeable future, is to clean up the internal-combustion engine. Since 1963 the automobile companies have installed crankcase devices that vent back into the intake manifold the unburned gases that push past piston rings during combustion. But these "blow-by" devices, which actually were used on some makes years ago and then dropped, reduce only one of the car's three pollutants, hydrocarbons, and by only 30 percent. For this reason, California state authorities, who seek to roll back the pollution in Los Angeles to the 1940 level, have insisted on controlling exhaust emissions. Chrysler Corp. has a "cleaner air package," which meets California's standards, and adds $13 to $25 to the price of a new car. The device, which sends a leaner mixture to the engine and advances the spark during deceleration for more complete burning of fuel, can be maintained for only a dollar a year more than the cost of a recommended engine tune-up, Chrysler claims. The other three auto companies have announced systems that, like Chrysler's, alter fuel-air mixture and timing. But they have added a pump that injects air into the exhaust manifold to aid the burn-up of contaminants. This system would increase the price of a new car by as much as $50. These devices are appearing for the first time on 1966-model cars sold in California.

Forcing Detroit to "find something"

The combination of crankcase "blow-by" device and exhaust controls, California authorities say, will reduce carbon monoxide emissions by 60 percent and hydrocarbons by about 70 percent. But, it will be ten years before 85 percent of the cars now on the road have them, and meanwhile the number of automobiles in the Los Angeles area may grow faster than smog is reduced. For this reason the state has ordered a further 15 percent cutback by 1970. At the moment, Detroit does not know how it will comply. "We have to find something, don't ask me what," says an official at General Motors' Warren, Michigan, research center. In addition, California may shortly set limits for emissions of oxides of nitrogen. The auto industry does not yet know how to control these, either, since they present totally different problems. But it seems safe to assume that Detroit will come up with something if it has to.

Now that Senator Muskie's bill has been passed, it is

fairly certain that the Secretary of Health, Education and Welfare will set automobile emission standards for the entire U.S. While reluctant to do so—even though it makes money on them—Detroit says it can install the control devices on all new cars beginning with 1968 models. In a nine-million car year, this would add as much as $400 million to what the public spends for automobiles. The later adoption of controls on oxides of nitrogen might conceivably double this figure, to about $800 million.

Any increase in the cost of gasoline-powered cars would improve the prospects for electric cars. Yardney Electric Corp. of New York City already has a special Renault Dauphine fitted with lightweight batteries that can propel it at speeds up to fifty-five miles an hour, and up to eighty miles on a charge. The catch is that these are military-type silver-zinc batteries costing $3,000. Nevertheless, several companies, including Yardney and General Dynamics Corp., are pushing ahead in the search for batteries that would cost only a fraction of this. Electric-utility men, of course, yearn for ways to put their off-peak generating capacity to use, and become rhapsodic at the vision of millions of battery-operated cars plugged in nightly for recharging. While a battery-operated car suitable for long journeys is a long way off, a smaller version might be available in a few years.

Smoldering trash fires

Not counting manufacturing wastes, Americans now generate 150 million tons of trash and garbage a year. About half of that mountain of waste is burned. But the conditions under which much of the burning takes place can be fairly primitive. In Denver back-yard incinerators account for 25 percent of the total air pollution. In Chicago many apartment houses still burn their garbage in heating boilers. Under these conditions, noisome odors and tons of soot spill over whole neighborhoods – an affront to the nostrils and a major cleaning problem.

The best prevailing practice is to construct large municipal incinerators. New York City has done this, but its incinerators are not equipped with precipitators, and they discharge into the air eight pounds of particulate matter for every ton of mixed trash and garbage burned. Yet they are immaculate affairs compared to the city's apartment-house incinerators, which spew out twenty-six pounds per ton. "It's like permitting outhouses," says a Los Angeles air-pollution man. But such conditions do not have to be tolerated: Europe's newest municipal incinerators not only are equipped with precipitators, but take advantage of the fuel value of rubbish to make steam and electricity.

It would not cost catastrophic sums for American cities to abate the nuisance caused by the burning of rubbish. New York City will shortly begin requiring double-flue incinerators in new apartment buildings, which will produce relatively little soot. Another solution would be to outlaw the construction of any incinerators in apartment houses, and to require modifications on the 12,000 existing ones. But since this far-from-ideal solution would cost the owners as much as $60 million, it might make more sense to shut the incinerators down and spend about $15 million to build a city incinerator that could reduce the soot and fumes by 99 percent. The city resists this idea because it figures that the added cost of hauling the refuse to an incinerator would be $19 million a year. But if it were hauled, and if precipitators were installed on all existing municipal incinerators, and if all capital equipment were written off over a ten-year period, the total additional cost of doing the job right would work out to a piddling 25 cents a month for each of the city's eight million residents.

The burning question

While small on a per capita basis, such expenditures would be large enough to present real problems in many areas. Between now and 1985, the Public Health Service has estimated, cities and towns may have to spend $506 million on municipal incinerators just to handle the expected increase in refuse collections. If the cost of building incinerators to handle a larger share of the existing load were included, that figure could easily be doubled. And this does not count the added cost of collecting and burning the stuff, which could easily total $2 billion a year. Not all of this represents the cost of abating air pollution, since most of these facilities may have to be built anyway to rid communities of heaps of refuse. But about a third of these operating and capital expenses, or an average of about $350 million a year between now and 1985, could be somewhat arbitrarily assigned to the cost of cleaning up the city air.

In view of the enormous costs of handling refuse, more cities are exploring ways to make some economic use of it. In addition to steam generation, some cities have recently gone over to the practice, long popular in Europe, of composting refuse and selling it to farmers as a soil conditioner. Ross McKinney, director of the University of Kansas' environmental health laboratory, has devised another system that is similar to composting except that it is anaerobic i.e., the refuse is broken down in the absence of oxygen. This not only cuts the bulk in half and produces a soil conditioner of possible value, but liberates a lot of methane gas, which could be used to generate power. McKinney, who frets that the U.S. is doing only about $500,000 worth of research a year on ways to dispose of rubbish, foresees trash-carrying pipelines in cities that will eliminate costly pickup services.

Not free as air, but . . .

In sum, cleaning up our badly soiled atmosphere is well within this country's means. To apply the best existing abatement techniques to all the plants in three main branches of manufacturing, not counting expenditures already under way, and effectively to curb fly-ash emissions throughout the country's present electric generating facilities, would require an expenditure on equipment of about $1 billion. This figure allows for the fact that it usually costs 25 to 30 percent more to install emission-curbing devices in an old plant than to design them into new ones. It should be doubled to take in all other branches of industry, and redoubled to include operating costs. Thus the cost of bringing the country's present industrial establishment up to the current level of technical knowledge in the field, if spaced over ten years, would run about $400 million a year. Meanwhile, industry could easily double what it is spending to curb air pollution in its *new* facilities—presumably where most of its current $300 million of spending is directed. Altogether, the application of the best existing technology to industry would cost about $1 billion a year.

This is a liberal estimate. Industry in Los Angeles County, where the strictest regulations prevail, has been spending

about $2.30 a year for each of the area's residents, which would work out to a figure of about $450 million for the nation. This probably understates things, however, as Los Angeles does not have as much heavy industry of the air-polluting type as some other areas. But despite this qualification, it is evident that U.S. industry could achieve standards of cleanliness like those of Los Angeles for far less than the $50-billion to $75-billion estimate given last year by a corporate witness at a Senate hearing.

To this $1 billion a year must be added the $600 million it might cost to remove sulfur dioxide from the flue gases of the utilities, the $800 million it could cost to apply all the foreseeable controls to the automobile, and the $350 million cost of ensuring soot-free rubbish disposal. These would boost the price of cleaner air to about $2.75 billion a year. Even if a few other items are tossed in—such as a ban on the use of high-sulfur fuel for home heating, programs to reduce the oxides of nitrogen emitted by electric utilities and to deodorize diesel exhausts, more research, and a fivefold step-up in state and local enforcement activities—it is difficult to see how the total could greatly exceed $3 billion a year. And this estimate makes almost no allowance for offsetting savings to industry from the recovery of marketable products. Also, it assumes there will be no major cost-cutting breakthroughs in controlling sulfur dioxide or in cleaning up automobile exhaust– an assumption that could turn out to be unduly pessimistic. This program will not buy city air as pure as that which greeeted the Pilgrim Fathers at Plymouth Rock. But it would reduce total pollution by at least two-thirds, so that we would only occasionally be aware of it.

For $1.30 a month each, we could all breathe easier.

Keeping out the feds

Unfortunately, American industry does not have a record it can be proud of in the abatement of pollution. Many corporations are reluctant to clean up voluntarily so long as their competitors in areas with weak or nonexistent air-pollution enforcement are going scot free. And the idea of a uniform clampdown across the nation is anathema to most industrial spokesmen. Conditions vary from place to place, they argue. New York's air is high in dust and sulfur dioxide but low in automotive smog, while Los Angeles' situation was the opposite. Therefore, they say, it is wasteful to crack down uniformly on all pollutants in all cities. In rebuttal, however, some experts point out that it made sense for Los Angeles, which, had lower sulfur dioxide readings than most cities, to curb emissions of this damaging gas as well.

Impatient with industry's progress, some economists have been exploring ways to speed it up. A special committee under Gardner Ackley, chairman of the Council of Economic Advisers, has been considering the feasibility of imposing a scale of charges on companies that pollute the air. Tax concessions in the form of faster write-offs, and a doubling of investment credits when equipment for controlling pollution is installed, have also been suggested. But a system of charges would be incredibly complicated to administer because of the difficulty of identifying and metering aerial contamination. Tax concessions, which in effect are subsidies, are objectionable because they amount to bribing companies to be good citizens; the federal government might as well arrange a payment to every child who refrains from dropping candy wrappers in the street. The experience of Los Angeles, where no economic gimmicks were employed, shows what can be accomplished by local enforcement.

Washington's role, in fact, can be a limited one. It seems clear, from industry's dismal record, that national standards for emission are needed for every industrial process. The federal government is best equipped to carry on the research needed to establish these standards. Their actual enforcement, however, can best be done by state and local governments. The federal government has limited policing powers under the 1963 law, and can intervene in interstate air-pollution situations if localities move too slowly (about 40 million people live in urban zones that straddle state lines), or in an intrastate situation if the governor requests it. But the main federal contribution to enforcement should be money. In the past year, when matching grants from Washington have become available for the first time, they have brought a 47 percent increase in the budgets of state and local air-pollution control agencies. Federal money spent in this way is far more potent than direct subsidies would be, and much less of it will be needed.

AIR POLLUTION

by

Seymour Tilson

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IN OUR OPINION

The smoke is beginning to clear: Our capacity to lick air pollution makes for optimism about our social tools

It's another hazy day in New York as I write this; smoke is drifting out of the four smokestacks I can see from my window. It would be easy to be depressed about this further evidence of the unpleasant side of urban living. Yet I'm filled with optimism about our ability to solve this problem—to clean the air in our cities and around our factories. And from that optimism springs a conviction that the technical and social approaches we're developing to solve this problem can, in other forms, solve other problems of a complex, urbanized society.

My bright view on a hazy day comes from reading Seymour Tilson's piece about air pollution, which starts on the next page, and from surveying some of the legislative activity in this field, particularly the Clean Air Act of 1963. Tilson's article demonstrates that the technical problems, while complex, are entirely soluble. Sure, there is much we don't understand about the photochemistry of smog formation or about the weather patterns that cause New Yorkers to inhale some of Philadelphia's exhale. But technology already exists to stop most pollution at the source, and the remaining more refractory sources—automobile exhausts are one—should yield to the research and development efforts that are being mounted in response to the new concern about the quality of our urban air.

So we possess the technical instrumentalities for cleaning our air; do we have the social instrumentalities for ensuring that we will employ them? Certainly it takes more than self-interest. Air-cleaning equipment is usually just an added cost and can return its investment only in those rare cases where the reclaimed material has value in the marketplace. One needs then new ways to encourage the installation of air-cleaning equipment and to penalize those who pollute the air.

Here again I'm optimistic, for we seem to be finding and refining such mechanisms. For example, the Clean Air Act provides for federal grants to match local expenditures for controlling air pollution. This seems an excellent way to strengthen local efforts without involving the federal government unduly. However, because pollution is a regional concern, the federal contribution is scaled up when two or more municipalities or states join in a regional pollution-abatement campaign—a nice bit of social innovation.

Also in the wind is a mechanism to encourage private efforts at air cleaning by providing faster write-off for capital investment in air-cleaning equipment. That sort of tax relief is a proven mechanism for encouraging socially useful investment; it's worked for capital investment generally and it will, I'm sure, go a long way to make companies invest in air cleaning.

Of course, the companies are not completely unwilling, and that is another, more subtle social mechanism. In the last few decades there has been a growing appreciation, particularly on the part of larger companies, of corporate social responsibilities. If for no other reason than to avoid public pressure and governmental interference, company after company has done on its own what the public would have them do.

Finally there is research and development as a social mechanism. Yes, a social mechanism, for that is what it is.

First of all, by accelerating the rate of innovation, we in the technical community speed the rate at which new plant is built, the rate at which smokeless nuclear power plants supplant the fossil-fueled sort, for example. Indirectly, research means a wealthier society, a society that can more readily afford the luxury of not treating the air as a sewer.

Secondly, the engineer's approach to problems like air pollution causes at least some of the issues to be reduced to quantitative terms. We can be rational about the relative contributions of auto exhausts and factory smoke stacks to the pollution in any area when we can put numbers on those contributions. This rationality has the effect of putting a vector on all the other social mechanisms I discussed; it becomes possible to describe the problem in terms of the sources of pollution, the limits to atmospheric dilution, the limitations in measurement, etc. In place of an emotional inveighing against all but the purest air, one has a basis for putting private and public concerns onto a scale. A rough scale, for there is still much we don't understand about pollution, but a scale nonetheless.

You have to be a natural-born optimist to believe that these new and sometimes fragile mechanisms will alter the self-interested patterns that have built up across the centuries. But I am an optimist, and, . . . look, the sun's shining!—Dan Cooper

AIR POLLUTION

by Seymour Tilson
associate editor

The problem and approaches to solving it have come a long way since smoke chasing days. Recent infusions of public concern and federal money may make it a systems problem more challenging than reaching for the moon

IN BRIEF: *The idea that polluted urban air is dangerous, widespread, costly, unpleasant, and perhaps unnecessary in societies affluent enough to pollute it so extensively has gained wide currency in recent years. The U. S. Clean Air Act of 1963 is the most far-reaching embodiment of this attitude; it authorized the Department of Health, Education and Welfare to spend $95 million through 1967 for a wide variety of research and control measures. This beginning promises to stimulate badly needed developments in many areas of meteorology, atmospheric chemistry and photochemistry, fuel chemistry, sensing and monitoring devices, and control devices for automobiles and industrial pollution sources. A pivotal need for a more systems oriented approach to air-pollution control is the definitive set of air-quality criteria which the Act charged HEW with developing. Innumerable technical and social difficulties stand in the way of establishing these, and of translating them into effective community control measures. It seems clear that a much larger commitment to safe, clean air will be needed to really do the job.—S. T.*

■ Researchers at General Motors are studying smog. They produce it artificially, in a chamber, by diluting automobile exhausts with air and irradiating the mixture with simulated solar ultraviolet. And they use a 5-stage filtering system to purify outside air to the levels required by their experiments. Nobody appreciates the irony of this more than those who are professionally concerned with the larger problems posed by polluted air.

Polluted air—to which auto exhausts are one contributor—is bad, they say. It's bad for people, plants, and materials. It's bad for aesthetic reasons and economic ones. It consumes ingenuity in sophisticated activities such as smog-chamber experiments, clean-room technology, and corrosion control. It poses unsolved risks whenever your plane is delayed or makes a blind landing made necessary by fog, which is up to twice as prevalent in polluted urban atmospheres as it is in clean air. Pollutants have changed the weather over urban areas in other ways also, mostly unpleasant and perhaps unhealthy. And some say the accumulation in the atmosphere of even such a non-pollutant as ordinary carbon dioxide, contributed by man's burning of fossil fuels, may turn out to have unwelcome effects on the climate, geology, and ecologic balance of the entire planet before the century ends.

Most immediate concern centers however on the health hazards of polluted air, and here the statistical and epidemiological portents are suitably harrowing. Over the long run, breathing polluted air may make us more susceptible to lung cancer, emphysema, bronchitis, and asthma—not to mention acute nonspecific upper respiratory diseases as well as good old-fashioned pneumonia. Over the short run, when pollutant concentrations become high enough, those with cardio-respiratory insufficiency who also happen to be very old, or even very young, are likely to stop breathing. The list of horrors could be extended in rather more exotic directions, if men were mice and responded to certain pollutants in the way that laboratory creatures do.

Documenting these health hazards—especially the ones which result from chronic long-term exposure to the characteristically exceedingly minute concentrations of pollutants—is a complex, tedious task. It's the subject of most current research in the air-pollution field. In spite of difficulties documentation is growing rapidly, but not as rapidly as the growth of pollution itself. This imbalance promises to be redressed, however, as rising public concern makes itself felt in many urbanized parts of the world. This concern crystallized in the U.S. two years ago when Congress passed a far-reaching Clean Air Act which authorized the Department of Health, Education, and Welfare to spend $95 million over the next few years on a broad spectrum of training, R&D, and control activities. The Act specifically focused technical attention on three major interrelated problems—motor vehicle exhausts, sulfur-containing fuels, and the development of air quality criteria.

Pollution sources and the research door

Motor vehicle exhausts are the chief contributor to the air pollution syndrome that once used to be known to the rest of the world, mostly through comedians' jokes, as Los Angeles smog. It involves a variety of unpleasant pollution effects which center around the photochemistry of dilute mixtures of hydro-



Fig. 1. European moth species named Biston betularia *adapted to pollution, in the Birmingham industrial district of England, by changing from dominantly light colored to dominantly dark in less than 100 years. Dark form, known appropriately as* carbonaria, *is safer from preying birds when it rests on soot-blackened trees; thus the gene for dark coloring has become more abundant in the population. Man's problems with polluted air are not so simple, nor so easily solved.*

Fig. 2. Limestone outside facing of the National Gallery in London (below) shows typical results of accelerated weathering caused by high concentration of SO_2 in urban air. SO_2 is oxidized and hydrated to sulfuric acid—H_2SO_4—which attacks limestone ($CaCO_3$) and converts it into the hydrous mineral gypsum ($CaSO_4 \cdot 2H_2O$). This reaction helps break up original surface and gypsum's greater solubility in rain water finishes the destructive job. The same difficulties, except for the last one, are encountered indoors, as in the Arena Chapel in Padua, Italy, where "Mission of Gabriel" fresco by Giotto shows tan powdery efflorescence of gypsum crystals formed by H_2SO_4 attack on lime in the underlying plaster.





carbons and oxides of nitrogen in the air. Automobile exhausts are a prime contributor of both of these raw materials, but large power plants add a fair share of nitric oxide, and open burning of wastes as well as imperfectly designed or operated incinerators add other organic materials to the picture. The problems caused by sulfurous fuels were formerly known as London smog, but they too are more widespread than the name suggests. This is an ash-soot-sulfur dioxide-sulfate complex to which industrial, electric-power generating, and domestic heating exhaust streams are the chief contributors.

Hydrocarbon compounds that may number into the thousands and that include carcinogenic polycyclic members of the family—such as 3-4 benz-pyrene—nitrogen oxides, sulfur dioxide, sulfates, soot (mostly carbon), and fly ash are not the only things present in re-

markable tonnages in the air over cities large and small. Add to these, uncomfortably high amounts of carbon monoxide from auto exhausts, and chlorides, fluorides, and ammonia from diverse sources and you begin to get the picture. Finally toss into the pot formaldehyde and other aldehydes, acrolein, and an array of intensely oxidizing substances including deadly ozone—which are just a few of the possible products of photochemical and other reactions among various of the contaminants and the ordinary components of air—and it becomes evident that the two problem areas that I described briefly above do only limited justice to the magnitude of the problems presented by polluted urban air.

But it is the third specific dictum of the Clean Air Act—which directs the Department of Health, Education, and Welfare, through the Public Health Service, to set up nationwide air quality criteria—that may really open the door to research opportunity.

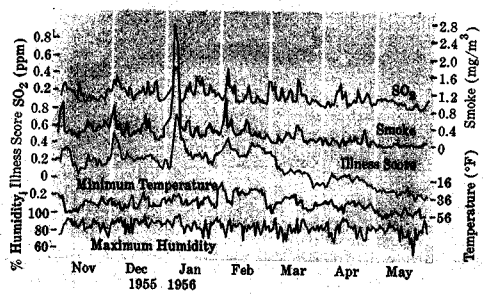


Fig. 3. In trying to separate effects of air pollution from those of climate on the health of patients with chronic bronchitis, British researchers found—as shown by graphs—that air pollution is the most important single factor in exacerbating the victims' conditions.

More to quality control than meets the eye

At first glance the problem of setting such concentration criteria for various contaminants in air seems simple. And so does using them for control purposes. Once the limit—stated as a concentration that ought not to be exceeded when either averaged or integrated over a certain length of time—is set, a series of control steps seem to follow logically.

First, inventory the volume of air available—again either averaged or integrated over a meaningful time interval—for diluting pollutants over an urban region or throughout a regional airshed. Then inventory the sources of pollutants in the region, as well as the sources of those pollutants coming from upwind regions in the airshed, in terms of kind and amount. At this stage don't overlook the possibility—a likely one—that photochemical and ordinary reactions in both local and transported pollution clouds may make more harmful products of initially innocuous substances, and vice versa. Next determine limits for the emission of each pollutant from each source, under the worst possible dispersal conditions, so that the time-averaged or integrated total of their individual contributions to the ambient air remains below allowable limits. And of course develop and enforce the use of whatever changes in processes or equipment may be necessary to keep emissions from each source within indicated limits. Finally work out techniques for monitoring air in the region for conformance to the ambient air standards—and maybe even also techniques for spotting sources of trouble when monitoring shows that ambient standards are being violated.

Getting to the moon may be easier. Little more than a moment's reflection is required to appreciate some of the difficulties that develop at each stage of this more or less "ideal" solution to modern regional air pollution problems. Political and economic factors are not the least of them.

Each step also presents major problems of meteorological understanding. Not so much on a scale as small as what happens to the pollution plume from a single exhaust stack, where much is known, but on a scale that permits fuller evaluation and prediction of the wind-stagnation and thermal-inversion conditions that can inhibit the ventilation of any region. Each step in control also poses largely unsolved problems and unprobed opportunities in chemical and meteorological sensing and monitoring, in atmospheric chemistry, in telemetry, and in data handling.

Controlling air quality is, in short, a systems problem of challenging magnitude in which social, political, economic, and technical factors mingle inextricably.

Controls need not—should not—wait

In many ways the situation with regard to engineering of devices and hardware, and to improving process variables, is in or can easily be put in much the best shape. While there's always room for technical improvements and lowered costs, there has long existed a formidable arsenal of scrubbers, filters, electrostatic precipitators, centrifuges, and more recently sonic agglomerators that can take most particulate matter out of industrial exhaust-gas streams. And burning waste dumps and faulty incinerators are largely political problems, not technical ones. Even the more recalcitrant problems of gaseous pollutants like SO_2, nitrogen oxides, and hydrocarbons promise to yield to research efforts that are now being prodded into higher gear.

If these efforts fail to produce results, there are always alternatives available—such as

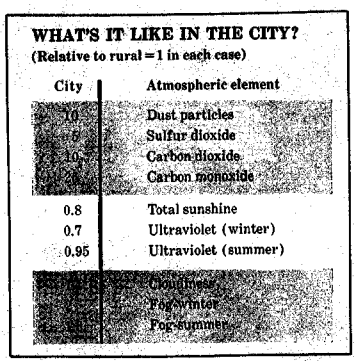


Fig. 4. The few substances shown in this table as being overly abundant in city air do not nearly exhaust the list. Absent are hydrocarbons by the hundreds—some of them potent carcinogens in laboratory animals—and the highly toxic gas nitrogen dioxide. Since these two react with each other under the stimulus of solar ultraviolet radiation—to produce photochemical smog with its characteristic haze, eye irritation, and damage to sensitive plants—it is perhaps fortunate that pollutants help cut down on solar ultraviolet reaching street levels in the city. Of course some air bacteria that might be killed by such uv are not, but one must be grateful for small favors when living in the urbs.

atomic powered instead of fossil-fuel-powered generating stations, or, farther in the future perhaps, cars operated by batteries or fuel-cells instead of internal combustion engines, or electrified mass transportation. The art of pollution-control is not so much primitive in technical means as deficient in social ones. Whether anybody *has to do* anything about the pollutants that their products or processes emit—and how well they must do it—depends in part on progress made farther back along the "ideal" pollution control chain. Here the first step—setting air-quality criteria—is the most crucial. It is also the most complex.

Though all the needed data are not in, most people would agree, I think, with Vernon MacKenzie, head of PHS' Division of Air Pollution, when he says that "we must . . . get on with the job of developing air-quality criteria and standards against a background of technical and scientific knowledge which is not now and probably never will be perfect." Engineers can recognize the validity of this approach; as professionals they live with it.

There's a worm or two in the apple

Nevertheless, in view of large gaps in existing knowledge about the chemistry of normal and polluted atmospheres, there are understandable differences in outlook between industrial and public health people over which substances'—and which industrys'—emissions should be controlled. Many industrial people, including the most enlightened ones, remain somewhat loathe to pursue very much control-orientated research in the absence of definitive legal standards based on equally definitive criteria. Indeed, the automobile industry claims it wants such criteria precisely so it will know where it stands over the longer haul. It points to its experiences of recent years in California, the State that has led the country—perhaps the world as well—in pollution-control activities. California has more cars and a more poorly ventilated climate, in the Los Angeles area anyway, than any State in the Union. It also is richly endowed with sunshine. So it's not surprising that it leads the country in its concern about the auto component of its air pollution problem.

Auto exhausts emit two main contaminants: hydrocarbons and nitrogen oxides. The hydrocarbons come mostly from fuel that is not completely oxidized to carbon dioxide and water during engine operating cycles. The hydrocarbons are diverse in kind—compounds originally in the fuel as well as new compounds that are formed during the high-temperature combustion process. Nobody has identified all of the compounds, but there were about 200 of them at last count. Nitrogen oxides, particularly nitric oxide (NO) with lesser amounts of NO_2, result from the high-temperature dissociation of molecular nitrogen and oxygen from the intake air used to burn the fuel. The liberated atomic nitrogen and oxygen then combine to yield the oxides. These reactions are reversible at high temperatures, but they are prevented from reversing—the two oxides are literally "frozen in"—as combustion temperatures drop rapidly from peak values during expansion of the gases in both auto engine cylinders and power-station exhaust stacks.

Of these two groups of contaminants California has so far established emission standards only for the hydrocarbons, chiefly because it was originally thought that the nitrogen oxides in auto (and other) exhausts would be far more difficult, and maybe unwise to eliminate. It was also felt originally that reducing the concentration of either one of the starting reactants would help reduce the build-up of troublesome final photochemical reaction products in the air.

Over the years, as California re-inventoried the dimensions of its pollution problems in finer detail, changes were made in automobile and other emission limits. The average uncontrolled automobile exhaust emits about 700 ppm hydrocarbons. Current California standards, set by the State Department of Health and approved by the legislature, limit this to 275 ppm and include an additional restriction

on carbon monoxide of 1.5% (the average exhaust emits perhaps 3%), for reason of its own toxicity and its rising concentration in Los Angeles air, not because it contributes to photochemical smog. By 1970 the state will reduce these limits still further, to 180 ppm and 1% respectively. But even now, for reasons that we will discuss shortly, the Los Angeles County Air Pollution Control District—the trail-blazing agency in photochemical pollution control—would like to see the hydrocarbon limit reduced to below 100 ppm.

Such differences in opinion on the part of different control agencies is of course not frivolous in intent. It reflects uncertainty about precisely what should be controlled, and by how much. But at each such turn in the road to inevitable controls, a good deal of prior research on control techniques gets bypassed. And at the spectre of a patchwork of differing, locally determined control limits a national industry, like the auto industry in particular, gets understandably upset. To more clearly understand the basis for some of these difficulties we need a closer look at the nature of the smog which now afflicts all urban regions that are highly populated with automobile traffic.

Sun-stewed auto exhaust→smog

Photochemical smog's chief immediate and obvious symptoms are eye irritation, damage to sensitive plants (as far as 100 miles from urban centers), accelerated cracking of rubber, and decreased visibility due to the formation of a haze of solid and liquid particles which are collectively described as aerosols. The first three symptoms are caused by the products of a complex of reactions that start, as we said, with hydrocarbons and oxides of nitrogen. In the course of the reactions some highly reactive intermediates and ozone are formed. These help polymerize the organic compounds in the mixture, according to Prof. A. J. Haagen-Smit of CalTech who pioneered work in this field, and lead to the formation of additional, non-volatile, oxidation and polymerization products which add to haze and eye irritants from other sources of pollution.

This kind of pollution is characterized by the same extreme dilution of reactive constituents and intermediate and final reaction products that characterize all air pollution. An ozone concentration of 0.3 ppm for instance is 10 times its normal background concentrations at ground levels. Haagen-Smit points out that this extreme dilution is one reason why it takes many years to unravel even relatively simple atmospheric reactions such as the photodecomposition of acetone. In ordinary laboratory work, "slow" and "fast" reactions are characterized against a backdrop of reactant concentrations that average about 10%. But in atmospheric reactions concentrations are only on the order of one-millionth as much. Under these conditions reactions which would proceed in thousandths of a second at ordinary laboratory concentrations take an hour in the atmosphere.



Fig. 5. High wintertime concentrations of SO_2 in air over (British) cities and surrounding regions come from burning of sulfur-bearing coals and add to ordinary cardio-respiratory hazards of winter weather, especially for the elderly. The map makes clear that pollution is not just a downtown problem; nor is the SO_2 problem exclusively a British one. Abatement efforts center on switching to low-sulfur fuels and eliminating SO_2 from flue gases.

This is important: It is essentially what permits the highly potent ozone to survive attack by reducing agents such as SO_2 in the atmospheric mixture. Ozone thus can go on to participate in reactions at several stages in the photochemical chain. The immense slowdown in reaction rates also gives ozone and various, highly reactive, free radicals that are formed a far better chance to survive long enough to play significant roles, not only in the over-all reactions but in some of the observed symptoms as well.

The still far from completely elucidated chain of daily reactions leading to smog is set in motion by the photochemical dissociation of nitrogen dioxide. It is a yellow-brown gas that most effectively absorbs pho-

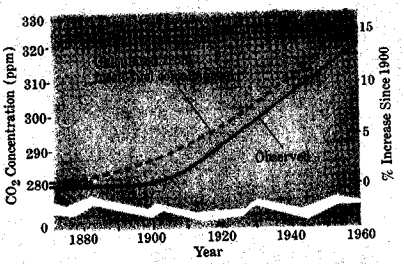


Fig. 6. Accelerating use of fossil fuels may result in 50% rise in amount of CO_2 in the air by year 2000. If not absorbed by sea and plants this could raise temperatures several degrees by enhanced "greenhouse" effect, enough perhaps to melt glaciers and flood coastal cities.

THE SUDDEN PEAKING OF POLLUTANTS

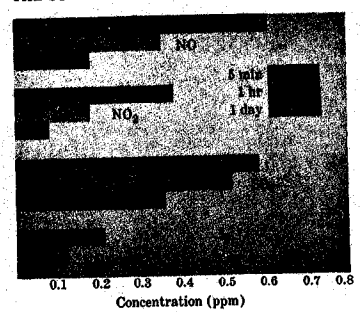


Fig. 7. Importance of continuous monitoring of pollutants—now being done by the Public Health Service's automated equipment in only nine cities—is emphasized by frequently observed higher short-time peaks such as these, which reveal inadequacy of using lower long-period averages in many medical studies.

tons in the blue and near ultraviolet. This dissociation produces nitric oxide and atomic oxygen $NO_2 + h\nu \longrightarrow NO + O$. The atomic oxygen thus formed combines with atmospheric oxygen molecules to form ozone (O_3).

Other photochemical reactions that contribute to the stew form excited oxygen molecules. These and ozone, perhaps aided by atomic O present in some dynamic equilibrium concentration, attack organic materials, probably by removing hydrogen atoms from the hydrocarbons. This oxidizing assault forms reactive intermediate substances such as alkyl and acyl radicals. These radicals can unite with oxygen to form still more reactive peroxyl radicals. And these, in turn, can react with oxygen to form more ozone, with NO to form larger quantities of chain-initiating NO_2, and with NO_2 to produce short-lived but plant damaging peracylnitrates (usually abbreviated to PAN) and an abundance of more stable oxidation products such as eye-irritating formaldehyde.

Bewildered? Let's go over it again with reference to Fig. 8. The pivotal group of oxidizing substances consists of atomic oxygen (from dissociation of NO_2), excited molecular oxygen (from solar irradiation of the atmosphere's abundant molecular oxygen), peroxyl radicals (from the action of other oxidants on hydrocarbons), and ozone (formed as a by-product in several of the photochemical reactions). During the daylight hours all of the oxidants contrive to react with the original starting materials—hydrocarbons (particularly unsaturated, olefinic ones and some aromatics) and nitrogen oxides—as well as with their reaction products. Thus at any particular time, the air is filled (relatively speaking—remember the troublesome concentrations are down at *or below* the part per million level) with a very complex mixture of intermediate oxidation and reaction products.

Unquiet controversy in California

A vast amount of experimental and theoretical photochemistry remains to be done at the low concentrations and low temperatures which characterize polluted atmospheres before we completely understand these processes. In the laboratory (Fig. 9, 10) symptoms of photochemical smog can be produced by irradiating with mock sunlight suitably low concentrations of hydrocarbons in the presence of oxides of nitrogen. But considerable controversy exists among both atmospheric chemists and simulators of smog about the precise course and time constants of each of the innumerable reactions occurring in polluted atmospheres. Not all such disputes are academic; indeed one such controversy is particularly instructive. It illustrates in a simple way the difficulty of understanding what our pollution problems really are and casts a long shadow over approaches to controlling photochemical pollution.

Although nitrogen oxides and hydrocarbons are the essential starting ingredients, only hydrocarbons are now being controlled in California, as was mentioned. This also is the control approach called for in a recent bill proposed to Congress and aimed specifically at the motor vehicle pollution problem. It should work; according to the tenets of the familiar chemical law of mass action this should inhibit formation of even the minute concentrations of final photochemical reaction products. Indeed, the consensus among pollution experts in Washington, Detroit and California is that by reducing hydrocarbons enough now,

most of the ill effects associated with high oxidant levels that characterize photochemical smog can be eliminated, without any need for controls on nitrogen oxides for the time being. Others, Haagen-Smit among them, want both ingredients controlled. Still others feel most uneasy about nitrogen oxides. They feel the consensus on the hydrocarbon control approach may be too naive, in that it equates the eye irritation symptoms exclusively with the end products of irradiation. These products reach peak concentrations in experimental chambers after some 4½ hours of irradiation. But Walter Hamming and colleagues of the Los Angeles County Air Pollution Control District have shown that there is an earlier peak of eye irritation observed in many irradiation chamber studies. It is equal in severity to the later one but it occurs only about 1½ hours after irradiation has begun, and not only in simulation studies but in downtown Los Angeles after sunrise as well. This is long before oxidants such as ozone or PAN have reached any appreciable concentration. Indeed, this early irritation peak seems to coincide most closely with maximum NO_2. Thus, Hamming and his coworkers feel that controlling nitrogen oxide emissions equals or exceeds hydrocarbon control in importance in alleviating Los Angeles' most obvious problem.

There's another interesting angle to all this. Hamming points out that the severity of eye irritation produced seems to relate to the intensity of sunlight involved. It turns out that for conditions in Los Angeles region partial control of hydrocarbons alone could possibly lead to more severe and extended periods of eye irritation. Since the early peaking NO_2 wouldn't have enough hydrocarbons available to be used up in zipping on down the photochemical reaction pike it might hang around longer and reach higher daily averages. In any case, Hamming feels that reducing nitric oxide emissions in any degree can only reduce the severity of eye irritations whereas hydrocarbons would have to be limited much more drastically than is currently envisioned to achieve equally effective relief.

This tempest over tearing eyes in Los Angeles may have deadlier ramifications.

The need for controlling NO and NO_2

Obviously, differences in opinion over needed control measures depend on the symptoms that concern one. The control waters have all too often been muddied by imprecise definitions here. Precise definitions are needed, and soon, before going too far with control attempts limited to single, more easily controlled components of complex reaction mixtures. NO_2 itself for instance is acutely toxic at about 100 ppm. The limiting concentration that industrial hygienists allow for it and other oxides of nitrogen in workroom air is 5

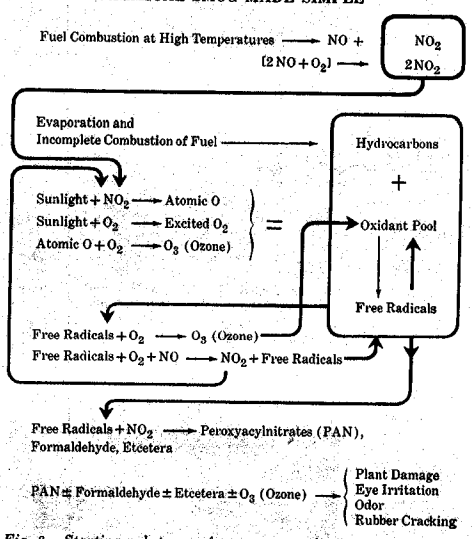


Fig. 8. Starting substances for smog are nitrogen oxides and hydrocarbons. The critical first step leading to group of oxidizing substances is photodissociation of NO_2; this yields atomic O that joins molecular oxygen to produce ozone. Oxidants attack hydrocarbons and produce reactive free radicals of several kinds which are also capable of attacking hydrocarbons and participating in other reactions as indicated. As discussed in story, eye irritation may relate more to NO_2 content than to final reaction products shown.

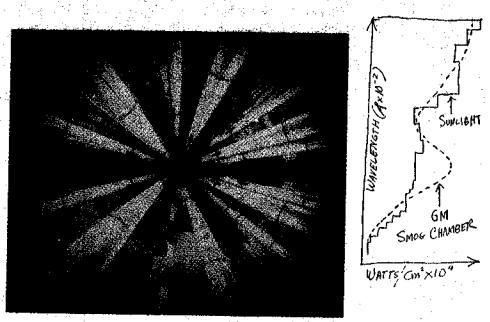


Fig. 9. Smog simulation chamber used by General Motors uses banks of fluorescent lamps enclosed within chamber to simulate sunlight. Spectral matching curves are sketched in the margin. Irradiation is carried out on dilute mixtures of hydrocarbons and nitrogen oxides.

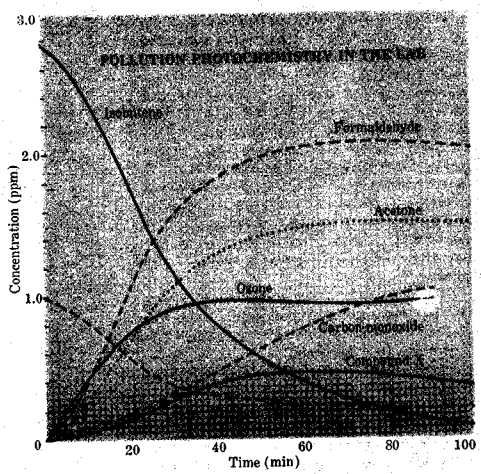


Fig. 10. Stanford Research irradiation chamber study of a few years back illustrates diversity and varying concentrations of substances produced, starting with isobutene and nitrogen dioxide. Compound X has since been tentatively identified by most workers as peroxyacyl nitrate.

ppm; this limit is for 5-day-a-week, 8-hr-a-day exposures of healthy adult workers. A value of twice this amount or 10 ppm observed in a single measurement in ambient air in Los Angeles would result in a so-called "third alert" in which all-out community protection measures would be authorized. Most of the time the LA concentration of NO and NO_2—which are usually measured together since there appears to be no control purpose to be served in distinguishing between them in view of the rapid conversion of NO into NO_2—stays below about 1 ppm. One thing that may help keep NO and NO_2 well below more potentially dangerous levels most of the time is that during the daylight hours, they are continually used up in maintaining the series of equilibrium reactions with ultraviolet light and hydrocarbons. But some knowledgeable scientists, such as Philip Leighton of Stanford University and Albert Bush of UCLA, have warned that reducing hydrocarbons alone—especially to drastically low levels such as 100 ppm or less—may in fact raise the total of nitrogen oxides in the air over the long term, eventually perhaps to more dangerous levels. Hamming and most others discount this possibility, however.

Such fundamental uncertainties as these must have been what Dr. P. J. Lawther (then of the British Medical Research Council Group on air pollution) had in mind, several years ago, when he said regarding British urban air pollution: "We have no more right to expect an easy solution than to overlook a simple answer. The field is bedevilled by paradox, not the least striking of which is the persistence with which we apply exquisitely fine techniques to crude problems and at the same time expect delicate mechanisms to yield to the hammer blows of our clumsier methods."

The British are plagued by pollution problems characterized more by SO_2 and its involved atmospheric permutations to SO_3 and sulfuric acid than by the automotive kind of smog. But this is changing, of course, as autos and traffic congestion increase, just as the SO_2-complex never was exclusively a British problem.

Sulfur dioxide in the air comes mostly from combustion of sulfur-containing fuels—coal and low-grade or residual fuel oils are the chief offenders. Natural gas and light petroleum fractions like kerosenes and gasolines are relatively low in sulfur or can be made so with little difficulty. Some SO_2 also comes from the smelting of sulfide ores. The ash constituents invariably present in the air help to catalytically oxidize SO_2 to SO_3, and hydration of SO_3 yields the sulfuric acid which is responsible for the blue color typical of SO_2-laden exhaust plumes.

The more difficult and critical transformation of SO_2 to SO_3 is probably accomplished photochemically by near ultraviolet radiation; this mechanism may be most effective in the presence of particles of manganese and iron salts or oxides, under the moisture-rich conditions available in most stack gases and during humid weather conditions more generally. No doubt the strongly oxidizing atmosphere created in typical photochemical (Los Angeles) smog also contributes significantly to this otherwise slow oxidation step. Both kinds of smog are invariably present to greater or lesser degree in urban atmospheres and their deleterious effects, as to some extent their photochemical histories, are intricately entangled, but distinguishable.

The U.S. Clean Air Act specifically recognized the sulfur problem too, and it directed Health, Education and Welfare to conduct a major R&D effort aimed at developing cheaper and better techniques for removing sulfur from the offending fuels. Much additional work is being done on an alternative potential solution—removing the sulfur compounds from exhaust gases before emitting them to the atmosphere. Several lines of development look promising here. Some involve adsorption of SO_2 on activated carbon char or reacting it with alkalized alumina. Others approach the problem as the atmosphere itself does, by catalytically oxidizing the SO_2 to SO_3 and con-

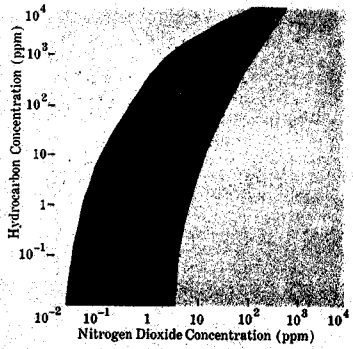


Fig. 11. Pioneering work by A. J. Haagen-Smit of CalTech established field of hydrocarbon and nitrogen dioxide concentrations—shown by tint—within which ozone is produced. Ozone concentrations are themselves quite low, < 1 ppm, but enough to be nasty in several ways.

verting the latter to sulfuric acid, which is apparently recoverable in amounts sufficient to at least partly defray the costs.

It's an ill wind that blows pollution your way

When you think about the huge dimensions of the ocean of air that lies above us, it's hard to believe that the activities of urban man, which are carried on over just about 1% of the total land surface, can create vast, slowly drifting, Sargasso-like seas of pollution. In fact, the major portion of man's airborne effluvia is carried away by turbulent winds and vertical updrafts and diluted to undetectable concentrations throughout the entire 10-mile thickness of the lower atmosphere. But a considerable proportion often cannot be dispersed this way.

With surprising frequency—an average of perhaps one-third of the time over much of the U.S. for example—there is an effective limit to the upward dispersion of contaminants, at altitudes of 500 feet *or less*.

This upper limit to dispersion is created either locally or over large regions by a thermal inversion, a condition you're probably familiar with, in which the normal decrease of air temperature with height above the ground which heats it is reversed. At some elevation above the ground—known as the inversion base—air temperatures begin to rise instead of continuing to drop (see margin). This anomalous temperature gradient persists upward throughout the inversion layer to an altitude which is determined by large-scale weather patterns that create the inversion in the first place. The base of the inversion layer acts as the effective lid.

Imagine a bold parcel of polluted air—such as a hot, high-velocity jet of stack gases—one that has the temerity to try to rise into the inversion layer itself. Although it cools markedly on the way up, on penetrating the inversion layer it finds itself much cooler and more dense than the surrounding air, in which the temperature is going up not down. Consequently, it quickly sinks back toward the inversion base and has little if any time in which to disperse its pollutants to higher altitudes. It and its burden of pollution are confined to the appropriately named "mixing layer" that lies below the inversion base and extends to the ground.

The average prevailing thickness or depth of this mixing layer varies with time and place—it reaches a mile or two at times—but it is always far less than the full thickness of the lower atmosphere. Yet, in general these mixing depths would suffice to dilute pollutant concentrations, if the winds that handle horizontal circulation blew hard enough and with enough turbulence for enough of the time. At some seasons of the year and at many places they don't. Still worse, winds that are too weak can compound pollution troubles.

Helmut Landsberg, head of the climatology section of the U.S. Weather Bureau, has shown this for the northeastern chain of cities, extending from Richmond, Virginia, to Portland, Maine. When weak winds involving 100 miles or less of net air transport a day blow the right way—in this case mostly from the south or southwest (see margin)—the pollutants emitted in any one city either stay in the local area or are wafted gently toward the next city in the chain, perhaps adding to its pollution burden. Such weather conditions are far from rare for at least parts of the chain.

This doesn't mean that recent comments by New York City's Mayor Wagner, in which he described the city as lying at the end of a "3000-mile long sewer" of air pollution, are technically correct (as pollution control people in California are at some pains to point out). It does mean however that *regional* airsheds exist. These, at some seasons and some places, are in many ways analogous to watersheds. In both cases pollution can increase in the downstream direction. But air, unlike water, cannot be cleaned up for general use. Pollution in it can only be controlled at the source. In order to do this we're going to need more and better ways to monitor and trace the movements of pollution clouds that migrate downwind, from the central cities into suburbs and the surrounding countryside. Characteristic patterns of pollution-caused damage to plants offers some grim help here.

In the U. S. some data vital for these and other purposes are starting to come in from a PHS National Air Sampling Network of more than 200 stations—urban and rural—



Fig. 12. Los Angeles County pollution control lab studies automotive exhaust problem in a novel way. Cars are driven in traffic and engine operating variables are tape recorded. Tapes you see here are then used to program engine dynamometer in test and simulation studies.

which have been operated since 1953 on an intermittently scheduled basis that has yielded some 4500 samples a year. A little closer approach to the kind of assault that's needed has been provided by a recently activated PHS system of highly automated, computer integrated monitoring stations which provide continuous 24-hr-a-day, every day, measurements of CO, SO_2, NO, NO_2, O_3, total oxidants, and total hydrocarbons—at *one* location in each of nine cities.

Society, or somebody, must call the shots

Technical needs in pollution research and control activities are in many ways obvious. They can and will be met as soon as sufficient resources are devoted to them. The problems of setting quality criteria for air, and seeing to it that they are enforced, are much more difficult. Solving them requires not only scientific, technical, and medical data and decisions but social and moral ones as well. There's nothing new about this. Society requires many such decisions.

In the field of nuclear energy for example, the Federal Radiation Council was established to assess social benefits versus risks in face of the current overwhelming scientific judgement that there is no threshold or limiting value below which adverse biological effects do not occur—there is no "safe" level of exposure to radioactivity other than zero. There are comparable problems in the air-pollution field, especially in the case of polycyclic hydrocarbons like 3-4 benz-pyrene which are potent carcinogenic agents in experimental animals. Vernon MacKenzie of PHS notes that polycyclic hydrocarbons in air appear to come mostly from coal combustion, whether in furnaces or engines, from burning waste materials, and from some industrial processes. They cannot be practically eliminated from the air unless the total economic and technical fabric of society is altered. Yet there is no safe exposure other than zero to chemicals such as these.

What should the attitude of an agency like the Public Health Service be in setting allowable limits for substances such as these, charged as it is with a vested interest and proper bias on the side of public health and safety? Should PHS do the job of setting criteria, or should it be delegated instead to a cabinet-level body like the Federal Radiation Council, or to some other august body like the National Academy of Sciences, which can juggle benefits versus risks through less safety-tinted glasses?

As one who has breathed for some time and hopes to continue doing so for a long time to come, I hope that someone with a more health-biased viewpoint will do the job, as it is now in the process of doing it. Soon.

A cosmic joker in the deck?

Even complete success in controlling pollution of the kinds we have been discussing may prove to be a Pyrrhic victory in the not very long distant end. There is inconclusive evidence that the atmosphere's total content of carbon dioxide has increased by some 13% due to man's increasingly industrial way of life since the 19th century. CO_2 is not usually thought of as a pollutant since it is not harmful. Indeed it and water are the ideal non-toxic end products of all fuel combustion and metabolic processes. The observed increase agrees strikingly well with estimates of the CO_2 increase that could be expected since the 19th century on the basis of sharp rises in fossil fuel use. Projecting such estimates into the future, it appears that CO_2 in the atmosphere may be 50% higher by the year 2000 than in pre-industrial days, assuming that atomic power doesn't replace power from fossil fuels to any significant degree.

This increase in itself shouldn't bother anybody's breathing or other activities, but it might have larger-scale effects on the climate of the entire earth. CO_2 is an important absorber of the longer wave infrared energy that the earth's surface reradiates as it cools through the nights and the seasons. If all of the extra CO_2 remains in the atmosphere, instead of being taken up by plants or dissolved in sea water, and nobody knows exactly how much is removable in these ways, it seems likely that the earth's average temperature could go up several degrees. Some provocative though largely speculative estimates suggest that this increase might be enough to melt all or most of the glacial ice on earth. In turn this would raise sea level everywhere by a few hundred feet—enough to put most of smoggy Manhattan and the Los Angeles Basin under water, for example. Which is indeed one long-range solution to the problem of polluted urban air.

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IEEE spectrum

Airborne asphyxia - an international problem

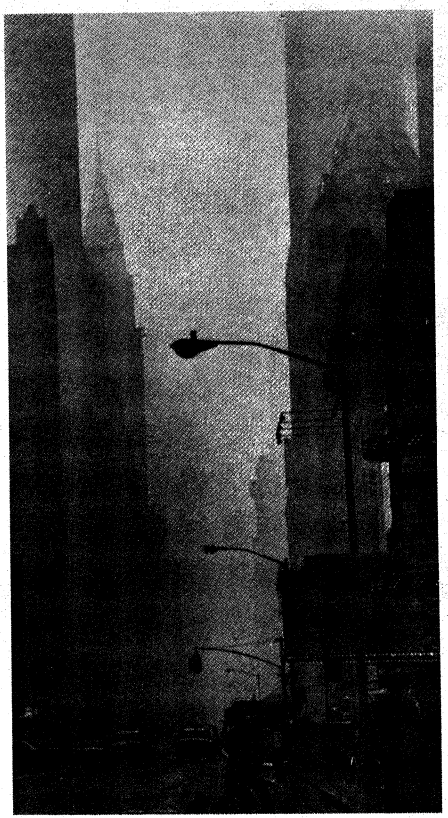
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U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service

Airborne asphyxia—an international problem

Air pollution is no longer a minor inconvenience; it is a tangible, frightening, and intolerable situation that affects virtually every major industrial city in the United States and Europe

Gordon D. Friedlander *Staff Writer*



Until quite recently, the smog in Los Angeles was the butt of every radio and television comedian. It was subjected to ridicule as the world's worst example of an out-of-control condition that was apparently without remedy.

But today the joke has gone sour. A recent—and disturbing—survey made by a special committee under the aegis of the New York City Council reveals that the type of air pollution—a dangerously high level of sulfur dioxide—in this huge metropolis, and particularly in the Borough of Manhattan, may be more hazardous to human life and health than that of Los Angeles.

It is estimated that the air is so foul over the island of Manhattan (see Fig. 1) that a monthly sootfall of more than 60 tons per square mile is commonplace during the winter. The City Council report alleges that most of the pollutants are belched out of the chimneys of industrial plants, electric utilities (see Figs. 2 and 3), and some 14 000 apartment house incinerators. Additional noxious fumes are spewed into the air from the tailpipes of thousands of motor vehicles that clog almost every square inch of city streets.

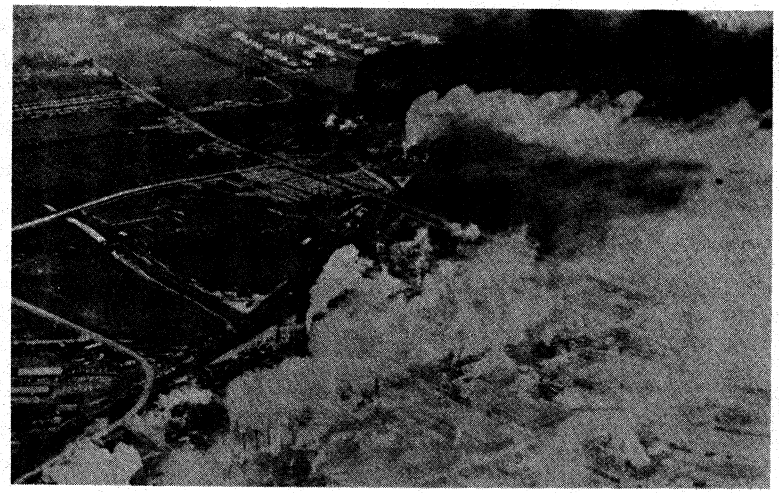
The commission's report asserts that breathing city air for one day would have the same effect on human lungs as inhaling two packs of cigarettes within the same time interval. So, as one wag put it: if one happens to be a habitual smoker in the two-pack-a-day category, and cannot shake the habit, it may be more healthful for one to give up breathing!

The sad story of air pollution, however, does not end with New York; Houston, Atlanta, Louisville, Chicago, St. Louis, Birmingham, and a host of other American and foreign cities are suffering the same atmospheric miseries (Fig. 4) in varying degrees and from various sources. In Germany, England, Belgium, France, and Luxembourg, where coal is the principal industrial fuel, the air pollution and smog problem is equally intense. Cities such as Essen, Dusseldorf, and other industrial centers in the Ruhr Valley are plagued by air

Fig. 1. "Darkness at high noon"—a view of 42nd Street in New York City under a blanket of heavy smog caused by a temperature inversion, on October 20, 1963..



Fig. 2 (left). Photo showing stack operation of industrial plant before the installation of air pollution control equipment. (Right) Same stack after installation of control equipment. Fig. 3 (below). Aerial view of St. Louis showing a several-square-mile area of the city under a pall of industrial air pollution.



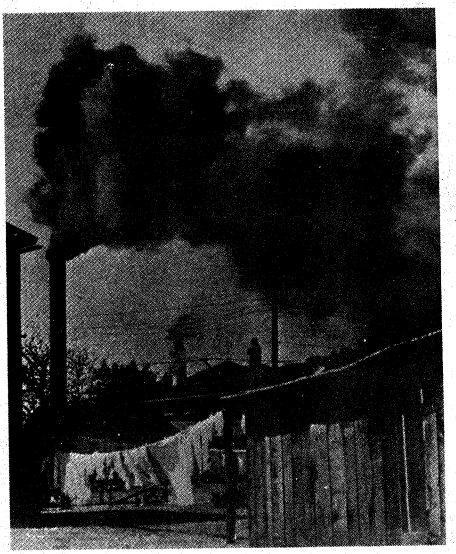


Fig. 4. Smoke belching from an electric utility company stack blankets an entire area.

contamination. In addition to London, the industrial midland cities of Birmingham, Manchester, Sheffield, and Liverpool suffer from the same malady. With the advent of the megalopolis and vast urban industrial sprawls, air pollution is no longer the exclusive property of any one country—it is rapidly becoming a worldwide menace. Later in this article we will discuss in detail the individual air pollution problems of five American cities and what efforts—if any—are being made to remedy the conditions.

The Fig. 5 bar graph dramatically indicates the major air contaminants and quantities emitted per year in the United States, while Fig. 6 shows the amount of suspended dusts and other particulates in relation to urban population classifications. Note that there is a steady rise in the number of particulates with every increase in population classification.

Mining, meteorology, and medicine

An entire session at the recent American Power Conference in Chicago clearly indicated that air pollution has become a prime interdisciplinary concern to both the electric utilities and industry. The participants in the panel discussion[1] on this subject included Dr. Bertram D. Dinman, Associate Professor of Preventive Medicine at Ohio State University; Francis E. Gartrell, Assistant Director of Health, Tennessee Valley Authority; Abraham Gerber, secretary of the System Development Committee, American Electric Power Service Corporation; James R. Jones, combustion engineer, Peabody Coal Company, Inc.; Harry Perry, Director of Coal Research, Bureau of Mines, U.S. Department of the Interior; and Dr. L. A. Ripperton, Associate Professor of Air Hygiene, University of North Carolina. This diverse group of panelists was moderated by T. T. Frankenberg, consulting mechanical engineer, American Electric Power Service Corporation, and R. L. Ireland of the Consolidation Coal Company, Inc., Cleveland, Ohio. Many of the following facts and figures were presented at this symposium.

Coal, CO, SO_x, and temperature inversion. At the present time, coal is used for the production of about 55 percent of the electric power in the United States, and electric generation represents almost half of the total domestic market for coal. And, although nuclear energy will be used increasingly for power production, estimates projected to the year 2000 indicate that the electric utility industry will require about 40 percent of the total available energy—the equivalent of 1.6 million tons of bituminous coal. Of this amount, coal is expected to account for at least 600 000 tons, even at the optimum rate of nuclear power introduction. This level of coal use would be 25 percent more than the total amount of coal mined in the United States in 1964. These statistics indicate the continuing importance of coal in providing a significant portion of the nation's total energy requirements.

Realistically speaking, any restrictions on the use of coal for electric generation would have a serious economic impact on the welfare of the coal-producing regions of the United States, and it would impose cost penalties for present and future power generation.

Air pollution, however, presents one of the most serious threats to the coal industry in the fulfillment of its predicted future as a source of fuel for electric generation. The 2000-MW conventional steam-electric power plants, presently in the design stages, will consume about 20 000 tons of coal per day. This could mean that, in addition to a large volume of carbon monoxide being produced through incomplete combustion, between 700 and 800 tons of sulfur would be burned to produce an intolerable level of sulfur dioxide.

In the vicious cycle wherein urban population densities are increasing, the quantities of energy required in our burgeoning economy will also spiral upward. At some predictable time it will be necessary to decrease the quality of coal used for electric generation as the reserves of high-grade fuel dwindle. And, since the lower-grade bituminous coals contain a higher sulfur content, the problem of air pollution control will be intensified.

Temperature inversion is a meteorological phenomenon which, when occurring over large cities, can have very serious consequences. Essentially, temperature inversion is a perverse atmospheric condition in which the air temperature increases with height above the earth's surface. Normally, temperature decreases with height in the lower atmosphere up to the troposphere, and then the temperature increases in the stratosphere. The rate of decrement, or *lapse rate*, is about 3.3°F per 1000 feet of altitude.

Inversions are caused by radiative cooling of a lower air layer, subsidence heating of an upper layer, or the advection of warm air over cooler air or of cool air under warmer air. Radiative exchange between the earth's sur-

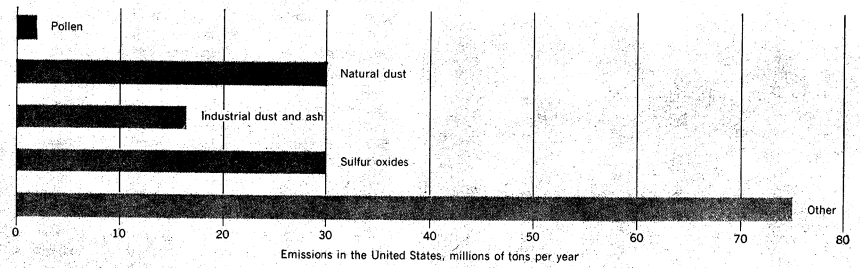
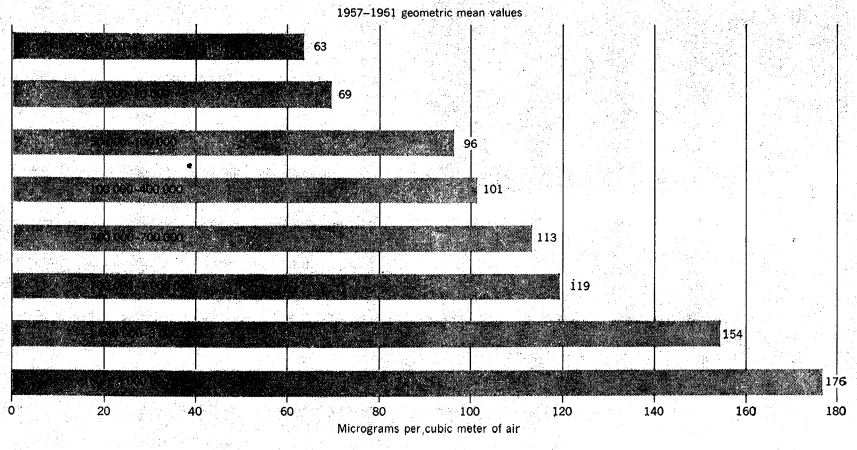


Fig. 5. Horizontal bar graph showing principal major air contaminants that are emitted per year in the United States.

Fig. 6. Graph showing the quantities of suspended particulates and their relationship to urban population concentrations.



face and the atmosphere on clear nights cools the ground and the adjacent layer of air. This makes the adjacent layer colder than the layers immediately above, and thereby creates a ground inversion that can vary from a few feet to a few thousand feet in thickness.

Radiative cooling of the top of a cloud bank or dust layer can also create an inversion. In this case, the sinking air warms at the adiabatic lapse rate of 5.5°F per 1000 feet, and this sinking air can produce a layer warmer than the layer of air that is immediately adjacent to the earth's surface.

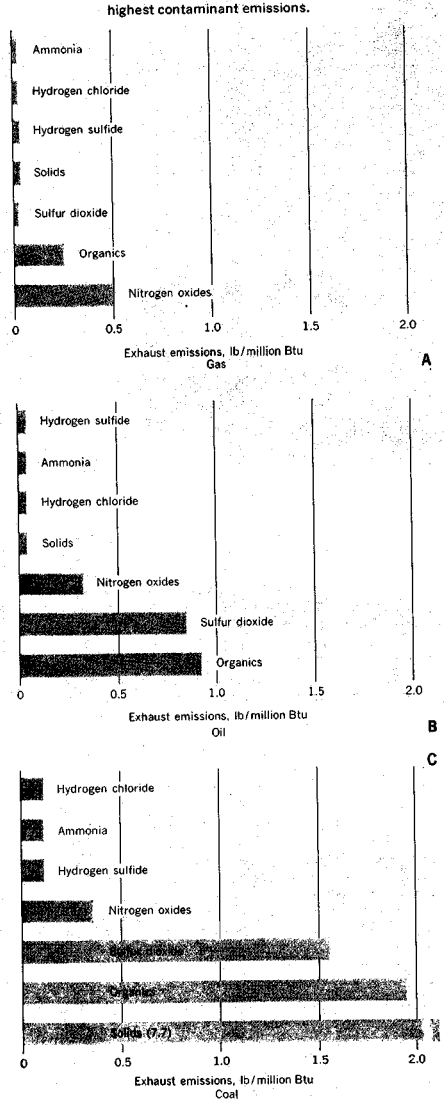
Cool air that displaces warmer air, such as air that blows from a cool ocean onto a warmer land, can cause a pronounced inversion that persists as long as the flow continues. Similarly, warm air may flow over a cold surface layer, especially one trapped in a valley, and this may cause an inversion. The episodes of acute air pollution in the Meuse River Valley of Belgium, in 1930; in Donora, Pa., in 1948; and in London, England, in 1952 were caused by this latter phenomenon.

Inversions effectively suppress vertical air movement and cause an atmospheric stagnation in which smoke and other volatile contaminants cannot rise from the earth's surface. Persistent inversions have been experienced in Los Angeles, New York, London, and other industrial metropolises. Under such conditions, lethal layers of sulfur dioxide, soot, carbon monoxide, ozone, and nitrous oxide can become statically entrapped for days at a time.

Climatological factors. There are meteorological and climatological factors that influence the action of airborne, volatile chemicals. The most common of these variables are temperature, wind velocity and turbulence, humidity, atmospheric pressure, and intensity and duration of sunlight.

Thermal reactions, involving the corrosion of materials,

Fig. 7. A—Chart of exhaust emissions from gas-fired furnaces. B—Similar chart for oil-fired furnaces. C—Chart for coal-fired equipment indicates highest contaminant emissions.



will approximately double in rate for each 18°F rise in temperature. While temperature is not usually considered to have an effect on photochemical reactions, recent research has indicated that photochemical oxidant production and the rate of photooxidation of hydrocarbons are accelerated by increased temperature in synthetic smog. And there is evidence to indicate that eye irritants could also be increased in the atmosphere by the elevation of air temperature.

It is known that when the air temperature is raised, the respiratory rates of humans and animals are increased. And the toxic effects of many pollutants are affected by temperature changes. For example, in one experiment, the lethal dose of ozone for rats in a temperature environment of 90°F was 2.6 ppm for a 4-hour exposure; while at 75°F, the lethal dosage for a 6-hour exposure was 6–8 ppm. This would seem to indicate that the permissible levels of air pollution should be revised in accordance with seasonal mean temperatures.

Humidity can influence the effects of air pollution. Its presence often causes more rapid corrosion of metals by certain chemical substances. Many acidic gases, such as sulfur dioxide, nitrous oxide, hydrogen sulfide, and chlorine, are much more corrosive in atmospheres that contain high humidity than they are in the presence of drier air. And since humidity directly affects the heat transfer between humans and their environment, it will, in turn, influence the effect of exposure on humans.

High wind velocity and air turbulence are generally beneficial because pollutants are dispersed and diluted more rapidly.

It is known that sunlight is an important factor in the effects of air pollution since eye irritants, plant toxins, and ozone are formed in the air by photochemical reactions. Air pollution experts are aware, for instance, that some types of soot deposited on motor vehicles will damage the lacquer in the presence of sunlight. If the soot is removed, however, before sunlight can touch the finish, no damage will result.

Atmospheric pressure has a relevant influence in air pollution. The oxygen pressure in the air decreases as the height above sea level is increased. The immediate physiological effect of increased altitude is a more rapid blood flow rate; then, the involuntary rate of respiration increases. As the body adapts to the new atmospheric environment, the concentration of blood hemoglobin rises. The ambient pressure in populated areas of the United States varies somewhat more than 0.2 atmosphere (assuming that 1.0 atmosphere equals about 15 psi). For relative comparison, the instantaneous rate for a given concentration of air contaminant may be expressed as $dx/dt = K$. At a higher elevation, such as Denver, Colo., with a pressure approximately 0.8 of that at sea level, the instantaneous rate would be $dx/dt = 0.64K$, or 36 percent slower. Therefore, pressure considerations are important in establishing standards that are designed to prevent the formation of secondary pollutants that are synthesized by either photochemistry or oxidation from primary contaminants.

Medically, a dim view. Sulfur dioxide is increasingly emerging as a prime villain in the air pollution drama. This contaminant is a major by-product of fossil-fuel combustion from the lower grade fuel oils and coal.

London's smog, a true smoke suspension in fog, has for many centuries been a prime example of traditional air

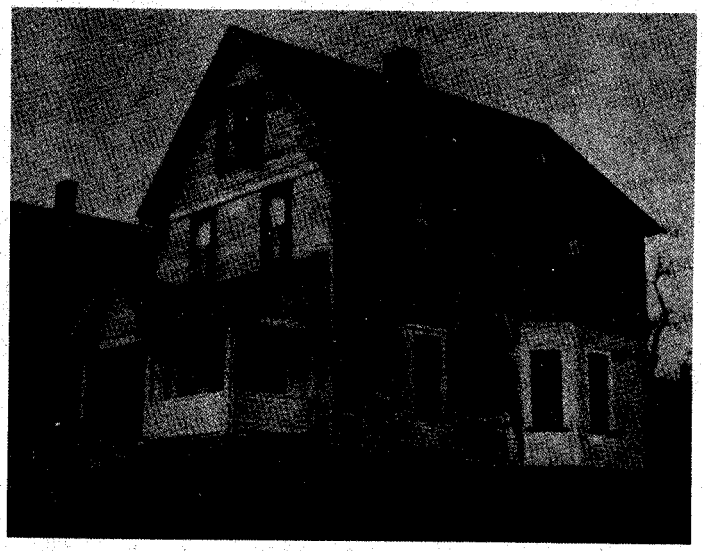


Fig. 8. Paint damage caused by air pollution. In this case, the pollutant was hydrogen sulfide.

pollution. Because England imports limited quantities of high-grade fossil fuels, the typical London "pea souper" consists mainly of sulfur compounds, particularly SO_2, which are produced by the combustion of bituminous coal, low-grade heating oil, acid manufacture, ore smelting, and other industrial manufacturing processes.

In the United States, New York and Chicago have record quantities of SO_2 in their atmospheres that are second only to London's. In all, about 60 percent of the American population is exposed to continuous peril from atmospheric contaminants (see Fig. 7). And it does not require a medical opinion to suggest that pollutants capable of corroding metal, darkening white paint (Fig. 8), disintegrating stone, dissolving nylon hose, and cracking rubber are somewhat less than beneficial to human lung tissue. There is ample circumstantial evidence to link air pollution with asthma, pneumonia, tuberculosis, pulmonary emphysema, lung cancer, and even the common cold. In 1962, the chairman of a panel of medical experts at the National Conference on Air Pollution Control stated: "The evidence that air pollution contributes to the pathogenesis of chronic respiratory disease is overwhelming."

During the symposium on the clean air problem at the recent American Power Conference, Dr. Dinman, in his opening statement, gave a concise description of the pathological effects of sulfur dioxide:

"To understand the effects of SO_2 on health, it is necessary to delineate those mechanisms whereby sulfur oxides alter human function. On a mechanistic basis, we may conceive of air conduction tubes (the tracheobronchial tree) as a series of interconnecting ducts. These ducts have the unusual capacity of changing their cross-sectional area. This is accomplished by contraction of circumferentially aligned muscles. Thus, given a proper stimulus at certain receptions in the wall of this air conduction system, input from these receivers arrives at the brain. A flow of impulses, in turn, is transmitted to these surrounding muscles, which leads to their contraction with a decrease in cross-sectional area.

"The consequences of such decrease in cross-sectional area are apparent. Consider that a fixed volume of air per unit time must be available for oxygen extraction by the blood. Therefore, an increase in velocity is the only method whereby this fixed volume may be moved through this attenuated system. Obviously, the energy required per unit time to obtain this work function is increased. In individuals who have cardiac disease, these increased demands are met with difficulty and subsequent deterioration. Another complication stems from one other consequence of SO_2 or SO_3 (sulfur trioxide) or H_2SO_4 (sulfuric acid) impingement on the lining of the gas–blood exchange surfaces. Impingement of these irritant polar compounds stimulates the release of a diluent at such affected surfaces. While this dilution increases pH toward normal levels, at the same time it imposes a *thickened barrier* to gas transfer across the membrane. Since this barrier is but a few hundred microns thick, this imposes no significant load on gas transfer in the normal person.

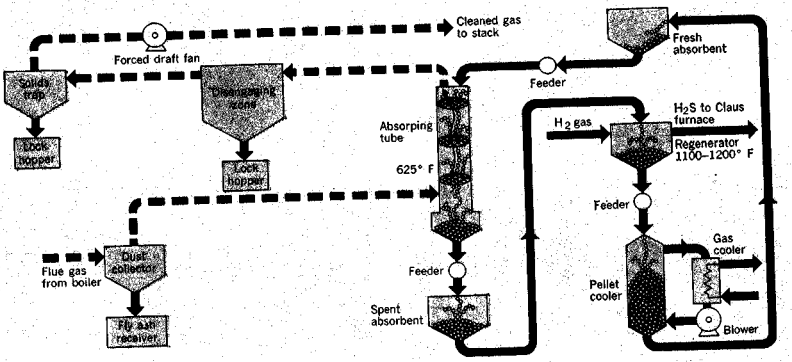


Fig. 9. Block diagram of the Bureau of Mines' alkalized alumina process.

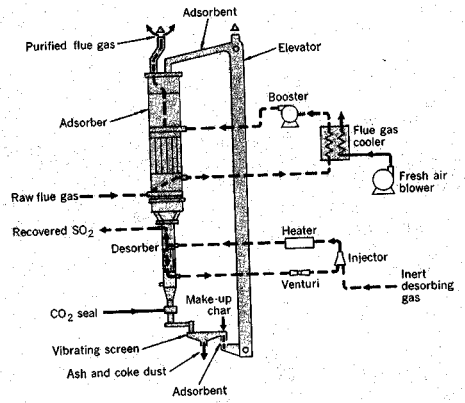


Fig. 10. Diagram showing the mechanical configuration of a Reinluft process pilot plant.

However, in those persons with already thickened gas exchange membranes due to chronic lung disease, this increased thickness essentially causes a barrier to oxygen diffusion with resultant asphyxia, and further deterioration as a result of decreased oxygen availability to the vital organs.

"... While there is much data from animal experimentation, there is relatively little human data even in normal persons. *In such persons, 4–6 ppm of SO_2 produces consistently reproducible changes in airway resistance within 10 seconds to 4 minutes ...*"

Nitrous oxide is no laughing matter. Some medical experts regard nitrous oxide (N_2O), the common "laughing gas" administered as an anesthetic by dentists for tooth extraction, in the same insidious category as SO_2. Recent evidence indicates that N_2O has teratogenic—and possibly carcinogenic—effects on animal and human receptors. In air pollution, this gas is emitted as a by-product of hydrocarbon combustion.

In therapeutic medicine, bone marrow depressant effects have been observed as a result of the protracted administration of N_2O to control convulsions in tetanus victims. And, although any conceivable concentration of the gas as an air pollutant would be very low, the cumulative effects of continued exposure to this gas may be deleterious to human receptors.

Catalysts and buffers. Dinman further observed that with the addition of any suspended particulates, of less than 5 microns in size, the response of the human receptor to SO_2 may be accentuated. The reasons for this physiological reaction are twofold, and may be ascribed to

1. The interposition of particulate surfaces of relatively large areas for irritant gas adsorption, which would increase the gas concentration per unit volume.

2. The increased probability of impingement, which is a result of the different kinetic behavior of particulate vs. gas phase.

Although many particulates tend to aggravate the biological damage potential of SO_2, it is apparent from actual case histories that the biopotency of these particulates is a function of their chemical properties. It is known that manganese catalyzes the conversion of SO_2 to H_2SO_4, but it is also possible for some particulates to buffer the physiological reaction of SO_2.

In the phenomenon of buffering it is known that inhaled hydrogen sulfide (H_2S) and other sulfhydryl compounds can protect mice from otherwise lethal exposures to ozone. Inhaled formaldehyde and SO_2 produced much more resistance to air flow in guinea pigs when applied with a physiologically inert aerosol than did the same concentrations of the gases alone.

Knowing the concentration of a pollutant does not necessarily indicate its physiological effect upon a receptor. The presence of other contaminants may either inhibit or increase the expected effect. Yet, almost no research has been conducted to determine the effects on re-

ceptors of long-term exposure to known admixtures of pollutants. Nevertheless, many proposed air standards for urban areas are predicated on consideration of the exposure effects of a single pollutant at a time.

The final medical factor is individual sensitivity or allergic reaction. Heretofore this has been a rather vague and nebulous concept, but recent evidence is accumulating to verify this phenomenon.

Methods of reducing SO_2 and SO_3 emissions from coal

Based upon statistics available for the year 1962, and by combining a knowledge of the sulfur content of coal seams being mined in various states, Table I indicates the range of sulfur contents and the corresponding percentages consumed in the United States.

In view of the very large estimated demand for electric power generation in geographic areas where coal is the preferred fuel, the quantities of SO_2 released to the atmosphere will rise alarmingly unless means are developed either to remove the sulfur before combustion or to remove the SO_2 from the stack gases. One of the prime difficulties in achieving the former objective is that a portion of the sulfur content (20–60 percent) is chemically bound as organic sulfur, and this can only be removed by very complex and expensive chemical processes.

At present, three high-temperature processes[1] are being operationally tested for electric utility applications. These are: the alkalized alumina, the Reinluft, and the Pennsylvania Electric.

Bureau of Mines' alkalized alumina process. In this process, flue gas containing SO_2 and SO_3 are absorbed by alkalized alumina—$Al(OH)_3$—in a vessel at a temperature of 625°F (see Fig. 9). The alkalized alumina is regenerated in a second vessel at 1200°F, by using producer gas or re-formed natural gas. The product gas from the regenerator is then introduced to a sulfur recovery plant in which elemental sulfur is produced.

The flue gas used in the Bureau's pilot plant is made from the combustion of powdered coal and it contains all the impurities that might affect the absorption and regeneration cycles. Tests have been conducted to establish the optimum conditions of temperature and time for both the absorption and regeneration, and various procedures for preparing the alkalized alumina have been tried because, in the repeated cycles, physical and chemical changes occur that may degrade or poison the absorbent.

The experimentation with this process has led to the construction of a larger pilot plant in which variables can be studied more efficiently. The advantages of the process include a low pressure drop of the flue gas during absorption, operation over a wide temperature range of 250°–650°F, and the ability to obtain elemental sulfur as the end by-product.

Reinluft process. In this method, flue gas at 300°F is forced upward through a filter bed of activated charcoal (see Fig. 10) that is slowly descending through the adsorber. The SO_3 is adsorbed directly and the flue gas is then cooled to 220°F. At this temperature, SO_2 is oxidized to SO_3, which is then adsorbed on the activated charcoal. The SO_3 combines with the adsorbed water from the flue gas to form dilute H_2SO_4.

The activated charcoal, with the adsorbed dilute H_2SO_4, is next regenerated in a separate vessel by the recirculation of product gas heated to 700°F. The dissociated H_2SO_4 products react chemically with a portion of the carbon to form a gas that contains a high concentration of C_2O and SO_2. The latter gas is converted to H_2SO_4 in a contact acid plant. After cleansing, the regenerated char is recycled to the adsorber.

At present, two commercial plants are under construction in Germany to use this method of SO_2 removal. One of these plants will service flue gases produced from low-grade fuel oil, and the other will be used in connection with a coal-fired installation.

The Reinluft process is particularly feasible if there is a nearby industrial requirement for sulfuric acid.

The Pennsylvania Electric process. The Pennsylvania Electric Company has constructed a pilot plant at its Sewart generating station to remove SO_2 by the catalytic conversion of SO_2 to SO_3. Sulfuric acid is formed and collected on the cooling water stream that contains the SO_3. The objectives of the pilot plant are fourfold:

1. To determine the effect of actual flue gas, with time, on catalyst activity.
2. To establish the degree to which the flue gases must be precleaned to prevent catalyst fouling.
3. To calibrate the rate of catalytic oxidation of SO_2 and flue gas pressure drop so that large-scale plants can be sized.
4. To determine removal methods for the acid and the quality of the acid produced.

Reports indicate that the pilot plant has been operated successfully and that adequate data have been gathered for the design and construction of a full-scale plant. Many variables, however, still must be investigated, such as the life expectancy of the equipment, required construction materials, and the character of the maintenance problems that will be experienced.

At the present time there is insufficient information

I. Quality of coal used by electric utility industry in the United States—1962

Sulfur Content, percent	Production, percent
0–1.5	32.0
1.5–2.0	9.0
2.0–2.5	6.6
2.5–3.0	19.7
3.0–3.5	23.0
3.5 plus	9.7

"Despite the evidence of our senses, only in relatively recent years have we recognized that pollutants in the air have a direct bearing on health. And there are still doubting Thomases who maintain that pollution cannot be linked to disease because no specific etiologic agent in the air has been identified as responsible for a specific disease."

—James E. Perkins, M.D.,
Managing Director,
National Tuberculosis Association

available to make accurate cost estimates for the comparison of the three methods. Each of the described processes has its unique advantages, but each requires additional development to verify critical process variables that have an important bearing on the eventual economics. Also, market studies are needed to evaluate the industrial requirements of the manufactured by-products.

Magnetic separation of sulfur. An interesting new process, called magnetic separation,[2] has been reported by the Russians. Essentially, this method involves a flash coking step in which the iron pyrites containing the sulfur fraction in the coal are modified into a magnetic form to simplify the separation procedure.

In this technique, pulverized coal is heated to about 640°F for a period of 2–5 minutes, during which time a jet of steam and air is blown through the heated coal. This treatment produces a surface layer of magnetized material on each pyrite crystal, and separation is made in a magnetic field of 10 000 gauss. By discarding this magnetic fraction, the sulfur content of the coal can be reduced by about 0.5 percent and the ash content by 50 percent. The U.S. Bureau of Mines is investigating this process to determine the feasibility of its application to the treatment of coal in the United States.

SO_2 monitoring and control—TVA experience

During the past 15 years, the Tennessee Valley Authority has added 52 coal-fired, steam-electric generating units, located in eight plants and ranging in size from 125 to 650 MW, to its power production facilities. And a single-unit plant of 900-MW capacity (Bull Run) is scheduled to go on the line in 1966.

Beginning with the first large steam-electric station, TVA conducted extensive air pollution studies at each plant site. The experience and data obtained by these studies have been applied in planning air pollution control at subsequent plants and for additional units in existing plants.

Long-term records of meteorological data and SO_2 concentrations from permanent monitoring stations have

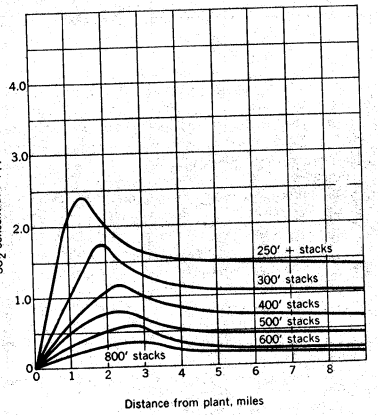


Fig. 12. Calculated profiles of SO_2 ground level concentrations, with various stack heights, for power plant with two stacks and an SO_2 emission rate of 810 tons per day.

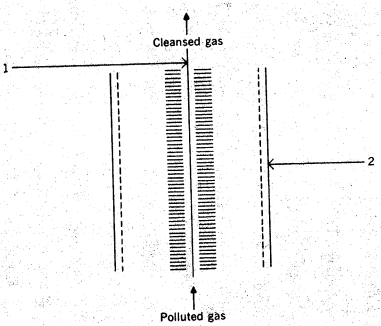


Fig. 13. Diagram of a simple electrostatic precipitator. "1" indicates corona wire; "2," grounded tube.

Fig. 11. Graph showing comparison-frequency distribution of 30-minute average SO_2 concentrations in an urban area and an area in the vicinity of a steam-electric power plant.

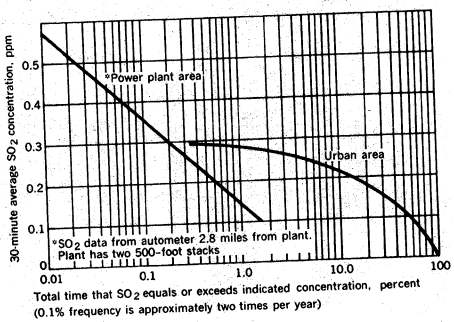
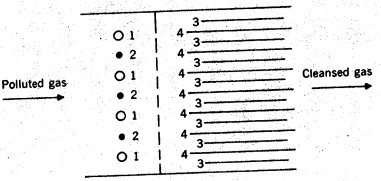


Fig. 14. Vertical-view diagram of a two-stage electrostatic precipitator. "1" indicates grounded cylinders; "2," corona wires; "3," grounded collector plates; "4," charged plates are similar to "2" in polarity.



been augmented by extensive mobile sampling by car and helicopter equipment and by full-scale atmospheric dispersion studies. Since most of the steam-electric plants in the TVA system are geographically located in areas remote from other significant sources of SO_2, it is felt that the test results are most closely representative of the flue gas distribution patterns of modern coal-fired power plants. The SO_2 concentrations in these tests refer to 30-minute average concentrations.

Frequency distribution of SO_2 concentrations. A logarithmic plot of frequency of SO_2 concentrations at fixed monitoring stations has consistently indicated a fairly straight line. Figure 11 shows this distribution as measured by an autometer situated where maximum concentrations occurred at ground level in the vicinity of a 4-unit plant, with two 500-foot-high stacks, and with a total generating capacity of 1050 MW. For the sampling period—approximately 19 months—the highest recorded concentration was about 0.6 ppm for three 30-minute periods. And SO_2 concentrations were 0.2 ppm or above for only eighty-four 30-minute periods, or approximately 0.40 percent of the time.

Similar data obtained from Public Health Service studies in Nashville, Tenn., are also plotted in Fig. 11. Although the maximum SO_2 concentration recorded was only about 0.3 ppm, the concentrations of this gas were 0.2 ppm or more 14.1 percent of the time. And the estimated SO_2 emissions in the urban area were less than half of that recorded at the power plant.

Although higher concentrations of pollution in urban areas tend to occur during periods of low wind velocity and temperature inversion, *the higher levels of pollution in the vicinity of large power plants tend to occur during moderate to high wind speeds and neutral atmospheric stability conditions.* Since none of the TVA plants are located in large urban areas, the data do not provide a direct quantitative measurement of the contribution of a large power plant to an urban pollution problem. But data analysis from an autometer located in a small town near one of the large plants indicated that SO_2 in detectable amounts was present 14 percent of the time.

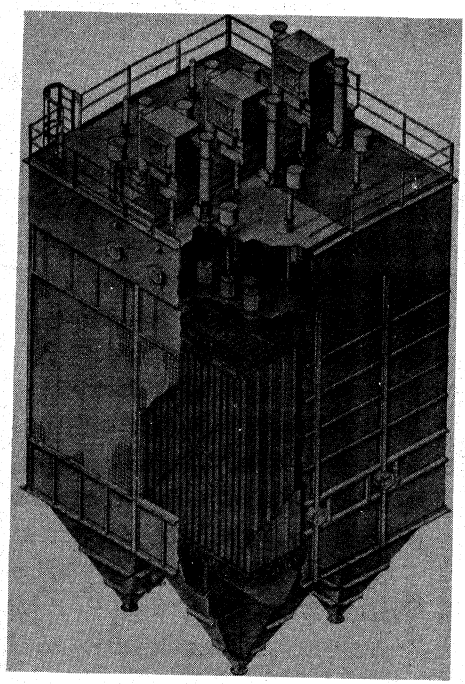
Effect and influence of stack height. Monitoring data and data obtained from full-scale dispersion studies have been used in estimating stack height requirements for TVA plants. An example of estimates made by empirically derived formulas, based upon monitoring data, is shown in Fig. 12. The subject of this graphic plot was a two-unit, two-stack plant, with a generating capacity of 1800 MW, and an estimated SO_2 emission rate of 810 tons per day. This emission rate is calculated empirically from SO_2 monitoring data at plants with 250-, 300-, and 500-foot-high stacks. The curve for a 400-foot-high stack is interpolated, while the curves for the 600- and 800-foot-high stacks were extrapolated.

The electrostatic precipitator—TVA experience. The practical application of the electrostatic precipitator was first demonstrated by F. G. Cottrell in 1906. Essentially, it is a device that is used to remove liquid chemical mists or solid particulates from a gas in which they are suspended. Electrostatic precipitation is a two-stage process. In the first step, the gas containing the suspended particulates is passed through an electric, or corona, discharge area in which ionization of the gas occurs. The ions produced collide with the suspended particles and impart an electric charge to them. These charged particles then drift toward an electrode of opposite polarity, and they are deposited upon this electrode, where their electric charge is neutralized.

In its most elementary form, the precipitator configuration may consist merely of a vertical tube that contains an insulated concentric wire (see Fig. 13). When a dc potential of 10–100 kV is applied to the central wire, a corona discharge occurs in a small area surrounding the wire. The suspended particulates are ionized in the corona discharge and migrate to the tube wall. If the suspension is liquid, it will accumulate on the wall and coalesce into droplets that can be drained from the base of the tube. Suspended solid particulates can be removed from the tube wall by mechanical vibrators or scrapers, and then discharged into a cyclone or dust collector at the bottom of the apparatus.

In more complex configurations, the ionization may occur in one vessel and the deposition and precipitation in another. Figure 14 shows the plan view of a simplified two-chamber apparatus. In the first chamber, the particles become charged but are prevented from depositing

Fig. 15. Cutaway isometric view of an Opzel Plate Precipitator, a type manufactured by Research Cottrell, Inc.



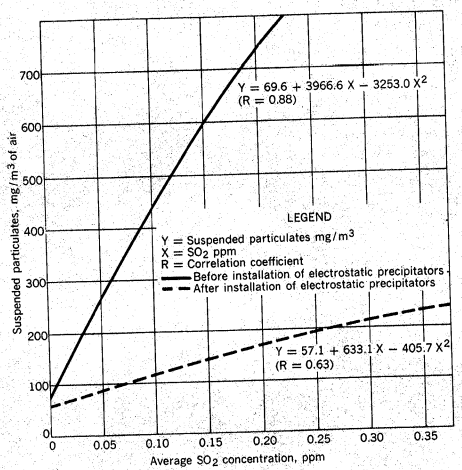
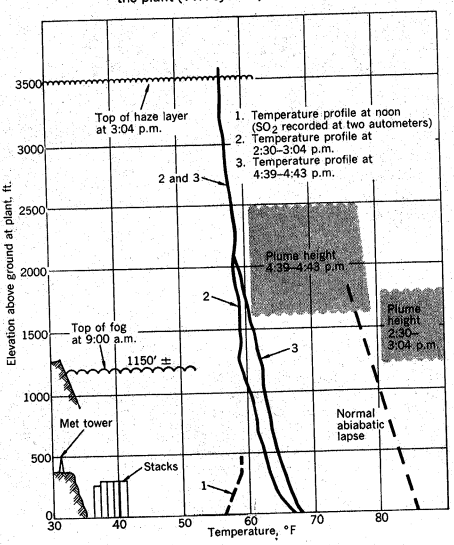


Fig. 16. Graph showing relationship between suspended particulates and SO_2 concentration before and after installation of electrostatic precipitators.

Fig. 17. Profile plot from aerial observations and temperature soundings at Kingston steam-electric plant (TVA system) on November 10, 1964.



on the grounded cylinders by the appropriate adjustment of the rate of gas flow. In the second chamber—consisting of alternately charged, loosely packed and parallel plates—satisfactory precipitation can be attained by applying a lower potential than that required in the charging chamber, since there is no need for a corona discharge.

The corona discharge is usually produced by making the center wire the cathode, because precipitation efficiency is greater under such an operating condition. Less ozone is produced, however, by reversing the polarity, and a positively charged wire is employed in the cleaning of air if the presence of ozone is objectionable.

The high-voltage direct current is generally produced by either mercury vapor or vacuum tube rectifiers. The power requirements vary from 2–5 kWh per million cubic feet of polluted gas being treated, and the variation will be a function of the quantity, size, and physical properties of the particulates that are being removed.

Figure 15 is a cutaway view of an Opzel plate precipitator, manufactured by Research-Cottrell, Inc.

Effect of precipitators on suspended particulates in an ambient atmosphere. Electrostatic precipitators were installed to supplement mechanical ash collectors at one of the TVA plants after a special investigation was conducted to determine the relationships between SO_2 concentrations and suspended particulates in the vicinity of the plant where maximum ground level concentrations of stack emissions occurred. Data were analyzed with the results shown in Fig. 16. From the two derived equations indicated on the graph, TVA estimated that the electrostatic precipitators reduced the suspended particulates by 85 percent in the ambient atmosphere at ground level during those periods when SO_2 was present.

The TVA believes that an additional—although unproved—possible benefit from the electrostatic precipitators is a reduction in the maximum ground level SO_2 concentrations in the vicinity of steam plant emissions. This is predicated on data indicating that the maximum recorded SO_2 concentration during the four years of precipitator operation is about 25 percent less than that recorded prior to precipitator operation.

Power plant pollution potential under air stagnation (temperature inversion) conditions. Air pollution control plans developed for the Kingston plant, until recently the largest steam-electric station in the TVA system, gave special attention to the SO_2 problem associated with periods of atmospheric stagnation.

This plant is located on the floor of an Appalachian valley. The local terrain has parallel ridge features that vary from 400 to 1000 feet above the plant grade level.

During the period from November 9–11, 1964, a temperature inversion occurred in the Kingston plant area. The U.S. Weather Bureau, by prearrangement, alerted the TVA beforehand, and précautionary air pollution control measures and monitoring were initiated.

Sulfur dioxide autometers were checked at regular intervals, and mobile sampling was conducted during the 3-day period by specially equipped helicopters and cars.

The frequency and concentration of SO_2 recorded at ground level were no higher than during normal atmospheric conditions. The absence of an SO_2 buildup was attributed to penetration of the low-level inversion by the hot, high-velocity stack gases and dispersion of the smoke plume from the area by light and steady winds. Figure 17 indicates the time and temperature conditions aloft,

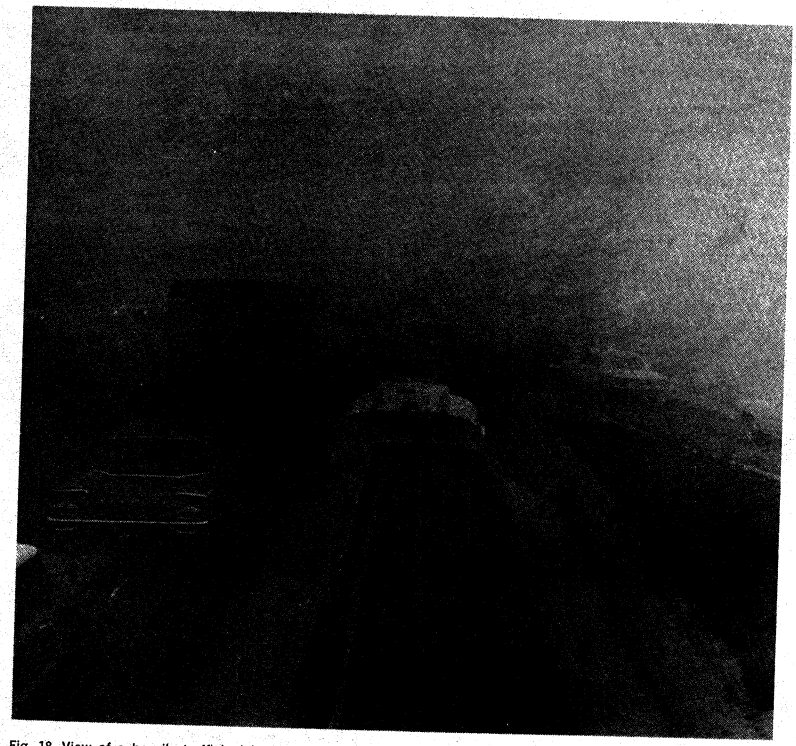


Fig. 18. View of a heavily trafficked Los Angeles freeway shrouded in smog.

and the plume elevation during a timed sequence on November 10.

From the data obtained during this monitoring, it is possible that air pollution predictions should consider power plants as a special case for which normal meteorological criteria may not apply.

The other half of the foggy, smoggy brew

If the witch's brew concocted in the smokestacks of American industry seems appalling, cheer up; for it is only half of the dirty story. Most of the other half may be found in Fig. 18. The U.S. Public Health Service estimates that the 88 million motor vehicles on the nation's highways belch into the atmosphere about 350 000 tons of carbon monoxide, volatile hydrocarbons, and nitrogen dioxide daily. The automobile population in the United States is increasing at more than double the rate of the human population! Urban traffic jams are providing civilization with one of its most diabolical methods of multiplying the problems of air pollution; and, unless something is done to correct this man-made plague, our metropolises will soon become obsolete and deadly places for human habitation.

Pollution control devices for cars. In addition to assuring more complete combustion of hydrocarbon fuels in internal combustion engines by simple carburetor and ignition system adjustments, there are two basic devices that can effectively reduce the amount of air contaminants released from motor vehicle exhausts. For an investment of about $5, crankcase blowby units, which return unburned gases to the combustion chambers, can be installed. Properly maintained blowbys can reduce an automobile's hydrocarbon emission by at least 25 percent. There is also an "afterburner" device, which, when attached to the tailpipe of a motor vehicle, will complete the combustion of carbon monoxide and other unburned gases. When used in conjunction with a crankcase blowby, the afterburner would eliminate the major portion of pollutants now poisoning the air from this source.

It is no secret that the automobile industry has been dragging its feet for a long time in resisting the factory installation of these control accessories. The weight of public opinion, and public officials who have been aroused by the menace of the motor vehicle situation, has forced the hand of the manufacturers. These devices will be required by law for 1966 model cars to be sold in California.

A pollution survey, city by city

The Pittsburgh story. Since the 1940s, a generation of young Pittsburghers has grown up convinced that the sky above them is really blue, ar.1 not murky gray as they were assured by their parents. And it is possible to put on a white shirt in the morning, wear it all day, and still find it reasonably clean. Housewives, too, are able to hang out a line of wash without having to relaunder it the same day.

Before the 1940s, Pittsburgh was the classic American example of continual air pollution. Since the middle period of the Industrial Revolution, the "Smoky City" blamed its railroads and concentrated industry for its plight. The Pittsburgh Chamber of Commerce appointed its first committee on smoke abatement in 1899, and a smoke control ordinance was passed in 1906. For the next 35 years, the Chamber of Commerce and other civic groups hoped that education in matters of proper fuel combustion and pollution control devices would help to solve the problem. But the results of self-regulation were negligible; the situation deteriorated, and enforced regulation seemed to be the only answer.

The City of Pittsburgh Smoke Control Ordinance was passed in 1941, and more stringent amendments were added in 1943, 1946, and 1951. Dual enforcement by Allegheny County and the city is in effect today.

Under the provisions of the ordinance for smoke and air pollution control, limitations are established on the emission of smoke, fly ash, soot, cinders, toxic or radioactive substances, noxious acids, fumes, oxides, gases, and odors, or any other matter that may create atmospheric pollution. These regulations further stipulate that the home owner should do one of several things:

1. Burn highly volatile bituminous coal by installing a stoker.
2. Burn briquettes or other forms of prepared coal, coke, anthracite, or less volatile bituminous coal.
3. Use gas or oil.

Emissions from furnaces of the steel and allied industries are generally restricted to two parts of solids in every 3000 parts of gas, but these limits can vary somewhat dependent upon the types of furnaces employed.

The installation and repair of furnaces, boilers, and other fuel-burning equipment must be done under a permit issued by the terms of the Rules and Regulations of the Pittsburgh Smoke Control Ordinance. With the exception of installations in private residences, furnaces or other fuel-burning equipment are subject to periodic inspection by the Bureau of Air Pollution Control.

To date, the result has been gratifying. Pittsburgh has an average sootfall of only 30 tons per square mile per month as compared with 60 tons for a similar area and time period in New York.

Chicago—soot, smoke, and steel. The nation's second largest metropolis—population 4 million—is gravely endangered by both air and water pollution from the Calumet region of neighboring Indiana. The concentration of steel mills at Hammond and Gary, a scant 15 miles from the Chicago loop, belch a continuous barrage of acrid fumes, and the smoke plumes from these emissions are an ever-present facet of the seascape over Lake Michigan. The legal aspects of this situation are complex. As one leading Chicago spokesman put it: "The cities and towns along the lakefront are not doing a good job of pollution control. And Illinois state agencies are unable to cope satisfactorily with the issues since interstate problems are involved." In view of this, the general sentiment among Chicago officials is that the Federal Government should enforce antipollution controls under Congressional authority.

Air pollution control is being handled by a special city agency. In the three years since its formation, this agency has held 2800 hearings, handled 5000 smoke complaints, inspected 50 000 furnaces, and has filed almost 600 suits for the prosecution of chronic violators. There are also 20 rooftop monitoring stations in the city that were established to trap pollutant particulates in the air, and another 35 specially equipped stations measure the dustfall and SO_2 content.

A three-year Federal grant of $357 000 has assisted Chicago in putting teeth into its enforcement of pollution control. It is hoped that, by 1968, all improper burning of combustible refuse will be banned. This would put the damper on about 30 000 Chicago apartment houses that foul the atmosphere with soot from coal-fired boilers.

Like all major cities, Chicago has its smog—a noxious blend of automobile fumes, industrial pollutants, and soot. The present sootfall is about 43 tons per square mile per month.

Recently, the four major steel producers in the Calumet region agreed to appropriate $50 million over the next seven years for pollution control equipment. It is believed, hopefully, that this equipment will cut the 60 000 tons of pollutants released annually to half that amount by next year.

Chicago has no illusions about quick and easy solutions to its overall pollution problems, but at least the city is doing something about them.

Houston—an industrial complex of chemicals and contaminants. Houston, Tex., is probably the fastest growing city in the United States. And concurrent with this phenomenal growth is the tremendous increase in the number of petrochemical plants, oil refineries, paper mills, and other heavy industries that gird the city's perimeter. Although pollutants from coal combustion are no problem here (natural gas is the most common fuel for both industrial and domestic use), the melange of chemical fumes released into the air is causing considerable apprehension. When the wind is from the southeast quadrant, the sickening fumes from "old smoky"—a sulfite process paper mill in suburban Pasadena—are very apparent in downtown Houston.

Carbon monoxide and the nitrogen dioxides, caused primarily by the heavy automobile traffic, are found in the same ranges of concentration as those reported in other large cities.

However, the general feeling in Houston is that the air pollution problem, at least, is under fairly good control. Private industry has shown an inclination to comply with local city ordinances, primarily because it knows that the

"The problem of sulphur pollution has grown (in New York) until now the measured concentrations of sulphur dioxide are higher than in any other major city in which such measurements are taken."
—*V. G. MacKenzie,*
Assistant Surgeon General,
Chief of the Air Pollution Division,
U.S. Public Health Service

city is quite willing to initiate court action to curb flagrant violations.

Los Angeles and New York. Reams of copy have been written over the past 20 years about the lethal smogs, principally caused by the fantastic motor vehicle population and domestic trash burners, in Los Angeles; and any further emphasis on the situation in this West Coast metropolis would seem boring and repetitious to the reader. Suffice to say that, in 1960, California passed a law requiring all new motor vehicles sold in the state to be equipped by the owners with the crankcase and tailpipe devices previously described. State officials estimate that more than 4 million California vehicles are now equipped with these devices and they are removing about 200 000 gallons of unburned gasoline from the atmosphere each day.

The air pollution situation in New York, however, is so far out of control that this writer could be panicked into leaving the city after reviewing his own copy. New York channels most of its air contamination problems into the municipal Department of Air Pollution Control, whose commissioner, Arthur J. Benline, frankly confesses that far too little money is appropriated either by the city or by the Federal Government to do an adequate job. During a recent television interview, Benline summed up the New York situation in two terse sentences: "The air over our city is helping our citizens to shuffle off this planet at a much higher rate than they would ordinarily go. Yet there has not been any overall demand from the public to clean up our dirty air." So, in the meanwhile, the city muddles through, and everyone hopes that, by some miracle, adequate corrective measures will be taken before any future prolonged temperature inversion produces the disaster that many health authorities fear.

The air pollution situation throughout most urban areas in the United States closely parallels the samplings just described in five major cities.

A utility answers its critics

At a recent hearing called by the Special Committee to Investigate Air Pollution (authorized by the New York City Council), the Consolidated Edison Company of New York replied to the Committee's accusation that Con Edison is one of the principal contributors to the air pollution problem. Otto W. Manz, Jr., the company's executive vice president, contended that the utility has done a conscientious job of providing adequate air pollution control equipment and devices in its city generating plants to minimize the emission of contaminants. In outlining future plans on the subject of air pollution control, Manz listed the following activities, presently under way, that will either decentralize electric generation to remote areas or significantly reduce objectionable stack emissions in city-located generating stations:

1. The construction of the Cornwall pumped-storage station, which will produce about 2000 MW of power, and will permit the retirement, or placement on cold standby, of about 750 MW of generating capacity that is presently being supplied by city steam-electric stations.
2. The possible substitution of more natural gas for coal as an alternative fuel for generating purposes.
3. The establishment of firm interconnections, by EHV transmission, with the CONVEX group of New England utilities and with the Pennsylvania–New Jersey–Maryland (PJM) complex.

Manz believes that the ultimate answer to the problem of air pollution in metropolitan areas, insofar as power generation is concerned, is the use of nuclear energy. He cited the Indian Point nuclear generating station in suburban Westchester County that has been in operation for almost three years and is a firm and reliable producer of power for the Con Edison system.

The Con Edison spokesman sounded a warning note, however, on the subject of who will eventually pick up the tab for air pollution control measures. To quote from Manz' 8-page prepared statement:

"Our estimate is that on and after October 1, 1969, when the maximum sulfur content in these [coal] fuels will be 2.2 percent by weight, the additional annual cost of the fuels used by Con Edison and which will be passed on to the consumer could be as much as $20 million."

Where do we go from here?

As one public health official bluntly put it: "Perhaps we are worrying about the wrong menace. Our urban civilization stands a much better chance of being suffocated by air pollution than being annihilated by atomic weapons."

From numerous surveys, it is obvious that the sources of air pollution are numerous and complex. There is no single group or interest toward whom we can point an accusing finger as being the sole villain of the drama. Until heavy industry, the utilities, car manufacturers, and the general public become totally aware of the truth about air pollution and the consequences of irresponsibility, the already intolerable situation will become impossible.

Piecemeal solutions are not the answer. A city committee cannot correct a situation—such as in Chicago and to some extent in New York—whose origins are interstate. Total and effective remedial action must be undertaken by joint commissions that represent municipal, state, Federal, and private interests.

Life depends upon the air we breathe.

The author wishes to acknowledge the following picture credits: Fig. 1, *N.Y. Journal-American;* Figs. 2 through 8, U.S. Public Health Service, Division of Air Pollution; Figs. 9 and 10, *Mechanical Engineering* magazine; Fig. 13, Research-Cottrell, Inc.; Fig. 18, *Los Angeles Times.*

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Solid waste management is an area in which innovative research and development activities are sorely needed. It is possible to put a rough price tag on the desirable level of research and development funding, if the practice of industry is used as a yardstick. Ordinarily industry invests something on the order of 5 percent of its gross income on research and development. These funds are used for basic research, the results of which may have no immediate practical applicability, and for efforts to improve quality of output and reduce costs. A segment of industry involved in an area of rapid technological change or growth may invest as much as 10 percent annually in research and development in order to secure a position in the forefront of technological advancement, and thus to maintain a competitive advantage.

The solid waste management field is somewhat analogous. Solid waste collection, processing, and disposal cost the Nation in excess of $3 billion each year. Since this is a field in which technological innovation is needed and will have to be paid for, it would seem reasonable to assume that an amount equal to 5 to 10 percent of the annual solid waste "business" should be invested in research and development—that is, somewhere between $150 and $300 million a year. In our view, taking into account the public health aspects of the solid waste problem as well as its economic, technological, and public policy ramifications, annual expenditures for solid waste research and development would best be allocated in the following way:

Public health and environmental pollution control, 50 percent;
Solid waste technology improvement, 35 percent;
Public administration, systems analysis, cost-benefit analysis, 15 percent.

A division of funds such as this is, of course, not without some areas of overlap. Technology improvement, for example, would have to take into consideration the public health implications of new, experimental techniques and procedures.

By no means all of the cost of solid waste research and development on this scale should be borne by the Federal Government. State and local governments should be expected to contribute, but industry should assume responsibility for a major share of these costs, particularly in the area of solid waste technology improvement. This assignment of funds should assure rapid progress toward the control of environmental health hazards associated with solid waste generation and disposal.

Question 3: During his testimony, Mr. MacKenzie indicated that there were numerous laws and regulatory codes which inhibited or appeared to inhibit progress or enforcement of pollution abatement action. Please furnish a list of such laws and regulatory codes and the extent to which such laws and codes interfere with pollution abatement and enforcement.

Answer: Mr. MacKenzie's testimony on this point was given in response to a question on whether more rapid progress could be made by spending more money for air pollution abatement. This was Mr. MacKenzie's response: "I think one of the impediments to making more rapid progress than has been indicated in Mr. Cohen's statement relates to the existence and scope of activity of State and local government regulatory control activities. I would like to point out to the

committee that not more than half of the urban areas which are in need of regulatory control programs for air pollution control now have them, and of these the majority of them are operated at an inadequate level to do the kind of job you are inferring might be looked for.

"On the State government level, it was only about 14 years ago, in 1952, that the first State set up a State air pollution control law and started operating a significant air pollution control program. In the intervening period, we now have about half the States that have significant laws on the books. But only a handful of these are operating programs that are at an effective level. So that I think what is lacking as related to this goal is not so much the technology as it is the development of the control programs on the State and local levels of government that would effectively see that the available technology is employed."

The following provides additional details concerning the inadequacy of State and local governmental programs of air pollution control: For the most part, local and State agencies are still not equipped to meet their present responsibilities for the prevention and control of air pollution, let alone the potentially greater responsibilities that may be thrust upon them as the potential for air pollution continues to grow. In many important respects, the progress made during the past 2½ years is not as impressive as raw statistics might indicate.

To begin with, people in many parts of the country will not share fully in the benefits of the increase that has taken place in State and local spending. A major share of such spending is still concentrated in the State of California. Local agencies in California accounted for 38 percent of all spending for local air pollution programs in 1965. The Los Angeles County budget alone represented about 25 percent of the national total for all local agencies and, combined with the budgets of the next five largest local agencies, made up over half the national total. And at the State level, nearly half of the increased spending has been in California. This means, of course, that State and local governments elsewhere in the country are still not attacking their air pollution problems with resources commensurate with the numbers of people those problems affect.

Though there are now 33 air pollution programs at the State level, many of them are scarcely more than nominal programs having neither the authority nor the resources needed to carry on effective control activities. In 19 States, some degree of abatement responsibility has been assigned to State agencies, but in most instances the abatement authority can be invoked only with respect to obvious nuisances or in response to complaints. Only a half dozen State agencies engage in more than nominal degree of abatement activity; the great majority are not even serving those communities which are too small to operate their own local programs but are nonetheless affected by serious air pollution problems, often from a single major source. There are many such communities in all parts of the country.

For the most part, efforts at the local level are equally deficient, indeed, more so when measured against the greater degree of activity that is generally expected of local governments. In the air pollution field, it has been traditional to take the position that local governments should bear the major responsibility for practical control action. In actual fact, however, tradition and practice have seldom coincided.

There has been some improvement in this situation in the past 2 years, but not nearly enough to take care of all instances of inadequate effort or total neglect of air pollution at the local level.

Our most recent estimate indicates that only 58 percent of the urban population of the United States is served by local air pollution programs. Even where local programs exist, they frequently, indeed commonly, do not have adequate resources. On a per capita basis, annual spending for local programs has increased in recent years from a median figure of 10.8 to 15.2 cents. This increase is hardly adequate in the light of estimates that an effective local control program for a middle-sized city requires an expenditure of at least 40 cents per capita per year. In most communities, the actual increase has barely been sufficient to keep pace with the rising cost of operating an air pollution program.

Only a handful of local agencies have adequate authority to deal with the complex modern problem of air pollution. These are agencies which have been given broad authority, either by local or State governments, to adopt rules and regulations for the control of all sources of air pollution. But many of these agencies have been slow to apply this authority to significant sources. And many others are still without adequate power to adopt and enforce control regulations applicable in any degree to important air pollution sources within their jurisdiction.

As for regional activity, the improvement that has taken place in the past 2 years has barely touched the largest urban centers of the country. Only 5 of the 24 largest metropolitan areas are now served by a regional air pollution program. These 24 areas are the homes of some 69 million people—about one-half of the Nation's urban population—and, in general, tend to have the most serious air pollution problems. Though air pollution in such metropolitan areas is inevitably a regional problem, the authority to deal with it is usually fragmented among many jurisdictions. A number of devices short of establishing regional programs are being used to achieve some degree of regional activity, but since most of them depend purely on voluntary cooperation by the participating governments, they are of limited effectiveness.

In brief, there are still many serious deficiencies in State and local air pollution programs in nearly all parts of the country. To achieve a really significant degree of improvement will require a much greater effort in the months and years ahead than has been made at any time in the past. The inadequacy of the present pattern of control efforts means that a great deal of new local and State legislation will be needed; it means that more trained manpower will be needed, particularly since the lack of enough trained personnel is already keeping many local and State programs from keeping up with their scheduled expansion; it means that local and State agencies must not only redouble their efforts to develop and carry on technically sound and sophisticated control programs but, at the same time, must begin dealing more effectively with the many obvious sources of air pollution which remain uncontrolled in virtually every city and town; and, not least important, it means that an increased investment of public funds will be needed to achieve and sustain the high level of control activity

that is so clearly called for by our knowledge of the present and probable future dimensions of the air pollution problem.

INDEX OF AIR POLLUTION CONTROL EFFORTS IN THE UNITED STATES

The following lists roughly index the geographical occurrence of air pollution problems in the United States and the efforts being made to control these problems. In compiling the lists several criteria were used. First of all, it was generally assumed that cities with a population of 50,000 or more had an air pollution problem (or the potential for one) that could be controlled at the local level of government. Therefore, all cities in the United States with a population of 50,000 or more are listed with an indication of whether or not they are served by a minimum or better local air pollution control program. A minimum program is arbitrarily defined as one spending no less than $5,000 a year. Supplementing this list of cities is a tabulation of local government agencies currently receiving Federal matching grant support, the amounts of these grants, and the amounts of current non-Federal budgets.

Secondly, it was generally assumed that every State had smaller communities whose air pollution problems were serious enough to warrant control programs, but whose resources were not adequate to support the necessary effort. These communities, it was generally assumed, depend on State air pollution control programs. Therefore, all the States and the U.S. possessions are listed with an indication of whether or not they are served by a minimum or better State air pollution control program. A minimum program is again defined as one spending no less than $5,000 per year. Supplementing this list is a tabulation of State and possession agencies currently receiving Federal matching grant support, the amounts of these grants, and the amounts of current non-Federal budgets and budgets prior to receipt of Federal grants.

Extent of local air pollution control efforts in cities with population of 50,000 or more

Population rank	City or place	1960 population in thousands	Agency
1	New York, N.Y.	7,782	New York City.
2	Chicago, Ill.	3,550	Chicago.
3	Los Angeles, Calif.	2,479	Los Angeles County (A).
4	Philadelphia, Pa.	2,002	Philadelphia.
5	Detroit, Mich.	1,670	Detroit.
6	Baltimore, Md.	939	Baltimore (B).
7	Houston, Tex.	938	Harris County (A) (B).
8	Cleveland, Ohio	876	Cleveland.
9	Washington, D.C.	764	District of Columbia.
10	St. Louis, Mo.	750	St. Louis.
11	San Francisco, Calif.	743	Bay Area Control District (A).
12	Milwaukee, Wis.	741	Milwaukee County (A).
13	Boston, Mass.	697	Boston area (A).
14	Dallas, Tex.	679	Dallas County (A).
15	Pittsburgh, Pa.	640	Allegheny County (A).
16	New Orleans, La.	627	Local program prohibited.

Extent of local air pollution efforts in cities with population of 50,000 or more—Continued

Population rank	City or place	1960 population in thousands	Agency
17	San Antonio, Tex	587	None.
18	San Diego, Calif	573	San Diego County (A) (B).
19	Seattle, Wash	557	Seattle King County (A).
20	Buffalo, N.Y	532	Erie County (A).
21	Cincinnati, Ohio	502	Cincinnati area (A) (B).
22	Memphis, Tenn	497	None.
23	Denver, Colo	493	Denver City and County (A).
24	Atlanta, Ga	487	Fulton County (A).
25	Minneapolis, Minn	482	Minneapolis.
26	Indianapolis, Ind	476	Indianapolis.
27	Kansas City, Mo	475	None.
28	Columbus, Ohio	471	Columbus (B).
29	Phoenix, Ariz	439	Maricopa County (A).
30	Newark, N.J	405	Newark (B).
31	Louisville, Ky	390	Jefferson County (A).
32	Portland, Oreg	372	Portland.
33	Oakland, Calif	367	Bay Area Control District (A).
34	Fort Worth, Tex	356	None.
35	Long Beach, Calif	344	Los Angeles County (A).
36	Birmingham, Ala	341	Jefferson County (A).
37	Oklahoma City, Okla	324	Oklahoma City County (A).
38	Rochester, N.Y	318	Rochester (B).
39	Toledo, Ohio	318	Toledo.
40	St. Paul, Minn	313	St. Paul.
41	Norfolk, Va	305	None.
42	Omaha, Nebr	301	Omaha (B).
43	Honolulu, Hawaii	294	None.
44	Miami, Fla	291	Dade County (A).
45	Akron, Ohio	290	Akron-Barberton (A).
46	El Paso, Tex	276	None.
47	Jersey City, N.J	276	Do.
48	Tampa, Fla	275	Hillborough County (A)(B).
49	Dayton, Ohio	262	Dayton (B).
50	Tulsa, Okla	262	Tulsa City-County (A).
51	Wichita, Kans	255	None.
52	Richmond, Va	220	Richmond (B).
53	Syracuse, N.Y	216	Syracuse (B).
54	Tucson, Ariz	213	Pima County (A).
55	Des Moines, Iowa	209	None.
56	Providence, R.I	207	Providence.
57	San Jose, Calif	204	Bay Area Control District (A).
58	Mobile, Ala	203	Mobile.
59	Charlotte, N.C	202	Mecklinburg County (A).
60	Albuquerque, N. Mex	201	Albuquerque.
61	Jacksonville, Fla	201	None.
62	Flint, Mich	197	Do.
63	Sacramento, Calif	192	Sacramento County (A)(B).
64	Yonkers, N.Y	190	Yonkers.
65	Salt Lake City, Utah	189	None.
66	Worcester, Mass	187	Worcester.
67	Austin, Tex	187	None.
68	Spokane, Wash	181	Do.
69	St. Petersburg, Fla	181	Pinellas County (A)(B).
70	Gary, Ind	178	Gary.
71	Grand Rapids, Mich	177	Grand Rapids (B).
72	Springfield, Mass	174	Springfield area (A).
73	Nashville, Tenn	171	Nashville-Davidson County (A).
74	Corpus Christi, Tex	168	None.

Extent of local air pollution efforts in cities with population of 50,000 or more—Continued

Population rank	City or place	1960 population in thousands	Agency
75	Youngstown, Ohio	167	Youngstown (B).
76	Shreveport, La	164	None.
77	Arlington, Va	163	Do.
78	Hartford, Conn	162	Do.
79	Fort Wayne, Ind	162	Do.
80	Bridgeport, Conn	156	Bridgeport.
81	Baton Rouge, La	152	None.
82	New Haven, Conn	152	New Haven.
83	Savannah, Ga	149	Chatham County (A).
84	Tacoma, Wash	148	Tacoma (B).
85	Jackson, Miss	144	None.
86	Paterson, N.J	144	Do.
87	Evansville, Ind	142	Evansville.
88	Erie, Pa	138	Erie (B).
89	Amarillo, Tex	138	None.
90	Montgomery, Ala	134	Do.
91	Fresno, Calif	134	Do.
92	South Bend, Ind	132	Do.
93	Chattanooga, Tenn	130	Chattanooga.
94	Albany, N.Y	130	Albany County (A).
95	Lubbock, Tex	129	None.
96	Lincoln, Nebr	129	Do.
97	Madison, Wis	127	Do.
98	Rockford, Ill	127	Do.
99	Kansas City, Kans	122	Kansas City-Wyandotte County (A).
100	Greensboro, N.C	120	Guilford County (A).
101	Topeka, Kans	119	None.
102	Glendale, Calif	119	Los Angeles County (A).
103	Beaumont, Tex	119	None.
104	Camden, N.J	117	Camden (B).
105	Columbus, Ga	117	None.
106	Pasadena, Calif	116	Los Angeles County (A).
107	Portsmouth, Va	115	None.
108	Trenton, N.J	114	Do.
109	Newport News, Va	113	Do.
110	Canton, Ohio	114	Canton.
111	Dearborn, Mich	112	Wayne County (A).
112	Knoxville, Tenn	112	None.
113	Hammond, Ind	112	Do.
114	Scranton, Pa	111	Do.
115	Berkeley, Calif	111	Bay area (A).
116	Winston-Salem, N.C	111	Winston-Salem (B).
117	Allentown, Pa	108	Lehigh Valley (A) (B).
118	Little Rock, Ark	108	Local program prohibited.
119	Lansing, Mich	108	None.
120	Cambridge, Mass	108	Boston area (A).
121	Elizabeth, N.J	108	Elizabeth (B).
122	Waterbury, Conn	107	None.
123	Duluth, Minn	107	Do.
124	Anaheim, Calif	104	Orange County (A) (B).
125	Peoria, Ill	103	Peoria (B).
126	New Bedford, Mass	102	None.
127	Niagara Falls, N.Y	102	Niagara County (A).
128	Wichita Falls, Tex	102	None.
129	Torrance, Calif	101	Los Angeles County (A).
130	Utica, N.Y	100	None.

Extent of local air pollution efforts in cities with population of 50,000 or more—Continued

Population rank	City or place	1960 population in thousands	Agency
131	Santa Ana, Calif	100	Orange County (A)(B).
132	Fall River, Mass	100	None.
133	Saginaw, Mich	98	Do.
134	Reading, Pa	98	Do.
135	East Los Angeles, Calif	98	Los Angeles County (A).
136	Waco, Tex	98	None.
137	Columbia, S.C	97	Columbia (B).
138	Roanoke, Va	97	Roanoke.
139	Springfield, Mo	96	Greene County (A).
140	Wilmington, Del	96	None.
141	Somerville, Mass	95	Boston area (A).
142	Lynn, Mass	94	Do.
143	Raleigh, N.C	94	None.
144	Stamford, Conn	93	Do.
145	Newton, Mass	92	Boston area (A).
146	Lowell, Mass	92	None.
147	Cedar Rapids, Iowa	92	Cedar Rapids.
148	San Bernardino, Calif	92	San Bernardino County (A).
149	Pueblo, Colo	91	None.
150	Alexandria, Va	91	Do.
151	Abilene, Tex	90	Do.
152	Burbank, Calif	90	Los Angeles County (A).
153	Hampton, Va	89	None.
154	Warren, Mich	89	Do.
155	Sioux City, Iowa	89	Do.
156	Racine, Wis	89	Do.
157	Davenport, Iowa	89	Do.
158	Norwalk, Calif	89	Los Angeles County (A).
159	Manchester, N.H	88	None.
160	Orlando, Fla	88	Do.
161	Quincy, Mass	87	Boston area (A).
162	Stockton, Calif	86	None.
163	Charleston, W. Va	86	Do.
164	Riverside, Calif	84	Riverside County (A)(B).
165	Garden Grove, Calif	84	Orange County (A)(B).
166	Tonawanda, N.Y	84	Erie County (A).
167	Fort Lauderdale, Fla	84	None.
168	Huntington, W. Va	84	Do.
169	Springfield, Ill	83	Do.
170	Santa Monica, Calif	83	Los Angeles County (A).
171	Parma, Ohio	83	None.
172	Springfield, Ohio	83	Do.
173	Downey, Calif	82	Los Angeles County (A).
174	Dundalk, Md	82	Baltimore County (A) (B).
175	Pontiac, Mich	82	None.
176	New Britain, Conn	82	Do.
177	Kalamazoo, Mich	82	Do.
178	Clifton, N.J	82	Do.
179	East St. Louis, Ill	82	Do.
180	Schenectady, N.Y	82	Schenectady.
181	Pawtucket, R.I	81	None.
182	Royal Oak, Mich	81	Do.
183	Odessa, Tex	80	Do.
184	Harrisburg, Pa	80	Do.
185	St. Joseph, Mo	80	Do.
186	Evanston, Ill	79	Do.
187	Durham, N.C	78	Durham County (A).
188	Decatur, Ill	78	None.

Extent of local air pollution efforts in cities with population of 50,000 or more—Continued

Population rank	City or place	1960 population in thousands	Agency
189	East Orange, N.J	77	East Orange.
190	New Rochelle, N.Y	77	New Rochelle.
191	St. Claire, Mich	77	None.
192	Mount Vernon, N.Y	76	Mount Vernon.
193	Binghamton, N.Y	76	Broome County (A).
194	Bethlehem, Pa	75	None.
195	Bayonne, N.J	74	Do.
196	Brockton, Mass	73	Do.
197	Hayward, Calif	73	Bay area (A).
198	Portland, Maine	73	None.
199	Terre Haute, Ind	73	Terre Haute (B).
200	Huntsville, Ala	72	Huntsville.
201	Hamilton, Ohio	72	None.
202	Richmond, Calif	72	Bay area (A).
203	Compton, Calif	72	Los Angeles County (A).
204	Waterloo, Iowa	72	None.
205	Redford Heights, Mich	71	Wayne County (A).
206	Lawrence, Mass	71	None.
207	Augusta, Ga	71	Do.
208	Ogden, Utah	70	Do.
209	Colorado Springs, Colo	70	Do.
210	San Mateo, Calif	70	Bay area (A).
211	Macon, Ga	70	Macon-Bibb County (A).
212	Altoona, Pa	69	None.
213	Cicero, Ill	69	Do.
214	Lorain, Ohio	69	Lorain.
215	Muncie, Ind	69	None.
216	Warwick, R.I	69	Do.
217	West Allis, Wis	68	Milwaukee County (A).
218	Kenosha, Wis	68	None.
219	Norwalk, Conn	68	Do.
220	Troy, N.Y	67	Do.
221	Ann Arbor, Mich	67	Do.
222	Galveston, Tex	67	Do.
223	Pomona, Calif	67	Los Angeles County (A).
224	Lakewood, Calif	67	Do.
225	Hialeah, Fla	67	Dade County (A).
226	Joliet, Ill	67	Will County (A)(B).
227	Cranston, R.I	67	None.
228	Livonia, Mich	67	Wayne County (A).
229	Port Arthur, Tex	67	None.
230	Silver Spring, Md	67	Do.
231	Greenville, S.C	67	Do.
232	Lakewood, Ohio	67	Do.
233	San Leandro, Calif	67	Bay area (A).
234	Charleston, S.C	66	None.
235	Sioux Falls, S.Dak	65	Do.
236	Levittown, N.Y	65	Nassau County (A).
237	Hamilton Township, N.J	65	None.
238	Metairie, La	65	Do.
239	Medford, Mass	65	Boston area (A).
240	Las Vegas, Nev	64	Clark County (A) (B).
241	Aurora, Ill	64	None.
242	Chester, Pa	64	Do.
243	Wilkes-Barre, Pa	64	Do.
244	Lake Charles, La	63	Do.

Extent of local air pollution control efforts in cities with population of 50,000 or more—Continued

Population rank	City or place	1960 population in thousands	Agency
245	Inglewood, Calif	63	Los Angeles County (A).
246	Tuscaloosa, Ala	63	None.
247	Miami Beach, Fla	63	Dade County (A).
248	Euclid, Ohio	63	None.
249	Green Bay, Wis	63	Green Bay (B).
250	Lexington, Ky	63	None.
251	Midland, Tex	63	Do.
252	West Hartford, Conn	62	Do.
253	Independence, Mo	62	Do.
254	High Point, N.C	62	Do.
255	Cleveland Heights, Ohio	62	Do.
256	Lawton, Okla	62	Do.
257	Chicopee, Mass	62	Springfield area (A).
258	Alameda, Calif	61	Bay area (A).
259	Oak Park, Ill	61	None.
260	Lancaster, Pa	61	Do.
261	Vallejo, Calif	61	Do.
262	Laredo, Tex	61	Do.
263	Covington, Ky	60	Do.
264	Asheville, N.C	60	Buncombe County (A).
265	Warren, Ohio	60	None.
266	Atlantic City, N.J	60	Do.
267	Irvington, N.J	59	Do.
268	Skokie, Ill	59	Do.
269	Santa Clara, Calif	59	Bay area (A).
270	San Angelo, Tex	59	None.
271	Santa Barbara, Calif	59	Do.
272	Pasadena, Tex	59	Harris County (A)(B).
273	Gadsden, Ala	58	None.
274	North Little Rock, Ark	58	Do.
275	Levittown, Pa	58	Do.
276	Pittsfield, Mass	58	Do.
277	Malden, Mass	58	Boston area (A).
278	East Chicago, Ind	58	East Chicago.
279	Wauwatosa, Wis	57	Milwaukee County (A).
280	Bakersfield, Calif	57	None.
281	Pensacola, Fla	57	Do.
282	Dubuque, Iowa	57	Do.
283	Bethesda, Md	57	Do.
284	West Palm Beach, Fla	56	Palm Beach County (A).
285	Fullerton, Calif	56	Orange County (A) (B).
286	Albany, Ga	56	None.
287	Waukegan, Ill	56	Do.
288	Council Bluffs, Iowa	56	Do.
289	Waltham, Mass	55	Boston area (A).
290	Great Falls, Mont	55	None.
291	Irondequoit, N.Y	55	Do.
292	Alhambra, Calif	55	Los Angeles County (A).
293	Lynchburg, Va	55	None.
294	Wheaton, Mo	55	Do.
295	York, Pa	55	Do.
296	Kettering, Ohio	54	Do.
297	Berwyn, Ill	54	Do.

Extent of local air pollution control efforts in cities with population of 50,000 or more—Continued

Population rank	City or place	1960 population in thousands	Agency
298	Brookline, Mass	54	Boston area (A).
299	Passaic, N.J	54	None.
300	Johnstown, Pa	54	Do.
301	Lincoln Park, Mich	54	Wayne County (A).
302	South Gate, Calif	54	Los Angeles (A).
303	Greenwich, Conn	54	None.
304	Bay City, Mich	54	Do.
305	Wheeling, W. Va	53	Wheeling (B).
306	Fort Smith, Ark	53	None.
307	Sunnyvale, Calif	53	Bay area (A).
308	Billings, Mont	53	None.
309	Holyoke, Mass	53	Do.
310	Cheektowaga, N.Y	52	Erie County (A).
311	Palo Alto, Calif	52	Bay area (A).
312	Monroe, La	52	Local program prohibited.
313	Union City, N.J	52	None.
314	Bloomfield, N.J	52	Do.
315	Rock Island, Ill	52	Do.
316	Meriden, Conn	52	Do.
317	Rome, N.Y	52	Do.
318	Penn Hills, Pa	52	Allegheny County (A).
319	Union, N.J	51	None.
320	Reno, Nev	51	Reno-Sparks-Washoe County (A).
321	University City, Mo	51	St. Louis County (A).
322	Tyler, Tex	51	None.
323	Lima, Ohio	51	Do.
324	Eugene, Oreg	51	Eugene-Springfield (A)(B).
325	Jackson, Mich	51	None.
326	West Covina, Calif	51	Los Angeles County (A).
327	Bloomington, Minn	50	None.
328	White Plains, N.Y	50	Westchester County (A).
329	Hicksville, N.Y	50	Nassau County (A).
330	Roseville, Mich	50	None.

NOTE.—(A), agency covers more than the city; (B), no Federal funds granted to agency for control program.

Extent of State air pollution control efforts based on annual budgets of $5,000 or more

[In thousands of dollars]

State	Funds	
	Non-Federal	Federal
1. Alabama	25	50
2. Alaska	*0	0
3. Arizona	*0	0
4. Arkansas	19	38
5. California	2, 313	0
6. Colorado	56	20
7. Connecticut	63	89
8. Delaware	*19	0
9. District of Columbia	45	33
10. Florida	*167	0
11. Georgia	39	46
12. Hawaii	50	24
13. Idaho	*10	0
14. Illinois	77	79
15. Indiana	38	42
16. Iowa	*0	0
17. Kansas	*0	0
18. Kentucky	120	197
19. Louisiana	36	48
20. Maine	*0	0
21. Maryland	*0	0
22. Massachusetts	*40	0
23. Michigan	62	55
24. Minnesota	5	10
25. Mississippi	*0	0
26. Missouri	23	46
27. Montana	22	10
28. Nebraska	*0	0
29. Nevada	*0	0
30. New Hampshire	6	13
31. New Jersey	409	250
32. New Mexico	9	17
33. New York	394	120
34. North Carolina	*0	0
35. North Dakota	5	10
36. Ohio	*0	0
37. Oklahoma	6	12
38. Oregon	126	54
39. Pennsylvania	251	84
40. Rhode Island (State law passed June 1966)	*0	0
41. South Carolina	23	45
42. South Dakota	*0	0
43. Tennessee	11	22
44. Texas	48	58
45. Utah	*0	0
46. Vermont	*0	0
47. Virginia	*0	0
48. Washington	*115	0
49. West Virginia	106	148
50. Wisconsin	*0	0
51. Wyoming	*0	0
52. Guam	*0	0
53. Puerto Rico	59	117
54. Samoa	*0	0
55. Virgin Islands	*0	0

NOTE.—Non-Federal funds when asterisked are reported by State as of November 1965. Otherwise all figures are current.

Local and regional air pollution control agencies receiving Federal program grant support

Grantee	Type of project	Population (in thousands)	Current budget			Previous year total	Pregrant expenditures
			Non-Federal	Federal	Total		
Alabama:							
Jefferson County	D	635	$45, 387. 91	$120, 000. 00	$165, 387. 91	$162, 204. 41	
Huntsville	E	72	5, 000. 00	10, 000. 00	15, 000. 00	15, 000. 00	
Mobile	D	314	7, 357. 00	22, 071. 00	29, 428. 00	29, 428. 00	
Arizona:							
Maricopa County	E	664	71, 768. 00	58, 657. 00	130, 425. 00	151, 984. 00	$7, 267. 14
Pima County	D	266	8, 500. 00	25, 000. 00	33, 500. 00	33, 322. 00	
California:							
Los Angeles County	I	6, 039	3, 475, 763. 00	98, 083. 00	3, 573, 846. 00	3, 509, 604. 00	3, 164, 476. 43
San Bernardino County	I	504	224, 504. 00	43, 800. 00	268, 304. 00	264, 777. 00	162, 509. 00
Bay Area APCD	I	3, 291	1, 034, 779. 00	91, 812. 00	1, 126, 591. 00	1, 048, 107. 00	710, 000. 00
Colorado:							
Denver City and County	I	494	70, 323. 00	104, 286. 00	174, 609. 00	150, 984. 00	18, 180. 00
Tri-County (Aurora)	E	234	15, 000. 00	45, 000. 00	60, 000. 00	47, 886. 00	
Connecticut:							
Bridgeport	E	157	11, 854. 45	22, 208. 90	34, 063. 35	34, 063. 35	750. 00
Middletown	D	33	7, 299. 00	14, 356. 00	21, 655. 00	19, 020. 00	
Fairfield	D	46	11, 240. 00	21, 600. 00	32, 840. 00	23, 067. 00	
Stratford	D	45	10, 752. 00	20, 624. 00	31, 376. 00	21, 922. 00	
Florida:							
Dade County	I	935	36, 637. 00	52, 220. 00	88, 857. 00	104, 190. 00	19, 230. 00
Palm Beach County	E	228	13, 768. 00	41, 048. 00	54, 816. 00	52, 446. 00	
Georgia:							
Fulton County	D	69	7, 500. 00	18, 000. 00	25, 500. 00	24, 000. 00	
Macon-Bibb Counties	D	141	5, 159. 95	15, 479. 85	20, 639. 80	21, 127. 80	
Chatham County	D	188	6, 114. 00	12, 983. 00	19, 097. 00		
Illinois:							
Chicago	I	3, 550	769, 694. 00	393, 000. 00	1, 162, 694. 00	1, 162, 694. 00	590, 972. 00
Cook County [1]	I	1, 579	103, 434. 00	50, 084. 00	153, 518. 00	150, 084. 00	8, 500. 00

Indiana:							
East Chicago	I	58	20,995.00	19,340.00	40,335.00	33,345.00	11,325.00
Gary	I	178	43,420.00	62,765.00	106,185.00	106,185.45	12,020.00
Evansville	I	142	14,085.00	11,147.00	25,232.00	25,232.68	8,511.68
Indianapolis	I	476	51,130.00	22,516.00	73,646.00	----------	39,872.00
Iowa: Cedar Rapids	D	92	5,200.00	10,400.00	15,600.00	15,600.00	----------
Kansas: Kansas City-Wyandotte County	D	185	12,000.00	36,000.00	48,000.00	32,496.00	----------
Kentucky: Jefferson County	I	611	86,577.00	21,000.00	107,577.00	----------	75,770.00
Massachusetts:							
Worcester	E	187	11,619.21	22,000.00	33,619.21	34,833.87	----------
Boston	I	912	98,675.00	120,000.00	218,675.00	172,895.00	56,447.06
Springfield	D	415	11,000.00	33,000.00	44,000.00	44,000.00	----------
Michigan:							
Muskegon	D	150	5,295.00	15,885.00	21,180.00	21,180.00	0
Wayne County	I	996	57,969.00	133,500.00	191,469.00	133,421.00	13,469.00
Wyandotte	I	44	7,066.24	13,632.00	20,698.24	27,090.25	250.24
Detroit	I	1,670	285,220.00	51,733.00	336,953.00	275,980.00	211,800.00
Minnesota:							
St. Paul	I	313	33,000.00	55,783.20	88,783.20	69,393.99	5,000.00
Minneapolis	I	483	29,192.39	37,895.00	67,087.39	67,087.39	10,244.89
Missouri:							
St. Louis County	E	704	70,852.19	120,000.00	190,852.19	168,614.00	28,428.00
St. Louis City	I	750	133,785.00	42,768.00	176,553.00	0	112,401.00
Greene County-city of Springfield	D	126	15,736.00	31,215.00	46,951.00	0	0
Nevada: Reno-Sparks-Washoe Counties	E	85	12,959.25	27,615.75	40,575.00	37,243.50	3,750.00
New Jersey: East Orange	D	77	6,500.00	8,000.00	14,500.00	0	2,500.00
New Mexico: Albuquerque	I	201	9,266.00	6,288.00	15,554.00	15,221.00	5,249.00
New York:							
New Rochelle	E	77	5,590.86	6,400.00	11,990.86	11,976.36	2,348.70
Erie County	D	1,065	36,097.01	72,193.99	108,291.00	113,580.00	----------
Broome County	D	213	5,116.66	10,233.32	15,349.98	11,841.00	----------
Dutchess County	D	162	2,671.67	5,343.33	8,015.00	4,830.00	----------
Chemung County	D	99	2,068.75	6,206.25	8,275.00	8,226.00	----------
Nassau County	D	1,300	135,646.00	101,850.00	237,496.00	149,919.00	77,719.00
Schenectady	D	82	2,066.67	4,133.33	6,200.00	4,376.00	----------

Local and regional air pollution control agencies receiving Federal program grant support—Continued

Grantee	Type of project	Population (in thousands)	Current budget			Previous year total	Pregrant expenditures
			Non-Federal	Federal	Total		
New York—Continued							
Albany County	D	273	$1, 675. 00	$3, 350. 00	$5, 025. 00	$4, 410. 00	
Mount Vernon	D	76	2, 751. 43	5, 502. 86	8, 254. 29	5, 254. 28	
Yonkers	D	191	4, 675. 25	9, 000. 00	13, 675. 25	12, 468. 36	
Columbia County	D	47	2, 033. 34	4, 066. 66	6, 100. 00	5, 754. 00	
Niagara County	D	242	12, 500. 00	37, 500. 00	50, 000. 00	46, 992. 00	
New York City	I	7, 782	1, 201, 913. 00	188, 000. 00	1, 389, 913. 00	1, 219, 780. 00	$832, 632. 00
North Carolina:							
Guilford County	D	247	6, 403. 00	19, 202. 00	25, 605. 00	24, 390. 00	
Durham County	D	112	5, 124. 00	13, 379. 40	18, 503. 40	17, 839. 20	
Buncombe County	D	130	7, 981. 94	23, 945. 82	31, 927. 76	33, 265. 40	
Rowan County	D	83	4, 217. 25	12, 634. 18	16, 851. 43	16, 868. 90	
New Hanover County	D	72	4, 201. 29	12, 524. 25	16, 725. 54	16, 699. 00	
Gaston County	D	127	6, 680. 00	14, 270. 00	20, 950. 00	25, 710. 00	
Mecklenburg County	D	271	10, 900. 50	32, 701. 50	43, 602. 00		
Ohio:							
Lorain	E	69	9, 693. 00	19, 386. 00	29, 079. 00	29, 079. 00	307. 00
Akron	D	324	36, 385. 00	94, 155. 00	130, 540. 00	130, 540. 00	5, 000. 00
Toledo	I	427	39, 095. 00	24, 417. 00	63, 512. 00	63, 512. 00	30, 956. 00
Cleveland	I	876	241, 730. 00	34, 922. 00	276, 652. 00	276, 652. 00	224, 269. 00
Canton	D	114	17, 682. 00	35, 358. 00	53, 040. 00		
Oklahoma:							
Oklahoma City-County	D	440	3, 392. 50	10, 177. 00	13, 569. 50	13, 570. 00	
Tulsa City-County	D	346	8, 378. 00	25, 134. 00	33, 512. 00		
Oregon: Portland	I	373	45, 175. 00	72, 598. 00	117, 773. 00	117, 773. 00	8, 876. 00

Pennsylvania:							
Macungie	E	4	260.00	520.00	780.00	780.00	
Philadelphia	I	2,003	264,470.00	172,336.00	436,806.00	365,295.00	178,302.00
Allegheny County	I	1,629	210,474.00	159,631.00	370,105.00	370,105.00	157,263.00
Rhode Island: Providence	I	207	35,554.03	7,052.56	42,606.59	42,606.59	32,027.75
South Carolina: Spartanburg	I	44	8,687.68	9,213.32	17,901.00	18,952.36	3,905.25
Tennessee:							
Chattanooga	I	130	24,870.00	15,740.00	40,610.00	36,785.00	16,398.00
Nashville and Davidson County	D	400	16,090.00	16,770.00	32,860.00	30,664.00	10,500.00
Texas: Dallas	D	951	18,960.00	48,755.00	67,715.00	0	0
Virginia: Roanoke	I	97	11,736.66	1,823.34	13,560.00	0	10,825.00
Washington: Seattle-King County	D	935	66,139.00	71,976.00	138,115.00	93,360.00	43,360.00
Wisconsin: Milwaukee County	I	1,036	187,279.00	12,978.00	200,257.00	0	181,651.00
Total	------	51,395	9,669,741.08	3,598,174.81	13,267,915.89	11,629,584.04	7,095,262.14

[1] Unincorporated area.

EXPLANATORY NOTE.—This table shows the budgets of local and regional air pollution control agencies as of July 1966. The Federal program grants shown in the 5th column are awards made from the fiscal year 1966 appropriation. The 2d column shows the type of project for which Federal grant funds were provided: D denotes a grant for the development of a new air pollution control program, E denotes a grant for the establishment of a program already authorized by local or State law, and I denotes a grant for the improvement of an existing program. The next-to-last column shows the preceding year's expenditures; in most instances, this total also includes Federal grant support. The last column shows expenditures for the most recent year prior to receipt of Federal program grants. Such grants were first authorized by the Clean Air Act, adopted December 1963, and were first made from fiscal year 1965 appropriations.

State air pollution control agencies receiving Federal program grant support

Grantee	Type of project	Population (in millions)	Current budget			Previous year total	Pregrant expenditures
			Non-Federal	Federal	Total		
Alabama	D	3.2	$25,000.00	$50,000.00	$75,000.00	$15,000.00	
Arkansas	E	1.7	19,340.00	38,680.00	58,020.00	58,020.00	
Colorado	E	1.8	55,780.36	20,060.00	75,840.36		$45,619.70
Connecticut	D	2.5	62,550.00	89,066.00	151,616.00	147,787.00	42,083.00
District of Columbia	I	.8	44,585.00	33,262.00	77,847.00		27,954.00
Georgia	D	3.9	38,515.00	46,452.00	84,967.00	78,097.06	14,274.00
Hawaii	I	.6	50,218.00	24,002.00	74,220.00	74,028.00	38,217.00
Illinois	I	10.0	77,050.00	79,416.00	156,466.00	124,270.00	5,146.00
Indiana	I	4.6	38,230.00	41,580.00	79,810.00	74,590.00	16,258.00
Kentucky	E	3.0	119,838.00	196,828.00	316,666.00	64,272.00	
Louisiana	E	3.2	35,882.81	48,448.20	84,331.01	61,831.01	6,500.00
Michigan	E	7.8	62,324.00	54,648.00	116,972.00		35,000.00
Minnesota	D	3.4	5,000.00	10,000.00	15,000.00		
Missouri	E	4.3	22,935.00	45,865.00	68,800.00		
Montana	D	.6	22,098.00	10,058.00	32,156.00	24,726.00	9,616.00
New Hampshire	D	.6	6,340.00	12,680.00	19,020.00		
New Jersey	I	6.0	409,037.00	250,000.00	659,037.00	522,754.00	120,472.00
New Mexico	D	.9	8,679.00	17,357.00	26,036.00	21,036.00	
New York	I	16.7	393,953.00	120,000.00	513,953.00	502,539.50	333,953.00
North Dakota	D	.6	5,000.00	10,000.00	15,000.00	15,000.00	
Oklahoma	D	2.3	6,000.00	12,000.00	18,000.00	12,000.00	
Oregon	I	1.8	126,301.00	53,557.00	179,858.00		86,892.00
Pennsylvania	I	11.3	250,980.00	84,475.00	335,455.00	247,390.00	162,187.00
Puerto Rico	D	2.3	58,580.00	117,156.00	175,736.00	171,529.00	
South Carolina	E	2.4	22,710.50	45,421.00	68,131.50		
Tennessee	D	3.5	10,762.00	21,523.00	32,285.00	25,391.00	
Texas	E	9.5	47,816.77	57,549.45	105,366.22	43,761.24	16,256.16
West Virginia	I	1.8	106,350.00	147,640.00	253,990.00	150,844.00	32,530.00
Total		111.1	2,131,855.44	1,737,723.65	3,869,579.09	2,434,865.81	992,957.86

EXPLANATORY NOTE.—This table shows the budgets of State air pollution control agencies as of July 1966. Federal funds are grants made from the appropriation for fiscal year 1966. The column headed "Type of project" shows the purpose for which Federal grant funds were provided: D denotes a grant for the development of a new air pollution control program, E denotes a grant for the establishment of a ro am alr

next-to-last column shows the preceding year's expenditures, which in most instances also includes Federal funds. The last column shows expenditures for the most recent year prior to receipt of Federal program grants. Such grants were first authorized by the Clean Air Act, adopted December 1963, and were first made from

Question 4: HEW witnesses referred to criteria used in the awards of grants and contracts for pollution abatement research. Please furnish all details on the criteria used for such awards and indicate how such criteria are used to promote technological breakthroughs on new innovations in pollution abatement techniques.

Answer: In the area of air pollution research grants, the Division of Air Pollution of the Public Health Service uses the review mechanism provided by the Division of Research Grants of the National Institutes of Health for initial review of research grant applications. All research grant applications sent to the Public Health Service are first reviewed by the Referral Office, Division of Research Grants, National Institutes of Health, where they are assigned to the appropriate Division or Institute. The applications are also assigned to a study section for technical review and recommendation to the National Advisory Environmental Health Committee (NAEHC) for a secondary review.

The study sections and the NAEHC are composed principally of outstanding authorities in the major fields of research. These special consultants are selected on a nationwide basis. They have accepted responsibility for (*a*) providing technical advice on applications, and (*b*) surveying the status of, and needs for, research in their fields.

The majority of the air pollution grant applications are reviewed by the Environmental Sciences and Engineering B Study Section, which has 13 members. These are chemists, biochemists, botanists, agronomists, chemical and mechanical engineers, and industrial hygienists who have broad scientific experience and insight, and in addition are actively engaged in air pollution research and are recognized experts in their respective fields. Some air pollution applications are reviewed by such study sections as allergy and immunology, biophysics and biophysical chemistry, bacteriology and mycology, behavioral sciences, cell biology, cardiovascular diseases control, hematology, medicinal chemistry, pathology, radiation, and toxicology.

For review of a research grant application for which no regular study section has been established, an ad hoc group is formed of experts in the field of the application. Due to the increasing number of air pollution-oriented applications in the social sciences, this form of initial review is becoming of increasing importance to the air pollution research grant program.

A prime purpose of the research grants is to stimulate advances in scientific knowledge of the nature and control of air pollution. The very nature of the grants program, in which the initiative must come in large measure from nongovernmental scientists, provides an opportunity for wide participation in air pollution research. Thus, the program offers some degree of assurance that promising new ideas and new approaches to air pollution control will be submitted for appraisal and, if deemed worthwhile, financial support. The criteria used in judging air pollution research grant applications are sufficiently flexible to permit awarding of grants to projects which may open up new areas of technical knowledge. In addition, the Division of Air Pollution staff members responsible for administering the research grants program maintain close liaison with the scientific community and encourage scientists with promising ideas to seek Federal grant support.

One of the ways in which the research grants program seeks to stimulate advances in the air pollution field is by supporting multidisciplinary conferences at which experts with experience in complementary areas can give intensive consideration to a single problem. An example was the Conference on Atmospheric Emissions from Sulfate Pulping (Kraft process), held April 25–28, 1966, at Sanibel Island, Fla. This meeting was supported in part by a research grant from the Division of Air Pollution. It was an international meeting, with representation from Canada, Finland, Italy, Mexico, Sweden, and the United States. Participants included scientists from Government, industry, and universities. Among the purposes of the meeting was to document the present status of control technology in the pulping industry and to identify needs for new technology and additional research.

An important segment of the research and development activities of the Division of Air Pollution is supported by contracts with commercial and industrial companies and nonprofit institutions and by project agreements with other Federal agencies. Work performed under contract is essentially an extension of in-house research activities; that is, the basic purpose of awarding contracts for research and development is to take advantage of the special technical capabilities available in industry and elsewhere in Government.

The Division of Air Pollution uses the contract mechanism as one of its prime tools for promoting technological advance in the air pollution field. As the one Federal agency with broad responsibility and experience in dealing with all aspects of the air pollution problem, the Division of Air Pollution is uniquely capable of identifying needs for new technical knowledge and making judgments as to the proper timing of projects which will help meet such needs. This approach enables the Division to see that research and development projects deemed essential to the national control effort are not neglected for lack of incentive; thus, the use of contracts complements the grants mechanism, in which the initiative must come in large measure from outside the Federal Government.

In short, the most important of the criteria for awarding contracts are basic considerations of whether the work to be performed will provide knowledge needed in the pursuit of better control of air pollution and whether the work can most effectively and efficiently be performed outside the Division of Air Pollution. Other criteria are employed, as necessary, to assign priorities to projects for which contracts have been suggested and to select the most qualified contractors for particular projects.

The review procedure for contract proposals from non-Federal sources includes the following steps: (1) Evaluation by technical staff of the Division of Air Pollution and assignment of priority among projects considered worthy of support; (2) review in the Office of the Chief, Division of Air Pollution, particularly from the standpoint of program integration; (3) if appropriate and desirable, evaluation by non-Federal consultants; (4) final assignment of priority. Awards are made, within the extent of available funds, in order of priority.

Two current projects, in which research by industry is being supported by contracts from the Division of Air Pollution, illustrate the way in which this mechanism is being used to promote technological

innovations. In both instances, the projects developed from perceptive observations by scientists originally engaged in work in fields other than air pollution. In the case of work being done by the Sperry-Rand Corp., the observation that variations in the temperature of oxygen interfered with the use of a specific microwave band in communications has led to the development of a promising way of investigating and measuring such meteorological phenomena as temperature inversions and air stagnations, both of which may lead to build-ups of pollution in the air. Use of the microwave probe technique could eliminate the need to employ aircraft to investigate these phenomena. In the case of work being done by the Dalmo-Victor Corp., research in another area led to the development of a promising new means of employing infrared beams to measure concentrations of sulfur oxides in stack gases. An infrared probe, capable of being used from the ground and at some distance from the pollution source, would greatly simplify stack-gas sampling.

Criteria for the planning and conduct of the intramural and extramural research program of the Office of Solid Wastes are based on the purposes stated in section 202(b)(1) of the Solid Waste Disposal Act (Public Law 89–272). The statement is as follows: "The purposes of this Act are (1) to initiate and accelerate a national research and development program for new and improved methods of proper and economic solid waste disposal, including studies directed toward the conservation of natural resources by reducing the amount of waste and unsalvageable materials and by recovery and utilization of potential resources in solid wastes."

The differences between research grants and contracts are significant and important. The grant mechanism, which by policy precludes support to profitmaking organizations, provides support to projects developed by non-Governmental investigators and are reviewed by an outside panel of experts for evaluation. The immediate criteria applied by the study section are (1) The merit of the proposed project; (2) the qualifications of the investigators; (3) the pertinence to the programs of OSW; and (4) likelihood of valid scientific results. Research grants are nondirected in nature, in that the concept is developed by the investigator and supported by the program only if it is considered scientifically meritorious and pertinent to the program of OSW.

The contract program, however, is considered a direct extension of the in-house research program, and proposals, necessarily, are reviewed in a manner different from that for grant proposals. Since the contract operation is an extension of the in-house program, the decision to contract requires that we develop the project protocol and then seek appropriate sources for the conduct of the work. Unsolicited contract proposals which are submitted must fall within the program priority areas to be formally considered. In execution, a contract effort differs from a grant supported effort by virtue of the extensive program participation. Under a contract, the program is in effect buying the time and talent of an investigator and satisfactory performance is achieved through careful contract monitoring.

The type of research which receives support will to a large extent affect the type of innovation which can be expected. Moreover, the direction of the research effort toward the achievement of defined research goals should encourage technological innovation. While it is

possible to encourage research, it is difficult to predict how scientific or technological breakthroughs are secured. Breakthroughs may only be apparent after many research attempts, both successful and unsuccessful, have been made.

The criteria for review of demonstration, study and investigation, and planning grants are found in the printed documents titled "Solid Waste Disposal Demonstration or Study and Investigation Project Grants; Terms and Conditions," and "Solid Waste Disposal Planning Grants; Terms and Conditions."

SOLID-WASTE DISPOSAL PLANNING GRANTS

TERMS AND CONDITIONS

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
OFFICE OF SOLID WASTES
WASHINGTON, D.C. 20201

MARCH 1966

TERMS AND CONDITIONS GOVERNING SOLID-WASTE DISPOSAL PLANNING GRANTS

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DISCRIMINATION PROHIBITED – Title VI of the Civil Rights Act of 1964 states: "No person in the United States shall, on the grounds of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." Therefore, the grant and award programs of the Public Health Service, like every program or activity receiving financial assistance from the Department of Health, Education, and Welfare, must be operated in compliance with this law.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
OFFICE OF SOLID WASTES

TERMS AND CONDITIONS GOVERNING SOLID-WASTE DISPOSAL PLANNING GRANTS*

I. Purpose of Planning Grants

This document sets forth the terms, conditions, and procedures governing the Solid-Waste Disposal Planning Grant Program administered by the Office of Solid Wastes, Public Health Service. The program is authorized by Section 206, Title II, Public Law 89-272, Solid-Waste Disposal Act, and the regulations pursuant thereto (42 CFR, Part 59). It provides for Federal grants to assist State and interstate agencies in making surveys of solid-waste disposal practices and problems, and in developing plans for new and improved methods of proper and economic solid-waste disposal within the jurisdictional areas of such State or interstate agencies (hereinafter referred to as "solid-waste disposal planning grants").

"Solid-waste" means garbage, refuse, and other discarded solid materials, including solid-waste material resulting from industrial, commercial, and agricultural operations, and from community activities. Excluded are solids or dissolved material in domestic sewage or other significant pollutants in water resources such as silt, dissolved or suspended solids in industrial waste water effluents, dissolved materials in irrigation return flows or other common water pollutants. "Solid-waste disposal" means the collection, storage, treatment, utilization, processing, or final disposal of solid waste.

It is not the purpose of these grants to provide financial assistance for State or interstate solid-waste disposal operations or services, other than survey and planning activities.

II. Eligible Applicants

Eligible applicants are (a) State agencies designated by the Governor, or other appropriate State authority, to represent a State, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, and American Samoa, and (b) interstate agencies designated as the sole agency responsible for solid-waste disposal planning within their jurisdictional areas.

The designated agency may be an existing agency of the State government or a new one established for the purpose of the solid-waste disposal survey and planning activity. It may be an interdepartmental agency, such as a commission, committee, or board.

A certification of the designation must be included as a part of the application for a planning grant.

III. Extent of Federal Financial Assistance

Federal funds may be granted to pay not more than 50 percent of the cost of solid-waste disposal survey and planning activities. The remainder is to be provided from non-Federal funds. Funds granted to applicants in any one State are limited to

*These terms and conditions are subject to change as deemed necessary by the Public Health Service.

not more than 12.5 percent of the Federal funds available for this program for each fiscal year's appropriation. For this requirement, planning grants to an interstate agency will be considered to be granted to the States involved in proportion to the amounts of non-Federal funds budgeted for the project by the participating States, or by the participating municipalities located in the respective States.

IV. Applicant Financial Participation Requirements

Applicants are required to provide at least 50 percent of the cost of the solid-waste disposal planning activity from funds other than any other Federal grants, or any non-Federal funds used to match other Federal grants.

V. Period of Support

Although the development of a comprehensive statewide solid-waste disposal plan may require a period longer than three years, applications for grant support will be considered for project periods up to three years. Budget periods within the maximum 3-year project periods are 12-month units beginning on the first day of the month requested in the application, or the first day of the month mutually agreed upon by the applicant and the Office of Solid Wastes. Support from Federal funds beyond an approved project period should be requested at least nine months prior to the termination date of the currently approved project period. (See Section XVIII, Continuation and Renewal Applications.)

VI. Program Direction

The agency designated to be the sole agency responsible for solid-waste disposal activities must have, or plan to employ, a full-time employee responsible for these activities, including solid-waste disposal planning. (See Section VIII, Use of Funds. Only that portion of the employee's time that is devoted to the survey and planning activities may be charged to the grant-supported project.)

VII. Conditions of Planning Grant

In order to be awarded a grant for an approved solid-waste disposal planning project, applicants must provide assurance satisfactory to the Surgeon General of the Public Health Service:

a. That any survey and planning project is directed toward the production of a comprehensive solid-waste disposal plan, including agricultural, commercial, industrial, and domestic solid-waste disposal for the entire geographic area of the State, or of the interstate jurisdiction;

b. That in the conduct of the project there shall be consultation and coordination with other State agencies which have responsibility for any aspect of planning essential to statewide planning for proper and effective solid-waste disposal consistent with the protection of the public health, including such factors as population, urban and metropolitan development, land-use planning, water pollution control, air pollution control, and the feasibility of regional solid-waste disposal programs;

c. That there shall be an effective arrangement to insure full participation and coordination with related State, interstate, regional, and local planning activities including those financed in whole or in part with funds granted under section 701 of the Housing Act of 1954 (40 USC 61); and

d. That non-Federal funds are available for at least 50 percent of the cost of the solid-waste disposal planning project in addition to those which are available for the applicant's solid-waste disposal program activities not included in the planning project.

VIII. Use of Funds

When approved in the application, grant funds may be used for the following costs of carrying out the survey and planning program:

a. Personnel - Salaries and wages, including fringe benefits, of professional, technical, clerical, and other staff, and consultants who will render direct services to the approved project. The salary levels of such personnel may be set by the grantee organization according to its own standards, provided no monetary differential is allowed for such personnel because they are to be paid from grant funds. Consultant fees must be the same as those usually paid by the applicant, but may not be paid to a staff member of the applicant organization or any person employed by the State, or the States participating in an interstate planning activity. Grant funds may not be used to pay the salary of a Federal employee.

b. Equipment - Specialized items which are needed for the project.

c. Supplies - Items which are consumable or expendable, and needed for the project.

d. Travel - Transportation, subsistence, and related costs for travel to be performed during the project period and essential to the conduct of the project.

e. Other Costs - Items not included in one of the above categories, such as communication costs, contractual services, rental of space (but applicant may not charge rent for space which is state-owned or owned by the applicant) utilized by project personnel. Each item for which funds are requested must be separately identified.

IX. Limitations on Use of Funds

a. Grant funds may not be used for activities for which other Federal grant funds are available, or for activities not described in the approved application.

b. Grant funds may not be used for any purpose contrary to the regulations and policies of the Public Health Service or the grantee.

c. All obligations of grant funds must be incurred within the approved project period, and liquidated within one year after the end of the budget period in which the obligation was established.

X. How to Apply

Interested State and interstate agencies are required to submit Form PHS-4872-1, Application for Solid-Waste Disposal Planning Grant, completed in accordance with these terms and conditions and the instructions for completing the application. The original and two copies must be mailed to the appropriate Public Health Service Regional Health Director. (For list of regional offices, see page 8.) In order to compete for Federal funds allocated for the fiscal year 1966, applications must be received in the regional office not later than May 1, 1966.

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In the future, planning grant applications will be considered once a year. Applications may be submitted at any time; however, those received by September 1 of each year will be in competition for the Federal funds available for this program in that fiscal year.

Applicants are urged to secure consultation and assistance through the Public Health Service Regional Health Director prior to the development of their proposals and the preparation of the application.

Applications are available through the regional offices of the Public Health Service or the Office of Solid Wastes, Public Health Service, Washington, D.C. 20201.

XI. Review Procedure and Notification

Applications will be reviewed and evaluated by the regional and headquarters staff of the Office of Solid Wastes. The advice of consultants will be sought as deemed necessary by the Chief of the Office.

Applicants will be notified in writing of the action taken on their applications about six weeks to two months after the cut-off date for receipt of applications.

The regional representative will contact approved applicants to negotiate the beginning date of the project period if it is different from that requested in the application.

XII. Payment Procedure

If the grantee organization has received awards from other Public Health Service programs which are being paid under a letter-of-credit system or other cash control system, the payment for solid-waste disposal planning grants will be incorporated into the same system.

For grantee organizations which have no other awards from the Public Health Service, generally an initial payment will be made shortly before the beginning of the project period, and in the amount necessary for the first quarter (or first three-month period). Subsequent payments will be made upon request and in the amounts needed for the next quarterly period.

XIII. Rebudgeting of Funds

It is expected that expenditures for the project will follow the budget categories (i.e., personnel, equipment, travel, supplies, and other) of the approved application. It is recognized, however, that transfers among the categories may be necessary on occasion. Transfers among budget categories may be made, except in the following instances where prior approval of the transfer must be secured from the Public Health Service:

a. Any expenditures in a budget category for which no funds were initially budgeted in the approved application.

b. When a transfer regardless of amount would result in and/or reflect a change in the scope of the planning activity described in the approved application; and

c. Any transfers into the equipment and travel categories.

Requests for approval of rebudgeting of funds should be submitted by letter to the Office of Solid Wastes.

XIV. Planning Project Revisions

Public Health Service approval of a revision of an approved planning project is required when: (a) a substantial change in the scope, character, or activities of the project occurs or is proposed; (b) a change in the project director is necessitated; or (c) an extension or other change in the project is desired. These revisions may be submitted in letter form, although the extent of the changes under (a) above may require submission of a revised application. Normally, a request for extension in project period will be made only near the scheduled terminating date of the project.

XV. Accountability and Audit

The grantee must establish and maintain a separate account for the grant-supported activity, reflecting all receipts, obligations, and disbursements of grant and matching funds. In addition, the grantee must maintain and make available for audit purposes supporting fiscal records and documentation as evidence of grant and matching fund expenditures. Such documentation shall be retained until the fiscal audit has been conducted and any questions arising from it have been resolved, and shall include:

a. The name of each employee whose salary in whole, or in part, is charged to the grant-supported activity. The agency in which such person is employed shall be identified, together with the total salary paid to such person during the grant period. Time or effort reports, filed within one month following each quarter in which service is provided, are required to support the salaries charged to the grant, and may be presented as best estimates shown in percentages for professional staff and daily time records for non-professional staff.

b. A copy of all travel vouchers, purchase invoices, and contracts charged to the grant-supported activity.

c. An identification of all other costs charged to the planning activity.

A fiscal audit will be made by the audit staff of the Department of Health, Education, and Welfare.

XVI. Expenditure and Program Reports

Reports of expenditures shall be made on the expenditure report form prescribed by the Public Health Service. Reports shall be submitted within 120 days after the close of each 12-month portion of the project period, and also at the end of the project period. These reports shall be submitted in triplicate to the appropriate Regional Health Director.

The State or interstate agency must submit, no later than six months after the end of the project period, a final report of its activities under the grant. When a State plan has resulted, the plan itself together with such additional material as is deemed appropriate may be the final progress report. This report shall be submitted to the appropriate Regional Health Director.

Interim progress reports must accompany applications for continuation grants. (See Section XVIII, Continuation and Renewal Applications.) In addition, the Surgeon General may from time to time request special reports.

XVII. Termination of Grant and Repayment of Grant Funds

A solid-waste disposal planning grant may be terminated at any time before the end of the approved project period by the grantee upon formal notification to the Public Health Service. The Surgeon General may revoke planning grants in whole or in part, or withhold future payments, at any time in the event that he finds that the grantee has failed in a material respect to comply with Federal law or established grant policies, or has failed to carry out the planning activity as approved.

Any unobligated balance in or due the Federal grant account at the end of the project period, at the time of earlier termination of the grant, or after audit, shall be refunded to the Public Health Service. Refund should be made by check payable to the Public Health Service, Department of Health, Education, and Welfare.

XVIII. Continuation and Renewal Applications

In the case of solid-waste disposal planning projects which have been approved for a period of more than one year, and for which an initial grant award has been made in an amount for a lesser period (usually a 12-month period), a continuation application is required. Contingent on the satisfactory development of the planning activity, continuation applications have first claim on available funds. Such applications must be submitted three months prior to the end of each 12-month portion of the project period. Grantees will be provided with the necessary application forms and instructions at the appropriate time.

Applications for renewal of a grant beyond the approved project period should be submitted at least nine months prior to the end of the currently approved period. Renewal grant applications are submitted according to the procedures for a new grant and are reviewed in competition with new and other renewal grant applications.

XIX. Publication and Copyright

As part of solid-waste disposal planning activities, grantees are urged to publish results and findings in the interest of developing public awareness of solid-waste disposal problems and enlisting public support for remedial efforts. Public Health Service review or approval of such publications is not required. It is requested, however, that Federal grant assistance be acknowledged by including in any such publication the following note:

> "This solid-waste disposal planning project was supported in part by a grant from the Public Health Service, Department of Health, Education, and Welfare."

Thirty copies of such publication should be sent to the Regional Health Director for appropriate distribution.

Similarly, an author is free to arrange for copyright without Public Health Service approval provided that the Public Health Service is assured of the right to reproduce and distribute copyrighted material resulting from Federally supported project operations.

XX. Patent Policy

All inventions arising out of activities supported in whole or in part by the Public Health Service grant funds must be promptly and fully reported to the Surgeon General.

Prior to the award of a grant, the Public Health Service must be advised of any outstanding commitments or obligations of the applicant organization, or the professional personnel to be associated with the proposed project, which conflict with the patent regulations of the U.S. Department of Health, Education, and Welfare. A statement concerning patent commitments of the applicant organization, signed by an official of the organization authorized to act in patent matters, must be submitted as part of the initial grant application. In addition, grantees must submit an annual invention statement in connection with continuation applications.

XXI. Compliance with Civil Rights Act of 1964

Title VI of the Civil Rights Act of 1964 states: "No person in the United States, shall on the grounds of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." The solid-waste disposal planning grant must be operated in compliance with this law, and the implementing regulations of the Department of Health, Education, and Welfare (45 CFR, Part 80). (See instructions for filing application).

XXII. Further Information or Assistance

Further information regarding the Solid-Waste Disposal Planning Grant Program, technical assistance, consultation, and application forms may be obtained through the appropriate Regional Health Director.

Information on other solid-waste disposal grant programs may also be obtained from the regional office.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

REGIONAL OFFICES

Region	States Included
Region I 120 Boylston Street Boston, Mass. 02116	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Region II Room 1200, 42 Broadway New York, N.Y. 10004	Delaware, New Jersey, New York, Pennsylvania
Region III 700 East Jefferson Street Charlottesville, Virginia 22901	District of Columbia, Kentucky, Maryland, North Carolina, Virginia, West Virginia, Puerto Rico, Virgin Islands
Region IV Room 404 50 Seventh Street, N.E., Atlanta, Ga. 30323	Alabama, Florida, Georgia, Mississippi, South Carolina, Tennessee
Region V Room 712, New Post Office Building 433 West Van Buren Street Chicago, Illinois 60607	Illinois, Indiana, Michigan, Ohio, Wisconsin
Region VI 601 East Twelfth Street Kansas City, Mo. 64106	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
Region VII 1114 Commerce Street Dallas, Texas 75212	Arkansas, Louisiana, New Mexico, Oklahoma, Texas
Region VIII Room 551 9017 Federal Office Bldg., 19th and Stout Streets Denver, Colo. 80202	Colorado, Idaho, Montana, Utah, Wyoming
Region IX 447 Federal Office Building Civic Center San Francisco, Calif. 94102	Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington, Guam, American Samoa

GPO 904-139

SOLID-WASTE DISPOSAL
DEMONSTRATION OR STUDY AND INVESTIGATION
PROJECT GRANTS

TERMS AND CONDITIONS

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
OFFICE OF SOLID WASTES
WASHINGTON, D.C. 20201

MARCH 1966

TERMS AND CONDITIONS GOVERNING SOLID-WASTE DISPOSAL DEMONSTRATION OR STUDY AND INVESTIGATION PROJECT GRANTS

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Office of Solid Wastes

TERMS AND CONDITIONS GOVERNING SOLID-WASTE DISPOSAL DEMONSTRATION OR STUDY AND INVESTIGATION PROJECT GRANTS*

I. Purpose of Demonstration or Study and Investigation Project Grants

This document sets forth the terms, conditions, and procedures governing the Solid-Waste Disposal Demonstration or Study and Investigation Project Grants Program administered by the Office of Solid Wastes, Public Health Service. The program is authorized by Section 204, Title II, Public Law 89-272, Solid Waste Disposal Act, and the regulations pursuant thereto (42 CFR, Part 59). It provides for Federal grants for the support of demonstration projects of new and improved solid-waste disposal methods, devices, and techniques, studies and investigations of municipal and regional solid-waste disposal problems, practices and programs, and studies and investigations of particular solid-wastes, solid-waste disposal problems, practices, and techniques. This program also provides support for demonstration, study, and investigation projects on the reduction of the amount of solid wastes and unsalvageable waste materials, and the recovery and utilization of potential resources in solid-wastes.

"Solid-waste" means garbage, refuse, and other discarded solid materials, including solid-waste materials resulting from industrial, commercial, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage or other significant pollutants in water resources, such as silt, dissolved or suspended solids in industrial waste water effluents, dissolved materials in irrigation return flows or other common water pollutants. "Solid-waste disposal" means the collection, storage, treatment, utilization, processing, or final disposal of solid-waste.

The Act also authorizes Federal financial assistance for the construction of facilities necessary to demonstration projects, but not for study and investigation projects as stated above. The term "construction" as defined in Section 203 of the Solid Waste Disposal Act means (a) the erection or building of new structures and acquisition of lands or interests therein, or the acquisition, replacement, expansion, remodeling, alteration, modernization, or extension of existing structures, and (b) the acquisition and installation of initial equipment of, or required in connection with, new or newly acquired structures or the expanded, remodeled, altered, modernized or extended part of existing structures (including trucks and other motor vehicles, tractors, cranes, and other machinery) necessary for the proper utilization and operation of the facility after completion of the project; and includes preliminary planning to determine the economic and engineering feasibility and the public health, safety, engineering, architectural, legal, fiscal, and economic aspects

*These terms and conditions are subject to change as deemed necessary by the Public Health Service.

of the project, and any surveys, designs, plans, working drawings, specifications, and other action necessary for carrying out the construction of the facility, and (c) the inspection and supervision of the process of carrying out the project to completion.

II. Eligible Applicants

Any public agency or private non-profit organization in the United States (including the District of Columbia, Puerto Rico, the Virgin Islands, Guam, and American Samoa) is eligible to apply for a grant. A private non-profit organization must provide evidence of its non-profit status.

III. Extent of Federal Financial Assistance

The Federal grant for a solid-waste disposal demonstration or study and investigation project may not exceed two-thirds of the estimated total cost of the project, including the estimated cost of construction of facilities, if any. The remainder is to be provided from non-Federal funds. Funds granted to applicants in any one State are limited to not more than 12.5 percent of the Federal funds available for this program from each fiscal year's appropriation. For this requirement, grants to interstate organizations will be considered to be granted to the States involved in proportion to the amounts of non-Federal funds budgeted for the project by the participating States, or by the participating municipalities located in the respective States.

IV. Applicant Financial Participation Requirements

Applicants are required to provide at least one-third of the estimated total cost of the demonstration project, including the cost of construction of facilities, if any, from funds other than any other Federal grants, or any non-Federal funds used to match other Federal grants.

V. Period of Support

The length of time for which demonstration or study and investigation project grant support may be requested is dependent upon the concept, the objectives, and the methodology proposed. The Public Health Service limits its approval to grant support to project periods up to three years. Budget periods within the maximum 3-year project periods are 12-month units beginning on the first day of the month requested in an approved application, or the first day of the month mutually agreed upon by the applicant and the Office of Solid Wastes. Grantees may request renewal beyond the originally approved project period for projects which require a longer period for completion. Renewal applications compete with new and other renewal applications in the same manner as original applications. (See Section No. XVIII, Continuation and Renewal Applications.)

VI. Program Direction

The demonstration or study and investigation project must be under the direction of a full-time director or coordinator responsible for the direction and supervision of all the activities involved in the project. This is the individual whom the Public Health Service will contact in matters concerning the project.

VII. Conditions of Grant

In order to be awarded a grant for an approved solid-waste disposal "Studies and investigation-Municipal and regional project", applicants must provide assurance satisfactory to the Surgeon General of the Public Health Service:

a. That there shall be an effective arrangement to insure full participation and coordination with related State, interstate, regional, and local planning activities; and

b. That non-Federal funds are available for at least one-third of the cost of the solid-waste disposal demonstration or study and investigation project in addition to those which are available for the applicant's solid-waste disposal program activities not included in the project.

Further, applicants for demonstration project grants must provide assurance satisfactory to the Surgeon General:

c. That open dumping or open burning of solid wastes is not authorized or is prohibited by law within the jurisdiction in which the applicant proposes to conduct the demonstration; except that if such assurance cannot be given:

(1) An applicant which is a unit of government responsible for enforcement of laws and regulations relating to solid-waste disposal practices must set forth a schedule acceptable to the Surgeon General for the elimination of open dumping or open burning within its jurisdiction, or

(2) An applicant which is not a unit of government responsible for enforcing laws and regulations relating to solid-waste disposal practices must submit a schedule officially adopted by the responsible unit of government.

Applicants for demonstration project grants which involve construction must also provide assurance satisfactory to the Surgeon General:

d. That there will be proper and efficient operation and maintenance of the facility after completion of its construction;

e. That the Surgeon General or authorized agents and other persons have access to any facility constructed as part of a demonstration project, and access to the records pertaining to the operation of the facility at any reasonable time;

f. That all laborers and mechanics employed by contractors or subcontractors on a project of the type covered by the Davis-Bacon Act, as amended (40 USC 276a-276a-5) will be paid wages at rates not less than those prevailing on similar work in the locality as determined by the Secretary of Labor in accordance with the Act; and

g. That he will comply with the requirement of Executive Order 11246, February 24, 1965, (30 FR 12319) pertaining to Equal Employment Opportunity, and with the applicable rules and regulations, and prescribed procedures.

Applicants for study and investigation project grants of national value must, in addition, provide assurance satisfactory to the Surgeon General:

h. That the findings of the proposed studies and investigations would be of significant national value in solid-waste disposal practices or programs.

Applicants for study and investigation project grants on municipal and regional solid-waste disposal activities must, in addition:

i. Be, in the judgment of the Surgeon General, legally responsible or is under existing law authorized or empowered upon compliance with legal requirements to assume responsibility for the provision of solid-waste disposal services throughout the geographic area covered by the proposed project; and

j. Give assurance satisfactory to the Surgeon General that the proposed project will be coordinated with any State-wide plans and programs relating to solid-waste disposal.

VIII. Use of Funds

When approved in the application, grant funds may be used for the direct costs of carrying out the demonstration, study, or investigation project. These are:

a. Personnel - Salaries and wages, including fringe benefits, of professional, technical, clerical, and other staff, and consultants who will render direct services to the approved project. The salary levels of such personnel may be set by the grantee organization according to its own standards, provided no monetary differential is allowed for such personnel because they are to be paid from grant funds. Consultant fees must be the same as those usually paid by the applicant, but may not be paid to a staff member of the applicant organization or any person employed by the grantee or by States participating in an interstate project activity. Grant funds may not be used to pay the salary of a Federal employee.

b. Equipment - Specialized items which are needed for the project.

c. Supplies - Items which are consumable or expendable, and needed for the project.

d. Travel - Transportation, subsistence, and related costs for travel to be performed during the project period and essential to the conduct of the project.

e. Other Costs - Items not included in one of the above categories. Examples include: communication costs, contractual services, rental of space (but applicant may not charge rent for space which is State-owned or owned by the applicant) utilized by project personnel. Each item for which funds are requested must be separately identified.

f. Construction of Facilities - When necessary to a demonstration project, (See definition of "construction," Section I, Purpose of Grants, and Sections III and IV on financial participation). Estimated costs of the construction of facilities must be included in the application. The estimates must include the estimated costs of major components or items, such as: land, engineering design, equipment, machinery, labor, and building materials. Final awards will be based on the completed

detailed design of the construction project, and a negotiated agreement as to other requisite terms and conditions.

IX. Limitations on Use of Funds

a. Grant funds may not be used for activities for which other Federal grant funds are available, or for activities not described in the approved application.

b. Grant funds may not be used for any purpose contrary to the regulations and policies of the Public Health Service or the grantee.

c. All obligations of grant funds must be incurred within the approved project period, and liquidated within one year after the end of the budget period in which the obligation was established.

X. How to Apply

Interested organizations are required to submit Form PHS-4873-1, Application for Solid-Waste Disposal Demonstration or Study and Investigation Project Grant, completed in accordance with these terms and conditions and the instructions for completing the application. The signed original and one copy must be mailed directly to the Office of Solid Wastes, Public Health Service, Washington, D.C. 20201. Two additional copies must be sent to the appropriate regional office. (For list of regional offices, see page 10.) In order to compete for Federal funds allocated for the fiscal year 1966, applications must be received by the Office of Solid Wastes not later than May 1, 1966.

In the future, applications may be submitted at any time, but should be submitted at least six months in advance of the anticipated beginning date of the project.

Applicants are urged to request consultation from the State solid-waste disposal agency early in the development and design of projects, as well as to consult with, and secure the support of professional and other groups, or appropriate local agencies that will be utilizing or assisting in the provision of the services contemplated by the project. Applicants also may secure consultation and assistance from the appropriate Public Health Service regional representative.

Applications are available through the regional offices of the Public Health Service or the Office of Solid Wastes, Public Health Service, Washington, D.C. 20201.

XI. Review Procedure and Notification

Applications will be considered for funding three times a year: February, May, and October. They will be reviewed and evaluated by the regional and headquarters staff of the Office of Solid Wastes. At the discretion of the Chief of the Office, expert advice will be secured from outside the Public Health Service on the technical merit of the project proposals.

Applicants will be notified in writing of the action taken on their applications about two to four weeks after the final review.

The regional representative will contact approved applicants to negotiate the beginning date of the project period if it is different from that requested in the application.

Review Criteria - The criteria for evaluating the merits of project proposals are:

1. Degree to which project objectives are clearly established, attainable, and for which progress toward attainment can and will be measured.

2. The substantive merit and potential contribution of the project toward developing knowledge and techniques for meeting the objectives of the Solid Waste Disposal Act.

3. Degree to which the project can be expected to yield or demonstrate results that will be useful and desirable on a national or regional basis.

4. Availability, adequacy, and competence of the personnel, facilities and other resources needed to carry out the project.

5. For those projects involving construction of a facility proposed, the feasibility of the facility to meet the objectives of the project.

6. Extent of participation and coordination of community groups with related interests in the area of solid-waste disposal.

7. Proportion of project costs to be borne by the applicant and, where appropriate, the applicant's plan to continue the activity as an on-going service, after termination of Federal assistance.

8. Degree to which the proposed project is in accordance with the State or regional overall plan, or proposed plan, and priorities with respect to solid-waste disposal services.

XII. Payment Procedure

If the grantee organization has received awards from other Public Health Service programs which are being paid under a letter-of-credit system or other cash control system, the payment for solid-waste disposal project grants will be incorporated into the same system.

For grantee organizations which have no other awards from the Public Health Service, an initial payment generally will be made shortly before the beginning of the project period, and in the amount necessary for the first quarter (or first three-month period). Subsequent payments will be made upon request and in the amounts needed for the next quarterly period.

XIII. Rebudgeting of Funds

It is expected that expenditures for the project will follow the budget categories (i.e., personnel, equipment, travel, supplies, construction, and other) of the approved application. It is recognized, however, that transfers among the categories

may be necessary on occasion. Transfers among budget categories may be made, except in the following instances where prior approval of the transfer must be secured from the Public Health Service:

a. Any expenditures in a budget category for which no funds were initially budgeted in the approved application.

b. When a transfer regardless of amount would result in and/or reflect a change in the scope of the project or when the grantee is uncertain as to whether a change affects the character or scope of a project as described in the approved application.

c. Any transfers into the equipment, travel, or construction categories.

Requests for approval of rebudgeting of funds should be submitted by letter to the Office of Solid Wastes.

XIV. Project Revisions

Public Health Service approval of a revision of an approved project is required when: (a) a substantial change in the scope, character, or activities of the project occurs or is proposed; (b) a change in the project director is necessitated; or (c) an extension or other change in the project is desired. These revisions may be submitted in letter form, although the extent of the changes under (a) above may require submission of a revised application. Normally, a request for extension in project period will be made only near the scheduled terminating date of the project.

XV. Accountability and Audit

The grantee must establish and maintain a separate account for the grant-supported activity, reflecting all receipts, obligations, and disbursements of grant and matching funds. In addition, it must maintain and make available for audit purposes supporting fiscal records and documentation as evidence of grant and matching fund expenditures. Such documentation shall be retained until the fiscal audit has been conducted and any questions arising from it have been resolved, and shall include:

a. The name of each employee whose salary in whole, or in part, is charged to the grant-supported activity, together with the total salary paid to such person during the grant period. Time or effort reports, filed within one month following each quarter in which service is provided, are required to support the salaries charged to the grant, and may be presented as best estimates shown in percentages for professional staff and daily time records for non-professional staff.

b. A copy of all travel vouchers, purchase invoices, and contracts charged to the grant-supported activity.

c. An identification of all other costs charged to the grant-supported activity.

A fiscal audit will be made by the audit staff of the Department of Health, Education, and Welfare.

XVI. Expenditure and Program Reports

Reports of expenditures shall be made on the expenditures report form prescribed by the Public Health Service. Reports shall be submitted within 120 days after the close of each 12-month portion of the project period, and also at the end of the project period. These reports shall be submitted in triplicate to the appropriate Regional Health Director.

The grantee must submit, no later than six months after the end of the project period, a final report of its activities under the grant. Six copies of the report should be submitted to the appropriate Regional Health Director.

Interim progress reports must accompany applications for continuation grants. (See Section XVIII, Continuation and Renewal Applications.) In addition, the Surgeon General may from time to time request special reports.

XVII. Termination of Grant and Repayment of Grant Funds

A solid-waste disposal demonstration or study and investigation project may be terminated at any time before the end of the approved project period by the grantee upon formal notification to the Public Health Service. The Surgeon General may revoke a grant in whole or in part, or withhold future payments, at any time in the event that he finds that the grantee has failed in a material respect to comply with Federal law or established grant policies, or has failed to carry out the activity as approved.

Any unobligated balance in or due the Federal grant account at the end of the project period, at the time of earlier termination of the grant, or after audit, shall be refunded to the Public Health Service. Refund should be made by check payable to the Public Health Service, Department of Health, Education, and Welfare.

XVIII. Continuation and Renewal Applications

In the case of solid-waste disposal projects which have been approved for a period of more than one year, and for which an initial grant award has been made in an amount for a lesser period (usually a 12-month period), a continuation application is required. Contingent on the satisfactory development of the project, continuation applications have first claim on available funds. Such applications must be submitted three months prior to the end of each 12-month portion of the project period. Grantees will be provided with the necessary application forms and instructions at the appropriate time.

Applications for renewal of a grant beyond the approved project period should be submitted at least nine months prior to the end of the currently approved period. Renewal grant applications are submitted according to the procedures for a new grant and are reviewed in competition with new and other renewal grant applications.

XIX. Publication and Copyright

As part of solid-waste disposal activities, grantees are urged to publish results and findings in the interest of developing public awareness of solid-waste disposal problems and enlisting public support for remedial efforts.

Public Health Service review or approval of such publications is not required. It is requested, however, that Federal grant assistance be acknowledged by including in any such publication the following note:

> "This solid-waste disposal (demonstration or study and investigation) project was supported in part by a grant from the Public Health Service, Department of Health, Education, and Welfare."

Thirty copies of such publication should be sent to the Regional Health Director for appropriate distribution.

Similarly, an author is free to arrange for copyright without Public Health Service approval provided that the Public Health Service is assured of the right to reproduce and distribute copyrighted material resulting from Federally supported project operations.

XX. Patent Policy

All inventions arising out of activities supported in whole or in part by the Public Health Service grant funds must be promptly and fully reported to the Surgeon General.

Prior to the award of a grant, the Public Health Service must be advised of any outstanding commitments or obligations of the applicant organization, or the professional personnel to be associated with the proposed project, which conflict with the patent regulations of the U.S. Department of Health, Education, and Welfare. A statement concerning patent commitments of the applicant organization, signed by an official of the organization authorized to act in patent matters, must be submitted as part of the initial grant application. In addition, grantees must submit an annual invention statement in connection with continuation applications.

XXI. Compliance with Civil Rights Act of 1964

Title VI of the Civil Rights Act of 1964 states: "No person in the United States, shall on the grounds of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance." The solid-waste disposal project grant must be operated in compliance with this law, and the implementing regulations of the Department of Health, Education, and Welfare (45 CFR, Part 80). (See instructions for filing application).

XXII. Further Information or Assistance

Further information regarding the Solid Waste Disposal Demonstration, Study and Investigation Project Grant Program, technical assistance, consultation, and application forms may be obtained through the appropriate Regional Health Director.

Information on other solid-waste disposal grant programs may also be obtained from the regional office.

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

REGIONAL OFFICES

Region	States Included
Region I 120 Boylston Street Boston, Mass. 02116	Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
Region II Room 1200, 42 Broadway New York, N.Y. 10004	Delaware, New Jersey, New York, Pennsylvania
Region III 700 East Jefferson Street Charlottesville, Virginia 22901	District of Columbia, Kentucky, Maryland, North Carolina, Virginia, West Virginia, Puerto Rico, Virgin Islands
Region IV Room 404 50 Seventh Street, N. E., Atlanta, Ga. 30323	Alabama, Florida, Georgia, Mississippi, South Carolina, Tennessee
Region V Room 712, New Post Office Building 433 West Van Buren Street Chicago, Illinois 60607	Illinois, Indiana, Michigan, Ohio, Wisconsin
Region VI 601 East Twelfth Street Kansas City, Mo. 64106	Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota
Region VII 1114 Commerce Street Dallas, Texas 75212	Arkansas, Louisiana, New Mexico, Oklahoma, Texas
Region VIII Room 551 9017 Federal Office Bldg., 19th and Stout Streets Denver, Colo. 80202	Colorado, Idaho, Montana, Utah, Wyoming
Region IX 447 Federal Office Building Civic Center San Francisco, Calif. 94102	Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington, Guam, American Samoa

Question 5: With respect to the coordination of Federal action regarding air, water, and solid waste pollution abatement, what agreements exist between HEW and other agencies and how is coordination effected to insure that Federal choices and emphasis among research programs do not create problems and deficiencies in other areas?

Answer: The recent transfer of the Federal Water Pollution Control Administration from the Department of Health, Education, and Welfare to the Department of the Interior will require that new lines of communication and coordination be established with this program. The necessary arrangements are currently being worked out by representatives of both Departments.

Coordination with the Bureau of Mines of the Department of the Interior, whose research in air pollution is supported in part by contracts with the Division of Air Pollution, is accomplished by frequent top-level meetings and almost constant liaison among lower level scientific personnel. The Bureau of Mines (and all other Federal agencies conducting research under contracts with the Division of Air Pollution) submits quarterly reports of technical progress and an annual summary report.

The need for close coordination with the activities of the Office of Solid Waste Disposal of the Public Health Service is met in large part through constant communication with staff of that program. The fact that both the Office of Solid Wastes and the Division of Air Pollution are in the same organizational unit of the Public Health Service facilitates liaison and provides opportunities for policy and planning coordination at the next highest level of authority.

The Interdepartmental Committee for Atmospheric Sciences of the Federal Council for Science and Technology is charged with promoting closer cooperation among Federal agencies concerned with problems in the atmospheric sciences, facilitating resolution of common problems, improving the planning and management of research in this area, and advising the President on coordination of Federal programs in the atmospheric sciences. The Division of Air Pollution represents the Department of Health, Education, and Welfare on this Committee.

The Division of Air Pollution also represents the Department on the Federal Committee for Meteorological Services and Applied Meteorological Research, which seeks to coordinate the activities of all Federal agencies that provide and use meteorological services or are engaged in meteorological research. The purposes of this group include coordination of research activities, sharing of facilities where possible, standardization of equipment, cooperation in recruitment and training, and identification of major limitations in meteorological knowledge.

A number of Federal agencies which are not directly concerned with air pollution are nonetheless involved in activities which have an important bearing on community air pollution problems. Examples of such programs include the urban renewal and urban mass transit activities of the Department of Housing and Urban Development and the activities of the General Services Administration with respect to purchases of motor vehicles for use by Federal agencies. The legislation authorizing the urban mass transit program required that new vehicles purchased with Federal aid meet air pollution control speci-

fications established by the Secretary of Health, Education, and Welfare. The development and application of these specifications have been a subject of regular contact between personnel of the Division of Air Pollution and the Department of Housing and Urban Development. In similar fashion, standards established by the General Services Administration for control of air pollution from the new motor vehicles it purchases were developed through consultation with the Division of Air Pollution.

No mechanism exists for regular liaison with the National Science Foundation. The National Science Foundation has not requested that it be kept advised of technological needs in the air pollution field.

The accompanying report provides additional information on coordination of Federal activities in the field of air pollution control.

CURRENT TRENDS IN FEDERAL INTERAGENCY RELATIONS CONCERNING AIR POLLUTION

(By the Division of Air Pollution, Public Health Service, Department of Health, Education, and Welfare, June 1965)

An important and interesting aspect of the Federal air pollution control program, since its inception in 1955 with the passage of Public Law 84–159, has been the participation in this program by several Federal departments and agencies. However, recent developments have been altering the pattern of interagency relationships in this field.

Prior to the enactment of P.L. 84–159 in 1955, "an Act to provide research and technical assistance relating to air pollution control," an Ad Hoc Interdepartmental Committee on Community Air Pollution was established, in accordance with an informal request from the Office of the President, to survey the Federal role in air pollution and to make recommendations. In its report of April 8, 1955, the Committee included, among its several recommendations, the following: "In conducting this program, the Department of Health, Education, and Welfare should utilize the available facilities and resources of other Federal departments and agencies for such necessary services as can best be provided by them."

P.L. 84–159, which was the first Federal statute authorizing an organized Federal air pollution program, incorporated many of the key recommendations of the Ad Hoc Committee. It authorized the Surgeon General, U.S. Public Health Service, of the Department of Health, Education, and Welfare, to develop broad air pollution research programs, in cooperation with other Federal agencies. The Report of the Committee and the Federal air pollution legislation which followed in 1955, clearly designated the Department of Health, Education, and Welfare to be the responsible agency for planning, directing, and conducting the overall program.

This early and definite recognition of the desirability of broad Federal agency participation, under the general direction of the Public Health Service, Department of Health, Education, and Welfare was based on several key factors:

(1) The potential serious health hazards of air pollution, as exemplified by the Donora and London disasters and the acute problem in Los Angeles, constituted the basic impetus for the initiation of the Federal program. As a consequence, central responsibility for the program was lodged in the PHS–DHEW. At the same time, the potential health hazards created a sense of urgency to protect the public health through the rapid development of an effective air pollution control program. The use of existing organizations, with applicable technical competence and experience, appeared to offer the most promise for the earliest possible progress.

(2) On general principles of efficiency and sound management, it appeared desirable to make use of existing specialized technical expertise in the Federal establishment, and to avoid the potential cost of unnecessary duplication in building up parallel technical groups. In essence, the rationale of the Economy Act of 1932, which authorized the transfer of funds between Government agencies for the exchange of appropriate services, is pertinent to this approach.

(3) The terms of P.L. 84–159 were such as to place major emphasis on research programs. Broad research activity was authorized toward the end of elucidating the causes, behavior, effects, and means for control of air pollution. Such research activity necessarily involves many scientific, engineering, and related

technical disciplines. These disciplines, with the related accumulation of organizational experience, were to be found in several of the Federal departments and agencies. Several prominent examples are the meteorological competence of the Weather Bureau, U.S. Department of Commerce, the plant physiology competence in the U.S. Department of Agriculture, and the combustion and fuel technology experience of the Bureau of Mines, U.S. Department of the Interior.

Accordingly, a series of contractual arrangements was developed between the Public Health Service and the several Federal departments and agencies. From the central Federal air pollution appropriation made to the Public Health Service, funds were transferred, under the terms of the Economy Act, to the contractor Federal agencies. A summary listing of these contractual arrangements follows:

FEDERAL AGENCY AND NATURE OF SERVICES PROVIDED

Department of Agriculture

Research studies and technical assistance activities to determine the effects of air pollutants on agriculture and to explore the use of agricultural damage as indicators of air pollution. Department of Agriculture scientific personnel have been assigned to the Division of Air Pollution laboratories in Cincinnati, Ohio, under this arrangement.

National Bureau of Standards, Department of Commerce

Research projects concerned with the chemical reactions of various pollutants in the atmospheres and with the development of analytical procedures for the determination and measurement of certain pollutants. This work has been principally carried out in the research facilities of the National Bureau of Standards.

Bureau of Mines, Department of the Interior

A variety of research projects relating to combustion processes, including work on sulfur dioxide removal from flue gas, desulfurization of fuel oil, removal of pollutants from motor vehicle exhaust, analytical methods for measurement of motor vehicle exhaust, extinguishment of burning coal mine waste piles, and incineration techniques. These activities have been carried out in several of the Bureau of Mines' laboratories.

Weather Bureau, Department of Commerce

Research and technical assistance activities concerned with the meteorological aspects of air pollution. These include the transport of air pollutants, diffusion and dispersal of pollutants, tracer studies, development of episode forecasting techniques, and adaptation of the meteorological factor to land use control in industrial zoning. The Weather Bureau has a team of professional meteorologists assigned to the Division of Air Pollution research laboratories in Cincinnati, Ohio, where the principal activities are conducted; some air pollution research is carried out in Weather Bureau facilities.

Library of Congress

Air pollution literature abstracting services which have been coordinated with the related activities of the Air Pollution Control Association and appear as APCA Abstracts. The Library concentrates on foreign journals and on the biological sciences.

Tennessee Valley Authority

Studies to document flume behavior and related elements under various meteorological conditions with emphasis upon studies concerned with sulfur dioxide emissions. This work is primarily carried out at TVA plants and facilities.

Census Bureau, Department of Commerce

The Census Bureau has been used intermittently, on a contract basis, as a key input factor for epidemiological studies involving large population groups. Studies associating various diseases with air pollution, particularly in urban areas, make use of data developed by the Bureau.

For the most part, these contractual relationships started in 1956 and have continued to date. The specific, discrete, projects which are undertaken by the contractor agencies are developed through technical discussions and negotiations and are documented in formal letters of agreement between the Public Health Service and the agencies concerned. Technical progress and related fiscal reports are submitted to the Public Health Service on a quarterly basis.

The common thread which runs through all of the arrangements listed above is the research and research-related nature of the services provided. As mentioned above, this was a logical consequence of the research emphasis of P.L. 84–159, the first Federal air pollution law enacted in 1955.

Much valuable scientific and technical information has resulted from this intra-Governmental research effort. It is not the purpose of this paper to document these contributions, but some degree of this contribution is evidenced by the many published technical papers, reports, monographs, and other manifestations of the work of these agencies.

CURRENT TRENDS SINCE THE CLEAN AIR ACT OF 1963

The Clean Air Act (Public Law 88–206), "an Act to improve, strengthen, and accelerate programs for the prevention and abatement of air pollution," was signed by the President December 17, 1963. The main thrust of this legislation may be summarized as an extension of the Federal air pollution program from one of a relatively limited research and technical assistance orientation to one placing much greater emphasis on prevention and control of air pollution.

While continuing to recognize "that the prevention and control of air pollution at its source is the primary responsibility of States and local governments," this new emphasis on control is revealed in several provisions of the Act. Grants-in-aid, on a matching basis, are authorized for award to States and communities for initiation, extension, or improvement of air pollution control programs. Limited Federal abatement authority is authorized, principally in areas of interstate air pollution. Another provision empowers the Secretary of Health, Education, and Welfare to carry out a permit system as a means of controlling air pollution from Federal installations.

This recent legislative emphasis on actual control activities is reflected in a newly emerging pattern of relationships between other Federal agencies and the Department of Health, Education, and Welfare which continues to have responsibility for and the overall coordinating and directing role in the Federal air pollution program.

Concomitant with these newly emerging patterns reflecting control emphasis, the Clean Air Act calls for a strengthening of the research program and, additionally, calls for special attention to specific areas of research. Examples of such areas are the development of processes, methods and prototype devices for control; the development of air quality criteria; and research toward the development of techniques for extraction of sulfur from fuels. This renewed emphasis on difficult research problem areas will probably result in a continued and accelerated use of certain of the Federal agencies as a means of moving ahead more rapidly. For example, the expertise of the Bureau of Mines in fuel technology will be most valuable in a stepped-up research activity concerned with the widespread problem of oxides of sulfur in the atmosphere.

Thus, the research challenges still before us will continue to require contractual research services of key Federal agencies. At the same time there is also now emerging a new pattern of Federal agency relationships, concerned principally with prevention and control activity.

AIR POLLUTION FROM FEDERAL FACILITIES

The activity involving the most broad and far-reaching set of Federal agency relationships relates to the provisions of Section 7 of the Clean Air Act, "Cooperation by Federal Agencies to Control Air Pollution from Federal Facilities." Section 7(a) essentially carries forward previous Government policy (Executive Order 10779 of 1958) and previous statutory provisions in P.L. 84–159 calling upon Federal agencies to cooperate, to the extent practicable, with the Department of Health, Education, and Welfare and with State and local air pollution control agencies, in controlling pollutant discharges from Federal installations. Section 7(b) authorizes the Secretary of the Department of Health, Education, and Welfare to establish classes of potential pollution sources under Federal jurisdiction and authorizes the operation of a permit system for such sources.

These provisions of the Act have their roots in Congressional intent that Federal installations perform in an exemplary manner and in general observe good community relationships. The legal problems involving Federal sovereignty and immunity from State or local regulations, of course, still obtain, but the intent is to encourage compliance and to place the Department of Health, Education, and Welfare in a position of leadership, guidance, and direction to insure

that this is accomplished. The Office of the President, through the Bureau of the Budget, is firmly in support of a vigorous implementation of Section 7. The latter agency has directed in its instructions to all Federal departments and agencies, that in preparing budget estimates for the design and construction of new Federal facilities, they include provisions for air and water pollution controls in accordance with technical instructions issued by the Public Health Service. Such instructions have now been developed by the Public Health Service for the guidance of Federal agencies. In addition, technical instructions, in the form of guides of good practice, for the use of Federal agencies in dealing with pollution from existing facilities are now being prepared.

The administrative and operational procedures for the operation of the permit system by the Department of Health, Education, and Welfare are being developed. The first class of pollution sources to be given attention is open burning of material for disposal or salvage. After an inventory of atmospheric emissions from Federal installations is completed, it will be possible to adequately classify the potential sources of other pollution from Federal installations.

If one were to assess the potential for success, from a strictly classical and theoretical management viewpoint, of the Department of Health, Education, and Welfare effectively operating a control program where sister departments are the objects of control, and where no administrative, bureaucratic, or hierarchial advantage exists for the Department of Health, Education, and Welfare, one might indeed be somewhat pessimistic. Classical theory notwithstanding, our experience to date gives us every reason for optimism on the future success of this program. Initial responses from the many Federal agencies which operate installations have indicated a clear recognition of their responsibilities and a desire to cooperate with the Department of Health, Education, and Welfare in carrying out Section 7 of the Clean Air Act. The Division of Air Pollution, of the Public Health Service, has established a Federal Agencies Section in its Abatement Branch, which is now implementing this program on a full-time basis. This type of program administration, involving practically daily contacts with the Federal agencies, is in contrast to the research contract type of relationship, where a Public Health Service technical monitor periodically reviews the work of the contractor agency, and consults on an intermittent basis.

There is continuing interest by the Congress in the problem of effective programs to insure exemplary air pollution control practices by Federal agencies. At this writing, the Senate has passed S. 560, which calls for the Secretary of Health, Education, and Welfare to establish automotive emission standards for Governmentally purchased vehicles. The Act would also provide for greater authority for the Secretary through a program of certification as to acceptability of proposed air pollution control measures in Federal installations.

URBAN MASS TRANSPORTATION ACT

Another area where the Department of Health, Education, and Welfare has entered into new relationships with another Federal agency, concerned with air pollution prevention and control, is in the field of urban mass transit. Section 11 of the Urban Mass Transportation Act (P.L. 88-365), enacted by Congress in 1964, directs the Administrator of the Housing and Home Finance Agency, in reviewing applications for Federal financial assistance, to take into consideration whether equipment and facilities financed under the Act will be designed and equipped to prevent and control air pollution in accordance with criteria established by the Secretary of the Department of Health, Education, and Welfare. The legislative history of this Act reveals the intent of the Congress, in encouraging needed solutions to the difficult problems of city traffic congestion, to avoid an aggravation of air pollution problems associated with the several forms of mass transit—such as bus operation and power stations for rail systems.

Technical criteria have been developed and transmitted to the Administrator of the Housing and Home Finance Agency for his use in reviewing applications for Federal financial assistance for transit equipment and facilities.

Technical representatives of the Division of Air Pollution and the Housing and Home Finance Agency plan to meet periodically to review the program under Section 11 of the Mass Transportation Act. Amendment to the air pollution criteria will be made as experience indicates a need therefor. The Division of Air Pollution anticipates being called upon periodically for specialized technical consultation in connection with special problems or questions of interpretation, which are likely to arise in the course of the administration of the mass transpor-

tation program by the Housing and Home Finance Agency. The Division of Air Pollution views this new program as a promising means for preventing new air pollution problems from developing as an unwanted side effect of a broad scaled, national program to promote urban mass transportation.

OTHER INTER-AGENCY RELATIONSHIPS

Principal attention in this paper has been given to the newly established Federal agency relationships outlined above because these relationships have their basis directly in recently enacted Federal legislation. Several other patterns of relationships, which have a control rather than a research emphasis, are also emerging, even though no specific legislation has conditioned or occasioned them.

Thus, in the field of air pollution, mutual interests of the Public Health Service and the Housing and Home Finance Agency are based upon the character of air pollution as both a cause of urban blight and deterioration, and an effect of the various facets of urban development. This mutuality of interests has been the basis for discussions directed toward the development of cooperative efforts between the two agencies which seek (1) to develop in State and local community leaders and planning agencies a recognition of this interrelationship, (2) to encourage communities to incorporate explicitly in their community, planning and survey activities and in their community development program operations, appropriate elements reflecting this interrelationship, and (3) to develop such policies and procedures within the two Federal agencies, particularly with respect to financial aids and technical assistance, as will foster the accomplishment of these objectives.

The purpose of the Urban Planning Assistance ("701") Grants administered by the Housing and Home Finance Agency is to provide assistance for comprehensive planning for entire urban areas. Studies of air pollution are considered important, both by the Housing and Home Finance Agency and the Public Health Service, as factors in sound comprehensive urban planning; based upon this recognition, the two agencies have worked closely concerning a study of air pollution in the Chicago metropolitan area conducted jointly by the Regional Planning Agency and the State and local air pollution agencies and financed in part by a "701" grant.

The Public Health Service has had discussions with the Housing and Home Finance Agency on a series of other areas although no formal operating programs involving the Service have as yet ensued. Some of the areas of joint concern include the possible incorporation of air pollution as an element of the Workable Program for Community Improvement required as a prerequisite to various forms of HHFA financial assistance, urban transportation planning, open space planning, general zoning developments, problems concerning the disposal of demolition debris from urban renewal projects, solid waste removal problems, and community facilities financial assistance as they relate to incineration. It is probable, that as these programs develop, the air pollution component will tend to be more formally and regularly incorporated into these programs. The Public Health Service will be continuing to work with the Housing and Home Finance Agency toward this end.

An interesting and potentially productive relationship has developed in recent years between the Federal Power Commission and the Public Health Service with respect to air pollution. The Public Health Service has been requested by the Federal Power Commission to provide technical information and testimony in connection with applications before the Commission concerned with the transmission of natural gas. The air pollution issue has arisen with respect to the pollution emitting characteristics of various fuels, the location of power generating plants, and the health and other effects of various pollutants. The Chief of the Division of Air Pollution, Mr. Vernon G. MacKenzie, has served on an air pollution advisory group which provided information for the Federal Power Commission National Power Survey issued in 1964. These relationships in general indicate the recognition of the air pollution problem as a factor to be given consideration in the types of determinations the Federal Power Commission has the responsibility to make.

In its January 1965 Economic Report to the President, the Council of Economic Advisors gave explicit attention, for the first time, to air pollution. The Report pointed out the lack of economic incentives for polluters to correct their pollution problems. The Department of Health, Education, and Welfare has a representative on a working group established by the Council to explore

possible avenues for presenting financial incentives for polluters to take prevention and control measures. The Division of Air Pollution has been providing technical background on air pollution to assist in consideration and formulation of Federal policy in this area.

IMPLICATIONS FOR STATE, LOCAL, AND REGIONAL AIR POLLUTION CONTROL PROGRAMS

The various kinds of interrelationships between air pollution and other facets of public and private activities, which are the basis for the interagency relationships at the Federal level discussed above, are, of course, relevant to State and local programs for the prevention and control of air pollution. In the United States the primary responsibility for the control of air pollution at its source rests with State and local governments; consequently, the need for and the opportunity to develop a high degree of coordination and cooperation among all agencies of local government is particularly great. The keynote to this approach to air pollution control was well stated by S. Smith Griswold, Air Pollution Control Officer of the Los Angeles County Air Pollution Control District, as follows:[1]

"Across the country thousands of municipal, county and State officials are vitally concerned with the development and redevelopment of our Nation's urban and metropolitan communities. We're demolishing old structures, redesigning our transportation systems, and executing a wholesale physical reconstruction of our community core areas. While we're doing this, we should also be concerned with the quality of air our citizens are breathing. We should place the protection and preservation of acceptable air quality on a par with the physical reconstruction of our communities, and we should give increased attention to the many facets of community design that must affect our future community air quality configuration."

The possible ways in which this concept might be implemented are discussed below:

(1) An obvious parallel at the State and local levels to the Federal program for control of air pollution from Federal installations, discussed above, is the importance of making sure that the State, county, and city conduct their activities with the least possible contribution to local air pollution problems. Steps need to be taken to insure that the very best available technology for controlling air pollution is incorporated in the plans and specifications for the construction of public facilities such as schools, hospitals, public housing, public works operations, incinerators and similar types of projects. There are many ways that this can be administratively accomplished but the essential ingredient is that an explicit element of the planning for such facilities be consideration of their air pollution potential. This can be accomplished by requiring all such plans to be reviewed by the air pollution agency or requiring adherence to technical criteria established by the air pollution control agency. The effective implementation of any such system will obviously require the strong support and commitment of top officials and legislative bodies to the need for air pollution control.

(2) Many of the crucial decisions concerning whether or not we are presently creating air pollution problems for the future are made prior to the actual time that a particular construction program is implemented. These decisions are made in connection with community planning with regard to land uses and the subsequent zoning decisions to administratively implement such plans. The kinds of uses to which land will be put and the criteria or standards used for determining the specific characteristics of activities permitted to be conducted can be crucial in determining the air quality of our communities in the future. As such, there is a clear need for the consideration of the air pollution potential involved in such decisions. In the light of these considerations, the air pollution agency should be recognized as an important technical advisor to planning and zoning agencies. There are, of course, in addition to the air pollution factor, a number of other important considerations and issues which will affect the final decisions which are made. It is important, however, that air pollution considerations be explicitly available to the decision-maker; the lack of information available to the decision-maker should not be the basis for creation of new air pollution problems by default.

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[1] "Response: The Reasonable Approach to Air Pollution Control," *National Conference on Air Pollution (1962)*, Proceedings (Washington: U.S. Government Printing Office, 1963), p. 14.

(3) Considerable room for cooperation and coordination, particularly at the municipal level, exists with regard to the regulatory programs concerning the health and safety aspects of housing and other types of construction. Such agencies as health departments, building departments, fire departments as well as air pollution agencies are frequently concerned with the inspection, surveillance, and enforcement of various local ordinances, rules, and regulations in this field. The difficult problems involved in attempting to coordinate these activities so as to avoid inefficiencies, overlaps, duplications and conflicting requirements upon those subject to such regulation have long been a matter of discussion and controversy. It is, however, an area of great importance to the overall quality of local government and should be of intense interest to air pollution agencies as a possible means of strengthening their programs while conserving scarce resources, funds and personnel.

(4) Greater coordination between air pollution agencies and agencies concerned with the construction of highways, urban renewal projects and other operations of this nature is desirable with respect to the problem of preventing air pollution associated with the disposal of demolition debris. Although improved technology is vitally needed with respect to this problem, greater attention to the utilization of presently available methods and practices can do much to improve existing situations. Further, concerted attention by all agencies and groups concerned is likely to stimulate needed research and development activities concerning this problem.

(5) A particular aspect of the general problem of governmentally controlled or aided construction and facilities relates to urban renewal projects and public housing. With respect to public housing, careful attention needs to be given to the incorporation in such projects of appropriate design criteria with respect to heating and incineration equipment. Further, attention needs to be given to the employment and training of personnel responsible for the maintenance and operation of such equipment. With regard to urban renewal projects, inter-agency coordination in developing criteria and standards with respect to demolition debris disposal, heating, incineration, and other potential sources of air pollution, to which the private developer would agree to conform, would be highly desirable. This, of course, is a special application of a more general problem of carrying out the responsibilities of air pollution control agencies with respect to apartment houses, commercial buildings and other sources under private as well as public control.

SUMMARY

Under the first Federal Air Pollution Act of 1955, which assigned the responsibility for developing a national program to the Public Health Service, a significant phase of the program involved other Federal agencies through a series of contractual relationships. These interdepartmental relationships were limited, however, to the objective of capitalizing on the diverse research facilities and specialized competencies within the Federal establishment, as a means of accelerating the research and technical assistance program authorized under the Act.

With the passage of the Clean Air Act of 1963, a major new emphasis has been added to the Federal air pollution control program. Application of technical knowledge, through broadly accelerated control programs, is the predominant theme of this Act. This emphasis is reflected in current trends in the nature and type of the Public Health Service's developing relationships with other Federal agencies. The emerging PHS programs to prevent and control air pollution from Federal facilities, the PHS role in preventing pollution arising from transportation systems aided under the new Urban Mass Transportation Act, and other developing interagency relationships and problem areas are examples of this recent trend. There are important parallels and implications of these new Federal relationships for State, local, and regional air pollution control programs.

Coordination of Federal efforts in the closely related fields of air pollution control and solid waste management is facilitated by the fact that both Federal programs are located within the same Bureau of the Public Health Service. Furthermore, close liaison is maintained between the staffs of the Office of Solid Wastes and the Division of Air Pollution to assure complete and productive coordination of the research and development activities of the two programs in areas where their interests and responsibilities merge.

The Department of the Interior is assigned certain responsibilities under the Solid Waste Disposal Act of 1965. A memorandum of understanding entered into by the Departments of Health, Education, and Welfare and the Interior, a copy of which is printed below, outlines the mechanism of coordination whereby the two Departments coordinate their respective efforts under the Solid Waste Disposal Act.

Coordination with the water pollution program of the Department of the Interior is managed through the Office of the Secretary of Health, Education, and Welfare. The recent transfer of the Federal Water Pollution Control Administration from the Department of Health, Education, and Welfare to the Department of the Interior has caused some disruption of communication between this Office and the FWPCA. It will be necessary to redefine effective avenues through which coordination in the area of solid waste research and development can be achieved.

Because the Department of Housing and Urban Development has certain programs and responsibilities relating to urban planning, which can involve solid waste management planning, close contact is maintained between the Office of Solid Wastes and appropriate agencies and officials of the Department of Housing and Urban Development to assure that the efforts of these two agencies complement, rather than conflict with, one another.

Enclosed for the information of the Subcommittee is a copy of a cooperative project agreement involving the Office of Solid Wastes, the Tennessee Valley Authority, and Johnson City, Tenn. (see p. 709). This agreement illustrates the type of cooperative coordinated effort which will increasingly call on the resources of two or more Federal agencies involved in programs directly or tangentially relating to the management of solid wastes and research and development in this field.

Attachments.

MEMORANDUM OF UNDERSTANDING; DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, PUBLIC HEALTH SERVICE; AND THE DEPARTMENT OF THE INTERIOR, BUREAU OF MINES

IMPLEMENTATION OF TITLE II, THE SOLID WASTE DISPOSAL ACT OF 1965, PUBLIC LAW 89–272

The Department of Health, Education, and Welfare, Public Health Service, and the Department of the Interior, Bureau of Mines, each has an area of responsibility for implementing the provisions of Public Law 89–272, the Solid Waste Disposal Act, and are mutually desirous of developing a coordinated program toward the attainment of common objectives under the Act. The report of the House Committee on Interstate and Foreign Commerce (Report No. 899, Page 27, lines 19 through 36), states that, under the provisions of the bill, subsequently enacted as Public Law 89–272, the Department of Health, Education, and Welfare "would be responsible for administration of the Act, except that the Secretary of the Interior will be responsible for 'solid waste resulting from the extraction, processing or utilization of minerals and fossile fuels where the generation, production, or reuse of such wastes is or may be controlled within the extraction, processing or utilization facility or facilities and where such control is a feature of the technology or economy of the operation of such facility or facilities'. This arrangement would make the Secretary of Health, Education, and Welfare responsible for administration of the Act with respect to solid waste problems of communities, including those problems which may affect the general environments of communities, and including those solid wastes or solid waste residues that result from business and industrial activities and become part of the community's solid waste disposal system. The Department of the Interior,

as above indicated, would be responsible for solving industrial solid waste problems within facilities engaged in extraction, processing, or utilization of minerals and fossil fuels in the circumstances above defined." To accomplish these objectives, the Public Health Service and the Bureau of Mines have entered into this Memorandum of Understanding in order to define and describe the principal areas of program interest of each agency and to clearly establish a mutually acceptable working relationship which insures proper coordination of all programs under Public Law 89–272.

It is mutually agreed that:

A. The Public Health Service and the Bureau of Mines will designate officials to act as the principal contacts and liaison officers at the program level in interagency matters pertaining to Public Law 89–272.

B. In regard to demonstration grant applications under Section 204 of Public Law 89–272, the Public Health Service will refer to the Bureau of Mines for necessary action, those demonstration grant applications pertaining primarily to mineral or fossil fuel solid waste problems as defined under Section 203(1) of the Act; and the Bureau of Mines will refer to the Public Health Service for necessary action those demonstration grant applications pertaining to other solid waste problems.

C. The Public Health Service will refer to the Bureau of Mines for review and comment those demonstration grant applications which give major emphasis to components involving mineral, metal, and fossil fuel solid waste problems as part of a broader solid waste disposal program; and the Bureau of Mines will refer to the Public Health Service for review and comment those demonstration grant applications in which the mineral and fossil fuel solid waste problems have significant community implications. In the above cases, it is understood that any comments the reviewing agency wishes to make will be forwarded within a period of fifteen (15) working days from the time of receipt.

D. The Bureau of Mines and the Public Health Service may support, on a joint basis, demonstration, research, or training projects which have implications for disposal of solid wastes from minerals or fossil fuels and from community sources.

E. The Public Health Service and the Bureau of Mines will perform reimbursable services for each other, when such action is appropriate and feasible and mutually beneficial to the agencies.

F. The Public Health Service and the Bureau of Mines will exchange information regarding program activities under Public Law 89–272. This will include information on grant awards and similar actions.

G. The Public Health Service in carrying out its responsibilities for developing comprehensive State and local solid waste programs, and in providing technical assistance to State and local agencies and industry, will need technical information from the Bureau of Mines. From time to time such information will be made available by the Bureau of Mines to the Public Health Service.

H. Since the processing and disposal of automobile and other metallic scrap involve problems of community environmental pollution, blight, and parallel resource problems in the technology of salvage and utilization, the Public Health Service and the Bureau of Mines may jointly conduct projects on broad phases of the junk and scrap auto problem, and individually on specific appropriate complementary segments.

This Memorandum of Understanding shall become effective upon acceptance of both parties, and shall continue indefinitely, but may be modified at the request of either of the cooperative agencies. This agreement may be terminated by either agency upon thirty (30) days notice in writing.

DEPARTMENT OF THE INTERIOR, BUREAU OF MINES	DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, PUBLIC HEALTH SERVICE
(Title)	(Title)
(Date)	(Date)

COOPERATIVE PROJECT AGREEMENT

I. Title of Project: "Joint U.S. Public Health Service-Tennessee Valley Authority Composting Project, Johnson City, Tennessee," hereinafter referred to as "the Project."

II. Parties to the Agreement:

A. U.S. Public Health Service, Washington, D.C., hereinafter referred to as "PHS."

B. Tennessee Valley Authority, Chattanooga, Tennessee, hereinafter referred to as "TVA."

C. City of Johnson City, Tennessee, hereinafter referred to as "the City."

III. Term of Agreement: This agreement shall be of full force and effect for a period of 7 years from the date of execution hereof, unless sooner terminated in accordance with the provisions of this agreement. This agreement may be renewed upon mutual agreement of the parties hereto.

IV. The parties hereby agree that the purpose of the project, which includes the design, construction and operation of a composting plant in Johnson City, Tennessee, is to demonstrate the engineering and economic feasibility of producing compost from mixed refuse and raw and digested sewage sludge; to conduct research into the health aspects of the use and processing of such compost and into the commercial and agricultural use and acceptability of the finished product and is not intended as a substitute for the maintenance of adequate sewage treatment facilities and refuse disposal service by the City.

V. The parties further agree as follows:

A. The City agrees—

1. To furnish, without cost to the other parties hereto, a site of approximately ten acres adjacent to the City sewage treatment plant, for the construction of the composting plant, which site is more particularly described in appendix "A" which is attached hereto and made a part hereof.

2. To furnish without cost to PHS and TVA, such road easements and utility rights-of-way as PHS and TVA may determine to be necessary for the use of the aforementioned site for the project.

3. To permit PHS and TVA access to such City property as necessary in connection with the conduct of the project.

4. To deliver to the compost plant such normal mixed refuse and special wastes as available from its refuse collection system in such amounts and at such times as PHS and TVA may request.

5. To deliver to the compost plant such raw sludge and such digested or partially digested sludge, in such amounts as may be available from its sewage treatment plant, and at such times as PHS and TVA may request.

6. To permit PHS and TVA to use City laboratory facilities at the City sewage treatment plant to the extent the City determines that such use will not interfere with its own use of the laboratory.

7. To remove from the compost plant upon request any solid, semi-solid or raw materials and processed or partially processed compost within 24 hours and to dispose of all such materials.

8. To accept at no charge to PHS and TVA all waste water (including sanitary sewage, effluent from sludge thickening and other compost plant processes, and wash water) from the compost plant, piping and pumping to be by PHS and TVA.

9. To maintain and operate at no cost to PHS and TVA such City property, buildings, equipment and facilities as may be required for the continued operation of the compost plant.

10. To furnish such other facilities and services as it can readily provide that may be requested by PHS and TVA.

B. TVA agrees, subject to the provisions of paragraph V, section C and without cost to the City—

1. To design a compost plant, including all buildings, structures and appurtenances thereto, to meet the following requirements. The plant shall be of the windrow type and which will have a rated capacity of 10 tons per hour of mixed refuse and up to 2,500 gallons per hour of sewage sludge. The plant shall be designed to be capable of providing maximum dependability of service and of providing information on comparative operation of individual units of processing equipment. The composting plant shall be designed so as to be capable of performing the following functions: (a) shredding to increase active surface area of processed material, (b) moisture control by

adding water or dry material, and (c) mixing to uniformly compost all the material being treated. The composting plant shall be equipped with necessary materials handling equipment, including receiving hopper, plate conveyor, belt conveyors, magnetic separators, sewage sludge thickener, rasping machine, hammermill, and windrow placing and turning machinery. The composting plant shall be capable of producing processed refuse, formed into windrows, approximately five feet high and seven feet wide at the base, to undergo decomposition. The processing equipment will be housed in a modular sheet metal industrial type building with concrete footings and concrete slab floor.

The composting plant shall provide for active composting to take place in unprotected windrows, but with a covered curing and storage building in which to complete the decomposition, dry, and store the finished compost. This temporary building will be near the processing building, will be roofed to protect compost from rain, and will be high enough to permit the entrance and maneuvering of dump trucks and front-end loaders.

Office, laboratory and visitor reception space on the site will be provided in a building of temporary construction.

2. To submit to PHS plans and specifications for a compost plant which meets the requirements of subsection 1 above, together with the estimated cost of construction of such plant.

3. To construct, operate, and maintain a compost plant in accordance with plans approved therefor by PHS.

4. To conduct studies, research, experiments and investigations of the feasibility of commercial and agricultural use of the compost produced.

5. To remove at the termination of this agreement all buildings, structures and appurtenances erected for the project, unless said buildings, structures and appurtenances are otherwise disposed of with the approval of the City and of PHS and in accordance with applicable Federal requirements for the disposal of Government property in effect at the time of termination.

C. PHS agrees:

1. To pay TVA for costs incurred in the design, construction, maintenance and operation of the compost plant and such costs as may be incurred in the removal of the compost plant.

2. To pay to the City the increased costs incurred by the City for its sewage and refuse disposal services resulting from the City's obligations under this agreement and such costs as may be incurred by the City pursuant to paragraph V, section A, subsection 10, if such increased costs are substantiated by actual cost data submitted by the City.

3. To conduct health-oriented studies, research, investigations and experiments relating to: (a) the composting process and the compost produced, and (b) the efficient and economic operation of the compost plant.

VI. The parties hereto further mutually agree:

A. That the compost plant will be located on a ten acre site adjacent to the City sewage treatment works near Johnson City, Tennessee, which site is more particularly described in appendix "A" hereof.

B. That this agreement may be terminated by mutual agreement of all parties hereto, or upon 180 days notice by PHS and TVA to the City of the intention of PHS and TVA to terminate this agreement.

C. That the project shall be referred to in all publications, press releases, signs, etc. as a "Joint U.S. Public Health Service-Tennessee Valley Authority Composting Project, Johnson City, Tennessee."

D. That all funds expended by the City in connection with this project will be accounted for in such a manner as deemed necessary by Federal auditors.

E. That obligations assumed hereunder shall be subject to the availability of funds for such purposes.

F. That the terms and conditions herein set forth, may, at any time hereunder be changed or modified by supplemental agreement with mutual consent of the parties concerned.

G. That the data collected will be the property of and will be used as deemed appropriate by PHS and TVA. All proposed publications by parties hereto of the data, or evaluations thereof developed in this project will be transmitted to the other parties hereto for review and comment a reasonable period of time in advance of proposed publication data.

H. That the City relinquishes title and interest in any refuse and sludge and products thereof, when such refuse and sludge are accepted by PHS and TVA at the compost plant, and all such materials when accepted shall be and become the property of the United States.

VII. PHS representative and project supervisor: Mr. Wesley E. Gilbertson, Chief, Office of Solid Wastes, EH, PSS, PHS, DHEW.

TVA representative: Dr. O. M. Derryberry, Director of Health, Tennessee Valley Authority.

City representative: Mr. D. A. Burkhalter, City Manager, City of Johnson City, Tenn.

EDWARD N. BACKUS,
Mayor, City of Johnson City, Tenn.
Dr. O. M. DERRYBERRY,
Director of Health,
Tennessee Valley Authority.
LEO J. GEHRIG,
(For Dr. William H. Stewart, Surgeon General,
Public Health Service).

Question 6: What research and development work is currently being pursued with HEW support on the creation of an "early warning system" to provide notice of potential hazards of pollution before they become acute?

Answer: 1. Research and development work currently being pursued with HEW support on the creation of "early warning systems" to provide notice of potential hazards of pollution before they become acute:

A. National air pollution potential research and advisory service (Project B–5–7). The object of this research is to develop and place in routine operation an objective, quantitative air pollution potential forecast service for the conterminous United States. Research effort is directed toward developing an objective computer technique which will provide forecasts of air pollution potential which are of equal quality to forecasts of air pollution potential now provided through application of a quasi-objective prediction technique by meteorologists of the Laboratory of Engineering and Physical Sciences, U.S. Public Health Service. Upon development of a satisfactory computer technique, responsibility for the Advisory Service will be assigned to the National Meteorological Center (Environmental Science Services Administration). Efforts to develop quantitative air pollution potential forecasts will be accelerated when the objective technique for delineating areas of high air pollution potential has become established. A quasi-objective technique for forecasting areas of high air pollution potential is in daily use. A national advisory service disseminating these forecasts to interested parties, both public and private, has been in operation for several years.

B. Local air pollution forecasting research (Project B–5–8). The object of this research is to devise or derive techniques and methodologies which will enable air pollutant concentrations to be forecast on local (urban) scales, up to 24 to 36 hours in advance, with practical precision. Models of atmospheric dispersion over urban areas are being validated through the use of observed (historical) meteorological parameters and pollutant concentrations. When a model is validated as sufficiently accurate, experimental forecasts of pollutant concentrations, based on forecast meteorological parameters and pollutant

emission values, are tested for accuracy. As necessary, research is conducted to develop and improve forecasts of the meteorological parameters. When the forecasts of pollution concentration attain a sufficiently high degree of precision, they will become operational. Urban diffusion models are currently being adapted and validated for New York, N.Y.; St. Louis, Mo.; and Philadelphia, Pa. by a meteorologist located in each city. In addition, Laboratory of Engineering and Physical Sciences staff meteorologists are testing experimental forecasts of air pollutant concentrations for Cincinnati, Ohio.

2. Current procedures for issuing air pollution potential advisories: Daily air pollution potential forecasts are prepared by Laboratory of Engineering and Physical Sciences meteorologists in Cincinnati, Ohio. Forecasts are based on reports received hourly via teletype from Weather Bureau stations in the United States and on numerous analyses and forecasts provided via facsimile by the National Meterological Center (NMC) in Suitland, Md. With its electronic computer facilities, the NMC prepares special mixing depth and wind speed data from all upper air observing stations in the United States (about 70 stations). NMC transmits these data to Cincinnati daily at 9:30 and 10:30 a.m., EST, for analysis, interpretation, and integration with other meteorological information. Air pollution potential forecasts based on these data are transmitted daily at 12:20 p.m., EST, to U.S. Weather Bureau stations (approximately 235 stations) via teletype service "C". When meteorological conditions do not warrant issuance of a high pollution potential advisory, the teletype message is "none today." When the forecast indicates that an advisory of high air pollution potential should be issued, the message designates the affected areas. The daily message indicates significant changes in the boundaries of advisory areas, including termination of episodes. To be notified of these advisories, interested persons must initiate arrangements with the nearest Weather Bureau station. Once arrangements have been made, the local Weather Bureau office will notify forecast users when their area of interest is included in an advisory.

3. Limitations to—

A. General weather forecasts: It should be noted that the ability to forecast the weather depends critically on the length of time for which the forecast is desired. Weather prediction for air pollution purposes for a matter of minutes to an hour in advance may be highly accurate, whereas forecasts many days in advance may be totally inaccurate. The size of the area for which forecasts are made is similarly crucial. Predictions for small areas on the order of city blocks presents serious difficulties, but an average forecast for a broad region of many square miles within a city can be made with some competence. The conversion of a prediction of conventional weather elements to an air quality forecast introduces an additional measure of uncertainty; a weather forecast can only provide the potential for pollution. The location of potential sources, the changes in their emission with time and the changes in pollution characteristics to photochemical and other reactions must also be known to predict the concentration of a contaminant.

B. National air pollution potential advisory service forecasts: The national air pollution potential advisory service conducted by the Laboratory of Engineering and Physical Sciences, U.S. Public Health Service, as noted above provides an advance notification of meteorological conditions which may lead to acute levels of air contamination if sources of air pollution are active. The ability to issue advisories for broad regions of the conterminous United States with a high degree of reliability has been demonstrated. Presently advisories are issued for meteorological conditions that extend over large areas for relatively long periods of time. Under the present system the forecasts are a qualitative indication of atmospheric conditions and do not provide a quantitative estimate of the air quality that may be associated with these conditions, further the forecasts do not adequately account for the large diurnal variations of dispersion within the advisory area.

C. Local air pollution forecasts: For each community for which advance prediction of pollution is desired, it is necessary that there be a continually updated emission inventory preferably on a block-by-block and hour-by-hour basis. The larger the smallest unit area and time interval for which emission data is available, the less reliable the results. Each such community must also have available ground level and upper air wind, temperature, and pressure measurements, intensive and frequent enough to allow their use for prediction. The less intensive and frequent the coverage, the less reliable the results. Each such community must also have available a mathematical model compatible with its topography and weather regime and must have an intensive air quality monitoring network against which to test the accuracy of prediction of the model. There must be a long enough period of such testing to refine the model and develop the correlation between the model and reality. The less intensive the air quality monitoring network, and the shorter the period of refining the model, the less reliable the results.

If the emission inventory, meteorological and air quality measurements and mathematical model are all optimized for the community, and if trained-experienced air pollution meteorologists are available, the capability to predict selected air quality parameters 4 to 12 hours in advance exists with about the same probability of error as predicting local variations in the weather of the community that far in advance. The success of the mathematical forecasting models depends not only on the accuracy of the analytical expression relating source and diffusion parameters to air concentrations, but also on the accuracy of the forecasts of the dispersion parameters. "Air pollution forecasting" cannot be separated from weather forecasting in general and improvements in either area will be reflected in the other. Considerable effort is presently being expended to improve forecasting techniques in general and specifically in the mesoscale area. To hasten improvements in mesoscale meteorological forecasts, a special committee has been appointed by the Federal Coordinator for Meteorological Research.

4. Utility of air pollution forecasts systems: The benefits of an air pollution potential and an air quality forecast system are many but because the capacity of the atmosphere to dilute wastes has a finite

upper limit predictions of air pollution potential or air quality cannot be a substitute for controls of air contamination at the source of emission. At times the atmosphere has a diluting ability which is as high as 1,000 times greater than at other times. Therefore the ability to predict with a high degree of confidence can make a significant contribution to the amelioration of air pollution problems. Given a satisfactory mathematical model, forecasts of meteorological parameters can be used to delineate the expected spatial extent and duration of critical concentrations of significant pollutants in a community and to forestall the occurrence of "critical" concentrations by alerting the proper control authority to the potential hazard to permit the early reduction or prevention of pollution by selected techniques before undesirable air quality levels are attained.

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Grant-supported research

The following research grants currently in progress are concerned with early warning and air pollution forecasting:

Ben Davidson, New York University, "Mathematical Models of Urban Air Pollution Dynamics." The aim of this project is to develop and verify numerical models of diffusion which can predict urban air pollution levels on a time scale of an hour and on a space scale of several miles. These models will be capable of application to any city but will be verified specifically for New York City. These models require an input data specification of source strength and meteorological conditions consistent with the time and space scale of the model. The research covers investigation of the source and meteorological conditions in the New York City area as well as meas-

urement of one or more air pollutants such as sulfur dioxide on a systematic basis.

E. Wendell Hewson, the University of Michigan, Ann Arbor, Mich., "Mesoscale Wind Systems Around the Great Lakes." This research is concerned with atmospheric flow patterns around and over the Great Lakes, with attention focused on Lake Michigan in those areas where interurban and interstate transport of air pollution is a major problem. A physical model of a bounded mesoscale lake wind system is being developed. This model is expressed in terms of a set of nonlinear partial differential equations to be solved by numerical methods employing a high capacity hybrid analog-digital computer. The input data is obtained from winter and summer programs of field observations taken over land and water from a headquarters located near Holland, Mich, on the eastern shores of Lake Michigan. The field measurements include: pilot balloon, smoke rocket, and tower observations of winds aloft; tethered balloon and a few airplane observations of temperature and humidity; and tetroon tracking with an M–33 radar for air trajectories. Surface winds are measured and used in conjunction with the standard surface and upper winds taken around Lake Michigan.

Herbert Riehl, Colorado State University Research Foundation, Fort Collins, Colo., "A Study of Denver Air Pollution." The project has as its purpose: (*a*) Description of the life cycle of pollution episodes from onset to termination; (*b*) analysis of the air motions and the physical principles governing them, which bring about the pollution episodes; and, (*c*) analysis of sources contributing to the contamination. The Denver area is especially suited for these purposes, since the city complex is isolated and hence can be studied as such without references to neighboring pollution sources. Further, important topograpically induced winds exist which bring out sharply the exchange of air between the city and its environment.

Wesley E. Yates, University of California, Davis, Calif., "Meso Wind Patterns in the Central California Valley." The purpose of this project is to study the meso wind patterns in the Central California Valley from Stockton to just north of Biggs. In addition to proving insight into a complex synoptic situation, this study applies to air pollution forecasting in the region.

Sidney R. Frank, Aerometric Research Foundation, Goleta, Calif., "Analysis of the Marine Layer—A Meso Meteorological Study." The project's specific aim is to define and model the marine layer of the atmosphere in terms of its diffusion and transport characteristics. In order to do this a systematic program has been developed in the Santa Barbara Channel area whereby several interested organizations and agencies have agreed to cooperate in obtaining geophysical data during specific times of the year. This program, called Operation COW (for Cooperative Observational Week), originated in 1961 and continues to operate 1-week periods during spring, summer, and fall. With the basic parameters that contribute to the definition and modification of the marine layer being orographic effects, ocean heat sources and sinks and meso-synoptic situations, all participants in Operation COW are equipped to obtain data pertinent to some facet of these parameters. The results of these studies are applicable to air pollution forecasting in this geographic area.

Victor H. Sussman, Division of Air Pollution Control, Harrisburg, Pa., "Air Pollution Forecasting Techniques for Pennsylvania," and, Hans A. Panofsky, Pennsylvania State University, University Park, Pa., "Meteorological Analysis, Pennsylvania Air Quality Data." The purpose of these interrelated projects is to develop a pollution potential forecast method for specific Pennsylvania communities by (*a*) selecting areas having varying topography, industrial and population density, and meteorology; (*b*) obtaining air quality and meteorological data; and then (*c*) developing a pollution potential forecasting procedure for the specific area. The areas studied are the Allentown-Bethlehem, Greater Johnstown, and Greater Erie regions.

Question 7: What research is being conducted for the development of additional techniques of the social sciences so as to better prepare the public for the efforts and costs involved in pollution abatement?

Answer: Efforts to build wide public appreciation of the problem of air pollution and public acceptance of governmental and other programs to deal with it have been an integral part ofthe Federal air pollution program ever since its establishment in 1955. These efforts have proceeded along two major pathways: information and education activities designed to give the American people easy access to the facts they need in order to understand the air pollution problem and research in the social sciences to develop improved ways of communicating with the public on the subject of air pollution.

In the area of information and education activities, the Division of Air Pollution conducts a comprehensive program utilizing all of the major methods of communication with the press and the public. In addition, the Federal program serves as a source of informational materials and professional guidance to other agencies and organizations, including State and local governmental control agencies.

Federal efforts to increase public awareness of the air pollution problem have indeed been productive. A decade ago, term air pollution was almost unknown, even to persons actively concerned with contemporary affairs; in contrast, air pollution is now widely recognized as a major national problem, though its full dimensions are not as widely appreciated or well understood.

The effect of two National Conferences on Air Pollution, both held under the auspices of the Federal program, has been to give the American people unique opportunities to acquire some basic facts about the nature and damaging effects of air pollution and the existence of techniques for bringing it under control. A third such conference has been called by Secretary of Health, Education, and Welfare John W. Gardner and will be held December 12–14, 1966, in Washington, D.C. Invited participants will include governmental officials, scientists, leaders of business and industry, and representatives of the public.

The Federal air pollution information program has assisted in the planning and production of some 50 local and national television broadcasts in which graphic and compelling facts about air pollution—both nationally and in specific communities—have been presented to millions of people. Two new programs concerned with air pollution, both prepared with assistance from the Division of Air Pollution, are scheduled for national network showing in September 1966.

As a source of informational materials, the Federal program has played a particularly important role in maintaining communications between experts in the air pollution field and the general public. The distribution of hundreds of thousands of publications has given the public access to information about air pollution which would otherwise have been almost unavailable.

The Federal information program is also actively involved in assisting nongovernmental groups in developing and carrying on programs designed to build greater public understanding of air pollution and its prevention and control. In recent years, the number and range of groups engaged in such activity has increased substantially. Among the national organizations involved in air pollution activities are the National Tuberculosis Association, the General Federation of Women's Clubs, and the National Council of State Garden Clubs. A number of scientific groups, such as the Scientists' Institute for Public Information, and many professional societies are giving increasing attention to air pollution. Various quasi-official organizations are using their influence to help promote effective control of air pollution; among them are the Conference of Mayors, the American Municipal Association, and the National Association of County Officials. To a very substantial degree, many of these groups rely on the Federal information program for guidance and materials.

In the area of social science research, the major emphasis has been on surveys of public perception and understanding of community air pollution problems and public attitudes toward such problems. In particular, such surveys have been conducted with support from the Department of Health, Education, and Welfare in Clarkston, Wash.; Los Angeles, Calif.; Buffalo, N.Y.; and St. Louis, Mo. One of the basic findings in these surveys has been that people generally classify air pollution as a problem roughly equivalent in magnitude to such other and perhaps more publicized problems as poverty, racial conflicts, and inadequate educational facilities.

In New York City, a survey taken in 1965 for a private company indicated that people considered air pollution the third most serious problem facing the community. Air pollution was listed below juvenile delinquency and traffic and ahead of such problems as unemployment, racial difficulties, and inadequacy of recreational, transportation, and educational facilities. In similar surveys conducted in Buffalo, N.Y., during 1959 and 1962 by the New York State Air Pollution Control Board, air pollution was listed as the fourth most serious local problem.

There is unquestionably a need for continued research in this area to identify the factors that influence public attitudes toward air pollution and to determine how the techniques of the social sciences can most effectively be used to stimulate public support of control efforts. A number of relevant studies are now being carried on with support in the form of research grants from the Division of Air Pollution.

One such study, being conducted by Dr. Robert E. Rankin, associate professor of psychology at the University of West Virginia, concerns air pollution and the community image. This research is being conducted in the Kanawha Valley area around Charleston, W. Va. It is designed to assess the role air pollution plays in the public image

of a community as a place to live and work, the conception the public has of air pollution in its community and what can be done to control it, and personal attitudes and characteristics which may influence people's attitudes toward air pollution.

Another grant-supported study of public attitudes toward one type of air pollution, effluent from kraft pulpmills, is being conducted by Dr. Donald F. Adams, Washington State University, Pullman, Wash. The purposes of this study include clarification of the odor detection threshold concentrations for the major constituents of the gaseous emissions from kraft pulpmills, definition of an "objectionability" threshold as a minimum concentration of these compounds which will elicit an unpleasant response, evaluation of the responses of a cross-section of the population to kraft mill-type odors, and separation of the influence of sex, age, smoking habits, place of residence, occupation, and so forth, upon reported thresholds of detection and objectionability.

In the area of public information, Dr. Murdock Head, director of the Airlie Center, George Washington University, Warrenton, Va., is receiving grant support for a project entitled "Audiovisual Methods for Air Pollution Information." This is a 3-year research project for the evaluation of present methods of audiovisual dissemination of information in the field of air pollution and development of new techniques. A series of six 20-minute color films are being developed as part of the project.

Three new grant applications in the social-political area are under consideration:

Michael E. Eckstein, New School for Social Research, New York, N.Y., "Organization Factors in Air Pollution Control." This application was approved by the June 1966 National Advisory Environmental Health Council and is awaiting payment. It is proposed to study the relationships between and among units of government, public agencies, public and private organizations, and citizens groups in a metropolitan region (New York) which have some responsibility or concern for air pollution.

Leslie P. Singer, Gary urban research, "The Cost of Air Pollution to a Community," to be reviewed by the November 1966 NAEHC.

Peter C. Rydell, assistant professor of urban planning, Urban Research Center, Hunter College, New York, and Benjamin H. Stevens, president, Regional Science Research Institute. Philadelphia, "Effects of Air Pollution on Optimal Urban Form," to be reviewed by the November 1966 NAEHC.

Despite an obvious and growing need, there is almost no research underway relating to the need to prepare the public for the increased national effort that will be required to meet the solid waste problem. One research project being supported by a grant from the Office of Solid Wastes, grant No. R01–SW–00003, is concerned with public attitudes as part of a comprehensive study of the application of systems analysis techniques to solid waste management.

The Office of Solid Wastes, through State planning grants, demonstration grants, study and investigation grants, and research contracts will seek to encourage needed research in the social sciences in order to provide a better basis than is now available for gaining public

understanding and support of programs for the control of the solid waste management problem.

Question 8: What research and development work is considered desirable to solve the increasing problem of disposable packaging and container material while at the same time giving consideration to the values of convenience of such packaging and container material to our society?

Answer: Several areas need to be investigated in detail to identify the critical factors involved in dealing with the disposable packaging and container material problem that is accentuated by industry's efforts to increase consumer convenience. Technical and economic studies should be carried out to determine the "total" costs involved in the use of alternate packaging materials. It seems fairly obvious that the indirect or hidden costs to the consumer, or more broadly the costs to society, of using packaging materials that are difficult or hazardous to dispose of is not being considered by manufacturers. Research and development work is needed to make commercially available soluble or biodegradable packaging materials, such as the newly developed "water soluble" paper.

Additional developmental work is needed to establish reasonable limits on the minimum product payload for many types of consumer products. Since many products have traditionally been marketed in in bulky packaging that contains relatively little of the product destined for the consumer's use, there would seem to be a legitimate need for research and development efforts to devise packaging that satisfies the seller's requirements to compete in the marketplace through attractive presentation of his wares but also keeps to the practical minimum the amount of waste which the consumer has to dispose of in the form of packaging or wrapping materials.

The feasibility of legal restrictions or economic incentives governing or influencing the use of nonreturnable containers requires considerable study, particularly with respect to containers whose disposal may be hazardous. The cost of returning insecticide drums, for example, may actually be considerably less than the cost of their disposal.

Question 9: How can Federal research and development be used to overcome "the planned obsolescence" feature of our economy in order to promote improved waste management procedures?

Answer: The subject of planned obsolescence, as it related to solid waste management, to economics, to public attitudes, and to conservation—and this is only a partial list of the research and development areas that are applicable—raises questions which the Nation has barely begun to recognize, let alone attempt to answer. If viewed only from the standpoint of the control of solid wastes, planned obsolescence is an area in which the Federal Government could well make a substantial research and development investment. However, it is difficult, perhaps impossible, to separate the many interrelated factors involved in planned obsolescence, factors, including the labor market, consumer buying practices, utilization of natural and manmade resources, and others which bear only tangentially on the technology of solid waste disposal.

Although not specifically a research and development undertaking, the Federal Government could devise and apply specifications for many

of the products and materials purchased by the General Services Administration which would motivate manufacturers to develop and produce goods with a usable lifespan longer than that now considered normal or acceptable. As has often been the case in the past, GSA specifications tend to influence design specifications for whole segments of industry. It should be pointed out here that increased durability of such goods as electronic parts and equipment and packaging materials is not primarily a technical problem, since industry now has the capability to produce such materials having a much greater useful life than those now made generally available to the buying public. Electric light bulbs are a case in point.

The question of increased durability is, of course, closely tied to the national norm of high rates of consumption, and this, in turn, is a factor of great importance to the economic vitality of the Nation. However, two points are important here. The economic vitality based on high production and consumption rates is a short-term vitality, which fails to take into consideration the long-term economic factor of conservation of natural resources, particularly mineral resources. It would seem very important in the national interest for the Federal Government to increase substantially its research and development efforts relating to the economics of conservation. And into this picture must be fitted the question of social cost. Does it cost society more to enjoy the abundance and convenience of high consumption rates, while disregarding the long-term costs involved in depleting resources and in adding to the waste disposal burden?

A second important point on which relatively little research has been carried out is the question of the long-term effect on the labor force of a shift from a philosophy of planned obsolescence to one of reduced production of more durable and serviceable commodities. To what extent could high rates of employment be maintained in an economy geared more to the production and use of long-lasting products than to replacement of items whose obsolescence is a function of the marketplace?

In any event, more information clearly is needed to reveal the costs to society of a shift away from planned obsolescence. It seems reasonable to assume that if an automobile were made to last three times as long as it does today, in other words if it were not designed, engineered, and advertised into premature obsolescence, society would benefit, even if that automobile cost three times as much as today's car. Society would benefit by avoiding the costs and the hazards involved in disposing of a product three times as often as necessary. It would benefit by the conservation of natural resources. And it would benefit through the development of new employment fields to expand a labor market now threatened by automation.

Many Federal departments and agencies either now have or could have a direct interest in problems associated with planned obsolescence. The Departments of Health, Education, and Welfare, Commerce, the Treasury, Labor, Agriculture, the Interior, Defense, and agencies such as the Federal Trade Commission, the General Services Administration, and the National Aeronautics and Space Administration all could become more involved in research and development in this field. Although partly a technological problem, planned obsolescence involves social and economic factors that have not been thoroughy

investigated and are not well understood. There is no question that the Federal Government, at least initially, will have to take a leading role in the conduct and support of this kind of research, since industry has demonstrated little interest in it, other than that motivated by short-term economic interests. Hopefully, after the Federal Government began to place needed emphasis on this type of research and development and the public became aware of where its interests lay, industry would join in the national effort to help resolve the solid waste disposal problem by reducing the volume of consumer materials to be disposed of.

Question 10: What is the strategy used for planning and programming for research and development and pollution abatement insofar as they affect the interdependencies in the environment? Is the National Science Foundation kept continuously advised of gaps and needs in technical knowledge? Are urban renewal activities coordinated with pollution research and development programs? What systems analysis techniques are being used to give proper consideration to all forms of pollution in a given area? What coordination is effected, for example, with the Corps of Engineers in the disposal of polluted material dredged from rivers and harbors?

Answer: A summary of the ways in which the Division of Air Pollution coordinates its activities with those of other Federal agencies is provided under the reply to question 5.

The challenge of dealing with problems of environmental contamination clearly requires a high degree of coordination among all those Government agencies which share in the responsibility for preventing and controlling such problems. There is a need for coordination with respect to planning and policymaking as well as day-to-day management and operation of pollution research and control activities. As yet, arrangements to meet this need have not been fully developed, either at the Federal level or at State and local levels.

One of the most important reasons why a high level of coordination is necessary in this field is that many contaminants of the modern environment reach man not through air or water or food alone, but through all of theses and often through occupational exposures, as well. Because the basis for concern about such contaminants is their potential hazard to public health, governmental agencies with responsibility and experience in the health field should logically be assuming leadership in assessing these problems and dealing with them.

On the Federal level, the Department of Health, Education, and Welfare is taking steps to permit a broader and more comprehensive attack on environmental contamination problems than has even been undertaken before. One of the principal steps, being taken as part of a reorganization of the Public Health Service, is the creation of a new Bureau of Disease Prevention and Environmental Control. This new component will coordinate research activities carried on by various Public Health Service units concerned with the separate segments of the total problem of environmental contamination, insofar as those activities relate to contaminants which may reach man through more than one environmental vector. The units involved include the Division of Air Polution, the Division of Radiological Health, the Office of

Pesticides, the Office of Solid Wastes, the Division of Occupational Health, and a new unit which will be concerned with the health aspects of water pollution.

In addition to its responsibility for coordination within the environmental pollution programs of the Public Health Service, the new Bureau of Disease Prevention and Environmental Control will be assigned responsibility for such activities as liaison with the National Institutes of Health to assure that their in-house and grant-supported research projects are evaluated in relation to problems of environmental contamination and coordination with other Federal agencies and industry in areas of research in which the Public Health Service cannot effectively work alone.

The need for coordination of activities in environmental pollution control extends to State and local levels of government, as well. This need is twofold. In the first place, State and local governments bear a major share of the responsibility for setting and enforcing pollution control regulations. For this responsibility to be effectively discharged, there must be cooperation and coordination among State and local agencies which administer programs concerned with the various aspects of environmental contamination. Too often, responsibility in this field is fragmented among many agencies, which often find themselves competing with one another for funds, personnel, and support from elected officials.

The second respect in which coordination is essential to prevent and control pollution in the Nation's cities and States arises from the fact that municipal, county, and State governments carry on many other activities which may contribute to such pollution. As an example, the frequent lack of adequate coordination between local agencies responsible for collection and disposal of solid wastes and those responsible for pollution control often results in needless air, water, or soil pollution problems. Other examples of State and local activities which have an important bearing on pollution problems include decisions on the construction and location of highways, urban planning, and zoning programs, and the establishment and application of regulations concerning construction of new industrial installations. In these and many other instances of activity at the State and local levels of government, adequate communication and coordination can often prevent new pollution problems from developing, usually at a far lower cost to government, industry, and the public than would be involved in later abatement measures.

The formal technique used for planning and programing to insure proper research coordination among the several agencies and programs concerned with pollution abatement is the program planning and budgeting system recently instituted by the Bureau of the Budget. The PPB system, which is essentially an information system to help management make major decisions, facilitates examination of program objectives and of alternative ways of achieving objectives. In addition to the program planning and budgeting system, the less formal approaches, such as conferences, technical reports, and working committees, provide planning and programing coordination among the programs concerned with pollution control and abatement.

The National Science Foundation receives general program and budgeting information from the solid waste disposal program. In-

formation on research projects being supported also is regularly reported to the National Science Foundation through the science information exchange reporting system.

Current practices in urban renewal activities often fail to take into account pollution abatement factors and environmental quality protection. The Office of Solid Wastes has initiated discussions with the Department of Housing and Urban Development principally regarding coordination of statewide planning activities and it is anticipated that these discussions can and will be broadened to include urban renewal activities.

The basic legislation for the solid waste program requires proper and careful consideration of the total problem of pollution of the environment. Accordingly, the Office of Solid Wastes has established an Operations Research Unit and is supporting research projects to develop and expand the use of systems analysis techniques for the solution of environmental pollution problems.

Coordination to resolve specific solid waste disposal problems encountered by other Federal agencies at Government facilities is being coordinated through cooperative arrangements. Solid waste disposal problems encountered by other Federal agencies and programs in the conduct of their activities are resolved generally on an ad hoc basis.

Question 11: Please summarize qualitatively the current backlog of proposals from both industry and universities for the undertaking of research and development in pollution abatement. What would your annual budget requirement be if all desirable proposals were accepted?

Answer: The Division of Air Pollution has a backlog of research proposals in the sense that funds are not currently available to support the proposed projects—currently amounting to several million dollars. In addition, there is a backlog of comparable magnitude consisting of proposals initiated by the Division staff. Approximately half of these proposals are in engineering and the physical sciences and are concerned in large part with technology for the identification, measurement, analysis, and control of pollutant emissions. Another large group of pending proposals is in the area of medical and biological research concerning the effects of air pollution on health. Most of the engineering research is proposed for funding by contracts with industry, while most of the research in other areas would be carried out by universities.

Currently there are 10 approved but unfunded research grants in solid waste totaling $431,472. These proposals include projects on utilization of compost as a soil conditioner, pipe transport of solid waste materials, and chemical conversion of solid waste components, as well as other promising and important areas needing additional scientific investigation.

High priority unfunded contract proposals received by the Office of Solid Wastes exceeded the funds available for contracts by approximately $750,000. These proposals included: studies of the economics of solid waste disposal; investigation of the feasibility of using existing transportation systems on a regional basis; systems analysis to improve solid waste management; studies of new and improved reduction facilities; incinerator energy utilization; and health investigations.

As funds available for solid waste research and development activities increase, it is reasonable to anticipate that the number of meritorious research proposals also will increase. It, therefore, is not possible to estimate what level of funding, if any, would be sufficient to permit support of all such proposals. The authorization for future appropriations in the Solid Waste Disposal Act makes allowance for increased support of research and development activities. However, this expansion will not permit Federal funding of all desirable research and development in the solid waste field.

Responses to Questions of the Subcommittee on Science, Research, and Development by the Federal Water Pollution Control Administration

Question 1: What does the Federal Water Pollution Control Administration believe should be the goal of water pollution abatement? What should be the timetable for reaching this goal?

Answer: The long-range goal of the Federal water pollution control program is to control and prevent pollution to assure an adequate supply of water suitable in quality for public and industrial water supplies, propagation of fish and aquatic life, wildlife, recreation. agriculture, and other legitimate uses.

A greatly stepped-up pollution control effort will be required to meet this goal, both by upgrading water quality condition of presently polluted waters and by protecting waters which are still of high quality.

While remedial schedules have been developed for many rivers, it is difficult to give a precise timetable for the Nation as a whole. Attaining the long-range goal will require overcoming the large existing backlog of unmet waste treatment needs resulting from years of neglect. The rate at which the backlog can be overcome will be dependent in large part on the nature and extent of Federal financial support. This issue is under consideration in legislation currently before the Congress.

In addition to overcoming the backlog of treatment needs, a rate of waste treatment works construction necessary to keep pace with population and industrial growth, urbanization, and obsolescence of existing facilities must be maintained. An accelerated research and development program will also be required to develop new and improved technology and to cope with new and emerging pollution problems. This improved technology must then be put into widespread practice. In addition, new basin planning and development, personnel training, and other related programs must be involved in the pollution-control effort.

The goal of pollution control is a continuous one, therefore it cannot be achieved on a "one-shot" basis. However, the Federal Water Pollution Control Administration believes that the Nation can be brought abreast of the problem within the next decade to the point where it can keep pace on a continuous basis.

Questions 2 and 3: 2. Please provide a listing of research contracts and grants in the field of water pollution abatement that have been provided by the Public Health Service and the Federal Water Pollution Control Administration within the last several fiscal years under the provisions of section 5 of the Federal Water Pollution Control Act as amended. Please divide this by category of contracts versus grants; university in-house effort or other; and also between basic research, applied research, and development. In addition please di-

vide this to the extent possible among the general categories referred to in your testimony. To the extent possible please provide the estimated amounts of funds requested for research in the various categories for the current fiscal year.

3. Please provide a breakdown for the last several fiscal years of in-house expenditures for research and development under section 5 of the Water Pollution Control Act, as amended, broken down by the categories used in your statement. If convenient, the answers to questions 2 and 3 may be combined in one tabulation showing the entire research and development program, in detail, for the last several years.

Answer: The listings requested are provided in following tables 1–8. Tables 2, 4, and 6 cover grants only while tables 1, 3, and 5 relate to our in-house plus contract program. In tables 7 and 8 are detailed breakdowns of in-house and contract effort according to research category.

TABLE NO. 1.—*Federal water pollution research and development by performer*

[In thousands of dollars]

INTRAMURAL AND CONTRACT

Fiscal year	Federal laboratories	State and local agencies	Universities	Other nonprofits	Profit organizations	Other	Total
1964	2, 719	14	31	------	206	21	2, 991
1965	2, 911	143	2	------	142	35	3, 233
1966 [1]	5, 604	318	------	------	164	5	6, 091
Subtotal	11, 234	475	33	------	512	61	12, 315
1967 [1]	6, 042			2, 600			8, 642
Total	17, 276						20, 957

[1] Estimate.

TABLE NO. 2.—*Federal Water Pollution Control Administration research and development by research performer—Research and demonstration grants, fiscal years 1964–67*

Year	Federal laboratories	State and local agencies	Universities	Other nonprofits	Profits organizations	Other	Total
1964	0	128, 000	4, 454, 000	225, 000	33, 000	14, 000	4, 854, 000
1965	0	701, 000	5, 291, 000	295, 000	0	17, 000	6, 304, 000
1966	0	1, 385, 000	5, 993, 000	797, 000	0	35, 000	8, 210, 000
1967 estimate	0	1, 870, 000	6, 634, 000	978, 000	0	37, 000	9, 519, 000

TABLE NO. 3.—*Federal water pollution research and development by type of research*

[In thousands of dollars]

INTRAMURAL AND CONTRACT

Fiscal year	Basic	Applied	Development	Total
1964	153	2, 651	187	2, 991
1965	219	2, 774	240	3, 233
1966 [1]	248	4, 103	1, 740	6, 091
Subtotal	620	9, 528	2, 167	12, 315
1967 [1]	500	5, 382	2, 760	8, 642
Total	1, 120	14, 910	4, 927	20, 957

[1] Estimate.

TABLE NO. 4.—*Federal Water Pollution Control Administration basic research, applied research and development—Research and demonstration grants, fiscal years 1964–67*

Year	Basic research	Applied research	Development	Total
1964	2, 320, 000	1, 895, 000	639, 000	4, 854, 000
1965	2, 819, 000	2, 320, 000	1, 165, 000	6, 304, 000
1966	1, 306, 000	4, 739, 000	2, 165, 000	8, 210, 000
1967 estimate	1, 399, 000	5, 071, 000	3, 049, 000	9, 519, 000

TABLE NO. 5.—*Federal water pollution research and development by COWRR category*

[In thousands of dollars]

CATEGORY V. WATER QUALITY MANAGEMENT AND PROTECTION—INTRAMURAL AND CONTRACT

Fiscal year	A	B	C	D	E	F	G	Total
1964	269	219	692	1, 354	163	226	68	2, 991
1965	777	240	520	1, 183	173	280	60	3, 233
1966 [1]	829	780	600	3, 492	130	70	190	6, 091
Subtotal	1, 875	1, 239	1, 812	6, 029	466	576	318	12, 315
1967 [1]	1, 190	990	1, 523	4, 300	300	100	239	8, 642
Total	3, 065	2, 229	3, 335	10, 329	766	676	557	20, 957

[1] Estimate.

NOTE.—
Subcategory A equals identification of pollutants.
Subcategory B equals sources of pollution.
Subcategory C equals effects of pollution.
Subcategory D equals waste treatment process.
Subcategory E equals ultimate disposal of wastes.
Subcategory F equals water treatment.
Subcategory G equals water quality control.

TABLE NO. 6.—*Federal Water Pollution Control Administration expenditures by research category (Breakout according to the Committee on Water Resources Research of the Federal Council for Science and Technology)—Research and demonstration grants, fiscal years 1964–67*

I. NATURE OF WATER—NONE

II. WATER CYCLE

[In thousands of dollars]

	F. Groundwater	G. Lakes
1964	22	22
1965	26	27
1966	23	39
Total	73	88
1967, estimate	25	42

III. WATER SUPPLY AUGMENTATION AND CONSERVATION

	C. Waste water reclamation	D. Use of water of impaired quality
1964	23	0
1965	28	0
1966	67	48
Total	118	48
1967, estimate	78	55

IV. WATER QUALITY MANAGEMENT AND CONTROL—NONE

TABLE NO. 6.—*Federal Water Pollution Control Administration expenditures by research category (Breakout according to the Committee on Water Resources Research by the Federal Council for Science and Technology)—Research and demonstration grants, fiscal years 1964–67*—Continued

V. WATER QUALITY MANAGEMENT AND PROTECTION

	A. Identification of pollutants	B. Source of pollution	C. Effects of pollution
1964	339	851	1, 304
1965	401	1, 036	1, 422
1966	453	1, 116	2, 216
Total	1, 193	3, 003	5, 042
1967, estimate	491	1, 228	2, 314

	D. Waste treatment process	F. Water treatment	G. Water quality control
1964	1, 387	268	339
1965	2, 331	312	384
1966	2, 922	266	290
Total	6, 640	846	1, 013
1967, estimate	3, 566	314	310

VI. WATER RESOURCES PLANNING

	A. Techniques of planning	B. Evaluation process	E. Water law
1964	53	54	40
1965	64	65	23
1966	303	435	0
Total	420	554	63
1967, estimate	539	539	0

	F. Nonstructural alternatives	G. Ecological impact of water development
1964	117	40
1965	153	0
1966	0	0
Total	270	40
1967, estimate	0	0

TABLE NO. 6.—*Federal Water Pollution Control Administration expenditures by research category (Breakout according to the Committee on Water Resources Research by the Federal Council for Science and Technology)—Research and demonstration grants, fiscal years 1964–67*—Continued

VII. RESOURCE DATA

	C. Evaluation, processing and publication
1964	15
1965	17
1966	17
Total	49
1967 estimate	18

VIII. ENGINEERING WORKS

	A. Design
1964	0
1965	15
1966	15
Total	30
1967 estimate	0

IX. MANPOWER, GRANTS, AND FACILITIES

	A. Education—Extramural	
	Training grants	Research fellowship
1964	2, 016	472
1965	2, 000	617
1966	2, 500	710
Total	6, 516	1, 799
1967 estimate	2, 910	633
Total:		
1964	2, 488	----------
1965	2, 617	----------
1966	3, 210	----------
Total	8, 315	----------
1967 estimate	3, 543	----------

TABLE NO. 7.—*Federal water pollution research and development by COWRR category*

CATEGORY V. WATER QUALITY MANAGEMENT AND PROTECTION INTRAMURAL ONLY

[NOTE.—Subcategory A—Identification of pollutants; subcategory B—Sources of pollution; subcategory C—Effects of pollution; subcategory D—Waste treatment process; subcategory E—Ultimate disposal of wastes; subcategory F—Water treatment; subcategory G—Water quality control.]

[In thousands of dollars]

Fiscal year	A	B	C	D	E	F	G	Total
1964	269	170	678	1,182	163	224	33	2,719
1965	777	240	520	1,032	173	280	55	3,077
1966 [1]	829	780	563	2,066	108	70	190	4,606
Subtotal	1,875	1,190	1,761	4,280	444	574	278	10,402
1967 [1]	1,100	1,000	1,200	2,300	200	100	200	6,100
Total	2,975	2,190	2,961	6,580	644	674	478	16,502

[1] Estimate.

TABLE NO. 8.—*Federal water pollution research and development by COWRR category*

CATEGORY V. WATER QUALITY MANAGEMENT AND PROTECTION CONTRACTS ONLY

[NOTE.—Subcategory A—Identification of pollutants; subcategory B—Sources of pollution; subcategory C—Effects of pollution; subcategory D—Waste treatment process; subcategory E—Ultimate disposal of wastes; subcategory F—Water treatment; subcategory G—Water quality control.]

[In thousands of dollars]

Fiscal year	A	B	C	D	E	F	G	Total
1964	0	49	14	172	0	2	35	272
1965	0	0	0	151	0	0	5	156
1966 [1]	0	0	37	1,426	22	0	0	485
Subtotal	0	49	51	1,749	22	2	40	1,913
1967 [1]	100	0	300	2,000	100	0	100	2,600
Total	100	49	351	3,749	122	2	140	4,513

[1] Estimate.

Question 4: Give a tabulation showing the budget requests for pollution abatement research and for construction grants and the appropriations and expenditures for the past several fiscal years.

Answer: The requested tabulation follows:

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

Grants for waste treatment works construction and sewer overflow control

	Estimate to Congress	Appropriation	Expenditures [1]
1962	$80,000,000	$80,000,000	$64,509,835
1963	90,000,000	90,000,000	92,228,028
1964	100,000,000	90,000,000	85,427,169
1965	93,000,000	93,000,000	84,523,492
1966	100,000,000	91,000,000	120,505,579
Supplemental	50,000,000	50,000,000	
1967	173,000,000	[2] 173,000,000	

WATER SUPPLY AND WATER POLLUTION CONTROL RESEARCH

1962	$3,423,000	$2,423,000	$2,128,157
1963	2,376,000	2,867,000	2,843,496
1964	3,207,000	3,284,000	3,283,697
1965	3,160,000	3,160,000	3,067,155
1966	5,557,000	[3] 5,657,000	4,074,899
1967	8,691,000	[2] 8,691,000	

[1] Obligations—Amounts for grants for waste treatment works construction and sewer overflow represent Federal share and may exceed appropriation because of carryover of previous years funds.
[2] Passed by House, still pending in Senate.
[3] Includes $1,000,000 still available for obligation and carried into 1967.

Question 5: Assuming no budget constraints, how much funds should be provided if the attack on water pollution is to be carried forth at optimum levels.

Answer: General estimates of the total cost nationally of controlling water pollution vary widely. The Environmental Pollution Panel of the President's Science Advisory Committee stated in its report "Restoring the Quality of Our Environment" that in order to provide secondary treatment of wastes for 80 percent of our population by 1975 an expenditure on the order of $20 billion, of which Federal funds would be a considerable part, would be required. In the report No. 1367 on the Federal Water Pollution Control Act amendments and Clean Rivers Restoration Act of 1966, the Committee on Public Works, U.S. Senate, indicated they believed the cost of pollution control could well exceed $100 billion. Because of this uncertainty, the committee directed the Secretary of the Interior to obtain detailed cost estimates for the 5-year period beginning July 1, 1968, for submission to the Congress no later than January 10, 1968.

Reasons for wide variation in cost estimates and consequently of amounts of funds required are as follows:

(a) SIZE OF THE BACKLOG

In the past, estimates of the backlog of unmet municipal waste treatment needs have been based upon an annual survey made by the Conference of State Sanitary Engineers. This year's preliminary report shows a backlog of 5,566 projects at an estimated cost of $2.1 billion. However, it has become increasingly clear that this estimate is extremely conservative. For example, the New York State clean waters program has shown a total need for that State alone of $1.7 billion. Among the factors contributing to the low estimates by the Conference of State Sanitary Engineers are the fact that costs of the interceptor sewers are included only when they are part of a new treatment plant construction, and the fact that 18 percent of the 5,566 projects included in the annual survey backlog are considered to require only primary treatment. Upgrading of treatment requirements to conform with water quality standards will further add to the cost of eliminating the backlog. For example, if secondary treatment is considered necessary for the 18 percent of the projects now estimated to require only primary treatment, this would increase the costs by $506 million. In addition, the need for tertiary treatment will emerge at many locations over the next few years which will further increase costs.

(b) COSTS OF REDUCING POLLUTION FROM INDUSTRIAL WASTES

Treatment needs for industrial wastes are generally assumed to be at least as great as those for municipal wastes. However, except for information collected in conjunction with specific studies, the amount of industrial wastes entering streams is not accurately known. In addition, industrial wastes may be greatly reduced by in-plant changes that require in some cases a significant modification in industrial processing. Older plants may require addition of waste treatment facilities while newer plants with more modern, efficient methods would be able to control pollution without necessarily adding specific devices for waste control. The determination of costs for reducing industrial pollution, therefore, is a very complex one that is not yet readily identifiable in the same way as costs of abating municipal pollution.

(c) OTHER FACTORS

Combined sewers: When storms occur, wastes from runoff are combined with municipal wastes in sewers with the result that treatment plants are overloaded and must bypass wastes into streams. Separating these wastes requires very high costs and involves disruption of street traffic. Estimates of the national cost of separating combined sewers run as high as $30 billion. However, other means of solving this problem are presently being explored chiefly through a 4-year $80 million program of grants and contracts.

Agricultural wastes: Wastes from nonpoint sources such as agricultural fertilizers and pesticides are extremely difficult to control. These wastes have significant impact on water quality through the indirect route of causing conditions that enrich waters for algae growth or through causing fish kills when pesticides build up in body tissues.

Control measures are related to land management practices which may contribute to pollution control but are most frequently associated with improved agricultural methods.

Sedimentation: Sediment produced by soil erosion caused by land runoff from agricultural practices or from removal of cover on watersheds is a highly significant cause of pollution. Control of pollution from these sources is dependent on land management and not usually directly linked with pollution control expenditures.

In any event, the amounts of Federal funds needed for an optimum pollution control will be dependent upon the nature and extent of Federal financial participation, as indicated above.

Question 6: Your statement suggests that many present water pollution problems can be alleviated by the application of existing technology and discusses the use of available knowledge to control pollution. In addition to alleviating and controlling pollution, are there any research programs aimed at preventing or eliminating pollution of water resources?

Answer: Let me reiterate the fact that much can be accomplished in water pollution control in this country through the increased use of existing waste treatment and control technology. Referring to figure 6 (see p. 743), for example, it can be seen that the nationwide load of BOD pollution from municipal sources alone could be reduced by some 40 percent from the present level through the application of conventional primary-secondary treatment to all municipal discharges. The committee has, of course, already recognized the looming inadequacy of existing technology (as shown below, BOD discharges will eventually inexorably increase due to expanding population despite the universal application of the most efficient waste treatment processes now available). We, too, have recognized this impending need and, in fact, essentially our entire research program is aimed at "preventing or eliminating pollution." Our Advanced Waste Treatment Branch, for example, has as its ultimate goal the development of "total pollution control" systems capable of completely eliminating pollution from confined, treatable sources such as municipal and industrial outfalls. Such systems would, as a corollary benefit, directly augment agricultural, industrial, recreational, and even municipal supplies through provision of purified water suitable for direct reuse. Our newly formed Pollution Control Technology Branch is directing its efforts toward the discovery and development of techniques to reduce pollution, on a source-by-source basis, to any degree necessary. We are, wherever possible, examining control-at-the-source principles to eliminate pollution before it is created; acid mine drainage abatement in particular is receiving attention of this sort. We also are investigating methods of environmental treatment to reoxygenate water or to eliminate nuisance algae growths, for example.

Questions 7 and 10: 7. Witnesses before this committee are talking in terms of spending $30 billion to separate storm and sanitary sewers, $20 billion to complete municipal sewage treatment and collection works, and an undetermined but substantial amount for treatment of industrial wastes. All told this would amount to from $70 to $100 billion. In your statement you pointed out that the techniques presently in use were designed to deal with the problems in existence 40 to 50 years ago when pollution was much less critical. Are these tech-

niques adequate to justify the massive doses of Federal funds that are now being contemplated in the currently proposed amendments to the Federal Water Pollution Control Act (S. 2947)?

10. Given the present stated 75 to 90 percent efficiency of existing complete treatment plants, that is primary plus secondary treatment, do you believe that the best approach to completing the pollution abatement job is through an improvement of the secondary treatment plants to increase their efficiency or through the development of tertiary treatment plants to take out the balance of pollution that is not handled in present plants? Is a massive increase in the construction of present-type plants justified under either alternative?

Answer: My answer to the preceding question provides a partial background for this combined response to questions 7 and 10. Additional background will be found in the following paper, "Solving Our Water Problems—Water Renovation and Reuse," published by the New York Academy of Sciences, which discusses certain aspects of the national water pollution problem and the impact that the application of emerging advanced waste treatment processes could have on the magnitude of nationwide pollution discharges from municipal outfalls.

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SOLVING OUR WATER PROBLEMS— WATER RENOVATION AND REUSE

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Aside from floods, the nation's water problems can be placed in two broad categories: water supply and water pollution. Water resource planning has, historically, been concerned with one or the other of these problems. In brief and very simplified form, the two problem categories are outlined below.

The Water Pollution Problem

Polluted water was first recognized by its unsightly appearance and disagreeable odors. The initial solution was the use of simple gravity clarification and/or screening, by which gross particulate matter was removed from raw waste water as sludge or skimmings. With this "primary" treatment, larger suspended solids could be removed, and the tendency of a stream to become anaerobic or septic could be somewhat reduced. However, lowered levels of dissolved oxygen downstream from waste outfalls remained as the major problem in water pollution.

Various types of filters, chemical additives, and even electrochemical techniques were then applied to municipal waste as second-stage or "secondary" treatment steps. When it became widely recognized that certain waste components accelerated the microbiological use of dissolved oxygen in streams, biological treatment itself became the accepted standard for secondary treatment. The biological treatment processes used today, such as oxidation ponds, trickling filters, and activated sludge, are simply deliberate attempts under controlled conditions to satisfy the biochemical oxygen demand (BOD) of a waste prior to its discharge to receiving waters.

Up to now, treatment of municipal wastes has been primarily designed to reduce the quantity of suspended, floating, and biochemically oxygen-demanding materials. Efficiently operated primary-secondary plants remove about 90 per cent of these materials and in addition, about 90 per cent of the bacteria, 50 per cent of the total nitrogen (organic plus inorganic), perhaps 20 to 40 per cent of the phosphorus, but only five per cent of the total dissolved matter.

However, as civilization changes, so does the nature of water pollution. Suspended solids and BOD are no longer the only measures of waste loads. Other pollutants are of increasing concern: persistent organics, radionuclides, nutrients, inorganic salts, even heat. Even if the real nature of water pollution did not change, our increased understanding of pollutional effects and mechanisms would still alter our *recognition* of "what is pollution?" It is

*This paper was presented at a meeting of the Division of Engineering on December 8, 1965 at the New York Academy of Sciences.

†The Federal Water Pollution Control Administration was created on December 31, 1965; previously it was the Division of Water Supply and Pollution Control of the Public Health Service, Department of Health, Education, and Welfare.

easy, therefore, to recognize that the present-day technology of waste treatment will not be adequate to meet the challenge of the future.

With respect to BOD alone, the generally-attainable 85 to 90 per cent removal efficiency will not prevent some streams from being overwhelmed by oxygen-demanding pollution within the foreseeable future. Even now, a relatively small but increasing number of our streams (FIGURE 1)[1] have already reached the stage where complete primary-secondary treatment is being applied to every municipal discharge. (Industrial discharges are not considered here because comprehensive data are not available.) In a much larger number of cases (FIGURE 2)[1] 90 per cent of the volume of municipal discharges to streams now receives primary-secondary treatment. On the one hand, this is a highly desirable and even comforting picture because it indicates the widespread utilization of available technology; on the other hand, in places where serious water pollution now exists or is imminent, what can we do to remedy the situation if the best available conventional treatment is already in use?

When considering other gauges of pollution, the picture becomes darker. As an aid to understanding the trend, FIGURES 3, 4, and 5 show the estimated total municipal discharges of phosphates, total nitrogen, and refractory organics released into the nation's waterways during the twentieth century. Refractory organics include organic matter that resists biological degradation either from natural or sewage treatment processes.

Phosphates, nitrogen compounds, and refractory organics are of importance because they can cause a variety of pollutional effects, some of which are known and others only suspected. Phosphorus and nitrogen, for example, can act as fertilizers promoting the growth of troublesome algae or other aquatic plants. The pollutional effects of these substances can accelerate the natural aging of lakes, thus causing major ecological changes. Serious taste and odor

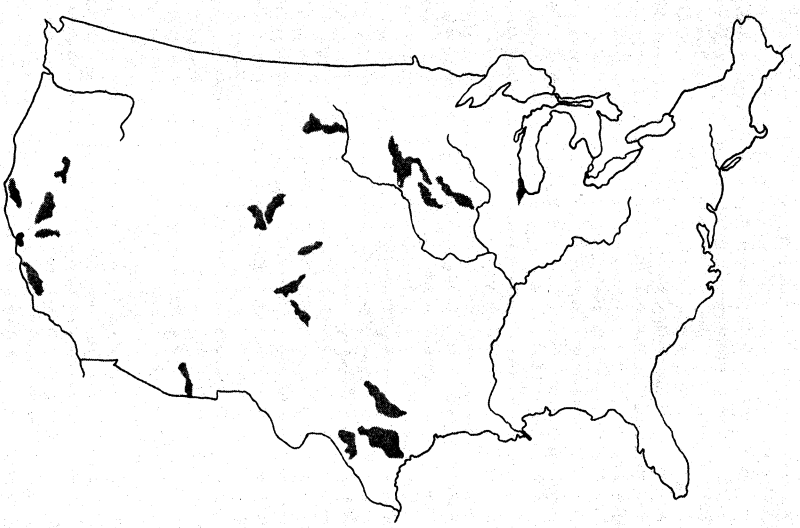


FIGURE 1. River basins in U.S. for which all municipal discharges have complete primary-secondary treatment.

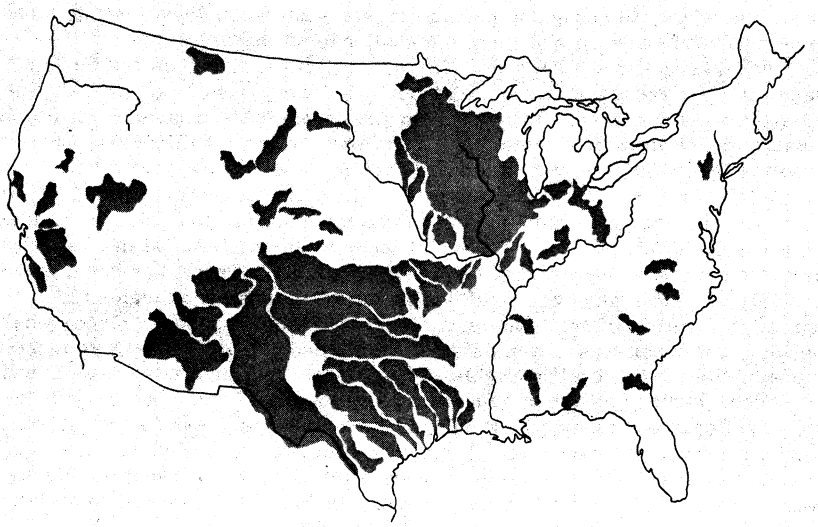


FIGURE 2. River basins in U.S. for which more than 90% of all municipal discharges have complete primary-secondary treatment.

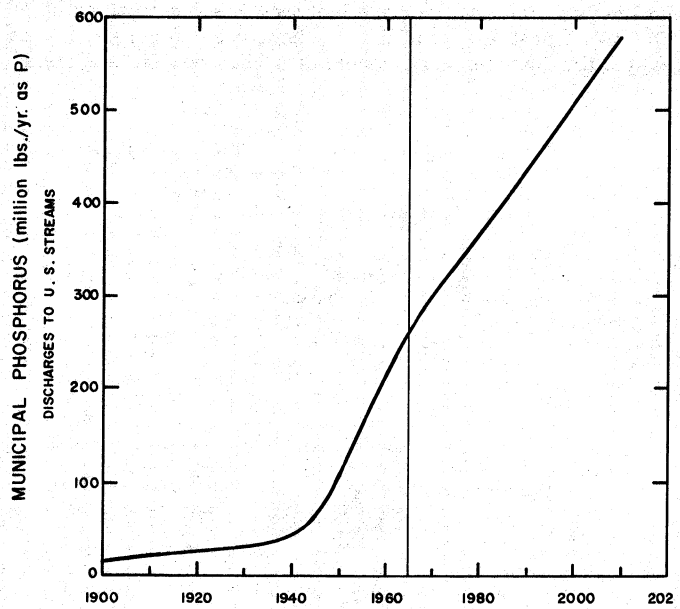


FIGURE 3. Estimate of phosphorus discharges to U.S. streams from municipal outfalls (A.D. 1900-2020).

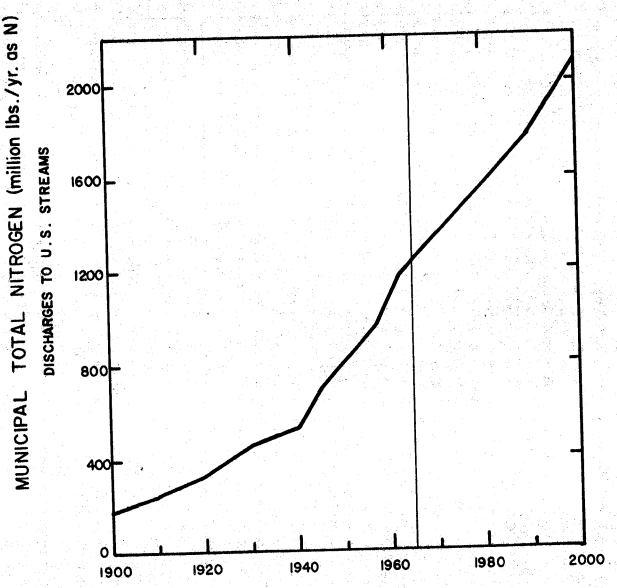


FIGURE 4. Estimate of total nitrogen discharges to U.S. streams from municipal outfalls (A.D. 1900-2000).

problems can also be created in downstream water supplies, and even sizable "fish kills" may be triggered.

The effects of refractory organics on water quality are not as well understood. Taste and odor, tainting of fish flesh, foaming, and fish kills have been attributed to such materials. Except for recognized toxicants, the effects of refractory organics on human health, if any, are unknown.

Even simple inorganic salts can pollute water if present in sufficient amounts. Public Health Service Drinking Water Standards specify that the total dissolved solids (TDS) in a drinking-water supply should not be present in excess of 500 mg./l. Yet each use of a water supply by a municipality adds an increment of 300 to 400 mg./l. of such salts to the water. Conventional waste-treatment techniques are virtually ineffective in removing these salts.

Deferring for the moment problems arising from treatment-resistant pollutants, what is the future picture of classic BOD pollution? On a nationwide basis, the changes in municipal BOD load over this century are estimated in FIGURE 6. That portion of the curve between 1900 and 1930 illustrates the increasing waste load due to the increasing population at a time when no facilities, either for primary or secondary waste treatment, were in common use. In 1930, for example, only about 15 per cent of municipal sewage received primary treatment and less than six per cent received secondary. During the 1930's construction of treatment plants was accelerated, and for the first time in the nation's history, BOD discharges decreased. During World War II discharges sharply increased, while during the postwar years they remained

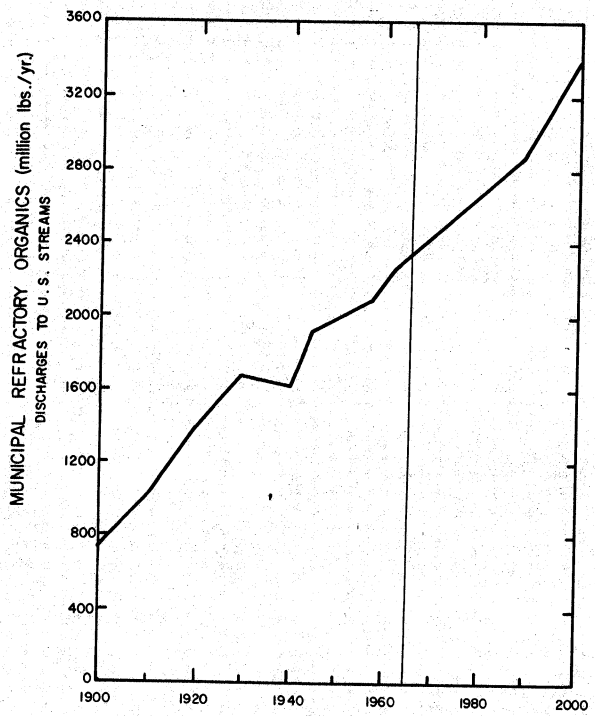


FIGURE 5. Estimate of refractory organics discharges to U.S. streams from municipal outfalls (A.D. 1900-2000).

almost constant. In the next 25 years, if we apply complete primary-secondary treatment to all municipal discharges, the national BOD load from these sources will be reduced by about 40 per cent. From that time on, BOD loads will increase continuously.

The graph in FIGURE 6 presents a potentially misleading view because it deals with a nationwide picture, while pollution is a much more "local" phenomenon. However, it is useful in making the following points. First, substantial improvements in pollution control can be achieved simply through the more widespread application of existing waste-treatment technology. Second, from 1990 onward, BOD discharges will inexorably increase due to expanding population *despite* the universal application of the most efficient waste-treatment processes now available. In fact, by 2015, just 50 years from now, BOD discharges will once again reach the present level and will be increasing by two or three per cent per year thereafter. Clearly, there are other pollutants which cannot be treated as effectively as BOD through the use of conventional techniques. For these resistant pollutants, there will not be even a temporary reduction in rates of discharge; rather, nationwide loads of these pollutants will increase from this time on, again, *despite* the universal application of existing technology (FIGURES 3-5).

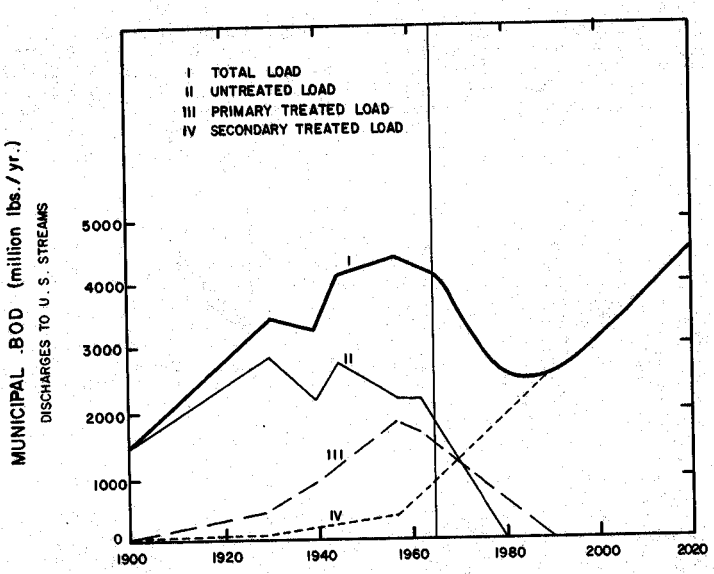


FIGURE 6. Estimate of BOD discharges to U.S. streams from municipal outfalls (A.D. 1900-2020).

The Water Supply Problem

An enormous amount of commentary on the water supply problem has been published in both the popular and the technical press. However, for the purposes of this paper, only one or two examples of this problem will be cited. First, it should be very clear to New Yorkers that water shortages occur not only in arid areas but also in water-rich areas of the world such as the eastern coast of the United States. It should also be clear that water supply problems may be more severe in regions of occasional shortage than in regions where such problems are an expected occurrence. Water supply can be a real problem in an area such as New York City, even without a "northeast drought." On Long Island, for example, water is pumped from the ground, and prospects of importing water overland are becoming progressively more difficult and more expensive as the New York City metropolitan area grows and forms an ever-widening barrier to importation. Population, industry, and water demand are growing; ground water levels are falling; and salt water is progressively intruding into the present underground supplies of fresh water.

In regard to the nationwide water supply, FIGURE 7 illustrates an estimate of the withdrawal rate of water for various uses as against the nation's dependable and developable supply during the twentieth century. This rather oversimplified projection indicates that we have already run out of water. In fact, it indicates we ran out of water in 1957, when our withdrawal of fresh water exceeded our "dependable supply." By 1983, our withdrawal will equal our estimated *total* developable supply, and we shall *really* be out of water!

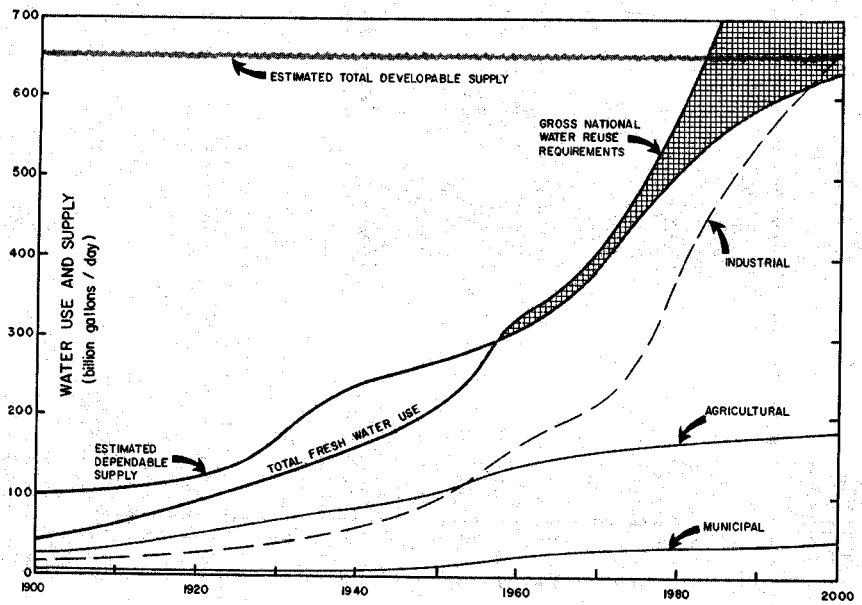


FIGURE 7. Estimate of withdrawal rate of water in U.S. for various purposes as against dependable and total developable supplies. (A.D. 1900-2000).

In spite of the obvious fallacies in FIGURE 7, it is amazing how many predictions of water doom are based exactly on this kind of oversimplification. The truth is that our nation as a whole is not running out of water and will not within the reasonably foreseeable future. The simplest explanation is three-faceted: (1) neither our water supply nor our water needs are uniformly distributed geographically; (2) neither our supply nor our demand are uniformly distributed with time; and (3) all water withdrawn and used is not consumed; much of it is returned to our fresh water resources for reuse.

Water Pollution and Water Supply, Inseparable Problems

Every use of water imposes some change in its quality. These changes, no matter how severe, are inconsequential if the water is not used further. But, in almost every case, some type of reuse does occur. Water may be reused for drinking, or as a habitat for fish and other aquatic life, or merely for aesthetic enjoyment. Reuse and multiple reuse of our water resources are common everyday occurrences. On the broadest scale, man has been using and reusing the same volume of water on the earth since Creation; here, purification and reuse occur naturally through the hydrologic cycle. More to the point, reuse occurs quite naturally and unavoidably from city to city and from factory to factory as water flows through our river systems to the ocean.

Recognizing the inevitability of reuse, deteriorations in water quality imposed by use become significant. If water quality is degraded to the extent that reuse is impossible or inhibited, downstream water supplies are reduced just as if the water had been consumptively used upstream. Water supply and water pollution, therefore, are closely interconnected.

In earlier days, dilution and stream self-purification were relied upon to remedy pollution, and the most readily available or most economical natural fresh waters were tapped as supplies. During this century, biological waste treatment has been used to supplement dilution and self-purification for pollution control, and gradually deteriorating water qualities or more distant sources of water have been accepted for water supplies.

Recently, scientists have begun to investigate methods of augmenting natural water supplies, e.g., desalination and weather modification, and have begun to explore new and different techniques of waste treatment. The "Advanced Waste Treatment" (AWT) techniques under investigation range from extensions of biological treatment methods capable of removing nitrogen and phosphorus nutrients to physical-chemical separation techniques such as adsorption, distillation, and reverse osmosis. These processes can achieve essentially *any* degree of pollution control desired, and further, as waste effluents are purified to higher and higher degrees by such treatment, the point is reached when effluents become "too good to throw away." Such effluents can and will be deliberately and directly reused for agricultural, industrial, recreational, and even municipal purposes. This is true water renovation: the simultaneous alleviation of both water pollution and water supply problems.

Water Renovation—Today's Capability

Under the 1961 amendments to the Federal Water Pollution Control Act, the Division of Water Supply and Pollution Control of the Public Health Service (now the Federal Water Pollution Control Administration) has conducted its Advanced Waste Treatment Research Program. Under this program, about 30 treatment processes are being evaluated to assess their technical and economic feasibility. Several processes are now available for application; one was recently installed in full-scale municipal service. Several of the processes can even be operated in series under certain circumstances to produce potable water from municipal waste water. For each of these processes, however, some degree of overdesign must still be incorporated to assure reliable performance. The higher the potential difficulty or hazard involved in performance failure, the higher the degree of conservatism and overdesign required. The ultimate perfection of these processes to minimize capital expenditures and operating costs must await further full-scale testing and improvements in design, materials, and equipment by consultants and equipment manufacturers.

Although it is conceivable that today's conventional processes will be replaced in the future, for the present, AWT would be applied to the effluent from well-operated, conventional primary-secondary treatment plants. Alum or lime coagulation-sedimentation may be used to increase the removal of suspended solids from the conventionally attainable 90 per cent to a 99 per cent level and to reduce effluent phosphate concentrations to 1 or 2 mg./l. Coagulation-sedimentation would not be considered as an "advanced" process in water treatment and industrial practice. However, it is included here as an

advanced process because it is not conventionally applied to the treatment of municipal waste effluents and because the efficient removal of suspended and even colloidal solids is a necessary pretreatment for many of the other advanced processes.

Assuming a good quality secondary effluent, 50-100 mg./l. of alum or perhaps 200-300 mg./l. of lime are required to remove suspended and colloidal solids and phosphates. Standard water treatment flocculation tanks and sedimentation basins would be used. The capital cost for this type of treatment will be less than $.10/daily gallon capacity for plants of the 10-20 million-gallon-per-day scale and about $.05/daily gallon capacity for 100 mgd plants. Operating costs, including capital amortization at 6 per cent interest for 20 years, will be about $.08/1,000 gallons at 10-20 mgd and $.05/1,000 gallons at 100 mgd exclusive of sludge disposal.

After removal of colloidal and suspended solids, the soluble refractory organics may be very efficiently removed by contact with activated carbon granules. Such carbon will adsorb up to 20-30 per cent of its own weight in mixed organics from waste water when used in counter-current flow fixed-bed contactors. At a mass velocity of 7 gal./min-ft.^{2} and a contact time of 40 minutes, more than 98 per cent of both BOD and total organic matter will be removed. To minimize cost, the activated carbon should be regenerated and reused. Fortunately, thermal regeneration of activated carbon following saturation with actual waste organics has been possible. A series of 15 successive saturation-regeneration cycles were performed with satisfactory regeneration efficiencies. This process is being studied in a 300,000 gallon-per-day pilot plant at Pomona, California, under a joint research project of the FWPCA and the Los Angeles County Sanitation Districts. The process also has been used since last summer in actual municipal service in a 2.5 mgd plant of the South Tahoe Public Utility District at Lake Tahoe, California.

The capital costs for an adsorption plant of 10-20 mgd capacity should be about $.15/daily gallon capacity and at 100 mgd, about $.09/daily gallon. Operating costs, including 20-year capital amortization at 6 per cent interest, should be less than $.10/1,000 gallons for a 10-20 mgd plant and about $.06/1,000 gallons at the 100 mgd scale.

Except for dissolved inorganic salts added during use, municipal waste water subjected to the foregoing treatment procedures in sequence will have been restored to a chemical quality generally comparable to that before use. As stated earlier, the salts added during one pass through a municipal system will normally total about 300-400 mg./l. (TABLE 1). Since many water supplies contain these same dissolved salts at approximately this concentration, one municipal use of water generally doubles the salt content. Fortunately, a single-pass electrodialysis reduces the concentration of dissolved inorganic solids by 40-50 per cent, the same percentage required to remove the increment of mineral pollutants added during use.

Extended bench-scale tests and operating pilot-scale studies at 75,000 gpd have established that the power requirements for electrodialysis of municipal waste water are only 6-10 kwh./1,000 gallons. For "typical" waste waters (TABLE 1), polarization can be avoided if a current density-to-concentration ratio of 750 (ma./cm.^{2})/(g.Eq./l.) is not exceeded. Under these conditions, effective cell-pair area requirements are less than 0.004 ft.^{2}/gpd. Concentration ratios greater than 10:1 can be readily achieved with proper pH control; ratios of 50:1 have even been attained.

TABLE 1

AVERAGE COMPOSITION OF MUNICIPAL SECONDARY EFFLUENT

Component	Average concentration in secondary effluent (mg./l.)	Average increment added during water use†	
		mg./l.	lb./day/ 1000 pop.
Gross organics	55	52	64
Bio-degradable organics (as BOD)	25	25	31
Methylene blue active substance (MBAS)*	6	6	7
Na^+	135	70	86
K^+	15	10	12
NH_4^+	20	20	25
Ca^{++}	60	15	18
Mg^{++}	25	7	9
Cl^-	130	75	92
NO_3^-	15	10	12
NO_2^-	1	1	1
HCO_3^-	300	100	120
$CO_3^=$	0	0	0
$SO_4^=$	100	30	37
$SiO_3^=$	50	15	18
$PO_4^{\equiv}$	25	25	31
Hardness ($CaCO_3$)	270	70	86
Alkalinity ($CaCO_3$)	250	85	100
Total dissolved solids	730	320	390

*Apparent alkyl benzene sulphonate
†Concentration increase from tap water to secondary effluent

The feed must be carefully pretreated to operate electrodialysis stacks in this service successfully. If suspended solids are removed to avoid plugging and dissolved organics are removed to avoid membrane fouling, electrodialysis of waste water is relatively straightforward, although very recent results may indicate some complications from microbiological forms. In tests to date, long-term ion removal has been largely nonselective. The concentration of each ion present is reduced by roughly the same fraction. This is fortunate, because generally uniform removal is what is required to provide water of satisfactory quality for most purposes of reuse. One exception exists. Only a few parts per million of ammonia can be tolerated in municipal water supplies and in many industrial supplies. Since typical municipal waste water may contain 20 mg./l. NH_4^+, the removal of 90-95 per cent would be required. To

achieve this by conventional electrodialysis would be prohibitively costly. The answer appears to be in operating secondary biological treatment under nitrifying conditions so that NH_4^+ is almost completely converted to NO_3^-. For simple discharge to stream when nutrients are a pollution problem, the nitrate levels present may be undesirable, but for reuse as a municipal, industrial, or agricultural supply, the NO_3^- concentration is not of concern in most cases.

Capital costs for electrodialysis equipment should be less than $.15/daily gallon capacity at 10-20 mgd and under $.11/daily gallon capacity at 100 mgd. Unless serious unforeseen difficulties are encountered in pilot-scale tests, total operating costs should not exceed $.15/1,000 gallons at 10-20 mgd and should be about $.10/1,000 gallons at 100 mgd.

The type of water renovation sequence described above, while not yet in any full-scale application, is undergoing pilot study and, with proper safeguards and conservatism in design, represents an existing technology within our present capability. On September 8, 1965, Dr. Donald F. Hornig, the President's Special Assistant for Science and Technology, testified before the Senate Interior and Insular Affairs Committee and stated that:

> At my request, the Department of Health, Education, and Welfare has just completed a feasibility analysis of a 100-mgd waste water purification plant which could be added to a secondary sewage treatment plant of the kind now used in New York City and northern New Jersey. Their report indicates that such a plant could be built for $33 million and would produce potable water at a cost of about 16¢ per 1,000 gallons. The Department of Health, Education, and Welfare has had a modest research program in waste water purification underway and the plant they considered would use the best proven, presently available technology. Almost certainly these costs could be reduced still further through a R & D program. The suggested plant employs aeration, chemical coagulation and sedimentation, carbon adsorption and chlorination to purify the effluent from a secondary sewage treatment plant. If the product water is mixed with water from other sources in a large system no further treatment is necessary. For a completely closed system in which all water is recycled a buildup of salinity would occur and a desalting unit would be needed. Because of the very low salt content, electrodialysis could be used and the additional cost would be only a few cents per 1,000 gallons depending on the amount of salts to be removed. The costs quoted above include cost of land, treatment, and pumping costs to return the water to the distribution system.

Direct delivery of purified waste water to a city distribution system is possible and can be completely safe. If it is too unattractive aesthetically, the purified waste water can be used for recreational and decorative lakes, watering parks and golf courses, industrial processes, or can be recharged to the groundwater. It must be noted, however, that there is very little practical difference between purification and direct reuse of waste water and the present widespread practice of discharging of wastes to a river from which a downstream city takes its water supply.

Water Renovation—Tomorrow's Promise

Only a year or so ago, the plan Dr. Hornig referred to could not have been offered. Today it can be proposed with confidence. Even with its realization,

it should only be regarded as an "early model" of future versions that will be more efficient and more economical. A whole range of new techniques are now being studied, not only by the federal government, but by state and local governments, by universities, and by industry.

One process, bio-denitrification, uses specially acclimated microorganisms to reduce nitrates to elemental nitrogen under certain process conditions. Another, foam separation, takes advantage of surface adsorption phenomena to make beneficial use, under controlled treatment conditions, of the hitherto unwanted billowy foam so common in many waste waters. Chemical oxidation of complex and unknown organic contaminants with hydrogen peroxide, ozone, or even hydroxyl free radicals generated by corona discharge is being considered. Phase separations such as distillation, freezing, and gas hydration are under study, as is reverse osmosis, which is perhaps the best "dark horse" candidate for total waste water purification.

The long-range objective in this research is to provide the necessary treatment systems for attaining *any* degree of waste treatment that may be required at minimum cost. Significantly, the word "systems" is used. Rarely will an advanced waste treatment process stand alone. Instead, systems of individual processes in series or in parallel will be required to meet particular needs.

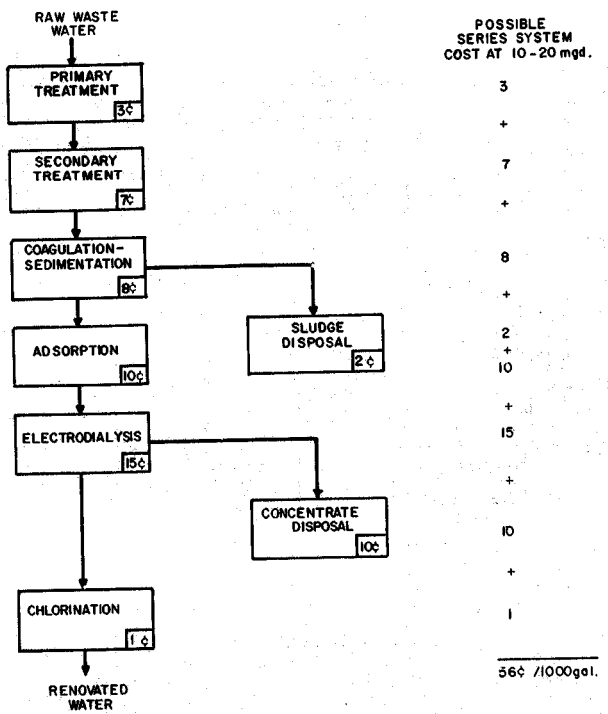


FIGURE 8. Generalized water renovation system, series flow.

Included with the treatment systems must be one or more of a variety of ultimate disposal processes. These processes are methods for permanent, nonpollutional disposal of the inevitable sludges and waste concentrates generated by the separation processes. These disposal techniques include such possibilities as incineration, digestion, or wet oxidation of organics; conveyance of various sludges and solid residues to the ocean or remote dump sites; and deep-well injection of brines into porous strata. Possible beneficial uses of waste concentrates as soil conditioners, fertilizers, or chemical raw material should also be included in the ultimate disposal category.

Two general system configurations can be used. In the series-type system already described (FIGURE 8), the total flow passes through all processes in sequence. Each process contributes to quality improvement. In the system illustrated, the conventional primary treatment removes material that readily settles or floats. The secondary biological step removes the biologically degradable impurities. Coagulation-sedimentation, in the third position, eliminates suspended solids and colloids. Carbon adsorption removes residual dissolved organics. Electrodialysis reduces the dissolved minerals level to an acceptable value. Finally, chlorination disinfects the processed water.

The same result can be obtained with a parallel-flow system (FIGURE 9). Here, primary and secondary treatment, coagulation-sedimentation, adsorption, and chlorination function as described above. Demineralization is achieved

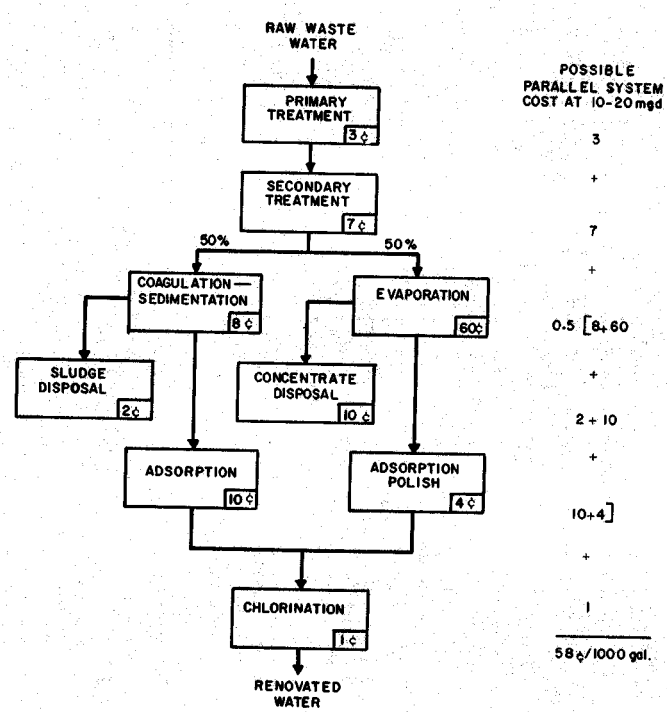


FIGURE 9. Generalized water renovation system, parallel flow.

by a "total removal" process, that is, evaporation plus distillate "polishing," which handles only about half of the total flow. Following this step, the completely purified water (the distillate) is blended with the flow from which all impurities except the salts have been removed.

In FIGURES 8 and 9, the unit costs are estimated for both a series-flow and a parallel-flow system at a scale of 10-20 mgd. First, the projected total system costs are so close ($.56 vs. .58/1,000 gallons) that one type of system cannot, at this time, be omitted in favor of the other. Second, the costs of conventional and advanced treatment steps can be compared.

In contrast to the present cost of $.10/1,000 gallons for primary-secondary treatment (FIGURE 8), coagulation-sedimentation, which very efficiently removes suspended solids and phosphates, costs an additional $.08-.10/1,000 gallons (certain biological treatment modifications being studied may be able to remove up to 80 per cent of the phosphates for a lower cost). If the adsorption step is incorporated to eliminate BOD and refractory organics, the additional cost is raised to $.18-.20/1,000 gallons. This total waste treatment cost of about $.30/1,000 gallons is almost three times the present level.

To complete the renovation with electrodialysis would add another $.25/1,000 gallons to give a total renovation cost of more than five times the cost of existing waste treatment. This is clearly not an illustration of "something for nothing." Yet, the cost picture is not really so dark. First, the AWT estimates were made intentionally high so that they should not be exceeded under normal circumstances. Second, costs should be reduced significantly as research and development programs bring us closer to the most efficient designs. Third, substitute processes now being investigated may reduce costs considerably. The powdered carbon process, for example, could conceivably replace both coagulation-sedimentation and granular carbon adsorption, which cost $.18-.20/1,000 gallons, at half their cost.

Another point is that cost comparisons would perhaps be more fair if made not just between waste-treatment processes, but also between advanced waste treatment costs and conventional waste treatment plus water supply. Water supply plus waste treatment costs, based on historical data and including source development, transmission, water treatment, and waste treatment, have been estimated to be about $.23/1,000 gallons on the average and to be nearly $.30/1,000 gallons in prevailing high-cost areas of the country.[2] Future costs for extending conventional treatment and for augmenting water supplies will undoubtedly be higher.

Now, what could be the physical impact of waste water renovation on our future water pollution and water supply problems? To derive an answer, FIGURES 3-6 were redrawn in FIGURE 10, incorporating the assumption that during the next 25 years, AWT processes of the type now available are applied to every municipal effluent in the land. For municipal BOD pollution, instead of facing a temporary reduction in national BOD discharge levels until the turn of the century, we could be very close to President Johnson's recent pledge to "doom water pollution in this century." With respect to phosphate and refractory organic loads entering our streams, no reductions can be expected with the use of present treatment methods. However, with the use of AWT, the first reductions in history could be accomplished. For nitrogen forms, on the other hand, even available AWT processes will not be highly effective. Processes still in development must meet this need.

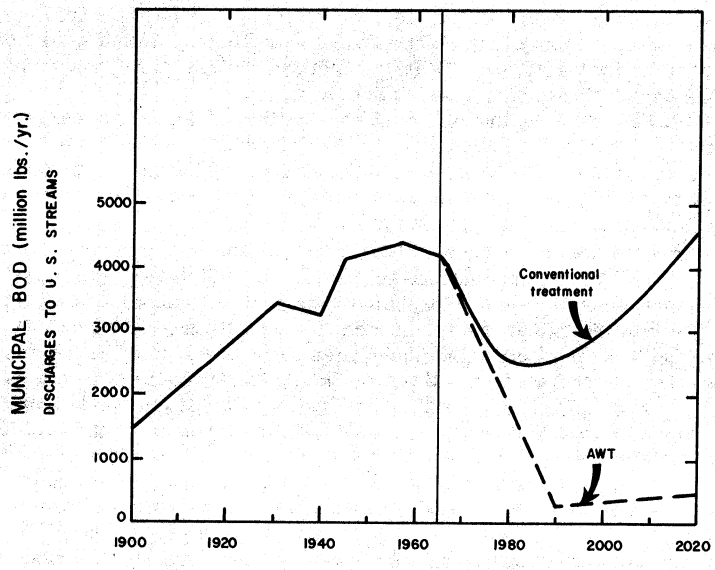


FIGURE 10 (a). Potential impact of "Advanced Waste Treatment" (AWT) on municipal discharges of BOD to U.S. streams.

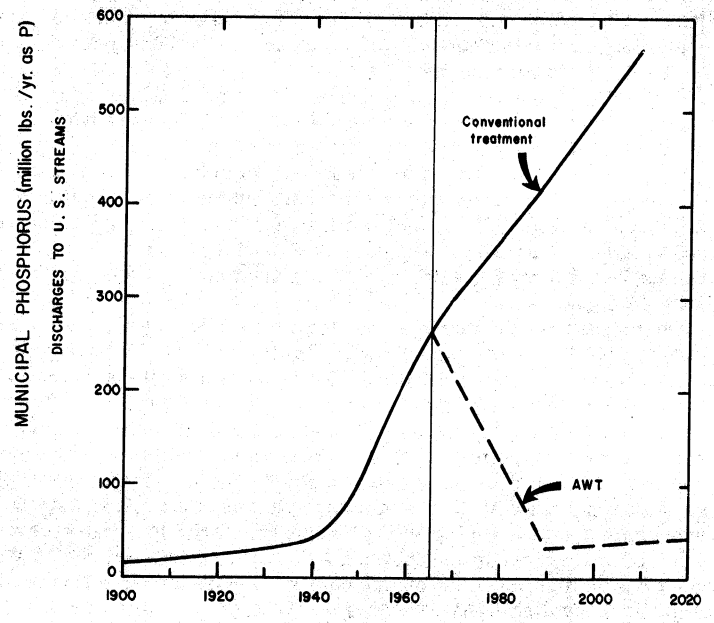


FIGURE 10 (b). Potential impact of AWT on municipal discharges of phosphorus to U.S. streams.

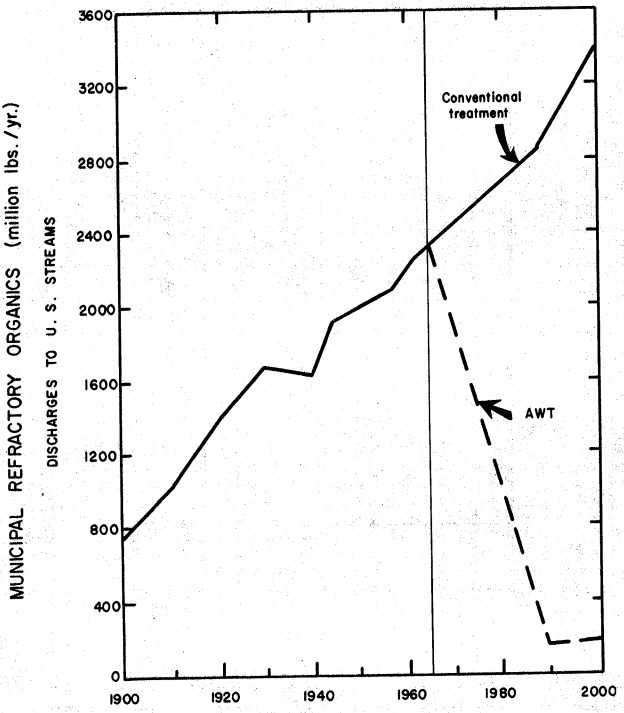


FIGURE 10 (c). Potential impact of AWT on municipal discharges of refractory organics to U.S. streams.

Unfortunately, the total effect that water renovation would have on water supply cannot be so readily estimated on a nationwide basis because of the present appreciable natural reuse of our fresh water resources. Possibly a better way of picturing this situation is to look at an individual water user. If 80 per cent of the water used by New York City were recovered and renovated for reuse, the city's water supply, which now provides some 1,200 mgd, would in effect be enlarged five times. This same general principle applies not only to all municipal but also to all industrial supplies. Irrigational supplies could not be extended to this degree because of the high consumptive losses involved.

Another major effect that water renovation would have on our water resources is less widely recognized. We refer to the "low flow regulation" concept, that is, the storage and later release of upstream water to dilute downstream waste discharges. This is a water supply requirement, although not a withdrawal requirement, and is created directly as a result of water pollution. What startles most people is that the projections[3] for water volumes just to dilute municipal and industrial BOD waste discharges are greater than for any other single use, even assuming that every discharge is treated to 90 per cent efficiency. In 1980, for example, the required flow magnitude would be

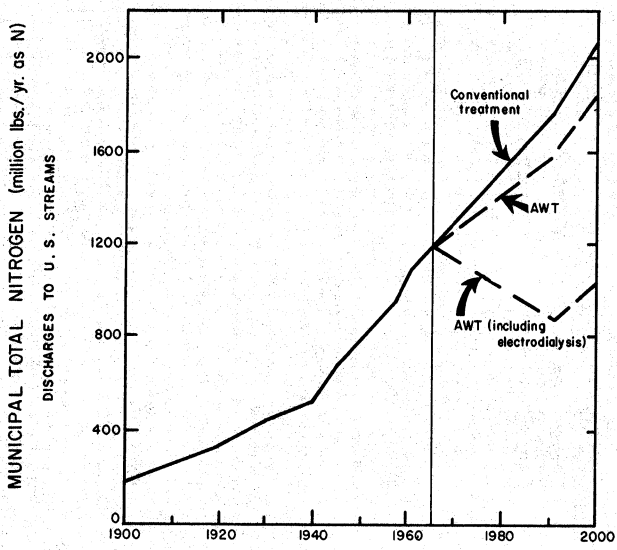


FIGURE 10(d). Potential impact of AWT on municipal discharges of nitrogen to U.S. streams.

about 300 bgd and by 2000, more than 475 bgd. Actually, the situation is vastly more complex than this, and a detailed discussion is beyond the scope of this paper. Briefly, however, with 95 per cent BOD removal, the calculated dilution volumes required would need be only one-half of those above, and with 99 per cent treatment, only one-tenth. The conclusion[3] that theoretical dilution water requirements for these wastes will not go to zero as treatment efficiency approaches 100 per cent is in error when physical-chemical treatment, and not extended biological treatment, is assumed.

In summary, new systems or mechanisms must be developed and maintained in this country to assure that adequate quantities of water of suitable quality are continuously available to meet our demands for municipal, industrial, agricultural, and recreational purposes and to protect our fish and wildlife resources. Past techniques for maintaining or improving the quality of water have included conventional waste treatment, dilution, and stream self-purification. These techniques by themselves, however, will be unable to serve the needs of the future.

Advanced waste treatment processes which may range from extensions of biological treatment methods to quite complex physical-chemical separation techniques are now under development. Such techniques could, in proper combination, not only provide complete elimination of pollution from municipal and industrial sources but even produce water suitable for direct and deliberate reuse. Advanced waste treatment or, more properly, water renovation will become a major tool in solving both of our major water resource problems—water supply and water pollution.

APPENDIX

ESTIMATING MUNICIPAL DISCHARGES OF BOD, TOTAL NITROGEN, PHOSPHORUS, AND REFRACTORY ORGANICS INTO U.S. STREAMS

Nine assumptions were used in estimating the municipal discharges of various materials into streams in the United States (TABLE 3). The formulas used to estimate each of the four components considered are described after the pertinent assumptions.

1. It is assumed that all sewered municipal effluents are discharged into U.S. streams.

2. It is assumed that by 1980 the discharge of raw municipal wastes will have ceased, and that by 1990 the entire sewered population will be serviced by primary-secondary treatment. For the period 1900-1962, the sewered populations receiving "no treatment," $(SP)_{on}$, "primary treatment," $(SP)_{pn}$, and "secondary treatment," $(SP)_{sn}$, were derived from References 4-8.

3. It is assumed that the waste treatment efficiencies for various materials are those shown in TABLE 2. The fraction (f) of each material remaining in

TABLE 2

MUNICIPAL PRIMARY AND SECONDARY TREATMENT REMOVAL EFFICIENCIES AND FRACTIONS REMAINING IN EFFLUENT (f) FOR BOD, TOTAL NITROGEN, PHOSPHORUS AND REFRACTORY ORGANICS

Removal of:	No Treatment		Primary Treatment		Secondary Treatment	
	Percent Removal	f_o	Percent Removal	f_p	Percent Removal	f_s
BOD	0	1.0	35	.65	90	.10
Total Nitrogen	0	1.0	20	.80	50	.50
Phosphorus	0	1.0	10	.90	30	.70
Refractory Organics	0	1.0	20	.80	60	.40

the effluent discharge, that is, $f = 1 - \frac{\text{treatment efficiency}}{100}$, is also given.

Biochemical Oxygen Demand (BOD)

4. Daily domestic BOD contribution, p_{BOD}, is 0.167 lbs./capita/day (a constant).

5. To account for the increase in industrial wastes handled in municipal sewerage systems between 1900 and 2000, a varying ratio of "industrial plus domestic BOD" to "domestic BOD" was used. This was sometimes expressed as "PE/capita." Based on PE/capita figures for 1900, 1970, and 1980, as given in Reference 11, and an assumption of PE/capita - 1.1 in 1930, a curve was prepared as shown in FIGURE 11. This curve was extrapolated to the year 2000 at a constant PE/capita of 1.75.

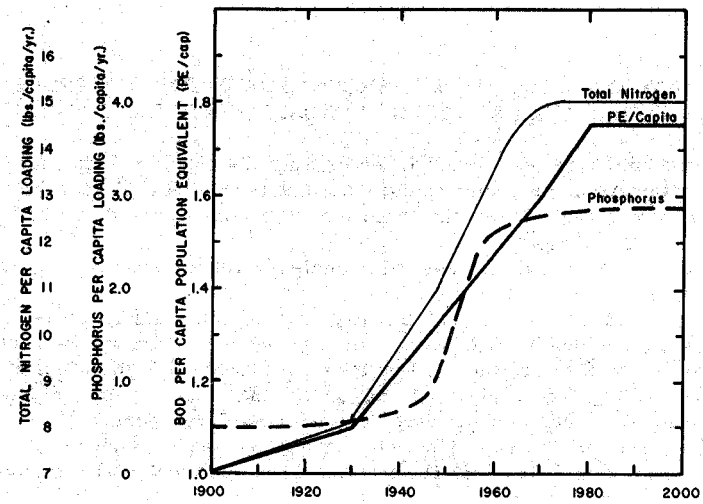


FIGURE 11. Variation in per capita loadings for BOD, total nitrogen, and phosphorus.

The amount of BOD discharged to U.S. streams from municipal outfalls for any year, n, was estimated from the formula:

$$(\text{lbs. BOD discharged per year})_n = 365\, p_{BOD}(\text{PE/capita})_n\left[(SP)_{on}f_{oBOD} + (SP)_{pn}f_{pBOD} + (SP)_{sn}f_{sBOD}\right]$$

Total Nitrogen

6. Assumed values for annual total nitrogen per capita loadings in raw municipal sewage (P_{TN}) between 1900 and 2000 were obtained from References 4, 12, 13, and 14. The data were plotted, and an "average" curve was drawn and extrapolated as shown in FIGURE 11.

The amount of total nitrogen discharged to U.S. streams from municipal outfalls for any year, n, was estimated from the formula:

$$(\text{lbs. total nitrogen discharged per year})_n = (P_{TN})_n\left[(SP)_{on}f_{oTN} + (SP)_{pn}f_{pTN} + (SP)_{sn}f_{sTN}\right]$$

Phosphorus

7. Assumed values for annual phosphorus per capita loadings in raw municipal sewage (Pp) between 1900 and 2000 were obtained from References 4, 13, 15, 16, 17, and 18. The data were plotted, and an "average" curve was drawn and extrapolated as shown in FIGURE 11.

TABLE 3

ESTIMATED MUNICIPAL DISCHARGES OF BOD, TOTAL NITROGEN, PHOSPHORUS, AND REFRACTORY ORGANICS TO U.S. STREAMS

Year	Sewered Population (millions)				PE Per Cap. (BOD)	BOD Discharged (million lbs./yr.)				P_{TN} Per Cap. Nit. Contr. lbs./yr.	Nitrogen Discharged (million lbs./yr.)				P_P Per Cap. Phos. Contr. lbs./yr.	Phosphorus Discharged (million lbs./yr.)				Refractory Organics Discharged (million lbs./yr.)			
	Total	That discharges				Raw	Prim.	Sec.	Total		Raw	Prim.	Sec.	Total		Raw	Prim.	Sec.	Total	Raw	Prim.	Sec.	Total
		Raw $(SP)_{on}$	Prim. $(SP)_{pn}$	Sec. $(SP)_{sn}$																			
1900	24.5[4]	23.5[4]	1.0[10]	0[10]	1.00	1430	40	0	1470	7.0	165	5.5	0	170	.50	11.7	.44	0	12.1	715	25	0	740
1910	34.5[4]	30.5[4]	4.0[10]	0[10]	1.03	1880	164	0	2050	7.0	214	22.2	0	236	.50	15.3	1.80	0	17.1	930	98	0	1030
1930	61.5[4]	43.5[4]	10.8[10]	7.2[10]	1.11	2940	435	49	3420	8.0	348	69.5	28.6	446	.50	22.0	4.91	2.52	29.4	1320	264	86	1670
1940	70.1[5]	29.4[5]	18.4[5]	22.3[5]	1.23	2210	900	167	3280	9.6	282	142	107	531	.65	19.1	10.8	10.1	40.0	895	450	270	1620
1945	82.0[6]	35.2[6]	23.0[6]	23.8[6]	1.29	2770	1180	187	4140	10.5	370	194	124	688	.80	28.2	16.6	13.3	58.1	1070	563	288	1920
1957	102.0[7]	24.7[7]	32.3[7]	45.0[7]	1.44	2170	1850	397	4420	13.2	326	341	296	963	2.10	51.8	61.0	66.0	179	752	791	545	2090
1962	123.5[8]	23.1[8]	27.4[8]	73.0[8]	1.50	2120	1640	668	4420	14.4	332	318	525	1180	2.40	55.5	59.4	123	238	703	677	887	2270
1980	192.6[9]	0	—	—	1.75	0	—	—	—	15.0	—	—	—	—	2.60	—	—	—	—	—	—	—	—
1990	236.0[10]	0	0	236.0	1.75	0	0	2520	2520	15.0	0	0	1770	1770	2.60	0	0	430	430	0	0	2870	2870
2000	279.4[9]	0	0	279.4	1.75	0	0	2980	2980	15.0	0	0	2090	2090	2.60	0	0	508	508	0	0	3390	3390

The amount of phosphorus discharged to U.S. streams from municipal outfalls for any year, n, was estimated from the formula:

$$(\text{lbs. phosphorus discharged per year})_n = (P_P)_n \left[(SP)_{on} f_{oP} + (SP)_{pn} f_{pP} + (SP)_{sn} f_{sP}\right]$$

Refractory Organics

8. The category, Refractory Organics (RO), was assumed to be the difference between COD (Chemical Oxygen Demand) and BOD. The concentration of refractory organics in raw municipal sewage was assumed to be 100 mg./l. (350 mg./l. COD less 250 mg./l. BOD). Assuming a daily per capita municipal waste flow of 140 gallons, the annual refractory organics contribution, P_{RO}, would be: 30.4 lbs./capita/year. This value was assumed to be constant during the period 1900 to 2000 because information on historical trends was not available.

9. The assumed efficiencies of primary and secondary treatment in removing refractory organics are shown in TABLE 3. To establish these estimates, the following BOD and COD concentrations in raw sewage, primary effluent, and secondary effluent were assumed.

Concentration, mg./l.

	Raw	*Primary*	*Secondary*
COD.	350	240	65
BOD.	250	160	25
RO.	100	80	40

The amount of refractory organics discharged to U.S. streams from municipal outfalls for any year, n, was estimated from the formula:

$$(\text{lbs. RO discharged per year})_n = (P_{RO}) \left[(SP)_{on} f_{oRO} + (SP)_{pn} f_{pRO} + (SP)_{sn} f_{sRO}\right]$$

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance of Mr. Charles F. Walters of the Federal Water Pollution Control Administration in preparing the estimates of municipal waste discharges shown in FIGURES 3, 4, 5, and 6 and described in detail in the appendix.

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Referring to figure 6 (see p. 743) the total biochemical ogygen demand (BOD) load to U.S. streams is represented by the curve, "I. Total Load." The nominal maximum removal efficiency of BOD from municipal wastes which can be expected of conventional treatment is 90 percent. On this basis, it can be seen that construction of conventional primary and secondary treatment installations will make a relatively large impact on the total pollution load discharged to the Nation's water resource because of the fact that many communities do not now employ even primary treatment, much less secondary. The degree of this impact is represented by the downward trend in the "Total Load" curve which can be seen to occur during the period from the present time to 1990. However, due to our ever-expanding population, the residual BOD load (that is the 10 percent not removed by treatment) will become increasingly more important. The curve "IV. Secondary Treated Load," represents this residual BOD load assuming the universal application of secondary municipal treatment. It can be seen that, based on present population projections, the total BOD load will again increase and by 2010 or 2020 will be equal once again to the total BOD pollution load in 1966.

From the foregoing analysis, I believe two things are clear: (1) we must proceed as rapidly as possible to apply available treatment in order to reduce pollution on a nationwide basis or even to "hold our own" in many local situations and (2) we must simultaneously accelerate our R. & D. to develop new, more efficient treatment methods. As you know, the FWPCA is even now accelerating its research, development, and demonstration activities in new waste treatment systems and in control of storm and combined sewer discharges.

With regard more specifically to question 10, let me state the following. Due to the fact that conventional secondary treatment processes are biological systems requiring certain "threshold" levels of food supply, nutrients, etc., and subject to "upsets" due to changing environmental conditions, toxic substances, etc., it appears that biological treatment systems of the type in use for the last half-century are at, or nearly at, their limit. Extensions of these biological processes substantially above their present performance levels would involve substantial capital outlays while gaining only marginal treatment ef-

ficiency returns. The processes are, however, both effective and economical for achieving treatment up to the 80 to 90 percent range. In addition, current treatment plants represent a very substantial capital investment. Accordingly, a major portion of our research effort will be to couple good biological treatment with tertiary advanced waste treatment processes which would be "built on" to existing conventional processes. We shall, also, be conducting research on entirely new processes or treatment system which could be more effective than current conventional treatment.

In direct response to question 10, I believe that acceleration of construction of conventional treatment plants is completely justified because (1) it is necessary to alleviate critical and near-critical pollution problems now and (2) many of the new waste treatment systems will involve tertiary processes which can be added to existing facilities.

Question 8: Has your agency ever worked out a timetable for an estimate of the total cost of works it believes to be necessary for an adequate program of water pollution control and planned such a program including the necessary research and development steps in advance of the need for the actual works? If this has not been done, can you produce such a plan, with costs and a timetable for carrying out the plan, for the Committee?

Answer: This question is related to question 5, in that an accurate estimate of the total costs of the measures for pollution control is not presently available. As indicated in question 5, a study to determine an answer to this problem was requested by the Public Works Committee, U.S. Senate. An optimum program of research and development, however, has been worked out in conjunction with the "Ten-Year Program of Federal Water Resources Research" prepared for the Office of Science and Technology.

Estimated expenditures for Federal Water Resources Research during fiscal years 1965–71 are listed on page 32 of the above-referenced document and shown below.

Estimated expenditures for Federal water resources research; fiscal years 1965, 1966, 1967, and 1971

[All figures are in millions of dollars in 1965–67 prices]

Category	1965 actual	1966 estimate	1967 estimate	1971 plan
I. NATURE OF WATER				
A. Properties of water	2.2	2.1	2.4	1.7
B. Aqueous solutions and suspensions	.7	.7	1.0	2.2
Subtotal	(2.9)	(2.8)	(3.3)	(3.9)
II. WATER CYCLE				
A. General	2.2	2.5	2.5	4.0
B. Precipitation	.6	.7	.7	1.0
C. Snow, ice, and frost	.3	.3	.3	.8
D. Evaporation and transpiration	.9	1.0	1.0	2.0
E. Streamflow	1.7	1.9	2.1	3.0
F. Ground water	1.4	1.7	1.8	2.5
G. Water in soils	1.0	1.1	1.1	2.5
H. Lakes	.5	.5	.5	1.5
I. Water and plants	.9	1.1	1.1	2.0
J. Erosion and sedimentation	2.1	2.5	2.4	3.0
K. Chemical processes	1.2	1.4	1.4	1.5
L. Estuarine problems	.5	.5	.6	1.0
Subtotal	(13.1)	(15.3)	(15.4)	(24.8)
III. WATER SUPPLY AUGMENTATION AND CONSERVATION				
A. Saline water conversion	8.5	18.2	23.4	15.0
B. Water yield improvement	2.1	2.6	2.2	6.0
C. Use of water of impaired quality	1.3	1.3	1.5	1.5
D. Conservation in domestic use	0	0	0	.5
E. Conservation in industry	0	0	0	.5
F. Conservation in agriculture	.7	.9	.9	3.0
Subtotal	(12.7)	(22.9)	(28.0)	(26.5)
IV. WATER QUANTITY MANAGEMENT AND CONTROL				
A. Control of water on the land	1.7	1.7	1.8	3.0
B. Ground water management	.3	.2	.3	2.0
C. Effects of man's activities on water	.5	.6	.8	1.5
D. Watershed protection	1.4	1.6	1.5	2.0
Subtotal	(3.9)	(4.1)	(4.4)	(8.5)

Estimated expenditures for Federal water resources research; fiscal years 1965, 1966, 1967, and 1971—Continued

[All figures are in millions of dollars in 1965-67 prices]

Category	1965 actual	1966 estimate	1967 estimate	1971 plan
V. WATER QUALITY MANAGEMENT AND PROTECTION				
A. Identification of pollutants	1.8	1.5	1.9	3.5
B. Sources and fate of pollution	1.8	1.4	1.5	4.0
C. Effects of pollution	3.5	2.3	3.4	9.5
D. Waste treatment processes	5.5	4.0	5.8	21.0
E. Ultimate disposal of wastes	1.5	1.3	1.4	4.0
F. Water treatment	1.7	1.2	1.2	1.8
G. Water quality control	.7	.6	.7	10.0
Subtotal	(16.5)	(12.2)	(16.0)	(53.8)
VI. WATER RESOURCES PLANNING				
A. Techniques of planning	.2	.2	.3	2.5
B. Evaluation process	.4	.6	1.0	4.0
C. Cost allocation, cost sharing, pricing/repayment	.1	[1]	[1]	1.0
D. Water demand	.4	.5	.5	1.5
E. Water law and institutions	.1	.1	.1	1.0
F. Nonstructural alternatives	[1]	.1	.1	.5
G. Ecologic impact of water development	1.7	.6	1.5	3.0
Subtotal	(2.8)	(3.0)	(3.4)	(13.5)
VII. RESOURCES DATA				
A. Network design	.2	.2	.2	.5
B. Data acquisition	1.0	1.2	1.2	2.5
C. Evaluation, processing, and publication	.6	1.0	.9	1.0
Subtotal	(1.8)	(2.3)	(2.3)	(4.0)
VIII. ENGINEERING WORKS				
A. Design	1.5	1.7	1.9	4.5
B. Materials	.9	.8	1.0	1.8
C. Construction and operation	1.9	2.0	3.0	4.0
Subtotal	(4.2)	(4.5)	(5.9)	(10.3)
IX. MANPOWER, GRANTS, AND FACILITIES				
A. Education—extramural	2.6	3.2	3.6	8.0
B. Education—in-house	1.0	1.2	1.4	4.0
C. Research facilities	1.6	1.6	2.4	2.0
D. Grants, contracts, and research act allotments	[2] 7.0	[3] 18.7	[3] 21.1	40.0
Subtotal	(12.1)	(24.7)	(28.5)	(54.0)
Grand total	70.0	91.9	107.3	199.3

[1] Less than $50,000.
[2] HEW grants in the amount of $6,304,000 allocated by subcategories.
[3] Does not include $20,000,000 available for research and demonstration grants.

NOTE.—Total may not add up due to rounding.

One of the most significant areas needing attention and which has the potential of a significant contribution to water pollution control is the program of advanced waste treatment research. This research effort is directed toward the development of new waste treatment processes. The objective is to develop by 1975 feasible techniques for complete removal of all point source wastes.

The Administration's advanced waste treatment program for accomplishing this has received the highest priority from the Committee on Water Resources Research, Federal Council for Science and Technology, and its panel of experts has recommended a greatly accelerated program.

To carry out an accelerated research and development program in advanced waste treatment, a 10-year $190 million expenditure is recommended to begin, in fiscal year 1967. This would provide for $26 million for direct research, $130 million for contract research, and $34 million for constructing field evaluation plants. In 1967, the Administration's laboratory research program will be well underway; contractors are even now prepared to undertake large-scale research, and several treatment processes will be ready for field evaluation.

Question 9: Are present methods for sewage and waste treatment adequate to eliminate the spread of disease by viruses? If not, what are you doing about it?

Answer: Conventional primary and secondary sewage treatment procedures used today by most communities do not completely eliminate viruses from sewage. Primary treatment removes some virus, and activated sludge treatment (secondary treatment) will remove even more, but field tests show that even when the effluents from activated sludge plants are chlorinated, viruses can still be detected. This is because chlorine is inactivated by certain of the impurities in the effluents.

The complete removal of viruses from sewage will require well-operated, more consistent secondary treatment, probably some form of tertiary treatment to remove the impurities that interfere with chlorination, and perhaps utilization of a disinfectant other than chlorine. Preliminary studies in this area have already been undertaken and a modest program is currently underway in research to remove viruses from waste effluents more effectively. Research in this and other areas relating to the removal of refractory components of wastes will be increased in fiscal year 1967.

Question 11: Your agency has responsibilities with respect to the amount of storage in Federal reservoirs under the 1961 amendments. Do you have similar responsibility with respect to locally constructed reservoirs? If you do not have this authority, would it be desirable to have it in view of the limited number of reservoir sites that are available and the need to make sure that such sites are not preempted by inadequate reservoirs?

Answer: While the Federal Water Pollution Control Administration has responsibilities in connection with provision of storage in Federal reservoirs under authority of the 1961 amendments, it has no such authority for locally constructed reservoirs. Similar responsibilities for locally constructed reservoirs would be highly desirable.

Such authority would permit fuller use of limited storage sites to be made for management of water quality to alleviate many pollution problems.

Local reservoirs constructed under the Soil Conservation Service authority contained in Public Law 83–566 also could provide augmented stream flows significant to alleviate local pollution problems. At present, however, the Soil Conservation Service does not consider that the Federal Water Pollution Control Act gives authority for them to expend funds for water quality control storage in these local reservoirs.

Question 12: Your statement indicates that the total expenditure of the Federal Government for research to develop new treatment technology through fiscal year 1966 has been less than $5 million. In view of the importance of this subject, why have expenditures been so limited? What is the request for funds for this type of research in fiscal year 1967?

Answer: Although research expenditures now appear to be limited in view of the importance of developing new treatment technology, they were in fact commensurate with other aspects of the water pollution control program in its early growth period. It is much clearer now that greatly accelerated expenditures are needed than it was in 1961 when amendments limiting the amounts to be authorized for research were added to the Federal Water Pollution Control Act. The 1961 amendment to the Federal Water Pollution Control Act which provided for a ceiling on research was not meant to limit the research effort but rather to accelerate that effort.

Since 1961, the national expectations to achieve higher levels of pollution control have been raised. At the same time, the problem has increased in magnitude and complexity with industrial expansion and population growth with the result that more sophisticated and expensive methodology must be brought to bear on the problem. The magnitude of the water pollution control problem, including needed research, has been updated to meet our national needs as now recognized.

The administration's research program has remained within the authorized limitations. To meet the problems as now recognized and defined, a greatly expanded research effort is needed and justified. The proposed research program can be effectively carried out using in-house and contract capabilities. The budgetary requirements for the three specified areas outlined in the act would now greatly exceed the $5 million annual limitation. By fiscal year 1968, the $25 million total limitation would have to be exceeded if the research program is to proceed at a reasonable pace in accomplishing its objectives. It is, therefore, apparent that some change in the existing legislative authorization for the research program should be obtained, including a revision in existing budgetary limitations.

The fiscal year 1967 request for research, including intramural research of all types and for contracts, is $8,690,750.

Question 13: Do you have any ideas as to how more glamour or dignity can be brought into the profession of sanitary engineering so as to remove one of the reasons that has apparently been keeping the inflow of people into this field at a minimum?

Answer: Aside from the psychological aversion in people's minds to matters dealing with the handling, treatment, and disposal of wastes, there are perhaps four major practical factors associated with sanitary engineering which have contributed to and continue to affect the status of the profession. These are: (1) sanitary engineering has not been a uniquely identifiable curriculum in the Nation's undergraduate schools, (2) there is confusion in the definition of the function of the sanitary engineer, (3) the public is not aware of the specific activities of the sanitary engineer and, in many cases, even of the existence of sanitary engineers, and (4) the salary structure. These factors are very much interrelated.

Historically, sanitary engineering curriculums have been associated very closely with civil engineering departments in most engineering colleges and universities. In order that the neophyte engineering student be aware of the opportunities and the challenges that exist for him in the study, the understanding, and the manipulation of the environment in which we live, sanitary engineering curriculums must be given specific identification. The interdepartmental nature of some elements of the curriculums is not in conflict with identifiability and is certainly not unique in today's university programs

There is confusion even among sanitary engineers themselves as to the function of the sanitary engineer within the engineering profession as a whole and within society. Recently, there has emerged the concept of "environmental engineering" which is concerned with all the environmental factors to which man is exposed and which directly affect his health and well-being. It is generally felt that the environmental engineer should be a generalist in terms of his knowledge of the broad areas related to air, land, and water pollution or to physical chemical, biological, radiological, etc., insults to man. Unfortunately, this generalist approach is in conflict with the ideas of this era in which the "glamour" of science is associated with the specialists. In order that our efforts be directed most effectively to the many scientific and engineering problems of the environment, both generalists and specialists are required. It is necessary to blend and utilize the talents and capabilities of the entire engineering profession and of mathematicians, physicists, chemists, and biological scientists, who may have been trained in other areas, for the solution of water pollution problems. Specialists in environmental sciences and engineering can be developed through the mechanism of intensive training programs.

The general public must be made more aware of the pressing environmental problems that we as a nation face. The problems of water resources, urban development, solid wastes and transportation require immediate, intensive research and development attention.

Inasmuch as sanitary engineers have been traditionally hired primarily by State health departments, schools and the Federal Government, the salary levels which a graduate sanitary engineer can expect to achieve are not comparable with those of other segments of the engineering profession. I believe it is fair to state that the "glamour" and dignity of a given profession are nearly always associated with the degree of public awareness of the functions of the profession, and this in turn is nearly always associated with expenditures of money by industries, State and local governments, and the Federal Government in areas associated with these functions. It is necessary to make salary levels more comparable to other fields of endeavor.

Question 14: Please furnish details of the criteria used for awards of grants and research contracts for water pollution abatement research.

Answer: Contracts—Research contract proposals are submitted to this administration as unsolicited proposals or in response to published requests for R. & D. qualifications and subsequent requests for proposals to solve specified research problems.

Upon receipt of a proposal, our technical staff reviews it to determine its general priority with respect to our research needs. That is, does it relate to a problem of significance, would it provide practical and usable results, what is its probable chance of success, what is the "payoff" if it succeeds and what is the negative impact on pollution control if it does not? Following this initial review, and assuming it is favorable, a more detailed evaluation is performed by other research staff, often located at our field laboratories, who are specialists in the subject area of the proposal, by scientists and engineers in other FWPCA activities, and by consultants (e.g., from universities, private industry, or other agencies). Based on these more detailed evaluations of the technical soundness of the project and approach proposed as well as on the project's priority with respect to accomplishing our program mission and the availability of funds, the final decision is then made to negotiate a contract or not.

In summary, contract proposals are evaluated on the following basis:

1. Relationship to program objectives and research needs;
2. Technical soundness of the proposal;
3. Cost of contract versus in-house project cost;
4. Capability of contractor;
5. Availability of funds and research priorities.

Grants—Proposals of independent investigators largely determine distribution of grant-supported research and development projects. Proposals are submitted to the program in the form of applications which are reviewed by panels of non-Federal advisory consultants. This review includes an evaluation of (1) scientific merit and significance of the project; (2) competency of the staff responsible for conducting the type of research proposed; (3) feasibility of the project and potentially useful results; (4) adequacy of the applicant's resources available for the project; (5) amounts of grant funds needed; and (6) the relationship to the Water Pollution Control Administration mission.

Question 15: There appear to be more and more opportunities for transferring pollution from one segment of the environment to another, that is, from water to air, or air to the soil. Now that Federal Water Pollution Control Administration has been transferred to the Department of the Interior, what means are provided for coordinating the efforts of your agency with the air and solid waste pollution control programs of the Public Health Service in the Department of Health, Education, and Welfare? Also with the public health aspects of the water pollution abatement programs which, the committee understands, have been retained in the Public Health Service because of their effect on public health?

Answer: Communication between the Federal Water Pollution Control Administration and Public Health Service, Department of Health,

Education, and Welfare, is a continuous process. There are no formal means yet established for coordinating the efforts of the FWPCA and the air and solid waste pollution programs of the PHS, Department of Health, Education, and Welfare. Since many of the staff of the Federal Water Pollution Control Administration were employees of the Public Health Service and a number of commissioned corps officers have transferred to these programs from the Federal Water Pollution Control Administration, a great number of professional contacts, both formal and informal, have been developed and are maintained.

With respect to the public health aspects of water pollution abatement programs, an interdepartmental agreement concerning consultation on health aspects of water pollution control has been developed. This agreement was signed by Secretaries Udall and Gardner on August 8, 1966. The President is now reviewing this agreement.

Question 16: Is your agency concerned with research into aspects of social science so as to better prepare the public to take necessary action in connection with pollution abatement? Please give details of what is being done, or reasons why this is not being done.

Answer: Under proposed expansion of research activities, the research and development program of the Federal Water Pollution Control Administration will conduct research into socioeconomic aspects of the water pollution problem where there are gap areas in the existing social sciences and to the extent that progress in the elimination of pollution is inhibited by these deficiencies of knowledge. Some of our research grants have dealt with socioeconomic research but because of limited funding in the past, direct research has not been conducted on socioeconomic aspects of water pollution. Definition of specific research needs in this area is planned during the current fiscal year. Several specific research needs already recognized include development of methodology to determine (1) the optimum modes of financing and cost allocation of water pollution control programs; (2) the most effective institutional arrangements, both on a nationwide basis and on a regional basis, for the most efficient quality management of the water resource. Research will be initiated in these areas in fiscal year 1968.

Question 17: Is your agency doing any research into the effects in the way effluent charges would work to reduce pollution? Please give details of what is being done, or reasons why this is not being done.

Answer: The Federal Water Pollution Control Administration completed a preliminary study of the effluent charge during 1965. This study was designed to determine the amount of the charge that would produce the same water quality objectives as would be achieved by prescribed treatment levels. Data and experience gained from the Federal Water Pollution Control Administration comprehensive quality control study of the Delaware River estuary were used. The theoretical computations showed that a variable charge from 5 to 8 cents per pound of biochemical oxygen demand (BOD) discharged to the stream would be appropriate.

Additional research on the problem is now being planned. Administrative and technical problems which were not considered in the first effort will be examined. It is necessary to evolve (*a*) the costs required to administer the system of effluent charges, (*b*) the optimal

institutional framework for the system and, (c) the necessary monitoring network for most effective operation of the system. The study will also attempt to determine methods for determining variations in the charges to allow for upgrading in the use characteristics of the Nation's water resource over time. Attempts will be made also to determine industry attitude and response to such a system. These preparations are being made in conjunction with the Delaware River Basin Commission.

Question 18: Recent news releases by the Department of the Interior suggest a "breakthrough" in control of algae in the waters receiving sewage plant effluent, through an inexpensive means of reducing the amount of phosphate in the effluent. Please explain the importance of the development reported, and how it relates to the testimony given the committee.

Answer: Recent investigations at the municipal sewage treatment plant, San Antonio, Tex., by the research staff of our Robert S. Kerr Water Research Center, Ada, Okla., have indicated that by a combination of modifications to activated sludge process operating parameters, removal of phosphorus to the 80 to 90 percent level may be possible. The experimentation is still in the preliminary stage and much work remains to be done before such modifications could be applied on a broad scale throughout the Nation. The findings, however, are of potentially breakthrough significance because of the possibility opened for achieving much higher phosphate removals in conventional treatment systems then thought possible. Effort in this area is undergoing substantial acceleration.

In terms of the importance of this development, however, the discussion presented in response to questions 7 and 10 must be borne in mind. Even with increases in phosphorus removal to the order of 80 or 90 percent, the remaining 10 to 20 percent residual load will become of real significance in the near future. Further, elimination of algal blooms, the primary manifestation of accelerated eutrophication is not absolutely tied to the attainment of high efficiency phosphorus removal from municipal outfalls. The mechanisms of accelerated eutrophication and the waste components that are primarily responsible for the development of algal bloom nuisance conditions are incompletely known at this time. Nitrogen and phosphorus compounds are generally believed to be associated with the development of such conditions but the critical controlling contaminant could conceivably be some other trace contaminant presently unknown.

Question 19: Is your agency doing any research on possibilities for stimulating growth of algae or other aquatic plants and harvesting them as a means of removing nutrients from sewage plant effluents?

Answer: Algae, when their growth is stimulated in shallow ponds with frequent mixing, can accumulate within themselves at least 80 percent of the nitrogen and from 75 to more than 98 percent of the phosphorus in waste water depending upon the operating and environmental conditions employed. Removals of this order can theoretically be achieved if an efficient harvesting technique is used to separate the algae from the water. A variety of harvesting methods have been studied by a variety of investigators but none has yet been highly successful from both technical and economic standpoints. Moreover, the process is probably applicable only in areas of consistently high

sunlight intensity for it appears that the provision of artificial light, to make the process more widely applicable, would increase process cost prohibitively. We have conducted research jointly with the Los Angeles County Sanitation Districts at Lancaster, Calif., on the removal of nutrients by algae with emphasis on the harvesting problems involved. A contract with North American Aviation (largely funded through a transfer of funds from NASA) was devoted to the study of forced algae growth for waste water treatment.

By physical-chemical methods now under study, more than 95 percent of the nitrogen and essentially all of the phosphate can be removed by adjustment of the pH of certain secondary effluents to approximately 11. The phosphates are precipitated chemically while the nitrogen, in the ammonia form, may be removed by air stripping.

In yet another approach to nutrient removal now under study, the activated sludge process is controlled and modified to achieve biological nitrification and subsequent denitrification. Potentially, a large percentage of the nitrogen may be removed by this process through biological conversion to harmless nitrogen gas.

Responses to Questions of the Subcommittee on Science, Research and Development by the Department of Defense

Question 1: Would you discuss, in the light of the Department of Defense experiences, the relationship between our capability to develop standards and criteria, and the establishment of realistic enforcement programs? (E.g., do we apply the same standards to our camps in the United States and at places like Adak?)

Answer: Based upon the experiences of the Department of Defense, any realistic program for enforcement must recognize the wide range on environmental quality which may be permitted to preserve or enhance a specific environment for its desired utilization. A major part of the problem, as indicated in our previous testimony is not so much in the realm of technical or professional environmental experts, as in that of socioeconomic-political value judgments.

Not only may different standards be appropriate for facilities in isolated and remote areas, such as Alaska, or some of the Pacific areas, but varying degrees of quality may be appropriate for different locations within the continental limits of the United States. Ipso facto application of a single "standard" for Federal installations would violate some of the fundamental principles of political economics. In that connection both the Executive orders on water pollution and air pollution recognize that varying degrees of control may be appropriate in different locations and for different situations, and provide for exemptions to the "standards" for water pollution and the use of "secondary treatment." This does not establish a degree of effluent quality, but rather establishes a treatment method to be used; and one that affords a widely varying degree of efficiency in waste water treatment. As an example, some secondary treatment processes might remove 85 percent of the organic loading from the influent to them, and others as high as 95 percent. In combination with other processes, depending upon the effluent desired, and the amount of expense willing to be undertaken, virtually any desired degree of removal might be achieved. The type of secondary treatment provided obviously must be based on professional judgment of the many methods which might be used to provide either effluent quality, or to prevent an adverse effect on desired conditions in the receiving environment.

The question of varying requirements for varying desired uses has long been studied by the specialists in the fields of water resources. As long ago as the 1930 time period, suggestions as to the possible classification of waters by intended usages were developed. (See "Tendencies and Standards of Rivers and Lake Cleanliness," Sewage Works Journal, vol. VI, July 1934; and "Sewage Treatment," Imhoff and Fair, McGraw-Hill Co., 1940.) The majority of existing statutes of the various States follow the general philosophy enunciated in these and similar authoritative works. The tremendous success of the participants in the Ohio River compacts may be attributed to the recognition of these differences in requirements, and the use of a wide variety

of enforcement techniques and procedures to attain the desired environmental situation.

Any enforcement program, therefore, to be effective must be related to a series of authoritatively established "value judgments." This infers that the beneficial use of the environment can be specified or defined in quantitative terms, that adverse effects can likewise be quantified and that there are means available to protect the public health and to provide for future needs. All of this must be capable of being translated into a series of "thou shalt" and "thou shalt not" rules.

There must be some effective means to determine if indeed an adverse situation in relation to the desired utility is actually existing. The relationship between environmental quality and enforcement also involves a means by which the regulatory procedures shall be enforced. In the Senate report on this subject (S. Rept. No. 10, on the Federal Water Pollution Control Amendments of 1965, 89th Cong., 1st sess.) it was stated that water quality standards, as an example were not designed for use primarily as an enforcement device. Rather their principal objective was intended to be for the orderly development and improvement of resources "without the necessity of adversary proceedings which inevitably develop in enforcement cases." This "performance standard basis" is utilized by a number of legislative authorities. This approach envisions that such "standards" provide an engineering base or series of engineering benchmarks or guidelines for the development of plans for facilities.

On the other hand, some regulatory agencies insist that they must check each individual project and engineering design to the last detail. In some instances, precise requirements are specified in the legislative action or in the enabling regulations, or that some permits or similar specific authorizations be utilized. This may result in a failure to provide adequately for changes in technology.

From the foregoing, it is evident that different requirements should and will exist for environmental quality depending upon geographical location and the desired utility of the environment at that location. Further, the time phasing of necessary actions will depend upon the current situation, anticipated future requirements, and the need for flexibility to accommodate the changing needs and desires of the community.

The range of environmental pollution control requirements for different geographical locations is the result of a number of considerations. These include the extent of the need; and the variety of available measures to control pollution; the structure of local laws and regulations; and to some extent the functional position of the enforcement authority within the particular governmental entities involved. This is not to say that there cannot be some general agreement regarding the quality objectives for the various usages.

In the case of water, and perhaps in the case of the air resource, objectives can provide a basis for both the required degree of treatment before injection of a potential pollutant into the environment and the quality of the environment desired as a source of supply. The approach used by the Food and Drug Administration in setting a tolerance for residues of pesticides on raw agricultural products is a case in point. That which is permitted is somewhere between what is prac-

tical to prevent and what might be truly harmful. It is never above what could be harmful and always is established at a level which is practicable to achieve and which is measurable.

In summary, any realistic enforcement program for environmental quality must have its basis in the state of knowledge and capability to establish standards or criteria and must envision sufficient flexibility to accommodate to changes as improvements in knowledge, or alterations in situations occurring. It is evident that in order to avoid unrealistic programs for public expenditures as well as those in the private sector that there must be a high degree of communication between the various disciplines involved including those of law, political science and economics, as well as of ecology and environmental engineering and science. Of even more importance to any realistic program is the improvement of communications between the specialists and the public at large.

Question 2: You have mentioned the need for a national plan for the Federal departments and agencies for environmental pollution abatement. Would you discuss further how the systems approach could be used in this effort?

Answer: In developing a national plan for environmental pollution abatement, it is essential that the three principal problem areas, namely, water pollution, air pollution, and disposal of solid wastes be viewed as part of an integrated larger effort to provide for the utility of the Nation's environment and resources for the future as well as for the present. As has been widely recognized by the subcommittee, there would appear to be solutions to certain of the pollution problems which may not take into account the fact that they in turn create or intensify others. Burning of refuse or disposal of it into so-called sanitary land fills instead of grinding it up and disposing of it through the waterborne route is a case in point. In the first instance, burning may create an air pollution problem, which admittedly might be offset by proper wet scrubbing and disposal of the residue from the burning operation. The extra cost of collection and transporting of the solid wastes might well be offset by the recovery of the heat energy of the waste and its use for power production (which the Department of Navy is currently experimenting with). However, in the zeal to overcome the pollution problem, the fact may be overlooked by some that grinding of food wastes at the point of origin and that prompt disposition into the water carried systems eliminates a source of rodent and fly breeding with attendent hazards of transmission of intestinal diseases.

There is a tendency in evaluating the potential of systems engineering and systems analysis to look at "objects" rather than the basic concept. Admittedly some of the byproducts of modern space technology which have been incidental to our systems approach do have an application to the problems of environmental pollution abatement. Some of these have been cited in our prepared testimony. Another byproduct which well might be investigated is the use of nutrient rich sewage effluents for the production of protein rich algae which could be utilized for animal foods or possibly, with sufficient refinement, for human consumption.

Be that as it may, the fundamental requirement in the environmental pollution problem is the need for the efficient allocation of resources.

As is the case with national defense the public desire is for an effective program. At the same time there are public pressures to maintain fiscal responsibility. The very nature of the environmental pollution problem eliminates a price mechanism or competitive forces in the classic sense.

Whether one is undertaking a problem in military planning, in industrial production, or other forms of systems analysis, the principal elements involved are: definitions of an objective or objectives; the selection of alternatives and the detailed accumulation of information thereon; a study of the costs of resources required which can trace relationships between inputs and outputs, resources and objectives and last, but not least, the selection of a criterion as a test by which one alternative system may be chosen rather than another. As in the case with most systems analysis problems and as has been repeatedly stated in these presentations, the central problem for both the near and long term is the selection of appropriate criteria. The words of Hitch and McKean in their book, "The Economics of Defense in the Nuclear Age," in relation to military problems appear to be most appropriate with regard to systems engineering and systems analysis as related to the environmental pollution problem. In that work they said:

> Whatever the particular problem, military or civilian, it is fairly obvious that in choosing among alternative means to our end, we need to scan the end themselves with a critical eye. New techniques or types of equipments may be extremely efficient in achieving certain aims, but these aims may be the wrong ones. Aims that are selected almost unconsciously or at least without sufficient critical thought * * *. While good intentions are sometimes reputed to be excellent paving materials, they do not pave the way to preferred action. In practical problems of military (or other) choice, there are always constraints which prevent us from simultaneously achieving all our objectives.

These exponents of the concepts of systems analysis further went on to say that while ideally we should choose a course of action which would maximize something like "the satisfaction of an individual" or "the well-being of a group" that such a prescription usually prescribes a little more than what is wanted as being "the best." They hypothesize that in practical problem solving, we have to look at an "approximate" criterion, as a practical substitute for the maximization of what we would ultimately like to have. Also there is a need for breaking down the problem into component pieces or subproblems which can be identified as components of the whole, but which are more readily susceptible to practical real time solutions. This is especially applicable to the environmental pollution question. An example of this approach was outlined by Harry Hanson while the Associate Chief for Environment Health, Office of the Bureau Chief, U.S. Public Health Service, in 1964. He suggested that these techniques could be used with smaller and simpler river basin basing systems. All of the existing hydrologic use and quality factors could be established as a framework for analysis. Such a system could then be challenged with hypothetical or predictable conditions of supply, demand, use, reuse, and quality requirements. Out of such an effort more precise environmental resource and environmental quality management programs could be developed. Similar applications to the larger problems of water use requirements, the relation between various pollution implication of solid waste procedures, could be

developed. Simple models also could be developed on a gross basis for regional, and even national planning and programing.

In making a critical examination of the alternatives, an assessment should be made of the cost (both in the sense of capital outlay and in the sense of adverse effect on resources if no action is taken) and the utility or benefits or gains associated with each of the alternatives.

Having defined broadly the problem and then addressed attention to concept and methodology, specific evaluation studies should be made on a geographical regional basis with attention directed first to those areas of known major problems. Obviously, since over 80 percent of the population is expected to be located in the 200 some odd standard metropolitan areas in the next few years, primary attention should be given to those Federal installations located in or adjacent to these centers of population.

It seems feasible to reduce some of the detailed planning of actual programs and control systems to the typical network analysis and programing documents used in the PERT system to establish appropriate reporting and control systems to measure progress toward the previously developed objectives. Inherent in this is the continued "roll forward" of the near-term plan, on an annual reprograming cycle.

In applying the systems methodology and the techniques suggested above, it must be kept in mind that neither the plan nor its implementation is solely the province of the technical expert. Specialists in public administration, law, sociology, and economics must be involved and must participate with the professional environmental pollution abatement workers of the Federal departments in developing a truly Federal plan. Professor Morrisy Gonzey of the University of Colorado, in his paper, "Proposal for a Program of Research and Graduate Training in Environmental Economics," makes this point very well as follows:

> Thus in the end, scientific analysis of the economic and social problems involved in maintaining and improving the quality of the natural environment becomes interdisciplinary. This view is of course inherent in the nature of systems analysis and program budgeting.

While there may be violent disagreement in some quarters regarding the results of the so-called systems analysis, and other efforts to integrate all of the multifacets of the pollution problem into a manageable form, the fact remains that some of the experience and expertise of resource management inherent in these approaches can be applied with suitable modification to the pollution abatement problem. While "experts" may disagree with the results, depending upon their specific orientation, the systems approach does produce analytical assistance upon which policy judgment can be based. There is a great need in the environmental pollution program as there is in those of defense and space for an assessment of alternatives, and of the effect thereon of what the economist terms "land, labor, and capital." The very pervasive nature of the questions concerning environmental quality and environmental pollution abatement make it vital that the requirements, constraints, and side effects on other national policies be examined in a systematic manner. In so doing, it must be recognized that the very nature of the problem, with many different governmental jurisdictions and varying public interest involved, indicates that there will result from such analysis a spectrum of program choices. The ultimate

decision as to which of the varying alternatives is selected rests in the public domain. It is here that the concept of "Federal leadership" is really put to the test. What is done in the Federal departments and agencies must submit to the test of practical results, economy of operation, and reasonable capital investment.

Question 3: How do you view the role of the professional specialist in providing a better state of knowledge on the part of the general public regarding the problems of environmental pollution abatement?

Answer: The professional specialist has a moral or professional obligation to give the facts of a given situation as he sees them without attempting to color the views with his personal opinions, motivations, desires, political or religious convictions. The "information explosion" that is accompanying the speeding advance of science and technology and the rapidity of communication (particularly in the public media) presents a major challenge to the professional specialists in informing the public regarding environmental pollution. Many aspects of the question of environmental quality in reality (as has been indicated in our prepared testimony and in response to these additional continuation questions) involve subjective reactions rather than objective analysis. The importance of providing information in a readily understandable form for use by the general public becomes immediately apparent.

The professional specialist in environmental pollution must recognize that individuals (and individuals collectively in groups) undertake action when the satisfaction to be derived from that action outweighs the discomforts and sacrifices that he may have to undergo in order to arrive at that particular goal. This does not infer that people and populations behave in a rational manner. Population prejudices, habits, and just sheer inertia may prevent what appears to be a perfectly logical and necessary course from being undertaken. Expectations and apprehensions based on past experiences or on inadequate information, although unfounded, may prove to be a deciding determinate in individual and group responses. Accordingly, some single or possibly only two or three elements affecting a problem in the public domain may influence the overall decision. The situation may become even more acute when the problem is a complex one in which an ill-defined or only partially valid premise or set of conclusions is present in an authoritative sense. The problems of environmental pollution presents just such a set of conditions.

The professional specialist, to properly communicate with the general public, must have available to him adequate communication within his own discipline and must insure that such communication exists with the other disciplines who have a proper interest and involvement. Without such communications, the inevitable differences of opinion or narrow specifities of interest within the professional community can only emerge to further confuse the general public.

This problem of information dissemination and information retrieval is a major one. The Department of Defense-NASA Information Life Sciences, Space Research and Technology Exchange (ILSSE), now being incorporated into the Defense Documentation Center and the services available to the various Federal departments and agencies through the National Research Council, National Advisory Center on Toxicology, represent efforts to make available on a

rapid recall basis the vast amount of data being produced as part of our research, development, test, and evaluation programs. What is needed however, is something similar to the NASA "Aerospace Medicine and Biology Continuing Bibliography," aimed at the broad problem of human ecology and environmental pollution. This latter publication, compiled through the cooperative efforts of the Library of Congress, the American Institute of Aeronautics and Astronautics, and the National Aeronautics and Space Administration, assembles within the cover of a single announcement groups of references that were formerly announced in separate journals to provide a convenient compilation for all scientists concerned with the problem. Development of such a program would provide for an improved state of knowledge within the various disciplines and for a better interchange of understanding of what is being done in the interest concerned.

Another major effort on the part of professional specialists to develop further general public awareness of the facts and problems of environmental pollution is that associated with professional society and intersociety actions. There are a great number of professional organizations such as the American Society of Civil Engineers, the American Association for the Advancement of Science, the American Institute of Biological Scientists, and many others, whose members are active in environmental pollution control. In addition to presenting testimony before congressional committees which some of these organizations have done in the past, a much more vigorous undertaking at the State and local level in presenting technical opinions and views before authorities concerned with legislative matters and in the development of statements for issuance in the general public press, as in form of reports of their committees, would serve a most useful purpose if the necessary care and restraint indicated above is exercised. Similarly the various professional and interprofessional groups can contribute a great deal to better understanding of the problems of pollution through working with the secondary schools in furnishing guest speakers, exhibits, and even instructional materials.

The professional specialist can assist greatly in better public understanding as he develops a better knowledge and appreciation of the techniques and principles of modern communications. Not all scientists are good speakers, nor are they endowed with ability to translate complex scientific and technical problems into readily understandable terms. However, an increasing awareness of the importance of the techniques utilized in television, radio, and other mass communication media including the traditional one of the public periodical and daily newspaper will assist in providing the general public with the necessary information upon which it can make the judgments at the polls and through their legislative representatives. The scientist and all other specialists in environmental pollution have the task of translating information to the public in readily understandable form. In so doing, the aim of providing a basis for judgment by those who must exercise some (the public up to through the legislative process) will be best served if the features of the scientific method described by Karl Pearson in the last decade of the 19th century are followed. These are:

(*a*) Careful and accurate classification of facts and observations of their correlation and sequence;

(*b*) The discovery of scientific laws by aid of the creative imagination; and

(*c*) Self-criticism and a final touchstone of equal validity for all normally constituted minds.

Question 4: Do the present procedures for obtaining funds for pollution abatement and the research thereon affecting the Department of Defense create any special problems?

Answer: The existing procedures for the military construction program do present some problems insofar as pollution abatement projects for the military departments and agencies are concerned. Normally the typical military construction cycle involves something over 3 years from the time of identification of the need for the project and its completion. National defense plans and decisions affect the size and scope of the military construction program and individual installations are continually engaged in evaluation of their requirements to meet approved Defense programs. There are no special provisions in the current statutes and procedures for the military construction program which apply to air and water pollution abatement projects or exempt them from the scrutiny required to establish their relative importance and urgency in budget prior to inclusion of specific projects in the budget program to be submitted by the President to the Congress. Development of a typical fiscal year's military construction program involves approximately 1 year of intensive planning and review. In this review, pollution abatement projects must stand on their merits as compared with other requirements directly related to the operational mission and personnel support.

Under the provisions of Executive Orders 11258 and 11282, new facilities must be provided with adequate measures for control of pollution, and pollution control for existing facilities must meet established standards. This will necessitate the inclusion of appropriate projects for expansion of existing facilities where they are inadequate. Normally this will not present very many problems, except in the case of installations in which existing waste disposal facilities are recognized as requiring upgrading or improvement but no immediate urgency exists. Assessment of priorities may be difficult particularly in view of the "leadership" requirement of the Executive order. Likewise, serious problems emerge in getting authorization and appropriations for initiation of work that is deemed necessary by a State or other regulatory authority with completion desired sooner than that provided in the military construction program.

This problem has been recognized by the military departments and it is currently being studied by a working group of the DOD Environmental Pollution Control Committee and representatives of the Office of the General Counsel of the Department of Defense. Proposals will be included in the Department's legislative program which will allow for special identification of environmental pollution abatement projects. In addition, it is envisioned that some special provisions might be requested which would allow expeditious authorization of projects of a special and urgent nature.

At the present time, there is no special identification of environmental pollution abatement research programs. A considerable amount of effort is undertaken by the military departments and agencies on research either directly associated with pollution control from

military facilities and associated with military systems, or which has a bearing upon pollution abatement problems. No specific problems have been experienced insofar as approval of necessary research, development, test, and evaluation programs is concerned. However, due to the structure of the research program of the Department, it is sometimes difficult to identify all elements of the research program which might be considered as having a relationship to pollution abatement. Here again, this problem has been recognized and is currently subject of study and evaluation to determine the best course of action to be followed in the future. There were a number of recommendations contained in the President's Science Advisory Committee's report which have definite implications to the Department of Defense's research activities. In addition to means of better identification of the projects and programs conducted by the military department, the need for some specialized overall research identification and program is being carefully considered.

Question 5: Do you believe that many of the currently proposed programs, such as the $30 billion program to separate storm and sanitary sewers are "cost effective" with regard to our military installations?

Answer: The question of "cost effectiveness" of pollution abatement works is extremely difficult to answer. Before elaborating upon some of the general issues, information on the specific case of separation of combined sewers may provide an insight into the larger question.

The majority of Defense facilities and installations have been built with either separate sanitary and storm drainage systems or storm water is carried away through surface runoff channels. At some installations, it has been found that there is a large volume of water infiltrating into the combined storm and sanitary sewer collection systems. As a result, the flow reaching the waste water treatment facility is vastly disproportionate to the population served. Cost of constructing new separated collection systems has been compared to the initial capital outlay and annual operating costs which would be required to provide for the total flow. In other instances, increasing buildup of the occupied areas of the installation has resulted in a decrease in the time of concentration of surface runoff reaching the combined sewers as well as an increase in volume. Here again, analysis has indicated that a tradeoff exists in the costs of new collection systems versus increases in plant capacity. At such installations, plans have been formulated for modification and improvement of the existing collection system.

Another consideration in determining separation of existing combined sewers at some military bases has been the heavy degree of industrialization of the military installation with resulting generation of industrial wastes which adversely affect domestic sewage treatment operations.

It is emphasized that these projects have been undertaken on an individual installation by installation basis based on demonstrated needs. Insofar as current and future construction projects are concerned, the three military departments have established policies for the construction of only separate systems.

With regard to the more generalized problems of cost effectiveness of environmental pollution, the established Department of Defense programing procedures take into account both near and long term requirements. The economics of environmental pollution abatement require that the problem of allocating resources efficiently within the present technology be distinguished from the problem of advancing the state of the art and for developing new technology. The question of cost effectiveness of environmental pollution abatement programs and procedures can be thought of as being somewhat analogous to the economic analysis utilized in some aspects of Defense Department planning and programing (see also answer to question 2). There is no question but that the problem of environmental pollution abatement requires immediate remedial and interim preventive measures or that new technology and new concepts will be developed to provide for the future. There is likewise no question but that the Federal departments and agencies must undertake activities to abate and prevent pollution from their installations and operations. From a truly cost effective viewpoint insofar as the Department of Defense is concerned, the direct cost associated with installing, operating, and maintaining environmental pollution abatement control procedures contributes only incidentally to the maintenance of military effectiveness. The principal direct gains and costs of the Defense program are associated with such desired ends as deterrent and limited war capabilities. Direct costs are the goods and services which are necessary to the national secuirty program. There are many indirect impacts of Defense operations, some of which may be described as benefits and others as costs. Since environmental pollution control programs contribute to the preservation of natural resources and through their effect on improvement in health and well-being of the population to the Nation's manpower potential, there are some Defense implications in the indirect benefits of these expenditures. In "The Economics of Defense in the Nuclear Age," Hitch and McKean point out that it should be recognized that there are numerous spill-over benefits to private sectors of the economy from Defense operations. They pointed out that highways built for Defense purposes, sea and air navigational aids, military education programs, and research on Defense activities provide contributions to the national well-being. This applies also to the environmental pollution abatement expenditures.

Like military problems, the central consideration in assessing cost versus benefits or cost effectiveness is the need for definition of the objective. In attempting to assess the cost effectiveness of a particular program, the ultimate end must be carefully scrutinized so as to arrive at criteria which allow a realistic judgment. The methods of operation of Department of Defense programing do result in this sort of analytical approach to our environmental pollution abatement programs. Where the objectives are not clearly specified in form of environmental quality standards or statements, necessary judgments are made utilizing the best available information and consideration of the various alternatives. When viewed against that rationale the military programs for environmental pollution abatement do indeed have a cost effectiveness basis. Insofar as the larger issue of the national programs, it is believed that the technique discussed with regard to question 2 and the comments relating to systems

analysis do provide a means whereby a cost effective approach can be taken.

Question 6: How does the Department of Defense arrange priorities and plans for pollution abatement for submission to the Bureau of the Budget and the Congress? Are these plans in consonance with national progams developed by the Federal Water Polution Control Administration, HEW, or however?

Answer: The military departments and agencies, in accordance with general guidance developed by Department of Defense Environmental Pollution Control Committee, analyzed their requirements for pollution abatement works and programs and developed their phased plans for inclusion in the consolidated Department of Defense reports to the Bureau of the Budget. Executive Order 11258 required the submission of the first plan for water pollution to the Bureau of the Budget on July 1, 1966, with an annual revision thereafter. This plan was required to be developed in consultation with the Federal Water Pollution Control Administration. The first plan for air pollution abatement will be submitted in accordance with the Executive order on July 1, 1967.

In the case of the water pollution abatement plan for fiscal years 1968–72, the plan was developed as a best estimate of the facilities to be provided and a time phasing schedule contemplated for its accomplishment. It was recognized that the plan does not constitute an actual budgetary program since it must be subjected in each fiscal year to the normal budgetary processes and will have to be revised annually. In the case of water pollution, the initial plan gave highest priority to those installations which could connect to municipal systems which would be constructed in the near future, and to those installations which were not in compliance with State and local regulations. Following this, priority was given to installations having no treatment, and then to those with primary treatment only.

Due consideration in assessing priorities was given to the recommendations outlined in the Subcommittee on Natural Resources and Power, House of Representatives Committee on Government Operations' reports.

The proposed military departments' plans and programs were reviewed with representatives of the regional program directors of the Federal Water Pollution Control Administration prior to submission to the Bureau of the Budget. Comments and recommendations regarding installations which they considered should have been included and were not, as well as other suggestions regarding the plan, were furnished to the Department of Defense. The plan has been forwarded to the Bureau of the Budget who, it is our understanding, will have a more detailed review from a national planning viewpoint accomplished by the Federal Water Pollution Control Administration prior to advising the various departments as to any changes or modifications required.

In the case of air pollution, instructions are currently being formulated for issuance in the form of a Bureau of the Budget circular which will provide guidance to all Federal departments and agencies. Representatives of the various Federal departments have been consulted regarding specific problems associated with the development of their plans. It is anticipated from information currently available

that a report will be required for those installations not meeting the requirements of the Executive order and regulations, and a phased and orderly plan for correction will be submitted. This plan will be reviewed by the Bureau of the Budget and the the Division of Air Pollution and the departments advised thereon.

In both air and water pollution control (and in the future on solid wastes disposal) it is hoped that by close communication with the department having primary responsibility (the Division of Air Pollution, U.S. Public Health Service; Office of Solid Wastes Disposal, U.S. Public Health Service; and the Federal Water Pollution Control Administration) the priorities and time phasing in the consolidated Department of Defense plan will reflect overall national concepts and programing philosophies. It is intended to expand the efforts of coordination at the departmental level and in the regional and field activities as well.

RESPONSES TO QUESTIONS OF THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT BY MR. BERTRAM C. RAYNES, RAND DEVELOPMENT CORP.

Question 1: In your testimony before the Subcommittee on Science, Research, and Development, Committee on Science and Astronautics, on July 28, in answering questions about the coal process in treating sewage, you made reference to the increased efficiency possible with this process when the coal could be burned after use and the energy of the coal recovered. You mentioned that this step was only feasible in the larger size plants; how is the coal to be disposed of after use in smaller plants if it is not to be burned? If it has to be buried or otherwise disposed of on land, does this not add to the pollution of the soil? In the larger plants where the used coal is burned does not this process merely transfer the polluted material absorbed by the coal from water into the atmosphere?

Answer: My reference is to increased economy possible when the coal-sewage solids mixture is burned with recovery of the thermal energy it possesses. Plant effluent quality remains the same regardless of the fate of this material. Incineration is the disposal means we favor. Incineration can be carried out regardless of the size of treatment plant involved and at some scale of operation (perhaps for a plant serving 25,000 to 50,000 persons), recovery of the energy becomes economically attractive in-plant. If the plant is situated near an already existing boiler it is entirely possible the coal mixture from even a very small plant can be used economically.

By no means are we interested in substituting one pollution problem for another. We do not want to pollute the air in the process of helping to control pollution of surface waters. Sewage treatment plants which produce sludges—both primary and secondary treatment plants—often incinerate those sludges for disposal. The coal-based sewage treatment process does not eliminate the air pollution problem, but it can decrease it because higher incineration temperatures and afterburner temperatures can be used than with sludge. I'd like to work on air pollution problems, but haven't yet.

Question 2: In your statement you made reference to the Federal Government forcing industry to take care of its wastes. Do you feel that if the Government does, through legislation, force this step to be taken, that the necessary technology will be produced by this action?

Answer: Necessity has always been the father of technology.

Question 3: In urging that the Federal Water Pollution Control Administration set up a troubleshooting group of experts to help work out the practical problems of operation of sewage treatment plants in smaller towns, does this not put the Federal Government in direct competition with sewage plant engineering firms?

Answer: I don't believe so. Engineering firms are not sewage plant operators. If equipment fails, engineering firms can help, or the

equipment manufacturer can help. My suggestion concerns plant operation and technique.

Question 4: Do you believe it is realistic to force industry to return "pure" water to streams regardless of the cost of necessary treatment? Are you not afraid that lack of capital will hinder any such effort?

Answer: Sir, a chemical engineer can never ignore costs. Granted that cleaning up pollution is expensive. But not cleaning up pollution is expensive, too. Industry pays to clean up its water supply. Municipalities pay to clean up their water supplies. There are damages to public and private property caused by filth and corrosion. And there are other costs, the esthetic losses. It may be, in fact, unrealistic not to require industry to return clean water to streams—on a cost basis alone. I haven't seen a balance sheet on these costs; some say it will cost too much, and some say it will be worth the cost. A good, complete balance sheet would be useful in permitting an objective assessment of which approach will actually cost less. Perhaps this committee could authorize the development of such a balance sheet.

Question 5: Your statement suggests that you are unwilling to consider use of streams for disposal of any waste material. Would you propose to eliminate even natural accumulation of wastes in streams? Is not a certain amount of organic waste healthy for a stream in providing the necessary food for the life cycle of plants and lesser species of living organisms that provide food for fish? How would you propose to set standards for what is permissible in streams to be used for various purposes, such as drinking water, recreation, industry, in the absence of studies of the problems and analytic techniques and the like which you suggest should be eliminated?

Answer: I'm proposing that the standards be set for effluents entering streams. These effluents should be as pure as present science and technology can make them, with aggressive technological and business management seeing to it that the cleanup is conducted efficiency and skillfully and that cleanup operations are upgraded just as constantly as production operations are.

I do not propose eliminating all studies. Meaningful studies suggest solutions and attractive suggested solutions should be tried in realistic programs. I endorse meaningful studies.

Question 6: Do you believe we should install devices to control emissions into the atmosphere even if the emissions are found to be harmless?

Answer: Well, if emissions are found harmless through the expedient of putting them out into our atmosphere and seeing who complains or what the environment suffers, then I'd certainly prefer prior control. Prior understanding at the very least.

Question 7: What kind of legislation do you believe is needed to bring about an upgrading of our pollution control efforts?

Answer: I think that uniform, countrywide enforcement of past and presently proposed legislation would upgrade pollution control efforts. Ways should be found to permit increasing use of pollution abatement field evaluation programs and funds to prosecute them forcefully should be provided.

I think that the approach to and the philosophy of pollution control has to be changed, as I suggested in my prepared statement.

Question 8: How much has been spent and is available for develop-

ment of the coal process for sewage treatment? Where did the money come from?

Answer: The development of the coal-based waste water treatment process is sponsored by the Office of Coal Research, U.S. Department of the Interior. All funds have been provided by that Office. The first effort was funded at about $200,000, and the present 2-year pilot program is funded at about $667,000.

Question 9: What percentage of total funds expended by your organization on pollution abatement research comes from Government? From industry?

Answer: While the funds for the pollution abatement research my company is doing at present come from Government, I should add that industry in general has been cooperative in supplying samples of their effluents at their expense, and in other ways. We would be glad to work directly for industry in this area of research and development.

RESPONSES TO QUESTIONS OF THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT BY DAVID C. KNOWLTON, KNOWLTON BROS., INC.

Question 1a: What has been the estimated savings to the industry through making these improvements in papermaking processes?

Answer: If the question relates to the recovery of usable values by waste treatment processes of any kind, such values are usually nonexistent or negligible. The references in the statement to improvements in the water economy and the fiber economy within our pulping and papermaking processes refer primarily to in-process changes which were economically justified by the resulting savings. However, it should be noted that such in-process changes have had significant collateral benefits in reducing the industry's waste discharges. There are a few exceptions where heat, water, or material savings are possible but only to a very limited degree.

Question 1b: Does the industry tend to make the changes in process to eliminate pollution only when there is an economic savings in the cost of producing paper?

Answer: With respect to the industry's attitude toward process changes or the installation of waste treatment processes to avoid pollution, such changes are made as needed to the extent it is practicable to do so in order to conform with applicable receiving water quality regulations.

Question 2: Can you develop figures on how much the industry itself is expending in its own laboratories on pollution abatement?

Answer: The current budget for the National Council is $428,000. In addition to the National Council expenditures for research and development directed at the abatement of air and water pollution—as well as those of the North West Pulp & Paper Association, the Sulphite Pulp Manufacturers' Research League, and the Institute of Paper Chemistry—individual companies of the industry are currently spending in their own laboratories in excess of $2,500,000 per year on air and water pollution abatement investigations. This amount does not include capital or operating expenses connected with waste treatment installations.

Question 3a: Can you give more quantitative estimates of the re-

sults of NCSI research and any actions which have been taken to alleviate pollution based on this research to date?

Answer: Although this question has been answered by the testimony and the annotated material submitted with the corrected testimony, the most important phase of the National Council work is in the distribution of the information and the assistance of technical service. Most of the findings from the Council research work are implemented by the member mills to make them suitable for their particular conditions or situations. Furthermore, equipment evaluation and treatment studies by member mills or groups of mills working cooperatively with the National Council are distributed to all member mills. This proves especially beneficial to small mills which are not able to afford major research programs.

Question 3b: Do you have any estimates of what else needs to be done or what other research must be carried on to completely eliminate the problems of pollution caused by papermill effluent?

Answer: Although this question was answered in the original testimony, it is acknowledged that much more needs to be done in new and novel processes for effluent handling and treatment. In addition to the projects mentioned in the testimony, i.e., decolorization and sluge disposal, much more needs to be done in new and novel processes for effluent handling and treatment. Greatly increased expenditures for research will be necessary in order to accomplish these objectives—variously estimated at 4 to 10 times the present rate.

Question 4a: In general, has the paper industry conducted research in response to regulatory action when its own sources of water are being imperiled or as part of a long-range program to return water to the streams in the condition it was before use?

Answer: In general, the industry has conducted research in response to the will of the people as expressed by the applicable law and regulations.

Research in these areas by the paper industry was started before regulatory action became the factor it is today. Both the Sulfite League and the National Council were begun more than 20 years ago.

There is no doubt that the research conducted by industry has been in response to long-range programs aimed at overall reduction of existing pollution problems. However, the approach to any program is composed of individual steps. These steps have varying importance and are assigned priorities in accordance with need, available money, and technical manpower. Since both trained personnel and capital can be limiting, pure research is ruled out in favor of practical research with immediate solutions to immediate problems.

In response to the question, then, work on an imperiled water supply would certainly proceed before research on effluent treatment could, especially in light of the limiting factors mentioned above.

Question 4b: What other reasons have motivated research carried on by the paper industry?

Answer: Going beyond the above and looking to the future, the industry, through the National Council, is still conducting research in attempting to develop more advanced waste treatment processes which will produce treated waste waters suitable for reuse without dilution.

Specifically, research in the paper industry has been motivated by:

(1) Need to solve problems detrimental to pulp and paper manufacturing.

(2) Need to conserve water supply.

(3) Required to meet stream standards in regard to downstream use, protection of aquatic life, and as a responsible citizen to preserve the esthetic values of our streams.

(4) To effect process economies where practical.

(5) To optimize existing treatment and abatement facilities.

(6) To explore, develop, and evaluate new and better equipment.

Question 5: What do you believe, from the viewpoint of the paper industry, should be the goals of pollution abatement legislation?

Answer: The pulp and paper industry of the United States is deeply conscious of the need to conserve the water resources of this country for the use of all the people. This is in keeping with the enlightened multiple-use concepts applicable in the case of water resource management. Some streams are best suited for recreation and water supply, while others best serve less stringent requirements. It should be our purpose to make the totality of our streams capable of serving the multiple interests of our society.

Thus in our opinion the desired goals and objectives of stream pollution legislation should be—

(1) To conserve water as a natural resource.

(2) To protect legitimate water users.

(3) To provide the needed incentive by economic measures.

(4) To develop individual master plans for each river basin.

(5) To provide money and facilities for long range practical research, in methods of treatment.

(6) To provide financial assistance to industries through grants or industry-municipal projects and tax relief for internal industrial abatement facilities.

(7) To be impartial and accurate in the analysis of individual problems so that costs are reasonable and livable. (Do not require treatment just for treatment's sake.)

(8) To be reasonable in enforced schedules by considering the depth of the problem, the cost for an adequate solution, and the reasonable approach to proceeding with the necessary work.

Question 6: With reference to certain aspects of pollution abatement being economically unfeasible, what is meant?

Answer: Each situation is different. Any situation requiring 100 percent treatment is impossible to meet. In many instances, complete treatment based on existing technology would not completely solve the problem. This depends upon the type and size of the mill and its location.

Stringent enforcement of standards without regard for the situation could and would discriminate against smaller companies or those companies unfavorably located on small tributaries or in highly industrialized areas. Expansion and growth at these existing mill sites can be greatly limited or prevented. For example, an older mill may be geographically situated where this is no land available for holding ponds, etc. This means that:

(1) The primary problem exists for companies less favorably located. They will be penalized in competition with other mills.

(2) Of secondary, but not insignificant importance, and dependent upon the extent of treatment required, paper could become less competitive with plastics and other substitutes.

Broadly speaking, our industry position is described fully in the statement of the American Paper Institute for the Committee on Public Works of the House, Congress of the United States, which was submitted on July 13, 1966. I refer you particularly to page 4 of the statement which is attached under the heading "Comments by Mr. Hickey on Financial Considerations in Constructing Water Treatment Facilities."

Question 7a: Do you believe that tax incentives would help in achievement of pollution abatement techniques that would permit substantial improvement in stream quality standards?

Answer: Water quality standards should be realistically established and the best pollution abatement techniques which can be developed should be utilized based on the merits of such standards and techniques and without regard to tax incentives. Financial incentives are a different aspect of the massive problem facing industry.

The entire program of pollution abatement will be facilitated and accelerated if meaningful financial incentives are provided. In fact, it is doubtful if proposed programs are feasible over a reasonably short period of years if financial assistance is not available. Government and industry working together should explore various financial incentives, such as: Federal, State and local tax relief, grants in appropriate circumstances, and loans. These should be evaluated and compared and a workable solution achieved just as technical personnel are expected to provide optimum solutions on standards and techniques.

Question 7b: Would facilities not now considered economically feasible be feasible with a tax incentive program?

Answer: A major expense in many facilities not now considered economically feasible is the operating cost. This includes material costs, power, equipment maintenance, and manpower. Unless a tax incentive program covered these operating costs, it would do little to make the presently prohibitive methods economically attractive. Rather research must find reasonable solutions with reasonable operating costs.

Additionally, there is further reference to this question in Mr. Hickey's statement to which reference is made in the answer to question 6 above.

Question 8: Can you give examples of other improvements resulting from research and demonstration efforts of your organization?

Answer:

(1) Improved utilization of waste clarifying equipment.

(2) Development of improved retention aids has reduced losses.

(3) Methods have been developed for disposal of residues obtained as a result of treating waste waters, for instance, centrifugal dewatering of sludge has been proved practical. This has improved the potential for disposal by burning, low nuisance landfill, and "byproduct" reutilization.

(4) Adapted the activated sludge process and a number of modifications thereof to the removal of BOD from papermill wastes.

(5) Aerated lagoons for improved waste treatment have provided a good degree of secondary treatment in some instances at reduced costs. Continued progress in this area is expected.

(6) Developed parameters for effective use of land disposal for liquid papermill wastes.

(7) Development of improved trickling filter media has successfuly handled several difficult treatment situations.

(8) Development of adequate sampling techniques for mill, stream and air surveys.

The testimony contains other examples.

Question 9: Is the pulp and paper industry doing anything to combat the problems of air pollution?

Answer. The National Council has researched air pollution problems for better than 15 years. Definite progress has resulted from their work and the work of the larger corporations. For example, in the kraft industry a recent survey indicated that approximately half the mills have installed equipment or processes to reduce odorous emissions.

Air pollution problems are more confined to specific localities than are those of stream pollution. Most papermills are cognizant of good-neighbor responsibilities and have installed control equipment where possible. These consist of:

(1) High stacks.
(2) Black liquor oxidation.
(3) Scrubbers.
(4) Precipitators and dust collectors.
(5) Catalytic furnaces.

Technology is limiting further progress in this area. Odor level measurement is expensive and not as precise as necessary. Odor abatement is impossible for many of the problem gases. Solutions are not known and so research is required before additional progress can be made. New methods of testing for odor pollutants have been developed at considerable cost as a necessary step toward finding specific solutions.

In April 1966, the National Council, along with the U.S. Public Health Service and the University of Florida, jointly sponsored a conference attended by scientists, engineers, and representatives of enforcement authorities from six countries whose objective was the assessment of the total current technology in the field of air pollution problems within the kraft pulp industry. The compilation of all presently known knowledge should provide an excellent base for determination of the direction of future research in this field.

Question 10: What type of legislation can the Federal Government pass to help the paper industry deal with its pollution problems?

Answer: The American Paper Institute has presented testimony this year before the appropriate Subcommittee of the Senate Public Works Committee (on May 12), and before the House Public Works Committee (on July 13), concerning proposed water pollution abatement legislation. In this testimony the institute has set forth in detail its position regarding the type of legislation which it supports at the

Federal level to assist the industry in its pollution abatement efforts.

Legislation will not solve problems where solutions are not known. Research grants to find better and more economical solutions must be the primary step. Recognition of the problems which face industry must be a guide for any legislation. Reasonable legislation would consider the particular situation with a variable enforcement pattern geared to technical progress. Enforcement can be best handled at the State and local level since they are most familiar with the individual situation.

Question 11. Can you give any specific examples of plants that have been forced to move or go out of business, of proposed plants that have not been built in localities that had been selected for other reasons, because of inability to economically meet State-imposed quality standards for the plant?

Answer: There are some examples of plants that have been forced to go out of business; in fact I know of two instances in New York State, one in which this factor was the principal cause and another in which the pollution abatement requirements were so stringnt that a plant was not rebuilt after a disastrous fire. In addition, I am aware of a large company that operates nationally that has shut down at least three mills where the effluent problem was critical, and the correction was great enough to be a factor in the final decision to close them down. Broadly speaking, the liberal application of the guidelines recently proposed for the control of water pollution would unquestionably require some mills, especially older ones, so to modify their operations as to be economically noncompetitive.

There are many locations which are otherwise suitable for pulp and papermaking facilities which can no longer be considered because of the increasing stringency of water and air pollution abatement requirements.

RESPONSES TO QUESTIONS OF THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT BY WILLIAM E. WARNE, CALIFORNIA DEPARTMENT OF WATER RESOURCES

Question 1: In the course of your testimony on August 3, you made reference to a papermill that was to have been built in California on the upper reaches of the Sacramento River, plans for which were abandoned when the cost of providing the necessary water treatment was taken into account. Can you give more details on the proposed plant? Was it relocated elsewhere? Is the process finally adopted for a plant on the Sacramento River—a more efficient process than the original plant? Any other specific information you can provide with respect to this case will be helpful to the committee.

Answer: The plant originally proposed for location on the upper Sacramento River some 10 years ago eventually located in Virginia, and on a river, I believe. The plant process proposed would have wasted about 60 percent of the raw material (logs) to the stream. About 3 years ago, a different company built a plant on the upper Sacramento River. This plant, which produces bond paper, wastes only about 40 percent of the raw material and this waste is much more amenable to treatment than that from the plant process originally proposed.

There is also another pulpmill on the upper Sacramento River located on the exact site originally proposed 10 years ago. This second plant produces cardboard and brown paper, as well as some pulp, which is transported to other plants for finishing.

Quite stringent waste discharge requirements have been imposed on the two pulpmills on the upper Sacramento River. Similar restrictions have been applied to pulping operations on the Pacific Ocean in California's north coastal area. In the latter case, a limited dilution zone is allowed in the immediate vicinity of the submerged outfall.

Question 2: With reference to the problem of brine disposal from desalting plants referred to in your statement, have any studies or research been performed by the State of California on how these wastes can be disposed of? If so, will you furnish details on the findings? How are the wastes from the Coalinga plant disposed of?

Answer: To my knowledge, no research or studies have been performed by the State of California on the problems of brine disposal from desalination plants.

The 28,000-gallon-per-day electrodialysis plant at Coalinga produces sufficient water only for drinking and culinary purposes, and a separate supply system is necessary for the main flow of water, which is not desalted and which is used for all other consumer purposes. Twenty gallons per minute of waste water from the desalination plant containing about 3,700 parts per million dissolved solids is discharged to the supply reservoir for the main water system. The total dissolved solids content of the other system is increased only about 1 percent by this concentrated solution.

There is an additional acid-rinse waste stream of about 1 gallon per minute, which is discharged directly to the sewer system where dilution renders it impotent.

Question 3: How much is the State of California spending annually on research on pollution abatement?

Answer: The State of California provides little direct funding of research on pollution abatement. Most of the money spent in the State on this item comes from Federal or private sources.

The State is, however, spending considerable money on water quality programs and investigations which could be classified as applied research. As you may know, it is usually necessary to develop new or revised techniques for an investigation of any specific problem area, especially in the water pollution field. This process of invention and development can be classified rightfully as research.

For the 1966–67 fiscal year, the State will spend about $100,000 directly on pollution abatement research. Probably 10 or 15 times that much will be expended on the management and execution of programs requiring some degree of applied research in the field.

Responses to Questions of the Subcommittee on Science, Research, and Development by Bureau of Mines, Department of Interior

Question 1: Please furnish a breakdown of research and development programs in the field of pollution abatement, including funding.

Answer: The following table shows a further breakdown of Bureau of Mines research and development programs in the field of pollution abatement. For the case of air pollution, a breakdown of funds used directly on pollution abatement projects is given back to 1956. This constitutes funds transferred by the Public Health Service to the Bureau of Mines for specific projects on the subject. The Bureau of Mines budget structure is not such as to make possible a similar breakdown for conservation or health and safety appropriations, except for the years 1966 and 1967. For the most part, directly appropriated funds for conservation or for health and safety have resulted in pollution abatement as well as conservation of natural resources. For the fiscal years 1966 and 1967, Bureau appropriated funds having air pollution implication are given. In years prior to 1966, the funding of projects having air pollution connotation would doubtless be similar, but somewhat less, than that shown for 1966. The figures given for waste disposal are those expended under the provisions of the Waste Disposal Act of 1965.

As in the case of air pollution, a number of Bureau research programs on the conservation and development of natural resources contributed toward the elimination of waste materials. However, the exact dollar value of these programs cannot be estimated with any degree of accuracy. The same difficulty occurs in connection with the Bureau's work on acid mine drainage. A small program—approximately $50,000 to $100,000 per year—has been in progress for many years. While the results of this work have been gratifying, the size of the program has been entirely too small to provide sufficient information for a reasonable solution to the problem. A number of other multipurpose research programs by the Bureau contribute toward the abatement of environmental pollution. For example, the mine fire control program is basically designed to conserve natural resources and to prevent subsidence. However, the fumes from the fires may contribute materially to the air pollution problem. While over $8 million will be available in fiscal year 1967 for these purposes under provisions of the Mine Fire Control Act and the Appalachian Regional Development Act, it is impossible to say what portion of this amount should be considered as contributing to air pollution abatement. Another example of this type of effort is the program on mine area restoration. While pollution abatement is not the basic purpose for this research, it does decrease acid mine drainage in many areas and prevents pollution of soil and water by silt.

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Environmental research, funds handled by Bureau of Mines

[Thousands of dollars]

Year	Air pollution		Water pollution		Solid wastes disposal		Subtotal		Grand total
	Outside funds	Bureau of mines [1] appropriation	Outside funds	Bureau of mines [1] appropriation	Solid Wastes Act	Bureau of mines [1] appropriation	Outside funds	Bureau of mines [1] appropriation	Reported
1956	98	------	------	------	------	------	(98)	------	(98)
1957	125	------	------	------	------	------	(125)	------	(125)
1958	227	------	------	------	------	------	(227)	------	(227)
1959	227	------	------	------	------	------	(227)	------	(227)
1960	243	------	------	------	------	------	(243)	------	(243)
1961	300	------	------	------	------	------	(300)	------	(300)
1962	350	------	------	------	------	------	(350)	------	(350)
1963	450	------	------	------	------	------	(450)	------	(450)
1964	500	------	20	36	------	------	(520)	(36)	(556)
1965	600	------	20	103	------	------	(620)	(103)	(723)
1966	670	1, 290	[2] 20	103	1, 400	------	(2, 090)	(1, 393)	(3, 483)
1967	[3]	2, 391	[2] 20	140	4, 300	------	------	(2, 472)	------

[1] Bureau of Mines program funds expended on projects contributing to pollution abatement.
[2] Does not include funds received from the Federal Water Pollution Control Administration for demonstration work on acid mine drainage control. It is expected these will total approximately $450,000 for fiscal year 1967.
[3] It is expected that Public Health Service will transfer $759,000 to the Bureau of Mines for air pollution research for fiscal year 1967.

Question 2: Do you believe that your current and near-term program for research and development is adequate? What additional effort do you believe is required?

Answer: As stated during the hearings, we estimate that the Bureau's efforts in abatement of air pollution at the source should be expanded by a factor of approximately five over that which was available in 1966. We believe that a program of this size would be sufficient to provide industry and Government with much needed technologic information on the handling and use of fossil fuels, without the resulting contamination of the atmosphere. If contract authority should become available to the Bureau for research contracts with universities, nonprofit organizations, and industry, even more funds could be used to advantage. This should provide a well-balanced program for the development of economically feasible methods for control of pollution at the source. Without doubt, research on solid wastes will have to be expanded beyond the present fund limitations if the solutions for the many complicated problems are to be achieved. However, since this program is relatively new, it is difficult to anticipate the percentage increase which may be required inside of the next 2 or 3 years. The greatly expanded efforts on mine drainage work which is being performed in cooperation with the Federal Water Pollution Control Administration is just getting underway. While funds for this work will doubtless have to be increased inside the near future, it is, again, difficult or impossible to make a realistic estimate of the increase in funds which will be needed.

Question 3: Has the inability to contract with universities and industry hindered your program?

Answer: Inability to supplement Bureau of Mines research programs with research contracts to universities and private firms has hindered some of our pollution abatement programs. However, this problem will be much more serious in the future if some of the additional funds requested become available for use by the Bureau, without at the same time being given authority to contract out some of the research.

Question 4: What is the extent of coordination between the Bureau of Mines and other agencies and to what extent does the Bureau maintain contact with overseas programs in other countries?

Answer: As stated during the hearings, the Bureau of Mines has an excellent working relationship with the Japanese and maintains close contact with work being done in Britain, Germany, and other European countries. For the most part, the Bureau of Mines research program on pollution abatement is markedly different than other Interior agencies with the exception of water pollution. In the field of air pollution, the Bureau has assumed primary responsibility in the Department's efforts. Periodic meetings with representatives of other agencies in the Department tend to keep them aware of progress in the field and needs for increased efforts. These contacts will be maintained to insure that there will be no overlapping of efforts among the various agencies. As stated previously, there is a close working relationship between scientists in the Bureau of Mines and those in the Division of Air Pollution, Public Health Service. Since that organization has primary responsibility for the overall Federal program, there would seem to be little need for further coordination with other departments. Additionally, Bureau scientists keep in touch with programs of other departments through interdepartmental-type committees. The Bureau of Mines work on acid mine drainage is unique to the mining industry, and the problem is of little or no interest to most other departments. Its recently expanded work is done in close cooperation with the Federal Water Pollution Control Administration, the Geological Survey, and State and local water pollution control organizations. Generally, solid waste disposal research and development is coordinated with the corresponding work in the Department of Health, Education, and Welfare. For the most part, the Solid Waste Disposal Act of 1965 clearly defines the areas of responsibility of the two departments, and no difficulties are anticipated.

RESPONSES TO QUESTIONS OF THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT BY P. N. GAMMELGARD, AMERICAN PETROLEUM INSTITUTE

Question 1: Concerning the eventual exhaustion of petroleum, what are your views on a policy which would reserve liquid fossil fuels for use as chemical raw materials and depend more on coal, coal gasification products, and nuclear energy for heat, electric power, and transportation?

Answer: In 1961, a special National Fuels and Energy Study Group was established by the Senate Committee on Interior and Insular Affairs to make a thorough evaluation of our Nation's fuels and energy resources. The motive for such an evaluation was a fear, expressed in some quarters, that this Nation may be in danger of running out of oil and natural gas, and that end-use controls were therefore needed to conserve these assets.

But after roughly 10 months of exhaustive analysis, the study group submitted its report to the Senate committee and, in effect, rejected any policy of end-use controls. The study group called the "wasting asset" argument for end-use controls irrelevant because total energy supplies are far in excess of anticipated needs for a long time to come. They further stated that "the fundamental cost of strict acceptance of the doctrine of controlled end-use would seem to be a broad range of cumbersome policies that in an economic sense would probably misallocate resources." One of the key points made in the report was that "competition among fuels has been a factor in making America an energy-intensive economy * * * Such competition provides the product—fuels in this case—at the least cost to the public."

Prior to publication of the study group's report, representative groups having an interest in fuels and energy policy were asked to submit statements to be included in the report. The consumer's right to select the product he wants, and the right of private business to compete fairly in supplying these products has and should continue to be the foundation of this Nation's policy toward business.

The adequacy of our liquid petroleum reserves has been examined time and again. Prophets of doom have been predicting for more than half a century that our reserves of this vital resource would be gone by 1925, then by 1941, and then 1962. But, year after year, oil exploration and development have increased, with the result that today our Nation's reserves of crude oil and natural gas liquids are a great deal higher than when pessimists were predicting their complete exhaustion.

Reserves fall into two principal categories—proved and ultimate. Proved reserves of oil and natural gas liquids now stand at over 39 billion barrels. These are the minimum reserves recoverable from existing fields, under present economic and operating conditions. They are our current working inventory underground which can be counted on as confidently over a period of time as money in the bank.

Ultimate reserves, on the other hand, represent the total volume of liquid petroleum which experts estimate will eventually be produced in this country. Just last year, the U.S. Geological Survey estimated that approximately 1 trillion barrels of crude oil and 75 billion barrels of natural gas liquids may eventually be found in this country through exploration. How much of this total will actually prove to be economically recoverable remains to be seen, but the Geological Survey estimates that at least 40 percent will eventually be brought to the surface. Thus, with liquid hydrocarbon production running at about 3.2 billion barrels per year, it is apparent why the Interior Department in their "An Appraisal of the Petroleum Industry of the United States," issued in January 1965 stated that "on the basis of these cold figures, it would appear that the United States is in no danger of running out of oil for many years."

Of course, in addition to conventional crude oil and natural gas liquid reserves, the shale deposits in the Green River formation in Colorado, Utah, and Wyoming will undoubtedly one day supplement our present sources of petroleum hydrocarbons. Experts currently estimate that the oil shale deposits in the United States represent a total of 2 trillion barrels of oil in place. And, besides these shale deposits, there are also the tar sand reserves in Canada which may contain an additional 600 billion barrels of petroleum energy.

While it is true that oil and natural gas are important sources of chemical raw materials, it should be pointed out that their manufacture is not being jeopardized by the continued consumption of liquid petroleum as a fuel. Currently, some 80 billion pounds of petrochemicals are being produced in this country—about 35 percent of the total organic chemicals manufactured in the United States. But the manufacture of these petrochemicals requires less than 5 percent of the crude oil we currently refine.

The remainder of our refined crude is primarily turned into fuel, both for heating and transportation. These are areas where petroleum has thus far proved to be the most economic and efficient fuel. Coal has already lost much of the residential heating and transportation markets—having been replaced by gas and oil. And as for atomic energy, AEC experts themselves admit that nuclear power cannot effectively and economically compete with petroleum as a fuel in motor vehicles or aircraft, or in the heating field—safety factors, the necessity of protective shields, and expense seem to rule out these markets for nuclear power. Just this past June, as a matter of fact, Dr. Glenn T. Seaborg, Chairman of the U.S. Atomic Energy Commission, had the following to say when addressing a meeting of the National Association of Manufacturers:

> Nuclear energy will be used increasingly for those purposes to which it is best suited—the large-scale production of electricity. Other energy sources will find their growing uses in those areas to which they are best suited.

Thus, it seems apparent that liquid hydrocarbons will continue to be the prime supplier of our Nation's energy, as well as the raw material from which much of our organic chemicals are derived. Reserves appear adequate to meet both needs for many, many years to come.

Experience indicates that competition among fuels has stimulated the increased use of energy in this country and thus our economic

growth. Under such an environment, rather than a policy of end-use controls, the petroleum industry feels assured that it can meet the challenges that lie ahead. This is a belief apparently shared by the Department of the Interior which said in its "appraisal" last year—

> The data developed by this study reveal an industry that is healthy and vigorous and capable of meeting the requirements that will be placed upon it in the foreseeable future * * *. It is evident that the petroleum industry has the financial and technological capability to accomplish it.

Question 2: Realistically, what are the near term prospects for an economically competitive replacement for tetraethyl lead in gasoline?

Answer: On a realistic basis, the prospects for the discovery of an economically competitive replacement for lead antiknock compounds are very slim.

An extensive search for such a compound has been carried out on a multimillion-dollar-per-year scale by the antiknock manufacturers, petroleum refiners, and chemical companies since World War I. To date, this vast research effort has not produced a suitable alternative antiknock compound. The major technical requirements for such a compound are formidable. They are:

1. High antiknock effectiveness in a broad range of hydrocarbon types under a wide variety of engine operating conditions.
2. High solubility in a wide range of hydrocarbon types.
3. Negligible solubility in water which is present to some degree in all fuel systems.
4. Volatility characteristics permitting relatively uniform distribution to the various cylinders of the internal combustion engine.
5. Sufficient chemical stability to permit normal handling and storage both in the concentrated form and when blended with gasoline.
6. The ability to be consumed in typical engines without causing significant engine durability problems.

Research for new antiknocks will, of course, continue. As new chemistry develops through basic research in universities, industry, and Government laboratories the new chemical compounds resulting from such research will be investigated as possible antiknocks. But, based on the present state of the art, the chances appear to be poor for a near term replacement for lead antiknocks.

Question 3: How does the present crude oil import policy affect the sulfur content of fuels for sale in the United States?

Answer: If the present crude oil import policy were relaxed, U.S. refiners would probably process more crude oil from the Middle East and from South America. Since these imported crudes generally contain a higher sulfur content and are heavier than domestic crudes, increased volumes of residual fuel with a higher sulfur content would be produced. It should be noted that among the imported crudes, Venezuela crudes contain somewhat less sulfur than Eastern Hemisphere production although they are generally higher than U.S. crudes. North African crudes are relatively low in sulfur, and to the extent they might be brought to the U.S. east coast refineries, they would tend to drop the sulfur content of residual fuels.

COMMENTS ON INDUSTRYWIDE, INDUSTRY-BY-INDUSTRY EFFLUENT STANDARDS

1. Industrywide, industry-by-industry, effluent standards would be inconsistent with the current Federal Water Pollution Control Act which requires the establishment of water quality criteria in receiving streams to protect the legitimate uses of each section of major river basins.

2. Since all receiving waters cannot be used for all purposes and their capacity to assimilate treated wastes are highly variable, there should be no uniform effluent requirements for all industries. This would impose an unjustified burden on companies discharging effluents into a large stream with limited water uses and understate the requirements for a plant operating on low-volume streams of high quality.

3. It is equally obvious, however, that the establishment of receiving water quality criteria alone will not be sufficient to guide industries and municipalities as to the effluent targets that must be met to achieve the goals for the particular receiving stream. Ultimately, the total allowable pollution load on a particular stream must be established and allocated back to industrial and municipal dischargers.

4. The imposition of nationwide effluent standards would result in an unnecessary expense to the consuming public. The availability of water for industrial use is only one of many factors in an industrial operation. If we are going to legislate that this factor is exactly the same for everyone, everywhere, whether local conditions require it or not, then we might as well legislate to equalize all the other factors such as labor costs, transportation, availability of raw materials, etc.

5. In the past it has been the prerogative of the individual plant to select treating methods to satisfy a condition in a stream at the most economical cost. Since stream conditions and flow vary for each individual stream and plant effluent volumes vary, the setting of a common effluent standard would result in unnecessary increased costs for many, but not all plants.

6. In this connection, industry should properly provide technical guidance to regulatory authorities in formulating programs for individual plant waste reduction. Industry is in the best position to assist in developing an equitable basis for allocating allowable waste loads among plants discharging into a particular receiving stream.

7. With respect to air pollution, the above principles apply as well to control of emissions to the atmosphere. Air quality criteria should be established as targets to be achieved. Individual air basins should then be studied from a meteorological, topographic, and population basis. An inventory of all emissions should be conducted and an equitable rollback of objectionable levels of pollutants prescribed where necessary.

8. During the course of the hearings, the question concerning the establishment of industrywide standards was raised a number of times. This concept was discussed by Dr. Abel Wolman during his summation of the hearings. We concur most wholeheartedly with his conclusion that industrywide standards would not be practical.

RESPONSES TO QUESTIONS OF THE SUBCOMMITTEE ON SCIENCE, RESEARCH, AND DEVELOPMENT BY DR. ARTHUR M. BUECHE, GENERAL ELECTRIC CO.

Question 1: Is the military space R. & D. on fuel cells and batteries compatible with specifications for these devices in transportation, or will special additional work be necessary?

Answer: The contribution to commercial fuel cells by space R. & D. is mainly the establishment of a technical base and a competent electrochemical development and production organization that can be reoriented to commercial fuel cell development after completion of space R. & D. There is the possibility of using a small portion of the materials and components, but modification is almost always necessary.

The contribution to commercial fuel cells by military R. & D. is greater than that from space R. & D. since the former R. & D. is usually oriented to air instead of oxygen operation. However, military R. & D. is usually directed toward fuel cells that use logistically available fuels, which are generally very "dirty" (containing lead or large amounts of sulfur). Also, military fuel cells must operate in a water-conservative manner. As a result of this required complexity, the fuel cells developed will be too expensive to penetrate the price-sensitive, transportation industry.

Specific R. & D. funds oriented toward power systems utilizing fuel cells to meet the different and less complex requirements of the commerical transportation industry will have to be spent by private industry or the Government before any significant strides can be made for commercial transportation. A substantial service test program similar to the military and space programs will be necessary to prove applicability to commercial vehicular systems.

(For additional information, please note the following article, "Fuel Cells and Fuel Batteries. An Engineering View.")

FUEL CELLS AND FUEL BATTERIES—AN ENGINEERING VIEW

(By H. A. Liebhafsky, General Electric Research and Development Center, Schenectady, N.Y.)

This is a welcome opportunity to attempt a paper on fuel cells primarily for electrical and electronic engineers, who may some day be joined by a new kind of engineer—the *electrochemical engineer*—if fuel batteries attain their expected usefulness. The kind of problems the new engineer will have to face are implicit in the questions and answers below.

WHAT IS A FUEL CELL? A FUEL BATTERY?

Fuel in its classic sense ought to be the key word in these definitions. Fuel cells and fuel batteries ought to react *conventional* fuels by which we mean the fossil fuels and substances readily derived therefrom) electrochemically with oxygen, preferably from air. A fuel cell thus is an electrochemical cell in which energy from such a reaction is converted directly and usefully into low-voltage direct-current electrical energy. Fuel cells electrically connected (in series, parallel, or series-parallel) make fuel batteries. The most common type of fuel cell is shown in Figure 1.