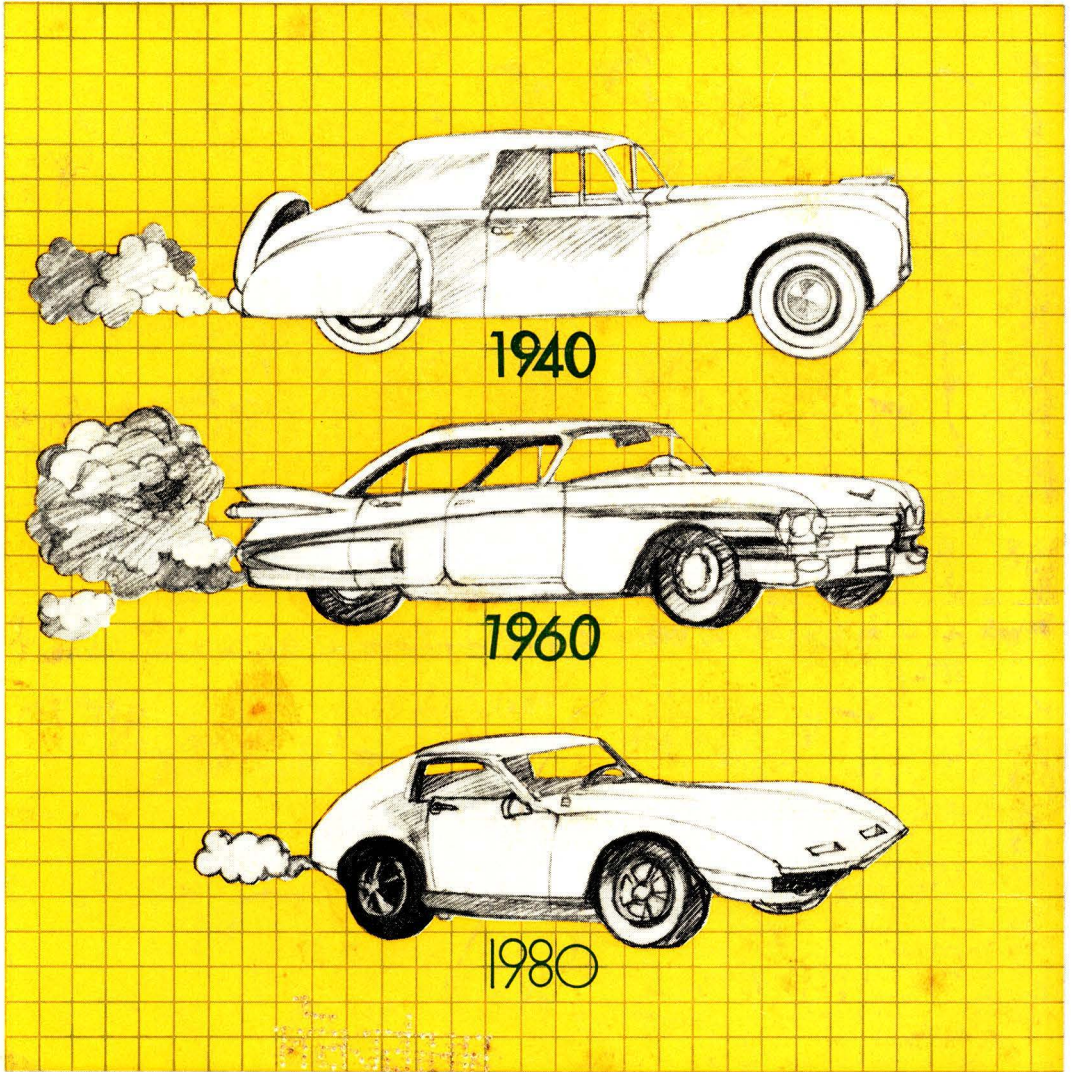


APRIL 1970

ENVIRONMENTAL Science & Technology



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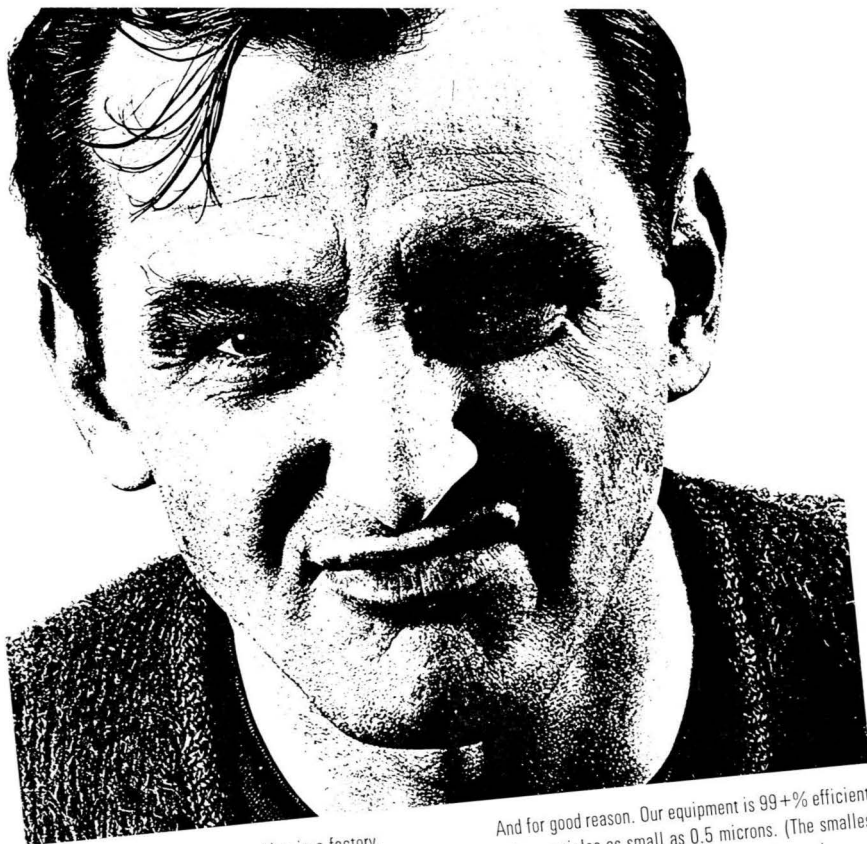
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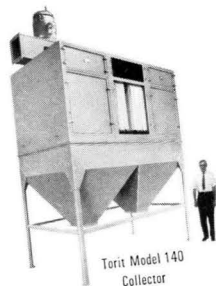
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ENVIRONMENTAL

Science & Technology

Volume 4, Number 4,

April 1970

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Editorial

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Plans for first environmental teach-in gain momentum **283**

HEW projects preliminary price tag for clean air package **284**

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Recent cost data make membrane processes attractive for tertiary treatment and water reclamation, says J. I. Bregman **296**

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Current research

Isotopic composition as a natural tracer of lead in the environment 305

W. U. Ault, R. G. Senechal, and W. E. Erlebach

Discussions by P. W. Gast and R. B. Holtzman

Differences in the isotopic lead ratio of environmental samples serve to distinguish the probable source of lead. Samples of topsoil, leaves, and grasses, from up to 500 feet distance from a busy highway, definitely have different ratios than samples taken at distances greater than 500 feet. Lead from fly ash samples showed ratios characteristic of the combusted coal; the lead in automobile exhaust particulate and in the combusted gasolines is the same.

Atmospheric lead: Its relationship to traffic volume and proximity to highways 318

R. H. Daines, H. Motto, and D. M. Chilko

Discussion by E. A. Schuck

Automobile traffic definitely contributes to lead in the atmosphere. At locations near the highway, the effect of traffic density on the lead content of the air is at a maximum, but, at distances greater than 250 feet, the effect of the traffic density is largely lost. More than 65% of the lead in the air from 30-1750 feet from a well traveled highway (48,000 cars daily) consists of particles under 2μ in diameter, and more than 85% consists of particles under 4μ in diameter.

Relationship of automotive lead particulates to certain consumer crops 324

E. A. Schuck and J. K. Locke

Discussions by W. W. Heck and H. L. Motto

The suggestion is made that automotive lead particulates exist as a simple topical coating on vegetation. About 50% of the dust can be removed by washing with water. Edible portions of five crops—cauliflower, tomatoes, cabbage, strawberries, and valencia oranges—do not absorb automotive lead particulates. These five crops showed no tendency to absorb lead by way of their root systems.

Study of lead levels in experimental animals 333

R. G. Smith, J. Szajnar, and L. Hecker

Discussions by E. A. Pfitzer and L. A. Chambers

Rodents breathing filtered and unfiltered urban air (Detroit) show only one significant difference, namely, the level of lead in the bones. These increased levels result from inhalation of approximately $2.5\mu\text{g}/\text{m}^3$ for a period of nearly four years. Although lead intake by ingestion is considerably greater than that by inhalation, the more efficient absorption of the inhaled lead accounts for the difference.

The growing pollution control business

National cleanup efforts may well be spearheaded not by idealists but by hardnosed, moneymaking companies

There has been much comment recently, especially from young people, to the effect that the biggest barrier to the abatement of industrial pollution is the preoccupation of executives with profit margins. Forget about profits, say the young—just clean up the mess you've made. Few industrial executives still deny that there is a mess, but, under the present economic system, their primary responsibility to their companies and shareholders is to make a profit. A business without profits is no business at all, they say, and an executive who would sacrifice profits—even for such a worthy cause as pollution control—runs a serious risk of bringing his executive career to an abrupt close.

Pollution problems are so large and complex, that for most industries to solve their own immediately (as practically everyone would like them to do) would gobble up profits for years to come. Consequently, industry's position generally is to resist the adoption of any control measures that are not justifiable economically (that is, all those that are expensive enough to make perceptible dents in profits). Technology already exists, of course, which would satisfy many of industry's most pressing air and water pollution control needs—for instance, there are many effective processes for removal of sulfur dioxide from stack gases—but these have been deemed economically unjustifiable.

Since industry has indicated that it wants to clean up, and since it is being harried into doing so by federal, state, and local governments, there does exist a ready market for pollution control technology and services that will allow industry to stop polluting and continue to make money in the bargain. The fact that firms already are moving into this market is reflected on Wall Street, where the so-called pollution

control stocks are the current favorites of investors. What is notable about this show of confidence in the new business of pollution control is that investors obviously believe it will be profitable. After all, the companies entering the field operate within the same financial framework as the manufacturing firms they hope to attract as customers; the same factors that are threatening to squeeze the profits of many industrial concerns are being relied on to provide profits for the new pollution control companies.

Of course, it is possible to be disheartened by the prospect of one of the biggest social problems of our time—environmental pollution—being removed by a group of profit hungry men rather than by huge commitment and sacrifice by the population at large. But at the same time, it is possible to be considerably encouraged to reflect that technically skilled firms are competing in the field of providing pollution control expertise. Past experience gives us good reason to hope that competition in itself will lead to acceptable, low cost solutions to industrial pollution problems.

Dow Chemical Co. president Herbert Doan (*ES&T*, March 1970, page 179), expresses great faith in the abilities of profit-making companies. One does not have to have Doan's confidence, however, to appreciate that the best hope for cleaning up the nation's mess may well lie with those who have financial incentive to do the job. Unless there is some radical change in the way that America conducts its economic affairs—and few think that either desirable or likely—pollution control will probably be achieved by those who make money by doing it.

D. H. Michael Bowen

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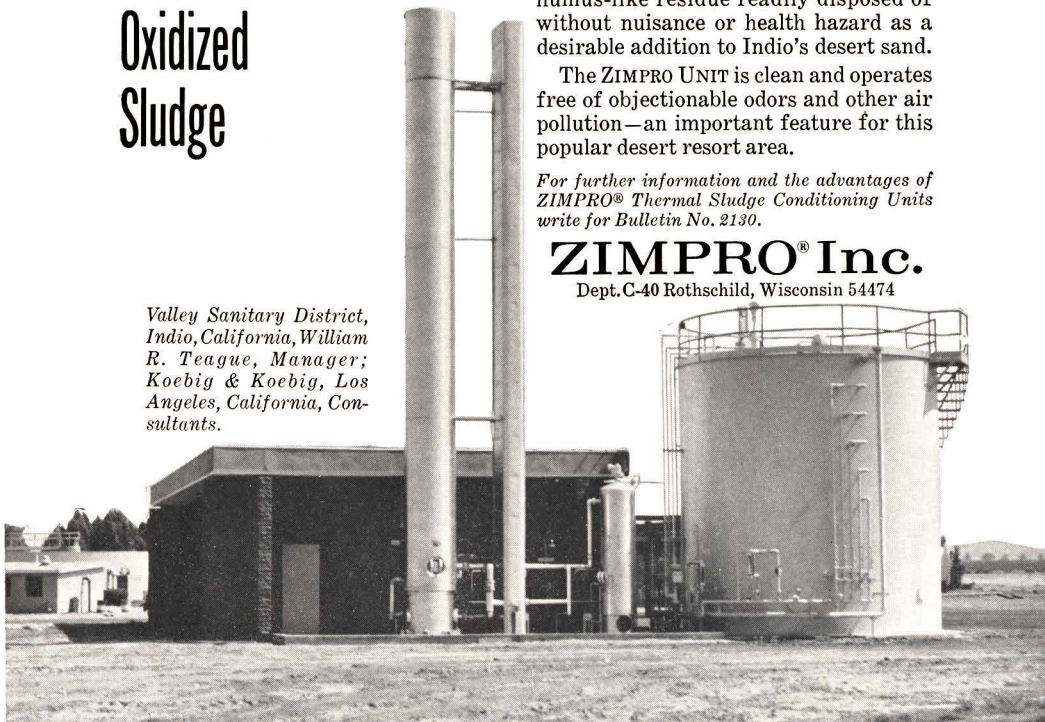
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Glenn T. Seaborg
Chairman, Atomic Energy Commission

Nuclear power—an environmental asset

The growing national concern for the environment has resulted in close scrutiny of various power sources as possible purveyors of pollution. Plants powered by nuclear energy have received their share of attention and a number of questions and comments indicate honest concern about radiation levels and waste heat discharges into rivers and lakes. Many comments, however, reflect a lack of understanding of the Atomic Energy Commission's (AEC) comprehensive system of safety review and regulatory controls and the extensive scientific data on which these are based. Taking all factors into account, I feel that nuclear power, in balance, is really an environmental asset.

The major advantage of nuclear power in the environmental context is that it diminishes significantly the air pollution caused by power generation. This advantage cannot be appreciated fully until one considers that a typically modern coal-fired plant of 1000 electrical megawatts capacity releases about 750,000 pounds of sulfur dioxide each day of operation. A second advantage for nuclear power is the general cleanliness of the plant and its environs. While it is necessary to refuel a nuclear plant only about once a year, a modern 1000 electrical megawatt coal-fired plant needs about 8000 tons of coal every 24 hours.

A characteristic which nuclear plants share with all steam electric generating plants is that they must release the waste heat of their cooling water to the environment. The thermal effects of this water may be detrimental, beneficial, or insignificant, depending upon the specific site and measures taken in the design and operation of the plant.

Today's nuclear power plants produce more waste heat than modern fossil-fueled units of the same generating capacity. But advanced reactors now under development will release substantially less waste heat, reducing the present disparity in thermal effects between nuclear and conventional plants.

The AEC and other federal agencies have been conducting research on the problems associated with the disposal of waste heat. In fiscal year 1970, the AEC anticipates spending more than \$1.6 million on the study of thermal effects. The electric utilities also are sponsoring considerable work in this area. Ways to make beneficial uses of heated water in agriculture and aquaculture also are being studied.

Another environmental aspect of nuclear power which has recently been the subject of more public discussion is the radioactivity associated with the production of nuclear power. Nuclear power plants do

release, under controlled conditions, very small amounts of low-level radioactive effluents. The maximum amounts allowed to be released are based on radiation protection standards set by the Federal Radiation Council in light of the knowledge of the biological effects of radiation resulting from decades of study by national and international scientific groups, and continuously reevaluated by them. According to the best scientific evidence available today, this tiny increment to the natural background radiation we live with daily creates no significant biological hazard.

A new national effort is underway to convince the public of the environmental assets of nuclear power. Furthermore, the public must be convinced that additional power plants are truly needed. With our current electric generating capacity of about 325 million kilowatts, our requirements are expected to double in about 10 years, and, by the year 2000, our capacity should reach more than 1.5 billion kilowatts.

There is no doubt that nuclear power is needed to help meet these massive energy requirements. Without it, the drain on our fossil fuel reserves and the air pollution problem that would result should we try to meet all our projected requirements only by burning fossil fuels both would be enormous. Fortunately, we have at hand in nuclear energy an abundant source of power that can be advanced with a minimum of environmental impact.

What we need now, in addition to better long-range energy planning, are increased efforts to improve public understanding of the nature of our energy sources, our energy requirements, and our need to utilize all energy resources wisely and with the utmost consideration of their environmental effects.



Glenn T. Seaborg was appointed AEC chairman by President Kennedy (1961), and reappointed by Presidents Johnson and Nixon. A discoverer of the transuranium elements (1940-58), he was awarded the Nobel Prize in Chemistry (1951)

WASHINGTON Council on Environmental Quality: Marching orders

By executive order, President Richard M. Nixon spelled out 11 responsibilities of the new Council on Environmental Quality (CEQ) and renamed the Environmental Quality Council (ES&T, December 1969, page 1249) the Cabinet Committee on the Environment. One responsibility of CEQ will be to provide executive clearance on all environmental legislation, estimated as 60% of the total, and to review all new and ongoing federal programs on environment. Russell E. Train, CEQ's chairman, will assist the President in directing the affairs of the Cabinet Committee. This responsibility formerly resided with the president's science adviser, Lee A. DuBridge. CEQ's first report is due July 1.

Interior steps up fight against water polluters



Interior's Hickel

Interior Secretary Walter J. Hickel asked the U.S. Army Corps of Engineers to require stricter observance of the dumping of taconite tailings into Lake Superior by Reserve Mining Co. Cited as a source of interstate water pollution, the tailing would not be carried beyond the three mile square limit specified in the original permit. At a meeting on lake restoration (Washington, D.C.), A. F. Bartsch, director of the Federal Water Pollution Control Administration's Pacific Northwest Water Laboratory noted that the four ways to prevent lake eutrophication, in decreasing order of recommendations, include limiting the fertility of waters, utilizing food chains to improve the lakes, stimulating disease and parasites to kill off aquatic plants, and using toxic chemicals to kill algae.

NAPCA proposes tighter automobile controls

Issuance of criteria and control technology documents and proposed tighter standards for automobile emissions are current activities of the National Air Pollution Control Administration. Documents for the air pollutants—carbon monoxide, hydrocarbons, and photochemical oxidants—have been issued. Now, officials in designated control regions are faced with standards setting and implementation plans. Proposed new standards for automobiles require NO_x control for 1973 model year vehicles (3.0 g./mile) and particulates control for 1975 model year vehicles (0.1 g./mile). By July, and for 1972 cars, a new test procedure will be proposed which will require the actual measurement of emitted pollutants and will incorporate a test cycle for cars in urban areas.

Congress gets a new raft of environmental bills



Minority leader Scott

Attesting to the continuing concern with environmental quality, a number of legislative proposals have been introduced and referred to various committees for action. These include: • The Nixon administration's package of seven bills (S. 3466-S. 3472) covering the 23 points for air and water pollution control and solid waste management. • Sen. Hugh Scott's (R.-Pa.) bill (S. 3388) to create an Environmental Quality Administration. • Sen. Edmund S. Muskie's (D.-Me.) air bill (S. 3546). • The auto disposal bill (S. 3522). • Authority for the General Services Administrator to set standards for the federal government's more than 50,000 pre-1968 cars (S. 3506). Last month, the Senate Commerce Committee approved S. 3072, the low emissions vehicle procurement act.

STATES Maryland plans reforms in handling pollution

Maryland offers some examples for dealing with environmental management problems. • Its proposed Environmental Services Act of 1970 would create a public utility type agency to provide waste treatment services on a wholesale basis. The new service would provide treatment of liquid wastes and disposal of solid wastes. • The bounty plan for disposal of junked cars was enacted last year. This law requires a tax on automobile hulks in junkyards and provides a cash incentive for turning junked cars over to scrap processors. • The operator training program at the Charles County Community College has produced 400 water operators so far; another 200 are being trained this year. • Its three largest industries are committed to invest about \$72 million to fight pollution over the next several years.

California tightens timetable on water polluters

California State Water Resources Control Board has accelerated enforcement proceedings against waste dischargers. "The board is serving notice on all dischargers that may or may not be in violation, that the nine California Regional Water Control Boards are not going to act under the historic timetable of the old Water Quality Control Act which tied their hands, but will act under the enforcement procedures of the Porter-Cologne Water Quality Control Act," says Kerry W. Mulligan, state board chairman. The commitment to rapid adherence resulted after hearing a report on long-standing water quality problems from Jerome B. Gilbert, the board's executive officer.

New Jersey gains in air pollution fight

Automobile and aircraft emissions and utility fuel changeover are significant in New Jersey's progress. • Automobile owners could be spending \$83 million annually to control auto exhausts. A major public hearing on control alternatives is scheduled April 8-9 in Trenton. • Governor William T. Cahill announced that the suit against nine airlines will be dropped. The airlines have agreed to install emission control devices costing \$30 million by June 1972. • Public Service Electric and Gas Co. (Newark), the state's largest public utility, is undertaking a fuel conversion program (from coal to oil) to be completed by June, costing \$12 million, according to C. E. Parker, general manager.

Pennsylvania makes air and water progress

Pennsylvania is providing for phosphorus removal from waste waters and has received air quality standard approval. Phosphorus removal facilities will be required on all new and existing treatment facilities discharging wastes to the lower Susquehanna River. By requiring phosphorus removal (80% removal) now, municipalities need only one modification to their facilities, at less cost than if upgrading and phosphorus orders were issued separately, according to the State Sanitary Water Board. The Philadelphia air quality control region—comprising portions of Delaware, and New Jersey, as well as Pennsylvania—is the first region approved by the Secretary of Health, Education, and Welfare. Expected improvements in air quality range from 38% for SO₂ in Delaware to 70% in Pennsylvania and from 45% for particulates in New Jersey to 56% in Pennsylvania.

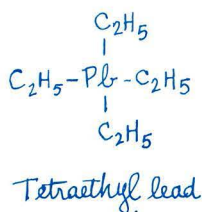
environmental currents

TECHNOLOGY Incineration of plastics under study

The Society of the Plastics Industry, Inc. (SPI), is funding a year long study at New York University (NYU) on the incineration of plastics. The \$82,800 program, by NYU engineers E. R. Kaiser and A. A. Carotti, will use a scrubber-equipped conventional grate-fed incinerator outfitted for corrosion testing of common incinerator construction materials and flue gas monitoring. The study is a follow-up of an NYU sponsored report made three years ago on the role of plastics in solid waste disposal that found "no quantitative evidence of problems uniquely assignable to the presence of plastics."

Leaded gas faces a shaky future

Ford, General Motors, and Chrysler say they will begin this fall to make cars designed to run on lead-free gasoline, shifting the onus to the oil industry to have such fuels ready in time. A growing list of oil companies, including such majors as Gulf, Shell, and Esso, say they'll have a product ready, but there are some significant holdouts, notably Texaco and Mobil. At the same time, tetraethyl lead producer Ethyl Corp. and the Lead Industries Association argue that the case against lead doesn't justify the added cost to the consumer. At stake for the oil industry is an estimated \$4-6 billion in changeover costs at the refinery plus additional outlays for added tanks and pumps at individual stations.

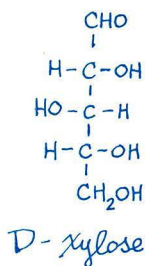


Low emission gasolines being studied

Other smog-free gasoline formulations also are getting some attention. AnPol Chemical Corp. says the city of Los Angeles is testing the company's Formula G³ gasoline additive for emission reductions; AnPol president Mel. A. Kirschner says the company's own tests show the additive reduced hydrocarbons emissions by 50-60%, carbon monoxide by 20%, and nitrogen oxides by as much as 30% in some cases. The LA tests will be conducted by Scott Research Laboratories in cooperation with the city's Bureau of Transportation, and results should be published this month. But another anti-emission additive, Standard Oil Co. of California's F-310, has come under strong criticism. Both the Federal Trade Commission and the California Air Resources Board reportedly are investigating advertising for the product, which some say is misleading.

Pulping liquor yields artificial sweetener

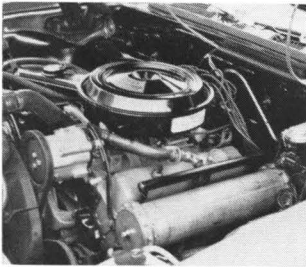
Recent federal action against cyclamate sweeteners may open a large market for waste xylose reclaimed from spent pulping liquors, according to A. J. Wiley, technical director of the Pulp Manufacturers Research League. In the league's recent annual report, Wiley argues that xylose wood sugars are of such high intrinsic quality—very sweet and containing few calories—that they should command a higher use than for fuel or other low value consumption. Wiley says that the league has developed a process for reclaiming wood sugars from waste effluents in commercial quantities at reasonable costs, and is generating a market research program to evaluate the total potential market for xylose sugars and their derivatives. Wood sugars have been used for some time in the production of food yeast, but this market is small and absorbs only a fraction of the total amount that can be reclaimed.



TECHNOLOGY Absorption, adsorption processes for SO₂ removal

The already impressive array of processes by which sulfur dioxide can be removed from stack gases was enhanced by two more which were described at the ACS National Meeting in Houston. The first process has been developed by Consolidation Coal Co. (Library, Pa.) and involves absorbing SO₂ in a concentrated solution of potassium formate. The resulting potassium thiosulfate is further treated with formate, then stripped with carbon dioxide and steam. All the sulfur is released as hydrogen sulfide which can be converted to elemental sulfur by the conventional Claus process. In the second new process, developed by Hitachi Central Research Laboratory (Tokyo, Japan), SO₂ is adsorbed on activated carbon. The sulfur is recovered as sulfuric acid by washing the carbon with acid in the presence of oxygen.

INDUSTRY Du Pont offers exhaust control device for public use



Du Pont's exhaust control device

Du Pont vice president Samuel Lenher has declared that the big chemical maker is putting its thermal exhaust manifold reactor in the public domain. The Du Pont device replaces the conventional exhaust manifold and uses no catalyst, an advantage because it can be used with leaded gasoline. Lenher says that test units installed on stock cars have been run for 100,000 miles, required no maintenance, and have had no significant effect on gasoline mileage. Du Pont, a major manufacturer of lead anti-knock compounds, may be unable to prevent the removal of lead from gasoline (see Current, page 272), however, although its thermal reactor device will continue to be tested along with the catalytic reactors developed by the automobile manufacturers.

Industries invest in air and water pollution controls

Republic Steel Corp. (South Chicago, Ill.) has awarded a contract to **Wheelabrator Corp.** (Mishawaka, Ind.) for design and installation of a \$3 million electrostatic precipitator system to control particulate emissions . . . The City of New York has contracted with **Scientific Pollution Control Corp.** to furnish a shredder to handle oversized wastes at a Brooklyn incinerator . . . **Firestone Steel Products Co.** (Wyandotte, Mich.) is installing airless blast cleaning machines for removing scale from steel; the machines will replace acid pickling lines . . . **Carter Bell Mfg. Co.** (Springfield, N.J.) has installed a scrubber system designed by **Schutte & Koerting Co.** (Cornwells Heights, Pa.) to control sulfur monochloride emissions at its vegetable oil plant.

Business developments in the pollution control market

Gulf Oil Corp. has started a program to identify and develop commercial opportunities in environmental control, including air and water pollution controls and solid waste handling. . . **Zurn Industries, Inc.**, has combined three of its subsidiary companies—Clarage Fan Co. (Kalamazoo, Mich.) Swartout, Inc. (Kokomo, Ind.), and Fly Ash Arrestor Corp. (Birmingham, Ala.)—into a new Air Systems division. . . **Crane Co.** has formed an Environmental Systems division and is expanding its coverage of air pollution and noise abatement to complement its basic expertise in water handling. . . **Envirotech Corp.** has formed Envirotech Systems, Inc. (Brisbane, Calif.), to provide pollution control systems and subsystems. Initial efforts will be concentrated on water and waste water treatment.

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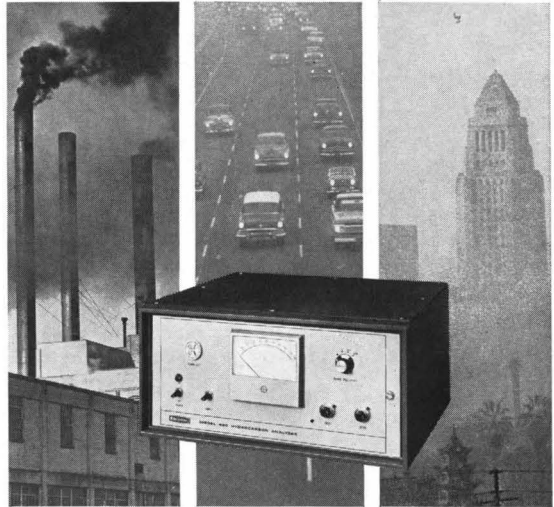
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You, your health, & environmental quality

National Institute of Environmental Health Sciences' director explains medicine's concern with man's surroundings

Environmental pollution—threatening man's health and the quality of his existence—heads the list of problems to be solved in the U.S. today. "As part of the federal role in environmental control, the National Institute of Environmental Health Sciences (NIEHS) is dedicated to establishing a base of scientific knowledge on which a sound approach to the problem of environmental quality can be built. In addition, the institute works toward the development of a science capability for predicting ways in which man's environment serves to aggravate or intensify such diseases as emphysema, bronchitis, and asthma, to mention only the respiratory disorders," notes Paul Kotin, NIEHS director.

Located in Research Triangle Park (N.C.), and part of the Department of Health, Education, and Welfare, NIEHS was elevated to the status of a national

institute on January 12, 1969. Today, the institute operates at an annual funding level of about \$17.7 million and employs about 200 personnel—the majority of whom are at NIEHS' interim facility leased from the Research Triangle Foundation—but expects to grow as additional facilities become available.

The institute's role is to conduct research into the effects of chemical, physical, and biological agents in the environment on man's physiological systems and the disturbances that result. Their total effect on the body, irrespective of the routes by which they may enter—air, water, food, or contact—is what is under study.

Environmental medicine

Environmental Medicine—a relatively new term, but one that Kotin always uses—applies the principles and

knowledge of the environmental sciences to an understanding of health disturbances resulting from environmental stresses. These disturbances are the end points which must be recognized and dealt with in medical practice.

The chain of events from an environmental cause to a definable disease is far from simple. The stages along the way must be identified, if only to permit remedial action when effects are still, hopefully, reversible. "Environmental medicine's main need now is a body of fundamental information which can serve as a basis for developing environmental standards that will improve our ability to deal with the potential threats from our environment," Kotin explains.

"One crucial problem which faces the new medicine is that patterns of morbidity and mortality are changing. Evidence based on data resulting from past effects may not be relevant to events in the future. People are changing, diseases are changing, and social patterns are changing. The illnesses which people will experience 15-20 years from now will not be the same as those which are causing today's suffering," Kotin adds.

The debilitating diseases and the killers in 1985 will be the chronic, degenerative diseases, which are incurable by definition. Cancer already is with us in increasing frequency; other degenera-

tive diseases include asthma, emphysema, bronchitis, pneumoconiosis, and central nervous system disorders, to name but a few. "Environmental factors certainly enter into their causation," Kotin notes. "But to just what extent and in what manner we really do not know enough to say."

Unlike most infectious diseases of the past, these increasingly common degenerative diseases are not followed by complete recovery. "If I were a practicing physician today, I would have to be content with preventing these patients from getting worse; cure is virtually out of the question," Kotin laments.

However, certain facts have been learned about these environmentally induced chronic diseases. It is known that they:

- Result from low-level exposures, insufficient to produce acute responses.
- Develop over phenomenally long time periods.
- Are often irreversible by the time disease is manifest.

"The pathogenic sequence leading to these diseases is just beginning to be revealed," Kotin adds. "Elucidation of this sequence is only one of NIEHS' goals, however. The new medicine also involves concepts of threshold limits, multifactorial responses, detoxification mechanisms, and total body burdens. These are the keywords for understanding progress.

"There is a level below which an agent has no significant effect, another level below which the effects are reversible, and another at which the effects are not only irreversible, but rapidly progressive," the NIEHS director explains. Irreversible effects include such morphological changes as breaking down of alveolar septa in the lung, scar tissue replacing muscle in the heart, and destruction of nerve cells.

"First, we must understand how the environmental agents act to produce their effects. Because of their very large number, it is impossible for all of them to be examined, so that we must content ourselves with studying well chosen examples, or with looking at the commonly occurring groups."

Diseases prevalent in the past, including pneumonia and tuberculosis, were caused by single, specific agents acting more or less on their own. This is not so with the newer environmentally induced diseases. A number of factors enter into the development of a disease like emphysema, in propor-



Paul Kotin, NIEHS' director

National Institute of Environmental Health Sciences

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tions that vary greatly from one case to another.

Research goals

So, physicians no longer can be concerned with single causes, but must consider many **interacting factors**, including self-medication. "Before World War II, when I was in medical school, digitalis was about the only drug taken on a continuous basis, and then under medical supervision," Kotin explains. "Not so today! Now, people take tranquilizers, antihistaminics, abnormally high doses of vitamins, diuretics, the pill, and the like, without limit and, very often, without medical advice. How can the body tell whether what it is getting is a prescribed drug, the result of self-medication, or a contaminant from the environment?"

The body only has a limited number of ways of **detoxifying chemicals**—chemicals of increasing variety, increasing frequency, and from increasing sources. For example, aspirin, phenobarbital, and benzo[a]pyrene—the last a carcinogenic agent found in urban atmospheres—all are metabolized through the same pathways. The presence of one may influence the body's ability to deal with the others. Any one substance, conceivably, could interfere, enhance, cancel, neutralize, or inhibit the metabolism of any other.

Better knowledge of **threshold responses** is another of the institute's goals. "What are the mechanisms that determine the threshold at which an agent will produce undesired effects?" Kotin asks. "More important, can we raise or lower these thresholds to the advantage of the exposed person?" Perhaps, someday, the threshold value can be changed by artificially introducing detoxifying enzymes to back up

overload, inadequate, or perhaps even impaired, body systems.

The significance of a given **body burden** is something else that research must clarify. "Many of the microchemical agents in the environment are stored in body tissues," Kotin points out. "Lead and radioactive elements are stored in bone, DDT in fat tissue, and so on. But we simply do not know what significance a given level of storage has for the well-being of the body, now or in the future."

Long-range objectives

Within the next five years, environmental medicine—and NIEHS in its service—would like to:

- Establish and understand the fundamental mechanisms that the body uses in handling certain representative agents.
- Categorize and group the environmental agents on the basis of their metabolic fates.
- Obtain behavioral indices of toxicity.

Lead, asbestos, and pesticides are good examples for application of the first objective. NIEHS is investigating lead as an example of toxic metals, asbestos as an example of inhaled fibers, and pesticides as a class of organic chemicals. How is the action of these substances in the body to be explained? What are the threshold levels for adverse response? How are these agents transported, metabolized, and excreted? These are the problems; answers are just beginning to appear.

More than 5000 new chemicals are added to man's environment each year—far too large a number for individual study. NIEHS would like to sort them into classes of similarly acting substances, from which certain ones

NIEHS' budget for fiscal year 1970
(millions of dollars)

Grants		Numbers
Research projects	\$4.5	108
Training	3.6	50
Centers	2.9	6
General research	0.5	—
Fellowships	0.2	12
Subtotal	<u>\$11.7</u>	
Intramural research	5.2	
Operations	0.8	
Total	<u>\$17.7</u>	

could be selected as examples for detailed study, particularly as to their metabolic handling. With such knowledge, the physician could see to it that a person who must take tranquilizers, for example, would not be placed in an occupational situation where another agent whose metabolism is by the same pathways will have to compete for detoxification.

Information revealed by these studies would have implications far beyond the original intent. It is entirely possible that deviations from normal pathways, revealed by these studies, may explain individual deficiencies or idiosyncrasies that now lead to institutional treatment, physical rejection, or behavioral peculiarities.

For many of the older infectious diseases, medicine was able to devise susceptibility tests, such as the Schick test for diphtheria. "Hopefully, tests may be developed for identifying unusual susceptibility or resistance to certain environmental agents," Kotin adds. "At this time, only a few such susceptibilities can be demonstrated, such as that for lead in people who lack a crucial detoxifying enzyme. Someday, medicine will have a large battery of such tests, and be able to warn the hypersusceptible individuals against certain occupations, drugs, or other environmental hazards."

While the present emphasis at NIEHS is on chemical environmental agents, the importance of such physical stressors as noise, heat and cold, vibration, electromagnetic fields, and time phase changes has not been forgotten. "Facilities and equipment for basic studies of these factors are included in the planning for the permanent center," Kotin assures.

Environmental stresses are not confined to physical and chemical agents alone. In addition—and often intimately linked with them—are psychosocial factors that may not only affect susceptibility, or alter the progress of response, but actually determine exposure to the material agents in the first place.

"There are social and economic reasons why some people live in rural areas and are exposed to pesticide sprays, while others stick to the cities and their smog," Kotin explains. "Anxiety, for example, is not simply a psychological manifestation; it affects the whole defensive system of the body, and with it the possible consequences of exposure to material agents. Alternatively, hazardous microchemical agents in the environment may manifest their effect exclusively through modification of man's behavioral systems."

Standards

NIEHS is not involved in the setting of standards. However, the institute has the important task of adding to and improving the knowledge needed for preparing criteria documents which set out existing data on these effects, the conditions under which effects develop, the levels that can be considered safe, and so on, and from which standards can be developed. But, through this supporting role, new information uncovered by NIEHS is applied to existing problems.

One important way in which NIEHS can assist in the formulation of criteria is by defining the relative susceptibility of different segments of the population. The London killer smogs of 1949 and 1951 found their victims among those who already had respiratory diseases. The healthy citizen shook off whatever temporary effects he had, but the sick were made worse or died from the added burden. Different degrees of susceptibility may be identified beforehand, and appropriate protective measures provided for the predisposed.

Perhaps more important in the long run is the answer to the question, "What about my future chances?" "Intuitively, I feel that a person's defense reserves may be reduced by any severe environmental exposure, with the possibility that he will hyperreact to a subsequent exposure," Kotin affirms. "In essence, he may have been started on the road to irreversible effects that will manifest themselves

later in life. This is the sort of thing for which NIEHS is seeking the answer—and the remedy.

Medical curricula

"Several reasons come to mind why physicians now being trained in medical schools must prepare themselves to deal with environmentally related diseases," Kotin muses. "Some of the problems that they face are:

- Disorders (as much as 80-90% of the total that confront them) will be environmentally related.
- Root causes of the diseases that they will be treating will lie buried in the past history of the patients.
- Environmental insults are in a continual state of flux; as old ones are controlled, new ones develop.
- Man himself is changing as the result of past exposures, so that experience gained on last decade's patients is not entirely applicable to this decade's.
- Checking the progress of disease, rather than curing it, will be the object of the physician's art.

"In the old days, medicine was satisfied if it cured or prevented the acutely disabling or killing diseases and prolonged the length of life. But this is no longer enough," Kotin states. "Now, people are interested not merely in not being very sick but in being very well. They want to feel well at home; they want to be able to work well; they want to drink water that is good, not merely acceptable; they want to see and breathe clean air; they want to eat good, not merely passable, food; they want clean working conditions; they want optimum temperatures at home, at work; they want the best. When they don't get these, they are unhappy; when they are unhappy, they get or feel sick. The physician is involved in all of these things.

"The medical curriculum must concern itself in a major way with training physicians to meet these new demands, and to add a new expertise to the old healing art," explains Kotin, a physician and pathologist.

Some of the necessary curriculum revision is under way. A full-fledged division of environmental medicine has been established at Duke and University of North Carolina, for example. Furthermore, the National Academy of Sciences Pathology Advisory Committee, at its meeting last December, agreed that the major thrust of the 70's would be in the field of environmental pathobiology; but very much more remains to be done.

Water money needs require more than promises

Officials from large city and small municipality agree that changes are necessary in the federal role of assistance

Money—which may or may not be the root of all evil—certainly is a necessity for any progress in pollution abatement in the U.S. The Nixon administration's program for water pollution cleanup is awaiting Congressional action. S. 3472 calls for \$10 billion for construction of municipal waste treatment plants and seeks an authorization of a full \$4 million federal share in fiscal year 1971. Under this proposal, the Secretary of the Interior will enter into contracts with municipalities for the construction of municipal waste treatment plants at the rate of \$1 billion for the next four years.

The remaining \$6 billion would be financed by state and local authorities or by the newly proposed Environmental Financing Authority (EFA). Faced with the inability to borrow necessary funds in the market at a reasonable interest rate, state and local authorities under the proposed S. 3468 will be able to sell their bonds to the new EFA. High interest rates have hindered the sale of many state and local bonds for such purposes. After purchasing these bonds, the EFA would sell them in the capital bond market under presumably more favorable conditions.

Also proposed is reform in the present allocation formula for granting funds to state and local municipalities. The proposal states that:

- 60% of the total federal money for a given fiscal year will be allocated to states in accordance with the existing allocation formula.

- 20% of the federal funds will be allocated to those states or localities with matching funds programs, thus insuring a positive incentive to states to contribute financing.

- 20% of the federal funds will be allocated by the Secretary of the Interior to those areas of greatest need and from which the greatest water pollution control benefits can be realized.

Under the provisions of proposed legislation, states which have pre-financed construction facilities, includ-

ing New York, Maryland, Pennsylvania, Wisconsin, Michigan, and others, will be refinanced the \$320 million that was spent from 1966 to the present. Proposed S. 3472 specifically protects the eligibility of those states which pre-financed the cost of treatment facilities. However, no new reimbursables would be authorized after 1973. Presumably, the entire water pollution control effort would be reviewed in 1974.

Views

A fundamental point made time and again on water cleanup throughout the U.S. is that the federal promise must be backed with a financial commitment from the federal government if the U.S. is to make progress on this pressing domestic problem.

At the recent 4th Annual Legislative Seminar (Washington, D.C.), sponsored by the Water Pollution Control Federation, the viewpoints of spokesmen from both large cities and small communities were aired in continuing cleanup dialogue.

The needs of a large metropolitan area were described by James R. Ellis, legal counsel for the municipality of metropolitan Seattle (Wash.). He noted that cities are in a catch-up situation and that the surface of the problem in large cities has just been scratched. During the period 1965-69, 35% of the sewerage population in the U.S. received only 5% of the federal grant dollar. In the same period, small municipalities (with less than 5000 population) received 74% of the federal dollar, according to Ellis.

Another factor Ellis considers significant is that, in the past few years, the cities have grown considerably while small municipalities essentially have remained static. He finds that the cost for all municipal services is 60% higher in cities than in small municipalities, but that the per capita income is only 20% higher.

In summary, Ellis makes six suggestions that would help cities, including the following:



James R. Ellis

- Amendment of the federal water pollution legislation to remove the funding restriction on construction of waste water treatment facilities. His suggestion would make such water pollution abatement works as combined storm and sanitary sewer systems eligible for federal funds.

- Assistance in the marketing of local bond issues. In this regard, Ellis considers the prospects for the new EFA favorable.

- Encouragement of sewage service charges. Wherever possible, local construction should use the element of sewer charges to finance their plants.

Sounding the concern of small municipalities, John L. Salisbury, executive secretary of the Maine Municipal Association (Hallowell) restated the need for adequate funding on federal promises already made. The need for secondary treatment (required by Federal Water Pollution Control Administration in doling out funds), is being challenged, according to the Maine spokesman. Projects upgrading facilities from primary to secondary treatment must be stopped, as these upgrading projects only produce marginal effects. What is needed is a more flexible regulatory approach, Salisbury notes. The water pollution abatement needs of the small municipality should be considered on a river basin management basis. The needs should be considered with regard to the assimilative capacity of the streams.

Salisbury also was critical of the greater than 250,000 people criteria for obtaining funds on federal projects. It is not a true measure of U.S. needs, he says. Rather, he prefers using a regional river basin planning approach to a small municipality's water pollution abatement plan.

Auto emission systems fail to do the job

NAPCA surveillance data find 1968-69 vehicles polluting the air to a greater extent than certified values

Approximately one third of the 1968 and 1969 model year vehicles tested in a recent program are polluting the air to a greater extent than that for which their exhaust emissions control systems were designed. "These are the findings of the National Air Pollution Control Administration (NAPCA), based on its surveillance programs on automobile vehicle emissions," says Charles J. Domke, chief of the surveillance and inspection branch at NAPCA's Department of Motor Vehicle Pollution Control (Ypsilanti, Mich.) (ES&T, July 1969, page 625).

Presumably, the average of all 1968 and 1969 model year vehicles, as produced, met federal standards for exhaust emissions. For the first time nationwide, 1968 models were required to control emissions—hydrocarbons 62% and carbon monoxide 53% of uncontrolled vehicles. Now, NAPCA's findings indicate that one third of the vehicles tested have emissions greater than the numerical certification values—hydrocarbons 275 p.p.m. and carbon monoxide 1.5%.

To evaluate the emission control devices on late model vehicles, NAPCA has two surveillance programs underway. Its first program obtained emissions exhaust data on rental car fleets and provided information on vehicles driven under extremely different driving patterns. Its second program, just underway and labeled the Great Plains Surveillance Program, will obtain data on privately owned and individually operated vehicles.

Rental fleets

In the earlier program, completed last December, some 700 vehicles were tested, only once each, for exhaust emissions. All vehicles were tested by the procedure used for certification purposes—the standard federal seven mode, seven cycle, cold-start procedure.

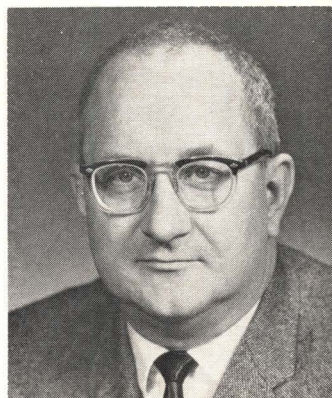
"The mileage on the vehicles averaged 10,000 miles but ranged from several hundred miles to 22,000 miles," Domke says. "In this program, 1968 and 1969 vehicles from the Avis and Hertz car rental agencies in Detroit were tested at NAPCA's certification facility. Another group of cars from the Hertz and Airways rental agencies in Los Angeles were checked at a NAPCA testing facility in Los Angeles."

All vehicles tested had engine modification emissions control systems, and, with the exception of Volkswagens, were equipped with automatic transmissions.

For analysis purposes, test data from a particular automobile manufacturer were grouped and analyzed by engine displacement. A total of 12 engine displacements were tested, with 15 or more complete exhaust emission tests for each displacement. "Nevertheless, these 12 engine classifications represent nearly 40% of the new engines sales in the U.S. for 1968 and 1969 model year vehicles," Domke explains.

"When interpreting data from these vehicles, it must be kept in mind that these vehicles generally differ from normal owner-driven vehicles by the

“. . . these vehicles generally differ from normal owner driven vehicles . . . one should avoid unqualified generalization of these data to vehicles driven by the motoring public at large."



Charles J. Domke

Rental car surveillance data

(On road vehicles failing to meet federal standards)

Company	Engine size (c.i.d.)	Number of vehicles tested	% Failing hydro- carbons	% Failing carbon monoxide	% Manufacturer's sales ^a		% Sales nationwide ^a	
					'68	'69	'68	'69
American Motors	290	32	0%	13%	12%	20%	0.3%	0.6%
General Motors—Chevrolet division	307	44	64	50	18	5	8.7	2.5
	327 (1968)	48	42	58	6	NF ^b	2.9	NF ^b
	327 (1969)	52	10	46	NF ^b	12	NF ^b	5.6
Chrysler	225	18	6	39	21	25	3.3	3.9
	318	49	12	10	24	36	3.8	5.6
Ford	289	45	62	22	12	NF ^b	3.1	NF ^b
	302	110	58	19	19	30	5.1	8.1
	390	116	16	16	17	18	4.5	5.0
General Motors—Pontiac division	350	25	16	56	3.1	4.1	1.5	1.9
	400	23	0	48	5.3	3.4	2.6	1.6
Volkswagen	91.1	31	32	16	73	75	3.0	3.7
Total		593					38.8%	38.5%

^a NAPCA estimates
^b Not manufactured

Source: NAPCA

care with which they are driven, the maintenance they receive, and the type and rate of mileage accumulated," he elaborates. "Since the effects of these parameters on motor vehicle emissions are not known with certainty, one should avoid unqualified generalization of these data to vehicles driven by the motoring public at large. Nonetheless, the data generated by this program provide important information on the effectiveness of air pollution control devices operating on vehicles driven under conditions quite different than those under which certification vehicles are driven."

Individually operated cars

The Great Plains Surveillance Program, NAPCA's more recent project, is looking at vehicles with 27 different engine and transmission combinations. "Selected vehicles in this program represent 1968 and 1969 vehicles with sales of 100,000 units or more per year and from 93-94% of the annual domestic production," Domke explains.

Actually, 26 privately owned vehicles of each of the 27 combinations will be tested, involving a total of some 702 vehicles. Half will be tested in Kansas City (Mo.) and a second half in Houston (Tex.).

In this 18 month program, which is funded for about \$330,000 to Olson Laboratories, Inc. (Dearborn, Mich.), each car will be tested at 0, 4000,

and 8000 mileage. "Obviously, these 1968-69 vehicles already have mileage on them, perhaps, from 15,000-23,000 miles," Domke notes. "This program started last September and will run through next February."

So far, NAPCA has obtained the base data—zero mileage value—for the vehicles chosen in Kansas City. "Next, we will move the testing operation to Houston for initial base data on the second set of vehicles. Then, the testing will move back and forth between Kansas City and Houston till all sets of data are recorded," Domke elaborates.

"When these data are evaluated, sometime in early 1971, we will have some preliminary indication of exhaust emissions under consistent driving conditions by the same person, who may or may not have his car serviced regularly, and note how this affects exhaust emissions. Also, we will find the extent of air pollution from these vehicles," Domke concludes.

From NAPCA's surveillance data, it is not too early to predict that automotive exhaust emissions will continue to rise in the future and that some alternative low emissions vehicles must be found. Whether it is an electric, steam, or gas turbine vehicle, the public—awakening to the fact that the automobile is the number one air polluter in urban areas—is anxiously awaiting a technological advance.



Checkup. Emissions are monitored using the federal certification procedure

Water quality begins at the local level

Cleveland demonstrates that an aggressive program will find financial support

President Nixon's State of the Union pledge that secondary sewage treatment facilities will be provided for every city needing them no doubt came as welcome news to municipal water treatment officials. Yet to be resolved, of course, is the ultimate formula for federal participation in providing the \$10 billion necessary to attain that goal. But most proposals advanced thus far still envision a healthy share of local financing and coordination. Thus, the question: Are U.S. cities able to marshal their resources effectively enough to accomplish the immense task outlined by the President, whatever the measure of cooperation forthcoming from Washington?

One hopeful straw in the wind is the water quality program in progress in Cleveland, Ohio. Underway for less than two years, this program already has chalked up impressive gains, leading some observers to comment that, within five years, Cleveland will have the best sewage treatment system in the U.S. And, whatever effect future infusions of federal money may have on the program, Clevelanders can take a certain amount of pride in the fact that the overall program was conceived and established before substantial federal assistance was anywhere near assured.

In its program, Cleveland has taken some approaches that are unique in themselves and that, at the same time, bear all the earmarks of a bootstrap operation. Specifically:

- The city administration was able to get voter approval of a \$100 million bond issue for water treatment facilities in November 1968, at a time when any type of municipal bond issues generally had tough going elsewhere.

- The city has set up, within its Department of Public Utilities, a Clean Water Task Force to draw public attention to, and provide the in-depth capability for solving, its problems.



Mayor. *Cleveland's Stokes celebrates reopening of beach on city waterfront*

- Last year, the city took the unconventional step of contracting with Dow Chemical Co. to operate one of its treatment plants, with an eye to generating design data for updating and expanding city facilities.

- Construction plans for the city's treatment expansions have taken an aggressive stance on two of the latest concepts in municipal water pollution control—advance waste treatment, and joint municipal-industrial treatment.

Problems

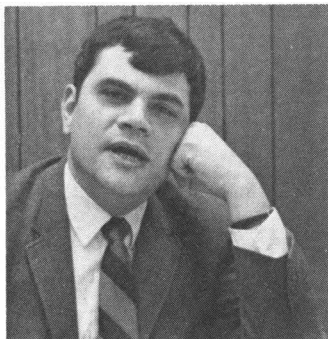
Even the most avid Cleveland boosters would have to admit that, a few years ago, only such radical measures could effect any improvement in Cleveland's water quality problems. The city has had secondary treatment facilities for some years. But, for a variety of reasons, the city's program had not kept abreast of advances in sewage treatment technology.

A heavy concentration of industry

within the city also has had its impact. Effluents from most of the city's industries drain to the Cuyahoga river, which bisects the city on its way to Lake Erie. The current state of the Cuyahoga has made it the butt of a standard repertory of antipollution jokes: "The only river declared a fire hazard," "Too thin to pave and not thick enough to plow," and so on. And national concern over the imminent death of Lake Erie focused attention on lakefront municipalities, few of which were more visible than Cleveland. Aerial photographs in which the flow of the Cuyahoga can be traced far into the lake have become a classic way of illustrating Lake Erie's plight.

Reforms

Against such a background, it is small wonder that, in 1967, incoming Mayor Carl Stokes placed water treatment facilities expansion high on the list of reforms he had in store for the



Task force's E. J. Martin

city. Realizing the close link between Cleveland's problems and the fate of Lake Erie, the mayor chose an appropriate setting to unveil his plans, the June 1968 Lake Erie water pollution abatement conference which was held in Cleveland. Armed with a study that showed the need for \$200 million as a first step in the city's program, the mayor announced his bond issue proposal and the program it would finance. The proposal came as a surprise to Clevelanders—final details for the program had been ironed out on the eve of the announcement—but the bond issue passed easily in the November 1968 election.

Ben Stefanski, Cleveland's director of public utilities, points out that "At the time the bond issue was passed, we had a master plan, but needed a firmer grip on the technology that would be required." This Stokes and Stefanski got from the Federal Water Pollution Control Administration (FWPCA)—in more than a figurative sense. On one of their many trips to Washington to consult with federal officials on Cleveland's needs, Stokes and Stefanski met with, were impressed by, and eventually hired Edward J. Martin, a former research and development man with FWPCA, who has since become the spark plug for Cleveland's program.

Martin assumed the newly created post of director of Cleveland's clean water task force in January 1969. This department has been superimposed over the former department of water pollution control, in such a way that the task force now has complete jurisdiction over all aspects of the city's water quality program. Martin views the long-range goals of the task force as comprised of three distinct areas: Design and construction of new facilities, construction of a new interceptor sewer system, and a new industrial

waste treatment program.

It is in the area of updating the city's three treatment plants—Easterly, Westerly, and Southerly—that the program has shown the most results to date. At Westerly, for example, the efficiency of secondary treatment—as measured by effluent quality—has been improved substantially. Construction will begin this year on a \$38 million expansion project. By taking advantage of new technology in the form of chemical treatment, adsorption, and ion exchange, the city has projected a savings of \$15 million on the Westerly project through eliminating construction of a huge artificial island in Lake Erie, once thought necessary.

At Easterly, a \$6 million modernization is underway, and contracts will be let soon for advanced waste treatment facilities, mainly to provide for phosphate removal. And, at Southerly, the largest and most complex of the three plants, a \$5 million reconstruction is almost completed. Included in this project are improved facilities for treating sludge from all three of the treatment plants. A new treatment unit is planned for Southerly that will incorporate chemical treatment and carbon adsorption; when this plant is completed, Cleveland probably will be the first major U.S. city to adopt physical-chemical treatment as an alternative to biological treatment.

The second major component of the task force program is to provide a new sewage collection and transportation network. Martin says "We're also undertaking this design work in a non-classical way. We're starting with the problem of water standards for Lake Erie, destination of all our effluents, and working back to the pollutant loads, not hydraulic loads, we'll have to handle." A \$2 million design project has just gotten underway, and the whole sanitary waste and storm water collection network probably will account for the major part of the \$1.2 billion water quality program Martin thinks Cleveland eventually needs.

The third major segment of the task force program is related to industrial waste problems." Up to 50% of the wastes generated in the city are from industrial sources, and a program that does not integrate treatment of industrial waste is, at best, only 50% effective," notes Martin. Part of Cleveland's current problem with industrial wastes is jurisdictional; most industrial waste effluents are discharged directly into the Cuyahoga, and, thus, are

under state, rather than local, control.

Martin is a firm advocate of joint industrial-municipal treatment schemes. In addition to the usual advantages, economies of scale and opportunities for additional federal financing, there are other technical advantages. Phosphate removal techniques being adopted by the city include provisions for use of acid discharges from steel pickling and coke ovens to precipitate the phosphorus.

Problems ahead

Despite his ambitious program, Martin is the first to admit that Cleveland faces difficulties in achieving its goals. The most immediate of his problems is a state deadline, only weeks away, to submit formal proposals for new treatment plant construction. And Stefanski points out the type of enforcement problems that arise from the fact that his public utilities department supplies water services to suburban communities that do not use Cleveland sewage treatment facilities. He argues that one possible interpretation of state enforcement pressure makes his department responsible for those communities whose own treatment facilities do not comply with state standards; such responsibility, of course, implies authority to withhold water service to those communities.

But, despite such short-term problems, both Stefanski and Martin are optimistic about solutions to water quality problems facing most U.S. cities. Stefanski feels that "Cleveland has become a barometer for the country by demonstrating that local commitments must come first; if the commitment is made, financing schemes are available." Martin adds that, although the city's \$100 million commitment fills only half of its immediate needs, the city is eligible for an additional \$100 million from the Ohio Water Development Authority.

But even this optimism is guarded; speaking of the impact of the federal treatment plant construction program, Martin says "the President is still not talking goals, which ultimately must be set regardless of the cost of attaining them. Estimates of the cost of solving the Lake Erie problem, for instance, include \$8 billion to eliminate polluted discharges, plus costs of such things as dredging, aeration, and so on, to restore lake quality. The total cost then looks more like \$80 billion, and a \$10 billion nationwide program looks like less than a total commitment."

Objective: A new environment

Student led teach-in aims to control pollution through education

Give Earth a Chance. This is the battle cry of the proposed April 22 Environmental Teach-In. The nationwide movement is gaining momentum as "Earth Day" approaches, and what started as a campus oriented educational campaign has mushroomed beyond expectations. High schools as well as colleges and universities are planning programs; communities, businesses, and citizens from every walk of life and political persuasion will take part in what—if successful—will be only the beginning in the drive to clean up the environment—to make a *new* environment, as it were.

While young people are articulating best the concern and need for action to preserve a habitable environment, support for the teach-in goes far beyond the campus, according to Steven Cotton, press representative for Environmental Action, the Washington, D.C., based national coordinating group for the April event. Young and old, radical and conservative, silent majority and vocal minority alike agree that something is very wrong. (In fact, there are those who are concerned that, perhaps, the movement has become *too* respectable, that, with everyone jumping on the bandwagon, lots of lip service will be paid, but little will be accomplished. However, most agree that the more publicity the deterioration of the environment receives, the better.) Through coverage in the media, the public is becoming aware of the problem and how it will affect their lives and the lives of their children. With information, the result can be "refined knowledge brought to bear where it counts," according to Cotton, resulting in more research, stronger enforcement, and still more knowledge. Where, not too long ago, few people attended Congressional hearings, today, hearing rooms are jammed—with housewives, lawyers, students, businessmen. In fact, pollution control has become big business, and that, too, is good.



Industry inevitably will be a major target of Earth Day activities—it can't escape. Through citizen action groups and stockholders meetings, as well as stricter governmental regulations, such firms as General Motors, Ford, General Electric, Consolidated Edison, and the like, are awakening to the fact that they must accept the responsibility for cleaning up—and preventing—industry generated pollution.

From California to New York, Florida to Alaska, more than 900 colleges and 4000 high schools in the 50 states will participate in the teach-in. In some areas, activities will continue for a week, in others, for a month or longer. The University of Michigan sponsored a pre-April 22 teach-in, which lasted for four days, featuring notable speakers; Ecology Action

(Berkeley, Calif.) is sponsoring a 500 mile "Survival Walk" from Sacramento to Los Angeles (March 21-April 22); in St. Louis (Mo.), a group called Black Survival is working with the Coalition for the Environment in the ghetto; in Washington, D.C., students plan to canvass drivers into the city as to possibilities of car pools to reduce the number of automobiles polluting the air of the nation's capital; groups in several major cities plan to block roads in an attempt to bar cars from the inner city; there will be panels and discussions, rallies and picketing. Local groups are encouraged to do their own thing, to tailor their programs to particular problems and needs of their community; the Environmental Action group is supplying encouragement and information in the way of newsletters, posters, bumper stickers, bibliographies, lists of available films, but they emphasize that there will be no mass demonstrations or march on Washington such as that for the antiwar moratorium.

Many of the organizers of the environmental teach-in are veterans of the antiwar movement. For, as Cotton says, "war and the environment are not two distinct issues. . . . environment does not mean just pollution—rather, making the world a livable place." In the same way, the students are not just talking about stopping a war, but a complete change in life-style. In their mind, this means changing priorities of government spending from defense to feeding the hungry, urban housing, cleaning up air and rivers, preserving our national resources, enhancing the much abused "quality of life."

Hanging on the wall in the offices of Environmental Action is a large painting made by 4th and 5th grade children. It is gaily colored, with handprints, footprints, and childish scribbles; it bears the legend: "Help us in planning a new environment for others." In essence, that's what Earth Day is all about.

Clean air by 1974 costs a lot

Governments, industries, and the public must pay for air pollution control

Long overdue, the first national assessment, "The Cost of Clean Air," contains estimates for:

- **Governmental budgeting**—federal, state, and local, for air pollution control for fiscal years 1970–1974.

- **Industry expenses**—for SO₂ and particulate control from fuel combustion and at the plants of seven different industries located in 85 metropolitan areas.

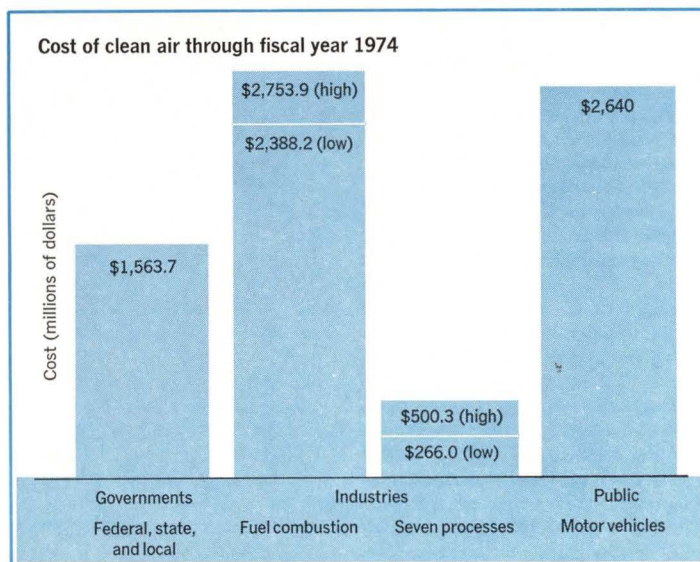
- **Consumer expenditures**—for air pollution control systems on vehicles in compliance with federal standards already promulgated and effective nationwide.

Required by the Air Quality Act of 1967, the report is quick to point out that an exact cost cannot be determined at this time, that the report does not supply the total cost for clean air, and that this total expenditure for bringing air pollution under control must await updated annual cost of clean air reports, additional investigations, and—perhaps more important—further experience with actual implementation of the Air Quality Act.

Assumptions

As with any cost analysis estimate on a national scale, this report contains certain assumptions which, obviously, must be borne in mind in considering the magnitude of these cost figures. One such assumption is that the 85 metropolitan areas discussed in the report contain 84% of the U.S. population. In addition to the 44 areas already specified in the Department of Health, Education, and Welfare's (HEW) 57 air quality control regions (which cover 70% of the population), 41 more areas were chosen on the basis of population. Another point to remember is that the boundaries of the air quality regions actually designated are not necessarily the same as the boundaries assumed for the purpose of this report.

It also is assumed that certain costs are projected for the first time for fiscal year 1971, the year in which actual implementation of the act will



begin. The 85 areas are divided into three groups with different implementation dates. The first group of 14 will begin implementation, controlling SO₂ and particulate emissions, by July 1970; the second group of 18 by January 1971; and the third group of 53 by July 1971.

Governments

In all, the three levels of government—federal, state, and local—will spend an estimated \$1.5 billion during the five year period 1970-74; furthermore, the air pollution programs will grow at a rate of about 30% each year.

The federal government is responsible for:

- Carrying on a comprehensive national program of research and control activities.

- Providing financial and technical support to state, local, and regional air pollution programs.

By the end of fiscal year 1974, it is anticipated that air quality control regions encompassing 90% of the U.S.

population will have been designated. Also, by that time, HEW expects to have criteria and technology documents issued for all of the more important air pollutants (estimated to number 25).

Since states have been given the responsibility under the 1967 act for adopting and implementing air quality standards, they will play an increasingly important role in the next five years. Illustrative of the growth of state, local, and regional programs is the fact that, in 1961, only 17 states operated air pollution control programs. Then, the total expenditure was \$2 million. Now, 46 states, including the District of Columbia, Puerto Rico, and the Virgin Islands, report that their expenditures (including federal support) total \$17.6 million.

The number of actual agencies existing in 1961 and now is another indicator of the growth of air pollution abatement programs. Then, 85 local air pollution control agencies spent \$8 million. Today, 142 agencies are spending about \$29.7 million, according to the HEW report.

Industries

The report covers the cost to industry in the areas of fuel combustion—involving steam electric power generation, and industrial and commercial fuel combustions—and abating air pollution in seven major industries:

- Integrated steel mills.
- Asphalt batching.
- Hydraulic cement manufacturing.
- Gray iron foundries.
- Sulfate (Kraft) pulp mills.
- Petroleum refineries.
- Sulfuric acid manufacturing.

But the estimates are presented only for SO₂ and particulate controls—the two pollutants for which HEW has issued criteria and control technology documents. For combustion sources, there are three general ways to control SO₂ and particulates—fuel changes (including both substitution and switching), stack gas cleaning, and improvements in combustion efficiency. Stack gas cleaning can be used to control both SO₂ and particulates, but, at the present time, it is used only for the latter. In the report, the use of stack cleaning devices at fuel burning sources was considered only for the control of particulates. Furthermore, the cost estimates are based on the assumption that SO₂ emissions will be achieved through fuel substitution. Also, the fuel substitution costs for power plants and commercial facilities differ for the 14 different U.S. fuel price areas.

A first cost to industry—actually the biggest—is the estimated annual expense of substituting lower sulfur coal and 1% sulfur oil with maximum particulate control at all plants in the 85 metropolitan areas. For the seven industrial categories, the control costs amount to less than 2% of each industry's projected shipments in 1974, with one exception, that of the sulfuric acid industry whose cost is 12.6% of the industry's 1974 projected value of shipments.

Particulate controls are needed for all seven industries but only two—petroleum refining and sulfuric acid manufacturing—are major sources of SO₂ emissions. Primary nonferrous metal smelters, the only major industrial process source of SO₂ and particulates not included, were omitted because only 10 such establishments are located in the 85 areas.

Cost estimates are presented for three levels of particulate control—80%, 90%, and maximum overall con-

Industries—estimated SO₂ and particulate control costs in 85 metropolitan areas, fiscal years 1971-74

(millions of dollars)

Fuel combustion	Estimate range		SO ₂ control alone
Steam electric power generation			
1.5% sulfur fuel	\$1,077.6-1,311.4		\$803.1
1.0% sulfur fuel	1,186.5-1,420.3		912.0
Industrial fuel combustion			
1.5% sulfur fuel	789.0-921.6		575.1
1.0% sulfur fuel	926.4-1,059.5		713.0
Commercial fuel combustion			
1.5% sulfur fuel	147.9		147.9
1.0% sulfur fuel	273.5		273.5
Industrial processes			
Steel mills (particulates)	Investment	Operating	Total
80% control	\$33.5-67.5	\$ 46.1-101.5	\$ 79.6-168.0
90% control	33.9-68.0	66.8-146.9	100.7-214.9
maximum control	63.9-126.9	122.7-268.9	186.6-395.8
Asphalt batching (particulate)			
maximum control	49.0-98.2	31.7-66.3	80.7-164.5
Hydraulic cement (particulates)			
80% control	1.4-2.1	1.4-2.9	2.8-5.0
90% control	4.5-6.9	2.7-4.8	7.2-11.7
maximum control	15.2-17.4	9.7-16.8	25.9-34.2
Gray iron foundries (particulates)			
80% control	17.2-31.2	11.3-23.5	28.5-54.7
90% control	30.3-44.4	17.7-32.9	48.0-77.3
maximum control	37.8-52.8	21.4-37.5	59.2-90.3
Sulfate (Kraft) pulp mills (particulates)			
80% control	0.5-0.9	0.3-0.7	0.8-1.6
90% control	1.3-2.3	0.9-1.7	2.2-4.0
maximum control	2.7-4.6	2.3-4.3	5.0-8.9
Petroleum refining			
Particulate control			
90% control	5.7-8.5	4.1-7.6	9.8-16.1
maximum control	11.2-16.5	7.4-12.8	18.6-29.3
SO ₂ control			
90% control	18.2	46.3	64.5
Sulfuric acid			
Particulate control			
90% control	4.8-7.1	2.6-4.7	7.4-11.8
maximum control	9.9-14.5	5.3-8.4	15.2-22.9
SO ₂ control			
80-90% control	29.1-77.7	32.1-67.7	61.2-145.4

Source: HEW Cost of Clean Air Report

trol efficiency (97-99+ %), defined as the amount of emissions after control is applied, divided by the amount that would be emitted if no control was applied. HEW's cost estimate is aware of and includes the fact that some plants in each of the seven industrial categories already are under some degree of control in the 85 metropolitan areas.

For the purpose of the report, all industrial particulates would be controlled by stack cleaning devices, including electrostatic precipitators, cyclones, wet scrubbers, fabric filters, and the like.

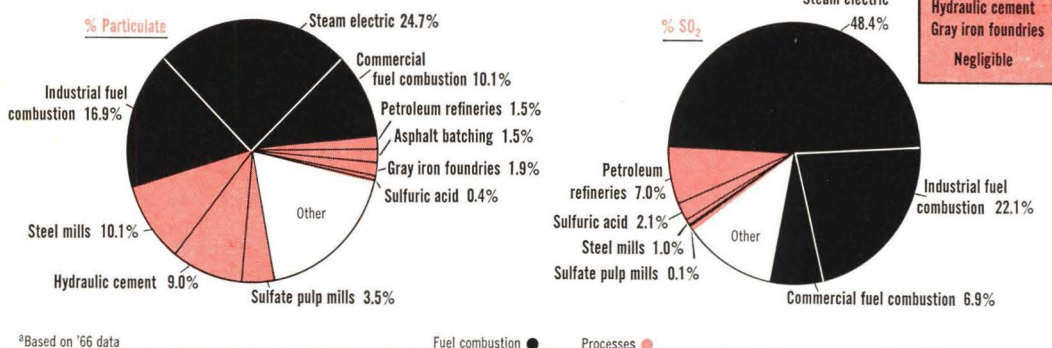
Industrial processes

For the steel industry, the highest estimate of the annual cost of maxi-

mum control of particulates is \$69.7 million in 1974, or 0.41% of the projected value of shipments for that year. (About 58% of this industry's capacity is located in the 85 areas.) SO₂ control costs were not estimated because the fuels generally burned in the process portion of the steel industry already are below 1% sulfur content for metallurgical reasons, the report explains. Wet scrubbers are required for all levels of control of each type of furnace—open hearth, basic oxygen, and electric; the extent of control is achieved by wet scrubbers of successively higher efficiencies.

Asphalt batching plants, which produce much of the nation's bituminous concrete, are expected to grow at an annual rate of 9%. (About 56% of

Nation's industrial emissions^a



this industry's capacity is located in the 85 areas.) Based on the estimated 1974 capacity of asphalt batching plants, the high annual cost of maximum particulate control is \$19.8 million, roughly 1.17% of the projected value of shipments (\$17 billion).

Many of these plants emit well over 1000 pounds of particulate matter each hour. Within each plant, the rotary dryer is the principal source of particulate emissions. Existing dryers are assumed to be under control by a relatively high efficiency cyclone. Additional control to achieve the maximum collection efficiency of 99+ % is obtained by adding an intermediate efficiency wet scrubber.

Hydraulic cement manufacturing, which produces much of the nation's portland, natural, masonry, and pozzolan cement, is projected to grow at an annual rate of 1.5%. (Approximately 57% of the industry's capacity is located in the 85 areas.) Portland cement accounts for 98% of the present production and will likely continue so in the next five year period. For cement plants, the high estimate of annual cost of achieving maximum control in 1974 is \$5.2 million, approximating 0.6% of the projected value of shipments in that year. The kiln is the principal source of particulate emissions from a cement plant, and these emissions can be controlled with cyclones, electrostatic precipitators, or baghouses.

Not a significant source of SO₂ emissions, **gray iron foundries**, nevertheless, are a considerable source of particulate emissions. (Approximately 52% of the industry's capacity is located in the 85 areas.) Ninety-three percent of all gray iron castings were

produced from metal melted in cupolas in 1966; electric furnaces produced the remainder. Based on the capacity of foundries with cupolas in the 85 areas, the highest estimate of annual costs for maximum particulate control is \$10.9 million in 1974, or 0.45% of the projected value of shipments.

The control system envisioned for the unit plant in this industry consists of a water spray cooling chamber at each level of control in combination with a high efficiency cyclone for 80% control, a medium-efficiency wet scrubber for 90% control, and a fabric filter for maximum control.

Only 13% of the nation's **sulfate (Kraft) pulpmill** capacity is located in the 85 metropolitan areas. For the projected sulfate pulp capacity, the high annual cost estimate for maximum control of particulates is \$1.5 million in 1974, approximately 1.66% of the value of shipments for that year.

The major sources of particulate emissions in sulfate pulping are recovery furnaces and lime kilns. The recovery furnaces are assumed to be controlled by electrostatic precipitators for all three levels of control. The smelt tanks (a lesser source of emissions) and lime kilns are assumed to be controlled by wet scrubbers. The amount of pressure drop across the wet scrubbers determines whether 80%, 90%, or the maximum level of control is achieved.

Approximately 58% of the nation's **petroleum refining** capacity is located in the 85 metropolitan areas. Furthermore, this industry is assumed to have 25% of its plants with maximum control and 75% of its plants with no control or minimum control.

For the petroleum refining capacity

in the report areas, the estimated high annual cost of maximum control of particulates and 90% control of SO₂ emissions is \$18 million, approximately 0.14% of the projected value of shipments in that year. While the value of the recovered sulfur could equal a substantial part of the cost of control, and in many cases, allow a net profit, the cost offset value was not considered in this analysis.

About 50% of the nation's **sulfuric acid manufacturing** capacity is located in the 85 metropolitan areas. These plants emit both SO₂ and particulate matter. Standing alone, the cost to this industry for maximum control of particulates and 90% control of SO₂ in 1974 will cost \$22.8 million, a sizeable 12.66% of the value of shipments for that year. But, if the value of additional recovered acid were considered, the net cost would be substantially lower.

The public

The public buyers of 1968 and 1969 model year vehicles paid an estimated \$18 per car for compliance with the national standards. For 1970 model year vehicles, which had to meet stricter federal standards, the cost of emissions control systems amounted to \$36 per car—costs presumably passed along to the consumer.

A projected additional \$12 per car will be passed on the consumer for evaporative emissions control devices which become effective nationwide with 1971 vehicles. So, in effect, \$48 per car will be spent by the consumer for these controls. Although the report does not include the maintenance and operating costs for these vehicles, it considers these costs to be small.

Canals offer vast cooling potential

*Utilization of this resource
could guide location of
future economic centers*

Control of thermal pollution from power plant cooling water discharges by natural evaporation from cooling ponds and artificial water impoundments is being generally discounted in the U.S., where recent emphasis has been shifting to the use of cooling towers. But natural evaporation systems may yet have a significant role in future power development, according to R. T. Jaske of Battelle Memorial Institute's Pacific Northwest Laboratory (Richmond, Wash.). At a recent meeting of the American Institute of Chemical Engineers (AIChE), Jaske contended that the "irrigation canal systems, navigational canals, and other artificial streams and unused canals offer a priceless resource of untapped cooling potential."

Developing this resource, of course, would be a substantial undertaking, and, according to Jaske, would require "planning on a scale in keeping with the resource under consideration as well as the long-range needs of the public." The planning would be indeed extensive, since one goal of the concept Jaske described—canal-lake systems to act as massive heat sinks for thermal effluents—would be a planned redistribution of population away from existing urban areas. In the second of two papers he presented at the AIChE meeting, Jaske stated the problem succinctly in a presentation of projected power demands in the year 2000. Preliminary figures, yet to be verified, indicate that the waste heat rejected by power stations in some areas of northeastern U.S. may reach as high as 50% of the solar energy incident on the area; thus, the need to shift power development—and population—into areas where such waste

heat loads can be assimilated safely by the environment.

Redirected growth

The canal-lake system that Jaske envisions consists of a series of natural and artificial waterways covering extensive distances, that provide a central power spline for redirecting the growth of population centers. The canal system also could supply water for new cities and industries along the route, as well as local transportation when desirable. Parks and green belts would be an intrinsic part of the development plan. But the principal objective would be to provide an extended heat sink away from regulated public water courses, capable of supporting power stations all along its route, and reuse of the water as many times as practical. "Electrical distribution systems would then play a role similar to, but potentially stronger than, that of the early western railroads in the development of economic centers," Jaske says.

Many locations in the U.S. have the potential for such development, Jaske notes. A few he mentions are rivers of the northeast with sources in the Great Lakes, and the proposed Ohio Canal which would use water from the presently overflowing Great Lakes to supplement the flow of the Ohio River. Plans to irrigate Texas, Arkansas, and other nearby areas with seasonal Mississippi River water also could benefit from a broader scope which would include cooling facilities and recreational lakes in the projects. And the success of the artificial cooling lakes of the Texas Electrical Service Co. at San Antonio is one example of how multipurpose development

can be achieved with improved planning, Jaske says.

To illustrate the potential of canal-lake cooling systems, Jaske and his colleagues, M. H. Karr and C. J. Touthill, have applied the concept to one of the routes suggested for a major diversion project in the northwest. This proposed 990 mile diversion would begin in Oregon, pass through northeastern California and Nevada via a series of natural lakes and man-made canals, and eventually discharge into Lake Mead. The thermal capacity of this system, according to Jaske, could support up to 30,000 Mw(e) of generating capacity, a substantial share of the total power needs projected for the area, with additional potential for pumped storage peaking along the line of flow. Furthermore, the restraints on the system were relatively conservative: No temperature rise greater than 5° C. and surface temperatures no higher than 32° C. at any point. As was expected, the total evaporation of the system was high, but the portion allotted to thermal plant cooling amounted to about 70% of that from cooling towers of equivalent capacity.

Implement

In addition to being an efficient way to handle power station thermal loads, any such system would provide recreational facilities to water short areas without distracting from the basic purpose of the system; at the same time, the water quality of the system can be optimized for industrial, municipal, or recreational uses without upsetting existing patterns, Jaske notes. He recommends the Water Resources Council and the National Water Commission for implementation of the concept.

Post-1974 auto emissions:

The Assembly of the California State Legislature, in passing House Resolution 451 on August 2, 1969, called upon the Air Resources Board to "... undertake a study to determine the necessity and technological feasibility of establishing stronger vehicle emissions standards following the year 1974." The results of such study were called out in the same resolution to be reported back to the Assembly "... no later than the fifth legislative day of the 1970 Regular Session. . . ."

The Air Resources Board referred the question, in turn, to its Technical Advisory Committee. The report which follows, adopted by that committee on November 10, 1969, is in response to that charge.

Technical Advisory Committee California Air Resources Board

E. S. Starkman, Chairman
A. H. Batchelder
Rodney Beard
Seymour Calvert
A. G. Cattaneo
Robert L. Chass
James Edinger
Milton Feldstein
John G. Hayes
Alfred C. Imgersoll
James Pitts, Jr.

John Maga, Executive Officer
Air Resources Board

In 1968, the California State Legislature passed the Pure Air Act (AB 357), which established motor vehicle emissions standards through the 1974 model year. The intent of this legislation was to control vehicle emissions in such highly polluted areas as Los Angeles, so that the atmosphere could be returned to a quality level no worse than that of the early 1940's. In framing AB 357, the State of California Assembly Committee on Transportation and Commerce utilized a technical advisory panel. This report is, in large part, supplementary to that of the technical advisory panel, dated May 1968. The intervening period of one and one half years has produced considerable additional information on vehicle emission control which bears directly on the questions to be answered. This report deals separately with the two considerations:

- Necessity for stronger standards.
- Technologically feasible minimum emissions from motor vehicles.

Projection beyond 1980 indicates that minimums will exist in the contributions by motor vehicles of all three pollutants—hydrocarbons, carbon monoxide, and oxides of nitrogen. This occurs in about 1985. Thus, we can observe that, in order to prevent deterioration in the quality of the atmosphere thereafter, tighter controls than now legislated must be put into effect. More important, more stringent controls must be legislated well before the early 1980's.

California has a motor vehicles population with an average age of 6-7 years; approximately 15% of the vehicles on the road are 10 years old. There is a considerable time lag between institution of a control and significant effect on the atmosphere. In addition, there is the indication that existing legislation will not reduce carbon monoxide and oxides of nitrogen to the levels of 1940. In the early

1980's, oxides of nitrogen still will be emitted at 250% of the daily rate which existed during the early 1940's. Carbon monoxide will be emitted from vehicles at a rate corresponding to 170% of that same period. At its September 17, 1969, meeting, the Air Resources Board adopted air quality standards which will have direct bearing on the maximum amount of the three principal pollutants which can be emitted by automobiles. The more pertinent of the air quality standards relating to vehicles exhaust are:

- **Carbon monoxide**—20 p.p.m. for eight hours.
- **Nitrogen dioxide**—0.25 p.p.m. for one hour.
- **Oxidant**—0.1 p.p.m. for one hour.

Carbon monoxide

The standard adopted by the Air Resources Board which limits carbon monoxide to an eight hour average of 20 p.p.m. is exceeded on many occasions in Los Angeles. Preliminary data for 1969 show a maximum eight hour average of 40 p.p.m. (with an existing average daily load of 9100 tons). Projection to 1980, with AB 357 motor vehicle limitations, is for 4000 tons per day; in the year 2000, the burden will be 4900 tons per day. The air quality goal of 20 p.p.m. for eight hours might be attained in the early 1980's, but will be exceeded soon after. Further, there is considerable effort being exerted to make the carbon monoxide standard even more stringent—at some future date, a level of 10 p.p.m. for eight hours may be prescribed.

The motor vehicle is now, and will continue to be, the major contributor of carbon monoxide. In order to maintain the atmosphere in Los Angeles after 1980 at a level which does not exceed the ambient air standards for CO, it will be necessary to further reduce vehicle emissions of this pollutant below the level prescribed for 1974.

a report from California

Oxides of nitrogen

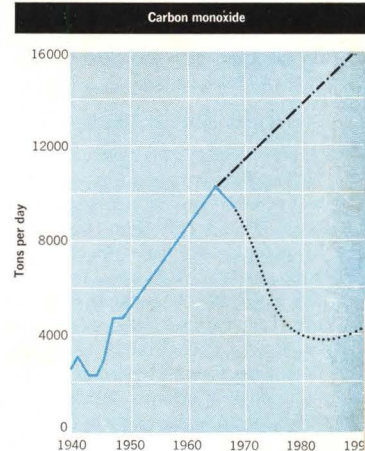
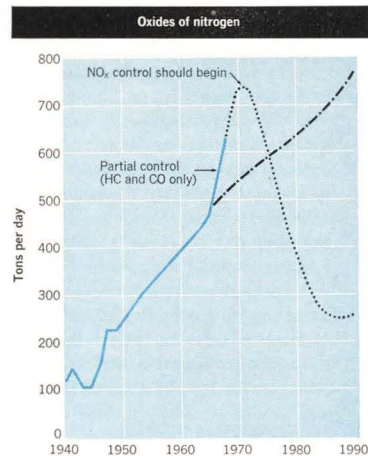
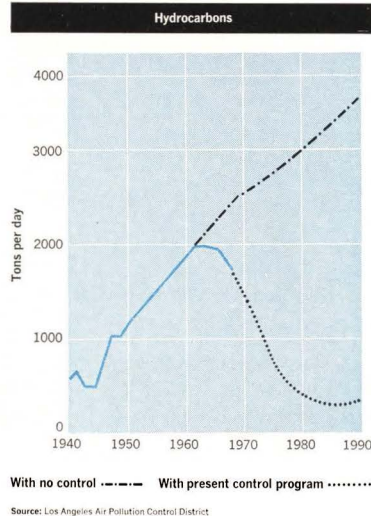
The 0.25 p.p.m. level of nitrogen dioxide for one hour was exceeded on 132 days in Los Angeles during 1968. Projections indicate that there still will be a significant number of occasions during the early 1980's when the standard will continue to be exceeded, even assuming that AB 357 levels will have been effected.

Unlike the case with carbon monoxide, the motor vehicle will not continue to be the principal contributor of nitrogen oxides in the 1980's. When the goals of present legislation are attained, daily emissions from motor cars in Los Angeles will be about 300 tons of combined oxides of nitrogen per day. If not subject to further control, stationary sources should, by that time, be contributing about 500 tons per day. Further lowering the levels of NO_x from motor vehicles beyond the 1974 requirements of 1.3 grams per mile obviously will help to reduce the number of projected occasions on which 0.25 p.p.m. of NO_2 will be exceeded. However, it is obvious that stationary sources also should be considered for tighter controls.

An even more stringent limitation on nitrogen oxides emissions is implied by the air standard of 0.1 p.p.m. oxidant level for one hour. The usual recurring high level in Los Angeles is about 0.4 p.p.m. There are also some 0.1 p.p.m. occasions in Los Angeles at present. While these 0.1 p.p.m. concentrations usually are experienced only during periods of ventilation, as opposed to complete stagnation of the atmosphere, they are of interest because the concurrently measured NO_x is about 0.15 p.p.m.

If it is possible to interpret this relationship literally and extrapolate to 1980, more stringent controls of NO_x will be required on stationary as well as vehicular sources. It also should be pointed out that the 0.1 p.p.m. of ox-

Projected vehicle emissions in Los Angeles County



dant for one hour is not only regularly exceeded in Los Angeles and other large metropolitan areas in California, such as San Francisco, but also in such relatively less populated places as San Rafael, Fresno, and Bakersfield.

Unburned hydrocarbons

Unburned hydrocarbons, other than polynuclear aromatics and ethylene, pose no great problem in the atmosphere. It is the photocatalysis process resulting in the production of oxidant which established them as undesirable. Thus, the maximum allowable quantity of hydrocarbon emission is determined by the air standard criterion for oxidant. By 1980, there will be a significant reduction in days on which 0.1 p.p.m. of oxidant (and, thus, increased eye irritation and other effects) will be attained. To completely eliminate such occurrences in Los Angeles beyond that date will, however, require a still further lowering of unburned hydrocarbons below that of the 1.5 grams per mile specified for 1974 by AB 357, even with the further projected restraint on NO_x .

Very important to the argument for further lowering motor vehicle emissions beyond the levels of 1974 is the relative contribution of other sources, particularly as projected to 1985. By 1985, more than 85% of the vehicles on the road will have been controlled to the 1974 requirement.

Social and political considerations

The question of necessity can be interpreted as more of a social, political, and possibly medical nature than technical. The people who are affected by pollution are most concerned and vocal in their efforts to obtain legislative curbs. Since the motor vehicle has been, and is projected to continue to be, the major contributor to air pollution, it is a most logical point of attack.

Through California legislation, the 1974 model passenger car will have been reduced in emission of hydrocarbons to about 10% of its uncontrolled counterpart. Carbon monoxide similarly will be limited to a level of about 30%, and oxides of nitrogen to about 35%, of pre-1966 vehicles. As a consequence, other sources will be contributing substantially equal amounts of some of these same pollutants to the atmosphere in the early 1980's.

Nonetheless, concurrent with adoption of legislation—and with growing momentum—the question is being put



forward: Why stop at the levels so established? The situation to be considered is not necessarily that which led to House Resolution 451. It is argued that motor vehicle emission control should be considered on an entirely different basis. The philosophy is changed radically from that which produced the presently projected limitations. The goal now is apparently parallel to that relating to other contaminants of the environment: *To reduce such pollutants to an absolute minimum, consistent with the technical capability to do so, at a not unreasonable cost and with greatest urgency.* This type of need is not subject to technological analysis. Rather, it can be answered only by responding with an opinion relating to a projected *minimum technologically feasible level.*

Technological feasibility

The term technological feasibility is, and has been, subjected to considerable interpretation. This definition is perhaps the most difficult task placed be-

fore the various committees and panels which have struggled with projections of what can be attained at some future date. One definition is very easy to obtain verbatim from Webster's unabridged dictionary. "*Capable of being done according to, or from the viewpoint of technology.*" At the other extreme, the argument sometimes is heard that technological feasibility of an item can be shown only if substantial numbers have been built successfully as, for example, in mass production. For the purposes of this report, the definition will be that which is generally accepted, according to the dictionary. However, there will also be taken into account the *further* criteria that the systems at least must have been demonstrated in application, and have been projected to be reasonable in cost.

In 1967, a U.S. Department of Commerce study, "The Automobile and Air Pollution," sometimes called the Morse report, assessed the technologically feasible level of emissions which should

Auto emissions: a summary of possibilities

(all figures in grams per mile)

Legislation and goals	Hydrocarbons	Carbon monoxide	Oxides of nitrogen
Prior to control	11.0	80.0	4.0
California Pure Air Act (AB 357) 1966	3.4	34.0	—
1971	2.2	23.0	4.0
1972	1.5	23.0	3.0
1974	1.5	23.0	1.3
California Low Emission Vehicle Act (AB 356)	0.5	11.0	0.75
Morse report goals for 1975	0.6	12.0	1.0
Interindustry Emission Council goals	0.82	7.1	0.68
Modified conventional engines			
Sun Oil Co. test vehicle	0.7	12.0	0.6
Chrysler-Esso engines			
Manifold reactor	<1.5	<20.0	<1.3
Catalytic reactor	1.7	12.0	1.0
Synchrothermal reactor	0.25	7.0	0.6
Ethyl Corp. "lean reactor" car	<0.7	<10.4	<2.5
DuPont manifold reactor	0.2	12.0	1.2
Alternative power plants and fuels			
Steam car	0.2-0.7	1.0-4.0	0.15-0.4
Gas turbine	0.5-1.2	3.0-7.0	1.3-5.2
Wankel engine	1.8	23.0	2.2
Stirling hybrid	0.006	0.3	2.2
Natural gas fuel	1.5	6.0	1.5

Source: Technical Advisors Committee, California Air Resources Board

be attained in spark ignition engines by 1975. These were reported as:

- **Unburned hydrocarbons**—0.6 gram per mile.
- **Carbon monoxide**—12 grams per mile.
- **Oxides of nitrogen**—1.0 gram per mile.

The emission levels were based on testimony from the automobile, oil, and chemical industries, and on fragmentary reports of progress with control systems on laboratory engines. No evidence was presented to the effect that operational vehicles had demonstrated such accomplishment in 1967. Furthermore, control to the levels quoted reportedly had not been demonstrated simultaneously for all three pollutants. The systems for hydrocarbons and carbon monoxide control were being developed separately from those for oxides of nitrogen.

Low emission vehicles

In 1968, the California State Legislature adopted AB 356, which relates

to a "low emission motor vehicle." This defines such a vehicle as one which produces no more than 0.5 gram per mile hydrocarbon, 11 grams per mile carbon monoxide, and 0.75 gram per mile oxides of nitrogen. The emission levels are close to those specified in the Morse report as attainable by 1975.

AB 356 further requires that the State of California purchase quantities of such vehicles when they have been developed and brought to a stage of manufacture, satisfaction of performance need, and cost not more than double that of conventional vehicles purchased in the previous year.

Another established goal is that of the Inter-Industry Emission Control (IIEC) program. IIEC was formed by Ford Motor Co. and Mobile Oil Corp. (April 1967). Additional automobile and oil companies subsequently became involved. The stated objective of the program is to achieve emission levels no higher than 0.82 gram per mile hydrocarbons, 7.1 grams per mile

carbon monoxide, and 0.68 gram per mile oxides of nitrogen.

Progress reports have appeared from time to time on the IIEC program. Although there is an implication in the latest paper (published in 1969), that the IIEC goals might be accomplished by the mid-1970's, no definite target date can be found in the available literature.

In the intervening time since these goals, laws, and targets were set, a number of integrated control systems have been demonstrated which limit emissions to that projected for attainment. These systems have involved operational vehicles as well as engines tested separately. The more prominent and successful of the methods used and the demonstrations of their effectiveness follow.

Conventional gasoline engines

It has already been demonstrated abundantly that carbon monoxide and unburned hydrocarbon emissions from motor vehicles can be reduced substantially. The accomplishments to date in bringing production vehicles into conformance with existing legislation have resulted from a combination of modifications. These include better fuel control; adjustments to spark timing; containment of crankcase, fuel tank, and carburetor vapors; and mechanical changes in combustion chamber shapes, gasketing, piston, and ring configuration, and compression ratio. Some vehicles still need the additional feature of a pump for supplying air to the exhaust manifold, but these are in substantial minority.

There is a limit to the approaches used thus far in effecting further reductions in carbon monoxide and unburned hydrocarbons. Other and more complex approaches probably will be necessary to attain the levels of exhaust emissions prescribed for 1974 and beyond.

Control of oxides of nitrogen to levels prescribed in 1971 model vehicles appears attainable with reprogramming of spark advance, as well as some internal engine modifications. For 1972 and later, additional steps will have to be taken.

Carbon monoxide and unburned hydrocarbons which appear in the exhaust are capable of being converted to a harmless form if kept sufficiently hot and exposed to oxygen. The exhaust gas temperatures are high enough and there is usually some oxygen

which has not been reacted in the engine cylinder. However, unless the exhaust heat is somewhat conserved, the gases cool off rapidly and, usually, the amount of oxygen in the exhaust is less than enough to complete the reaction.

To attain these conditions, several organizations have proposed the use of exhaust gas reactors. These are devices which can be attached to the exhaust manifold and are designed to contain the heat. They are additionally supplied with air from an engine driven pump to more fully complete the combustion reactions. Most of the proposals for further reducing emissions from gasoline engines anticipated using some form of the so-called Du Pont reactor.

Exhaust recycle

The quantity of nitrogen oxides which appears in the exhaust of a combustion engine is determined by the relative amounts of fuel and air provided and the maximum temperature occurring in the combustion chamber. Thus, modifying the fuel:air ratio or the combustion temperature will influence the exhaust content of nitrogen oxides correspondingly. The more obvious methods to reduce peak temperature include retarding the spark and lowering the compression ratio. One of the less obvious but effective means to accomplish the same thing is to dilute the fuel:air mixture before it enters the combustion chamber. Among the readily available diluents is the exhaust gas. A method of recycling exhaust gas was pioneered at the University of California at Los Angeles and has been brought to practical application by Atlantic Richfield Corp.

Recycling of exhaust gas is reasonably simple. Valving is provided to allow up to 25% of the exhaust gas to be introduced to the inlet manifold. Control of the valve is linked to the throttle. In practice, the recycling takes place only at intermediate throttle settings. At full throttle, the flow of gas is shut off, and, thus, maximum power is not reduced.

There have been reports of adverse side effects in some of the vehicles which have been so equipped. One of these is a long-term, rapid buildup of deposits in the engine intake system. Another is a loss in vehicle drivability. Both of these problems are under observation. An example of the research underway is the program of

outfitting a fleet of 60 vehicles owned by the State of California to learn more about exhaust gas recycle and potential problems resulting from its use.

The application of recycle for reducing oxides of nitrogen is almost always made in conjunction with means for controlling carbon monoxide and unburned hydrocarbons. Reports on effectiveness cannot, therefore, be separated easily, since fuel mixture and spark timing usually are modified to optimize the total control over all three emissions. All other factors being equal, however, this approach has been credited with reducing oxides of nitrogen by 75-90%.

There are proposals relating to other methods for reducing emissions to levels needed for 1974 or later, such as flame afterburners, catalytic mufflers, and various methods of fuel treatment. These will not be dealt with here, however, in view of the implicit question of technological feasibility and lack of reliable and definitive reports on their performance. This does not mean that such systems are beyond possibility. Indeed, some as yet unproven approach may succeed in limiting emissions more effectively than anything yet tested.

Existing technology

One of the more recent and reasonably complete bits of reliable information on overall control of emissions with existing technology is Sun Oil Co.'s report on application of a Du Pont baffle reactor and other modifications to a 1967 Chevrolet Camaro, 350 cubic inch V-8, four barrel carbureted, manual transmission vehicle. Emphasis was on the manual transmission, since it represented a more difficult situation for emission control than its automatic counterpart. The vehicle as received by Sun was equipped with a 1967 California manifold air injection system.

The vehicle was operated alternately as an economy and power pack version by changes in the carburetor (from two barrels to six). Selected test results with the California seven mode, hot and cold cycle, were reported along with results of other important determinations.

The emissions level in this vehicle was well below the levels of that projected for 1975 by the Morse report. The accomplishment was not without penalties: 11% loss in fuel economy and a necessity for better cooling of

the engine compartment, and provision of more heat resistant under-hood materials. Otherwise, the vehicle performed in a manner expected by and acceptable to the motoring public.

During the June 1969 annual meeting of the Air Pollution Control Association (New York City), Standard Oil Co. of New Jersey and Chrysler Corp. exhibited a number of engines which had been equipped with highly effective emission control systems. These engines were the product of a joint effort by the two organizations. Three engines were on display, each representative of a progressively increasing level of exhaust emission control. The emissions levels and system characteristics were reported, but no statement was made relative to the actual installation of these engines in vehicles. It might, therefore, be assumed that the results reported were limited to dynamometer tests.

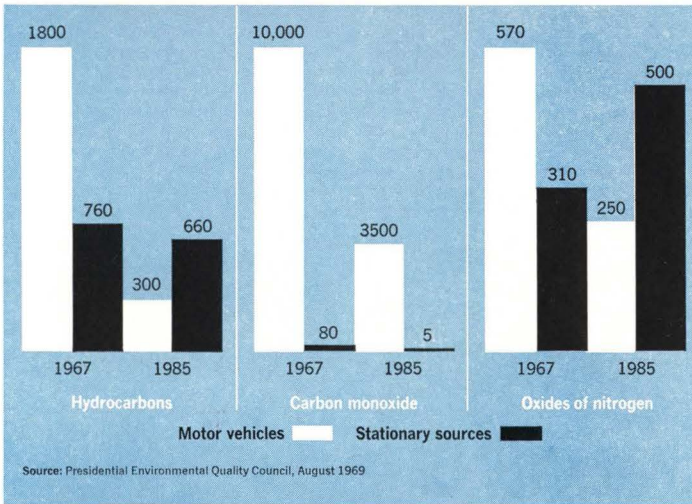
Ethyl Corp. has modified and tested a 1967 Pontiac with a 400 cubic inch engine and automatic transmission in order to demonstrate the potential for reduction of vehicle emissions. The modification included a high velocity carburetor, optimized spark timing, and a heat conserving exhaust manifold. Lean fuel mixture allowed operation without an air pump, since the necessary oxygen for consuming carbon monoxide and unburned hydrocarbon was available in the exhaust gas itself. The results reported were:

- **Unburned hydrocarbons**—0.7 gram per mile (50 p.p.m.).
- **Carbon monoxide**—10.4 grams per mile (0.4%).
- **Nitrogen oxides**—2.5 grams per mile (600 p.p.m.).

Drivability, fuel economy, and performance were reported as being the same as in a conventional vehicle. The reduction in unburned hydrocarbons and carbon monoxide is encouraging; the results for oxides of nitrogen are not spectacular.

The most recent report from Du Pont, which has diligently pursued the development of exhaust manifold reactors, involves an unidentified car fitted with a series of appropriate reactors and provided with exhaust gas recycle. The results for carbon monoxide and unburned hydrocarbons are very impressive. Those for oxides of nitrogen are low enough to meet California's 1974 requirement, as called for by the provisions of the Clean Air Act, but only barely so.

Total Los Angeles County emissions, 1967 and 1985 (tons per day)



Other power plants

Some reliable reports (and some which are suspect) are available on engines which possibly could supplant the gasoline spark ignition engines in passenger cars.

The promise of the **steam engine** to produce inherently low levels of exhaust emissions is well-founded. The capability to utilize combustion processes which are not highly productive of the three principal pollutants is confirmed by available technical knowledge of flames and of the formation of those pollutants. A staff report of the U.S. Department of Commerce contained accounts of exhaust gas content of 0.7 gram per mile hydrocarbons, 4 grams per mile carbon monoxide, and 0.4 gram per mile oxides of nitrogen. There are also other reports of 20 p.p.m. hydrocarbons, 0.05% carbon monoxide, and 40 p.p.m. oxides of nitrogen, but these data are difficult to substantiate.

The tests carried out are fragmentary. Not many steam automobiles have been tested. It remains to be seen if the steam vehicle can be built at a price competitive with internal combustion engines, and if it will provide operating economy (miles per gallon of fuel), conveniences such as short startup time, and a simple capability for operating such auxiliary de-

vices as an air conditioner, power steering, power brakes, and high capacity electrical systems. From all available technology, it appears impossible for the vapor power plant to compete on equal ground with spark ignition engines in any of these respects.

There are many efforts underway in the steam or vapor cycle power field. These are being monitored closely. It cannot be stated yet that the steam engine has proven that it can be a satisfactory substitute engine.

In contrast to the steam engine, the **gas turbine** already has been tested in a number of conventional and non-conventional passenger cars. The technology developed in aircraft applications has aided in bringing the gas turbine to the state of development where it can compete with diesel engines for heavy trucks. Such turbines are now in the first stages of production and will appear in 1971.

Fuel consumption, simplicity, low noise, weight, and size favor the possible application of gas turbines to passenger cars, but cost is a deterring factor. The gas turbine, in its present state of development, can be built to compete with the relatively expensive heavy duty diesel truck engine, but some of the materials and fabricating methods make it cost more for passenger cars than the gasoline piston engine. It remains to be seen if the costs can be reduced to allow this type

of power plant to become competitive. It also must be shown that it can be built in the smaller sizes, appropriate to light or economy vehicles.

Data on emissions from gas turbines are readily available, and the gas turbine shows promise as a reasonable replacement for the gasoline engine, in view of its low level of emissions, and its already proven applicability and acceptability to the motoring public.

Other than the diesel, the largest volume production principal contender to the reciprocating gasoline engine is the **Wankel or rotary engine**. Two foreign firms—the Toyo Kogyo Co. of Japan and the NSU Co. of Germany—are marketing vehicles with such power plants. Production to date in Germany has exceeded 10,000 units of the NSU Ro80 vehicle, a full-scale sedan with rotary engine.

Because of its combustion system, the rotary engine is inherently prone to high levels of unburned hydrocarbon emissions, moderate levels of carbon monoxide, and relatively low quantities of nitrogen oxides. The unmodified engine yields 2000-2500 p.p.m. unburned hydrocarbon, 4% carbon monoxide, and 600 p.p.m. oxides of nitrogen. However, recent tests of both the Toyo Kogyo and NSU Ro80 vehicles by the National Air Pollution Control Administration (Ypsilanti, Mich.) yielded about 150 p.p.m. hydrocarbon and about 1% carbon monoxide. Ox-

Committee's summary and recommendations

In its report to the California Air Resources Board, the Technical Advisory Committee summarized its conclusions as follows:

"The necessity to control emissions to levels lower than presently legislated in AB 357 (the 1968 Pure Air Act) for 1974 model vehicles sold in California can be demonstrated. The extent of further control depends upon the basis for consideration. In order to return the atmosphere in Los Angeles to its 1940 quality and to maintain it there until the year 2000, vehicle exhaust emissions will have to be further reduced.

"Measurement on laboratory vehicles with gasoline reciprocating engines has demonstrated that exhaust contents of pollutants can be reduced to levels substantially below that called out in AB 356 (the 1968 Low Emission Vehicle Act). The requirements of AB 356, and authoritative judgments of what can be attained by 1975, are about 0.5 gram per mile hydrocarbons, 11 grams per mile carbon monoxide, and 0.75 gram per mile oxides of nitrogen.

"Steam, gas turbine, and Stirling engine demonstrations have yielded emission levels which are, in some cases, below the requirements of AB 356. However, these alternative power plants have yet to demonstrate that, by 1975, they will be equal in cost, operating economy, flexibility, and acceptability to the gasoline engine controlled to the level of AB 356. Natural gas has been shown to be superior to gasoline as a spark

ignition fuel, from the standpoint of emitted reactive hydrocarbons and carbon monoxide. Among accompanying problems are limitations on vehicle range and power.

"Control of vehicle emissions beyond the levels described by AB 356, as demonstrated attainable in the laboratory with controlled conventional engines, cannot be justified without also considering the relative contributions of pollutants from other sources."

The committee, therefore, recommended that:

"Exhaust emission standards should be established to further restrain emissions in 1975 model vehicles sold new in California to a level of:

- 0.5 gram per mile hydrocarbons.
- 12 grams per mile carbon monoxide.
- 1.0 gram per mile oxides of nitrogen.

"Effort should be directed statewide to effecting more stringent control over organic compounds and nitrogen oxides from sources other than motor vehicles."

The Air Resources Board subsequently has adopted the above recommendations at an open hearing on January 21, 1970. The next—and final—step before putting the above standards into effect is issuance of the necessary waiver by the U.S. Department of Health, Education, and Welfare (HEW) pursuant to the federal Air Quality Act of 1967. Application for such a waiver is now pending before HEW.

ides of nitrogen, although not measured should not have exceeded the amounts from an uncontrolled engine (600 p.p.m.). The dramatic decrease in emission from the Ro80 engine was accomplished by outfitting it with Dupont exhaust reactors.

This development is noteworthy for two reasons: It illustrates that the reactor scheme can be quite effective in a production vehicle. Equally important, however, is the observation that the rotary engine is simple, of small size and weight, and without vibration. Its potential for replacement of the piston engine is good, since it performs all of the functions required, without need for vehicle modification.

Another possible contender for application to passenger cars is the **gas cycle (Stirling) engine**, an external combustion engine which has the same low pollution characteristics as the steam engine. Very few Stirling engines have been constructed and tested. The one notable example demonstrated so far is a General Motors hybrid Stirling-electric which yielded a remarkably low 0.006 gram per mile of hydrocarbons, 0.3 gram per mile of carbon monoxide, and 1.0 gram per mile of nitrogen oxide.

As is the case with steam, the Stirling engine has been around for as long as or longer than internal combustion engines. Lack of development is, in large part, a consequence of its comparatively greater complexity, weight, size, and lack of flexibility. The promise for overcoming these limitations is not great. The hybrid arrangement of the General Motors vehicle was an attempt to accommodate the Stirling engine's poor startup and load response characteristics.

Studies in the Morse report and subsequent research have shown that the application of **batteries or fuel cells** for vehicular propulsion will be restricted for at least a decade to limited

range and speed. Replacement of some urban cars with modest requirements could be made, but competition with gasoline engine equipped vehicles is beyond technical knowledge and capability.

Fuel substitutes

Suggestion has been made that substitute fuels other than gasoline would be means for reducing emissions. The proposals principally include ammonia, alcohol, liquified petroleum gases (propane), and natural gas (methane). As of this date, the most promising fuel—from the standpoint of reasonably simple utilization, ready availability, and minimum loss of performance and economy—seems to be natural gas. Southern Counties Gas and Lighting Co. has been most active in this area and has equipped a number of fleet vehicles with natural gas fuel systems.

The installations have used both the high pressure gas and liquid gas at very low temperature. The most practical system calls for bottled gas with gasoline available for suburban use or in the event of emergency exhaustion of the natural gas tanks. Vehicle range on bottled natural gas appears to be limited, however. The figures quoted are from 40-60 miles on one fill with the present system. Average emissions, measured on 13 cars, were:

- **Unburned hydrocarbons** — 151 p.p.m.
- **Carbon monoxide**—0.35%.
- **Oxides of nitrogen**—462 p.p.m.

The most important aspect of the natural gas application is the relative reactivity of the exhaust hydrocarbons. Because most of the unburned hydrocarbon consists of methane, its reactivity is about 20% of that from the same vehicle operating on gasoline.

The New England town that weatherproofed its sludge drying operations

How Bird Centrifugals can help you take the waste out of waste treatment

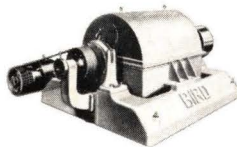


In New England, if you don't like the weather all you have to do is wait a minute. This can pose problems with drying beds — one reason why a town in Southeastern New England now handles waste dewatering with a Bird Centrifugal. Drying beds (and weather problems) are eliminated. So is odor nuisance. Moreover, a Bird Centrifugal — unlike filter equipment — needs little operator attention.

The Bird Concurrent Flow Centrifugal — latest product of Bird's long experience with sanitary and industrial waste treatment — offers today's most efficient method of sludge dewatering. The machine is uniquely engineered to assure thorough separation and clarification. Sludge is introduced into the machine ahead of the settling zone so that hard-to-settle solids are undisturbed. And solids travel the length of the bowl to produce a dryer, better compacted cake. Little or no flocculents are needed. Capacity is up to twice that of conventional centrifugals.

Look into this modern method of sludge dewatering. Contact your Bird Application Engineering Office. Or write for Bulletin LBS.

Bird Machine Company, South Walpole, Mass., 617 668-0400 • Application Engineering Offices:
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Membrane processes gain favor for water reuse

Recent studies hold promise of cost reductions and improved efficiency in many applications

A phenomenon is occurring in the U.S. that would have been unbelievable a few years ago. We are running out of clean water. This is disconcerting because our country is blessed with many large streams and rivers. The U.S. abounds in lakes varying in size from farm ponds to the mighty Great Lakes. We have one of the most highly developed dam and reservoir systems on earth. Our average rainfall is sufficient to water most of the nation plentifully. Nevertheless, our population explosion and industrial growth have made the need to clean up and reuse our waters a new and painful fact of life.

The U.S. Water Resources Council predicts that municipalities which now use 23.7 billion gallons of water a day will need more than 50 billion gallons a day by 2000. In other words, our cities will need more than twice as much water within the short span of 30 years. Water demands by industry make these figures seem almost insignificant. Already using twice as much water as cities, U.S. industry, by the year 2000, will be demanding almost three times its present consumption.

To varying degrees, depending upon the state of development and population, this is the situation facing most the countries of the world—how to make the same amount of water stretch farther. This requirement calls for the development of new treatment processes, since conventional water and waste treatment processes are only partially effective against an expanding list of compounds resulting from our advanced technology. Dilution water is becoming less and less available, and stream self-purification treatment does

Reverse osmosis for industrial wastes

Capital costs ^a	10 m.g.d.	50 m.g.d.
Desalting equipment	\$2,037,500	\$ 9,323,710
Pumps, piping, valves	1,194,850	4,653,000
Pretreatment and feed intake system	252,000	1,072,000
Membrane casting, energy recovery, chemical injection systems	164,000	510,000
Instrumentation and electrical equipment	420,000	1,770,000
Buildings, land, and storage facilities	332,850	761,000
Miscellaneous and financing costs	397,950	1,957,220
Total capital costs	\$4,799,150	\$20,036,930
Operating costs (cents per 1000 gal.)		
Annual fixed costs	12.0	10.0
Supplies, labor, maintenance	23.1	15.1
Total product water costs	35.1	25.1

^a Basis: Costs in 1968 dollars, 800 p.s.i.g. operating pressure, 70% product water recovery, and membrane life of one year

Municipal tertiary treatment

Capital costs ^a (thousands of dollars)	Conventional plant	Conventional plant plus electrodialysis	Conventional plant plus reverse osmosis
Primary and secondary treatment	\$ 6,626	\$ 6,626	\$ 6,626
Surge pond	—	405	405
Carbon filters	—	2,492	2,492
Electrodialysis unit	—	6,025	—
Reverse osmosis unit	—	—	4,020
Product water storage	—	332	332
Buildings, land, and services	2,119	2,964	2,964
Engineering and miscellaneous costs	1,560	3,120	2,786
Total capital costs	\$10,305	\$21,964	\$19,625
Operating costs (cents per 1000 gal.)			
Fuel and electricity	1.6	3.5	4.8
Chemicals	2.6	5.2	5.5
Supplies	1.0	5.4	7.1
Brine and solids disposal, labor, and miscellaneous costs	11.5	23.3	21.7
Total product water costs	16.7	37.4	39.1
Net costs of demineralization	—	20.7	22.4

^a Basis: 30 m.g.d. plant at 1968 prices with 7.1% capital charges

not work for many compounds that resisted waste treatment. The result is that tertiary treatment must be utilized if polluted water is to be made usable again. Nine tertiary treatment research and demonstration projects were operational in 1968 in various parts of the U.S., and 11 others were in the design or construction stage. Evaluation of these processes has proceeded to the point where preliminary cost estimates can be made. Some typical tertiary treatment costs appear in a table accompanying this article.

The cost of the removal of organic and inorganic nutrients by tertiary treatment range from 26-30 cents per 1000 gallons, depending on the techniques employed; this compares to 11 cents per 1000 gallons for secondary treatment. However, the waste water reclaimed by the higher degree of treatment has an economic value depending on the reuse application selected for it. This introduces an offsetting cost factor which is generally comparable to or higher than the cost of tertiary treatment.

There are economics of scale for the electrodialysis and reverse osmosis processes for removal of dissolved inorganics. Current work by the Office of Saline Water (osw) indicates that a 30 m.g.d. plant in a Southern California location could produce renovated water from influent sewage at 21 cents per 1000 gallons for the electrodialysis process, and at 22 cents for the reverse osmosis process, at 1968 prices.

Reverse osmosis

Recent research indicates waste water reclamation by reverse osmosis offers great promise for substantial reductions in cost as well as marked improvements in efficiency. The Federal Water Pollution Control Administration (FWPCA) is sponsoring a large number of reverse osmosis waste water reclamation projects. Results have been obtained on the use of the process for a variety of waste effluents.

Reverse osmosis originally was developed for the conversion of brackish water to fresh water, and is now in practical field use for that purpose. To evaluate the results that we will ex-

amine for waste waters, values obtained by osw in a typical brackish water field test can serve as a baseline.

At an operating pressure of 600 p.s.i.g., and with a product to waste ratio of 3:1, the total dissolved solids (TDS) in this study drops from 5170 p.p.m. to 320 p.p.m., a reduction of almost 94%, and the hardness, iron, manganese, phosphate, and sulfate are removed almost quantitatively.

An example of converting polluted water to a usable state by reverse osmosis is a study on acid mine drainage water (Norton, W.Va.). This cooperative effort between FWPCA and osw shows that the low pH, high iron sulfate water is upgraded substantially with practically all of the iron and a good deal of the acid removed.

Another cooperative FWPCA-osw reverse osmosis project is a field test (Fresno, Calif.) on high salinity irrigation return flow. Results to date show reduction in TDS from 4890 p.p.m. to 340 p.p.m. with elimination of almost all of the hardness and sulfate. A similar study on agricultural runoff (Firebaugh, Calif.) is being carried out by FWPCA, the Bureau of Reclamation, and the California Department of Water Resources. In this test, the DuPont Permapex permeator system is converting the 6000 TDS agricultural drain water to a soft potable water meeting U.S. Public Health Service (USPHS) standards. Conversion of the feed water from slightly alkaline to slightly acidic values increases the unit's ability to reduce nitrates from 30% to 70-80%.

Paper mill effluents

One of the most severe water pollution problems in the U.S. is that caused by effluents from paper mills. A number of states restrict the location where new mills may be established and insist on far better cleanup of the used water than hitherto has been the case. For that reason, the Pulp Manufacturers Research League has been examining reverse osmosis for application to these problems. Excellent cleanup has been obtained on small-scale units, in that the major con-

taminants of one of the main effluents, spent sulfite liquor, can be controlled. The ability to achieve 95% or greater reduction in TDS, chemical oxygen demand, and color is particularly encouraging, since these are the main sources of concern in paper mill pollution control requirements.

Other applications for which reverse osmosis is being tested include treatment of photographic process wastes, maple syrup and fruit juice concentration waste, chemical and biological warfare agent removal, virus and bacteria control, laundry waste, waste water recovery in spacecraft, and sewage plant effluent renovation.

FWPCA began evaluating reverse osmosis for renovating municipal waste water in 1963, just two years after the development of an asymmetric membrane at the University of California. Early laboratory efforts by Aerojet-General Corp. showed the necessity of pH control and prior removal of dissolved organic materials to prevent fouling of the membrane surface and the resulting rapid decline in efficiency.

The first study also indicated that the cellulose acetate membranes may be biologically degraded by waste water. The product quality, however, was excellent, with rejection of more than 90% of the contaminants from a secondary effluent. Since this study, FWPCA, cooperating with the Los Angeles Sanitation District, has investigated reverse osmosis in equipment with capacities up to 10,000 gallons per day at the Pomona advanced waste treatment pilot plant. The project has included studies on tubular membrane units produced by Havens Industries and Universal Water Corp., and on spiral-wound modules from Gulf General Atomic. A flat-plate unit from Aerojet-General also is being evaluated at FWPCA's pilot plant (Lebanon, Ohio).

These studies have verified the necessity of pH control, but have shown that, under proper operating conditions, the membranes are relatively stable. FWPCA has not been able to overcome the flux decline caused by the organic materials but, in recent months, has developed membrane

Federally funded reverse osmosis projects

Contractor	Project title	Contract	Description
Douglas Aircraft Newport Beach, Calif.	Use of improved membranes in tertiary treatment	\$ 84,800	Evaluation of chemically modified cellulose acetate membranes, developed by contractor, for improved flux and stability
Gulf General Atomic San Diego, Calif.	Membrane materials for waste water treatment	65,138	Preparation and testing of three new types of membranes: cellulose acetate with varying acetyl contents, polyvinyl pyrrolidone-polyisocyanate copolymers, and membranes formed from polymer dispersions or latices
U.S. Atomic Energy Commission Oak Ridge, Tenn.	Application of hyperfiltration with dynamically formed membranes to treatment of municipal sewage effluents	85,000	Study of membrane support materials of different pore sizes and the use of filter aids and film-forming additives
Syracuse University Syracuse, N.Y.	Mass transfer analysis in reverse osmosis	19,738	To obtain analytical expressions for rate of production, effect of natural convection, and optimum geometrical configuration
Eastern Municipal Water District Hemet, Calif.	Removal of dissolved solids from reclaimed water in ground water recharge project	225,000	Use of reverse osmosis to maintain satisfactory concentration of salts and refractories in recycled groundwater
Gulf General Atomic San Diego, Calif.	Waste water reclamation	112,410	Provide two spiral wound reverse osmosis modules for operation at the Pomona, Calif., test facility of the Los Angeles County Sanitation District
Aerojet-General El Monte, Calif.	Renovation of municipal waste water	203,299	Lab scale studies with flat membrane cells on several grades of municipal waste water representing a broad spectrum of effluent quality

Paper mill waste treatment

Constituent	Before treatment	% Reduction by reverse osmosis
Solids	1,461 gm./l.	95
Color platinum—cobalt method	74	99
BOD	5,100 p.p.m.	92
COD	17,400 p.p.m.	95
Inorganics	650 p.p.m.	99

Demineralization of irrigation return

Constituent	(p.p.m.)		
	Feed	Product	Waste
pH	7.9	6.0	7.4
Total dissolved solids	4,890	340	7,420
Total hardness	1,290	15	2,060
Ca ⁺²	274	6	505
Mg ⁺²	147	0-1	194
Na ⁺	1,020	102	1,620
SO ₄ ⁻²	2,690	43	4,370
Cl ⁻	371	107	532
NO ₃ ⁻	43	32	54
SiO ₂	44	13	62

Acid mine drainage

Constituent	(p.p.m.)		
	Feed	Product	Waste
Total dissolved solids	1,235	4	4,650
pH	2.9	4.5	2.4
Total iron	101	0.1	392
Aluminum	24	0.1	92
Sulfate	820	0.5	3,000
Magnesium	104	0.1	370
Calcium	218	0.2	810

Operating pressure—600 p.s.i.g.
Product to waste ratio—3:1-4:1

Brackish water treatment by reverse osmosis process

Constituent	(p.p.m.)		
	Feed	Product	Waste
pH	6.7	5.3	6.8
Total dissolved solids	5,170	320	20,600
Total hardness as CaCO ₃	1,880	20	7,350
Ca ⁺²	360	7.6	1,400
Mg ⁺²	240	0.5	940
Na ⁺	900	110	3,400
HCO ₃ ⁻	340	12	1,150
SO ₄ ⁻²	630	0	2,580
Cl ⁻	2,020	170	7,850
Total alkalinity	280	10	940

Operating pressure—600 p.s.i.g.
Product to waste ratio—3:1

Agricultural waste water reclamation

Ion	(p.p.m.)		
	Feed	Product	Reject
Ca ⁺²	331	4.8	483
Mg ⁺²	172	1.9	245
Na ⁺	1,308	111	1,755
SO ₄ ⁻²	3,596	88.0	4,885
Cl ⁻	450	117	578
NO ₃ ⁻ (as N)	11.4	3.7	20.6
SiO ₂	46.3	30.7	52.3
Total hardness	1,760	26.6	2,487
Total dissolved solids	6,046	400	8,280
pH	5.1	4.9	5.3



Inspection. Cellulose acetate is a common material for reverse osmosis membranes

Tertiary treatment costs

Process	Cost (cents/1000 gallons for 10 m.g.d. plant)
Conventional	
Primary treatment	7.5
Activated sludge	11
Filtration	
Microscreening	1.5
Coarse media	2.5
Fine media	3.5
Phosphate removal	
Mineral addition to aerator	3
Coagulation, sedimenta- tion	3.5
Coagulation, sedimenta- tion, filtration	7
Ammonia stripping	1.5
Granular carbon adsorption	3.5-8
Dissolved inorganic removal	
Electrodialysis	14
Reverse osmosis	25
Ion exchange	25

cleaning procedures that are both effective and economically attractive. These procedures employ commercial laundry presoak formulations containing enzymes.

Studies are continuing at Pomona and Lebanon and at the laboratories of selected contractors. In addition, an extensive effort incorporating all the physical configurations presently on the market is in the planning stage. This will result in the installation of five reverse osmosis units on the grounds of the conventional waste treatment plant (Hemet, Calif.). A wide variety of pretreatment processes also will be available so that their effect on the reverse osmosis process can be determined.

Aerojet-General Corp. has conducted a study of the decline in product water flux from various municipal waste streams. The use of certain proprietary additives has been shown to inhibit solids deposition in some cases, and, therefore, minimize flux decline.

FWPCA previously had tested the application of electrodialysis to sewage treatment (Lebanon, Ohio). The results with both reverse osmosis and electrodialysis have shown that it is technically feasible to convert secondary sewage effluents to potable quality. Based on these results, preliminary cost estimates have been prepared for three types of 30 m.g.d. plants:

- A combined sewage treatment reverse osmosis plant.
- An integrated sewage treatment/electrodialysis plant.

This comparison indicates that the net cost of producing potable water from secondary sewage effluent is 22.4 cents per 1000 gallon for reverse osmosis and 20.7 cents per 1000 gallon for electrodialysis.

A 1400 gallon per day spiral-wound module was evaluated (Bergen County, N.J.) on secondary sewage effluent. Rejection of all species except nitrogen compounds was 90-95% or better. The rejection of TDS was about 96% while ABS, odor, and turbidity were removed completely. The biological oxygen demand (BOD) was reduced from a range of 8-26 p.p.m. to 1 p.p.m. Rejections of nitrate and ammonia were about 70% and 90%, respectively. Water flux was about 8 gallons per day per square foot with only a negligible decline during the test.

The same equipment showed interesting results on bacteria during tests on contaminated Potomac River water. The high *E. coli* count was reduced to negligible values. Tests at the Point Loma sewage treatment facility (Calif.) showed that high quality water was obtained even from primary sewage effluent, but that the problems of membrane fouling and module clogging were much more serious than in secondary effluent. Another test on dilute radioactive wastes showed that the beta and gamma activity in a waste stream contaminated primarily with uranium and thorium and their daughter products was reduced by a factor greater than 10,000.

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Dorr-Oliver installed a 3000 gallon per day sewage treatment plant (Sandy Hook, Conn., August 1967) which had a reverse osmosis unit following a grinder, aerated holding tank, and an activated sludge tank. Another plant was installed at Norwalk (February 1968), where the effluent from a biofiltration plant treating 20,000 gallons per day of domestic sewage went through the reverse osmosis unit. Performance of both systems was similar. Typical data indicated that 90% of the time, the BOD was less than 14 mg./l., and the suspended solids were completely removed. Fifty percent of the time, the coliform density was less than 100 organisms per 100 ml. and 85% of the time, it was less than 1000 per 100 ml. Less than five units of color were obtained consistently. Suspended solids tended to settle in the membrane forcing a shutdown for cleaning three times in seven months. The membranes showed a continuing decrease in the flux restored by each cleaning cycle, until after seven months, only 35% of the initial flux could be attained.

A rather unique but critical problem that lends itself to solution by use of reverse osmosis is the conversion of hospital wastes to potable water. A study of this problem by AiResearch on a 46,000 gallon per day system indicated that kitchen and other hospital wastes, excluding human waste, can be treated to recover more than 90% of the waste as potable water by a sequence of flotation, filtration, and reverse osmosis. The overall rejection of dissolved salts across the membrane exceeded 99%. The product water was low in TDS but has some free CO₂ and a pH in the range of 3.5-4.0.

Activated carbon was used to remove traces of taste and odor forming compounds and surfactants. After pH adjustments and dosing with calcium hypochlorite solution, potable water containing 5 p.p.m. residual-free chlorine was obtained.

Studies on supplying industrial water by reverse osmosis treatment of either secondary sewage effluent or industrial wastes show that costs of 20-35 cents per 1000 gallons are reasonable to expect. This could have substantial appeal since industry today pays from 12.5-40 cents per 100 gallons for water with up to 1000 p.p.m. dissolved solids. Sometimes, this cost must be supplemented with additional treatment costs to meet specifications.

Problems to be solved

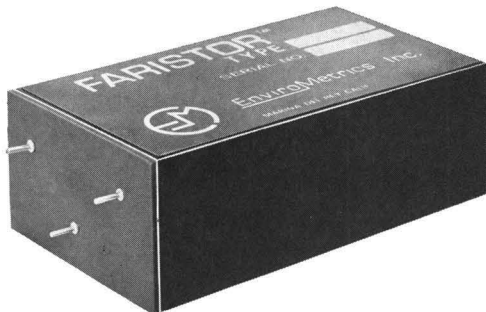
There are still a number of problems that need solution so that costs of sewage and industrial water reclamation by reverse osmosis techniques may be made even more attractive. Active research on these problems is underway, and many interesting answers should be available soon. This research is being carried out by industry and government, since both have a large stake in the outcome.

One obvious need is for tailor-made membranes for the retention or passage of specific materials. The experiments I have described were carried out with commercial units with membranes designed primarily for the conversion of brackish water to fresh water. What is needed is a whole new family of membranes tailored to the chemical and bacteriological content of sewage waste. For instance, the reduction of ammonia, phenols, detergents, and carbon chloroform extract with conventional membranes does not seem to be good. Without doubt, cellulose membranes are relatively permeable to ammonia. In some cases, phenols have negative rejections, and actual permeate enrichments as high as 20% have been observed. The question of rejection of the new linear alkyl benzene sulfonates needs to be resolved, since the USPHS standard for potable water is only 0.5 p.p.m. Carbon chloroform extract is a combination of many types of organic matter, and cellulose acetate membranes are relatively permeable to a number of the low molecular weight organic compounds. It is likely that waters reclaimed by reverse osmosis from many sources will not pass the USPHS standard of 0.2 p.p.m. carbon chloroform exhaust.

Reverse osmosis membranes in use today tend to be susceptible to fouling by organics or other trace contaminants. This problem still must be overcome, either by new membranes or by devising satisfactory *in situ* cleaning techniques.

Membrane fouling, coupled with membrane compaction reduces membrane flux and the effective service life. The membrane flux reduction pattern appears to occur in three stages. First, there is a small rapid initial compression when the membrane is put under pressure, resulting in a flux decrease to 85-90% of the original value. The second phase of flux reduction appears related to the buildup of

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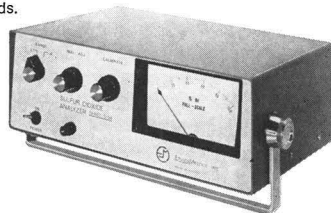
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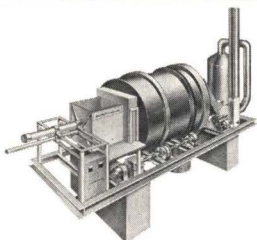


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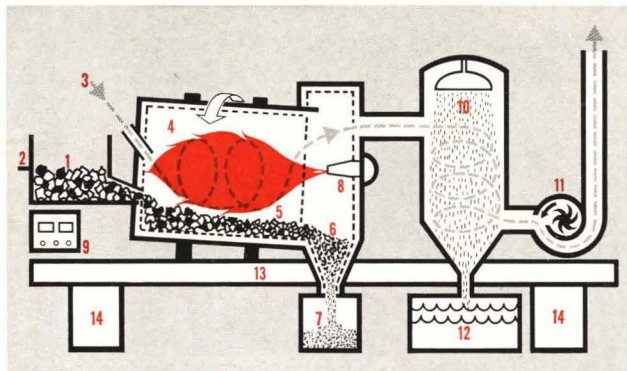
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solids and inclusion of waste molecules in the membrane openings. The third phase is probably caused by the slow compaction of the film or cake. Therefore, work is needed on the mechanism of membrane fouling to reduce the effect of cake buildup on the flux, and to increase the washing or self-regeneration characteristics of the system.

A variety of approaches have been taken either to prevent flux decline or to restore the flux. Methods used with some effectiveness include aeration of the primary effluent, diatomaceous earth filtration of both effluents, and partial redesign of the membrane-containing part of the system to prevent the solids buildup. osw has found it possible to maintain the average flux of the present membranes at a fairly high level by periodic cleaning of membrane modules with chemical solutions. As an example, a membrane module whose flux has degraded from 13 gallons per day per square foot to 6 gallons was restored to its initial value by recirculating 5% sodium hydrosulfite for four hours. Acetic acid and enzymes also have shown promise as membrane cleaning agents. These procedures have doubled the effective service life of the present membrane to two years.



Jacob I. Bregman is President, *Water Pollution Research and Applications*, a position he has held since 1969. Previously (1967-9), he was deputy assistant secretary, *Water Quality and Research*, U.S. Department of the Interior, and commissioner, *Ohio River Valley Water Sanitation Commission*. Bregman received his B.S. from Providence College (1943), his M.S. (1948) and Ph.D. (1951) from Polytechnic Institute of Brooklyn. The author of "Corrosion Inhibitors," Bregman is a member of ACS, American Water Resources Association, Water Resources Research Council, N.Y. Academy of Sciences, Sigma Xi, Phi Lambda Upsilon, and American Inst. of Chemists.

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Chen, D. H. T., M.S. thesis, University of Rhode Island, Kingston, R.I., 1961.
Handbook of Colorimetric Chemical Analytical Methods, 5th ed., pp. 13-15, Tintometer Ltd., Salisbury, England (1959).
Luthy, R. V. (to California Research Corp.), U.S. Patent 2,855,444 (Oct. 7, 1958).
Pollard, N. D., FMC Corp., Baltimore, Md., private communication, 1962.
Saltzman, B. E., *Anal. Chem.* **26**, 1949-55 (1954).
Schmauch, L. J., Grubb, H. M., *Anal. Chem.* **26**, 308-11 (1954).
U.S. Department of Health, Education, and Welfare, Public Health Service, Cincinnati, Ohio, "Selected Methods for Measurement of Air Pollutants," 1965.

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AIR QUALITY AND LEAD

Sponsored by the Division of Industrial & Engineering Chemistry, with the Divisions of Water, Air, & Waste and of Petroleum Chemistry, this American Chemical Society Symposium was presented in Minneapolis, Minnesota, April 14-15, 1969. Four of the papers with their discussions were published in the March issue, pp. 217-253. The remaining papers are published in this issue.

Isotopic Composition as a Natural Tracer of Lead in the Environment

Discussions Follow

Wayne U. Ault,¹ Ronald G. Senechal, and Woodland E. Erlebach

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■ The object of this research was to determine if the isotope ratios of lead were significantly different in various environmental media and if such differences could be used to distinguish the lead in the media. Significant differences in the lead isotopic ratios in rock and soils, grasses, tree leaves and tree rings, air particulate, and in some industrial products such as coal, fly ash, gasoline, and fuel oil have been found. Leaf, grass, and soil samples taken across the New Jersey Turnpike showed a change in lead isotopic ratios from the Turnpike to a point one mile to windward. The mean value of the Pb-206/Pb-204 ratio in topsoil within 500 feet of the Turnpike was 18.2 ± 0.2 and beyond 500 feet was 18.7 ± 0.15 . Lead sampled from soil profiles in two forested locations in northern New Jersey showed an increase in Pb-206/Pb-204 ratios, with depth from 18.7 to 19.9 in a 30-inch profile. The lead abundance decreased from 47.5 to 12.0 p.p.m. The mean ratios of Pb-206/Pb-204 from coal and gasoline analyzed were found to be 18.8 ± 0.2 and 18.3 ± 0.3 , respectively. The mean value for the same ratio in the published data on coal is somewhat higher. Fly ash and the coal from which it came both contained lead of the same isotopic ratio.

Before stating the purpose of this research, let us point out that large variations in lead isotopic ratios, as much as a factor of two, exist in the rock strata and mineral deposits of the world. Industrialized countries use large ton-

nages of lead annually. In an average recent year, the United States alone consumed 1.1 million tons (U.S. Bureau of Mines Minerals Yearbook, 1966). From this use data, one can infer that typically about one third of this lead is widely distributed in the air, water, soil, and vegetation of the environment. It is possible that lead which is accumulated in man's environmental soil reservoir may be recycled indefinitely through the biological systems which depend upon the soil for food.

For this research we posed two fundamental questions: Is the lead isotopic composition significantly different in various environmental media such as soil, water, air, plants, and fuels? And further, does the lead isotopic composition within these groups vary sufficiently so that the various environmental media in a particular locality can be distinguished by their lead isotopic composition? If the answers to the above questions are positive, then analyses of the contained lead isotopes should permit the characterization of various environmental media and suggest the probable sources of the lead.

As background, recall that elemental lead is composed of four stable isotopes, 204, 206, 207, and 208. Lead-204 is not known to have been formed by any radioactive decay process or by any other nuclear reaction. It thus constitutes a measure of the original lead which was formed when the elements were formed, sometimes known as primeval lead. The isotopic ratio of common lead mined today results from the addition to primeval lead of radiogenic lead-206, lead-207, and lead-208 formed from the decay of uranium and thorium. Figure 1 shows the decay scheme mechanism for the radioactive family U-238 which results in the addition of stable Pb-206 to primeval lead. Decay schemes for U-235 \rightarrow Pb-207 and Th-232 \rightarrow Pb-208 are similar. As the long-lived natural radioisotopes of

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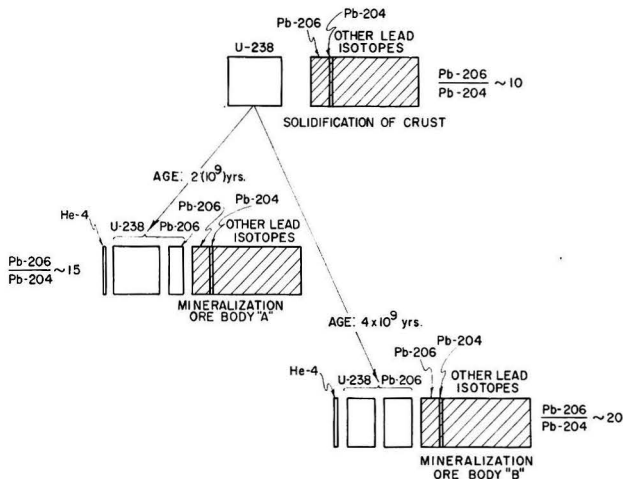


Figure 1. Mechanism for the production of different Pb-206/Pb-204 ratios in lead ores

uranium and thorium decay, relative abundances of lead-206, 207, and 208 have each been increasing at known independent rates throughout Earth's history. Indeed, the ratios of Pb-206/U-238, Pb-207/U-235, and Pb-207/Pb-206 are widely used in determining the geologic age of rocks and minerals.

Lead ore deposits were formed at different times during the last three billion years. The geological processes of mineralization tend to homogenize the lead from a portion of the Earth's crust and concentrate it in the mineral deposit. Thus, the lead isotopic composition of such a mineral deposit would correspond to average crustal lead of that geologic period, which in turn depends on the original uranium to lead ratio in the locale. Other types of mineral deposits, formed perhaps at lower mineralization temperatures from incomplete or inhomogeneous mixing, show lead isotopic ratios that are anomalous to the geologic age of the deposit. Table I shows the Pb-206/Pb-204 ratios for a selected list of lead samples from well-known lead mines. It is evident that lead from some sources has Pb-206/Pb-204 differing from the mean value by over $\pm 25\%$. It should not be construed that the isotope ratio Pb-206/Pb-204 from a single sample in a mine is representative of all the lead in the mine. For example, Russell

and Farquhar (1960) report Pb-206/Pb-204 ratios on samples taken at two different locations in the same mine which differ from the mean by $\pm 17\%$. This large variation in isotope ratio in the ores may raise the question of ambiguity in distinguishing leads in the environment. However, when the mixing and averaging processes which occur during mining, smelting, distributing, stockpiling, and compounding are considered, it is also possible that there would be reasonably uniform isotope ratios in large volume products.

Analytical Methods

This research primarily concerned the isotopic ratio Pb-206/Pb-204 as a means of defining the lead in various environmental media. This isotopic ratio, together with appropriate abundance data, would allow distinguishing between leads from different sources.

Since samples of mineral and plant materials were com-

Table II. Replicate Isotopic Composition Analyses of NBS-200 (Galena)

Isotopes	Atom Per Cent			
	Pb-204	Pb-206	Pb-207	Pb-208
	1.549	22.60	22.65	53.20
	1.552	22.56	22.56	53.32
	1.536	22.47	22.56	53.44
	1.527	22.40	22.63	53.44
	1.545	22.59	22.72	53.13
Mean	1.542	22.52	22.62	53.31
S.D.	± 0.0046	± 0.039	± 0.030	± 0.063
P.E.	$\pm 0.30\%$	$\pm 0.17\%$	$\pm 0.13\%$	$\pm 0.12\%$
Cal. Tech				
T. J.				
Chow ^a	1.540	22.48	22.62	53.36
S.D.	± 0.002	± 0.01	± 0.01	± 0.02
P.E.	$\pm 0.13\%$	$\pm 0.04\%$	$\pm 0.04\%$	$\pm 0.04\%$

^a Analysis reported in NBS Technical Note 51, "Isotopic Abundance Ratios Reported for Reference Samples Stocked by the National Bureau of Standards"—Mean of 36 analyses, triple filament technique.

Table I. Isotopic Composition of Selected Lead Samples^a

	Pb-206/ Pb-204	Pb-206/ Pb-207	Pb-208/ Pb-207
So. Africa (Rosetta Mine)	12.6	0.894	2.33
Northwest Terr. (Con. Mine)	14.1	0.934	2.25
Broken Hill, N.S.W.	16.2	1.03	2.30
Coeur d'Alene, Idaho	16.5	1.06	2.36
Balmat, N.Y.	16.9	1.08	2.37
Franklin, N.J.	17.4	1.11	2.40
Montana (Boulder Batholith)	18.1	1.16	2.47
Cerro de Pasco, Peru	18.8	1.20	2.48
S.E. Missouri (Av.)	20.5	1.28	2.49
Tri-State (Joplin) (Av.)	22.2	1.38	2.60
Mean Value	17.4		

^a Russell and Farquhar (1960) and other general references.

pletely digested with mineral acids, the analyses represent the total lead present. The lead was extracted and purified by standard ion exchange techniques. The low abundances of lead involved, often only a few parts per million, required lead-free laboratory techniques. Chemical reagents were purified by repeated distillations or by synthesis using triply distilled water from a quartz still and the appropriate anhydrous gas.

Analyses were made on a CEC 21-703B solid source, 12-inch radius, 60° sector mass spectrometer, equipped with an ion multiplier. Abundance measurements were made by isotope dilution with a calibrated Pb-204 solution. Isotopic ratio measurements represent the average of about 20 scans across the isotopic peaks during the period of best emission stability. The errors reported on single samples correspond to the standard deviations calculated from the scans. Errors on mean values for a number of samples represent a single standard deviation calculated in the normal fashion. Accuracy

is indicated by replicate isotopic analyses of a reference galena sample, NBS-200, provided by the National Bureau of Standards. These results are shown in Table II.

For a more complete description of samples, sample preparation, analytical techniques, and treatment of the data, one is referred to the final report (Ault, Senechal, *et al.*, 1968) on this research which is on file at the libraries of the American Petroleum Institute and the International Lead Zinc Research Organization.

Discussion of Results

Although the results reported here are not extensive, every area examined showed variations in Pb-206/Pb-204, and many showed significant differences. These include rock and soil, grasses, tree leaves and tree rings, air particulate, and some industrial materials such as coal, fly ash, and gasoline. The results can be discussed best in terms of the environmental suites sampled.

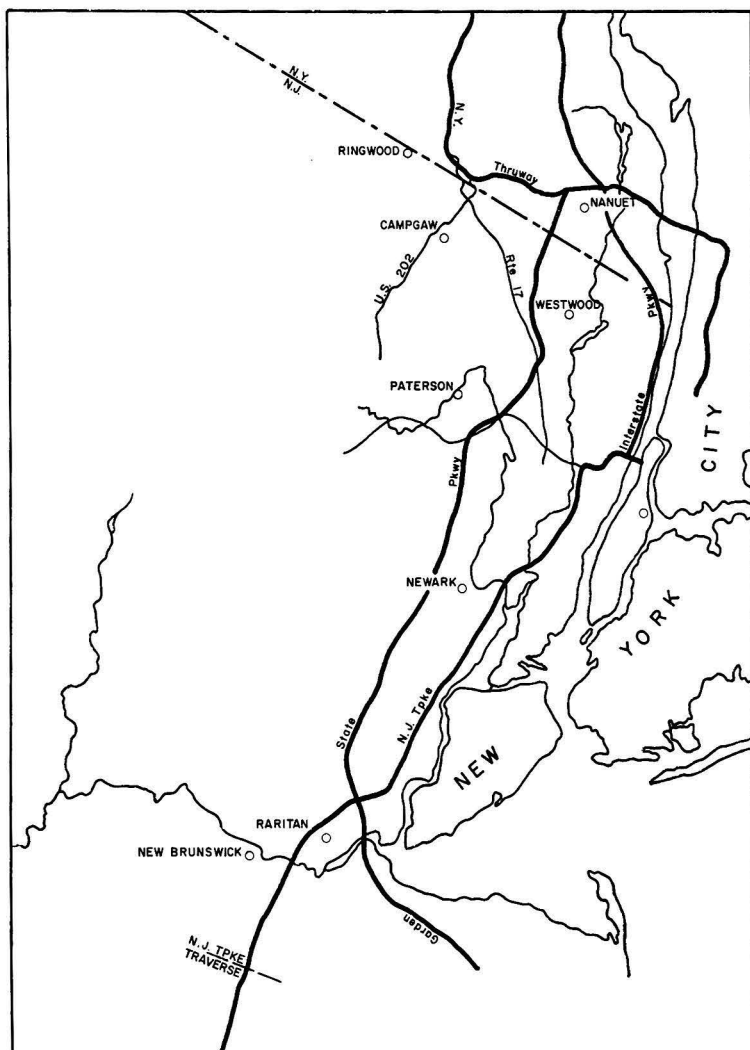


Figure 2. Map of metropolitan New York City showing sampling sites

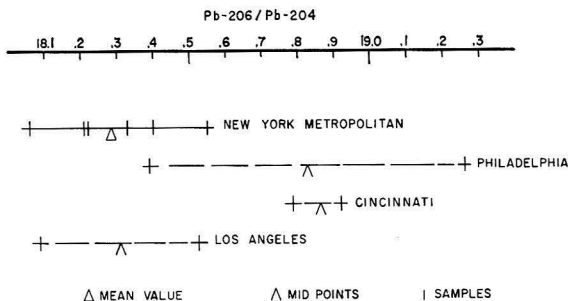


Figure 3. Ratios of Pb-206 to Pb-204 in lead from air particulates collected in the New York Metropolitan area from October 1966 to January 1967 and in Philadelphia, Cincinnati, and Los Angeles between June and November, 1961

Air Particulate

Air particulate samples were taken at several sites throughout the New York Metropolitan area (Figure 2), all within a radius of 35 km. of Newark, N.J. They represent a variety of conditions from the densely populated downtown areas of New York City and Newark to the suburban area of Nanuet. The samples of air particulate were collected on Whatman #41 filter paper, except for the two collected on fiber glass filters in Manhattan by the New York City Department of Air Pollution Control.

The data are presented in bar graph form in Figure 3. The mean value where applicable is also shown. Although the range of values for the New York Metropolitan area is limited, 18.06 to 18.55, the data indicate that a small but distinct isotopic difference exists between the samples collected in the downtown Manhattan-Newark region and those from suburban Nanuet. Application of Student's *t*-test to the mean of the three Manhattan-Newark samples (18.18 ± 0.02) and the mean of the two Nanuet samples (18.48 ± 0.08) indicates a low probability that these means exhibit the observed difference due to chance alone. Two samples collected on Manhattan's East Side on Nov. 25, 1966, during the Thanksgiving weekend "severe" air pollution alert averaged 18.2. Samples from Philadelphia, Cincinnati, and Los Angeles were from the PHS "Tri-City Lead Study" and represent "commercial" and "industrial" sites. The data show that lead in air particulate within a city or from city to city can vary widely in isotopic composition. Systematic sampling would be required to define the different sources of the aerosols.

Traverse Across the N.J. Turnpike

In order to determine the influence of lead particulate fallout from automobiles on the isotopic ratio of lead in soil and vegetation, a traverse across the N.J. Turnpike was selected for sampling. Figure 4 is a map showing the location of each sample. The section of the N.J. Turnpike shown has carried 163 million vehicles during the last 15 years (1952-1966) or an average of 30,000 per day. During the last five years of this period, the total has been 71.5 million vehicles or an average of 39,000 per day. The sampling location is in a rural area located approximately midway between New York City and Philadelphia. One would expect the contribution of lead to the environment from conglomerate industrial sources to be substantially lower here than in the metropolitan area.

The samples taken consist of shallow cores of the topsoil sampled from the Turnpike right-of-way and at intervals along a traverse across the Turnpike to a distance of approximately

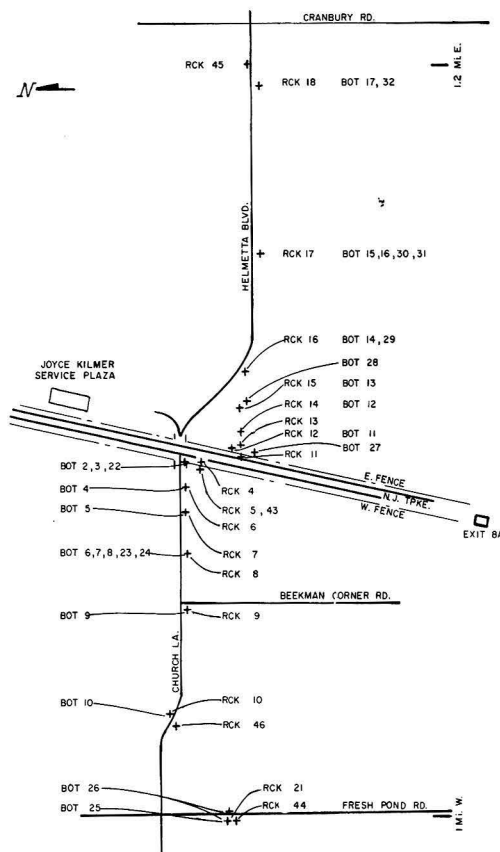


Figure 4. Sketch showing sampling locations along a traverse across the New Jersey Turnpike midway between Philadelphia and New York City (BOT indicates leaves or grass and RCK indicates soil)

one mile on either side. Tree leaves and grasses from the topsoil locations were also sampled where possible.

To bring out more clearly the lead isotopic ratio differences for the samples in the traverse across the N.J. Turnpike, the samples 0 to 500 feet distant from the Turnpike were plotted in one histogram and those farther than 500 feet in another.

These are shown in Figure 5. The mean topsoil values are also shown to be statistically different when the Student *t*-test is applied. The mean isotopic ratio values for tree leaves and grass are clearly similar within each of the zones.

When this sampling area was selected it was not known that the Cretaceous age rock and sediment of the area had Pb-206/Pb-204 ratios (~18.55) not greatly different from that found for the gasoline analyzed in this study (18.33). In spite of this proximity of ratios, the results are striking. The topsoil close to the Turnpike shows a mean Pb-206/Pb-204 ratio decidedly different from that in the topsoil farther from the Turnpike, but similar to that in the grass and leaves within the 500-foot zone bordering the roadway. The soil values may reflect the effect of dilution by the original soil lead.

The isotopic ratios for the Turnpike topsoil samples are plotted in Figure 6. The length of the vertical line through each point represents the standard deviation of the mean of the ratios determined by repeated measurements on one sample. Where more than one sample from a given location was analyzed, each is plotted and the mean value used to establish the curves. The change in isotopic ratio from the highway toward the west is somewhat greater than the change to the east, an effect perhaps due to the dominant westerly winds. The pronounced dip to lower Pb-206/Pb-204 values at the Turnpike gives an indication of the limited distance to which the larger particulate from automobile exhaust travels.

For a number of soil samples, the lead in a portion of the

core located at about 5 inches depth was also analyzed for comparison. These values are indicated in Figure 6 by a special notation. It can be seen that these results are generally consistent with the analyses of the tops of the cores. It is not surprising that the top few inches of soil contain isotopically similar lead when we consider that Hirschler, Gilbert, *et al.*, (1957) have shown that the compounds of lead in automobile exhausts are largely halides. These relatively soluble compounds may be carried downward some distance into the soil before becoming fixed by chemical reactions such as the formation of lead phosphates. Two samples near the Turnpike had ratio results lower than the others; however, they are included since they are located hundreds of feet apart and there is no apparent basis for excluding them.

The same general pattern of isotopic ratio variations as seen in the topsoil was also seen for grass and tree leaves sampled along the Turnpike traverse. The effect is not as pronounced and not so well established because fewer analyses were made. Nevertheless, the dip at the Turnpike is present in the Pb-206/Pb-204 ratios. The above results indicate this type of study to be a fruitful area for additional research.

New Jersey Highlands

Another detailed study was made at Ringwood State Park and Campgaw Reservation located in the New Jersey Highlands (see Fig. 2). The ridge on which Ringwood site is located is mapped geologically as Precambrian hornblende gneiss,

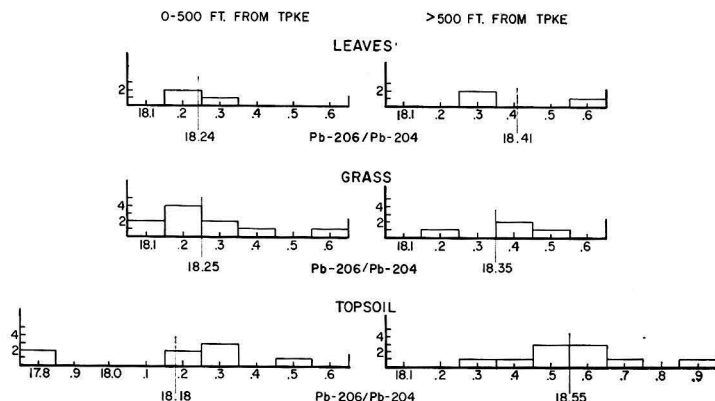


Figure 5. Graphs comparing lead isotopic ratio averages and ranges for samples of tree leaves, grasses, and topsoil from traverse across New Jersey Turnpike and separated into samples located (1) 0-500 feet and (2) >500 feet from the Turnpike (Numbers of samples are shown as ordinates)

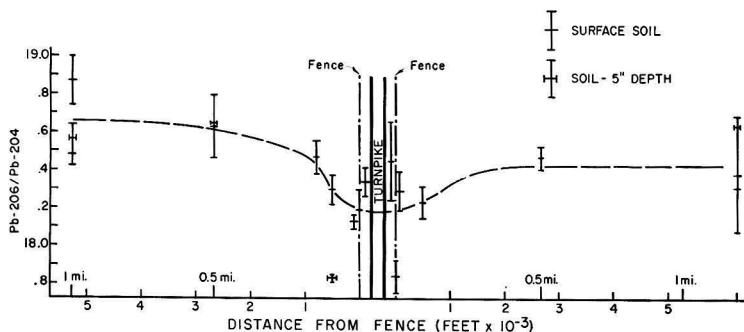


Figure 6. Graph showing lead isotopic variations for topsoil from a traverse across the New Jersey Turnpike

Table III. Ringwood State Park, N.J.

Comparison of Lead Isotopic Ratios for Samples of Bedrock, Soil Cores, Tree Leaves and Twigs

Sample description	Sample no.	Pb p.p.m.	Pb-206/Pb-204
Leaves, mixed	BOT-1A		18.42 ± 0.05
Twigs, new growth	BOT-1B		18.44 ± 0.09
Soil cores ^a			
Top (0-2.5 inches)	RCK-1		18.75 ± 0.10
	RCK-1A		18.70 ± 0.19
	RCK-1 avg.		18.73 ± 0.22
(7-8 inches)	RCK-40		19.29 ± 0.08
Bottom (14-16 inches)	RCK-2B		19.82 ± 0.20
	RCK-2B		20.02 ± 0.18
	RCK-2B avg.		19.92 ± 0.27
	RCK-2L	16.48	
Country bedrock			
hornblende			
gneiss	RCK-3		20.86 ± 0.12

^a The values for lead in the soil cores increase with depth, becoming more like that in the country bedrock. The organic rich topsoil has a Pb-206/Pb-204 ratio consistent with a large contribution from leaf-lead.

having an age of one billion years. It is located about two miles southwest of Sloatsburg, N.Y., on the New York-New Jersey state line. Reportedly the area was once farmed, but for the last 75 years, or longer, it has been woodland. Samples of soil (RCK-1, 2, 40) shown in Table III were taken on a topographic ridge about 3 feet from a 12-inch diameter tree and near a large hornblende gneiss boulder (RCK-3) of the bedrock material. The freshly fallen leaves and twigs (BOT-1) were sampled at the same locality.

The lead isotopic composition in the new growth of twigs and leaves is the same. Further, it can be seen that there is a systematic increase in the isotopic ratios from the leaves and twigs (Pb-206/Pb-204 = 18.43) to the topsoil (18.73), to the bottom of the core at 16 inches (19.92), and finally to the bedrock (20.86).

This observed relationship is consistent with a model in which the soil is derived from the bedrock by weathering processes. In the processes of weathering and mixing the soil-lead becomes a mixture of lead derived from leaves and rock, with the topsoil containing a larger fraction of leaf-lead than the deeper soil. For the sake of illustration, we could define a simple model wherein the lead present is limited to three types, namely, leaf-lead (Pb-206/Pb-204 = 18.4), topsoil-lead (18.7), and rock-lead (20.9), and where the topsoil-lead is a mixture of the other two. Then, from the isotopic ratios we can calculate the atom and weight per cent of Pb-206 and hence the amount of lead in the topsoil derived from each source. Refinements on the model could include the dustfall and aerosol lead intercepted by the leaves and the rainout and washout lead.

Campgaw site is located east of the Ramapo fault on the Upper Triassic conglomeratic shales of the Newark group, Brunswick Formation. These shales have an age of about 190 million years. The location is about 3 miles southwest of Mahwah, N.J., in a rocky woodland area with large hardwood trees up to 1.5 feet or more in diameter. A 14-inch diameter cross section of a freshly cut red oak was sampled (BOT-33) as well as one soil core sample taken to a depth

of 16 inches (RCK-22) and located about 2 feet from the tree and another (RCK-39) located about 6 feet from the tree and sampled to a depth of 31 inches. At a later date green red oak leaves (BOT-68) were sampled from a smaller tree about 25 feet distant, in addition to dead leaves and twigs from the sectioned red oak.

The isotopic ratios obtained on the Campgaw cores show a systematic trend from the top to the bottom at 30 inches depth (Figure 7). The Campgaw soil profile is notably similar to that at Ringwood. In both sampling locations the Pb-206/Pb-204 ratio in the topsoil was about 18.7 and increased to 19.9 with depth. At Ringwood, the lead of the bedrock gneiss analyzed at 20.86. The lead abundance in the Campgaw core systematically decreases from 47.5 p.p.m. at the surface to 34.5 p.p.m. at 7-8 inches depth, to 12.0 p.p.m. at 15 inches depth.

Figure 8 is a graph showing for comparison purposes the Pb-206/Pb-204 values for the Ringwood and Campgaw samples. The similarities of the tree leaves and twigs and topsoils from Ringwood and Campgaw are readily apparent. The subsoil profiles from both sites also show a similar change in Pb-206/Pb-204 with depth.

Tree Ring Study

The sketch of the red oak tree cross section (Figure 9) shows the lead abundance and ratios obtained for the rings which grew 1-3, 14-16, and 30-33 years before 1967. Fifty-

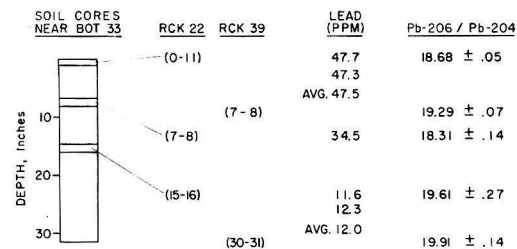


Figure 7. Schematic cross section of soil core, Campgaw, N. J., showing lead abundance and isotopic data. The lead abundance decreases with depth in the soil. The change in lead isotopic ratios with soil depth compares well with that observed at Ringwood, N.J.

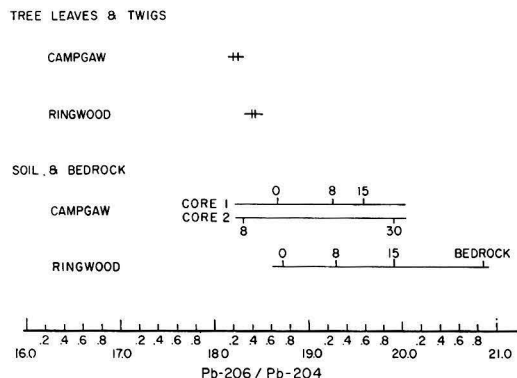


Figure 8. Graph showing lead ratios for tree leaves, twigs, and soil at Campgaw Reservation and Ringwood State Park, N.J. (Sample depths in the cores are shown in inches)

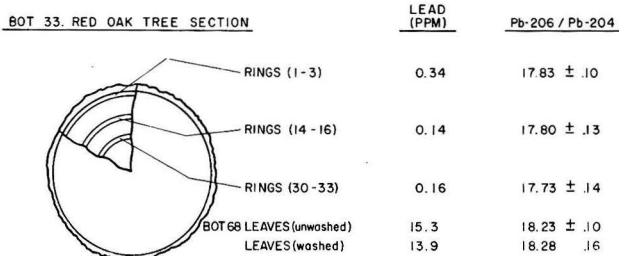


Figure 9. Schematic of cross section of 24-inch diameter red oak tree, Campgaw N.J. The lead abundance shows a decrease in the inner tree rings

seven growth rings were clearly visible. The lead abundance in the outermost tree rings (0.34 p.p.m.) was observed to be twice that (± 0.15 p.p.m.) in the 15- and 30-year-old rings. It appears that either the uptake of lead was constant and lower in the past or that lead is excluded from the xylem layers after formation. It is not likely that the tree's uptake of lead has changed by a factor of two during the last 15 years, hence it may be more probable that lead is translocated from the xylem. Stewart (1966) describes a possible mechanism for excretion of toxic matter from active cells and translocation along the radial ray cells of the woody part of the tree. Additional measurements of abundance and isotopic ratios are required to confirm the observed variations when such changes in lead abundance take place.

The Pb-206/Pb-204 values obtained for all the tree rings are essentially constant at about 17.8 and are significantly lower than the lead from the leaves (18.25). Washing one portion of the leaves briefly in a 1% solution of detergent did not noticeably affect the lead ratios but did decrease the lead abundance by about 12%.

Because of the prospect that tree rings may provide an annual sampling of the atmospheric lead and thus preserve an historic record of the environmental lead, it is desirable that other types of trees be studied along with monitoring the environment. Some trees grow rapidly and do not form hard heartwood. Another interesting problem is to determine whether the tree gets its lead from the leaf or root systems.

Fly Ash and Particulate from Coal and Gasoline

Figure 10 presents lead isotopic data for coal and fly ash. Coal feeding the power generating station and the fly ash resulting from its combustion were both analyzed. Although limited in number, the Pb-206/Pb-204 values, as expected, are very similar. The mean Pb-206/Pb-204 value for the four samples of coal analyzed was 18.74 and for the resulting

fly ash sampled by various mechanical and electrostatic methods was 18.70.

We were aided in a special test by the Texaco Research and Technical Department. A sample of gasoline, API Fuel No. 1, was burned in a test automobile and the exhaust particulate collected. Lead in the test fuel analyzed Pb-206/Pb-204 = 17.97 and in the particulate 18.00.

These measurements verified that aerosols resulting from combustion of fuels are representative of the lead in the fuels.

Coal and Gasoline

For additional background data, the range of isotopic ratios available for coal from scattered United States localities (Chow and Earl, 1967) is included in a bar graph (Figure 11). Consistently, the mean isotopic ratio for each of several coal regions is a value similar to, or greater than the values obtained for coal in this research. All of the coals analyzed in this research were the Appalachian bituminous type. It should be especially noted that the mean values for coal are markedly different from the average value obtained for gasoline in this investigation.

The mean value of Pb-206/Pb-204 for all brands of gasoline analyzed, weighted equally, falls at 18.33 ± 0.33 ; the mean values for available data for the coal mining regions fall from 18.71 to 19.38, with the average of the means falling at 18.97 ± 0.35 , if each region is weighted equally. The Student *t*-test again shows that the probability that these means have this difference by chance is less than 1%.

The average ratio for the limited number of gasoline samples in this report may be higher than the mean for all gasolines used on the eastern seaboard for a number of years if the average values for topsoil, grass, and leaves near the N.J.

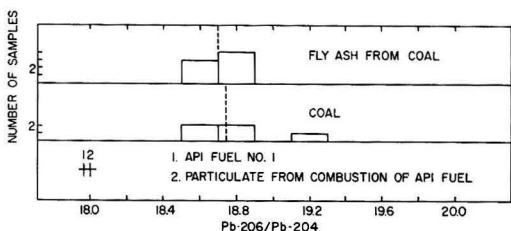
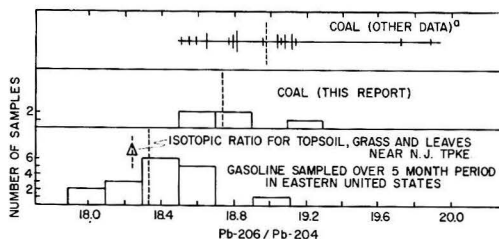


Figure 10. Graph showing lead isotopic ratios for fly ash from coal and particulate from gasoline



o CHOW AND EARL, (1967)

Figure 11. Graph showing Pb-206/Pb-204 range and average for coals and gasoline

Turnpike represent a valid long-term integrated sample of gasoline lead in this region. Furthermore, the few isotopic ratio analyses for gasoline reported by others, sampled chiefly on the West Coast (Chow and Johnston, 1965) all have a lower Pb-206/Pb-204 value than those reported here.

The topmost surface soil along major traffic arteries provides, perhaps, the best long-term average sample of automobile exhaust particulate readily available, providing that other contributing sources are minimal. Additional analyses could readily be taken from other locations to further determine the best average value for any local region. Even so, the average value of 18.18 obtained from topsoil within 500 feet of the N.J. Turnpike may be somewhat higher because of the contribution of the original lead in the soil. Analysis of the soil lead at 15 inches depth sampled near the west fence of the N.J. Turnpike [RCK-43(14-15)], gave a Pb-206/Pb-204 value of 18.83 and may be representative of the native soil lead of the region.

Figure 12 presents, for ease of comparison, the mean Pb-206/Pb-204 values available for various types of samples. This comparison summarizes what has already been pointed out from the preceding figures—namely that lead from gasoline is very similar to that in topsoil and vegetation near a main traffic artery. In addition, it also shows the striking differences between certain types of environmental samples such as automobile exhaust particulate, represented by leaves, twigs, grass, and topsoil less than 500 feet from the N.J. Turnpike, and coal and fly ash. Although the number of environmental media investigated to date is not large, those examined show significant differences in the lead isotopic ratios.

Observations and Conclusions

The Pb-206/Pb-204 isotopic ratios of samples of topsoil taken along a traverse crossing the N.J. Turnpike show an abrupt change approximately 500 feet from the Turnpike proper. The isotopic ratios close-in averaged 18.18 ± 0.21 . Beyond 500 feet the ratios gradually change, reaching a value of 18.6 one mile upwind. The change on the downwind side is not so pronounced.

The Pb-206/Pb-204 ratios in grasses taken along the same traverse confirm the trend with values similar to those shown by the topsoil.

The mean values for the Pb-206/Pb-204 ratios from the tree leaves, grasses, and topsoil taken within 500 feet of the Turnpike are similar and all are consistently lower than the mean values for the same materials sampled beyond 500 feet.

Lead from a limited number of gasoline (TEL) samples analyzed in this research gave a mean lead isotopic ratio (Pb-206/Pb-204) of 18.33 ± 0.33 .

The mean value for the Pb-206/Pb-204 from gasoline used in the New York-New Jersey area may be lower than that obtained from the limited number of gasoline samples (18.33). This supposition is valid if the mean Pb-206/Pb-204 value obtained for topsoil and grass close to the N.J. Turnpike (18.2) represents a maximum for the long-term average of lead in gasoline consumed by vehicles using the Turnpike. This hypothesis should be tested along other heavily traveled highways and the contribution from indigenous soil-lead from these samples evaluated.

The tree rings studied did not show any significant historical increase or variation in the lead contained. Other species of trees should be studied to verify this.

The limited data on lead ratios in air particulates show sufficient differences to warrant further investigation in order to relate them to their sources. The isotopic ratio of the lead should be correlated with distance of collection upwind and downwind from a main highway, particle size, and location with respect to other sources such as power stations, incinerators, and other industries.

The distinctly higher mean values of the lead 206/204 ratio in coal compared with lead in gasolines make it possible to distinguish lead-in-air particulates according to such source. The lead from fly ash samples analyzed in this work all showed ratios characteristic of the lead from the combusted coal. The lead-in-automobile exhaust particulate and in the combusted gasoline are the same.

The Pb-206/Pb-204 ratios in soil cores taken at Campgaw and Ringwood in New Jersey show a continuous increase with depth from a surface value of 18.7 to a value of 19.6,

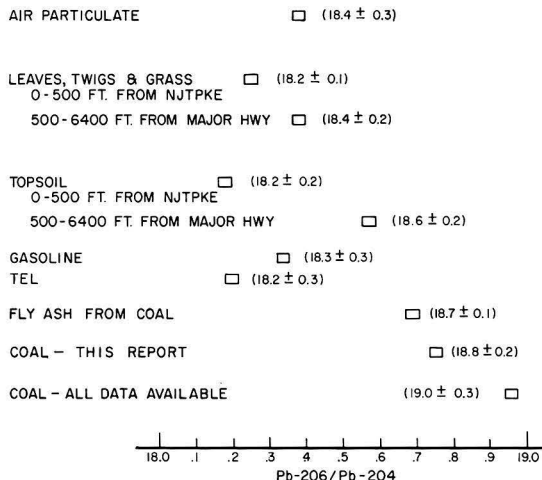


Figure 12. Comparison of mean values for various sample types. The numbers in parentheses give the isotopic ratios and the standard deviation from the mean

approaching that of the bedrock. In addition, the lead abundance in a core from Campgaw shows a decrease from 47 p.p.m. at the surface to 34.5 p.p.m. at 7 inches and to 12 p.p.m. at 15 inches.

The leaves and new growth of twigs from Ringwood have very similar lead isotopic ratios. The source of the leaf-lead is not apparent. It is unresolved whether the leaves get their lead mainly from the soil through the roots or from the air particulate through the leaf stomata. Isotopic measurements on associated air particulate and leaves, as well as controlled laboratory grown plants, are needed to determine the source of leaf-lead.

An isotopic mass balance can be a very useful tool in calculating the fraction of lead obtained from different sources in cases where distinctive ratios are observed, and where the lead isotopic ratios have been determined in the various source materials.

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Discussion

Isotopic Composition as a Natural Tracer of Lead in the Environment

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We have in recent years become thoroughly conscious of man's capability to perturb his environment on a global scale. The problem of planetary pollution is the subject of much controversy. Pollution has become a color word rather than a technical term. Its connotation is always bad. I should like to suggest that there is a need to be more precise and accurate in choosing terms. We must distinguish between man-made perturbations of the environment and man-made degradation of the environment. The introduction of lead into the environment on both a local and global scale is a demonstrated effect. To what extent this may be a degradation relative to other perturbations cannot be established without a much more thorough study and much better understanding of the environment. This particular study may reassure or alarm us. In either case, it should also satisfy our curiosity. An attempt to understand the movement of lead in the atmosphere, hydrosphere, and biosphere will, like earlier studies of Sr⁹⁰, tritium, and other fallout products, lead to a better understanding of our environment. It will suggest and has already suggested uses and applications of this man-made natural phenomena that are in large part pure science.

Turning now to the specific study we have just heard described, it should be stated at the outset that it just scratches the surface of a number of interesting possibilities. Several specific comments which may be helpful in guiding future studies will be made.

(1) It is important to note that isotopic compositions complement studies using concentrations. They do not replace the need for a knowledge of lead concentrations in natural materials. The usefulness of concentration data is particularly well illustrated in the two soil profiles. The absence of concentration data in the first of these profiles is very unfortunate.

(2) The interpretation of some of the results that are reported is necessarily limited by the experimental uncertainty in the isotope ratios. This is particularly evident in the New Jersey Turnpike traverse. Recently developed methods for high precision lead isotope ratio determinations (Compston & Oversby, 1969) (1) will be very useful in the kind of studies reported here. A factor of 3 or 4 improvement in resolution of isotopic differences should be obtainable.

(3) The authors have not stated very clearly the significance of their results for the two soil profiles. Both of these are far away from a major highway, and still show very significant lead enrichments at the surface. When compared to studies of lead in the air in the vicinity of major highways, this is a clear indication that transfer of lead from the point of dispersal takes place by more than one mechanism. The lead transferred long distances is probably brought down in the form of rain rather than by direct deposition of particulate matter.

(4) The interpretation of lead isotope compositions in tree rings and soil in which the tree is growing is not given. Until the reason for these differences is understood, it seems un-

wise to speculate on the usefulness of using tree rings to monitor past environments.

(5) It is clearly understood that any preliminary or exploratory study must bypass some interesting possibilities. Nevertheless it seems pertinent to inquire why no attempt was made to study lead in the reservoirs of the Hackensack Water Company, which virtually surround the laboratory in which this work was done.

In conclusion, I would like to take this opportunity to propose a positive application of an otherwise unfortunate technological dilemma. In lead ores with Pb^{206}/Pb^{204} ratios ranging from 16 to 21, nature has provided us with probably the only metal that is naturally available for large-scale isotopic tracer experiments. The availability of such tracer

materials and the extensive use of lead in a single commodity make possible an intriguing and definitive study of the urban environment. The deliberate isotopic tagging of gasoline in a given human ecosystem and study of the dispersal of this tagged material will determine how a technological waste product is taken up and stored in our environment. Such a unique and large-scale experiment would require industry-wide support and cooperation both from the petroleum and lead industries.

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Discussion

Isotopic Composition as a Natural Tracer of Lead in the Environment

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In this paper the authors demonstrate the power of the method of variations in isotopic ratios to trace the sources of environmental lead, and, ultimately, to determine the respective fractions originating from natural and from artificial causes. In addition, the data suggest some important and interesting problems in trace element metabolism of plants. Their results also indicate some of the limitations and weaknesses of the method.

As a tracer method, isotopic ratio measurement appears to be quite good. The tracer is premixed in nature, chemical processes are not likely to change the isotopic composition, large variations in composition are possible from source to source, and the analytical techniques are quite sensitive to these variations.

One of the weaknesses of the method is demonstrated in their results in that the source of atmospheric Pb is not necessarily obvious. This effect is consistent with the origination of lead in different batches of gasoline to be from different types of ores. Their mean 206/204 ratio for New York area gasoline was 18.3, with a range of 18.0 to 19.0. This value was higher than the mean value of 17.9 of Chow and Johnstone (4) from San Diego in 1964 and lower than the 1947 tetraethyl lead values of 18.6 found by Diebler and Mohler (5). The ratio for gasoline of Ault, *et al.* (3) in the New York area was similar to that found in air particulates, leaves, and grass near New York, and to the air particulates in two samples from Los Angeles. However, their ratios in topsoil near the turnpike, presumably from gasoline, were lower than those measured in the gasoline; the ratios in Philadelphia and Cincinnati (18.8) were greater than in New York and the two samples from Philadelphia alone were 18.4 and 19.2. Apparently the ratios in atmospheric aerosols, which presumably originate

from gasoline, can vary drastically from place to place and time to time. Evidence for Pb contamination can in many cases be obtained easier by measurement of Pb concentration than by isotopic ratios.

Possibly good proof of the origin of the major part of atmospheric Pb being in gasoline, in addition to that evidence based on the correlation between atmospheric concentrations and automobile traffic, could be done by much more extensive sampling under various conditions. A combination of several different methods, such as measurement of differential concentrations of Pb in the atmosphere, plants and soils, would first prove contamination, and isotopic ratios could then define the sources. In addition, thought might be given to the future use of lead tracers by requiring that Pb used in gasolines be of constant and of a drastically different isotopic composition than that found in materials to be studied.

One of the striking sets of data on this paper, particularly from a biological standpoint, is the isotopic composition of the wood in the trees in which the ratios of about 17.8 are significantly lower than those of either soil, bedrock, leaves, or air which range from about 18.3 to almost 21.0 in bedrock. Thus, the Pb in the wood appears to originate from sources outside the range of mean isotopic compositions of the soil and air. Possibly, the tree is capable of acquiring Pb only from particular minerals or clays. This result is probably not spurious, since Dr. Ter Haar, when he was in our laboratory, found similar effects using the ^{210}Pb to stable Pb ratios in various plant materials (7). In these cases the ratios of the ^{210}Pb specific activities to stable Pb concentrations were lower in the plants than in either soil or air.

As suggested by Ault, *et al.* (3) the use of the growth pattern to show contamination over the lifetime of the tree raises the question about translocation of lead through the heartwood. They think circulation is unlikely, as based on the metabolic arguments of Stewart (8). However, in softwoods water does appear to move through the ray tracheids toward the center

¹ Work performed under the auspices of the U. S. Atomic Energy Commission.

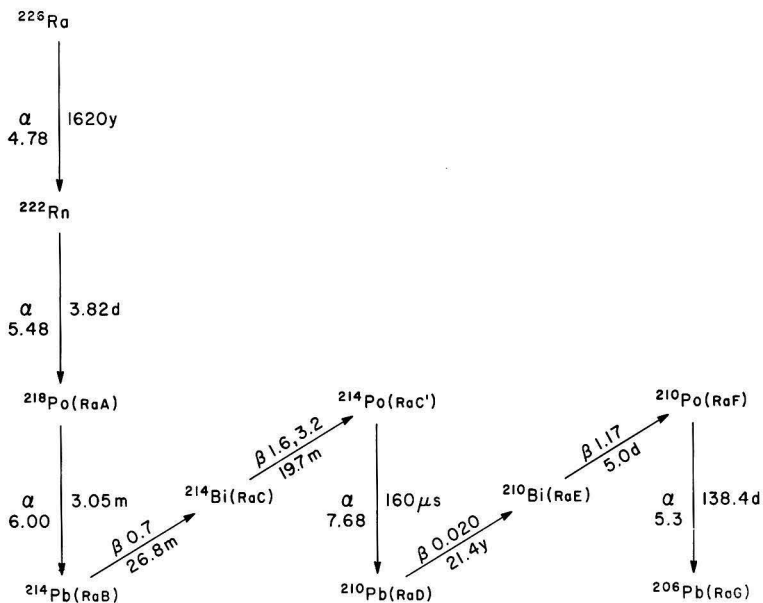


Figure 1. Decay scheme of ^{226}Ra series

of the tree and fission products are also found in the parts of the tree formed before the year 1945 (1). We checked this question in hardwoods by using a time-dependent tracer; the concentration of a radioactive lead isotope, ^{210}Pb , was measured radially in the tree. This nuclide occurs in nature and is derived from ^{238}U which decays to ^{226}Ra and then through a chain of short-lived nuclides to the 21-year half-life ^{210}Pb , as shown in Figure 1. Because of their different chemistries and because the radioactive rare gas intermediate, ^{222}Rn , may be translocated, the ^{210}Pb moves through the biosphere independently of its predecessors. Although the origins of the stable and radioactive lead in the tree may differ, one would expect that after entry their metabolic characteristics would be similar, if not identical. Thus, if we assume no circulation, no excretion, and that the input rate is constant, the ^{210}Pb concentrations would decrease with the 21-year radioactive half-life, as one goes from the outer rings toward the center.

The measurements of ^{210}Pb and stable lead were made on four trees 100 to 120 years old, a hickory, a black oak, and two white oaks, cut in 1966 on the grounds of Argonne National Laboratory, which is in a rural-suburban area about 25 miles southwest of the Chicago Loop. A cross section of each trunk, 12 to 18 inches in diameter and 18 inches thick, was taken about 6 feet above the ground. A fifth tree, a 30-year-old elm from a nearby suburban street, was also examined for stable Pb.

The wood from two to five adjacent rings was removed by a power drill, the bit of which had been carefully washed and used in the wood several times before the samples were taken. Only one particular drill bit was used in all this work. The drillings were dried 8 hours at 110°C . and wet ashed in nitric and perchloric acids. (The samples shown here for the stable Pb analyses were dry ashed at 500°C .) The solutions were converted to $0.5N\text{ HCl}$ and the ^{210}Po daughter of the ^{210}Pb was plated onto a silver disk by heating 6 to 8 hours at 95°C ., after which the ^{210}Pb was alpha counted. The solutions were then stored 4 months or more to allow the ^{210}Po to grow in

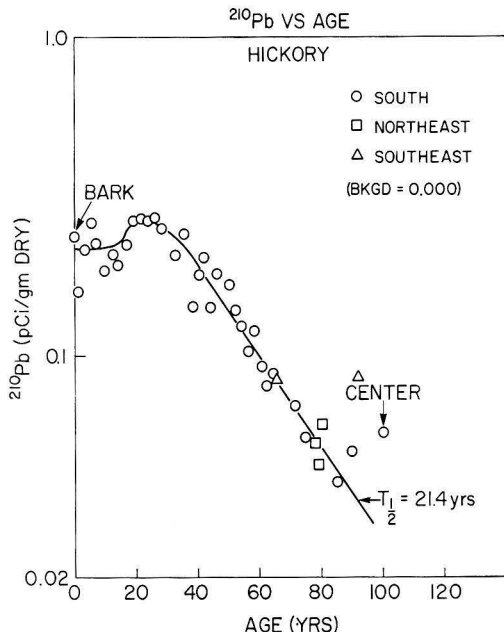


Figure 2. Variation of ^{210}Pb specific activity with age of wood in hickory

and were then replated and counted. The amounts of both ^{210}Po and ^{210}Pb present were calculated from the Bateman equations for radioactive growth and decay (6). Stable Pb was estimated by the spectrophotometric dithizone extraction method (2). The errors were about 10% at the 90% confidence level for the ^{210}Pb , and 5% for the stable Pb.

The results of the ^{210}Pb analyses are shown in Figures 2-5.

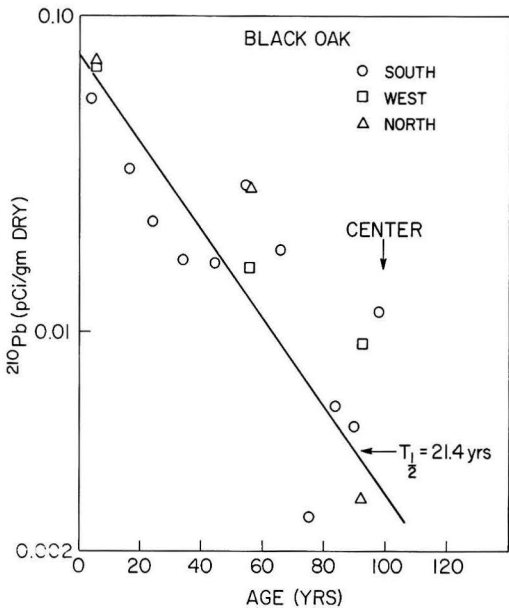


Figure 3. Variation of ^{210}Pb specific activity with age of wood in black oak

Figure 2 shows the ^{210}Pb concentrations in hickory wood as a function of age (number of rings from the outside). The concentrations in the 20 outer rings are constant or even increase, *i.e.*, the ^{210}Pb circulates, but after this time the concentration drops off with a 21-year half-life. The concentrations are fairly constant within a ring, as seen from the correlation between the circles representing values of samples within a ring (or set of rings) along one radius of the tree and the squares and triangles representing values along other radii. The directional representations of the radii in this and the following figures are relative, and are not necessarily the actual directions in the living tree.

The curves for the three oak trees are less spectacular and less uniform. The black oak data shown in Figure 3 do not fit the 21-year half-life nearly as well as do those of the hickory. The fit of White Oak I data is poorer, and of White Oak II poorer yet, as shown by the upper sets of data points in Figs. 4 and 5. This tendency to level off with age indicates either that the ^{210}Pb may circulate in these trees, 10 to 30%, or that a "background" of a parent nuclide, ^{226}Ra or ^{222}Rn , may be present in the wood with the consequent continuous production of ^{210}Pb . Thus, if values of 0.010 and 0.015 pCi/gm. are subtracted from the White Oaks I and II, respectively, 21-year half-lives are obtained, as shown in the lower curves of Figs. 4 and 5. It should be noted that this manipulation is not arbitrary. In order to obtain an exponential residual, the value of the subtracted "background" must be chosen properly, otherwise on a semilog plot the line will be curved. This curvature will also likely occur if a true exponential is not present. The slope of the line (half-life) is then not arbitrary, but is determined within the statistical variations of the data. Measurements of ^{226}Ra concentration and ^{222}Rn emanation from the wood are in progress to verify the presence of such a background.

The oaks follow the 21-year half-life moderately well, but

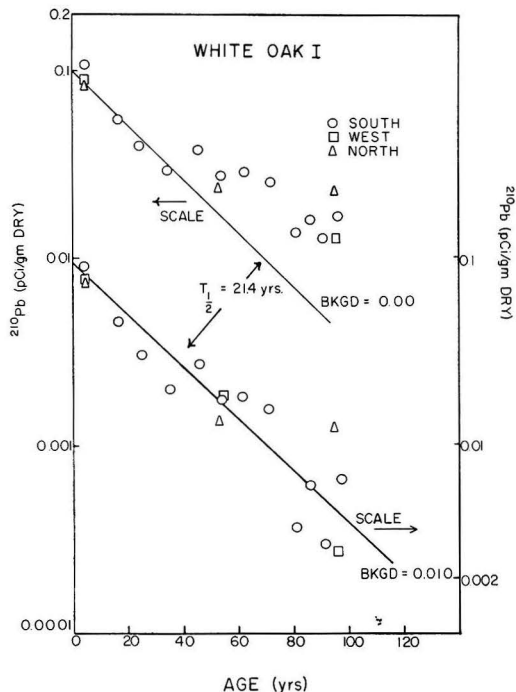


Figure 4. Upper curve shows variation of ^{210}Pb specific activity with age of wood in White Oak I

Lower curve is these data with a constant background of 0.010 pCi ^{210}Pb /gm. substituted (see text)

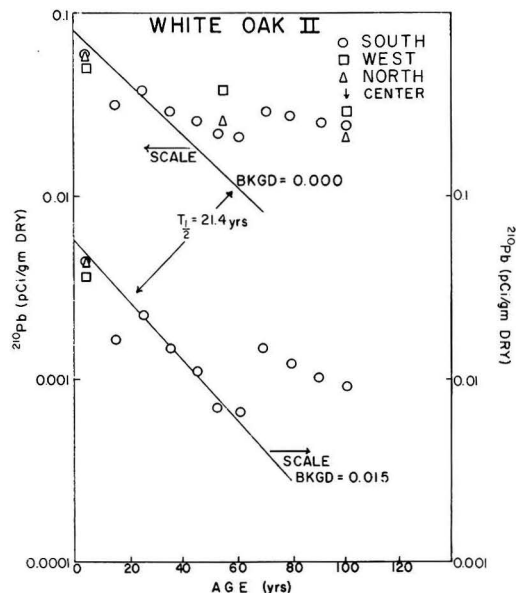


Figure 5. Upper curve shows variation of ^{210}Pb specific activity with age of wood in White Oak II

Lower curve is the same with a constant background of 0.015 pCi ^{210}Pb /gm. subtracted (see text)

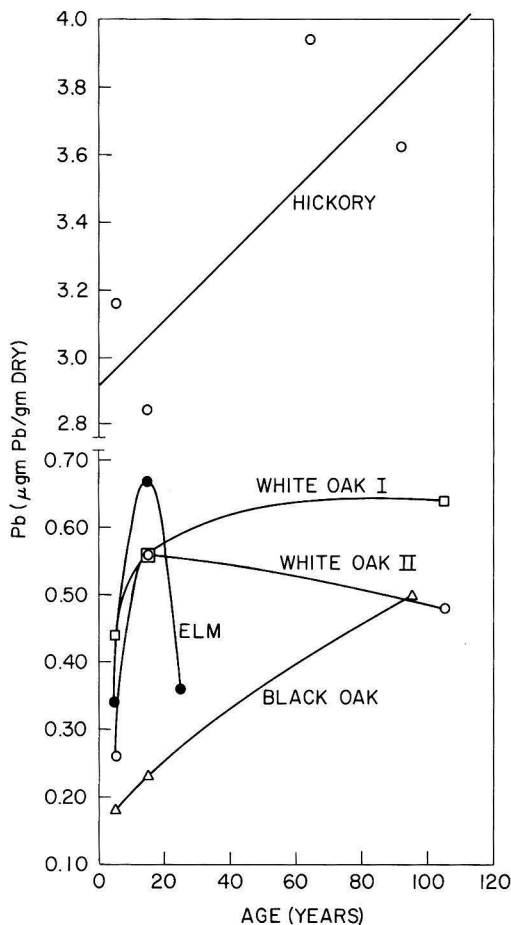


Figure 6. The variations in concentrations of stable lead in the various trees with age

they appear to have taken up more ^{210}Pb in their first 30–60 years than afterwards, so that two decay curves may be present. More detailed data are necessary to check this point, but in hickory there appears to be little or no circulation of ^{210}Pb after 20 years, and in oaks, little, but not necessarily zero circulation after 5 years.

Thus, if any significant portion of the Pb was derived either

from direct atmospheric uptake, or from increased concentrations in the soil from atmospheric fallout, the wood might show the effects of changes in exposure over the years. Some measurements of the Pb concentration in these trees made by Dr. Ter Haar (7) are shown in Figure 6. Because the few points available may not be representative of all the wood, and because those rings near the outer edges (near $t = 0$) may have been metabolically active, these results do not allow conclusions to be drawn as to the possibility of increased uptake of Pb in recent times. It is also possible that increases in atmospheric and soil concentrations over the years may not be available to the wood and so the effects are not seen in this type of measurement.

In conclusion, the method of isotopic ratios in its various modifications is a powerful tracer method. It appears that it can solve some interesting problems in biology and environmental pollution.

Thus, this method could be very useful for tracing the ultimate sources of Pb in man, such as that supplying plants, which, in turn, appear to provide the major source of the Pb in man. If food plants are like wood and discriminate between the 204 and 206 isotopes (by some means, such as selective metabolism of particular minerals), and if the 206/204 ratios are significantly higher or lower than in the gross sources (atmosphere and soil), then these could be studied under various conditions. Important considerations would be the effects, not only on the isotopic ratios, but also on the total Pb uptake, caused by contamination (artificial sources), soil type, composition, and treatment, and by atmospheric fallout. Such a solution will take the application of many different analytical techniques and multidisciplinary approaches, but until it is done, control of Pb in the environment can be neither reasonable nor effective.

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Atmospheric Lead: Its Relationship to Traffic Volume and Proximity to Highways

Discussion Follows

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■ These studies show that a relationship exists between traffic volume, proximity to the highway, engine acceleration *vs.* constant speed, wind direction, and the amount of lead in the air. They also reveal that a marked effect of traffic on the lead content of the air is limited to a rather narrow zone bordering the lee side of the highways. Lead values can be expressed as a quadratic function in time and linear to traffic volume. Particle size studies reveal that 65% of the lead in the air between 30 and 1750 feet from a highway consists of particles under 2 μ , and 85% under 4 μ in diameter.

Lead as a pollutant in the air, on plants, and in soils has elicited increasing attention during the last few years. The discovery of increasing lead (Muruzomi, *et al.*, 1969) (0.16 to 2.6 μg . liter between 1904 and 1964) in Greenland snow, the "survey of lead in the atmosphere of three urban communities" [U.S.D.H.E.W. (1965)], the lead measurements of the National Air Sampling network [U.S.D.H.E.W. (1958, 1965)], and the recommendation of the Environmental Pollution Panel of the President's Science Advisory Committee [E.P.P.S.A.C. (1965)] that the lead content of the air, water, food, and soil be studied, has catalyzed this interest. Reports of atmospheric lead and traffic volume have not been limited to the U.S., but are more widespread.

In a monumental "survey of lead in the atmosphere of three urban communities" conducted by the U.S. Department of Health, Education, and Welfare, samples were taken over a 1-year period of 20 sites in Cincinnati, Philadelphia, and Los Angeles. These sample locations were selected to represent broad areas. From this study, it is reported that downtown samples averaged from 2 to 3 μg . per cubic meter of air, while the outlying areas of the cities revealed from 1 to 2 μg . of lead per cubic meter. The highest concentrations occurred during the autumn and winter months. Cholak, *et al.*, in 1961 reported lead levels for cities of less than 100,000 to over 2,000,000 population that agree well with those listed, and in addition also reported that the highest lead levels occurred during the cold months.

The mean concentrations of lead taken in heavy traffic during the morning rush hour on a major Los Angeles freeway (Konopinchi and Upham) ranged from about 14 μg . to as much as 38 μg . per cubic meter of air. These same investigators report that samples taken from moving vehicles in Los Angeles, Cincinnati, and San Francisco during the rush periods revealed lead concentrations as high as 40 μg . per cubic meter.

In 1959, Horiuchi, *et al.*, reported that studies had demonstrated that the lead in the air over the main streets in Osaka City was higher than that found over open lots in factory (nonlead) districts or residential areas. These investigators reported finding the highest concentrations over streets

supporting dense traffic. In 1967, Yamate, *et al.*, reporting on a study of lead concentrations of the air on streets in 11 major cities in Japan, recorded that concentrations at crossings and at road sides were between 0.78 to 11.17 μg . per cubic meter. The highest reading was obtained on Route 20 in Tokyo. These investigators stated that atmospheric lead levels are influenced by traffic density, traffic stagnation, road conditions, meteorology, and geographical conditions. In a similar experiment in Parma, Italy (1967), Caghi and Bellelli report lead levels from 0 to 40 μg . per cubic meter from air taken over busy streets, with the samples taken during the rush hours. Bullock and Lewis (1968), working in Warwick, England, found that the lead in the air averaged 3.5 μg . per cubic meter over Jury Street (busy) and 0.8 μg . per cubic meter in the air to the rear of Jury Street. From this, one might assume that the reduction in the lead content of the air diminished rapidly as one proceeded from the traveled road. They also reported slightly elevated lead levels during the cold months.

Although the above studies indicate that elevated lead concentrations occur in the air over the highways, the relationship to traffic volume, or the influence of distance from the highway on atmospheric lead concentrations is not made clear.

Materials and Methods

Air sampling sites were selected to represent a range of traffic densities and to allow collection of samples at distances of 10, 30, 50, 100, 150, 250, and 500 feet from U.S. Highway 1. One sampler was located 1750 feet from the highway. The locations were selected where side or back roads were not close enough to interfere with the lead gradient from the road under study. All sample lines were located at a 90° angle from the highway extending to the southeast (130° to 145°) along a 28-mile section of U.S. 1. The sample lines extended to the southeast so as to have them as uniform as possible with respect to wind direction (a wind to the southeast occurs 19% of the time). The four sites represented traffic densities ranging from 19,800 to 58,000 vehicles per 24 hours. All samples were collected 4 feet above the ground and the filter membranes were changed each Friday. The continuous sampling period covered a period of two years.

Air sampling equipment consisted of a vacuum pump, a 10-liter limiting orifice to control the air flow, and a sample unit consisting of two plastic filter holders (Millipore aerosol monitors) in series, connected by a glass tube. The holder connections were sealed with tape. The first holder contained a 37-mm. diameter Millipore membrane filter with a pore size of 0.8 μ and a second holder with a similar filter having a pore size of 0.2 μ . At the beginning and end of each sample period, the air flow through the filter units was measured with a rotameter to check the constancy of the flow, and before each pump was installed at the site, the volume of air flow through a sample unit was measured with a wet test gas meter.

In tests to check the efficiency of the length of sampling

period, the total lead collected during a week's time agreed well with that collected during seven one-day intervals.

Lead determinations were made by atomic absorption spectrophotometry after decomposition of the samples by the following procedure. The membrane filters and cellulose support pads from both holders were transferred to a 200 ml. tall beaker and the filter holders rinsed with a 0.1N HNO₃. Fifteen ml. of an 80 to 20% mixture by volume of 70% HNO₃ and 72% HClO₄ were added and the beaker covered with a watchglass. The samples were digested on an electric hotplate until the dense white fumes of perchloric acid appeared. The samples were then allowed to cool and the watchglasses and sides of the beakers rinsed with distilled deionized water. The watchglasses were removed and the samples again heated until perchloric acid fumes appeared. A clear solution of about 2 ml. remained in the beakers. This solution was transferred to a 10 ml. volumetric flask and diluted to volume with distilled deionized water.

Particle size distributions were made at 30, 250, and 1750 feet from U.S. Highway 1 at a location where 47,000 cars pass each day. These determinations were made using cascade impactors operated 4 feet above the ground. Each sample was collected continuously for one week and samples were taken over an eight-month period.

The particles in the air samples were sized by passage through four stages of the impactor and the particulate materials collected on glass plates covered with a double-faced tape. After going through the impactor, the air sample was passed through two Millipore membrane filters with pore sizes of 0.8 and 0.2 μ .

The particles were dislodged from the collecting surface by adding the cut sections of the tape to the acid digesting

solution and the lead solubilized and determinations made as described.

The effects of environmental parameters on lead concentration or dispersement could not be determined by comparing meteorological records with the weekly lead data. Because of this, 6-hour samples covering the evening rush hours have been taken during the last 7 months at 30, 75, and 150 feet from the highway at a location supporting 47,000 cars daily.

Results

The great variability in lead values per cubic meter of air, obtained from week to week, indicated the need for prolonged air sampling periods if the data were to have maximum value. Table I gives the minimum, maximum, and average values for the 2-year period of continuous sampling of the lead in the atmosphere at various distances from sections of U.S. Highway 1 supporting traffic of from 19,800 to 58,000 cars per 24 hours. These data clearly indicate that there is a relationship between traffic volume and distance from the highway to the amount of lead occurring in the atmosphere. The samples collected 1750 feet from a section of the highway supporting 47,000 cars were considered to represent background levels for that general area. It is of interest to note that a similar lead level was achieved near the sampling station located 100 feet from the highway supporting 19,800 cars daily. At the 250 and 500 foot distances from the highway, the airborne lead reached levels significantly lower than that obtained at 1750 feet from the highway, in the area of greater industrial, residential, and traffic density.

Figure 1 (2 years data) illustrates, in chart form, the relationship of distance from the highway, traffic density, and

Table I. Yearly Minimum, Maximum, and Average Concentration of Lead Per Cubic Meter at Sampling Stations

Distance from highway in feet	Cars per 24 hrs.	1967-68			1968-69		
		Min.	Max.	Av.	Min.	Max.	Av.
30	19,750	1.5	3.3	2.12	1.1	5.3	2.37
100		1.0	2.3	1.56	0.8	3.0	1.62
150		0.8	2.4	1.36	0.7	3.0	1.48
250		0.7	1.7	1.11	0.6	2.5	1.18
500		0.6	1.5	0.93	0.5	2.5	1.02
30	44,750	2.4	6.8	4.34	2.9	7.0	4.59
100		1.6	4.8	3.09	1.9	6.4	3.31
150		1.6	4.6	2.72	1.5	5.0	2.84
250		1.3	4.2	2.42	1.3	5.7	2.68
500		0.9	3.7	1.99	0.9	4.6	2.11
30	46,800	3.8	13.0	7.45	2.2	6.2	4.55
100	3% grade	1.6	7.0	3.75	1.4	5.4	2.84
150	accelerating	1.4	6.1	3.24	1.5	4.8	2.59
250	area	1.2	4.7	2.67	0.7	4.0	2.25
1750		0.6	3.0	1.36	0.6	2.9	1.46
10	58,050				4.3	15.6	10.10
30		4.1	9.5	6.14	3.1	9.9	6.60
100					2.4	7.3	3.99
150					1.7	5.7	3.21
250		1.3	4.1	2.42	1.5	5.3	2.65
500		1.1	3.6	2.05	1.7	4.7	2.16

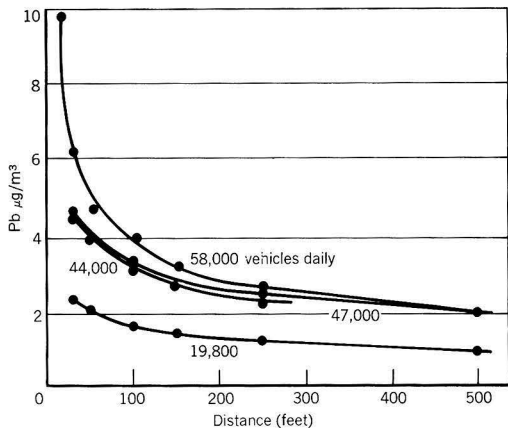


Figure 1. Air-lead values as a function of traffic volume and distance from the highway

the lead content of the air. From this figure it is clear that the lead level near the highway is relatively high, but drops off rapidly during the first few feet (150) from the highway. It is of interest to note that the concentration of airborne lead (minus the lead level secured at the 1750 foot station) was reduced about 50% between the 10 and 30 feet sampling stations by the section of the highway supporting 58,000 cars daily. From Figure 1 it is also seen that the concentrations of lead in the atmosphere were reduced very slowly and quite uniformly between 150 to 200 and 500 feet from the highway. This same flat line was found to continue to the sampling station located 1750 feet from the highway supporting 47,000 cars daily.

One sampling location was changed during the period of the study. During the early part of the investigation, it was located 400 feet from a traffic light on a 3% upgrade where traffic was accelerating. Later the location was changed to a nearby level point where cars traveled at constant speeds. Analyses showed that lead values were significantly different between the two locations although traffic volume remained the same. This suggests that the operative factor in increasing lead values was not traffic volume *per se*, but rather the amount of gasoline used and perhaps the difference in the percentage of the lead exhausted into the atmosphere resulting from engine acceleration (Cholak, 1961; Hirschler, 1957).

The average lead values for all three sampling locations (20,000, 45,000, and 58,000 cars daily) that were not moved during the 2 years sampling period (Table I), revealed an increase during 1968 over the 1967 values. This increase averaged 7.9%. During this same period the traffic increase amounted to less than 0.5%. Perhaps the increase in lead values resulted from meteorological variations or the general growth that occurred through the area.

One of the first things that became obvious after analysis of the filter membrane from the various stations began was that, despite the comparative uniformity in vehicle density, the atmospheric lead levels varied significantly from week to week. Accordingly, a running chart was kept of the air analysis data for the two years of continuous sampling. This chart, a section of which is shown in Figure 2, indicates that while there were some variations between sampling locations, the fluctuations in the chart were remarkably similar for all four sampling locations. This would seem to eliminate local influences as

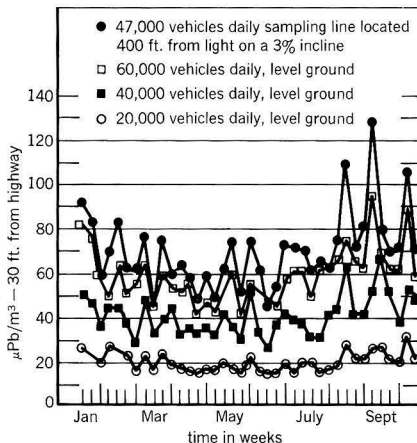


Figure 2. Graph shows variations that occur in the lead content of the air between sampling dates

It also illustrates the uniformity in trends that occur between the various sampling locations along the U.S. Highway 1

being responsible for these variations in the weekly lead averages, and suggest parameters that were operative over a wider area as influencing dispersions or concentration of the lead at the sampling points. These same sharp fluctuations in lead levels were amplified for the 6-hour sampling period. From a study of meteorological parameters, very significant correlations between lead concentrations and wind direction exist, as indicated in Table II. In addition, the quantity of lead in the atmosphere seems to be reduced with increasing wind speeds and increasing depths of atmospheric mixing.

Figure 3 shows the average monthly lead values 30 feet and 500 feet from the highway by the section of the road supporting 58,000 cars daily. This graph indicates that the air-lead values vary with the seasons of the year. In the two year period illustrated here, the lowest lead values were obtained during the month of February through May or June. An examination of the wind data from the Trenton area of New Jersey (Biel, 1958) indicates that the wind blows out of the northwest 20.2% of the time during the months of February through June, and 18.6% for the remaining months of the year. However, the wind velocity during the period of February, March, and April is the highest of the year according to 17- and 25-year records taken in Newark and Trenton, N.J. The months of September, October, and November, all high lead months, represent the period of the year when wind velocity and atmospheric mixing depths are at a minimum.

The average lead levels for the spring months of March, April, and May, and the fall months of September, October,

Table II. Relationship of Wind Direction to Atmospheric Lead Values at Three Distances from Highway Supporting 47,000 Cars Daily^a

Wind Direction	Average $\mu\text{Pb}/\text{m}^3$ at feet from highway		
	30	75	125
East to south	1.00	1.08	0.71
North to west	5.31	4.23	3.54

^a Daily air samples taken for a 6-hour period from 1400 to 2000 hours. Sampling line extended to the southeast at a 90° angle from highway. Sampling period 5 days a week for 7 months.

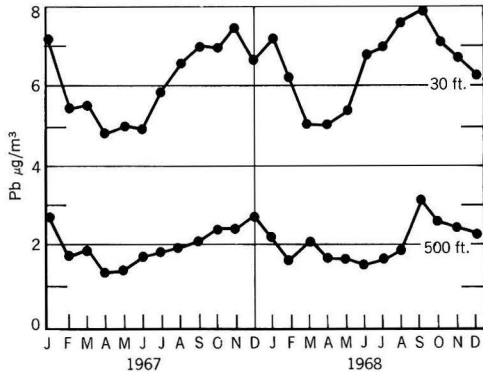


Figure 3. Monthly atmospheric lead averages as a function of the time of year traffic volume 50,000 cars daily

and November, are illustrated in Figure 4. To make the data more indicative of the influence of the highway, the lead levels secured at the sampling stations located 500 feet from the traffic were subtracted from all averages. The data recorded in this figure also reveal the difference in atmosphere lead concentrations between the spring and fall months. This chart suggests that near constant lead levels are achieved during the spring months within 150 feet of the highway from all locations supporting the traffic volumes under study. In addition, it appears that at the lower traffic levels studied, such lead levels may have been reached nearer the highway than that indicated above. During the fall months, when atmospheric turbulence is at a minimum, however, the zone of maximum highway influenced was somewhat wider.

Analysis of Air Data. The analysis of the air samples was directed toward an attempt to describe lead, measured in μg . per cubic meter, as a quantitative function of three factors: proximity to the highway, measured in feet; traffic volume or density measured in vehicles per day; and the time of year quantized as number of the week (e.g., Feb. 1-7 was week no. 5). The nature of the function relating these factors to lead was suggested by three considerations:

Regressions analysis confirmed that a quadratic function in distance provides adequate descriptions of lead values at each traffic volume.

Mathematically, lead values can be expressed as a quadratic function in time and linear to traffic volume.

In addition, analysis of lead values in soil and on plants suggested that an interaction between traffic volume and distance existed.

Based on these considerations, an equation was obtained by regression. The equation was linear in traffic volume, quadratic in distance, quadratic in time with an interaction between volume and distance, and interaction between time and distance, and an interaction between volume and time. Symbolically the following equation was fitted to the data by multiple regression

$$y = b_0 + b_1x_1 + b_2x_2 + b_{22}x_2^2 + b_3x_3 + b_{33}x_3^2 + b_{12}x_1x_2 + b_{122}x_1x_2^2 + b_{13}x_1x_3 + b_{133}x_1x_3^2 + b_{23}x_2x_3 + b_{222}x_2^2x_3$$

where y represents lead value, x_1 traffic volume, x_2 distance, x_3 week number, and the coefficients (the b 's) were estimated from the data.

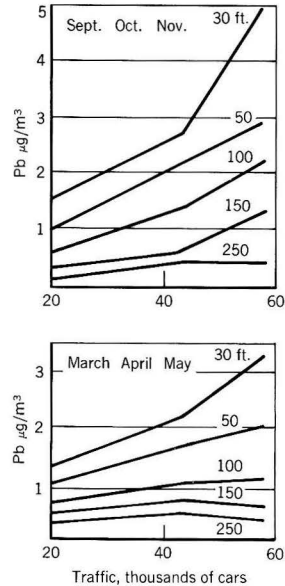


Figure 4. Atmospheric lead values (minus average levels, at 500 ft) as a function of season of the year, traffic volume, and distance from the highway

Because of the lack of independence, the significance of each b (significant differences from zero) cannot be tested individually. However, based on the size of the contribution of some of the terms in the above equation to the ability of the equation to predict lead values, several of the above coefficients were judged to be significant. The regression equation judged to be the best predictor of lead is as follows

$$y = 2.049 - 9.327x_2 + 20.962x_2^2 + 1.573x_3 + 10.992x_2^2 - 0.391x_1x_2 + 1.654x_1x_2^2$$

where y is lead values in $\mu\text{g}/\text{cubic meter}$ and

$$x_1 = (\text{traffic volume} - 42,000) \div 1000$$

$$x_2 = (\text{distance} - 172.4) \div 1000$$

$$x_3 = (\text{week} - 26.5) \div 100$$

where the x 's and y have the same meaning as above. This regression equation has an F-value of 237.8 with 6 and 1734 degrees of freedom, which is highly significant.

The equation shows the effect of traffic volume is to maximize quantities and differences in lead values near the highway, and to minimize them at 250 feet and beyond. From our data we visualize that the areas of background lead values are not static nor equivalent from area to area, but change with ventilation parameters (horizontal and perpendicular). The effect of time in the regression equation is to increase lead values in the early and especially in the late weeks of the year.

The particle-size data secured by the use of the cascade impactors were averaged for each distance from the highway (for each impactor separation state), used in Figure 5, and recorded in Table III. From these data it is clear that the percentage of larger particles is somewhat higher near the highway, with the percentage of the lead present in the smaller particles slightly increased at the 1750 foot location.

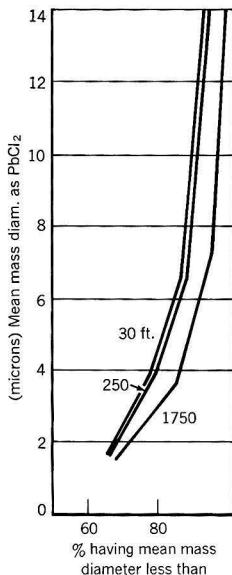


Figure 5. Relationship of the diameter of the particles (mass) to distance from the highway

Table III. Per Cent of Lead and Mean Mass Diameter (μ) of Particles on Various Stages of the Impactor at Three Distances from a Highway Supporting 47,000 Cars Daily

Impactor stage	Per cent of lead at			Particle diameters ^a in μ
	30 ft.	250 ft.	1750 ft.	
1	7.1	6.2	2.1	14.0
2	6.4	6.5	4.3	6.5
3	9.7	10.7	9.7	3.5
4	10.8	11.6	15.6	1.6
Filter	66.0	65.0	68.3	<1.6

^a Particle diameters calculated using density (5.85 of lead chloride).

Conclusions

From the data presented it is clear that automobile traffic contributes to the lead in the atmosphere. It is also clear that traffic density and distance from the highways greatly affect the lead levels that occur. From an examination of the lead averages from the two year sampling period, it can be seen that the lead content of the air decreases over 50% between 10 and 150 feet from the highway. In addition, the data reveal that at 250 feet from the highway, the area of slow gradual decline in air lead values has been reached.

The data recorded in Figs. 1 and 3 show that at locations near the highway the effect of traffic density on the lead content of the air is at a maximum. However, at greater distances (250 feet) the effect of the traffic density on the quantity of particulate lead in the atmosphere is largely lost since, at these distances, all sites were near the level secured at the greatest sampling distance from the highway. It appears, therefore, that the marked effect of traffic on the lead content of the atmosphere is limited to a rather narrow zone bordering the lee side (Table II) of the highway.

These studies show that while averages from long time

sampling periods show a curvilinear decrease in lead levels with distance from the highway (Fig. 1), short time considerations reveal that lead level distance curves for a given location may not be so described. From short period analysis (Table II, Fig. 4) the distance to near background levels is found to be constantly changing, depending on such meteorological parameters as wind direction, velocity, and perhaps perpendicular ventilation. The influence of traffic contributions to the lead in the atmosphere in areas showing background levels is not clear at present.

The particle size studies indicate that over 65% of the lead in the air from 30 to 1750 feet from a well-traveled highway (48,000 cars daily) consists of particles under 2 μ , with over 85% consisting of particles under 4 μ in diameter.

Acknowledgment

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Discussion

Atmospheric Lead: Its Relationship to Traffic Volume and Proximity to Highways

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When you summarize the results of research represented by this paper, you find that the avowed purposes were accomplished. Thus, as pointed out in the introductory remarks, there existed minimal data relating atmospheric lead concentrations to traffic volume and to the influence of distance from a highway source. Clearly, the results of this study as summarized in Figs. 1, 3, 4, and 5 have provided answers to these undetermined relationships. However, this research also provides other information which leads to additional thoughts and discussion.

For example, this research raises the very interesting subject of background lead concentrations. What is the source of these levels and what percentage of these so-called background levels is due to smaller particles found in automobile exhaust gases. Further reflection leads to the question of whether or not these small particles interact with vegetation. At the moment we have evidence which suggests the larger lead particles interact with vegetation by simple surface deposition. Yet, such data tell us nothing concerning the fate of the smaller particles which tend to remain suspended. Examination of the data in Table I shows that 50% of the lead containing particles with diameters greater than 6.5μ settles out by the time the air mass has moved 1750 feet from the highway. However Table I also tells us that the major portion of lead particles (87% to 94%) are less than 3.5μ in diameter and show little evidence which suggests surface deposition. Reflecting on this data as well as the data in the next paper (Schuck and Locke) suggests little if any interaction between vegetation and these smaller lead particles. Obviously what is needed are

additional studies to determine the fate of the bulk of the lead particles.

Another interesting fact pointed out by this paper is the influence of time of year on atmospheric lead concentrations. This seasonal variation is similar to the one found in the Three City Survey. One of the cities in this latter study was Los Angeles, for which a wealth of meteorological data exists. This author has shown that the seasonal lead concentration variation in Los Angeles can readily be accounted for by mixing volume and wind speed. These factors are of course the same ones suggested by Daines, *et al.*, as being responsible for the seasonal variation they observed.

It is interesting to compare the results obtained in this study (Daines, *et al.*) with those obtained in the Schuck-Locke study. Variation of atmospheric lead levels in the Daines, *et al.*, paper is summarized in Figure 1 and in the Schuck-Locke paper by Figures 1 and 3. The first point to note is that both studies resulted in similar atmospheric lead concentrations. Furthermore, and of greater importance, both studies gave similar results in terms of variations due to distance from the highway. Calculation from Figure 1 of the Daines, *et al.*, paper shows that between the 100 and 500 foot distance the lead loss rate was $32\% \pm 2\%$ for each 100 feet. A similar calculation (Fig. 1) of the Schuck-Locke paper shows loss rate of $23\% \pm 2\%$. To attempt to explain the differences and similarities of these values is unwarranted due to the large variation in sampling parameters shown by the two studies. Suffice it now to note the two studies essentially agree regarding variations in lead concentration as a function of distance from a highway.

Relationship of Automotive Lead Particulates to Certain Consumer Crops

Discussions Follow

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■ Five crops were analyzed for their lead content—cauliflower, tomatoes, cabbage, strawberries, and valencia oranges. In addition, the soil, water, and air in contact with these crops were analyzed for lead. The combined findings from the edible portion of four of these five crops strongly suggest that automotive lead particulates are not absorbed. They exist rather as a topical dust coating of which at least 50% can be removed by simple water washing. Neither did these crops show any inclination to absorb lead *via* their root systems. Similar conclusions relative to the fifth crop, *i.e.*, strawberries, cannot be drawn except by analogy to the other crops. In spite of growing near heavily traveled highways, *i.e.*, up to 50,000 vehicles per day, the amount of lead associated with the five crops in an untreated state was never greater than 1 μg . of Pb per gram of fresh weight. The average Pb concentration for the entire crop areas studied was one or two orders of magnitude less than 1 μg . of Pb per gram of fresh weight.

Lead in our environment has been the subject of many investigations. These have included studies of lead associated with soils (Tatsumoto and Patterson, 1963; Chow and Johnstone, 1965); lead in water (Poldervaart, 1955); lead in air (USPHS Publ., 1965; Kehoe, 1964); and lead associated with biological systems (Bagchi, *et al.*, 1940; Kehoe, 1940; Kehoe, 1961). The intent of many of these studies has been to determine the possible effect of man's use of lead compounds on his environment. In this current study the emphasis is on the interaction of airborne automobile lead particulates and consumer crops. This implies more than a knowledge of the concentration of lead found in crops. It implies a knowledge of the environmental system which is important to crop growth. Thus, without additional details, the analysis of crops in terms of their lead content leaves many unanswered questions. One major question is: How is the lead associated with the crop? Is it absorbed, and if so, is it absorbed *via* the surface of the plant or is it absorbed *via* the root system?

Assuming lead is found associated with consumer crops, what is the source of that lead? Many soils normally contain lead and past agricultural practices may have increased these lead levels. Therefore, knowledge must be generated concerning the lead found in the air, the water, and the soil, in addition to that found associated with the crops.

Experimental

The success of a research plan depends in most cases on the development and maintenance of specialized analytical skills. This is particularly true in this present study which required accurate determination of small amounts of lead found in a variety of materials. The method used was the colorimetric dithizone technique. Technical personnel associated with this project were trained in this latter technique at the Air and Industrial Hygiene Laboratories of the California State Department of Public Health in Berkeley, Calif. In addition to this specialized training, a continuous program of cross checking with other laboratories was established. Participating groups in addition to the California Public Health Agency were the Ethyl Corporation in Detroit, Mich., and American Smelting and Refining in Salt Lake City, Utah.

In all cases reported herein, the terms washed or unwashed refer to simple water washing such as might be used in the preparation of food in the home. Unless otherwise specified, the Pb content of a given edible crop refers to an aliquot taken from a blended sample containing one or more of the fruit or vegetable items being analyzed. The soil analysis is restricted to that portion of the lead which is soluble in 10% nitric acid during a three-day contact time. Particulate air samples were collected on 2-inch Gelman Triacetate Metrical filters having a 0.8- μ pore size. All air samples were collected at a point 18 inches above the ground with the filter holder facing down. Pb concentrations relating to crops are reported in terms of fresh weight. Although not reported herein, the crops were also analyzed in a dried state. The fresh *vs.* dry values are completely comparable, providing the original moisture content of the crop is known. With the exception of the airborne particulate samples, the concentrations are given in units of μg . of lead per g. of material analyzed (μg . Pb per g.). One μg . Pb per g. is equivalent to one part per million (1 p.p.m.) by weight. Airborne particulate concentrations are reported as μg . of lead per cubic meter of air (μg . Pb per m^3). One μg . Pb per m^3 is equivalent to 8.5×10^{-4} p.p.m. Pb by weight.

The area chosen for investigation of a cauliflower crop was immediately adjacent to and downwind from a highway with an average daily vehicle count of 58,000. Samples of ripe cauliflower were collected at 42 arbitrary grid points in this 10-acre plot. Table I contains the results of lead analysis of the edible portion of these collected flowers at the 42 sampling points. Interior edible portions of the flower were also analyzed. These portions were collected by cutting into the base of duplicate flowers collected at the same 42 sample sites. The

Table I. Pb Content of Fresh Cauliflower

μg. Pb per g. of Cauliflower

Distance from Highway (ft.)	Distance Along Highway (ft.)													
	0		70		134		197		272		362		Average	
	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b
50	0.25	0.00	1.02	0.11	0.23	0.00	0.20	0.00	0.13	0.00	0.16	0.05	0.33	0.03
250	0.16	0.00	0.32	0.35			0.05	0.00	0.00	0.00	0.01	0.16	0.11	0.09
450	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.11	0.17	0.13	0.00	0.04	0.03
650	0.01	0.00	0.00	0.35	0.08	0.00	0.00	0.00	0.04	0.07	0.00	0.00	0.02	0.07
850	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1050	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1195	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

^a A = average value for entire flower.

^b B = average value for interior portions of flower.

Table II. Pb Content of Soil in Cauliflower Field

μg. Pb per g. of Dry Soil

Distance from Highway (ft.)	Distance Along Highway (ft.)													
	0		70		134		197		272		362		Average	
	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b
50	107	3.2	151	2.0	91	0.6	132	0.6	123	0.005	105	0.3	118	1.1
250	97	0.005	92	0.005	82	0.3	82	0.9	76	0.005	82	19.7	81	3.3
450	75	0.005	64		79	1.2	76	1.2	63	0.005	93		85	0.6
650	93		67		95		74		67		114		74	
850	69		95		71		66		69		73		85	
1050	102		90		68		74		97		79		75	
1195	115		68		89		84		72		56		85	

^a A = at surface.

^b B = at 26" depth.

Table III. Vertical Profile of Lead in Soil of Cauliflower Field

μg. Pb per g. Dry Soil

Sample Site 7		Sample Site 8	
Depth (")	μg. Pb	Depth (")	μg. Pb
0	72	0	80
3	84	3	73
6	79	8	52
10	83	14	41
16	22	18	31
20	<	21	< ^a
26	<	26	<

^a < = less than 0.005.

results of this latter analysis are also shown in Table I. The results of lead found in the surface soil and at a depth of 26 inches are shown in Table II. Typical vertical profiles for lead in soil at two of the sample sites are shown in Table III. The lead found in collected airborne particulates during a three-day continuous sampling period is shown in Table IV. Wind variables during this three-day period are listed in Table V. This particulate sampling program was conducted three weeks prior to harvesting. Development of the edible portion of the cauliflower requires a one-month period.

After the harvesting of the cauliflower, the field was tilled and replanted with tomatoes. The results of analysis for lead on the ripe collected tomatoes both in washed and unwashed states are shown in Table VI. From bloom to harvest of the tomato crop required two months.

A 1200 ft.² section of a 30-acre cabbage field was investi-

gated. The sample plot was located one mile north and downwind of a highway with an average daily count of 58,000 vehicles. The sample plot is bordered on the north and west sides by roads with a 4000 to 5000 average daily vehicle count. The results of analysis of the outer leaves of cabbage heads are shown in Table VII. No lead was detected in cabbage heads with outer leaves removed. Lead in soil analysis at the surface and at a 26-inch depth is shown in Table VIII.

A 12-acre section of a 30-acre strawberry field was investigated. From bloom to harvest the berries require a four- to six-week growing period. The sample section is located one-half mile south and upwind from a highway carrying 48,000 vehicles per day. A road carrying 1000 vehicles per day is located on the north edge of this sample site. Analysis of the washed berries is summarized in Table IX. The results of analysis of surface soil are presented in Table X. Soil at a 26-inch depth from all 30 sample sights contained an average of 1.5 μg. Pb per g. of dry soil. Two samples of irrigation water, initially free of lead, were found to contain 0.02 and 0.6 μg. Pb per g. dry soil after flowing a distance of 200 feet in the furrows.

A 48-acre portion of an orange grove was investigated. This grove was bisected by a north-south highway carrying 48,000 vehicles per day. The winds blew toward the eastern half of the sample plot during the daylight hours and toward the western half during nighttime hours. Analysis of orange peel and orange meat after various treatments is summarized in Table XI. Each Pb concentration value reported in these tables is the average of 18 oranges analyzed from three trees. Acid washing consisted of vigorous scrubbing with detergent

Table IV. Lead in Collected Particulate Samples

 $\mu\text{g. Pb per m.}^3$ Air

Date and Sample Time (hrs.)	Distance from Highway (ft.)							
	35	100	200	300	400	500	600	900
<i>Date 3-18-68</i>								
0540-0636	1.3			1.00			1.06	
0630-0736	1.20			1.08			0.83	
0729-0905	3.20			1.97			1.55	1.29
0828-1103	4.23			1.09			0.65	0.33
1055-1307	3.05			1.08			0.57	
1312-1508	3.89			1.95			1.22	
1501-1715	6.11			2.76			1.77	
1706-1911	3.76			1.61			0.93	
1903-2113	0.92			0.05			0.02	
2105-2305	0.37			0.56			0.34	
<i>Date 3-19-68</i>								
0627-0903	1.88		0.98				<0.02	
0855-1101	<0.02		<0.02				<0.02	
1054-1303	<0.02		<0.02				<0.02	
1257-1506	3.61		2.00				1.30	
1500-1714	4.98		2.94				1.15	
1705-1913	5.39		3.55				2.55	
1907-2109	1.22		0.65				0.72	
2103-2305	1.03		1.00				0.71	
<i>Date 3-20-68</i>								
0625-0900	<0.02	0.01			<0.02			
0858-1123	0.04	<0.02			<0.02			
1117-1313	<0.03	0.07			<0.03			
1307-1517	0.05	<0.02			0.02			
1512-1709	0.76	0.49			<0.03			
1705-1910	2.42	1.75			1.04			
1905-2108	1.75	1.62			0.88			
2104-2304	3.10	2.40			1.80			

followed by immersion for 10 min. in 10% nitric acid. Analysis of airborne particulates and soil is not completed as of this time.

Discussion

In investigating possible interaction of airborne particulate lead and consumer crops, one searches for conditions where such an interaction appears most likely to occur. Thus, initially the primary interest was in crops growing downwind and immediately adjacent to heavily traveled highways. Obviously, this represents an extreme case which is not representative of the condition under which the bulk of consumer crops is grown. Nevertheless, such data will be quite useful in establishing the upper limit of contamination, and along with knowledge concerning changes with variation in distance, they can be used to predict expected results in large agricultural areas.

The first item to establish is whether or not the particulate lead emitted on the highway reaches the crop being investigated. To demonstrate this phenomenon particulate samples were collected at varying distances from the highway and under a variety of time and wind conditions. The data in Table IV are representative of the measured lead concentration found in the air during the time period covering growth and harvesting of the cauliflower and tomato crops. Examination of the air movement variables in Table V shows the air movement during daylight hours is, in general, toward the crop while

it is from the crop toward the highway during nighttime hours. When the Pb data in Tables IV and V are separated and arranged according to these two air directions, one obtains the information shown in Figure 1. Examination of this figure shows that the particulate lead from the highway source is carried by the air for a considerable distance over the field. From such data we can predict that the air in the 12-acre field contained on the average 1 $\mu\text{g.}$ of Pb per cubic meter during the entire growing period of the cauliflower and tomato crops. It is also apparent that the average air Pb content was much higher than this at points in close proximity to the highway. We can therefore conclude that ample opportunity did exist for interaction of these crops with airborne lead particulates.

Referring again to Figure 1 it will be noted that the drop in airborne lead concentration is quite rapid as a function of distance from the highway. This is, of course, most apparent when the air movement is from the highway toward the field. An important question is how much of this drop-off is due to fall-out of the heavier lead particles as opposed to a simple dilution process. Evidence relative to these effects was obtained at another highway location where total particulate concentrations as well as Pb were measured. The summarized results of this later study are shown in Figures 2 and 3. From Figure 2 it becomes apparent that the mixing process on and near the highway is very complex. It can be seen that total particulate concentrations are 20% higher at 200 feet from the highway

Table VI. Lead Content of Fresh Tomatoes

μg. Pb per g. of Tomato

Distance from Highway (ft.)	Distance along Highway (ft.)													
	0		210		402		591		816		1086		Average	
	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b
50	0.30	0.04	0.45	0.01	0.70	0.11	0.65	0.21	0.57	0.10	0.45	0.04	0.62	0.09
250	0.09	0.03	0.04	0.04	0.17	0.02	0.08	0.01	0.06	0.03	0.06	0.02	0.10	0.03
450	0.06	0.01	0.07	0.02	0.06	0.03	0.09	0.02	0.07	0.01	0.05	0.01	0.07	0.02
650	0.03		0.03		0.04		0.06		0.04		0.02		0.04	
850	0.04				0.02		0.02		0.03		0.01		0.02	
1050	< ^c		0.01		< ^c		0.01		< ^c		< ^c		0.003	
1195	0.05		0.04		0.04		0.04		0.02		0.01		0.03	

^a A = untreated.
^b B = washed.
^c < = less than 0.005.

Table V. Wind Variables during Air Sampling in Cauliflower Field

Date	Sample time	Wind Speed, m.p.h.		Wind Direction ^a		
		Near highway	1000 ft. from highway	Near highway	1000 ft. from highway	
3-18-68	0540-0636	4.2	4.8	10	9	
	0630-0736	1.8	5.4	8	8	
	0729-0905	3.9	6.1	11	11	
	0828-1103	5.0	5.2	2	1	
	1055-1307	5.5	5.2	3	3	
	1312-1508	11.9	9.3	3	3	
	1501-1715	9.9	9.0	2	2	
	1706-1911	6.7	5.8	1	1	
	1903-2113	3.2	3.2	11	10	
	2105-2305	3.0	3.0	9	9	
3-19-68	0627-0903	9.2	10.0	9	8	
	1055-1101	12.1	11.9	9	8	
	1054-1303	7.4	7.4	Variable	Variable	
	1257-1506	11.6	9.8	4	3	
	1500-1714	13.9	11.2	3	3	
	1705-1913	6.4	4.8	2	1	
	1907-2409	4.7	3.9	11	10	
	2103-2305	3.0	3.0	10	10	
	3-20-68	0625-0900	15.9	12.8	9	8
		0858-1123	15.3	12.8	9	8
1117-1313		14.0	13.2	9	8	
1307-1517		10.1	11.7	8	8	
1512-1709		5.9	8.7	7	6	
1705-1910		3.1	5.8	6	5	
1905-2108		4.1	4.6	9	6	
2104-2304	3.5	4.7	Variable	Variable		

^a Highway heading set at 12 o'clock. Actual heading NW (310°).

Table VII. Pb Content of Untreated Outer Cabbage Leaves
(μg. Pb per g. Cabbage)

Distance from Northern Road (ft.)	Distance along Northern Road (ft.)			
	0	200	400	600
25	1.14	0.21	< ^a	< ^a
125	< ^a	< ^a	0.08	0.11
225	0.04	0.40	< ^a	< ^a

^a < = less than 0.005.

Table VIII. Pb Content of Soil in Cabbage Field at the Surface and at a Depth of 26 Inches
(μg. Pb per g. Dry Soil)

Distance from Northern Road (ft.)	Distance along Northern Road (ft.)							
	0		200		400		600	
	0"	26"	0"	26"	0"	26"	0"	26"
25	67	2	67	2	17	1	17	2
125	11	1	1	2	3	1	8	1
225	10	1	1	1	< ^a	1	1	1

^a < = less than 0.005.

Table IX. Pb Content of Fresh Washed Strawberries
(μg. Pb per g. Strawberries)

Distance from North Road (ft.)	Distance along North Road (ft.)					Average
	0	175	375	575	735	
15	0.06	0.04	0.05	0.03	0.08	0.05
165	ND ^a	ND	0.04	0.06	0.03	0.06
315	ND	ND	ND	ND	ND	ND
465	ND	ND	0.03	0.06	0.08	0.06
615	ND	ND	0.02	0.05	0.06	0.04

^a ND = no data.

Table X. Pb Content of Soil in Strawberry Field at Surface
(μg. Pb g. Dry Soil)

Distance from North Road (ft.)	Distance along North Road (ft.)					Average
	0	175	375	575	735	
15	1.8	5.6	5.2	4.5	10.9	8.2
165	6.5	4.2	5.5	3.5	6.4	5.3
315	6.4	7.8	4.7	3.5	4.2	5.2
465	3.4	2.6	2.7	1.2	5.2	2.5
615	4.4	4.2	3.9	3.6	4.7	4.0

than they are at a 50-foot distance. There are, of course, many complex processes which can be proposed to account for this behavior. The most likely, however, is that for various reasons an updraft condition exists over the highway and that spillage from the top of this air column is responsible for the increase in particulate concentration at the 200-foot distance. No such comparable behavior is to be noted in the accompanying lead concentrations shown in Figure 3. This lack of effect probably results because of the dominance of fallout of the large lead-containing particles. Assuming that dilution is mainly responsible for the change in total particulates after the first 200 feet, we find that a 17% drop in total particulates occurs between

Table XI. Analysis of Oranges

µg. Pb per g. of Material

Distance from Highway (ft.)	Orange Peel								Orange Meat	
	Untreated		Water washed		Acid washed		Water washed		Acid washed	
	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b	A ^a	B ^b
0-99	3.39	1.66	1.12	0.93	0.55	0.26	0.05	0.05	0.01	0.01
100-199	1.61	0.93	0.63	0.51	0.18	0.14	0.03	0.05	< ^c	0.01
200-299	1.45	1.01	0.54	0.53	0.24	0.14	0.02	0.03	0.01	0.01
300-399	1.10	0.79	0.50	0.50			0.03	0.03		
400-499	1.21	0.57	0.45	0.37			0.02	0.04		
500-599	0.96	0.48	0.34	0.29			0.02	0.06		
600-699	0.71	0.51	0.32	0.22			0.02	0.03		
700-799	1.07	0.58	0.53	0.37			0.02	0.03		
800-899	1.58	0.60	0.45	0.34			0.01	0.02		

^a A = east of highway.

^b B = west of highway.

^c < = less than 0.005.

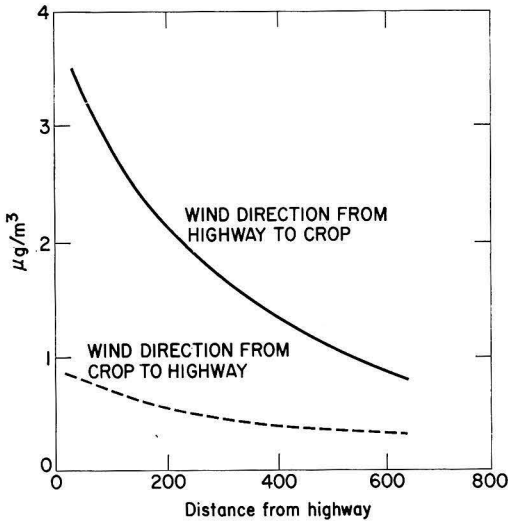


Figure 1. Variation in ambient lead concentrations

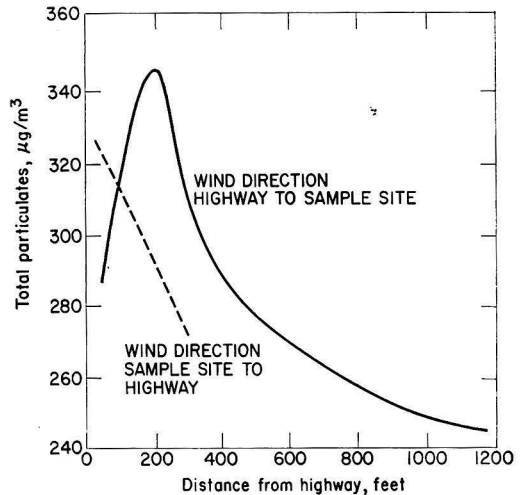


Figure 2. Variation in total particulate concentrations in air as a function of distance

200 feet and 400 feet. On the other hand, the drop in lead concentration between these two distances is 31%. Thus, a minimum of 18% of the airborne lead must have been deposited either on the soil or crop between these two points. This is not surprising since other investigations have shown that at least 50% of the lead emitted by automobiles is in a size range which would be expected to settle out rapidly.

In addition to contact with air, the roots of the growing crop are in intimate contact with soil and water. The crops studied are watered by flowing water into the furrows. In all cases analysis of this supplied water failed to exhibit the presence of lead. If present it thus was less than 0.005 µg. per g. of water. Rechecking this water after it had flowed through 200 ft. of furrows in the strawberry field resulted in concentrations of 0.02 and 0.6 µg. Pb per g. of water. In neither case were the samples filtered, thus it is quite probable that these values represent soil particles rather than dissolved lead. In any event the irrigation water itself can be eliminated as a possible source of Pb.

The soil, on the other hand, contains an ample supply of lead. The soil in the field where the cauliflower and tomatoes were grown shows a surprisingly high content. Inspection of the values in Table II also shows a surprisingly even distribution of lead throughout the field. It is only at the closest points to the highway where consistently higher values are observed. Records of field use revealed that this area was previously a walnut grove, in which lead arsenate was extensively used. Such application of insecticide probably accounts for the Pb values in the soil. The even distribution of Pb can partially be the result of the extensive plowing which takes place between crops. Such a conclusion is supported by the vertical profile of lead shown in Table III. Thus, as evidenced in Table III and in the samples at the 26-inch depth in Table II, there is very little lead found below the 18-inch depth. These data also clearly show that most if not all the lead present in the soil is not in a water soluble form. This same point is clear in the strawberry and cabbage fields which show very little lead at the 26-inch depth when compared to surface lead concentrations. The

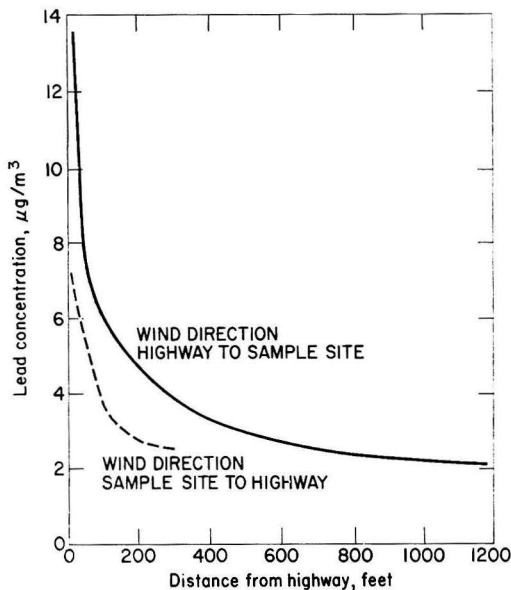


Figure 3. Variation in ambient lead concentrations as a function of distance

data relative to surface soil Pb concentrations does show an indication of increases at points close to the highways or roads. There are many unknown factors which prevent us from saying other than that the indication of Pb fallout is consistent with the Pb in air data.

The previously discussed air, soil, and water data give indications of the following:

The air in contact with the crops contains Pb which originated in automotive exhaust streams.

The air concentration of these lead particulates is quite high on the downwind side of the highway, but drops off rapidly with distance.

A considerable fraction of these lead particles are deposited on the soil and crops within a few hundred feet of the highway.

The soil in which the crops were growing contains sizeable quantities of lead which does not appear to be water soluble.

Taken by themselves these indications only show that contact between lead and the crop occurs both above and below ground. Even the fact that the soil lead appears water insoluble does not prove it is unavailable to the root system. Knowing that airborne lead compounds are probably being deposited on the crop does not tell us the fate of these lead compounds. Thus, in our analysis of the edible portions of the crops we attempted to see if there existed a difference between lead on the outside and lead in the interior. The success or failure to gain information in this manner may be judged in terms of the results for each individual crop. The clearest information came from the cabbage crop. In this case examination of the data clearly indicates that lead is deposited on the outer leaves and that there is no detectable lead in the interior of the cabbage head. The next most definite information comes from analysis of the cauliflower crop. Analysis of the entire flower indicated the presence of detectable lead when the crop was grown within 450 feet of a heavily traveled highway. Analysis

of the interior portions of the flower is inconclusive because examination of the data shows that the detection of lead in these interior portions is irregular. This leads to the thought that contamination associated with the collection process may be contributing. In the case of the cabbage, it was relatively simple to remove the outer leaves without contaminating the interior portions of the head. The cauliflower interior section, however, could only be collected by a series of cuts which can readily lead to contamination from exterior lead.

With the tomato crop we made no attempt to separate the thin skin from the interior portion. Rather, we relied on analysis of the fruit before and after washing. According to the data in Table VI, this washing process removed a minimum of 80% of the lead. Obviously, the bulk if not all the lead is deposited on the exterior surface.

The strawberries represent the most complex case investigated to date. This berry has a rather rough yet thin surface. Thus, separation of interior from exterior portions without contamination problems is much more difficult. Simple water washing also would not be expected to be as effective as with a smooth skinned crop such as the tomato. Thus, while disappointing, it is not unexpected to find that simple washing does not significantly change the concentration of lead found associated with the strawberries. Attempts to separate interior and exterior parts of the strawberries were not successful in that both portions resulted in similar lead concentrations. Subsequently, samples of the field soil were removed to a greenhouse location. Analysis of the strawberries grown in this soil indicated a lead content which was less than 0.01 µg. of Pb per g. of crop. Thus, again the data suggest that little or no translocation of Pb from soil to fruit occurs.

Analysis of the orange crop differs in certain significant details from the other crops investigated. Since the orange is a tree crop, it is separated by a several foot distance from the soil surface. This makes direct contamination from soil much less likely. In contrast, the strawberry crop was observed to be well contaminated with dust. Thus, in the case of the strawberries, it became impossible to say how much of the analyzed Pb was the result of exterior soil contamination, airborne particles, or plant uptake. The orange also differs in the length of its growing season, and therefore exposure time. The particular oranges investigated spent 12 to 15 months on the tree prior to harvesting. This is in contrast to the 1 to 3 months of growth associated with the other crops investigated. Examination of the orange meat data quite clearly indicates that the Pb present is a result of contamination from the lead on the peel. Although the orange is readily peeled the data indicate that, in spite of the care taken, some contamination of the meat still occurs. The orange peel data again indicate that 50% or more of the deposited lead can be removed by simple water washing. As with the other crops, the lead deposited on the orange increases as one approaches the highway. Likewise as expected, the east field which is downwind during the daylight hours has a significantly larger concentration of these deposits. There are, of course, other factors which might indirectly influence the measured concentrations. For example, it is well-known that auto exhaust contains many gaseous compounds which seriously affect the growth rate of many crops. The particular oranges sampled were selected so as to conform to a uniform size. Weight of peel, weight of meat, and average diameter were recorded. Checking these data failed to uncover any statistically significant variations which might influence the Pb concentration data. Thus, we again conclude that the observed variations in surface Pb deposits are the result of wind, mixing, and automotive variables.

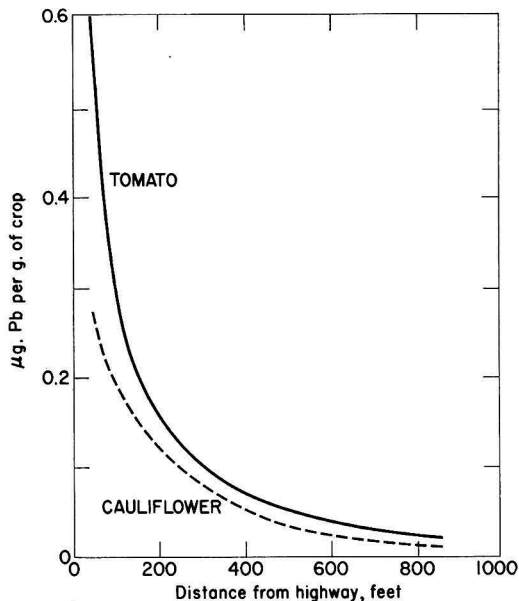


Figure 4. Variation of lead found on crops

One other concept relative to surface deposition can be checked by examination of the variation of lead crop values with distance from a highway. The clearest evidence in this regard comes from examination of the cauliflower and tomato crops. Both were grown close to a heavily traveled highway where the airborne concentration of lead dropped rapidly within a few hundred feet of the highway. Both crops also provide evidence which strongly suggests that most if not all of the lead is present as a surface deposition. If simple surface deposition is the predominant factor, it would be reasonable to expect a correlation between distance and crop lead concentration—a correlation which would vary in much the same way as distance and airborne lead concentrations. Plotting the lead content of the untreated cauliflower and tomato crops

as a function of distance from the highway results in the curves shown in Figure 4. In general these can be seen to be similar to the type of curve shown in Figures 1 and 3 for the variation of Pb in air as a function of distance from a highway. Further investigation shows that the relationships described by the Pb variation curves in Figs. 1, 3, and 4 are first-order relationships since they become linear functions when log of Pb concentration is plotted as a function of distance. Furthermore, the slopes of these lines for Pb deposited on the cauliflower and tomato crops have values which differ by less than 2%. Thus, this evidence also strongly supports the dominating mechanism as one of lead deposition on the surface of the crops.

Conclusion

The results of this investigation suggest, but do not prove, that automotive lead particulates exist as a simple topical coating on vegetation. Further support for this suggestion is obtained when one examines the results from other crop studies which show that the highest Pb concentrations are associated with those portions of the plant which have the greatest surface to volume ratio, *i.e.*, leaves. Again, however, this is only suggestive evidence and leads to the conclusion that we are in dire need of experimental procedures which are applicable to the investigation of these questions.

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Relationship of Automotive Lead Particulates to Certain Consumer Crops

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Schuck and Locke suggest that this study serves more as a guideline for further studies, rather than providing unequivocal answers. Their main objective was to examine possible interactions between airborne automotive lead particulates and consumer crops. They suggest that much of their data prove lead particulates are deposited, but not absorbed by the five crops studied.

Schuck and Locke stress the need for a detailed knowledge of the environmental system that carries the airborne lead particulates before one can determine the source of lead or the potential for lead uptake. This detailed knowledge was not always obtained nor, when obtained, always fully used.

The authors stress the difficulties in analyzing for small amounts of lead, but on several occasions they suggest contamination as a reason for high values with no suggestion of analytical problems.

In their section on experimental methods they indicate that crop lead values were obtained using an aliquot from a blended sample of one or more of the crop parts being analyzed. They give no indication, however, of the number of duplicate analyses that went into the data. They did not outline methodology for collecting the soil or water samples; therefore, we might assume a soil or water aliquot was taken from blending samples at a given location. Again, no mention was made of whether duplicate analyses were performed. Details for analyzing the filter papers for lead values are also lacking. This section of the report should be more inclusive so the reader will have some appreciation for possible variations within the analytical procedures.

For easier comparisons with other work the crop values should have been reported as $\mu\text{g. Pb per g. dry wt.}$

The geographic location chosen for the cauliflower and tomato studies was a good one in relation to traffic density. The finding from land use data, however, that heavy lead contamination from lead arsenate insecticide was present detracted from the main objective of studying the effects of levels of airborne lead particulates.

The area in which cauliflower and tomato were grown was more intensively studied than the other areas and includes much of the meteorological data. Soil studies at this site suggest that higher lead levels were found at the line 50 feet from the highway. However, high levels were found uniformly from 250 to 1200 feet. The variability was so great that the higher values at the 50 foot line might not be significant even though the average value was about 50% higher than at the other distances.

Soil lead levels 26 inches beneath the surface of the soil and

levels indicated in the soil profiles suggest uniform mixing with little or no mobility of the lead within the soil. Thus, water soluble forms probably are not present.

Considerable effort was spent at the above field site trying to correlate concentrations of airborne lead at various distances from high traffic density highways with wind speed and direction. A correlation was found between wind direction and concentrations of airborne lead. Although not discussed, the tabular results suggest this correlation would be interrelated with wind speed, traffic density at given times, and other weather parameters (such as precipitation). The basic correlation of wind direction and airborne lead particulate concentrations was well shown in Figure 1. A study of another site gave similar curves but much higher lead levels. Data from the second site also showed a greater rate of lead particulate fallout, which could be directly related to wind speed. It would be interesting to know more about the second site—especially information on traffic density.

Analyses of cauliflower lead concentrations showed a good correlation with concentrations of both airborne and soil lead. Curves for lead concentrations of whole cauliflower and unwashed tomato are similar to the curves for airborne lead in relation to distance from the highway. These values could be from contamination, but three of the values are well above those of comparable whole cauliflower analyses.

The washed tomato fruits have higher lead close to the highway, which could represent absorption of airborne soluble lead into the leaf or fruit tissues or the uptake of small amounts of lead from the soil.

The studies on cabbage and strawberries were evidently set up to study crops at some distance from high traffic density highways, because results from the cauliflower and tomato would suggest that at one mile downwind and a half mile upwind the road effects would be lost. The value of these studies is lost because there were no comparable studies with these crops near high traffic density highways.

Some interesting data were generated from the cabbage at the intersection of the north and west roads with traffic densities of about 5000 cars per day. The soil lead data suggest that the north road travelers have to stop at the west road, which would be a through road. High levels of soil lead within 200 feet of the intersection suggest a slowdown of traffic along with acceleration as cars move east from the stop sign. This is conjecture, but could explain the results presented. The soil levels close to the intersections are much higher than one would expect from the traffic density listed. The lead levels of the outer cabbage leaves at the site closest to the intersection could be ex-

plained in the same way and are the highest crop level reported in the paper (excluding unwashed orange peel data). Thus, a case might be made for a more thorough study at major stop-go intersections.

The strawberry data showed no correlation between distance from the highway and lead levels of either the fruit or the top layer of soil. With a traffic density of 1000 cars per day, no special effects should have been expected.

Irrigation water at the strawberry site was sampled and found to contain no lead. Lead was found after the water ran in furrows for about 200 feet, but no attempt was made to determine if the lead was soluble in the water or merely part of the suspended particulate. It would be interesting to check for soluble lead in the soil. The authors state that although the lead appears to be immobile in the soil, it could be available to the plant. This should be determined for all sample areas by growing test plants in the soils away from contaminated air.

The orange study was perhaps the best designed. The lead data for both washed and unwashed orange peel from the two sides of the highway correlated well with wind direction at the time of highest highway density. However, except for the 100-foot interval, neither side of the highway showed a correlation of orange peel lead levels with distance from the highway.

Discussion

Relationship of Automotive Lead Particulates to Certain Consumer Crops

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The objective of the investigations reported in this paper was to examine the interaction of airborne lead and consumer crops. The authors correctly conclude that in order to investigate such interactions, studies must be conducted on lead in air, soils, and crops. The studies conducted, however, appear to be lacking in several aspects.

The results obtained for the lead content of air, soils, and plants with respect to distance from highways are quite similar to what we have found in New Jersey. The studies in California and New Jersey support each other in this aspect.

The levels of lead found in the two studies, however, are quite different. The variations may be due to several reasons. Lead in air in New Jersey may be higher due to more industry, a denser population, or to the fact that in this study the air sampling device was facing downward. The authors give no reasons for their sampling technique and the writer fails to see any reason for using this system. This sampling technique may not have collected the total particulate matter in the air.

The lower levels of lead in soil found in this study may also be due to generally lower lead levels, or due to the method used to extract lead from the soil (10% HNO₃ in contact with the soil for three days). This method will not extract all the lead and may remove variable percentages from different soils. A method that would measure the total soil lead should remove any effects of differences in soil properties regardless of soil or location.

The authors chose to analyze only the edible portion of the

The authors state that the results clearly show all positive lead values for the orange meat are a result of contamination when the orange was peeled. This conclusion does not appear warranted from the results presented. It could be suggested that some absorption takes place or that some translocation from root absorption might occur.

In summary, the authors have presented good evidence supporting their thesis that particulate lead from automobile exhaust contaminates crops growing in the vicinity of high traffic density roadways. Their contention that this contamination is entirely a surface coating is not well substantiated. Some of the results are inconclusive and others suggest a surface adsorption or the absorption of some lead into the plant parts studied. The possibility of the uptake of lead from soils is not eliminated. Soil lead levels in the vicinity of high traffic density highways could eventually become of concern. Although lead appears to be immobile in the soils, some work suggests that the lead does become available to some crops at certain high concentrations.

The levels of lead in crops reported in this study are well below those suggested for human or animal consumption. Possibly the lead from automobile exhaust is not yet of critical concern.

crops studied. Except for cabbage, this was the fruiting bodies of the crops. The inorganic composition of such plant parts is influenced relatively little by the environment and more so by the genetics and physiology of the plant. Analyzing only these plant parts has led the authors to conclude that lead is not absorbed by plants but exists only as a dust coating on the plant surfaces. Analyzing other plant parts such as leaves and roots, which are better indicators of the inorganic composition of the plant's environment, possibly would have brought them to a different conclusion. Certainly only the edible portion of the plant may be important in regard to human consumption, but, in studies of the interactions of lead and plants, the total plant must be examined.

In the reported investigation, the collection of air samples covered only a period of three days. Lead content of air is extremely variable with time (as is shown by the authors' data). With respect to plants, it is not the short-term lead concentration in air that is important, but rather the average lead concentration over the growing period of the plant. A longer sampling period is necessary to establish the amount of lead in contact with the plant.

In summary, Schuck and Locke demonstrate adequately the distribution of lead with respect to highways. However, it is their conclusion that lead is not absorbed by plants that is not warranted by the data shown. Perhaps a more exhaustive study using different techniques would have produced a different conclusion.

Study of Lead Levels in Experimental Animals

Discussions Follow

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■ A large number of rodents were maintained in chambers breathing air from an intersection in central Detroit. A comparable group of animals were maintained in identical fashion, but breathed filtered air, and as a consequence were assumed to have inhaled no lead compounds. Tissues from animals in each of the two groups were analyzed for lead content, and although lead levels tended to be higher in the exposed group, the difference was significant only in the case of bone levels. Both rabbits and guinea pigs displayed significantly increased bone lead levels, and on the basis of the data, it was concluded that the increased levels resulted from the inhalation of approximately $2.5 \mu\text{g./m.}^3$ for a period of nearly 4 years. Estimates indicated that although the lead intake *via* ingestion was considerably greater than that by inhalation, the more efficient absorption of the inhaled lead accounted for the reported difference.

At the conclusion of an air pollution study in which a large number of rodents had been maintained in environments which were identical except for air pollution exposure, the surviving animals were sacrificed and frozen for subsequent trace metal analyses. The protocol of the study and principal findings have been reported elsewhere (Smith, 1968), but of concern with respect to the present study is the observed difference in the quantity of particulate matter in the air which the animals breathed. The exposed animals spent their entire lives (periods up to 4 years) breathing air typical of Detroit and similar large cities, containing on the average about $225 \mu\text{g.}$ of suspended particulate matter per m.^3 (Table I). By contrast, the control animals, originally litter-mates of the exposed animals, spent identical lengths of time breathing air containing virtually no particulate matter, the result of filtration through prefilters and absolute filters.

The animals were raised on identical diets, drank the same

water, lived in nearly isothermal identical rooms, experienced the same number of hours of light and darkness, were subjected to the same noise levels, and were tended by the same caretakers. So far as can be determined, the only variable which could influence the trace metal burdens of the animals was the inhaled particulate matter which was retained in the animals' lungs. These animals afford a unique opportunity to study several trace metal levels in relation to urban air pollution, and a number of different analyses are being performed. This paper describes the analytical studies related to lead levels.

The suspended particulate matter which was collected and analyzed throughout the several years of exposure proved to contain a small quantity of lead as expected, and values were comparable with other published data. The mean level of $2.46 \mu\text{g./m.}^3$, based on the analysis of conventional high-volume fiber glass filter samples, was remarkably close to the mean of $2.41 \mu\text{g./m.}^3$ obtained during a 3-month study in which membrane filters were employed (Table II).

All samples extended over periods of 24 hours or more, so short-term concentrations could have been substantially higher. Analysis of the fiber glass filters was performed by cutting a measured area of each filter, transferring to a borosilicate flask, and adding 5 ml. of 2 to 1 nitric-perchloric acid mixture. The samples were next heated until fumes of perchloric acid were evolved, cooled, and diluted with distilled water, then filtered and adjusted to known volume. Aliquots were analyzed by the dithizone procedure.

Tissue Analyses

On the basis of previously performed analyses of lung tissue, obtained spectrographically (Elton, Szajnar, *et al.*, 1968), tissue from exposed animals contained somewhat more lead as well as several other metals, indicating a contribution by airborne particulate matter. As noted in Table III, however, the range of values found was great, and statistically

Table I. Total Suspended Particulate Matter High Volume Samplers

Wayne State University—Air Pollution Study
Detroit, Michigan

Year	Mean $\mu\text{g./m.}^3$	Maximum Daily Loading $\mu\text{g./m.}^3$
1962	179	818
1963	200	457
1964	263	502
1965	202	381

Table II. Air Lead Analyses

March 1960–June 1966

	Number of Samples Analyzed	Range of Values $\mu\text{g./m.}^3$	Mean Values $\mu\text{g./m.}^3$
Weekday	48	0.90–5.30	2.67
Weekend	15	0.20–2.03	1.57
Total	63	0.20–5.30	2.46

During a special lead study conducted by the University of Michigan for the USPHS, Nov. 1, 1962–Jan. 31, 1963, the mean concentration was $2.41 \mu\text{g./m.}^3$. During an inversion period extending from Nov. 26, 1962, to Dec. 4, 1963, a high value of $11.5 \mu\text{g./m.}^3$ was found.

Table III. Concentrations of the Elements in Lungs of Two Exposure Groups of Animals*

	Clean Air		Ambient Air	
	Range	Mean	Range	Mean
		p.p.m. ash		p.p.m. ash
Al	40-952	170.0	20-925	249.0
Ba	<0.1-7.1	2.9	0.4-22	5.6
Be	<1	<1.0	<1	<1.0
Bi	<1	<1.0	<1	<1.0
Cd	<10	<10.0	<10	<10.0
Cr	<1-2.8	1.7	<1-4.5	1.9
Co	<2-2.2	2.0	<2-2.5	2.0
Cu	71-200	117.0	52-170	114.0
Pb	3.5-19.5	10.4	3.8-103	23.5
Mn	6.1-33.6	16.0	2.6-20.7	13.4
Mo	<1-7.5	4.8	3.9-10.7	5.5
Ni	2.5-16	6.8	<1-11.5	5.1
Ag	<0.1-0.9	0.15	<0.1-0.75	0.25
Sr	1.6-10.7	5.6	2.4-7.9	4.8
Sn	<1-7.5	2.5	<1-4.5	0.9
Ti	<2-15.7	5.0	<2-9.2	5.2
V	<4	<4.0	<4	<4.0
Zn	725-2550	1480.0	1125-2475	1750.0

* Most results based on analysis of tissue from 12 animals.

the significance of group differences was low. In the present study the use of a method specific for lead, as well as a greater number of samples, was expected to yield results which were of good statistical significance.

At the time of sacrifice, each animal was autopsied, and tissues removed by dissection. Ordinarily, the various organs were removed completely, small portions were taken for histopathological examination, and the remainder transferred to polyethylene bags for storage in a freezer. The remaining carcass was separately bagged and stored in similar fashion. All possible precautions were taken to minimize the risk of sample contamination, and it is believed that such contamination was negligible. Prior to analysis, the desired samples were removed from the freezer, and allowed to thaw at room temperature. Again, in an effort to prevent contamination, no tissues were homogenized, but were instead cut with a clean, stainless steel knife in such fashion that representative portions were obtained. The samples were then blotted between pieces of clean filter paper to remove excess moisture and weighed to the nearest tenth of a gram. Stainless steel forceps were used to transfer the tissue to acid-washed borosilicate beakers. At least one reagent blank was run with each set of analyses.

Procedure

Fifty milliliters of concentrated nitric acid were added to each sample and the beakers covered with acid-washed Speedi-Vap watchglasses. The beakers were then placed on a hotplate at a low setting (2 or 3 on a Lindberg). The beakers were watched and sometimes swirled until tissues had dissolved and foaming ceased. When the samples were boiling evenly, the heat was increased (5 or 6 on a Lindberg), and the samples taken to dryness. A dry, charred residue remained at this point.

The Speedi-Vaps were then removed, and 50 ml. of 2 to 1 nitric-perchloric acid were added. The samples were then covered with close-fitting, acid-washed watchglasses and again

placed on the hotplate (4 or 5 on a Lindberg). At this point, the solutions were initially brown in color, and as the heating progressed, the color changed to yellow, and finally to colorless. The samples were then evaporated to dryness using high heat (6 or hi on a Lindberg).

The amounts of reagents used for ashing are sufficient to ash about 20 to 25 g. of tissue. Caution must be used when the tissues are ashed in this fashion, however, because of the hazardous nature of hot, concentrated perchloric acid in contact with organic material. The color of the larger samples must be watched carefully, for in the transition from yellow to colorless, the solution may suddenly start to boil with foaming. If this occurs, distilled water or nitric acid must be added immediately to dilute the perchloric acid; otherwise, the sample may turn brown and explode. More 2 to 1 nitric-perchloric acid mixture is added to such a sample, and the ashing is continued.

Extraction

The white residue from the ashing is dissolved with high heat in 5 ml. of concentrated HCl. Fifteen milliliters of dilute ammonium citrate solution, followed by 2 drops of thymol blue indicator, are added to each beaker. The samples are then titrated to a green color (pH > 8) with concentrated ammonium hydroxide and quantitatively poured into acid-washed, 60-ml. separatory funnels. The solution is now extracted with 10-ml. portions of concentrated dithizone (100 mg. per liter) until the extract remains green.

To the dithizone extracts, in another acid-washed, 60-ml. separatory funnel, 10 ml. of 5% nitric acid and 2 to 3 drops of saturated hydroxylamine hydrochloride solution are added. The funnels are shaken for about 1 min. until the dithizone layer turns green again, and the chloroform layer is discarded. The aqueous layer is washed with about 2 ml. of chloroform, and the wash is discarded. The chloroform and dithizone should be drawn off as completely as possible to prevent subsequent errors in color measurement.

Ten milliliters of lead extractive solution are then added to the acid solution, and the sample is shaken with 5 ml. of weak dithizone (10 mg. per liter). The samples may now be compared visually with standards, or measured spectrophotometrically at 510 μ . If the aliquot of the sample contains more than 10 μ g. lead, an additional 5 ml. of dilute dithizone solution are added, and the sample is compared to higher standards similarly treated. A reagent blank is run along with the samples, and its lead content subtracted from the values obtained for the tissue sample.

Standards

- Master Standard: 1.000 mg./ml. 10% HNO_3 (v./v.).
 Intermediate Standard: 0.01 mg./ml. (10 μ g./ml.) 5% HNO_3 (v./v.).
 Working Standards: Most conveniently made in quantities of 100 ml., or more. Standards containing from 0.5 to 10.0 μ g. Pb are so made that 10.0 ml. contain the stated amount of lead in 5% (v./v.) HNO_3 .

To prepare a set of comparison standards for the samples, add 10 ml. of working standard, 10 ml. of lead extractive solution, and 2 drops of sat. hydroxylamine hydrochloride, and 5 ml. dilute dithizone solution to an acid-washed, 60 ml. separatory funnel and shake. The color of these standards will range from green to blue to violet to red. Standards containing up to 10 μ g. Pb may be prepared as stated. For larger amounts of lead, standards containing 10, 15, and 20 μ g. Pb may be made, to which 10 ml. of dilute dithizone rather than 5 ml. are added.

Standard Solutions and Reagents

Only reagent grade chemicals are used in the procedure, and all dilutions are made with distilled water unless otherwise specified.

Master Lead Standard: Dry $\text{Pb}(\text{NO}_3)_2$ at 100° C. for 2 hours. Weigh 1.5980 g. and add to a 1000 ml. volumetric flask. Add 100 ml. HNO_3 and dilute to 1000 ml. with water.

Dilute Lead Standard: Dilute 10 ml. of the master standard to 1 liter with 5% nitric acid in a volumetric flask. Concentration is 0.01 mg. Pb/ml.

Ammonium Citrate, Conc.: 150 g. citric acid and 165 ml. concentrated ammonium hydroxide diluted to 550 ml. with distilled water.

Ammonium Citrate, Dilute: 61.5 g. citric acid and 65 ml. concentrated ammonium hydroxide diluted to 1000 ml. with distilled water.

Lead Extractive Solution: Add 9 g. KCN to 120 ml. dilute ammonium citrate solution, add 315 ml. ammonium hydroxide and dilute to 2 liter.

Strong Dithizone Solution: Dissolve 100 mg. of diphenyl-dithiocarbazon in 1 liter of chloroform.

Dilute Dithizone: Dilute 100 ml. of the strong dithizone solution to 1 liter with chloroform.

Analytical Reproducibility of Muscle Tissue Analyses

The precision of the dithizone method as applied to tissue analysis was tested by taking about 100 g. of muscle from various locations on two different stock rabbits not part of the study group. The muscle was diced thoroughly, and ten 10.0-g. aliquots were ashed and analyzed according to the procedure described. The mean lead content (wet basis) was found to be 0.14 ± 0.01 p.p.m., indicative of satisfactory analytical precision.

Variations in Lead Content of Muscle

A study was made to determine to what extent muscle tissue varied in lead concentration and, hence, whether the analysis of one type of muscle could be considered representative of other muscle tissue in the same animal. Two stock rabbits, not part of the study, were sacrificed, and six different muscles were removed from each animal. Two portions of each muscle were ashed and analyzed according to the usual dithizone procedure. The muscles used and the results obtained are presented in Table IV.

The weight of sample used ranged from 7.6 to 10.7 g., and the standard deviation was 0.03. Inasmuch as all but one value fell within two standard deviations, the analysis of any one muscle is probably representative of all muscle tissue.

Analytical Reproducibility of Bone Tissue Analyses

Because bone samples are considerably different from muscle and other soft tissues, a study was made to determine the precision of the method as applied to bone analysis. Bone samples, obtained from two stock rabbits, not part of the study, were again used for this purpose.

The analysis of bone is somewhat more difficult than that of other tissues. A large amount of residue is present after ashing, and the ash is difficult to dissolve if the procedure used for other tissues is followed. For this reason, the following modifications in the concentration and amounts of reagents were made when bone was analyzed. To a sample weighing 2 to 3 g. or less, add 5 ml. of concd. HCl and heat. Add distilled water until all salts are dissolved, then add 60 ml. of concd. ammonium citrate solution, 2 ml. of 10% KCN solution, and proceed with the extraction using strong dithizone solution.

A total of 83.4 g. of bone tissue were dry-ashed in a muffle furnace at 550° C. The resulting ash weighed 28.6 g. and was thoroughly mixed by grinding in an automatic mortar and pestle. Eleven aliquots of 2.00 g. were treated as described above, and the resulting mean lead content (ash basis) was 1.61 ± 0.12 p.p.m. By using the appropriate factor for converting ash to wet weight, the equivalent lead content on a wet weight basis was 0.56 ± 0.04 p.p.m. It appears on the basis of these data, that good precision was achieved and significant differences in actual samples, if found, could be attributed to the samples rather than to the method.

Table IV. Variations in Lead Content of Muscle

Muscle	Rabbit #1 Mean Conc., p.p.m.	Rabbit #2 Mean Conc., p.p.m.	Mean p.p.m.
Quadriceps femoris	0.13	0.14	0.14
Thigh adductor	0.19	0.15	0.17
Psoas major	0.15	0.10	0.12
Triceps	0.12	0.11	0.11
Pectoralis major	0.14	0.19	0.16
Abdominal	0.16	0.15	0.16

Average concentration in μ g. Pb/g. wet tissue = 0.14 ± 0.03 .

Variations in Lead Content of Bone

Six different bones from two stock rabbits were removed, anatomically identified, and analyzed to determine whether or not bone location influences lead concentration. Two samples of each bone were analyzed, and the results are summarized in Table V. Although some differences are observed, all except one value fall within two standard deviations of the mean, so relatively little error would be expected due to bone selection alone.

Atomic Absorption Analyses

It was initially hoped that atomic absorption analysis would be faster and more convenient than the dithizone procedure actually used, but early attempts at direct tissue analysis were unsatisfactory. Some of the tissue samples were ashed, however, dissolved in 5 ml. conc. HCl, diluted to 20 ml. with

Table V. Variations in Lead Content of Bone

Bone	Rabbit #1 Mean Pb Conc. (wet wt. basis) p.p.m.	Rabbit #2 Mean Pb Conc. (wet wt. basis) p.p.m.	Mean all samples
Long Bones			
Femur	0.68	0.59	0.63
Humerus	0.70	0.56	0.63
Radius & Ulna	0.67	0.86	0.76
Flat Bones			
Scapula	0.80	0.68	0.74
Skull	0.59	0.53	0.56
Ribs	0.45	0.62	0.53
Mean \pm S.D.	0.65 \pm 0.12	0.67 \pm 0.13	0.64 \pm 0.12

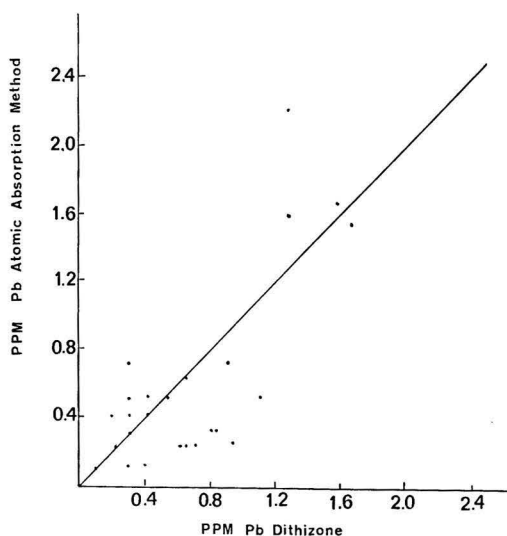


Figure 1. Comparison of analyses performed by atomic absorption and a dithizone procedure.

distilled water, and divided into two equal portions. The first aliquot was analyzed colorimetrically using the dithizone procedure, while the second aliquot was analyzed as in the dithizone extraction procedure, except that the final acid extract was run by atomic absorption. The instrument used was a Perkin-Elmer Model 303 fitted with a Boling burner head, and burning air-acetylene mixture. The lead line at 2170 Å. was measured, and under conditions of use, as little as 0.05 p.p.m. could be detected. As shown in Figure 1, agreement in general was good, but better precision is needed at the lower concentrations.

Results of Analysis

The results of analyzing tissues from as many as 41 rabbits and 46 guinea pigs are summarized in Table VI. The actual numbers of analyses for each of the several tissues are shown and were kept minimal in order that determinations of other metals could be made. In the case of guinea pigs, every tissue from the exposed animals except kidney tissue was found to contain slightly more lead than did that of control animals, but in rabbits, five of the exposed tissues were higher and four were lower. Statistical calculations were made for all tissues, and only bone from the exposed animals was found to be significantly higher in both rabbits and guinea pigs. In Figure 2, the differences are shown graphically, along with *t*-values and significance levels.

The total lead intake of the animals consists of lead from the diet, drinking water, and air, and it is of interest to estimate the magnitude of each source. Several samples of animal diet were analyzed, and guinea pig food averaged 1.3 p.p.m.

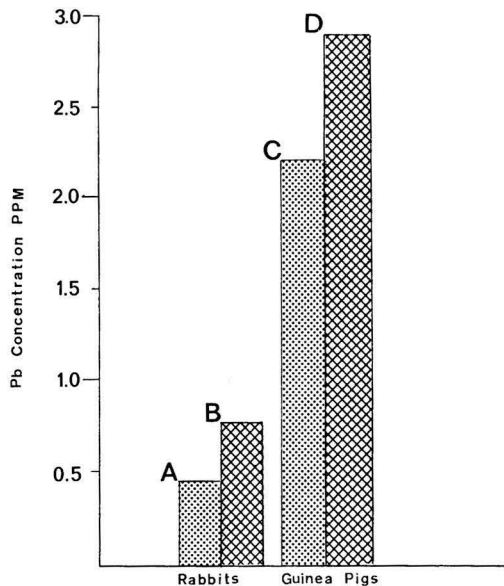


Figure 2. Bone lead levels, p.p.m. Pb, wet weight basis.

- A. Control animals: 0.47 ± 0.16 p.p.m.
- B. Exposed animals: 0.77 ± 0.36 p.p.m. 63% higher than controls; $t = 3.38$, significant at 99.9%.
- C. Control animals: 2.20 ± 0.60 p.p.m.
- D. Exposed animals: 2.89 ± 0.78 p.p.m. 31% higher than controls; $t = 4.27$, significant at 99.9% +.

Table VI. Summary of Rabbit and Guinea Pig Tissue Analyses

	Control Animals		No. of Animals	Exposed Animals	
	No. of Animals	Mean Conc. Pb., p.p.m. Wet Wt. Basis \pm S. D.		Mean Conc. Pb., p.p.m. Wet Wt. Basis \pm S. D.	
Rabbits:					
Liver	10	0.38 \pm 0.27	19	0.50 \pm 0.23	
Lung	9	0.20 \pm 0.18	18	0.26 \pm 0.14	
Kidney	10	0.14 \pm 0.06	19	0.25 \pm 0.16	
Heart	10	0.25 \pm 0.19	19	0.28 \pm 0.18	
G.I. tract	10	0.33 \pm 0.37	19	0.25 \pm 0.16	
Pelt	10	0.12 \pm 0.08	19	0.18 \pm 0.11	
Spleen	10	1.3 \pm 0.8	17	2.0 \pm 1.3	
Muscle	10	0.08 \pm 0.08	18	0.11 \pm 0.11	
Bone ^a	17	0.47 \pm 0.16	24	0.77 \pm 0.36	
Guinea Pigs:					
Liver	12	0.33 \pm 0.27	15	0.37 \pm 0.30	
Lung	13	0.25 \pm 0.19	15	0.47 \pm 0.56	
Kidney	13	0.46 \pm 0.28	14	0.41 \pm 0.26	
Heart	13	0.49 \pm 0.30	14	0.52 \pm 0.44	
G.I. tract	13	0.33 \pm 0.16	14	0.39 \pm 0.25	
Pelt	12	0.19 \pm 0.18	14	0.20 \pm 0.13	
Spleen	13	3.1 \pm 2.0	15	3.2 \pm 2.6	
Bone ^b	22	2.20 \pm 0.60	24	2.89 \pm 0.78	
Muscle	13	0.12 \pm 0.12	15	0.18 \pm 0.21	

^a Ash wt. basis: 1.42 \pm 0.48; 2.22 \pm 1.04.
^b Ash wt. basis: 7.80 \pm 2.13; 8.88 \pm 2.40.

Pb, while rabbit and rat food contained 0.9 and 0.4 p.p.m., respectively. Detroit city water contained 0.0026 p.p.m. Pb. Unfortunately, no samples of diet actually consumed during the study years were saved or analyzed, for at the time there was no thought of performing the detailed lead studies reported here. On the basis of opinions from those charged with caring for the animals, and the suppliers of the diet, however, it seems probable that similar values would very likely have been obtained, for no basic changes are known to have been made. Similarly, no water consumed during the years of exposure was analyzed, but it is a matter of record that lead levels in Detroit water are very low, and intake from water is almost certainly negligible. It should be noted that all of the diets were greater in lead content than the typical human diet, although within the range of values suggested by Lewis (1965), who stated that, "The average daily lead intake from the diet (human) is about 0.3 mg./day, and ranges for most people between 0.1 and 2.0."

On the basis of the analytical data, and several assumptions concerning the quantities of food, water, and air consumed daily, it is possible to estimate the total lead intake as presented in Table VII. All of the assumptions are subject to considerable uncertainty, as are those relating to the probable extent of absorption, so the values cited must be considered suggestive only. In estimating the lead intake by ingestion of food, for example, it was assumed that guinea pigs consume 30 g. and rabbits 170 g. of their diets, containing 1.32 and 0.92 p.p.m. of lead, respectively. Water consumption was estimated to be 50 ml. per day for guinea pigs and 200 ml. per day for rabbits. Air intake was based on minute volumes from the "Handbook of Respiration" of 0.16 liter per minute and 1.45 liters per minute for guinea pigs and rabbits, respectively. By altering these assumptions somewhat and assuming varying degrees of absorption, it is probable that the absorbed doses from inhalation of lead could range from 5 to 50% of the

Table VII. Estimated Lead Intake, Rabbits, and Guinea Pigs

	Est. Daily Intake μ g.	Est. Extent of Absorption %	Amount Absorbed μ g.	Total Absorbed Dose %
Rabbits^a				
Food	160	5	8.0	73
Air	5	50	2.5	23
Water	0.5	100	0.5	4
Total	11.0	...
Guinea Pigs^b				
Food	40	5	2.0	83
Air	0.6	50	0.3	13
Water	0.1	100	0.1	4
Total	2.4	...

^a Length of exposure: 1470 days; calculated lifetime dose: 16.2 mg. Pb.
^b Length of exposure: 1340 days; calculated lifetime dose: 3.22 mg. Pb.

total lead intake, rather than the values shown, but it does appear that the contribution from air cannot be considered negligible.

Discussion

The single important conclusion that appears to result from a study of our data is that the inhalation of urban air containing, on the average, approximately 2.5 μ g. Pb/m.³ can result in a statistically significant elevation in bone lead levels, even though the air exposure is superimposed on a substantially greater dietary lead intake. The health-effects study from which these animals derived failed to disclose any adverse health effects due to this difference or any other parameter of the study. Although by no means could the study results

be considered to have resolved some of the questions concerning the effects of exposure to ambient levels of lead on the health of the community, it is significant that mortality and longevity were identical in the two colonies of animals and no effect on rate of gaining weight was attributable to exposure.

Several factors argue for the validity of the conclusion that increased bone lead levels are attributable to air intake. First, although we lack positive knowledge of the quantity of lead in the diet of the animals, there is no reason to believe that one colony consumed more or less of these diets, offered to them equally *ad libitum* and by the same handlers. Next, the failure of soft tissues to exhibit a significant difference in lead levels is consistent with our understanding of lead metabolism, and would seem to strengthen the finding of elevated bone levels in two different species of animals. Finally, analytical reliability and reproducibility have been demonstrated to be adequate for the measurements made and cannot be responsible for a difference of the magnitude found.

In general, the bone lead levels of the animals are lower than those reported in human bone. Kehoe (1962), for example, states that long bones range from 6.7 to 35.9 p.p.m., with a mean of 18.8 p.p.m., and flat bones range from 2.1 to 11.1 p.p.m., with a mean of 4.7 p.p.m., all values on a wet tissue basis. More recently, Becker, Spadaro, *et al.* (1968) reported finding 5 to 110 p.p.m., average 50 p.p.m. of lead in five specimens of modern human bone ash, and <5 p.p.m. in excavated bones which were several hundred years old. (In our studies, the wet weight of bone is approximately three times the ash weight, and 1.7 times the dry weight.) An analysis of bones from 175 autopsy cases from Los Angeles County Hospital (Nusbaum, Butt, *et al.*, 1965) yielded mean ash concentrations of 69 ± 2 p.p.m. lead, with somewhat more in males than in females, but with no apparent correlation with length of residence in Los Angeles.

Schroeder and Tipton (1968) summarized a great deal of bone lead data, citing an average ash level of 43 p.p.m. in 150 adults from nine United States cities, and much lower values (0 to 12, median 2 p.p.m.) for 23 children between the ages of 0 and 19 years. In addition, considerable variations by geographical area throughout the world are noted, presumably reflecting differing dietary intakes.

Hueter, Conter, *et al.* (1966), and Lutmer, Busch, *et al.* (1967), reported on the results of 15 months of exposure of mice to controlled levels of auto exhaust containing measured concentrations of lead and with levels of 2.6, 7.8, 8.7, and 15.6 $\mu\text{g. Pb/m.}^3$, bone levels (dry basis) of 14.3, 11.2, 13.8, and 20.9 p.p.m. resulted. Control animals with an air exposure of 0.32 $\mu\text{g./m.}^3$ had a bone level of 10.2 p.p.m. Although the lowest level of air exposure, 2.6 $\mu\text{g./m.}^3$ is nearly identical to that of our animals, the resultant bone levels differ, most likely as a result of dietary lead intake which is not described by the authors. Additionally, of course, there may be a species difference which affects the extent of lead storage. Aside from the difference in absolute levels of lead, it is of interest that both the mice study and our study appear to demonstrate that exposure to a low level of atmospheric lead such as 2.5 $\mu\text{g./m.}^3$ can result in increased deposition in the skeleton.

It is probably unwise to extrapolate animal findings such as reported here to predict human responses, for so many variables are involved that uncertainties are great, but it does seem possible that humans with a dietary intake averaging 0.2 p.p.m. lead (Lewis, 1965) breathing air containing several $\mu\text{g. per m.}^3$ could be expected, by analogy, to give

evidence of increased lead storage when compared to a lesser exposed group with comparable dietary intake. Goldsmith and Hexter (1967), reasoning from data resulting from the "Three City Survey," as well as other data, predicted that such differences should exist, and our data appear to confirm this prediction. Using somewhat different assumptions than used by us in Table VII, for example, Schroeder and Tipton (1968) estimated that 17.6% of the total lead absorbed by an adult could come from breathing air containing 1 $\mu\text{g. Pb/m.}^3$. Blood lead levels from several community studies also suggest that some elevation due to inhaled lead is found, but present evidence is somewhat inconclusive. Perhaps the extensive studies now underway will yield conclusive data in the days to come.

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Correction

PHOTOCHEMICAL REACTIVITIES OF AROMATIC HYDROCARBON-NITROGEN OXIDE AND RELATED SYSTEMS

In this article by A. P. Altshuller, S. L. Kopczynski, W. A. Lonneman, F. D. Sutterfield, and D. L. Wilson [ENVIRON. SCI. TECHNOL. **4**, 44-49 (1970)], dosages throughout the text and in Figures 2 through 7 should read p.p.m. \times hr. not p.p.m. per hr.

Study of Lead Levels in Experimental Animals

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It is, indeed, fortunate that it has been possible to obtain concentrations of lead and other metals in the tissues of experimental animals exposed to air from a large U.S. city for approximately 4 years. The unique aspects of this study include these two features: (1) the long-term exposure of four years—few studies, if any, have included exposures beyond 2 years; and (2) the exposure to the identical air to which man has been exposed—most other studies have utilized either a relatively pure lead compound, or auto exhaust, with and without irradiation.

The authors have made it clear that this study on lead levels has been added to a research project which was primarily designed to investigate other factors. Thus, it is no direct criticism of the experimental design to note that the greatest loss from this study, in my opinion, is the absence of information which would demonstrate whether or not the concentration of lead in bone was approaching a steady state by the end of 4 years. It is regrettable that a study unique in its length does not provide data which would indicate the attainment of a potential steady state—that information which uniquely requires such a long-term exposure.

It is relevant to enumerate some of the pieces of missing information which might be desirable for maximum utilization and interpretation of the data. Many of these items are probably available, although unreported, and others might be estimated or obtained by secondhand methods. The items include: the age and weight of the animals at the initiation of the study; the weight of the animals at the end of the study; measurement of weights of organs and tissues for purposes of estimation of the total content of lead in the body; the sex of the animals from which tissue was analyzed for lead; the source and quantity of bone analyzed for lead; relationship between particle size, concentration and diurnal pattern of lead in the particulate matter breathed by the animals; concentration of lead in blood of the animals; and concentration of lead in the bones of the animals at the initiation of the study.

One is tempted, when discussing a research paper, to take liberties with the author's data and, by making assumptions, attempt to interpret to a greater degree than the authors have done. Time does not permit such liberties, if one would do full justice to such efforts, and I will limit myself to one such observation. The authors have noted that Schroeder and Tipton estimated that 17.6% of the total lead absorbed by an adult man could come from breathing air containing 1 μg . lead per m^3 . They have also calculated that guinea pigs and rabbits could receive 13 and 23%, respectively, of their absorbed dose from air containing 2.5 μg . lead per m^3 . It is of interest to calculate that the relative increase of the concentration of lead in bone, presumably attributable to lead in air, is 12 and 36%, respectively, for guinea pigs and rabbits. It would be of considerable additional interest to estimate how much of this absorbed dose was actually retained by the animals over the 4-year exposure period.

The finding of this study was that the concentration of lead

in bones of animals was visibly elevated due to the intake of lead in air. The term "visibly elevated" is used because, I believe, there should have been no question that elevation would occur. The question at issue was, "Is the elevation of sufficient magnitude to be detectable by the methodology utilized?" The answer was affirmative and, I believe, valid.

The conclusion to the study has been interpreted in this manner for a specific reason, and I would maintain that it is not a semantic issue. There appear to be some individuals who have concern for the setting of an air quality standard for lead and who take great stock in the ability to show no visible uptake due to a given exposure. To be sure, it may be comforting, and is indeed relevant to know that uptake under certain conditions is negligible for practical purposes. However, experience in the field of setting standards is replete with examples that show that researchers find increasingly more sensitive methods and that they suggest more subtle criteria, so that what was "negligible for practical purposes" yesterday, today is measurable and requires decisions about its significance. If our logic for setting standards is simply the visible detection of uptake, we are tying ourselves to a system which will inevitably, and with the arbitrary success of research analysts, carry standards to ever lower and lower levels. It may confidently be anticipated, for example, that animals exposed for 10 years to a concentration lower than 2.5 μg . of lead per m^3 will show increased levels of lead in bone attributable to such exposure.

Thus, the basic discussion of this research should not deal with whether or not the findings are applicable to man or the setting of standards. They are certainly applicable in that they provide one landmark of quantitation based on animal models, for an understanding of the relationship between lead in air and lead in the body.

The utility of the findings for setting of standards must await definition of the criteria upon which a standard will be based. This decision has not been brought into proper focus. Should the criteria be: illness based upon colic and anemia, biochemical changes as measured by urinary coproporphyrin and delta-aminolevulinic acid, concentrations of lead in blood, urine or bone, excretion rates of lead, or estimates of body burden of lead. Should the criterion simply be, as some have indicated, progressively cleaner air for its own sake. These possible criteria do not all have direct interrelationships and our discussions about setting standards will remain confused until we consistently and deliberately state our criterion when we interpret data relevant to a standard.

The decisions about criteria bring us face to face with the questions which have long plagued researchers in the field of safety evaluation. Can you have measurable changes within the "normal" range? When are measurable changes desirable homeostatic responses? When are measurable changes permissible and when are they adverse effects? The questions have not as yet been completely resolved for the safety evaluation of lead, but recent progress has been both encouraging and stimulating.

Discussion

Study of Lead Levels in Experimental Animals

Leslie A. Chambers

University of Texas, School of Public Health, Houston, Tex. 77025

The authors of this paper have concluded that "the single important conclusion that appears to result from a study of (their) data is that the inhalation of urban air containing, on the average, approximately 2.5 $\mu\text{g. Pb/m}^3$ can result in a significant elevation in bone levels, even though the air exposure is superimposed on a substantially greater dietary lead intake." Such a finding is consistent with results of other related studies cited by the authors; any other would be surprising.

In view of the persistent hypothesis that exposure, over long periods of time, to lead levels commonly encountered in urban atmospheres may contribute to eventual abnormalities, it seems to me that the major finding might well be set forth in relationship to the results of the extensive study of which the presently reported analyses were a part. The authors note that "the health effects study from which these animals derived failed to disclose any adverse effects due to this difference (in Pb level) or any other parameter of the study."

The "health effects" study referred to was one of two major efforts initiated and supported by the U.S. Public Health Service in an effort to discover any deviations from normality in small animals exposed to polluted urban air throughout their lives. The Detroit study was paralleled by another which I supervised in Los Angeles. We observed rates of weight increase, longevity, frequencies of infections, pathology, numerous aspects of blood and tissue chemistry, submicroscopic changes, respiratory physiology, and behavioral characteristics in large populations of rodents of several species and strains. While it was clear that subtle biochemical and functional changes were detectable, and that

these, in some instances, were associated with peak air pollution episodes, it was equally clear that the observed responses were transitory and not associated with any cumulative or irreversible process reflected at population or individual levels. In brief, our findings support those of the overall Detroit study. It should be recalled that pollution levels in general, and Pb levels in particular, were substantially higher in Los Angeles than those obtained in Detroit.

Our interpretation of the results has taken into account the remarkable physiological adaptability of the organism. The several means of defense available to an exposed animal are activated and mediated through sensory, neurologic, humoral, endocrine, and cellular mechanisms, the functioning of which are detectable with sufficiently sophisticated probes. Similarly, the processes of clearance of foreign substances, or temporary deposition in body sinks such as bone, are detectable. But one should not forget that biochemical variations associated with defense mechanisms are normal. Unless the magnitude of the changes can be associated with some morphological or functional change correlatable with deterioration of some aspect of behavior, well-being, growth, longevity, illness, or death, one can only conclude that the magnitude of the stress imposed is within the limits of organismic tolerance.

Thus, the statistically significant Pb deposits in bones of animals exposed to 2.5 $\mu\text{g./m}^3$ airborne lead associated with other substances should be viewed as positive evidence of biological insignificance. The extreme view that any change necessarily is associated with adverse consequences is neither supportable nor reasonable.

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Water pollution control. A new 6 page brochure describes the company's line of equipment for handling air and gas in water pollution control. Such devices as rotary positive blowers, vacuum pumps, single-stage centrifugal compressors, multi-stage centrifugal compressors, and rotary positive gas pumps are detailed. Scope of services, equipment capabilities, accessories, and advantages of equipment also are considered in "Roots Air Handling Equipment for Water Pollution Control." Dresser Industries **61**

Reference booklet on sanitary landfill. "Sanitary Landfill Methods and Benefits" is an 8 page reference booklet explaining trench and area landfill methods, and citing the benefits of these procedures for garbage and ref-

use disposal. The publication (catalog CM-715) also contains tables for computing annual per capita cost for sanitary landfill, acres per year required for population services, and estimated equipment required, as well as photographs and drawings to illustrate the methods discussed. Allis-Chalmers **62**

Speedy, precise, and convenient metal determinations. The Jarrell-Ash 800 Atomic Absorption Spectrophotometer is described in an 8 page publication. Bulletin 157 includes specifications, applications, component description, and ordering information for the equipment. Fisher Scientific Co. **63**

Pumps, skimmers, and aerator units.

The Floating Saucer line of floating pumps, aerators, and surface skimmers is described in a 6 page bulletin. All models are portable and lightweight, and require no suction or priming. The water and sludge pump can be used for moving up to 42,000 gallons of water per hour; for surface skimming (as in cleanup of oil, gasoline, or chemical spills); and water aeration. The full color publication includes photographs of the various models, as well as a 4 page price list supplement. Acme Products, Inc. **64**

One company's pollution control efforts. "Keep It Clean" is a 32 page brochure detailing the highlights of a steel company's pollution control

(Continued on page 344)

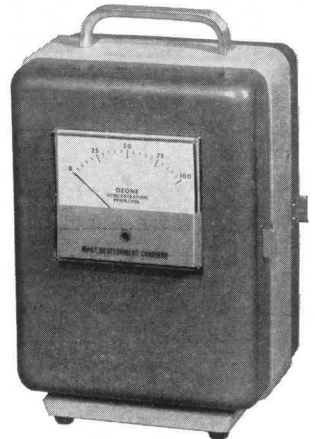
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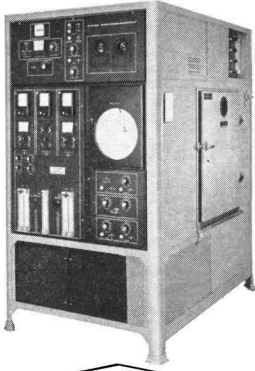
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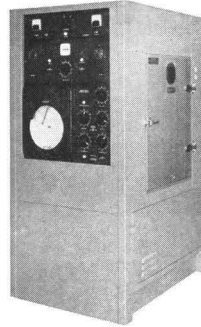
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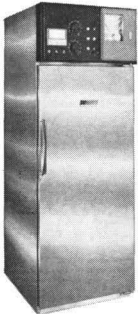
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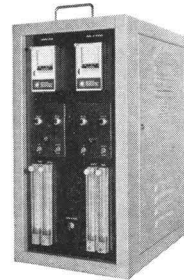


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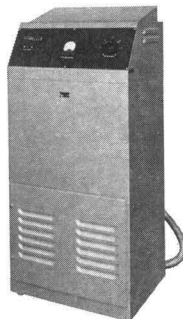
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program. Six sections—pollution is a dirty word; the air we breathe; water, water everywhere; how green are our valleys; research and safety; and a plan of action—comprise the text of the full color publication. Diagrams illustrate how various pollution abatement devices operate in controlling contamination throughout the company's plants, mines, quarries, and shipyard. Also described are the planting programs employed to reclaim wasted areas and restore the natural ecological balance at the mines and quarries. Bethlehem Steel Corp. **65**

Felt materials in air and water pollution control. A 13 page article describes possible applications of various felt materials to air and water pollution control, filtration, vibration dampening and noise reduction, grease and oil retention, etc. Wool felt, needleloomed felts and other nonwoven materials are included, along with specifications, design data, and performance characteristics. Wool, polypropylene, polyester, Teflon, and other synthetic fibers also are discussed. Felt Manufacturers Council. **66**

Preserving wetlands. "Your Wetlands Are Not Wastelands" is a 6 page folder discussing the destruction of Maryland's wetlands. What is happening to these valuable environmental assets, why they must be preserved, and what the individual citizen can do to help are detailed in the publication. Isaak Walton League of America, Maryland Division, 6700 Needwood Rd., Derwood, Md. 20855 (Write direct)

Status report on stream pollution. "Stream Pollution by Coal Mine Drainage in Appalachia" is a 261 page status report (prepared in 1967, revised 1969) of Federal Water Pollution Control Administration studies on the sources and extent of coal mine drainage stream pollution in the area. Topics covered include formation of pollutants in mine drainage, sources of coal mine drainage pollution, water quality evaluation, and subarea discussions. Office of Information, Ohio Basin Region, Federal Water Pollution Control Administration, 4676 Columbia Pkwy., Cincinnati, Ohio 45226. (Write direct)

Effects of urbanizing forests. "Hydrologics effects from urbanization of forested watersheds in the Northeast" is available. Research Paper NE-146 says that urbanization of forest areas tends to reduce interception and filtration, increase overland flow, reduce soil-moisture storage, increase runoff, and reduce water quality. Other results of study into the problem are described. Northeastern Forest Experimentation Station, 6816 Market St., Upper Darby, Pa. 19082 (Write direct)

Water pollution in Great Britain. A 167 page publication discusses the problems of effluent control, and the knowledge and specialized plant available to deal with them in Great Britain. "Water Pollution Control Engineering" includes chapters on such topics as scientific management of pollution control, sewerage, sewage treatment, activated sludge treatment, and role of the consulting engineer. Commercial Department, British Embassy, 3100 Massachusetts Ave., NW, Washington, D.C. 20008 (Write direct)



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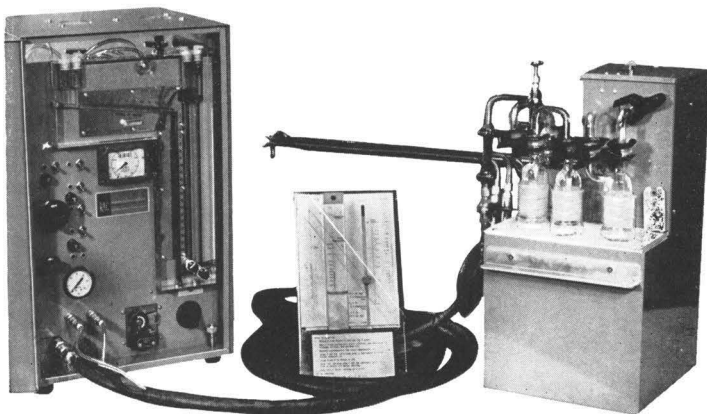
Films

The necessity for solid waste management. "Sink or SWM" is a color sound filmstrip which explains the urgent need for proper management of solid wastes. The terms and technologies in solid waste management are discussed in nontechnical language, and optional courses of action available to communities and counties are explained. Available free of charge to interested individuals and organizations. Tocks Island Regional Advisory Council, 612 Monroe St., Stroudsburg, Pa. 18360 (Write direct)

Ion exchange. "The Role of Ion Exchange" is a 16 mm color and sound motion picture. The 25 minute film attempts to explain the nature and use of ion exchange so as to give experienced chemists and nontechnical personnel alike a fundamental understanding of ion exchange as a process tool. In addition to description of laboratory and industrial applications, the film includes details of setting up ion exchange columns for lab use. Film is available on loan. Ion Exchange Department, Rohm & Haas Co., Independence Mall West, Philadelphia, Pa. 19105. (Write direct)

Solving corrosion problems. "Stainless Steel: Effective Corrosion Control in Water and Waste Water Treatment Plants" is a 20 minute slide presentation and talk of particular interest to those engaged in the purchase, design, construction, or operation of water or waste water treatment plants. The presentation discusses typical problems in such plants and how they can be controlled through use of stainless steel. Such areas as tubing, handrails, gates, filters, and incineration equipment are emphasized, and diagrams, charts, and photographs are used to compare cost, strength, and corrosion resistance of stainless steels with other materials. Committee of Stainless Steel Producers, American Iron and Steel Institute, 633 Third Ave., New York, N.Y. 10017. (Write direct)

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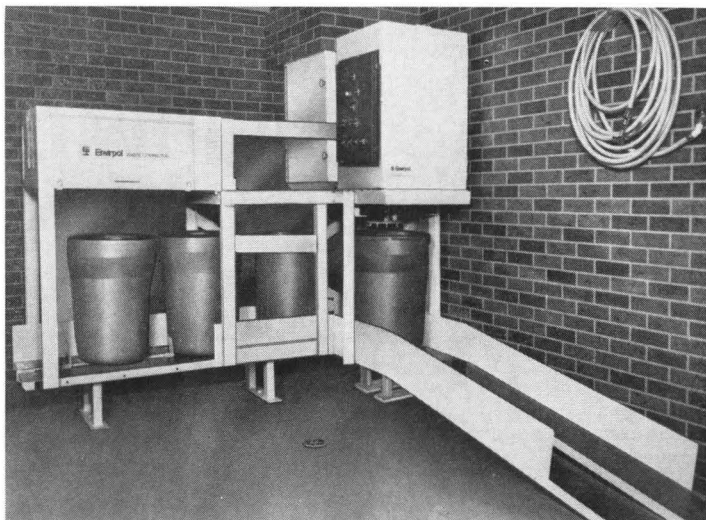


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Waste compaction system

The Enviropol Automatic Waste Compaction System for use in apartment buildings with incinerators is available. The self-contained unit offers automatic change of containers (paper, metal, or plastic), liner to prevent

tearing of bags, straight drop from chute to container, and vertical compaction, the company says. Modular construction allows several types of installation. Environmental Pollution Research Corp. 93

Low cost pollution control

Requiring no maintenance, no external power, and having no moving parts, Static Mixers provide low cost aeration of sludge, mixing of chemical additions to influents, and chemical content sampling, according to the manufacturer. Described as a mixer-in-a-pipe, Static Mixer units are in process systems in chemical plants, refineries, plastics fabrications, blending and reacting liquids, solids, and gases with each other and in combinations. Kenics Corp. 94

Sterilized air

The Echo Filter uses PVA foam rather than conventional filter media to remove microbes from air streams. The company claims that the filters, which are about 1/50 the size and about half

the cost of conventional fiber or granular filters, will—under optimum conditions—remove to 99.99999% of airborne microbes, last for two years, and can be resterilized by steam methods. Dinsmore Instrument Co. 95

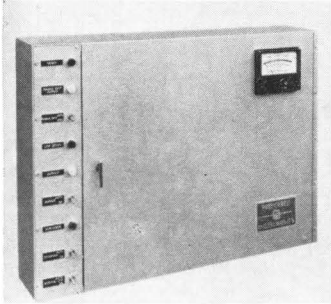
Nonclog pumps

A line of redesigned dry-pit, nonclog pumps for all types of sewage and waste in municipal, industrial, and domestic installations, is available. Having capacities to 5000 g.p.m., and heads to 16 feet, as well as the ability to pass solids to 6 inches in diameter, the four models include: NCVU Vertical Unitype pump; NCP Vertical Frame-Mounted pump; NCF Vertical Frame-Mounted pumps; and NCH Horizontal Frame-Mounted pump. Pacific Pumping Co. 96

Air pollution abatement

A new line of thermal fume incineration equipment for air pollution abatement is available. Providing for capacities to 14,000 s.c.f.m., and featuring modular construction, the incinerators reduce objectionable hydrocarbons to carbon dioxide and water vapor, the company says. Despatch Oven Co. 92

new products digest



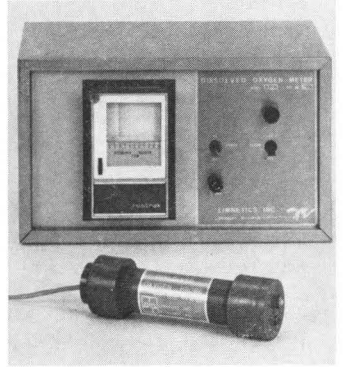
Smoke scrubbing in incinerators

A new Preferred Instruments Control System integrates, times programs, and automatically controls commercial, industrial, and large apartment size incinerator smoke scrubber installations, according to the manufacturer. Controlled high temperature burning and

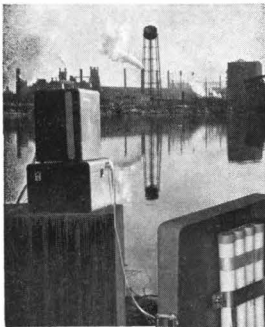
efficient smoke scrubbing result in more efficient incinerator loading, and reduction in emissions of air pollutants, the company says. Preferred Utilities Manufacturing Co. **97**

Water determinations

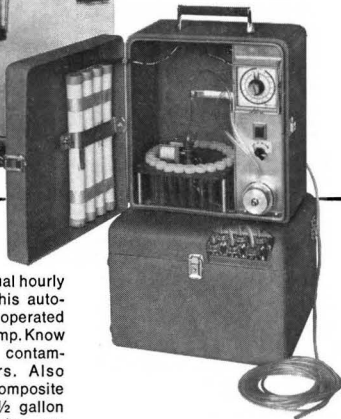
The Model KF-4 Aquameter Titrator for water determinations in solids, liquids, and gases is available. The solid-state titrator consists of two positive displacement buret assemblies to enable an operator to perform Karl Fischer titrations in rapid succession. Moist air is purged from the reaction vessel by electric pump, and the system is protected by drying tubes and vapor trap from ambient moisture. The manufacturer claims that the de-



vice measures water in solids from less than 50 p.p.m. to saturation, in liquids from 10 p.p.m. to 100%, and in gases from 10 p.p.m. to saturation. Beckman Instruments, Inc. **98**



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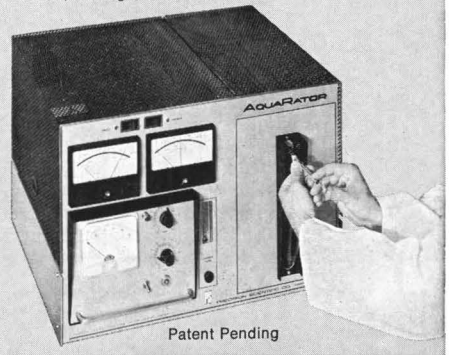
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Volume 4, Number 4, April 1970 347



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Dissolved oxygen analyzer

A new dissolved oxygen analyzer is designed for use in applications requiring continuous on-line submerged operation in waters ranging from pure to concentrated sewage sludge. The company claims that the device—which is resistant to fouling and virtually unaffected by wide variations in temperature, pH pressure, salinity, and flowrate—can be used in concentrations ranging from 20 p.p.m. to 10 parts per billion. Limnatics, Inc. **99**

Aqueous waste disposal

The Liqui-Datur is a unit for complete elimination of liquid industrial wastes. Installations can handle a variety of aqueous wastes, with combustible organic content ranging from 50% or more to virtually pure water, according to the manufacturer. Units are available for any flowrate or condition and feature unattended operation, accurate sensing system, and greater fuel economy. Thermal Research and Engineering Corp. **101**

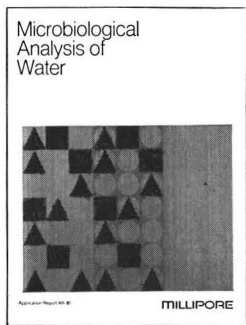
Sewage polishing

The Eddyflow is an upward flow clarifier used for final effluent polishing to enable tertiary treatment to be carried out within an existing conventional sewage plant, by modifying performance of final sedimentation tanks. The manufacturer claims 70% improvement in the quality of a settled effluent through use of the clarifier. Hendrick Manufacturing Co. **102**

Scrubber for lime kiln gases

The AirPol Lime Kiln Gas Scrubber is a venturi scrubber which, the company claims, combines optimum efficiency, minimum maintenance, and low initial cost, and is ideal for all types of kilns and dryers, as well as other pyro processing operations. The device features a flooded wall inlet, absence of jets or nozzles to clog, superior water distribution through use of an open shelf rather than a Weir, and a flooded elbow which allows layers of water and solids to act as a cushion between the metal wall and dust. Air Pollution Industries, Inc. **103**

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Environmental Problems—Pesticides, Thermal Pollution, and Environmental Synergisms. Edited by Billy Ray Wilson. 183 pages. J. B. Lippincott Co., E. Washington Sq., Philadelphia, Pa. 19105. 1968. \$5.25, hard cover. *D. MacDougall is executive director for research and development, Chemaagro Corp., Kansas City, Mo. 64120*

By D. MacDougall

During the past few years, tremendous public interest has arisen in the whole problem of environmental contamination. One small book which has received relatively little public attention and which certainly warrants more is entitled "Environmental Problems."

This book is a series of lectures presented in a symposium at Rutgers Uni-

versity in the spring of 1968 under the title "Graduate Opportunities in Environmental Health Sciences." The book is notable for its readability; the technical subjects are treated in a manner that should be readily comprehended by the general public.

In scope, the text includes a general chapter on environmental health sciences, and chapters on urban development problems, life support for extended manned space flight, behavior of man in his society, pesticides, thermal pollution, and synergism.

The text can in no way be considered to give general coverage of the environmental contamination field. Important areas which are not discussed in detail are solid waste disposal, general air quality, water contaminants other than pesticides, and photochemical smog. However, the book makes up for these deficiencies with

the inclusion of the chapters on the behavior of man in his society, determinants in urban development, and life support equipment for manned space flights. These latter subjects are not usually covered in texts of this type, and the reader will find the subjects well handled and intensely interesting.

I was impressed by the objectivity of all the authors. (Chapter 7 on "The Effects of Pesticides" is the one exception to this general statement.) The concept is put forward by several of the authors that "we cannot avoid modification of our environment and this modification is not necessarily bad." The chapter on "The Effects of Pesticides" takes an extreme position and contains several inaccuracies.

I believe that both scientists and nonscientists will enjoy this informative and entertaining publication. ■



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The Smoake of London: Two Prophecies. Selected by James P. Lodge, Jr. xii + 56 pages. Maxwell Reprint Co., Fairview Park, Elmsford, N.Y. 10523. 1970. \$5.00, hardcover.

The two selections contained in the volume are "Fumifugium: Or the Inconvenience of the Air and Smoake of London Dissipated," by 17th century author John Evelyn; the second work, "The Doom of London," is by Robert Barr. "Fumifugium" contains a graphic description of London's air pollution and the suggested remedy of planting sweet smelling trees. The 19th century "Doom of London" is a science fiction essay.

Advances in Environmental Sciences. Volume I. Edited by James N. Pitts, Jr., and Robert L. Metcalf. 356 pages. John Wiley & Sons, Inc., Publishers, 605 Third Ave., New York, N.Y. 10016. 1969. \$15.95, hard cover.

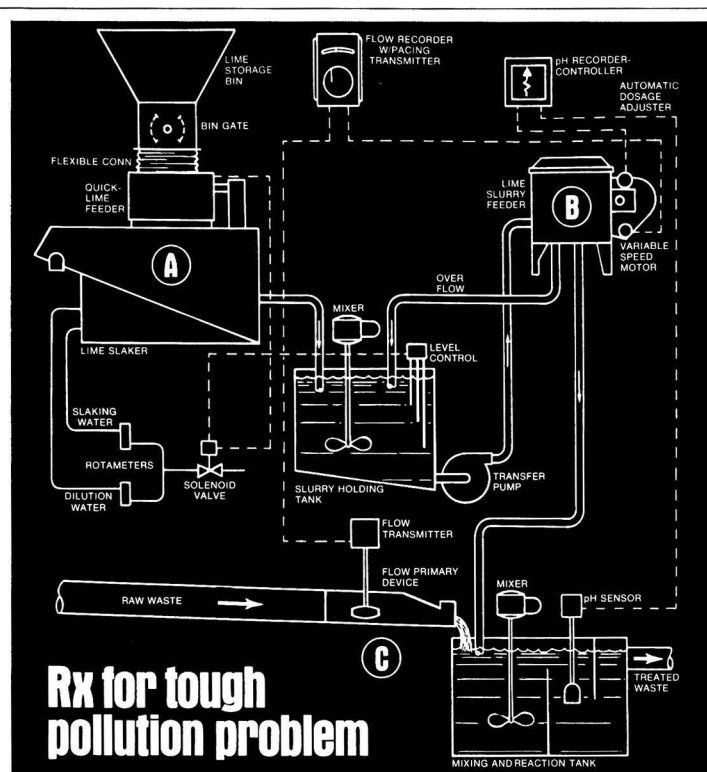
This first volume in a series devoted to the study of the quality of the environment and the technology of its conservation begins with an outline of environmental sciences, including man and environmental quality, air, water, soil, waste, and ecology. Such pertinent topics as the federal role in pollution abatement and control, our nation's water, oxides of nitrogen, and photochemical air pollution are covered in the book.

Master Plan for Solid Waste Collection and Disposal—Tri-parish Metropolitan Area of New Orleans. Final report on a solid waste management demonstration. Public Health Service Publication 1932. 349 pages. Bureau of Solid Waste Management, Environmental Control Administration, 222 East Central Pkwy., Cincinnati, Ohio 45202. 1969. \$5.50, paper.

Universities, National Laboratories, and Man's Environment. Proceedings of a conference. Publication CONF-690705. viii + 167 pages. Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151. 1969. \$3.00, paper.

Solid Waste Management, a Comprehensive Assessment of Solid Waste Problems, Practices, and Needs. Publication #PrEx 8.2:So 4. 111 pages. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. 1969. \$1.25, paper.

Reports of the President's Panel on Oil Spills, 1969: First Report, The Oil Spill Problem. Publication #PrEx 8.2:Oi 5. 25 pages. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. 1969. 35 cents, paper.



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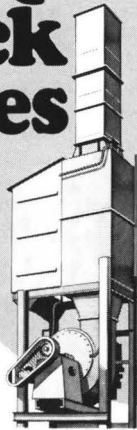
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Air Pollution Control: Guidebook for Management. Edited by A. T. Rossano, Jr. v + 214 pages. Environmental Science Service Div., E.R.A., Inc., 750 Summer St., Stamford, Conn. 06901. 1969. \$15.00, hard cover.

Written to serve as an introduction to the complex problem of community air pollution, this publication discusses basic principles of control, as well as giving a description and evaluation of the problem. Chapters include coverage of such topics as sources of air pollution, methods of air sampling and analysis, measurement and control of community malodors. Chemical, meteorological, and biological aspects of air pollution, and administrative, regulatory, and legal aspects of control also are discussed in some detail. The book concludes with a selected air pollution reading list. ■

Radionuclides in the Environment. A symposium xii + 529 pages. Advances in Chemistry Series 93. American Chemical Society, 1155 16th St. NW, Washington, D.C. 20036. 1970. \$15.00, hard cover. ■

A Systems Study of Solid Waste Management in the Fresno Area: Final Report on a Solid Waste Management Demonstration. xiii + 386 pages. Public Health Service Publication No. 1959. U.S. Government Printing Office, Washington, D.C. 20402. 1969. \$4.00, paper. ■

Winds of Opportunity. Robert Calvert. xi + 309 pages. Scarsdale Press, 222 Nelson Rd., Scarsdale, N.Y. 10583. 1969. \$4.70, hard cover. ■

Effects of Watershed Changes on Streamflow. Edited by Walter L. Moore and Carl W. Morgan. Water Resources Symposium Series, Vol. 2. 316 pages. University of Texas Press, P.O. Box 7819, Austin, Tex. 78712. 1969. \$12.50, hard cover. ■

Environmental Contamination by Radioactive Materials. 746 pages. International Atomic Energy Agency, Unipub, Inc., P.O. Box 433, New York, N.Y. 10016. 1969. \$20.00. ■

Conversion of Organic Solid Wastes into Yeast, an Economic Evaluation. Publication #FS2.2:y₃. 173 pages. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. 1969. \$1.75, paper. ■

meeting guide

April 1-3

American Chemical Society

5th Middle Atlantic Regional Meeting
University of Delaware, Newark

A conference on chemistry and the environment will be a major feature at this meeting. Panels will discuss air pollution, water purification, ocean and estuary chemistry, space chemistry, and a public panel will consider cleaning our environment.

April 1-3

**Houston Junior Chamber
of Commerce**

3rd Annual National Pollution Control
Conference and Exposition

Fairmont Hotel, San Francisco

Theme of this year's meeting is The Environment 1980: Management, Cost, Technology. The 3 day conference will explore programming, planning, and budgeting necessary for government and industry to achieve environmental goals of 1980. Air pollution, water pollution, solid waste problems, noise, and thermal pollution will be considered and discussed at panel sessions and technical meetings.

April 6-8

**Federal Water Pollution Control
Administration, National Canners
Association, and others**

National Food/Wastes Processing
Symposium

Portland, Ore.

The 3 day meeting will investigate research and development efforts on control of pollution by wastes from food processing plants—fruits and vegetables, seafoods, and the like.

April 6-10

Institute of Gas Technology

Symposium on Pollution and Its
Control

IGT, Chicago, Ill.

The 5 day symposium will cover mechanical, chemical, and thermal methods of pollution control, with emphasis on controlling pollution by incineration. The program will include discussion of the history of pollution control, pollutants and their effects, criteria limits, and methods of control.

April 9 and 10

**Duke University, University of North
Carolina, and North Carolina State
University**

19th Southern Water Resources and
Pollution Control Conference

Engineering Auditorium, Duke Uni-
versity, Durham, N.C.

Representatives of government, industry, universities, and private organizations will present papers on such topics as public concern for environmental quality; urban water resources; and economic factors related to oil refining and pollution control. One session will consist of a symposium on classification of waters.

April 12-16

Institute of Environmental Sciences

16th Annual Technical Meeting,
Tutorial Session, and Exposition

Sheraton-Boston Hotel, Boston

The Environmental Challenge of the 70's is the theme of the 5 day session. Topics to be discussed include air pollution—today and tomorrow; hostile environments: human aspects; marine environments; acoustic pollution; and the environment—challenge to communications. A 3 day tutorial will investigate the living environments.

April 14

**Midwest Chapter Filtration Society
and the Chicago Industrial Water,
Waste, and Sewage Group**

Seminar on Air and Water Pollution
Control

Svithiod Singing Club, Chicago

The one day session will seek to cover all aspects of both air and water pollution, as well as possible control techniques. The morning session will be devoted to codes, monies, and approaches to problems, while the afternoon session will consider methods and controls.

April 19-22

**American Association for
Contamination Control**

9th Annual Technical Meeting and
Exhibit

Convention Center, Anaheim, Calif.

Technical sessions will feature presentation of papers on new work or developments for contamination control in industrial manufacturing or processing related to products and environment, or related to biological, pharmaceutical, hospital, or other applications in the life sciences. Subject areas include standards, control of environment, quality control, and packaging. For further information, contact: William T. Mahoney, AACC, Six Beacon St., Boston, Mass. 02108

May 4 and 5

American Medical Association

Congress on Environmental Health

Statler Hilton Hotel, Washington, D.C.

This meeting will include presentation of papers and discussion concerning the population problem in the U.S. and the world, in accordance with the theme The Population Problem and the Physician.

May 22

**New York State Action for Clean
Air Committee**

Spring Meeting

Atmospheric Sciences Research Center,
State University of New York,
Wilmington

In addition to reports of local committees and councils, a program will be presented on the meteorology of air pollution. Also included is a tour of the center's facilities. For information: New York State Action for Clean Air Committee, 105 W. 22nd St., New York, N.Y. 10010

May 31-June 3

**Institute of Fuel, American Society of
Mechanical Engineers, and Institute
of Combustion and Fuel Technology
of Canada**

North America Fuels Technology
Conference

University of Ottawa, Ontario, Canada

Energy from Fuels—New Development from Fuel Technology is the theme of this year's conference. More than 15 papers will discuss such topics as utilization and conservation of fuels resources, trends in fuels science, new applications of fuels technology, and effects of fuels on the environment. For additional information: E. R. Mitchell, 555 Booth St., Ottawa, Ontario, Canada

June 4-5

**Vanderbilt University, Tennessee
Department of Public Health, and
Tennessee Stream Control Division**

9th Annual Environmental and Water
Resources Engineering Conference

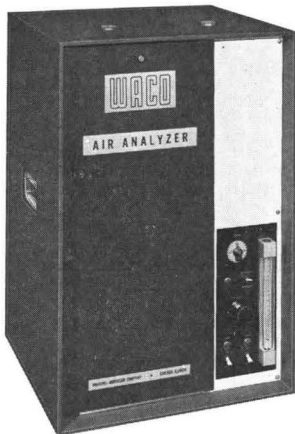
Sheraton Motor Inn, Nashville

Emphasis at the 2 day conference will be on the interrelationship among water resources engineering, water quality control, water supply, and municipal and industrial waste treatment. A concurrent session on air pollution control activities is scheduled.

(Continued on page 354)

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(Meeting guide continued)

June 7-10
Technical Association of the Pulp and Paper Industry

7th Water and Air Conference

Pick Nicollet Hotel, Minneapolis

Papers presented at the conference will cover such topics as air pollution, sludge disposal, water treatment and reuse, and effluent treatment. For information: H. O. Teeple, TAPPI, 360 Lexington Ave., New York, N.Y. 10017

June 14-19
Air Pollution Control Association

63rd Annual Meeting

Chase-Park Plaza Hotel, St. Louis

Aiming to disseminate information about all areas of air pollution control, this year's meeting will include special sessions on implementation plans and national emission standards. Representatives of governmental agencies, industry, and the public sector will participate in the meeting.

July 8-10
American Society of Civil Engineers, and University of Massachusetts

National Specialty Conference on Disinfection

University of Massachusetts, Amherst

Technical sessions and papers to be presented will cover such topics as water disinfection (including sewage and industrial wastes, combined sewage overflow, sludge, and recreational waters), effect of waste water disinfection on natural streams; and air disinfection.

July 21-23
Conference of State Sanitary Engineers, Water Pollution Control Federation, and others

National Symposium on Data and Instrumentation for Water Quality Management

University of Wisconsin, Madison

The contribution that collection and use of data can make to bettering the environment is the central theme of the conference. Papers will cover such topics as basic data requirements to evaluate water pollution and quality control programs; and a systems approach to water quality data management. Six concurrent panels will discuss pertinent subjects, including effective use of approach to water quality planning and data, operation, evaluation and interpretation of water quality data, and remote collection, sampling, measurement and handling of water quality data.

July 22-24
Institute of Water Resources, University of Alaska

International Symposium on Water Pollution Control in Cold Climates

University of Alaska, College

The 3 day symposium will be devoted to papers on waste treatment and receiving stream studies in cold climates. For information: R. Sage Murphy, Institute of Water Resources, University of Alaska, College, Alaska 99701

July 26-August 1
International Association on Water Pollution Research

5th International Water Pollution Research Conference

San Francisco

Technical sessions at this year's conference will include workshop/seminars and presentation of papers and discussion. In addition, air tours of California water projects will be available, as well as a film festival, and the international exhibits. The conference will reconvene in Hawaii from August 3-5.

November 19 and 20
Center for Research in Water Resources, University of Texas

Conference on Conflicts in Water Resources Planning—What Are the Remedies?

University of Texas, Austin

The 2 day session will feature a series of lectures and papers concerning various aspects of the topics water, land, and people; government's role in water resources planning; and ecology as a planning parameter.

Courses

April 16-18
Institute of Environment Sciences

Short Course on Thermal Pollution

Sheraton-Plaza Hotel, Boston, Mass.

Purpose of the 3 day seminar is to acquaint attendees with the problem of thermal pollution and its impact, and to discuss methods of controlling the problem for preservation of our natural resources. Lectures and discussion will cover such topics as the nature of the problem; analysis of the problem; potential solution. Enrollment limited. For information: Institute of Environmental Sciences, 940 E. Northwest Highway, Mt. Prospect, Ill. 60056

**May 12 and 13
Gulf General Atomic, Inc.**

3rd Annual Seminar and Workshop on
Reverse Osmosis
San Diego, Calif.

Lectures and demonstrations will be used to illustrate the principles, economics, advantages, and limitations of reverse osmosis. The short course also will include discussion on equipment and component specifications and reports on the outlook for reverse osmosis applications. For information: Reverse Osmosis Training Programs, Gulf General Atomic, Inc., P.O. Box 608, San Diego, Calif. 92112

**May 25-29
Manhattan College and the Federal
Water Pollution Control Administration**

15th Summer Institute in Water
Pollution

Manhattan College, Bronx, N.Y.

Two one week courses will be offered for advanced study in stream and estuarine analysis and biological waste treatment. U.S. citizens associated with universities and state regulatory agencies are eligible for stipends and travel allowance. For information, contact: Donald J. O'Connor, Environmental Engineering and Science Program, Manhattan College, Bronx, N.Y. 10471.

**June 1-5
Department of Civil Engineering,
University of Missouri**

Short Course on Water Pollution Control
University of Missouri, Rolla

Particular emphasis will be placed on discussion of waste treatment and disposal. Designed for engineers and scientists associated with consulting, industrial, educational, and governmental organizations concerned with pollution control, the course will cover such topics as activated sludge and effects of pollution on the stream environment. For information: Ju-Chang Huang, Civil Engineering Bldg., Rolla, Mo. 65401

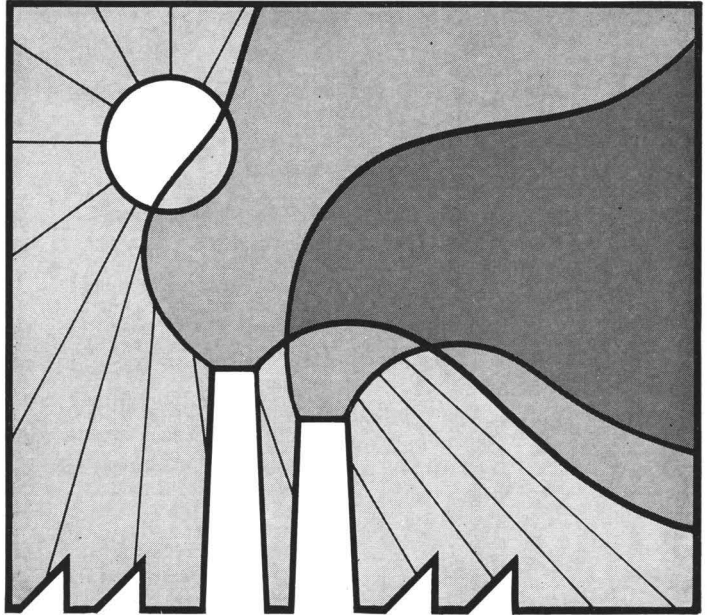
**June 22-August 28
Center for Air Environment Studies**

Training Program in Air Pollution and
Control Administration

Pennsylvania State University, University Park

Funded by the U.S. Public Health Service, the 10 week course is open to any person employed by an air pollution control agency, as well as college juniors, seniors, and graduate students interested in air pollution control administration career training. Credit may be obtained for the course. For information: Director, Specialist Training Programs, Center for Air Environment Studies, 226 Chemical Engineering II, Pennsylvania State University, University Park, Pa. 16802

(Continued on page 356)



Garden City Fans for air pollution control systems

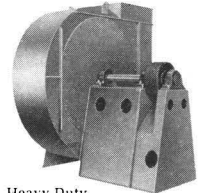
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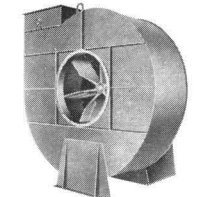
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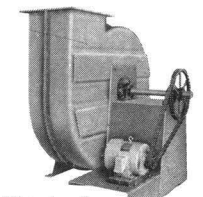
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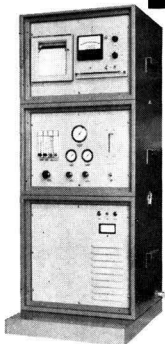
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(Meeting guide continued)

Call for papers

May 15 deadline Purdue University

9th Annual Indiana Air Pollution
Control Conference

Purdue University, Lafayette, Ind.

Proposals for papers are being accepted. Topics include odor (sources, control techniques, measurement, chemical classification of odorous compounds), community air sampling surveys, air pollution from solid waste disposal. For information: David L. Brenchley, Purdue University, School of Civil Engineering, Lafayette, Ind. 47907

May 31 deadline Society of Engineering Science, Inc.

8th Annual Meeting
Washington, D.C.

Theme of the meeting (to be held Nov. 2-4) is environmental engineering. Abstracts are invited on such topics as environments of major U.S. cities, ecological aspects of pollution, and social and legal aspects of environmental pollution. For further information: N. D. Singpurwalla, School of Engineering and Applied Science, George Washington University, Washington, D.C. 20006

July 30 deadline University of Delaware

4th Mid-Atlantic Industrial Waste
Conference

University of Delaware, Newark

Abstracts are being solicited for presentation at the conference to be held November 18-20. Industrial air or water pollution control may be the general topic with particular emphasis on industries in the Mid-Atlantic region. Abstracts should be mailed to: S. K. Banerji, Department of Civil Engineering, University of Delaware, Newark, Del. 19711

Special notice

September 1970 University of Colorado

Federal Water Pollution Control
Traineeships

Financial assistance is available for graduate study in water resources and sanitary engineering. Annual stipends for master's candidates (having a background in engineering, chemistry, or microbiology) are \$2600 per year plus \$500 for each dependent. Applicants should contact: J. E. Flack, Director, Water Resources Program, Engineering Center T4-34, University of Colorado, Boulder, Colo. 80302

University of Illinois, Urbana

U.S. Public Health Service Traineeships
in Solid Wastes Management

An interdepartmental effort, this program leads to an M.S. degree in sanitary engineering, food science, or agricultural engineering, while specializing in solid waste management. Stipend for the one calendar year program is \$2400 plus \$500 for each dependent. Applicants should contact: R. S. Engelbrecht, 3239 E. Civil Engineering Bldg., University of Illinois, Urbana 61801

Colorado State University

Multidisciplinary International Educational and Research Program in Water Resources Management (WATREMAN)

The program supports professional training and research in several academic disciplines involved in water resources management, with emphasis on application to such problems in arid and subhumid areas of the U.S. and less developed countries of the world. Graduate research assistantships and graduate teaching assistantships are available to qualified applicants. Programs lead to M.S. and Ph.D. degrees. For information: Maurice L. Albertson, Office of International Programs, Colorado State University, Fort Collins, Colo. 80521

University of Washington

Air Resources Program

This program of study and research in the field of air resources leads to degrees of M.S. and Ph.D. Graduate students in the program may specialize in the engineering or scientific problems related to air resources. For information: A. T. Rossano, Jr., Department of Civil Engineering, University of Washington, Seattle, Wash. 98105

Johns Hopkins University

Interdepartmental Graduate Training
Program in Air Science and Management

Students at master's and doctoral level are enrolled in the participating departments, studying a variety of air pollution related topics. Focus of the training program is a core seminar in which outside speakers present various aspects of air pollution research and control. Persons interested should contact: Jerome Gavis, Department of Geography and Environmental Medicine, Johns Hopkins University, Baltimore, Md. 21218

September 1970 Pennsylvania State University

Program in Air Pollution Control
Technology

This 2 year associate degree program aims to train graduates for work as air pollution control technicians. Applicants must be graduates of an accredited secondary school. For further information, contact: H. W. Perkins, Berks Campus, 814 Hill Ave., Wyomissing, Pa. 19610

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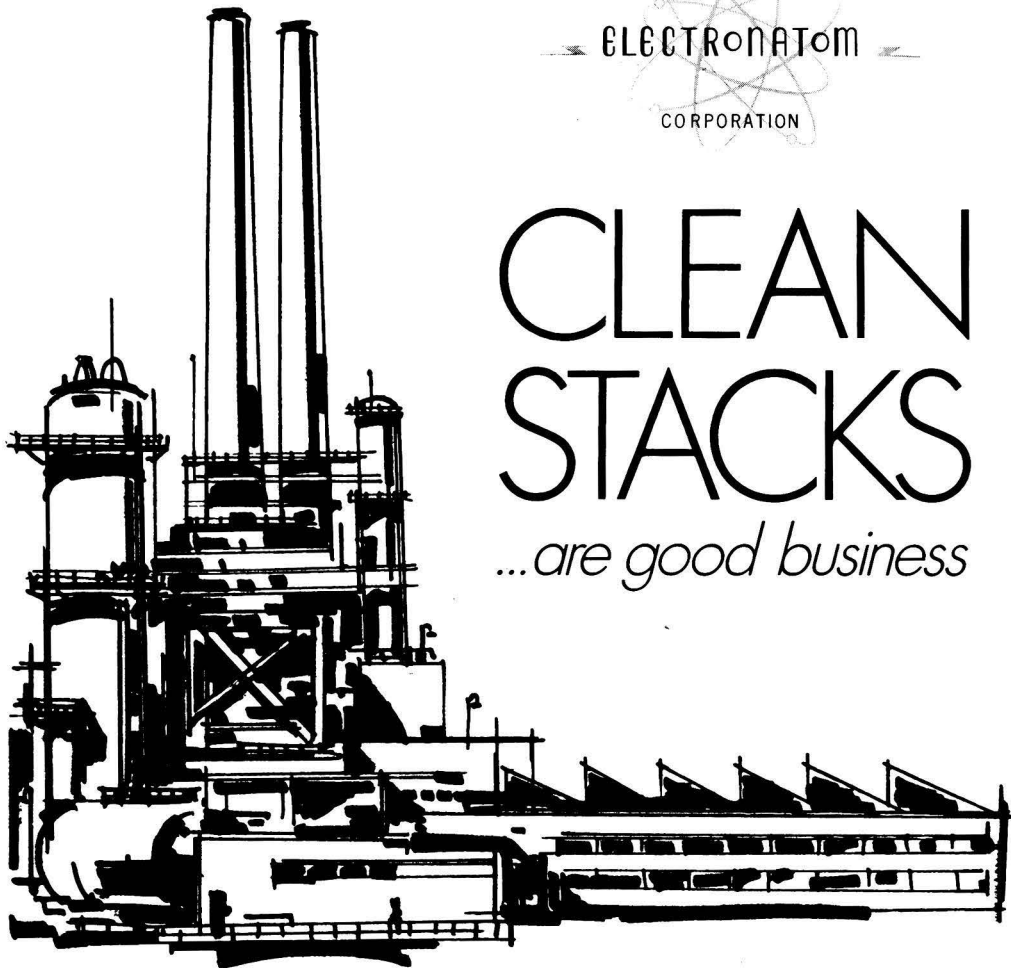
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