# Environmental Science & Technology DECEMBER 1971

ห้องสมุด กรมวิทยาศาสตร์ Clean energy from coal 1178



# Introducing a breath of fresh air..Cen-Trific-Air.

MECHANICAL SEPARA-TION AND CLASSIFICATION INTEGRATED WITH CHEMICAL ABSORPTION IN ONE COMPACT UNIT

PREDESIGNED BASIC OPER-ATING UNITS WHICH CAN BE TAILORED TO YOUR SPECIFIC PROCESS REQUIREMENTS

COMPACT • RECIRCULAT-ING • LOW MAINTENANCE

MODULAR DESIGN CON-CEPT USING STANDARD INTERCHANGEABLE SUBAS-SEMBLIES WHICH PERMIT EASY AND ECONOMICAL UPGRAD-ING AS YOUR SYSTEM NEEDS CHANGE

#### A FIELD PROVEN, PAT-ENTED, PRODUCT SYSTEM OFFERING THE FOLLOWING ADVANTAGES-

First stage dry separation/collection with integral wet second stage model DW

First stage wet separation/collec-

tion with integral wet second stage model WW

Isolated separate liquor chemistry for first and second stages of the WW model

Two stage recirculating sump for effective by-product removal, and liquor chemistry make-up

Integral foam control baffle permitting high energy design when needed

Final stage after-filter for controlled air discharge to ambient or for recycling into plant, and optional use of filter media

Final after-filter permits use of a third liquor system when required by the nature of the contaminents

Proven nozzle application technology

Balanced mechanical/chemical system for dependable long service

Can be operated as a negative or positive pressure system

Economy of – operation, and initial purchase

Complete system with-pumps, piping, nozzles, control valves, inspection ports, media, gasketing and warranty

Circle No. 3 on Readers' Service Card

UNITARY AND MODULAR CONVERGENCE TUBE DESIGN PRODUCTS PROVEN PERFORM-ANCE

Standard single convergence tube design from 100-10,500 CFM

Standard modular convergence tube design from 10,500-25,000 CFM

Application engineered modular tube designs over 25,000 CFM

Application engineered modular tube design units for critical process needs are available from 100 CFM– upward

All Cen-Trific-Air® product systems are application engineered to meet each individual process variable

Materials of Construction: steelalloy steel-stainless steel-fiberglass-PVC-PPL-PE

Send for your Klean-Air-Kit and brochure to

Cen-Trific-Air Products, Inc. One Planet Drive Ridgefield Park, New Jersey 07660



CEN - TRIFIC - AIR PRODUCTS, INC. INDUSTRIAL AIR POLLUTION CONTROL EQUIPMENT

### Environmental

Science & Technology

Volume 5. Number 12 December 1971

#### Editor: James J. Morgan

WASHINGTON EDITORIAL STAFF Managing Editor: D. H. Michael Bowen Associate Editor: Stanton S. Miller Assistant Editor: H. Martin Malin, Jr. Editorial Assistant: Carol Knapp Lewicke

MANUSCRIPT REVIEWING Manager: Katherine I. Biggs Assistant Editor: Norma Yess

MANUSCRIPT EDITING Associate Production Manager: Charlotte C. Sayre

Editorial Assistant: Julie Plumstead

ART AND PRODUCTION Director of Design: Joseph Jacobs Production Manager: Bacil Guiley Associate Production Manager: Leroy L. Corcoran Art Director: Norman Favin

Layout and Production: Dawn Leland

Advisory Board: R. F. Christman, G. F. Hidy, P. L. McCarty, Ulrich Merten, J. C. Morris, C. E. Moser, P. K. Mueller, E. D. Palmes, J. N. Pitts, Jr.

AMERICAN CHEMICAL SOCIETY 1155 Sixteenth St., N.W. Washington, D.C. 20036 Executive Director: Frederick T. Wall

**Books and Journals Division** Director (Acting): John K Crum Head, Business Operations Dept .: Joseph H. Kuney

Assistant to the Director: Ruth Reynard

ADVERTISING MANAGEMENT Century Communications Corp. For offices and advertisers, see page 1234

Please send research manuscripts to Manager, Manuscript Reviewing, feature manuscripts to Managing Editor

For author's guide and editorial policy, see April 1970 issue, page 303 or write Manager, Manuscript Reviewing. In each paper with more than one author, the name of the author to whom inquiries should be addressed carries a numbered footnote reference.

Copyright 197 by the American Chemical Society ESAT ON MICROFLIA. This publication are table to microfilm, Special Issues Sates, ACS, 1155 Sisteenth SL, N.W., Washington, D.C. 2008 SUBSCRIPTION SERVICE: All communications related to handling of subscriptions, including notification of CHANGE ment, American Chemical Society, 155 Sisteenth SL, N.W., Washington, D.C. 2003. Change of address notification should include both old and new addresss, with ZIP numbers, and be accompanied by mailing label from a recent issue. Allow SUBSCRIPTION RAFECT SPIT: Members, domestic and for-eign, 1 yeer 35.00; nonmembers, domestic and foreign, 57.00; SUBSCRIPTION RAFEST PIT: Members, domestic and for-eign, 1 yeer 35.00; nonmembers, domestic and for-eign, 1 yeer 45.00; nonmembers, will not be allowed if tracelved compared because of failure to notify a Scietar. No clams ellowed because of failure to notify a Scietar. No clams ellowed because of allower to notify its and tracelar Chemical periodice. The fourth of the American Chemical Society, form Published monthy by the American Chemical Society, form

Those interested in joining the American Chemical Society should write to Admissions Department at the Washington Orice, hed monthly by the American Chemical Society, from 20th and Northamption Star, Esston, Person, 18042 Executive Offices, Editorial Headquerters, and Subscription Service Department, 1155 Sixteenth St., N.W., Washington, D.C. 2006. Advertising Office: 142 East Ave., Norwalk, Conn. 0851. Second-class postage paid at Washington, D.C. and at Addi-tional Maaing Offices. The American Chemical Society assumes no responsibility for the attements and opinions advanced by contributors to its publications.

#### Features

- 1178 Gas from coal: fuel of the future by Alex Mills, U.S. Bureau of Mines
- 1184 Strategies for control of man-made eutrophication by Richard Grundy, U.S. Senate staff

#### Outlook

- 1168 NYC—A nice place to visit; Kretchmer likes living there
- 1170 Waste heat is a tough problem for the foreseeable future
- 1174 EPA puts the squeeze on Hawaii's sugar cane mills
- 1176 Uncle Sam begins to clean up his own back yard

#### Departments

Letters 1158	New literature 1226	
Editorial 1159	Bookshelf 1227	
Currents 1161	Meeting guide 1229	
Industry trends 1223	Professional consulting services	1231
New products 1124	Classified section 1234	

Current research contents 1155

#### Annual index, vol. 5, 1971

Names 1235

Subjects 1238

### contents

### Reactions of gaseous pollutants with solids. I. Infrared study of the sorption of SO $_2$ on CaO 1191

M. J. D. Low, A. J. Goodsel, and N. Takezawa

The technique of infrared spectroscopy has been so successfully applied to heterogeneous catalysis that it was chosen as a means to investigate the fundamental interactions of CaO and SO<sub>2</sub> in stack gas environments. The main interaction is irreversible and leads to the formation of a surface sulfite. Heating in oxygen results in species resembling bulk CaSO<sub>4</sub>.

#### A controlled environment for trace metal experiments on animals 1196

L. M. Klevay, H. G. Petering, and K. L. Stemmer

Animal quarters and support facilities can now be constructed which permit rigid controls of the exposures of various metallic elements. Control of both harmful and beneficial elements is achieved through air filtration, water demineralization, dietary purification, and use of cages which do not contribute to dietary intake.

#### Lead contamination of some agricultural soils in western Canada

M. K. John

The lead content of some 700 agricultural soil samples from British Columbia has been correlated with the concentration of industrial and population centers. The soluble lead content ranged from 0.5–180 ppm in the agricultural soils but went as high as 59,580 ppm for surface samples collected near a battery smelter.

### Selenium in lake sediments—Analytical procedure and preliminary results 1203

J. H. Wiersma and G. F. Lee

The selenium content of sediments from 11 Wisconsin lakes and one South Dakota reservoir ranged from 1-3  $\mu$ g Se per gram of dry weight sediment. A sensitive fluorometric method for the selenium determination is described. No selenium buildup in the sediments of the lakes studied was recognized.

#### An empirical method for determining the concentration of solids in suspension 1206

J. W. Liskowitz

The optical method for measuring mass concentration of suspended solids in hydrosols is useful in monitoring water pollution because it offers rapid and continuous operation. Measurement of the so-called depolarization of back-scattered polarized radiation shows promise as a method for determining the concentration of particles in suspension and can be applied to streams, waste waters, and sewage.

#### Spark replica technique for measurement of sulfuric acid nuclei 1211

J. E. Stickney and J. E. Quon

In the past, the spark replica counting technique has been used for the counting of nuclear particles; now, it has been adapted to count sulfuric acid aerosols. The technique offers the potential of counting the reaction spots of submicron particles without the aid of an electron microscope. The technique involves exposure of a thin plastic film to a sulfuric acid aerosol and counting the number of defects (holes) in the film.

#### Communications

Characterization of four major components in a technical polychlorinated biphenyl mixture 1216

A. C. Tas and R. H. de Vos

Polychlorinated biphenyl, such as the commercial Phenochlor DP 6, constitute isomeric materials, all of which are referred to generically as chlorinated biphenyls. The four isomers have been separated by gas chromatography and identified.

#### A smog chamber study comparing blacklight fluorescent lamps with natural sunlight 1218

J. L. Laity

1199

The use of blacklight fluorescent lighting is justified in laboratory investigations of photochemical smog. In a direct comparison of this lighting with artificial and natural sunlight of comparable experiments in a glass chamber, only slight discrepancies were observed.

#### High-speed collection of organic vapors from the atmosphere

A. Dravnieks, B. K. Krotoszynski, J. Whitfield, A. O'Donnell, and T. Burgwald

Atmospheric odorous materials can now be extracted by adsorption on polymeric materials. The system works with materials at concentrations as low as  $10^{-10}$  g/l. of air. The materials are extracted at the rate of 4 l./min and then transferred to a gas chromatographic column for identification. The entire method of sampling and transfer is reproducible to within  $\pm 3\%$ .

#### Correction

Hydrocarbon composition of the atmosphere of the Los Angeles Basin—1967

1222

1220

A. P. Altshuller, W. A. Lonneman, F. D. Sutterfield, and S. L. Kopczynski

This article appeared originally in ES&T, October 1971, p 1009.

Photo credits: 1167, The Firestone Tire & Rubber Co. and Sugar Research Foundation, Inc.; 1168, Joe Phillips; 1171, WAPORA, Inc.; 1172, Zurn Industries, Inc.; 1174, Marty Malin; 1184, 1185, Minneapolis (Minn.) Star. Cover: Norm Favin and Joe Phillips

# There are two ways to analyze air quality.



# **Technicon does them both!**

Air quality can be determined by continuous analysis of ambient air on-site, or by analyzing impinged samples in the laboratory. Technicon has AutoAnalyzer®systems that meet both these requirements.

The Air Monitor IV is a completely automated, compact, self-contained unit that is versatile enough to allow easy change of location and test parameters, and rugged enough to monitor many of the critical chemical constituents in air (including SO<sub>2</sub>, NO<sub>2</sub>, NO<sub>x</sub>, total aldehydes (MBTH method), H<sub>2</sub>S, F, NH<sub>3</sub>, Cl<sub>2</sub>, and total oxidants) 24 hours a day, every day.

For individual impinged samples, the Industrial AutoAnalyzer®II is the most advanced system for performing automated chemical analysis. It is capable of analyzing virtually any chemical constituent in air from impinged samples 10 times faster and at one-tenth the cost of manual methods. In addition, the unique design of AutoAnalyzer II analytical cartridges makes it easy to change from one parameter to another in minutes.

Both the Air Monitor IV and AutoAnalyzer II utilize the principles of continuous flow analysis, which insure superior performance and results, sample after sample. Both systems use Technicon's new industrial colorimeter which permits linear readout of test results, with a telemetry output that facilitates data handling and storage capability.

An additional plus with all Technicon® systems is free training, unmatched service, and fast reagent order processing from any one of six distribution centers located throughout the United States.

For more information about Technicon AutoAnalyzer systems for air analysis, write to Department 131:



**Technicon Industrial Systems** A Division of Technicon Instruments Corporation Tarrytown, New York 10591

Circle No. 14 on Readers' Service Card

### letters

#### Nothing new under the sun

#### DEAR SIR:

Your article on alternatives to pesticides (May 1971, p 399) has two prime examples of how information, although well known by many people in one area is somehow not available to others who need it!

"A USDA laboratory in Hawaii has applied methyl euginol to 1-in. cardboard squares . . . and demonstrated the eradication of the oriental fruit fly . . ." For many years, Honolulu residents have set out jars of water, added a few drops of citronella, and collected male fruit flies by the thousand.

"Eventually, perhaps, both parasites or predators could be mass produced and released into the environment to help attack various pests." The Hawaiian sugar industry has been doing this for over 60 years, with such success that we need not worry about the environmental effects of insecticides; we do not use them.

#### Hugo P. Kortschak

Hawaiian Sugar Planters' Assn. Honolulu, Hawaii 96822

#### **Ecological tragedy at Franklin**

#### DEAR SIR:

If I were to write a book entitled "Contemporary tragedies resulting from a misunderstanding of the ecological perspective," I would include the Franklin, Ohio solid waste plant as a prime example (ES&T, October 1971, p 998).

The basic thrust of ecology (household study) reveals that the reductionist philosophies and methods of science, engineering, economics, and politics have precipitated a multifaceted survival crisis. Our present enforcement and technological focus on pollution control is not an example of applied ecology but an extension of reductionist thinking. Such myopic vision must be replaced with holistic resource planning and administrative and accounting procedures. I believe that while the plant at Franklin is an example of what is "possible" now, we must move on and accomplish what is the most desirable solution. This movement will not be alluded to, planned for, or attempted if we continue to think of pollution control as the ultimate goal. We must maximize resource utilization and reuse and minimize our per capita draw of resources from the environment.

As a nation in which 7% of the world's population now utilizes over half the world's resources, our task is not waste reduction, or disposal, but maximum utilization of every pound of material and Btu that supports our standard of living. This will only come to pass when representatives of basic resource industries, manufacturers, secondary material dealers, bankers, government agencies, and consumer groups all jointly face the task of minimizing our impact on the common household.

Clifford C. Humphrey, Director Ecology Action Educational Institute Box 3895 Modesto, Calif. 95352

### An environmental chromatograph from the people who build process chromatographs.

You know us. We build first-rate process chromatographs. And now, we're using the same technologies to build environmental chromatographs, too. Same sampling techniques. Same analytical skills. Using hydrogen flame-ionization detectors, our chromatograph detects methane, carbon monoxide and total hydrocarbons. Sensitivity? To an incredible parts per billion.

Operation is automatic, too. Concentrations are automatically recorded on a moving strip chart.

Our environmental chromatograph is just one weapon in an arsenal of equipment we offer to help you fight the dirty dozen, today's twelve most common air pollutants: total hydrocarbons, NO,  $NO_X$ , CO,  $CO_2$ ,  $SO_2$ ,  $SO_3$ ,  $H_2S$ , mercaptans, phosphorous,  $O_3$ ,  $NH_3$ .

Whether you want to tackle one or the whole dirty bunch, we have the detection capability to help you do it. The Bendix Corporation, Process Instruments Division, Ronceverte, W. Va. 24970. (304) 647-4358.



**Bendix** 

Bendix declares war on the dirty dozen.

Circle No. 22 on Readers' Service Card

### editorial

### Hurrah for the end of an era

Confrontation on environmental issues won't disappear, but the raw antagonisms of the past are fast fading

Our next issue will mark the beginning of the sixth year of ES&T's existence. As 1971 draws to a close, it is instructive as well as enjoyably nostalgic to look back over our first five years and to see whether, on balance, the nation and the world have made any progress in solving environmental problems. Despite much of the cynicism and frustration that we, among others, have felt from time to time and in fact have expressed on this page, there seems now to be little doubt that real, tangible progress has, in fact, been made. Painfully slow progress, to be sure, but progress for all that.

One of the reasons why we can express what diplomats always seem to call "cautious optimism" is that the protagonists in environmental battles are moving closer together philosophically—something that they themselves may not yet realize. On the one hand we have the "environmentalists"—the term coined by the media for the loosely coordinated group of conservationists, university professors, and concerned citizens and allied thorns in the corporate side. On the other, we have "industry," that supposedly monolithic collection of cigar-chomping boors bent solely on profit and environmental destruction. A remarkable development that has occurred during the short life of ES&T is the shift in attitudes of these two groups.

Environmentalists are no longer naive birdwatchers and little old ladies. They have become better organized, better informed (although still prone to making unsubstantiated charges). Most important of all, they have learned how to use legal and political machinery as well, if not better, than their corporate opponents. And industry has changed its attitude toward environmental concerns so radically and in so short a time that environmentalists' distrust of the change is both apparent and understandable. In our opinion, industry's remarkable metamorphosis from inward looking chrysalis to socially responsible butterfly is both real and encouraging. It is, in fact, a major factor that is surely going to enable us to win the shortterm war against pollution. (The long-term war is another matter.)

The plain fact is that the country has changed, and it is highly unlikely to change back. Quite simply stated, people want a cleaner environment, their political representatives want to get it for their constituents, and a growing number of businesses are staking their financial future on making the hardware and providing the services that will eventually ensure that the environment truly will be cleaner. The number of people who will benefit—socially and financially from control of pollution is rapidly exceeding the number of those who benefit from its continuance. Given the American political system of compromise between adversary positions of relative strength, it is not difficult to see who will ultimately win and who, in fact, is winning right now.

The tangible signs of progress, true, are not so numerous to justify complacency. But they are there: lower sulfur dioxide levels in cities, many rivers are cleaner than they were 10 years ago, and new plants are replacing old ones that were gross polluters. Current progress allied with that which will undoubtedly be made under the whip of a fired-up, strongly mandated federal bureaucracy make it look to us as if 1984 will be a much brighter day than painted either in Orwell's novel or the books of the doomsday folk.

The dangers lurking in the background that we have barely begun to tackle, however, are those connected with undisciplined growth of populations, and industrialization. Getting rid of gross air and water pollution in the seventies will be child's play compared to arranging the social and political changes needed to consolidate our gains in the years after 1980.

J. H. Mirael Rowen



# Would you fall for a line like this?

... when knowledgeable metal cleaning experts faced with the elimination of TRICHLORETHYLENE —know that it takes far more than just a solvent switch to provide a maximum efficiency cleaning operation?

Baron-Blakeslee doesn't make wild claims about solvent savings—but we do deal in definitive, proven degreasing operations that make *whatever* solvent you switch to deliver maximum cleaning efficiency. Because your metal cleaning operations must deal with hard realities rather than vague promises, we have prepared an easy-to-understand guide to the new National Ambient Air Quality Standards as set forth by the Federal Environmental Protection Agency (EPA).

It tells you what you need to do *now* about the restrictions on TRICHLORETHYLENE— and gives you solid help in reducing parts cleaning costs.

Here's the real scoop on efficient metal parts cleaning— prepared by the company that has spent 35 years developing America's broadest line of solvents and degreasing systems.	THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NAME TITLE COMPANY ADDRESS	AND HOW ITS REGULATIONS WILL AFFECT VAPOR DEGREASING
ADDRESS CITY/STATE/ZIP B B B B B B B B B B B B B B B B B B B	Baron Blakeslee

#### WASHINGTON



Sidney Marland

#### ON White House announces high school awards program

The President's environmental merit awards program is aimed at recognizing individual or group environmental achievement at 38,000 high schools throughout the nation. Sidney P. Marland, Jr., U.S. Commissioner of Education, and EPA personnel will explain the program to principals throughout the U.S. along with the criteria for judging projects. Later, an awards panel composed of faculty, student, and community representatives will be appointed by each participating school principal. Examples of the types of programs include: • Environmental awareness projects such as ecology fairs, and publications in school newspapers • community services such as operating waste recycling centers and • public affairs such as presenting environmental information to zoning boards and sewage districts.

#### EPA: baseline data and performance standards

Baseline environmental data for both air and water simply are not known with any certainty in some areas. The quality of coastal water will be monitored under a national program that is being developed by Interstate Electronics Corp. Data for air quality in the southwest area of the U.S. are also inadequate. As part of the southwest energy study, data are being collected till the 20th of this month to establish a baseline. EPA will be making recommendations on the most practical air monitoring network to yield continuous air quality data. Last month, EPA administrators met with a number of electric power utility executives in Washington, D.C. concerning the impact of regulations on their industry. Performance standards for new stationary source emissions are due imminently (Es&T, September 1971, p 749).

#### Corps' permit program is making headway

By the end of October, approximately 20,000 firms and individuals had applied for permits under the Refuse Act program of the Corps of Engineers which was announced last December. Of these, 15,000 are from the so-called critical industries which were required to furnish detailed chemical analyses of their effluents. More than 8300 of the applications have been processed by the Corps' district field offices, sent to the EPA regional offices for review, and referred to appropriate state water pollution control agency for certification. "The program is just beginning and, although a few permits have been issued, it may be two years before some of the more complicated applications are completely processed," says Lt. Gen. F. J. Clarke, chief of the Army Corps of Engineers.

#### What are the economics of recycling solid wastes?

Recycling sounds good, but how economical it is no one is quite sure. The National Commission of Materials Policy, authorized by the Resource Recovery Act of 1970, has started looking into this question, and Jerome L. Klaff, chairman of the seven-member commission, told the Joint Economic Committee that its principal charge is to recommend incentives and disincentives to accelerate the reclamation or recycling of materials for solid waste. The Commission's findings are due June 30, 1973, by Klaff indicated that some first estimates may be forthcoming by mid 1972. Among the specific studies is one designed to determine the best means for extraction, development, the use of materials which are susceptible to recycling, reuse, or self-destruction.

### Olin has found a way of monitoring mercury in air and water. We've installed it in our own plants. Now we offer it to the world.

Years ago, "mercury pollution" wasn't a problem.

But now it is.

Trouble is, there's never been a way to measure continuously the exact extent of the mercury pollution to do something about it.

But now, there's a precise way. Because we've developed it.

The Mercury Monitor.

And we've been using it. For a year now.

The Mercury Monitor analyzes, detects, measures, and records traces of mercury (in any of its forms) ranging from zero to five parts per billion. Instantly. Automatically.

Around the clock. (Without an attendant.)

It's so efficient it measures pollution levels constantly, to prevent a momentary discharge from becoming a major problem.

Right now, there's a Mercury Monitor working to help keep Niagara Falls clean.

There's one at Weyerhaeuser's plant on the Columbia River in Washington.

And there's one doing a job on Puget Sound.

And overseas too. We're installing one right now in Europe.

We believe the Mercury Monitor can help.

Help immeasurably.

We know. Because we developed it. And it helped us. Now we're giving everyone the opportunity to benefit from the Mercury Monitor.

Industries and cities alike. For more information, contact the Olin Corporation, 120 Long Ridge Road, Stamford, Connecticut 06904 (203) 356-2459.



Come and see us put the Mercury Monitor through its paces. At the Chemical Show, Booth #3109, Third Floor, New York Coliseum, November 29th—December 3rd. Circle No. 20 on Readers' Service Card

### environmental currents



III.'s Blaser

#### STATES Illinois issues tough policy on close-down threats

Any company that says it will be forced to close if ordered to comply with Illinois pollution control laws or rules will be asked to substantiate such claims, says William L. Blaser, director of the Illinois Environmental Protection Agency. Financial statements will be demanded from any firm raising the close-down issue during future enforcement proceedings.

#### New Jersey cracks down on air and water polluters

Nine industrial firms have been ordered to comply with New Jersey air pollution regulations. The companies involved—Johns Manville Products Corp., W. R. Grace & Co., E. I. du Pont de Nemours & Co., Great Notch Granule Co., Beecham, Inc., G. A. F. Corp., Atlantic Casting and Engineering Corp., Owens-Illinois Inc., and S. B. Penick & Co.—have entered into consent agreements to cease violations and will follow abatement timetables. Rollins-Purle's waste treatment plant, which handles industrial sludge, oil, and chemical wastes, has been cited for violating water pollution laws and must take corrective action by next month. Also, the president of the High Ridge Sewer Co. will go to jail if his company fails to meet N.J. phosphate level requirements.

#### Air emissions, noise dealt with in Ky., Minn., & Pa.

This month, the Kentucky Air Pollution Control Commission (KAPCC) will decide if Western Kraft Corp. (Hawesville, Ky.) will have a one-year deadline to comply with state particulate matter regulations. The Minnesota Pollution Control Agency has adopted open-burning, odor, and smoke emissions rules which became effective in September, although the timetable specifies that compliance will be complete by 1974. Atlas Alloy Co. has been charged with noise pollution by the Pennsylvania Department of Environmental Resources. This action resulted from a community complaint; occupational noise regulations became effective last month.

#### Sewage waste water will find industrial use

Denver, Colo. plans to supply industrial water from reclaimed water currently being disposed of as sewage. After several pilot plant operations, a 10-million gal/day pilot plant will be constructed by 1975–76. At that point, a 100-million gal/day plant will be constructed to provide water to the Denver Metropolitan system perhaps around 1987.

#### 180-Day notices; Cleveland receives promised money

The Environmental Protection Agency took 180-day notice action against two Indiana cities, Whiting and Hammond; two Wisconsin cities, Superior and Hurley; and Superior Fiber Products Co. (Superior, Wis.) for alleged violation of federal-state water quality standards. Cleveland, Ohio has received more than \$13 million from EPA for sewage treatment plant construction. Last December, Cleveland, along with Detroit, Mich. and Atlanta, Ga., received 180-day notices and disputed promised government aid.

# Portable stack sampler measures stack gases and solids at low cost APCO\* Approved

Now you can easily—and at low cost—collect and measure solids, mists and gases directly from your stacks with Research Appliance's new portable Staksamplr.<sup>™</sup> Developed and used successfully by the National Center for Air Pollution Control, this new sampler provides isokinetic collection of pollutants from most chemical and combustion processes. With a trained two-man crew, it can provide three samples per eight-hour day.

\*Air Pollution Control Office (APCO) of Environmental Protection Agency



**RESEARCH APPLIANCE CO.** ALLISON PARK, PA. 15101, U.S.A. (412) 486-0500 Send for complete catalog of sampling, testing and metering devices available to industry and government.

Circle No. 12 on Readers' Service Card

#### TECHNOLOGY Rankine cycle engine patent goes to Du Pont

An improved Rankine cycle engine which may be useful at ratings up to 200 hp has been patented by Du Pont engineer William Doerner. Du Pont says that laboratory tests on a 20-hp prototype engine indicate that many of the problems of size and complexity in external combustion engines have been solved. Du Pont's design features a cylindrical boiler and air condenser rotating as a single unit at a controlled speed. An interior turbine rotates in an opposite direction, powered by an organic fluid. The rotation of the boiler unit results in more efficient heat transfer which leads to the engine's compact size. The chemical company will not market the engine, but is looking for licensee to do the mechanical development while Du Pont would continue to work on the fluids.

#### Limestone barriers reduce acid wastes in streams

"Lime aid, on the rocks" is being considered as a recipe for cleaning up streams that are fouled by acid mine drainage. A series of limestone sieves—carefully engineered barriers designed to maximize transfer area, mixing, and flow rates—will be installed on Trough Creek near Huntingdon, Pa., to determine if the calcium carbonate contained in limestone will neutralize the acid leachate from coal mines. The project, sponsored jointly by Pennsylvania's Department of Mines and Mineral Industries and the Environmental Protection Agency, is under the direction of Penn State's Water Resources Research Center. A possible handicap: iron, usually found in acid mine drainage, forms iron sulfate on limestone surfaces and renders the rock ineffective.

#### SO2 removal process tested by copper producers

American Smelting and Refining Co. (ASARCO) and Phelps Dodge Corp. are testing a new process which will recover elemental sulfur, rather than sulfuric acid, from sulfur dioxide in stack gases. The process uses primary and secondary reactors and condensers to convert SO<sub>2</sub> in the gas stream liquid sulfur; SO<sub>2</sub> concentrations of at least 12% must be present. Commercial operation on gas streams containing less than 12% SO<sub>2</sub> and most copper smelter streams contain less than that—would require adsorption and preconcentration of SO<sub>2</sub>. Recovery of elemental sulfur might be preferential to sulfuric acid production because of economic advantages in storing and shipping, according to the companies.

#### Ceramics may be another answer for sludge disposal

UCLA Engineering Professor John Mackenzie has developed a ceramic compound from waste sewage sludge and scrap glass which he says can be used as a substitute for roofing or bathroom tile. The product, as yet unnamed, is said to be odorless, fire resistant, and impermeable to water. The ceramic is produced by adding carbonized sludge cake to powdered glass in roughly equal amounts and heating at relatively low temperatures and pressures in molds. "Bricks or tiles can be made," Mackenzie says, "depending on the ratio of glass to sludge." The tiles can be colored by adding metal shavings or inorganic oxides before thermosetting and are 50% lighter than conventional ceramic tiles.





# The Greatest Thing That Ever Came Down The Pike...



It could be coming to you where you need it, when you need it.

A wastewater treatment plant on wheels, Environment|One's Mobile Pilot Plant arrives fully staffed by experienced operators and technicians with full scale laboratory support. Here is a highly flexible biological treatment facility (suited to various types of treatment and adaptable to tertiary stages), representing a significant scale-up over bench scale processes.

If you're uncertain about your wastewater treatment needs (or if you have only temporary small scale treatment requirements), call for our Mobile Pilot Plant. It may be the greatest thing that ever came down the pike to you. Call collect (518/346-6161) or write James L. Setser, Manager, Measurement Services Division.

### CORPORATION PROTECTING MAN'S ENVIRONMENT 2773 Balltown Road • Schenectady, New York 12309

#### **INDUSTRY** Japanese steelmakers double control spending

By the end of 1971, the Japanese steel industry will have spent more than twice what it spent in 1970 for pollution control. Figures released by the Japan Steel Information Center in New York reveal that the 1971 tab for air and water pollution control will be \$220 million, more than 10% of the industry's total capital expenditures for the year. While a precise breakdown of expenditures is not available, the main thrust of the Japanese steelmakers appears to be in three directions: • Reduction in sulfur dioxide emissions, being achieved through the use of higher smoke stacks and by intercompany desulfurization programs • dust control, largely through installation of electrostatic precipitators and • industrial waste water treatment by the use of settling tanks or dilution.

#### Sugar beet industry volunteers to clean up

The Environmental Protection Agency (EPA) and sugar beet refineries in 15 states have reached a voluntary clean-up agreement which will cost the industry some \$13 million over the next two years. Under the agreement, the refiners will recycle flume water—used both to transport beets to the mills and to wash them—rather than following the standard practice of direct discharging. The water contains organic wastes, EPA says, which promotes growth of undesirable bacteria and has an undesirable odor. Ruckelshaus praised the industry saying the agreement was "an example of corporate responsibility that should serve as a model to others." Prior to the agreement, 17 of the 57 refineries in the 15-state beet producing region had already installed full controls.

#### Con Ed executive calls for streamlined permit procedures

A power company executive has recently called for removal of a "major stumbling block" in his industry's quest for adequate generating capacity. Louis H. Roddis, Jr., president of Con Edison, New York City's public utility, says that the main barrier is "the lengthy, often overlapping, and always cumbersome series of reviews and permits required by the city, county, state, and federal jurisdictions before any new project can be located, approved, constructed, or operated." What is needed, said Roddis, is "a way to bring environmental issues into focus at an early stage of planning and to get the issues resolved quickly." Roddis cited the case of Con Ed's expansion of its Astoria, N.Y. plant which requires the company to obtain at least 27 different permits from various agencies.

#### Firestone rubber plant reduces water effluents 90%

The Firestone Tire & Rubber Co.'s giant rubber-producing plant on Lake Charles, La. opened its secondary waste treatment facilities on October 21. The treatment facility is the first of its kind in the rubber industry. "The water treatment system was the culmination of long-term study of synthetic plant waste at the company's plants in Akron, Ohio and Lake Charles," says T. E. Salisbury, president of Firestone Synthetic Rubber & Latex Co. The plant produces 35 types of butadiene-styrene rubber, uses more than 4500 gal of water per ton of rubber produced, and produces 330,000 long tons of rubber each year. The system includes: • Isolation of industrial wastes from storm waters and domestic waters • coagulation and flocculation • clarification, biological treatment, sludge dewatering, and final clarification.



Sugar beets



Aeration lagoon at rubber plant

### **Gotham's EPA: Expertise, Pizazz, Action**

New York City EPA chief Jerome Kretchmer sets the style for a freewheeling war against pollution

It is definitely not true, despite rumors you might have heard to the contrary, that New York City plans to solve its solid waste problem by restricting littering to alternating sides of the street on odd and even dates. But that's about the only antipollution measure not under active consideration by the city's Environmental Protection Administration (EPA). Consider the following:

• There's a tough new air code which eliminates asbestos spraying, phases lead out of gasoline by 1973, limits allowable sulfur content in fuel oils, outlaws the use of bituminous coal except under emergency conditions, bans by 1972 the use of solvents likely to add to photochemical smog, and tightens limits on permissible emissions from incinerators, boilers, and industrial processes.

• New enforcement machinery has been set into motion to deal with violators of the air code. An Environmental Control Board (ECB) functions as a court with broad powers to issue subpoenas, compel testimony, seal equipment or order installation of abatement equipment, issue cease-anddesist orders, authorize emergency repairs to faulty equipment at the owner's cost, and impose civil or criminal penalties including fines up to \$5000 and prison sentences up to four months.

• Citizen involvement is likely to gain momentum because the man on the street can collect up to 25% of the fine imposed under certain circumstances. The state has a smoke-watchers course which leads to certification as an expert witness whose testimony is accepted as evidence before the ECB.

• The city is working on similar codes for noise, solid waste, and water pollution. Noise will be next. The only problem now is that the city council wants to put more bite into the code than the EPA has asked for.

• Along with its legislative programs, the city is experimenting with tech-



nological solutions to its pollution problems. In the area of solid waste, pilot composting and pyrolysis units show promise. Limited-scale recycling projects are under way in several locations throughout the city.

• EPA is zeroing in on the automobile. Starting with city-owned cars, EPA is looking at alternative fuel systems, retrofit devices, new engine designs, and even smaller cars to minimize emissions and noise.

#### What else is new?

New York City certainly doesn't lack for environmental control programs. But neither does any other major city. What sets New York apart from the rest is the fact that it has centralized administration of virtually all agencies concerned with environmental problems.

New York City was the first governmental unit to recognize the need for a comprehensive pollution control authority. When Mayor John V. Lindsay first took office in 1966, he began a sweeping reorganization of city government which consolidated more than 60 separate agencies into 10 "superagencies" (see "Reorganizing to Fight Urban Pollution," ES&T, July 1968, p 504). In May 1968, more than two years before its federal counterpartthe New York City Environmental Protection Administration was born, incorporating the old departments of air pollution, sanitation, and water resources and the newly formed bureau of noise abatement.

Lindsay tapped former New York University Professor of Environmental Medicine Merril Eisenbud to head up the EPA. Retired Naval Capt. Griswold

### outlook

Moeller was picked as Commissioner of Sanitation, Engineer Maurice Feldman was made Commissioner of Water Resources, and former Public Health Service Officer Austin Heller remained in his post as Commissioner for Air Resources.

Eisenbud's organization of the EPA into three semiautonomous subagencies has outlasted him and his three commissioners as well. Today, New York City's EPA has something else nobody else has—Jerome Kretchmer. That's either an asset or a liability, depending on whom you ask. Kretchmer—a former Democratic state assemblyman who felt he was becoming less and less effective against the conservative Republican leadership in Albany—took over the top slot at EPA nearly two years ago at Lindsay's request. Today, old timers would scarcely recognize the place.

Kretchmer's commissioner of water resources is Martin Lang, who was chief engineer under Feldman and director of the old Bureau of Water Pollution Control. Robert Rickles, previously head of his own consulting firm, is commissioner of air resources. Herbert Elish left his post as first deputy administrator of the EPA to become commissioner of sanitation after a brief period during which Kretchmer filled that post as acting commissioner.

Kretchmer's commissioners give his management team top-notch engineering expertise (Kretchmer cheerfully admits to ignorance when he first took over the post). In addition to his technocrats, Kretchmer surrounded himself with a group of energetic young lawyers. Then, he rode garbage trucks and salt spreaders around town, rapping with the public and the rank-and-file sanitation man, trying to build, as he put it, "a constituency for the environment."

#### **Radical chic**

Undeniably, what separates the city's EPA from its somewhat more staid state and federal counterparts is more a matter of style than organization or programs. The organization is, as Kretchmer puts it, "nice and loose."

Loose but not sloppy. Underneath a veneer of chaos is an orderly game plan. The goal is a broad but basic mandate-do what can be done for the environment in New York City. The strategy: Look at new technology but take advantage of what already exists; toughen up the laws and enforce them, if necessary by creating more effective institutions to deal with them, like the ECB; push the limits of existing authority in the courts to deal with issues like auto emissions which have been previously written off as lost causes because of conflicting jurisdiction; and, above all, as Kretchmer said in a recent speech, create "a vast lobby that will force a massive reordering of our warped national priorities, that will compete in the traditional bump and shove of American pressure politics. That lobby does not exist today and the energies of many who might form its backbone are drained by the criminal war in Indochina."

#### Mayor Kretchmer?

That's headier stuff than comes from the pens of most pollution control officials. Kretchmer is unabashedly outspoken in public. He delights in rankling the opposition, and epithets like "socialist" and "technocratic hippie" bounce off him without leaving a mark. Because he shoots from the hip, he is a copy writer's dream. But the press catches its share of flak, too. "I asked a newspaper, whose yearly output costs us and neighboring sanitation departments an estimated \$15 million a year to collect and dispose of, to consider some recycling," Kretchmer recently told an American Bar Association audience. "A week later, I received a letter from a vicepresident asking politely if I would drop the idea because he didn't want little old ladies in tennis shoes picking up the notion and pestering the girls at the newspaper's switchboard."

Clearly Kretchmer sees his job in a

broader frame of reference than many of his counterparts. "The environment is a radicalizing issue," Kretchmer says. "Environmental questions deal with life itself and social systems." And it is precisely life itself and those social systems which apparently capture Kretchmer's imagination and fuel the enthusiasm of those around him. Kretchmer makes no secret of the fact that he may seek the mayoral nomination as early as the 1973 primaries. And he thinks that if he can clean up the city's streets, he stands a good chance for the city's top executive job.

Some measure of success is evident, Kretchmer says, from the air quality data collected over the past few years. The city ranks air quality as good, acceptable, unsatisfactory, or unhealthy. Until 1971, New York never had officially recorded a good day. This year there have been fourteen of them; 33 days in 1970 were acceptable, and 118 were unsatisfactory. In 1971 there have been 109 acceptable days and 61 unsatisfactory ones. Though ambient sulfur dioxide levels are still among the highest in the nation, they have fallen more than 50% in the past few years. With the legislation and enforcement machinery only recently approved by the courts, the city's EPA expects to make significant gains during the next year.

But, why would he want to be mayor anyhow? Kretchmer replies that he loves the city. He is a native of Brooklyn and he lives in Manhattan with his family. His kids go to public schools. The city, he thinks, can be a good place to live. The environmental crisis, as Kretchmer sees it, is an urban crisis, and the American way of life is the urban way of life. For him, the two are inseparable. There are huge problems-slums, overcrowding, pollution, and corruption-but there is vast opportunity. Kretchmer would perhaps agree with longshoremanphilosopher Eric Hoffer: "It is cheering to see that the rats are still around-the ship is not sinking." HMM

### Thermal pollution in uncharted waters

The approach to setting temperature limits for heated water discharges is becoming more flexible as a lack of biological information hinders the regulators

Because of its impact now and in the foreseeable future, thermal pollution is one of the "bad guys" of environmental quality. Thermal pollution— the introduction of waste heat into the environment—results almost entirely from industrial use of natural water for process cooling.

The power industry uses about 80% of all water taken in by industry for cooling purposes; other industries utilize only a fraction of the total. "The demand for electricity will double within the next decade," Rod J. McMullin, General Manager, Salt River Project, told the National Conference on Waste Heat Utilization in October. By 1980, the power industry may require one sixth of the total freshwater flow from the entire U.S. land mass for cooling, says Burgess H. Jennings, professor of engineering at Northwestern University.

Today, hydroelectric plants, which are not main contributors to thermal pollution, account for less than 20% of the power produced in the U.S. As remaining suitable sites for hydroelectric power become limited, more and more power will be produced by less efficient thermal power generation. Also, the trend is toward nuclear power generation which is less efficient in heat utilization than fossil fuel generation.

#### Effects

Although 95% of the water used for once-through cooling purposes is returned to the stream, the increased temperature of the water may have several deleterious effects:

• Capacity of the stream to assimilate wastes is decreased

• Oxygen content of the stream is reduced relative to the cooler water of the natural stream state

• Temperature change has a pronounced effect on the life-cycle regulation of aquatic organisms

• High-temperature changes can have lethal and sublethal effects on fish and other aquatic organisms

Nuclear plants waste more than 40-50% more energy (much of which is

(Mac North Land

released to condenser cooling water as heat) than do fossil-fueled plants. Discharged condenser cooling water from a power plant is usually 10–30°F warmer than the source from which it came.

After its discharge, heated effluent water tends to float and spread in a plume on the surface of the receiving water before being dispersed by stream currents. Dispersal rate depends on current speed, turbulence of the receiving waters, temperature difference between the water and air, humidity, and wind speed and direction.

Heated discharge water can be handled in several ways. If the oncethrough method is employed, several approaches can reduce effluent temperature before it reaches the receiving

#### Eleven states do not have EPA-approved thermal standards

Alabama—will adjust to National Technical Advisory Committee recommendations

California—public hearings are now being held to revise water quality standards

Georgia-action forthcoming

Illinois—standards will be submitted in the near future

Kentucky—changes are being processed

Louisiana—changed standards, awaiting administrative approval

Michigan-submission under review

Mississippi—action undertaken to meet recommendations

Ohio-hearings just completed

South Carolina—revision is being processed

Tennessee-revision under way

Note: State actions as they stand at press time

water. Large-capacity pumps can be used to reduce cooling water temperature by using more cooling water; jet and multiport diffusers can reduce the size of the mixing zone; deep cold water can be taken from intake points 20-70 ft deeper than the discharge points (to use naturally cooler water available to reduce the difference between discharge water temperature and natural water body temperature); and dilution in long discharge canals can be employed.

In addition to once-through cooling methods, cooling ponds and various types of cooling towers (wet mechanical draft, wet natural draft, and dry cooling towers) can be constructed. Each method has its limitations, however, Cooling ponds and lakes require vast amounts of land (for example, 2000-3000 acres of lake surface for a 2-million kW nuclear power plant) and still may not reduce effluent temperature enough. A cooling tower may add large amounts of water to the atmosphere in the vicinity of the plant. The total effects of this additional moisture are difficult to predict. Possible fog, ice formation on roads and power lines, reduction in visibility, and even the formation of snow have been predicted (although some claim that if towers are properly located and designed, these potential problems would be minimal). Also, within cooling towers themselves, chemicals must be added to inhibit biological growth, corrosion, and deposition of dissolved salts, and these may be discharged through airborne spray or water blowdown.

One must not forget the vast amounts of water lost through cooling towers. For example, a 2000-MW station loses approximately 14,000 gal/min. And there are arguments as to the best type of cooling tower for the U.S. (see ES&T, March 1971, p 204). Furthermore, cooling towers on a stream may lower stream flow to a point where there is inadequate dilution for municipal waste discharges from upstream and downstream. Where there is inadequate



**Power station.** Plants like this one on the Ohio discharge heated water

appear," says Nalesnik. The NAS Committee on Water Quality Criteria is making a complete reappraisal of water quality criteria that will result in a new volume.

The charge to NAS is "to concisely discuss problems with whatever pollutant is involved, to research the literature supporting the facts, to summarize appropriate limits and ranges, and to make recommendations based on the best scientific knowledge available," says Carlos Fetterolf, scientific coordinator of the NAS Committee on Water Quality Criteria. A first draft of the NAS report was scheduled for preparation by December 1, and the final version will be completed in early spring of 1972.

Since it is widely recognized that the capacity of receiving waters for dissipating waste heat varies, the most logical approach to the control of thermal discharges is the "case-by-case basis." Says Fetterolf, "The requirements must be related to each body of water and its particular community of organisms."

Although obvious problems are created when discharges greatly exceed the dissipative capacity of the receiving stream, when intakes and discharges are located in biologically important areas, and when important species are greatly reduced or completely eliminated, direct

stream capacity, thermal discharges are a problem.

Dry cooling towers are, at present, prohibitively expensive and are not competitive with other methods and systems for accomplishing cycle heat rejection. Therefore, few are built unless water for cooling purposes is not available.

#### Water quality standards

Federal EPA water quality criteria guidelines for thermal requirements fall into three categories: lakes, rivers and streams, and coastal waters (estuaries or enclosed bays). Water quality criteria guidelines were developed by the National Technical Advisory Committee and published in 1968 as Water Quality Criteria or "green book."

The green book recommendations suggest a maximum  $3^{\circ}F$  temperature rise above natural water temperature for lakes, a  $5^{\circ}F$  maximum rise above natural for rivers, and, for estuaries and coastal waters, no more than a  $1^{1}/_{2}^{\circ}F$  rise during the summer months or a  $4^{\circ}F$  rise over the other months of the year. In all instances, the temperature rise should not be higher than the allowable, depending on the particular conditions, or  $90^{\circ}F$  maximum, whichever is the lesser.

"We almost have complete agreement among the states for these temperature criteria," says Richard Nalesnik, formerly director of EPA's Water Quality Standards Office. Eleven of the 54 states and territories have not received approval for their water quality standards (which include temperature criteria) (see box). EPA Administrator Ruckelshaus will not approve a state's water quality standards unless they conform to National Technical Advisory Committee recommendations.

"It is important for us and the states to know what are the natural conditions and the normal seasonal variations and fluctuations affecting those natural conditions," continues Nalesnik. "We have 14% of the  $3^{1}/_{2}$  million miles of streams covered by federal and state standards under the law." Federal control does not yet extend to intrastate waters, "although all but a few states have voluntarily adopted intrastate criteria," explains Nalesnik.

However, it is difficult to set one stream standard for the entire country. For example, the tides and currents on the California coast are so great and of such a capacity that degradation due to waste heat is very hard to demonstrate. Because of these particular circumstances in California, Nalesnik explains, the federal government is willing to consider a 20°F effluent discharge limitation for coastal waters in California. That 20°F effluent is reduced over a reasonable distance to standard in a short time.

The California situation points up a need for a flexible approach: "We are going to take the time to work on a case-by-case basis on these discharges. Attention will be given to each individual discharge so that every equitable and reasonable solution will be investigated before any discharge permit is federally approved," emphasizes Nalesnik.

EPA sponsors research programs on the physical and biological effects of thermal discharges. These programs are geared to meeting water quality criteria requirements by providing a more scientific basis for recommended criteria.

#### **Green book revision**

EPA Water Programs Office has awarded a \$458,000 contract to the National Academy of Sciences (NAS) to address itself to ambiguities or shortcomings in the existing green book. "We feel that as new scientific and technical information becomes available, it requires and justifies an upgrading or improvement to standards," explains Nalesnik.

"So-called 'mixing zones' of the past have been to some degree expressions of our technical ignorance. In the future, as we approach closed systems complete water reuse and effluent controls—the mixing zone panacea will discause-and-effect relationships are not, in practice, easy to establish. "Demonstration of significant biological damage due to heated discharges has been difficult to obtain at many sites until recently," says Fetterolf, "but more sophisticated techniques and approaches are being developed to provide biologists with predictive abilities."

In order to provide input to the new green book, NAS panels considered biological consequences to aquatic organisms at intakes, during passage through condensers and discharge canals, and in the thermal plume. They also considered design of the discharge structure.

#### **Citizens and courts**

Thermal pollution can be-and isthe topic of legal action as well as citizen complaints. One of the most publicized court cases is that of the federal government vs. Florida Power & Light Co. After months of litigation, the suit was absolved by a consent decree. The consent decree terminates a water pollution suit filed by the Department of Justice in March and requires Florida Power & Light to install a cooling system at its electric power generating plant at Turkey Point on Biscayne Bay. The company is now undertaking an extensive construction program to halt the discharge of heated water within five years.

Indiana & Michigan Electric Co. filed suit in July against EPA Administrator Ruckelshaus, challenging EPA's thermal water quality standards. The company charges that no thermal damage to Lake Michigan (where it is building a power plant) has ever been documented, and that the proposed standards fail to give adequate consideration to legitimate industrial use of the lake.

Another much-debated item is that of the Calvert Cliffs nuclear power plant in Maryland. EPA says that anticipated heat discharges are not expected to violate approved federal-state water quality standards. However, permissible Maryland discharges are much higher than the limits established in most approved federal-state standards, and public opinion has been opposed to the plant.

EPA further recommends that cooling system alternatives be developed if proposed methods of plant operation prove detrimental to aquatic life, or if Maryland's thermal standards are made more restrictive. Also, EPA questions the possibility of "thermal shock" caused by rapid decrease in temperature should the plant shut down.

The Atomic Energy Commission (AEC) is also looking into thermal requirements for nuclear power plants. The present court-ordered overhaul (based on the National Environmental Policy Act) of AEC regulations may cause construction delay of 81 plants and affect operations at another 20. A nuclear power plant may discharge as much as 1 billion gpd of water 10°F or hotter than ambient stream temperatures.

#### Heat utilization

A great deal of effort and research is being applied to waste heat utilization. However, there are many very practical problems to be solved since the heat that is discharged is a very lowgrade heat. It's too hot to discharge to natural waters but too cool for maximum heat utilization.

In order to solve the water pollution problem, beneficial uses of waste heat must satisfy at least one of two criteria, says Richard Tucker, staff water resources engineer, National Water Commission—either they must reduce the actual heat discharged to water, or they must provide an economic payout to help defer abatement costs.

A number of projects are under way to utilize waste heat. Vitro Corp. of America has experimented with thermal water irrigation. Cooling water varying

**Cooling tower.** This natural-draft unit is rated at 43,200 tons/hr of water



in temperature from 90–120°F was pumped from a Weyerhauser Co. pulp and paper plant to nearby farmlands in Oregon's Willamette Valley. A hotwater frost protection system (overtree sprinkler system) protected a cherry orchard from frost. In the summer, plants were cooled and did not develop the water stress that is so prevalent on hot summer days. Also, plants experienced accelerated growth due to increased soil temperature.

Catfish farming is another beneficial use of waste heat. Catfish, being a warm-water species, do not eat and grow well when water temperature drops. By using warm water effluent, the catfish farmer can go from a season of seven or eight months to a full year. At least three companies in the U.S.-Texas Electric Service Co., Mississippi Power & Electric Co., and a TVA plant-are engaged in catfish farming. San Diego Gas & Electric Co. is experimenting with shrimp, lobster, crab, and pompano in heated cooling water. Japanese utilities, too, are undertaking extensive mariculture programs (and are selling shrimp for \$10-12/lb!).

Waste heat from diesel electricity generator sets is used by the University of Arizona to desalt seawater which is subsequently used to irrigate crops within controlled environment greenhouses.

It has been suggested that waste heat could eventually heat and cool cities; however, this is not an economic reality unless, possibly, a new city is built. This concept is soon to be tested near Anchorage, Alaska. "The first total environmentally controlled city," says V. M. Piland, vice-president of engineering, Great Northern Corp., "covering 3200 acres and housing 50,000 people, will be completed in 20 years."

Long Island Oyster Farms, Inc. uses the discharge lagoon of the Long Island Lighting Co. as a nursery for oysters. These oysters can be raised in three years rather than the normal five-six years.

Westinghouse Electric Corp. has experimentally investigated the possibility of using waste heat to increase the capacity and efficiency of sewage treatment processes, airport defogging and deicing, and greenhouse heating.

Many of these waste heat utilization projects involve tremendous capital costs and must compete economically to offset initial costs and maintenance. However, waste heat may indeed be one of the resources of the future. CKL

### **Revolutionary** Calibrator!

#### ON-SITE, INLET-TO-OUTPUT CALIBRATION OF AIR QUALITY ANALYZERS

**DYNAMIC**, reliable certification with Monitor's low-cost Model 8500 Calibration Gas Source. An accurate, portable calibrator for the total analyzer; end-to-end. Without the mess and problems of static calibration.

TAKE THE 8500 ON-SITE WITH YOU. Generate precisely variable ppm levels of  $SO_2$ ,  $NO_x$ ,  $O_3$ , or  $TO_x$  to check response times, repeatability, accuracy, and linearity.

**OR CONFIDENTLY BUILD IT INTO YOUR SYSTEM.** Zero and span calibration cycles will operate unattended. And the unique, rechargeable permeation cylinders will last at least two long years.

**GET COMPLETE DETAILS** on Monitor's Dynamic Revolution — the Model 8500. Only \$800 plus \$200 per source gas. Write or call today.





#### COMPLETE SELECTION FOR AIR POLLUTION CONTROL

Industry's largest selection of spray nozzle types, capacities and materials for GAS or AIR SCRUB-BING. Permits choice of nozzles for maximum spray nozzle efficiency and dependability in scrubber applications. Obtain the spray characteristics that best meet your requirements! Patented nozzle designs, precision manufactured by spray nozzle specialists. Sixty-four page Catalog 25A gives complete information.

SPRAYING SYSTEMS CO. 3202 Randolph Street, Bellwood, Illinois 60104

WRITE FOR CATALOG 25A



0.



The DL620A Digital Data System accepts 18 channels of analog data and contains a presettable crystal controlled clock. Lightweight design makes the DL620A easily portable and ideal for airborne, mobile, remote site or laboratory data acquisition.

Check these features: Self contained analog/ digital converter and multiplexer = Four-track '%" tape cartridge = Selectable recording rates or remote command = Visual real time data display (any channel) = Low power requirement — only 35 watts, 115 volts, 50-400 Hz = Accepts direct digital input (BCD) (optional) = Dimensions: 8.3 x 11.1 x 11.0 inches = Weight: 18 lbs. (approx.)

Data recovery is accomplished with the DL622A tape reader which may be interfaced with any computer, such as the IBM 1130 or a half-inch IBM compatible tape recorder. Note: Weather Science, Inc., parent company of Metrodata Systems, offers a fast turnaround service for processing all tape generated by customers using the DL620A system.



Norman, Oklahoma 73069 Address all inquiries to: P. O. Box 1307 Telephone 405 329-7007 Circle No. 9 on Readers' Service Card

Volume 5, Number 12, December 1971 1173

### Hawaii's sugar industry faces tough problems

Roses are red, violets are blue. Sugar is sweet, but mill wastes pollute the ocean

Hawaii, perhaps more than any other state in the Union, inspires a visceral respect for the warp and woof of the environment. It is a land of primal elements: fire, earth, air, and water. It is a land where the luxuriant is juxtaposed against the sterile, an entire continent in miniature.

Slightly less than 1 million people inhabit the seven westernmost islands of the chain which stretches some 1600 miles from Kure and Midway in the east to Hawaii—or the Big Island, as the natives call it—in the West. Apart from military operations and tourism, the economic mainstay of the islands is agriculture.

By far the most important crop is sugar cane. In 1972, Hawaii will produce some 1.2 million tons of sugar compared with about 1.5 million tons for the mainland's cane producers and 3.4 million tons for beet sugar producers. Cane brings about \$1.6 billion to the islands each year. Some 240,000 acres of land are under cane cultivation.

But it's beginning to look like the cane industry on the islands is headed for trouble. One of the state's 26 sugar mills will close this month. Two more will close in 1973. Others will merge to stay alive. A major reason, industry spokesmen say, is that the cost of pollution control facilities will make some of them unprofitable to run.

#### **EPA** cracks down

There is considerable pressure on the industry to abandon waste disposal practices which have been standard for many years. Last September, the Environmental Protection Agency (EPA) asked the Justice Department to take court action against nine sugar mills on the island of Hawaii for causing "severe pollution" off the island's Hamakua coast (see map). The com-EPA Administrator panies cited, William D. Ruckelshaus said, were discharging "untreated and inadequately treated wastes into coastal waters in

violation of the Rivers and Harbors Act of 1899."

The mill managers were miffed, to say the least. All had applied for discharge permits (Ruckelshaus noted, however, that that did not exempt them from prosecution) and were under a statesanctioned abatement program to clean up operations "as quickly as possible." At a Honolulu press conference, Karl H. Berg, president of the Hawaiian Sugar Planters Association said that the industry would be spending from \$10-12 billion in the next five years for pollution control.

Many sugar planters (and state officials as well) privately branded EPA's push as little better than a publicity stunt. Others saw more sinister implications. "Let's face it," one industry spokesman said privately, "EPA is making a whipping boy out of the sugar industry. They wouldn't seriously consider puting Detroit in the profit squeeze they're forcing us into, and the auto industry is a far worse offender. But, by showing the world that they're not squeamish about putting a few thousand people out of work, they hope to bring the big boys to heel."

#### **Cane processing**

Cane processing on the islands is limited to harvesting, milling, and boiling. There is little refining. Most mills ship only crude, impure sugar to the mainland to be refined by California and Hawaiian Sugar Co., an industrycontrolled co-op in Crocket, Calif. Only the small amount of sugar needed for local consumption is refined in Hawaii. But at every stage in the operation—from planting to final shipment the Hawaiian cane sugar industry faces some challenging problems.

Cane is one of the few commercial crops that thrives in the harsh volcanic soils of the islands. It is planted in furrows that follow the terrain of the plantation to minimize soil erosion and conserve water. Because many



plantations are located on steep volcanic slopes—quite literally between the devil and the deep blue sea—pollution abatement practices which are technologically simple elsewhere may, on the islands, assume quite different proportions.

Geography is often critical. Rainfall, for example, may vary between 50-200 in./year from the higher elevations to the coastline on a single plantation, often a distance of less than a mile. Consequently, over half of the cane under cultivation in the islands must be irrigated. Since the soil is loose and porous, large volumes of irrigation runoff—or tail water—may find its way into the ocean, carrying with it fine volcanic particles.

An obvious solution would be settling ponds to clarify water and reclaim soil. And some of the plantations in more level spots on the islands do use lagoons. In other locations, notably along the Hamakua coast of the Big Island, settling ponds are not as useful. The tail water problem, like so many problems faced by the industry, is aggravated by the fact that milling operations really haven't changed very much over the years. Only rarely is enough land available—in the right place—to allow sedimentation basins.

Because planting and harvesting of cane was carried out by hand until the labor shortage arising in the aftermath of World War II, mill sites were placed at the lowest elevation on the plantation—frequently poised precariously on the edges of cliffs dropping several hundred feet into the sea below. The design made engineering sense. Cane could be flumed down from the fields in water troughs, and wastes from the milling operations could be conveniently dropped into the ocean. Since



the shoreline in this part of the country is remote and inaccessible, few complaints were voiced, except those by occasional fishermen who complained that floating cane trash was fouling nets or interfering with navigation.

Now, although some sugar processers still argue that their effluents are not particularly harmful to the marine environment, they would be willing to keep their wastes onshore—if they could find the room at reasonable prices. Recycling wash water and irrigation tail water would be nice, they say, except that it means pumping it back up the slopes at considerable expense.

#### **Harvesting problems**

Mechanical handling of cane has brought yet other problems. Harvesters are not particularly well suited for the rough terrain on which cane grows. A typical method of harvesting, for example, is one in which cane is pushed into windrows by a plow or push rake. Cranes then load the cane onto trucks to be taken to the mill site. But the machinery gathers, in addition to the cane, huge amounts of mud and rocks which must be removed at the plant by water and mud baths. That means still more soil put into the ocean-soil which allegedly destroys coral and dirties the sparkling water so vital to the tourist industry.

Before cane can be milled, leaves must be removed from the stalks. Traditionally, the best way to clean cane has been to burn the fields before harvesting. The water content of the cane protects it from burning while leafy material—called trash—is quickly and cheaply removed.

Sugar planters will probably have to find another way to remove trash,

however, as prohibitions against open burning gain more support. It is a task which one industry spokesman describes flatly as "impossible."

Once cane is harvested and brought to the mill site, another set of pollution problems must be solved. In addition to removing mud, stones, and the remaining trash, cane must be chopped up, untangled, and pressed between a series of rollers to extract the sugar-laden juice. Water consumption in these steps is high. Average waste water flow rates for a plant which produces about 200 tons of raw sugar per day run as high as 10 million gal/day, according to EPA.

The water is not very clean, either. EPA says that typical wash water contains 1850 lb settleable solids, 1750 lb suspended solids, 650 lb chemical oxygen demand, 12 lb nitrogen, and 5 lb phosphorus for each ton of raw sugar produced. Total coliform counts averaged about 4.85 million/ml in one EPA study, and the concentration of fecal coliforms was around 130,000/ml.

The crushed cane stalk yields a coarse, fibrous material called bagasse. About 80% of the bagasse produced at one mill visited by ES&T was used to fire boilers, and the rest was routinely dumped into the ocean. There is simply too much bagasse produced at most mills to use in-house, mill engineers say, but experiments are under way to determine if it could be used elsewhere.

Burning bagasse presents problems of its own. It's not a particularly clean fuel, and most mills are in the process of installing stack scrubbers to clean up the emissions.

After the juice is pressed from the stalks, it goes to the boiler room where lime is added to precipitate insoluble nonsugars. Clarified juice is thickened in evaporators, and the resulting syrup is boiled in vacuum pans to form raw sugar crystals. Crystals are separated from molasses by centrifugation, and the molasses may be further evaporated to recover more sugar. The final products—coarse, pebbly raw sugar and molasses for animal feed—are packed for shipment to the mainland.

#### **Technology available**

The EPA says that "facilities for controlling sugar mill wastes are available." And it would seem to be true that control of cane processing wastes requires little in the way of new technology. Old standbys like hydroseparators are used to clarify process water by some mills in the more level plantations, and lagoons for tail water recovery are becoming more common. One mill is experimenting with a "dry cleanet" which uses forced air instead of water to clean cane.

But the problem is more one of economics than technology. Like other industries, Hawaii's sugar industry must reward investors with reasonable dividends. Even with the protection against foreign competition offered by the Sugar Act of 1948, Hawaii faces tough competition from mainland sugar producers.

Because of well-organized unions, the island plantation laborer enjoys a daily wage in excess of \$30/day including benefits, according to U.S. Department of Agriculture statistics—twice as much as some of his mainland counterparts. Return on investment, on the other hand, runs between 5–6% after taxes, USDA estimates. "A better investment could be found in bonds," says Frederick Gross, engineer for Castle and Cooke Co.'s Waialua mill. HMM Plans of 15 federal agencies must be finalized by the end of 1972; their facilities receive equal yet fair treatment as other polluters under today's environmental laws

### **Cleanup orders hit federal facilities**

Environmental cleanup at federal facilities began early, at least on paper. A half dozen orders for such cleanup have been issued, dating back to 1955, but a total cleanup at federal facilities has not yet been achieved. Nevertheless, the push has been on, and under Executive Order 11507, signed by President Nixon on February 4, 1970, the deadline for cleanup plans is the end of calendar year 1972. By then, corrective actions for all federal facilities are to be under way; it is unlikely, however, that all construction will be completed by that time.

In fiscal year 1972, the federal government will program nearly \$185 million to correct environmental pollution control problems at federal facilities. The Department of Defense accounts for the largest part of the expenditure; the remainder will be spent to correct problems at 14 nondefense agencies. The second largest expenditure goes to the Department of Interior; their expenditure will be used principally to improve recreational facilities at National Parks and on water pollution problems of fish hatcheries. The earlier executive orders excluded fish hatcheries. Another top category includes expenditures to correct water pollution problems of the Forest Service, a unit of the Agriculture Department.

#### Size of the problem

George Marienthal, acting director of the EPA office of federal facilities, estimates that there are approximately 20,000 federal facilities; approximately 1500 of them experience air or water pollution problems. The new EPA office was established five months ago in response to the need for coordination of federal environmental activities and is at three-fourths strength today, with 15 professionals on the staff.

Although 20,000 seems like a very large number of facilities, Marienthal points out that many of them-remote radar sites and federal lands with no structures, for example—do not generate wastes and so are not involved in the federal facilities cleanup program.

"One of the main functions of the new EPA office is to serve as technical advisor to the Office of Management and Budget," the acting director explains: "The key is to know the applicable standard (air or water) and to know whether the actions specified in plans submitted from the federal installations comply with the standards."

In addition to the executive orders, federal environmental laws cover the subject of cleanup at federal facilities quite adequately. In the recent round of legislation, applicable sections of the laws include: Sec. 118 of the Clean Air Amendment of 1970, Sec. 21(a) of the



Col. Herbert Bell. "DOD Clean Boys"

Water Quality Improvement Act of 1970, and Sec. 211 of the Resource Recovery Act of 1970. Within this executive and legislative framework, federal facilities have adequate legal incentive to clean up pollution problems.

Simply put, federal facilities receive the same treatment as industrial polluters. For example, if it has an industrial waste water discharge and is not tied in with a municipal waste treatment plant, then a federal facility must apply for a permit under the Refuse Act program of the Corps of Engineers. If the facility has an air pollution problem, federal agencies must ensure that corrective actions are in compliance with the most stringent of standards, which, in some cases, may be included in the state implementation plans due on January 30, 1972. With regard to solid wastes, federal facilities are required by the Resource Recovery Act to comply with solid wastes guidelines which now are in draft form in the EPA Cincinnati office. Hopefully, the guidelines will be finalized early next vear.

#### **Military move**

Responding to the charge set forth in an earlier executive order, the Department of Defense established its DOD Environmental Pollution Control Committee on January 4, 1966; the committee is thus no Johnny-come-lately on the federal government's environmental bandwagon. The committee came up with a five-year correction plan starting in fiscal year 1967 through fiscal 1972. The DOD will have spent more than \$300 million on environmental pollution control projects at military installations.

The committee membership represents both medical and engineering expertise in the area of environmental health and pollution control. Col. Herbert E. Bell, an Air Force Biomedical Sciences Corps officer, is the present chairman of the committee whose membership totals

#### Examples of military cleanup projects

#### Army

▶ The Tank and Automotive Command has been working on the stratified charge engine to obtain more complete combustion and a pollution-free engine.

#### Air Force

▶ With 60% of the U.S. jet engine inventory, the USAF has initiated R&D for improved combustor cans for the J-79 engine used on the F-4 aircraft. The estimated cost of fleet conversion of the J-79 engine is about \$35 million.

▶ Put into operation an electric power generating plant whose turbine operates on natural gas producing more than 9000 kW of power.

#### Navy

▶ Built the first complete water-cooled incinerator which is capable of handling 360 tons of refuse each day and is used to raise steam for navy ships and buildings at Norfolk, Va.

► Developed a new type of fuel oil (Navy distillate) for ships; this reduces particulate matter and SO<sub>2</sub> emissions significantly.

► Has under construction several systems for controlling emissions from jet engine test cells; a prototype is under construction at the Naval Air Station (Jacksonville, Fla.) at a cost of more than \$300,000.

▶ Installed a prototype system to eliminate smoke discharges from the advanced fire-fighting schools at Treasure Island in San Francisco Bay. A second unit is being installed at the San Diego fire-fighting school.

25. In addition to three representatives from each of the military services— Army, Navy, and Air Force—the committee membership includes representatives from the Defense Supply Agency, the Office of the Assistant Secretary of Defense for Installation and Logistics, the Organization of the Joint Chiefs of Staff, and the Office of the Director of Defense Research and Engineering.

All chairmen of the DOD committee in the past have been career officers with either medical service or engineering backgrounds. In fact, Col. Alvin F. Meyer, Jr., its first chairman (now retired from the military service), currently heads up the new EPA Office of Noise Abatement and Control. A later chairman was Col. John Redmond of the U.S. Army.

The DOD committee acts in an advisory capacity to Richard L. Wilber, the Assistant Secretary of Defense for Health and Environment. John A. Busterud, the recently appointed Deputy Assistant Secretary of Defense for Environmental Quality, acts as the focal point for all environmental quality programs of the military establishment.

#### **Military cleanup**

According to the consensus of the DOD pollution control committee, there are approximately 800 major military installations in the U.S., and for fiscal year 1972 alone, 197 projects will be funded at a cost of \$121 million. In addition, the military authorization bill, now before the Congress, includes another seven projects on air and water pollution problems at military bases outside the U.S. These projects are programmed at approximately \$8.9 million.

In the total military cleanup program, there are costs associated with air and water programs from fixed military installations as well as from mobile sources such as vessels; the major emphasis to date has been the correction of pollution from fixed installations.

"Plans for correcting these problems are the ones that will be under way by the end of next year and meet all existing criteria," says Thomas Casberg, a member of the DOD pollution control committee.

The military has other problems which are to be corrected after calendar 1972. Jet engine test cells and vessel discharges are among these. The vessel discharge requirements have not as yet been published by EPA but when they become available, military ships certainly will have to comply. Correcting the problems of jet engine test cells is farther down the cleanup road. Air pollution controls will be required for such test cells unless clean-burning engines are developed.

At military installations today, heating plants and incinerators are the big air pollution problems. "Many of the heating plants have either coal or oil-fired units," Col. Bell explains. Although some of the units have collectors for air pollutants, the collectors simply do not come up to current requirements, which are very tight.

The current military thinking includes plans for phasing out old incinerators. One possible solution is landfill operations on the installations. This operation would be made more feasible by grinding up the solid wastes in a shredder or similar piece of equipment before proceeding with the landfill operation. In this way, volume reductions of up to 90% of the original are possible.

Akin to the current municipal industrial experience, the military trend in the water category is to go to joint municipal military systems. Joint treatment plants already have been planned for areas in Alaska and the Great Lakes region. Others are planned.

The problems of vessel discharges will be corrected after 1972. "Current programs for fiscal year 1973 and future years include projects for collection facilities at piers to solve the vessel discharge problems," says Sam Gorelick, another member of the DOD pollution control committee.

Looking ahead, the committee is interested and aware of the fact that noise pollution is becoming a problem; the big question which looms is that of noise from jet engines and jet engine test cells. There are 200-300 stationary cells in the country and in large part, they are located in relatively remote areas where a large land mass is the noise attenuating factor. In addition, there are a large number of relatively mobile sound-suppression units which probably will require improvement to meet projected noise control criteria. Although no federal noise requirement has been issued, the DOD committee awaits the report from EPA on noise pollution which is due to go to Congress by the end of this month. SSM

# Gas from COAL fuel of the future



With natural gas supplies unable to keep up with demand, coal gasification may provide a convenient, clean-burning fuel

Rapidly growing demands for energy coupled with increasingly stringent requirements for a clean environment have created an extraordinary and indeed critical fuels supply situation. Although not generally recognized until recently, coal gasification can play a uniquely important role in providing an abundant supply of clean-burning fuel from resources which are secure within national boundaries.

The spotlight was turned on coal gasification in the President's June 4 energy message which said, "As we carry on our search for cleaner fuels, we think immediately of the cleanest fossil fuel—natural gas. But our reserves of natural gas are quite limited in comparison with our reserves of coal. Fortunately, however, it is technically feasible to convert coal into a clean gas which can be transported through pipelines. The Department of the Interior has been working with natural gas and coal industries on research to advance our coal gasification effort... We are determined

U.S. Bureau of Mines Washington, D.C. 20240

### feature

to bring greater focus and urgency to this effort."

The Secretary of the Interior asserted that coal gasification has top priority among all Departmental programs related to coal conversion. In August, the Department of the Interior signed an eight-year agreement with the American Gas Association to develop jointly facilities to turn coal into pipeline gas. Federal expenditure for this program will be doubled to \$20 million a year, and industry has agreed to provide \$10 million a year.

#### **Changing energy requirements**

Natural gas supplies one third of the Nation's total energy requirements, including approximately half the demand of residential, commercial, and industrial consumers. One fourth of the needs of steam electric power plants is also supplied by gas. While oil supplies 43% of U.S. energy needs, currently about one fourth is imported. Therefore, at the present time, natural gas represents the largest energy fuel produced and used in the United States.

The fuel use situation is the reverse of fuel supply. Oil and gas supply three quarters of U.S. energy fuel, whereas coal, which supplies 20% of U.S. energy, represents three quarters of the fossil fuel reserves.

Both the growth of total energy demand and the interrelationship of the different energy fuels are changing (see left). During the 30-year period ending 1970, energy demand grew at an average yearly rate of 3.4%. A 3.5% average annual increase is projected by the Bureau of Mines for the 1970 to 2000 period. At this projected rate, energy use will grow from 69 quadrillion Btu in 1970, to 133 quadrillion Btu in 1985, and 192 quadrillion Btu in the year 2000.

While the use of nuclear power will increase enormously, in 2000 it will still only supply 23% of the total energy demand. However, the demand for each of the fossil fuels—oil, gas, and coal—is projected to double by the year 2000.



#### **Pipeline gas demand**

For many years before air quality standards imposed their special requirements for clean fuels, gas consumption far exceeded the growth rate of other fuels, averaging an annual increase of 6% between 1950 and 1970. But, the level of proved reserves of natural gas in the lower 48 United States dropped in 1970 for the third successive year. The reserve/production ratio is currently 12/1 compared to 21/1 in 1960. The Potential Gas Committee reported in 1969 that, in addition to the proved reserves of 287 trillion ft<sup>3</sup>, that there are yet 1227 trillion ft<sup>3</sup> of domestic gas.

The gas demand-supply situation is such that while there may be undiscovered gas supplies which could last beyond the year 2000, the proved reserves are small, the rate of discovery is rapidly falling behind, and there are demands which apparently will not be met in the next few years. Nor can we depend on imports to satisfy demands. The Canadian National Energy Board has forecast that, at most, Canada will be able to supply the United States with not more than 2.3 trillion ft<sup>3</sup> of gas in 1980. If all goes well with the current proposals for importing Liquid Natural Gas (LNG), as much as 0.9 trillion ft<sup>3</sup> may be expected from this source in 1975. The price of this gas is expected to range from 75 to 85 cents/million Btu.

Attesting to the pressing need for pipeline gas, commitment for six U.S. synthetic gas plants to produce gas from naphtha has been announced recently. The total design capacity of these plants will be 860 MMcfd, and it is estimated that the cost of this gas will be in the range of \$1.15–1.41/million Btu.

Consideration of all factors has led to the projection of a dramatic gap between gas supply and demand (above). This gap will reach as much as 17 trillion ft<sup>3</sup>/year by 1985 if synthetic gas is manufactured only on the small scale shown. Such considerations have led to proposals for a massive "crash" program for coal gasification.

An additional use for methane as automotive fuel, although controversial, has tremendous potential. Methane is a high-octane fuel (130 O.N.); it can be used in an internal combustion engine with markedly decreased air pollution relative to gasoline; and it can be manufactured from coal which is in abundant supply at a cost which compares favorably to that of gasoline. It will almost certainly be necessary to supply a synthetic fuel from coal for transportation in about 10 years.

#### **Coal** gasification

Coal gasification consists of the chemical transformation of solid coal into gas and, in the present discussion, includes those process steps which result in the manufacture of pipeline-quality gas. Pipeline gas is composed essentially of methane, is virtually free of sulfur, and contains no carbon monoxide or free hydrogen. The heating value is about 1000 Btu/ft<sup>3</sup> of gas.

Synthetic pipeline gas approaching the specifications of natural gas from coal can be manufactured by producing a synthesis gas followed by purification and catalytic methanation. A typical process begins with coal preparation in which coal is ground to a powder (right). It is then pretreated with air or oxygen to destroy the caking property since heating causes some coals to swell and plug the reactor. Then follows the gasification step in which synthesis gas is formed when steam and oxygen react with coal. This synthesis gas will contain varying amounts of carbon monoxide, hydrogen, and methane as valuable components and carbon dioxide and sulfur compounds as impurities that must be removed in further processing

After removing tar and dust from the gasifier product, the gas is conducted over a "shift" catalyst where the reaction

$$CO + H_2O \rightarrow CO_2 + H_2$$

partially occurs. The objective is to bring the  $H_2/CO$  ratio to 3, which is required for the subsequent methanation step:

$$CO + 3H_2 \rightarrow H_2O + CH_4$$

An intensive purification precedes methanation—strict sulfur removal being required to keep the catalyst active. Following methanation, the product gas is virtually sulfur free, essentially void of carbon monoxide, but contains a

#### **Coal gasification process steps** (Investment for 250 million ft<sup>3</sup>/day plant)



small amount of hydrogen gas. The heating value is typically about 50 Btu/ft<sup>3</sup> less than natural gas.

Gasification occurs at reasonable rates only at high temperature, 1700° to 2500°F. Pressure alters the gas composition with higher pressures resulting in higher proportions of methane. While gasification can be carried out at 300-1000 psi, commercial processes are expected to operate near 1000 psi (the pressure used in gas transmission).

#### Technology

Since the hydrogen content of coal (averaging about 5 wt %) is very low compared to that of methane (25%), coal gasification consists of adding hydrogen to coal. In addition, the sulfur, nitrogen, and oxygen constituents of coal are converted to H<sub>2</sub>S, NH<sub>3</sub>, and H<sub>2</sub>O, respectively. (Illinois #6 coal, for example, has a composition represented by the formula  $C_{100}H_{85}S_{2.1}N_{1.5}O_{9.5}$ .)

As bituminous coal is heated, it becomes soft and may stick together or cake at about 600°F, then devolatilizes about 1000°F, and finally undergoes the gasification reactions in the presence of steam at 1800°F. Gasification reactions of significance are:

	Δ	H, kcal/g-mol
		@ 25°C
(1)	$C + O_2 \rightarrow CO_2$	-94.1
(2)	$C + H_2O \rightarrow CO + CO$	$H_2 + 31.4$
(3)	$\mathrm{C} + 2\mathrm{H}_2 \!\rightarrow \!\mathrm{C}\mathrm{H}_4$	-17.9

(negative values indicate that heat is given off, and positive values indicate that heat must be supplied).

The rates of reaction, equilibria, and heat requirements are all of critical importance. Reaction 2 is relatively slow, and a temperature of above about 1800°F (lower for lignite) is required for sufficiently rapid gasification.

From a heat balance viewpoint, it is important to supply heat to endothermic Reaction 2 by having as much possible of exothermic Reaction 3 occur in the gasifier. If the methanation reaction

(4) CO + 
$$3H_2 \rightarrow CH_4 + H_2O (-49.3)$$

is carried out as a separate step, much of the heat generated is lost.

The two most expensive process steps in conversion of coal to pipeline-quality gas are gasification and purification. The gasification reaction absorbs large quantities of heat. The required heat can be furnished by any of several methods:

• partial combustion of coal with oxygen

• heat released by reacting carbon dioxide with a metal oxide

• by inert heat carriers

· by electrical energy.

Using oxygen is effective but expensive so these processes attempt to minimize the amount of oxygen required. To do this, a maximum quantity of methane must be produced in the gasifier. Not only is the quantity of coal needed to react with steam to make synthesis gas reduced, but the formation of methane in the gasification reactor produces a significant fraction of needed heat (since the heat of formation of methane is large and exothermic). When large amounts of methane are formed in the gasification reactor, the reduced volume of gas has a salutary effect on process costs involving purification, shifting, and methanation. For each volume of methane produced in the gasifier, the quantity of synthesis gas to be treated subsequently is reduced by 75%.

#### **Types of processes**

There are a great number of significant coal gasification processes. When air is used instead of oxygen, a so-called producer gas is manufactured which has a low-volumetric heating value, for example, 150 Btu/ft<sup>3</sup>. Although not considered suitable for pipeline gas since transportation costs are relatively high for gas on a volume basis (18 cents/1000 miles/1000 ft<sup>3</sup> for methane), producer gas may have a future for steam plant generation of electricity.

About 60 coal gasification plants of the Lurgi or fixed-bed type which require a noncaking and sized coal (3/8 to 1 in.) are operating in Europe. Pipeline gas made by this older technology will result in a gas which is still generally too expensive. However, since the fixed-bed technology is well developed, such a process may be adopted for the short term. El Paso Natural Gas has announced that they will build a \$250 million plant to produce 250 million ft3/day using the Lurgi process (which necessitates adding a new methanation step to meet U.S. gas specifications for increased heat value).

New processes (below) being intensively investigated for pipeline gas manufacture differ primarily with respect to the method of gas-solid contracting, supply of heat to the steam decomposition reaction, and the extent to which direct hydrogenation of coal to methane is combined with steam decomposition in the high-temperature reaction. Others of current interest are the Bureau of Mines hydrogasification process, the M. W. Kellogg "molten salt process," the FMC, and the Batelle Foundation gasification systems. Underground gasification and nuclear energy are longer range possibilities.

Special features of each process include:

 In the IGT HYGAS process (hydrogasification), residual char is gasified with steam using electrical energy as the heat source. The gas so formed, rich in hydrogen and low in carbon dioxide, is reacted with pretreated coal in two hydrogenation stages to produce a gas

Process	Laboratory	Sponsor	Federal Funding FY 1972		
HYGAS (Electrothermal)	IGT	OCR-AGA	\$3,500,000		
HYGAS (Oxygen)	IGT	AGA			
CSG (CO <sub>2</sub> Acceptor)	Consolidation Coal Co.	OCR	3,420,000		
SYNTHANE	BuMines	BuMines	1,500,000		
BI-GAS	BCR	OCR-NCA	3,300,000		
STEAM-IRON	IGT	Industrial			
FIXED BED	BuMines	BuMines	750,000		
FIXED BED	Lurgi	Lurgi			

with high methane content. When processing caking coals, the coal is first introduced into a pretreater and oxidized with air at relatively low pressure to render it noncaking. Slurried with oil and pumped under pressure to a fluid bed where the oil is stripped off for recycle, the coal is then contacted with hydrogen-rich gases in two successive stages, consisting of an entrained fluid and a fluid bed. The residual char then enters an electrothermal gasifier. If desired, additional char is produced for power generation. After shifting and purification, a "cold gas" methanation system is used, circulating product gas to control heat rise over a number of fixed beds of supported pelleted nickel catalyst.

• A variation of the HYGAS process produces hydrogen-rich gas as a raw synthesis gas (CO +  $H_2$  + CO<sub>2</sub>) by contacting char with oxygen instead of electrothermal means.

• The CSG process (also called the  $CO_2$  acceptor process) utilizes the reaction between hot lime (calcium oxide) and  $CO_2$  to furnish required gasification heat. Purified oxygen is not needed.

Preheated lignite is fed to a devolatilizer and heated with synthesis gas from the gasifier and hot lime to drive off the volatiles, which are largely converted to methane. Char and spent lime are carried by steam to the gasifier, where they come in contact with the additional hot lime. The reaction of steam with the char forms a synthesis gas containing CO2 which reacts with the lime converting it to limestone (calcium carbonate) and generating additional heat. The char is totally gasified except for that needed for reburning the limestone. The process has been tested in the laboratory, and a pilot plant (without a methanation system) is under construction to gasify about 36 tons of lignite per day.

· Synthane process carries out pretreatment of caking coals under pressure, integral with the gasifier. That is, a small amount of oxygen is added, all solid and gaseous products are carried forward into the reactor where carbonization occurs in a dense fluid-bed zone, and gasification occurs in a dilute fluid-bed zone. Process simplicity is important to operability. More than half the ultimate methane is made in the gasifier under nonslagging conditions. After shifting and purification, methanation occurs in either of two systems, hot gas recycle or tube-wall reactor, both using Raney nickel catalyst.

• BI-GAS process is a steam-oxygen process designed for complete conver-



sion of coal. Coal and gas are introduced in an upflow (entrained) gasifier, where the coal is devolatilized and the volatiles are largely converted to methane. The char produced is carried overhead by the gas flow through a char separator and returned to the gasifier to react with oxygen and steam at a temperature that slags (melts) the ash. The hot gases produced furnish heat for the first-stage gasification reaction. The synthesis gas containing methane is shifted and methanated to produce a pipelinequality gas. In contrast to the other processes discussed, the gasification temperature is sufficiently high to melt or slag the coal ash which is drawn off as a liquid.

• The steam-iron process uses hydrogen produced by reacting steam with reduced iron ore, FeO. The resulting magnetite,  $Fe_3O_{45}$  is then reduced to ferrous oxide with a producer gas derived from devolatilized char, air, and steam. The hydrogen is used for hydrogasification of coal and for catalytic methanation of carbon monoxide.

• Fixed Bed. The fixed-bed gasifier is the only type now being operated commercially. The BuMines pilot plant has an agitator or stirrer which operates to break up coke masses which form when American caking coals are used. Most bituminous coals, particularly those located in the eastern half of the United States, are too strongly caking to be gasified in a conventional fixed bed. Noncaking coals can be gasified in this type of unit without a stirrer in the bed of coal, and moderately caking coals have been used in some commercial producers with a mechanical stirrer. Several processes are planned for pilot plant testing by 1975. A full-scale plant could be built by 1978. Thus, large-scale commercialized coal gasification will not occur until 1980 or later.

#### Cost of gas

There are three basic price levels for pipeline gas-the wellhead price (16.4 cents/thousand ft3 in 1968), the city gate or wholesale price (35.2 cents), and the consumer price (\$1.00). The consumer price varies and includes residential, commercial, and industrial uses. The need for gas has recently initiated higher priced alternatives for gas supply. Liquid natural gas, mentioned earlier, is one alternative. Pipeline gas from coal offers another alternative, and its costs have been analyzed in some detail. Revised estimates in 1971 raised estimated selling price to 64 cents/thousand. Columbia Gas estimates 85 cents/1000 ft3 with coal at \$5.50/ton. The price of gas is sensitive to coal costs-an increase of \$1.00/ton being equivalent to 7 cents/ million Btu.

An economic examination of the new coal gasification processes is shown above. The fraction of the total price of the methane contributed is shown in each process step, and includes capital, labor, and other charges in accordance with federal and state regulations for utilities.

Methane comes principally from two sources: first, from the coal's volatile matter by heating pretreated coal to devolatilization temperature. The second source of methane is devolatilized char which is reacted with steam to form CO and H<sub>2</sub>. These are converted to methane, either through external catalytic methanation or in-situ gasification.

The cost of adding heat to the steamcarbon reaction represents nearly one third of the total cost of the methane produced. To reduce the cost of methane from coal, a process must optimize devolatilized methane production and keep the cost of added heat to the steamcarbon system to a minimum.

#### **Coal gasification consequences**

The enormous scale of the potential coal gasification industry has tremendous environmental, economic, demographic, and political implications. As mentioned earlier, there is a projected gap between gas demand and supply of as much as 17 trillion ft<sup>3</sup> by 1985. Manufacture of 10 trillion ft3 of pipeline gas from coal would require 120 plants of 250,000,000 ft<sup>3</sup> daily capacity each (12 such plants/ trillion ft<sup>3</sup>). Estimating plant costs at \$200 million each, including the mine, corresponds to a total capital investment of \$24 billion. Moreover, each plant would consume about 6 million tons of bituminous coal annually or a total of 720 million tons; this would more than double U.S. coal production (currently about 600 million tons per year). The American Gas Association has reported that there are at least 176 potential coal gasification sites in the U.S.

To supply energy needs in the next 30 years, synthetic fuels from coal or corresponding increases in oil importation will be required. Oil importation is now at the \$2.7 billion/year level. By 1980, projections predict \$10 billion with higher amounts later.

#### **Environmental factors**

From an environmental viewpoint, land, water, and air are all critically involved. As mentioned earlier, 120 coal gasification plants would more than double present coal consumption. Strip mining is expected to be utilized to a large extent. The greatly increased amount of mining will require restoration of mined areas.

Water management is also an important factor. For each plant, 100,000 gal/min would be circulated, of which 20,000 would be consumed. Special precautions are necessary to prevent discharging water-soluble contaminants such as phenols.

Thermal pollution in coal gasification is significant since the conversion of coal to pipeline gas is only about 65% thermally efficient (120 plants would require disposal of about  $5 \times 10^{15}$  Btu/year). Heat disposal to the air is planned by evaporative cooling, which consumes most of the water mentioned above. Disposal of coal ash from the coal processed is also necessary. Fortunately, coal gasification is carried out in closed vessels which prevents air pollution. An important fact is that the gas produced is usually free of sulfur, having only a few parts per billion. The sulfur in coal is removed in the gasification process and is transformed to elemental sulfur for storage, shipment, or use in a satellite industry. Therefore, the conversion of coal to gas represents a net environmental benefit in reducing pollution by sulfur oxides and particulate matter.

#### **Additional reading**

- Statement, Hon. Rogers C. B. Morton, before Committee of Interior and Insular Affairs, U.S. Senate (SR 45), June 15, 1971.
- "Fuels Management in an Environmental Age," G. A. Mills, H. Perry, and H. Johnson, **ES&T**, Vol. 5, 30 (1971).
- "An Economic Study of Pipeline Gas Production from Coal," J. P. Henry, Jr., and B. M. Louks, Chem. Tech., 239 (1971).
- "Electrothermal HyGas Process, Escalated Costs," C. L. Tsaros and T. K. Dubramanian, O. C. R. Contract 14-01-0001-381, Report No. 22, Interim No. 6, February 1971.
- "A Reassessment of the Prospects of Coal Gasification," H. R. Linden, *Coal Age*, **73**, May 1971.
- Age, 73, May 1971. Presentation to the National Coal Association, J. W. Partridge, The Columbia Gas Systems, Inc., June 14, 1971.



G. Alex Mills is Chief, Division of Coal, Energy Research, U.S. Bureau of Mines. He has received degrees from the University of Saskatchewan and Columbia University. Author of over 100 patents and technical articles, Dr. Mills is particularly interested in the conversion of coal to liquid and gaseous fuels to supply energy needs without air pollution.



#### **Richard D. Grundy**

Professional Staff U.S. Senate Committee on Public Works Washington, D.C. 20510



## Strategies for control of I

Edutrophication is a natural process which involves an increase in the biologic productivity of a body of water as a result of nutrient enrichment from natural sources. Environmental concern is for those instances where the natural aquatic growth processes are accelerated or increased. Under man's influence, excessive amounts of nutrients can enter an aquatic ecosystem, accelerating the eutrophication processes—this is known as "cultural eutrophication."

In the early stages, cultural euthrophication may produce beneficial effects e.g., increased fish productivity. However, in the advanced stages, cultural eutrophication can eventually lower dissolved oxygen levels, interfere with recreational uses of water, affect drinking water taste, and result in summer blooms of undesirable blue-green algae.

Although all nutrient discharges into the aquatic environment contribute to the reservoir of material available to support aquatic productivity, current control efforts tend to emphasize nutrients limiting aquatic productivity, in particular, phosphorus. Although carbon and nitrogen also have been suggested as "limiting" nutrients, both have an atmospheric reservoir available to the aquatic environment. Phosphorus, however, has a sedimentary cycle, with no atmospheric reservoir.

This distinction between nutrients with, and without, a gaseous phase is basic to formulating a strategy for the control of cultural eutrophication. Nutrients with a gaseous phase (for example, carbon, nitrogen, oxygen, and hydrogen) have more or less perfect or complete biogeochemical cycles in which there is a continuous transfer of nutrients between the living (organic) and nonliving (inorganic) components of ecosystems. Nutrients without a prom-

Source	Millions of	WHEN PROPERTY AND A P		
	pounds/yr	%	Millions of pounds/yr	%
Natural	245-711	64.41	1,035-4,210	21.51
Man-generated Domestic sewage Runoff from	686–1,015 (387–446)	74–57	3,990 (1,330)	79-46
Urban land Cultivated land Livestock areas	(19) (110–380) (170)		(200) (2,040) (420)	

inent gaseous phase (for example, phosphorus, calcium, silica, and potassium) are circulated to a greater extent by processes such as erosion, sedimentation, and biological activity.

Controlling phosphorus alone and detergent phosphates, in particular, may retard cultural eutrophication where phosphorus limits aquatic productivity. However, long-term control strategies must reflect regional variations in limiting nutrients and other factors contributing to aquatic productivity. Regional variations are experienced in the contributions of nutrients entering the aquatic environment from municipal waste water, urban runoff, agricultural runoff from fertilized fields and livestock feedlots, and erosion. Agricultural runoff exhibits large seasonal variations.

#### **Phosphorus sources**

Detergents are unique among consumer products as a source of nutrients. Nationally they represent about 5.5 billion lb annually, approximately 20 lb for every man, woman, and child. The phosphate fraction amounts to 2.2 billion lb or 30-40% of all the phosphorus entering the aquatic environment. The environmental implications of such quantities cannot be discounted; however, the potential nutrient properties and public health and environmental implications of alternative ingredients also must be considered. For lack of regional data, national estimates on the respective contributions of natural and man-generated phosphorus entering the aquatic environment are presented in the table at left.

### feature



Long-term solutions to cultural eutrophication will need to go beyond control of detergent phosphates and even beyond the control of phosphates in general

## man-made eutrophication

Principal sources of phosphorus in domestic sewage are human excrement and detergents. The fraction from human excreta varies with diet, averaging 1.0 to 1.2 lb/person annually. The contribution from detergents has increased with expanded use to approximately 3.0 to 3.3 lb/person.

Significantly, some 40% of the increase in phosphorus in municipal waste waters between 1957 and 1968 resulted from an increase in the number of people discharging into municipal treatment systems rather than increased phosphorus usage. Obviously, water pollution control strategies could be more comprehensive.

Industrial utilization of detergents, processing phosphate and phosphorus products, and natural sources (such as decomposition products, bottom sediments, and erosion) also contribute to aquatic nutrient availability; however, there is insufficient data to estimate the quantities involved.

Although nitrogen has a gaseous phase, it also is worthy of consideration in control strategies, particularly where estuaries are involved. Data in the table on the previous page indicate that as much as 80% of the nitrogen entering the aquatic environment nationally comes from man-generated sources. Because of man's tremendous impact, an integrated control strategy for cultural eutrophication should consider both phosphorus and nitrogen.

#### **Scientific arguments**

In an undisturbed lake, eutrophication is a slow, natural aging process, eventu-

ally terminating in the disappearance of the lake itself. Because a lake acts as a settling basin, the input of organic and inorganic matter directly affects its productivity and life-span. Under man's influence, this process can be vastly accelerated by the discharge of excessive amounts of nutrients.

Some 15 to 20 nutrients play an essential part in eutrophication. These nutrients include carbon, nitrogen, phosphorus, silica, iron, potassium, and trace metals introduced from natural sources or as a result of man's activities. Vitamins also may act as growth stimulants after being introduced by man's activities or biological synthesis within the receiving waters themselves. Physical characteristics of a water body, such as increased light penetration and temperature rises, also affect aquatic productivity where appropriate nutrients are available.

Continuous transfers of nutrients between the living and nonliving components of an ecosystem are known as biogeochemical cycling. Nutrients with a gaseous phase such as nitrogen, carbon, oxygen, and hydrogen are important in this continuous flow between inorganic and organic states. These nutrients are considered to have "complete" cycles.

In contrast, nutrients without a prominent gaseous phase, such as phosphorus, calcium, silicon, and potassium, have cycles which are less perfect or complete. These nutrients are naturally circulated by a "sedimentary cycle" involving erosion, sedimentation, and biological activity.



Various compensating mechanisms tend to prevent major changes in the distribution, abundance, or availability of nutrients with a perfect cycle. Nutrients with a sedimentary cycle, however, are released into the aquatic environment more slowly by erosion, runoff, and physicochemical and biological processes such as the weathering of plant litter, soil minerals, and bedrock. They accumulate in deep lake and ocean sediments and are, for the most part, unavailable to support aquatic productivity.

Control strategies have focused on three nutrients—carbon, nitrogen, and phosphorus—as nutrients limiting eutrophication. Phosphorus, however, is believed to be the nutrient most frequently limiting aquatic productivity. It also has a sedimentary cycle and lacks the atmospheric source available to carbon and nitrogen. Therefore, it is considered the preferable nutrient for control.

Recent data for estuaries and oceans suggest that, although phosphate concentrations are very high, normally phosphorus does not limit productivity. Instead, nitrogen is apt to limit eutrophication. In such circumstances, replacement of detergent phosphates with a nitrogen-containing material might very well enhance eutrophication.

This does not mean that phosphorus could not be rendered limiting. High levels of phosphorus and carbon in estuaries result largely from river discharges. As upstream sources are brought under control, phosphorus may well become limiting.

Feasibility for controlling phosphorus is enhanced by, first, the high concentrations in domestic sewage and certain industrial waste waters, and, second, by phosphate's high reactivity and ease of precipitation by a variety of waste water treatment processes.

Phosphorus occurs in municipal waste waters in several chemical forms, including phosphates in suspended solids, polyphosphates, and orthophosphates (see figure, bottom right, p 1185).

The insoluble suspended solid fraction, human excreta and food solids, represents 30-40% of the phosphorus in municipal waste waters. Soluble polyphosphates are virtually all contributed by synthetic detergents. Soluble orthophosphates are mainly the degradation products of detergent polyphosphates, human wastes, and food solids containing phosphorus.

This distinction is significant because the suspended, insoluble forms of phosphorus are usually removed by primary or secondary treatment processes. The soluble fractions, however, are only partially removed in secondary treatment by bacterial action. The major unaffected fraction is discharged into receiving waters and available to support eutrophication, unless advanced waste



water treatment methods or land disposal are employed.

Typically, conventional secondary treatment effluent contains about 4000 parts per billion (ppb) of phosphates. This is at least 100 times the concentration for maximum rate of growth for the algal species *Chlorella pyrenoidosa*.

A dilution of greater than 100 would be required before such an effluent would have no perceptible affect on algal growth. Such dilution capabilities are rarely attainable in receiving waters in the United States.

Two complementary elements for inclusion in control strategies are advanced waste treatment and consumer product controls.

#### **Phosphate substitutes**

Since detergents amount to 30–40% of the phosphorus (as phosphates) in municipal sewage, they are often singled out for special attention. (Some six states and 47 communities have enacted legislation restricting phosphate levels in detergents. The majority restrict detergent phosphorus levels to 8.7% immediately and zero in 1972. Whether these restrictions can be met without substituting new public health or environmental problems remains to be seen.)

New and reformulated detergent products are being introduced so rapidly that the federal EPA recently announced suspension of its publication of data on detergent phosphorus content. There are potential human health hazards for some of the low-phosphate and nonphosphate detergent formulations. Surgeon General Jesse L. Steinfeld has advised "great care must be exercised to assure that the alternative does not create equal or greater hazards to the environment or to human health."

Some "low-phosphate" or "nonphosphate" detergents employ sodium silicate or sodium metasilicate in addition to carbonates or phosphates. The resultant products are often highly alkaline; some have required labeling under the Federal Hazardous Substances Act. Introduction of these materials under the guise of pollution control, without preassessment of their potential public health and environmental effects, may, in effect, perpetuate a fraud on the consumer.

		phosph (millio	ns of doll	<b>noval</b> ars)		
	TOTAL TR	EATMENT	COSTS FOR	SELECTED U	JNIT TREAT	MENT
			(CENTS,	/1000 GAL)		
<b>%</b> a	5 Cents	4 Cents	3 Cents	2.5 Cents	2.0 Cents	1.5 Cent
100	280	224	168	140	112	84
75	210	168	126	105	84	63
50	140	112	84	70	56	42
25	70	56	42	35	28	21

Potential public health effects identified for some highly alkaline detergents include severe damage to the throat, larynx, esophagus, or stomach and severe damage to the eyes or skin. Consumer product effects include loss of fabric strength and dye retention, loss of nonflammable characteristics for current fabrics, and corrosion of washing machines. The risks vary with alkalinity and the particular ingredient employed.

Prudent public health policy dictates that any regulatory action to ban phosphates in detergents consider the public health and environmental implications of alternative detergent formulations. Other control strategies are available to control or reverse cultural eutrophication—advanced waste water treatments, diversion, dilution, and land disposal.

#### **Regional differences**

Phosphate input to U.S. waters from detergent sources varies regionally. Lake Washington, near Seattle, is an excellent example of a lake ecosystem where conventional secondary treatment of municipal waste waters was insufficient to control cultural eutrophication. In the mid 1960's, Seattle initiated total diversion of its treated municipal waste water around Lake Washington (although phosphate removal might, in fact, have been sufficient). Since then, cultural eutrophication in the lake apparently has reversed.

The Potomac River Basin exemplifies a river ecosystem where municipal waste waters are the primary source of phosphorus and other nutrients (see left). Approximately 65% of the waste water phosphorus is from detergent phosphates, or about 50% of the total phosphorus in the Potomac River Basin. The Alafia River in Florida is an estuarine ecosystem where the mining industry is the primary source of phosphorus. The 14 phosphate processing plants located on the Alafia River discharge some 43,470 lb of phosphates (as phosphorus) daily into the Alafia River. Municipal and industrial waste water discharges from Tampa amount to 2700 lb of phosphorus. The overall detergent phosphorus contribution is about 4%.

Then there is Lake Erie, often cited as the worst example of cultural eutrophication. Detergent phosphates represent roughly 50 to 70% of the combined municipal and industrial sources of phosphorus. This amounts to 35 to 50% of all the phosphorus sources to Lake Erie, excluding that amount which comes from Lake Huron. Several experts believe that control of detergent phosphates alone will probably produce no noticeable improvement in the existing conditions. Restoration of Lake Erie may very well require control of all sources of nutrients, including municipal and industrial wastes, agricultural runoff, and erosion, as well as of nutrients already in the lake. This may require harvesting of algae or treatment of lake waters in situ.

A recent five-year agreement on the Great Lakes, between Canada and the U.S., calls for accelerated municipal waste water treatment for phosphorus. With the existing level of detergent phosphorus in the U.S., 95% removal of phosphorus from municipal waste waters is necessary to achieve target loadings. Were detergent phosphorus levels to be lowered to 2–3%, around 80% removal of phosphorus would be required.

The Canadian government has adopted a dual approach combining a reduction of phosphates in detergents with phosphorus removal from municipal waste waters with a residual phosphate objective of "as near zero as possible." Detergent formulations in Canada are currently restricted to a maximum phosphate content of 20% (8.7% phosphorus).



It was recognized that this action on detergents alone would have little impact in the critical Great Lakes areas. In other areas, the Canadian government believes it will make a quick and significant contribution to retarding eutrophication.

#### Waste water management

An attractive alternative to banning detergent phosphorus is to reduce phosphate content to reflect regional water quality and wash water characteristics, and to combine this with waste water treatment for phosphorus. An EPA study will list those waters which have an actual eutrophication problem. Longterm solutions to cultural eutrophication may also require waste management practices which dispose of treated liquid effluents and sludges on the land.

Control of erosion and agricultural runoff must rely on improved soil conservation practices and the proper use of fertilizers. Waste management practices for feedlot wastes appear to be land disposal rather than waste treatment.

When waste water treatment is considered as a control alternative, the following technical points emerge:

· The economics of nutrient removal in general, and phosphorus removal in particular have been successfully demonstrated

· Chemical precipitation processes not only remove phosphorus but improve removal of BOD, toxicants, and other nutrients

· The amount of chemical required is frequently independent of the concentration of phosphorus in the waste water.

The cost for chemical methods applicable to existing primary and secondary treatment plants is comparable to anticipated increased detergent costs for formulating a nonphosphate detergent.

#### Economics

An important consideration in any solution to cultural eutrophication is

#### State and local detergent legislation on product restriction (passed through 9/29/71)

Area	% P	Date	No phosphate date	Area	% P	Date	No phosphate date
New York State	8.7	1/1/72	6/1/73	Dade County, Fla.	8.7	4/30/71	1/1/72
Connecticut	8.7	2/1/72	6/30/73	(Injunction against labeling t	ill 8/1)	a rest Card	
Maine	8.7	6/1/72	Sector Street	(Suit filed to enjoin total P ba	an and l	abeling pi	ovisions)
Florida	Enat	ling Act a	uthorizing reg.	Cocoa Beach, Fla.	8.7	9/30/71	
Tiorida	ulati	on of P	content as of	Orange County, Fla.	8.7	5/31/71	1/1/72
	12/31	./72		Pinellas County (St. Pete), Fla.	. 8.7	9/1/71	1/1/72
Indiana (Suit filed 6/8/71)	12%	"phosphat	1/1/72	(St. Petersburg itself excepte	ed)		
	5%	phospha	le <sup></sup> 1/1//5	Pembroke Pines, Fla.	8.7	6/19/71	1/1/72
Minnesota	Enat	on of nut	rient content	(Enforcement temporarily su	spended	i)	
	etc., effective on passage		on passage	Kennebunkport, Me.	14%	6/2/71	1/1/72
Oregon	Pack	aging legis	slation-		phos-		
an on a stand of the stand of the	9/3	0/71	Jacon		pnate		
Chicago, III. (Suit filed 5/4/71)	8.7	2/1/71	7/1/72	Bridgton, Me.			6/1//1
Hillside, III.	8.7	2/1/71	7/1/72	Naples, Me.			7/1/71
Elgin, III.	8.7	7/1/71	7/1/72	Madison, Wis.	8.7	7/1/71	(Law applies
Aurora, III.	8.7	//1//1	7/1/72			State 1	to city depart
Chicogo Unighto III	8./	5/1//1	1/1/12				ment pur-
Chicago, Heights, III.	8./	//1//1	6/30/72				chases only
Jollet, III.	8./	5/1//1	0/30/72	Erie County, N.Y.	8.7	4/30/71	1/1/72
Niles III	8.7	7/1/71	6/30/72	Suracuse N Y	87	7/1/71	7/1/72
Skokie, III.	8.7	6/30/71	6/30/72	Syracuse, N.T.	0.7	1/1/11	1/1/12
Franklin Park, III.	8.7	7/1/71	6/30/72	Suffolk County, N.Y.	Total	ban on	ABS, alcono
Lombard, III.	8.7	6/1/71	1/1/72		sul	tates, m	etnylene blu
Elmwood Park, Ill.	8.7	6/1/71	12/31/71		act	ive substa	inces (nonioni
Harwood Heights, III.	8.7	6/1/71	6/30/72		am	endment	approved)
Lake County, III.	8.7	6/1/71	6/30/72	Bayville, N.Y.	Same	e as Suffo	Ik County
Laconia, N.H.	8.7	6/1/71	5/31/72	Kalamazoo, Mich.	8.7	11/1/71	
New Hampshire Lake area			6/1/71	Grand Rapids, Mich.	8.7	1/1/72	
(Nine cities in Carroll, Belkna	p Coun	ties)		Wyoming, Mich.	8.7	1/1/72	
Akron, Ohio	8./	8/6/71	//1//2	Detroit, Mich. area			
(consent judgment accepted)				Detroit	8.7	7/1/71	7/1/72
Cleveland, Ohio area				(Suit filed 5/3/71)			
Painesville	8.7	7/1/71		Flint, Michigan			7/1/72
Berea	8.7	6/1/71	6/30/72	Ypsilanti Township	8.7	6/1/71	6/1/72
Brook Park	8.7	//1/71	6/30/72	Grosse Point Woods	8.7	7/1/71	6/30/72
Fuelid	8./	6/1//1	6/20/72	Inkster	8.7	7/1/71	7/1/72
Block Island, R I	0.7	0/1//1	A/1/71	Ypsilanti, Mich.	Ban	on nonbio	degradable de
Kiccimmoo Ela	07	1/1/72	1/1/72		Po	gents co	rams P/use i
Kissininee, ria.	0.7	1/1/72	1/1/72		sto	res	
(Consent judgment accepted)	8.7	4/1/71	12/31/72	Prince George's County, Md.	8.7	1/1/72	1/1/73

1188 Environmental Science & Technology
the comparative costs for alternative control strategies. Ultimately, any costs will be borne by the consumer either as increased product costs or increased waste water treatment costs.

Estimates of increased product cost for detergent phosphate substitutes are available for nitrilotriacetic acid (NTA), although it is currently not being used. Manufacturers report a differential cost of approximately 5 cents/lb for raw materials. Complete replacement of the 2.5 billion lb of detergent phosphates manufactured each year would have increased product costs \$145 million to \$150 million and increased consumer costs by about \$200 million to \$400 million annually.

Several basic assumptions are necessary to estimate the cost for phosphate removal during waste water treatment: first, that the total U.S. pollution of 205 million people is discharging into municipal waste water treatment systems; second, that the average waste water volume entering a treatment plant from all sources is 150 gal per capita per day; third, that the average. phosphorus concentration is 10 mg/l. from all sources; and fourth, that detergent phosphates account for approximately 50% of this phosphorus.

On the basis of these assumptions, the maximum total national cost to treat municipal waste waters to remove phosphates can be calculated (table, p 1187). (Product cost increments are calculated per pound of phosphates, not per pound of detergents; treatment costs do not reflect percentage removal of phosphates.)

Assuming a phosphate replacement cost of 5 cents/lb and treatment costs of 5 cents/100 gal, 45% of municipal waste waters could be treated for costs comparable to use of a detergent phosphate substitute (figure, p 1187).

Should treatment costs be 2.5 cents/ 1000 gal, then almost 90% of the municipal waste water could be treated for less cost to the consumer than the increased product costs.

The significance is that waste water treatment reduces total phosphate levels while product controls affect the detergent phosphate fraction alone. Treatment also has the added benefit of increased removal of BOD and suspended solids.

# **National policy**

In 1969, the Council on Environmental Quality advocated a three-phase approach to the control of cultural eutrophication. Current control strategies tend to emphasize detergent phosphates. Complementary control efforts for municipal waste waters and nonpoint sources such as agricultural runoff are not receiving comparable attention.

There is cause for concern should the consumer equate control of detergent phosphates alone with control of cultural eutrophication. Even if the socalled "nonpolluting" detergents do the cleaning job as well as phosphate detergents, their efficacy and human and environmental safety often are poorly tested. Effective long-term control strategies for cultural eutrophication must reflect both consumer products and municipal waste waters as sources of nutrients. Ultimately, regional solutions will be required which reflect limiting nutrients and reduction of all sources of nutrients.

To implement such a comprehensive control strategy for cultural eutrophication, the following definitive information is needed on a regional or watershed basis:

· sources of nutrients contributing to the available environmental reservoirs of nutrients

· critical nutrient or nutrients limiting aquatic productivity

· cost to the consumer and the degree of control that can be accomplished through reduction of the critical nutrient in consumer products

· degree of control and costs to the consumer for removing critical nutrients from municipal waste waters

· increased removal of BOD, toxicants, and other nutrients that is accomplished by advanced waste water treatment

 potential uses for resultant sludge and precipitated nutrients from advanced waste water treatment

· potential public health and environmental hazards associated with some phosphate-free or low-phosphate detergents.

Additional elements affecting consumer products that may be required in an effective long-term policy are:

· federal guidelines which encourage detergent manufacturers to develop and market products on a regional or watershed basis which reflect local contributing factors to cultural eutrophication

· federal guidelines for preassessing public health and environmental implications of any alternatives.

The key concerns for both long- and short-term control strategies for cultural eutrophication are: first, controls which reflect the regional character of the problem; and second, concern for the potential public health and environ-

# DEPEND ON US!

To provide the most advanced instruments for particles sampling, generating, and monitoring.



PAPER TAPE READER

PAPER TAPE READER Automatically evaluates sampler tapes in percent transmission or COH units; all solid-state circuitry with BCD out-put; features logarithmic converter to accommodate a wide range of sampling parameters for COH read-out; processes up to 480 spots per hour; meets ASTM, standards; solidstate printer available.



TAG SAMPLER Collects particles by impaction in nine stages; all stainless steel con-struction; permits isokinetic sampling of velocities from 500 to 2500 feet per minute by nozzle selection; re-tains particles by featuring low im-paction velocities; temperature up to 1800°F; size ranges from 0.1 to 30 microns, plus in-line filter; ideal for stack and industrial application.



FLUID ATOMIZATION AEROSOL GENERATOR MODEL 7330 Size range 0.03 to 3 microns; output up to 1 billion particles per second; variable dilution rates; all stainless steel contact areas. electrical-ly neutral aerosol; liquid or solid all particles.



St. Paul, Minnesota 55112 (612) 484-8591 You Can Depend on ERC

Circle No. 4 on Readers' Service Card



the technology that separates

Here's a new, easy way to test untreated waters for **coliform bacteria.** Simply dip the Millipore Coli-Count into the water to be tested, incubate and count the coliform colonies. You don't have to be a microbiologist—and there's nothing to prepare or clean up. The Coli-Count **water tester** is presterilized and disposable. It's a simplified version of the standard MF technique, used in 43 states to test the bacterial quality of drinking water. Send for details. Millipore Corporation, Bedford, Mass. 01730



Circle No. 19 on Readers' Service Card 1190 Environmental Science & Technology mental implications of the detergent nonphosphate and low-phosphate detergent formulations.

Immediate control strategies must reflect the following elements:

• cost effectiveness of nutrient control for all sources, such as detergents, land runoff, and municipal waste waters

 cost effectiveness of nutrient removal from municipal waste waters with particular concern for methods applicable to existing primary and secondary treatment plants

 cost effectiveness of returning nutrient-containing treatment sludges and effluents to the land for ultimate disposal

• cost effectiveness and public health implications of reduction of detergent phosphate levels.

In the interim, man may have to accept detergent cleaning abilities less than those achievable with phosphate detergents.

# Additional reading

- Environmental Protection Agency, Water Quality Office, "Cost of Clean Water, Cost Effectiveness and Clean Water, Volume III," Washington, D.C., March 1971.
- Ferguson, F. A., "A Nonmyopic Approach to the Problem of Excess Algal Growths," ES&T, 2, 188–93, (March 1968).
- 1968). King, D. L., "The Role of Carbon in Eutrophication," JWPCF, **45**, 2035–51, (December 1970).
- phication, JWPCF, 49, 2039-01, (December 1970).
  Likens, G. E., Bartsch, A. F., Lauff, G. H., and Hobbie, J. E., "Nutrients and Eutrophication," *Science*, 171, 873-4 (1971).
  Ryther, J. H. and Dunstan, W. M. "Nitrotrophysication," and eutrophication
- Ryther, J. H. and Dunstan, W. M. "Nitrogen, phosphorus, and eutrophication in the marine environment," *Science*, **171**, 1008–13 (1971).



Richard D. Grundy has been a member of the professional staff, U.S. Senate Committee on Public Works, since 1967. He is'a 1963 MPh graduate of the University of California, in radiological health, and completed one year of predoctoral studies in sanitary-radiological engineering. Grundy was with the USPHS Bureau of Radiological Health (now part of EPA) from 1959–67. This article summarizes a staff report prepared for the Senate Committee on Public Works. Reactions of Gaseous Pollutants with Solids

I. Infrared Study of the Sorption of SO<sub>2</sub> on CaO

M. J. D. Low,<sup>1</sup> Arthur J. Goodsel, and Nobotsune Takezawa

Dept. of Chemistry, New York University, New York, N. Y. 10453

• The sorption of  $SO_2$  on CaO at 25°C and the thermal decomposition of the sorbed layer in vacuum at temperatures up to 750°C were studied by use of infrared spectra recorded with a Fourier transform spectrometer.  $SO_2$  is sorbed in at least three forms. The main interaction of  $SO_2$  with degassed CaO is irreversible and leads to the formation of a surface sulfite. A reversible chemisorption occurs at high degrees of surface coverage.  $SO_2$  is then physically adsorbed on top of the more tightly bound species. On heating in vacuum, some surface sulfite is converted to surface sulfate at 550°C; at higher temperatures, conversion to sulfate and polymerization occur, a mixture of species being formed. Heating in oxygen converts the mixture to species resembling bulk CaSO<sub>4</sub>.

Horization included a variety of processes based on gas-solid interactions, such as catalytic oxidation or the injection of powdered limestone into the stack stream. Being of actual or potential technological importance, suitable gas-solid interactions have been studied. However, much of the work in this area seems oriented to the development of commercial processes, the fundamental aspects of the gas-solid interactions being neglected somewhat. Specifically, judging from the literature, nothing definite appears to be known about the surface species produced in many such reactions. As information about the nature and structure of surface species would be of mechanistic significance and also of potential utility, we have started a program of study with the intent of obtaining such information.

The present paper deals with the reaction of  $SO_2$  with CaO, studied by means of the infrared spectroscopic techniques which have been so successfully applied to adsorption and heterogeneous catalysis. CaO was of interest because of the reported use of calcium compounds for  $SO_2$  removal (Arai et al., 1960; Wickert, 1963; Pechkovskii and Mal'tseva, 1964; BASF 1965).

# Experimental

CaO powder (Baker and Adamson Co.) was formed into self-supporting sample disks of  $^{3}/_{4}$ -in. diameter by pressing 55–75 mg of powder in a steel die at a pressure of 80–100 tons/in.<sup>2</sup> A sample disk was tied with thin platinum wire to a quartz carriage bearing a quartz-enclosed magnet. The carriage and specimen were then placed within the body of a quartz cell, shown schematically in Figure 1. The sample was

positioned within the furnace during heat treatments. A calibration procedure permitted estimation of the temperature at the sample position by means of an external thermocouple. After installation in the cell, a sample was subjected to one of two degassing procedures by use of conventional high-vacuum equipment capable of 10<sup>-6</sup> torr. Some samples were degassed at 800°C for three hr and cooled to 25°C in vacuum. Others were degassed for two hr at 800°C, heated for one hr at 800°C in 15 torr oxygen, degassed for one hr at 800°C, and then cooled in vacuum. Identical results were obtained with the two types of samples. The N2 BET surface area of the CaO was 10.7 m²/gram. C.P. grade SO2 (Matheson) was further purified by repeated vacuum distillation from a Dry Iceacetone bath, the first and last distilled portions were discarded. SO<sub>2</sub> was introduced into the sample cell by means of a calibrated dosing system. The SO<sub>2</sub>-CaO reactions were carried out at room temperature, nominally 25°C. The extent of the reaction was kept low, because it was desirable to study surface effects; it is known that high degrees of reaction lead to the formation of bulk CaSO<sub>4</sub>.

Infrared spectra were recorded of the degassed adsorbent, after the adsorbent had been exposed to SO<sub>2</sub>, after the SO<sub>2</sub>-treated adsorbent had been subjected to degassing at various temperatures up to 750°C, and also after the SO<sub>2</sub>-treated adsorbent had been heated in 15 torr oxygen at 750°C.

Infrared spectra were recorded with a Digilab, Inc. Model FTS-14 Fourier transform spectrometer system (Low, 1970a,b). As only the region of S–O absorptions below 1700 cm<sup>-1</sup> was of interest, the instrument's PbSe detector was switched off and measurements were carried out by use of the spectrometer's triglycine sulfate detector. The instrument's reference beam was not used to improve precision. A single-beam background spectrum was recorded and stored. The sample cell was then placed in position, and the sample spectrum was recorded. The stored digitized sample spectrum was ratioed against the stored background spectrum and the resulting spectrum was plotted out over a preset spectral region, the ordinate scale being expanded by a factor of 1.5. These operations were carried out automatically under control of the



Figure 1. Infrared cell

<sup>&</sup>lt;sup>1</sup> To whom correspondence should be addressed.



The background spectrum A was recorded after a fresh CaO sample had been degassed at  $815^{\circ}$ C for three hr. Successive increments of SO<sub>2</sub> were then introduced at  $25^{\circ}$ C, all the SO<sub>2</sub> was taken up by the sample. The estimated percent surface coverages (see text) were: A, 0; B, 4; C, 8; D, 15; E, 30; F, 45; G, 85; H, 95

instrument's computer. The spectrum was then replotted with a fourfold abscissa expansion. Absorption-band centers were obtained from such expanded plots; consistently reproducible values were obtained. Usually 200 consecutive 1.5-sec scans were used to obtain a spectrum having a constant resolution of 2 cm<sup>-1</sup> over the entire spectral range. Increasing the resolution to 1 cm<sup>-1</sup> was not useful.

# Results and Discussion

**Sorption.** Trace A of Figure 2 shows the "background" absorption of a typical fresh sample. Two broad bands at 992 and 929 cm<sup>-1</sup> were immediately observed when such a freshly degassed sample was exposed to even quite small amounts of SO<sub>2</sub> (trace B). Sequential addition of small amounts of SO<sub>2</sub> (trace B). Sequential addition of small amounts of SO<sub>2</sub> led to substantial increases in the two broad bands and the formation of a smaller band centered near 632 cm<sup>-1</sup>. The two broad bands shifted toward lower wave numbers, being centered at 973 and 925 cm<sup>-1</sup> for trace D, and finally coalesced to form one broad absorption. These effects are illustrated by the sequence of traces A to E of Figure 2. Further addition of SO<sub>2</sub> caused a broadening of the intense absorption, a continuous increase of the 632-cm<sup>-1</sup> band, and the formation of bands in two other regions.

A small band was observed near  $1150 \text{ cm}^{-1}$  (trace F) after the 973- and 925-cm<sup>-1</sup> bands had coalesced and "bottomed out." The 1150-cm<sup>-1</sup> band increased in intensity and exhibited a marked shoulder on its high-frequency side.

A second small band was observed at 1338 cm<sup>-1</sup> after the formation of the 1150-cm<sup>-1</sup> band (trace G). The 1338-cm<sup>-1</sup> band shifted gradually to 1344 cm<sup>-1</sup> and grew in intensity as more SO<sub>2</sub> was added (Figure 2, trace H and Figure 3, trace A). All absorptions became more pronounced with further addition of SO<sub>2</sub>. Finally, the  $\nu_3$  and  $\nu_1$  bands of gaseous SO<sub>2</sub> became superimposed on the 1344- and 1150-cm<sup>-1</sup> bands, respectively.

The bands above  $1100 \text{ cm}^{-1}$  (Figure 3, trace A) could be removed by pumping at 25°C. Degassing for 10 min caused

the 1344-cm<sup>-1</sup> band to disappear completely and diminished the 1150-cm<sup>-1</sup> absorption (Figure 3, trace B). Further degassing then decreased the absorption in the 1200–1000 cm<sup>-1</sup> range until, after 18 hr, the 1150-cm<sup>-1</sup> band and its shoulder had disappeared entirely (Figure 3, trace C). The 25°C degassing did not affect the 632-cm<sup>-1</sup> band and appeared to have no effect on the 1100–800 cm<sup>-1</sup> absorption. However, the latter was so intense that small intensity changes would not be readily detectable. There were no significant changes in the residual bands on degassing at temperatures up to 500°C.

The degassing experiments showed that several species were involved, and it is possible to use the criterion of stability to group the absorptions. The weakest-bound SO<sub>2</sub> gave rise to the 1344-cm<sup>-1</sup> band and contributed to the absorption in the 1250-1100 cm<sup>-1</sup> region. The 1150-cm<sup>-1</sup> band and shoulder resulted from the overlapping of several bands, a portion of the 1150-cm<sup>-1</sup> band being associated with the 1344-cm<sup>-1</sup> band. The residual absorption in the 1250-1100 cm<sup>-1</sup> region is attributed to a somewhat more strongly bound adsorbate. The 973, 925, and 632-cm<sup>-1</sup> bands are attributed to a strongly bound material. Consideration of the stability of the species, the surface area of the adsorbent, and amounts of SO<sub>2</sub> added indicate that all surface species were involved.

The SO<sub>2</sub> was added to the cell incrementally and, after the addition of each increment except the last, the pressure within the cell rapidly fell to below 1  $\mu$ . Also, gaseous SO<sub>2</sub> was not detected, so that it is reasonable to assume that the known amounts of SO<sub>2</sub> introduced into the cell were taken up by the CaO. We can estimate surface coverage using the known surface area of the adsorbent and a cross-sectional area of 19.2 Å<sup>2</sup> (Young and Crowell, 1962) for the SO<sub>2</sub> molecule, and assuming that the cross-sectional areas of all surface species formed by SO<sub>2</sub> sorption are like that of physically adsorbed SO<sub>2</sub>. If chemisorbed SO<sub>2</sub> as seems likely,



A sample was treated with SO<sub>2</sub> (trace A) and was then degassed for 10 min (trace B) and 18 hr (trace C) at 25°C. The ordinates of the traces are displaced to avoid overlapping

that assumption will lead to estimates of surface coverage which are somewhat too low. Adsorption data indicate that the 1150-cm<sup>-1</sup> band was only observed after the surface coverage had reached 45-50%—e.g., trace F of Figure 2 would correspond to a surface half covered with SO<sub>2</sub>. Also, the 1344-cm<sup>-1</sup> band was not observed until the surface coverage had reached 80–90%—e.g., trace G, Figure 2.

The 973, 925, and 632-cm<sup>-1</sup> bands were caused by a strongly bound species and bear a general similarity to the bands of  $XY_3$  ions (Nakamoto, 1963), are similar to the general fundamental frequencies at 1010, 961, 633, and 461 cm<sup>-1</sup> of the SO3-2 ion in solids (Evans and Bernstein, 1955; Nakamoto, 1963), and closely resemble the bands at 980, 941, 649, 487, and 448 cm<sup>-1</sup> of CaSO<sub>3</sub> reported by Ricchiccioli (1957). The latter concluded that the structure of the sulfite ion was pyramidal and gave the general fundamental frequencies as 1000-930, 630, and 480 cm<sup>-1</sup>, the 1000-930-cm<sup>-1</sup> region having one or more bands depending on the metal ion of the salt. Nakamoto pointed out that in the case of most  $XY_3$ ions, the  $v_1$  and  $v_3$  frequencies are close to each other and only one strong band is frequently observed. This behavior is similar to that encountered in the present work, where two bands at 973 and 925 cm<sup>-1</sup> were resolved when only small amounts of SO2 had been added but only one broad band was observed when larger amounts of SO2 had been added, the two bands overlapping to the extent that only a single broad band was observed.

The shifts of 992 to 973 cm<sup>-1</sup> and 929 to 925 cm<sup>-1</sup> observed may not be entirely real because the background spectrum (e.g., Figure 2, trace A) shows two bands near those positions. It is possible that when small amounts of SO<sub>2</sub> were added, the background and adsorbate bands coincided and the bands were centered near 992 and 929 cm<sup>-1</sup>; introducing more SO<sub>2</sub> caused the adsorbate bands to become stronger so that the band centers of the adsorbate bands became dominant. Alternately, or in addition, the frequencies of the adsorbate bands could have been influenced by the electronic states of the surface (Blyholder and Sheets, 1970).

The  $\nu_4$  absorption of SO<sub>3</sub><sup>2-</sup> near 480 cm<sup>-1</sup> of metal-sulfur stretching frequencies in the range 480–210 cm<sup>-1</sup> (Adams, 1968) were not observed because the samples became opaque below 500 cm<sup>-1</sup>.

It is not likely that the 973, 925, and  $632\text{-cm}^{-1}$  bands were caused by a planar SO<sub>3</sub> species because four fundamentals would be expected near 1330, 1069, 652, and 532 cm<sup>-1</sup> (Nakamoto, 1963). Also, an SO<sub>4</sub> species is ruled out because sulfates commonly give rise to bands above 1000 cm<sup>-1</sup> and do not absorb strongly in the regions where the three absorptions occurred (Nakamoto, 1963, 1968). The various results thus suggest that the three bands were the fundamentals of a pyramidal SO<sub>3</sub><sup>2-</sup> species formed by the reaction of SO<sub>2</sub> with CaO, the assignments being:

973 cm <sup>-1</sup> : ν <sub>3</sub>	$\nu_{\rm asym}$	S–O str.
925 cm <sup>-1</sup> : ν <sub>1</sub>	$\nu_{ m sym}$	S-O str.
632 cm <sup>-1</sup> : v <sub>2</sub>	δ	O-S-O def

The species responsible for absorption in the 1250–1100 cm<sup>-1</sup> region—i.e., the residual 1150-cm<sup>-1</sup> band plus shoulders—is difficult to consider because essentially only one absorption is available. However, simple adsorbed SO<sub>2</sub> species cannot be involved—i.e., the 1250–1100 cm<sup>-1</sup> absorption could not be due to the  $\nu_1$  fundamental of such species—because the corresponding  $\nu_3$  vibration expected in the 1300-cm<sup>-1</sup> absorption is one of a group of several absorptions, the rest of the group being sub-

merged in the intense  $1100-800 \text{ cm}^{-1}$  band. Several surface species could be invoked, a not unreasonable one being a structure consisting of an SO<sub>2</sub> molecule coordinated to a surface oxide ion. Such structures, as they are more tightly bound than the third type of sorbed SO<sub>2</sub>, will be termed chemisorbed SO<sub>2</sub>.

The bands at 1344 and 1150 cm<sup>-1</sup> of the weakly held SO<sub>2</sub> are similar to bands at 1332 and 1157 cm<sup>-1</sup> or 1330, 1308, and 1147 cm<sup>-1</sup> of aqueous or solid SO<sub>2</sub>, respectively (Jones and McLaren, 1958; Wiener and Nixon, 1956), and are not greatly shifted from the positions of bands of gaseous SO<sub>2</sub> (Polo and Wilson, 1954). The 1344 and 1150-cm<sup>-1</sup> bands are consequently assigned to the  $\nu_3$  and  $\nu_1$  fundamentals of SO<sub>2</sub> weakly held to the surface. This surface species is termed physically adsorbed SO<sub>2</sub>.

The following mechanism is proposed for the low-temperature reaction. SO<sub>2</sub> immediately adsorbs and forms a coordinated complex I. At low coverage I converts rapidly to form the pyramidal sulfite, II. An oxide ion is plucked from the surface. The rapid  $I \rightarrow II$  conversion continues until sterically



and energetically suitable sites usable for  $SO_3^{2-}$  formation have been diminished; some of the weaker bonded type I structures may then form. Continued uptake of SO<sub>2</sub> leads to some further  $SO_3^{2-}$  formation and a buildup of type I structures. When the surface is "full"—i.e., in the vicinity of the 90% surface coverage estimated earlier—physically adsorbed SO<sub>2</sub> is able to exist, SO<sub>2</sub> molecules then becoming weakly bonded to the surface layer—i.e., on top of structures I and II.

Sulfite Decomposition. Although no significant changes were observed on heating an SO<sub>2</sub>-treated sample in vacuum to 500 °C, marked changes occurred at higher temperatures. These are illustrated by the sequence of spectra A to G of Figures 4 and 5. Band positions are summarized in Table I.

On degassing at 550°C, new bands appeared at 1229, 1202, 1134, and 1115 cm<sup>-1</sup>, and the intense absorption in the 1200-900 cm<sup>-1</sup> region declined and appeared as major bands at 947 and 864 cm<sup>-1</sup> with a shoulder near 1044 cm<sup>-1</sup>. There was a slight decline in the 632-cm<sup>-1</sup> band (Figure 4, spectrum B). The surface sulfite was thus declining and converting into other species. Heating at slightly higher temperatures produced even more pronounced changes. At 560°C, the 1229, 1202, and 1134-cm<sup>-1</sup> bands sharpened and became more intense, the 1115-cm<sup>-1</sup> band decreased, the bands in the 1050-850 cm<sup>-1</sup> region decreased and sharpened, and new bands appeared at 1077, 997, 968, 912, and 878 cm<sup>-1</sup> (Figure 4, spectrum C). Degassing at 580°C caused a continuation of these changes, the 1229, 1202, and 1134-cm<sup>-1</sup> bands increasing in intensity with the bands in the 1050-850 cm<sup>-1</sup> region declining but becoming more distinct, the 632-cm-1 band also decreasing (Figure 4, spectrum D). Increasing the degassing temperature to 650°C only appeared to speed up the conversion processes, no new bands being formed. The spectrum became clearer, however, and resolved into a definite pattern of bands (Figure 5, spectrum E). Degassing at temperatures



A sample was treated with SO<sub>2</sub> at 25 °C and evacuated at 25 °C for 18 hr (spectrum A). The sample was then degassed sequentially for three hr at the following temperatures: B, 550 °C; C, 560 °C; D, 580 °C. The sequence is continued in Figure 5: E, 650 °C; F, 665 °C; G, 750 °C

up to  $750^{\circ}$ C produced no major changes: several weak bands appeared, there were changes in band intensities, but the overall band pattern remained (Figure 5, spectra F, G).

The new bands produced by the  $550^{\circ}$ C degassing appear to be caused by a surface sulfate. Steger and Schmidt (1964) studied a number of ionic sulfates and found major bands in the regions 1235–1200, 1205–1175, 1165–1140, 1120–1085, 1085–1050, 1000–990, and 705–610 cm<sup>-1</sup>; for CaSO<sub>4</sub> the bands were at 1185, 1160, 1120, 1020, and 675 cm<sup>-1</sup>. The present bands (Table I) do not match the bands of ionic CaSO<sub>4</sub> in that they show some shifts, but do fit the general pattern of sulfate bands. Also, Tai and Underwood (1957) have shown that the nature of the cation affects the shape, position, and number of sulfate bands. It is therefore reasonable to assign the present bands to a sulfate species, shifts in band positions relative to those of the ionic sulfate of crystalline CaSO<sub>4</sub> being caused by the influence of the environment on the sulfate on the surface of the adsorbent.

The surface sulfate formation occurred at a temperature appreciably lower than that of  $650^{\circ}$ C reported for the beginning of the CaSO<sub>3</sub> disproportionation,

$$4 \operatorname{CaSO}_3 \longrightarrow 3 \operatorname{CaSO}_4 + \operatorname{CaS}_4$$

by Foerster and Kubel (1924). They considered the bulk compound, however. For the "surface compound" it is plausible to suggest that the disproportionation could occur between suitably spaced surface  $SO^{2-}$  groups at a temperature about 100°C below the beginning of the bulk reaction. At the lower temperatures the surface reaction would be slow and self-inhibiting as suitably spaced  $SO_{3}^{2-}$  groups are used up. As the temperature is increased, migration of surface  $SO_{3}^{2-}$ groups could set in so that  $SO_{4}^{2-}$  formation could proceed. This proposed mechanism is supported by the observed changes in bands outlined earlier. However, the proliferation of bands indicates that other reactions occurred simultaneously.

The infrared bands produced at the higher temperature, other than those attributable to SO42-, cannot be related to any one compound. It is suggested that they are brought about by species of a general formula  $S_y O_x^{-n}$  resulting from the polymerization of undecomposed SO32-, SO42-, and S2produced by the disproportionation. Comparison of the spectra obtained after degassing at temperatures above 650°C to those of species such as S2O32-, S2O52-, S3O82-, etc., shows distinct similarities in band patterns, and such structures give rise to bands in the region of the bands found in the present study (Dalmer, 1961; Meuwsen and Heinze, 1952; Simon et al., 1956; Simon and Richter, 1957). However, the complexity of spectra such as those shown in Figure 5 is too great to permit assignments to be made. It appears that a mixture of species was produced by the high-temperature vacuum treatment.

In an attempt to provide additional information, some samples were treated with oxygen. Some results are shown in Figure 6. When a degassed sample (spectrum A, Figure 6) was treated with oxygen at 750°C, all bands below 1050 cm<sup>-1</sup>, except for a band of medium intensity at 987 cm<sup>-1</sup> and a rather weak band at 891 cm<sup>-1</sup>, were eliminated. Also, bands were formed at 1505 and 1434 cm<sup>-1</sup>, and there was a marked increase in absorption between 1250 and 1050 cm<sup>-1</sup> (Figure 6 spectrum B). The 1505, 1435, and 891-cm<sup>-1</sup> bands cannot be assigned. However, the spectrum of the oxygen-treated sample otherwise agrees quite well with those of metal sulfates obtained by Steger and Schmidt (1964). The strong absorption centered near 1150 cm<sup>-1</sup> is consequently assigned to the  $\nu_4$ fundamental and the 981-cm<sup>-1</sup> band to the  $\nu_1$  fundamental, of the SO<sub>4</sub><sup>2-</sup> group. The three unassigned bands may be caused by unoxidized species. The changes in the band patterns suggest that most of the complex species had been converted to SO42- species. Also, as the sulfate band pattern became more like that of an ionic sulfate, it is likely that a change occurred in the structure of the adsorbed layer, the surface SO42- species and SO42- produced by the oxidation arranging themselves with Ca2+ to form small patches or microcrystals of CaSO4 on the CaO surface.



Table 1. Summary of Danus Observed on Heating SO2-Heated CaO in vacu	ble I. Summar	mary of Bands Observ	ed on Heating S	O <sub>2</sub> -Treated CaC	) in Vacu
--	---------------	----------------------	-----------------	-----------------------------	-----------

constant	(no prefix) on carrying	numbers indicate that the out the heat treatment.	ie band intensity increas	ed (i) or decreased (d) (	or remained
550°C	560°C	580°C	650°C	665°C	750°C
	(i) 831 sh	(i) 831 sh	(i) 831 s	(i) 831 s	(i) 831 s
864 sh	(d) 864 m	(d) 860 m	(d) 858 m	(d) 858 w	(d) 858 sh
	(i) 878 w	(i) 878 w	878 m	878 m	878 m
	(i) 912 m	(i) 912 m	(i) 918 s	(i) 918 s	(i) 918 s
			(i) 940 w	(i) 940 m	(i) 940 m
(d) 947 vs					
	968 vs	968 vs	968 vs	968 vs	968 vs
			(d) 988 sh		
	(i) 977 sh	(i) 1000 m		(i) 1008 m	(i) 1008 m
			(i) 1008 w		
				1038 m	1038 m
(i) 1044 w	(i) 1044 w	(i) 1044 w	(d) 1045 sh		
				(d) 1046 w	(d) 1046 vw
			1068 m	1068 m	1068 m
				(i) 1080 vw	(i) 1080 vw
	(i) 1077 sh	(i) 1077 w			
			(i) 1087 w	(i) 1087 w	(i) 1087 w
(i) 1115 m	(d) 1115 m	(d) 1115 w			
(i) 1134 w	(i) 1134 w	(i) 1134 m	(i) 1134 s	(i) 1134 s	(i) 1134 s
			(i) 1170 sh	(i) 1170 sh	(i) 1170 sh
(i) 1202 w	(i) 1202 m	(i) 1202 s	(i) 1202 vs	(i) 1202 vs	(i) 1202 vs
(i) 1229 w	(i) 1229 w	(i) 1229 m	(i) 1229 s	(i) 1229 s	(i) 1229 s
			(i) 1264 w	(i) 1264 w	(i) 1264 m





Figure 6. Heating in oxygen

A CaO sample was treated with SO2 and subjected to a degassing sequence ending with a 3-hr heating in vacuum at 750 °C (spectrum A), see text

# Acknowledgment

Support by Grant 5RO1 APO-0669 from the National Air Pollution Control Administration and the use of instrumentation acquired through Grant 1RO1 FD-GM-00333 are gratefully acknowledged.

# Literature Cited

- Adams, D. M., "Metal-Ligand and Related Vibrations," St. Martin's Press, New York, N. Y., 1968.
- Arai, Y., Takenouchi, H., Nagai, S., Sekko To Sekkai 44, 5 (1960).
- BASF, German Patent 1,191,793 (1965).
- Blyholder, G., Sheets, R., Dept. of Chemistry, Univ. of Arkansas, Fryetterville, Ark., private communication, 1970.
- Dalmer, W. G., J. Chem. Soc. 1961, 1552.
- Evans, J. C., Bernstein, H. J., *Can. J. Chem.* **33**, 2170 (1955). Foerster, F., Kubel, K., *Z. Anorg. Chem.* **139**, 261 (1924).
- Jones, L. H., McLaren, E., J. Chem. Phys. 28, 995 (1958).
- Low, M. J. D., J. Chem. Educ. 47, A163, A255, A349, A415 (1970a).
- Low, M. J. D., Naturwissenschaften 57, 280 (1970b).
- Meuwsen, A., Heinze, G., Z. Anorg. Allg. Chem. 269, 86 (1952).
- Nakamoto, K., "Infrared Spectra of Inorganic and Coordina-tion Compounds," New York, N. Y., 1963, p 87.
- Nakamoto, K., in "Spectroscopy and Structure of Metal Chelate Compounds," K. Nakamoto and P. J. McCarthy, Eds., New York, N. Y., 1968.
- Pechkovskii, W., Mal'tseva, T. G., Zh. Prikl. Khim. 37, 240 (1964).
- Polo, S. R., Wilson, M. K., J. Chem. Phys. 22, 900 (1954).
- Ricchiccioli, C., Compt. Rend. 244, 2704 (1957)
- Simon, A., Richter, R., Naturwissenschaften 44, 178 (1957). Simon, A., Waldman, K., Steger, E., Z. Anorg. Allgem. Chem. 288, 131 (1956).
- Steger, E., Schmidt, W., Ber. Bunsenges. h. Phys. Chem. 68, 102 (1964).
- Tai, H., Underwood, A. L., Anal. Chem. 29, 1430 (1957).
- Wickert, K., Mitt. Ver. Grosskesselbesitzer 83, 74 (1963). Wiener, R. N., Nixon, E. R., J. Chem. Phys. 25, 175 (1956).
- Young, D. M., Crowell, A. D., "Physical Adsorption of Gases," Butterworths, London, England, 1962, p 226.

Received for review Dec. 14, 1970. Accepted April 12, 1971.

# A Controlled Environment for Trace Metal Experiments on Animals

# Leslie M. Klevay,<sup>1</sup> Harold G. Petering, and Klaus L. Stemmer

Dept. of Environmental Health, University of Cincinnati, College of Medicine, Cincinnati, Ohio 45219

■ The construction of a laboratory for study of the effects of metallic element exposure on small mammals is described. Absolute exposure control is obtained by careful attention to structural materials, air filtration, and purification of animal diets. Data on temperature, humidity, light intensity, noise intensity, and on the metal content of air, feed, water, and cage materials were presented.

cientists are becoming increasingly aware that the "land, air, and water environments are all coupled in one way or another. The role and significance of chemistry in the study and control of the environment are often linked to other physical (and) biological...sciences." (Morgan, 1967).

Rigid control of known variables is fundamental to any scientific experiment. Such control is difficult or impossible to attain in the study of animal responses to environmental agents with the usual animal facilities available. For example, standard animal feeds, guaranteed only in their carbohydrate, fat, and protein content, vary considerably in the amount of pesticide residues and essential trace nutrients they contain. The generic terms carbohydrate, fat, and protein can include chemical species that vary considerably even though the percent composition of the diet remains within the stated limits.

Galvanized cages are usually the dietary source of zinc for the animal and may contribute aluminum, antimony, cadmium, chromium, and tin as impurities (Harding, 1967). Tap water used for drinking can vary in its electrolyte content depending on whether the pipes have lain full overnight or whether the water is used following thorough flushing of the plumbing (Kehoe, 1961). Atmospheric pollutants vary in concentration with the meteorological conditions, settle on food and fur, and are ingested.

While temperature and humidity of animal guarters are now generally controlled, environmental vagaries such as those enumerated can perhaps explain difficulties in reproducing experiments in a single laboratory and conflicting results in apparently similar experiments conducted in different laboratories.

This paper describes the construction of animal quarters and supporting facilities now in use which permit rigid control of the exposures to various metallic elements. This control, of both beneficial and harmful elements, is accomplished mainly through air filtration, water demineralization, dietary purification, and the use of cages which do not contribute to dietary intakes.

# Methods

General Plan. The floor plan is shown in Figure 1. Previously subdivided for use as office space, the 8.84  $\times$  13.12 meters room was completely stripped; all partitions, utilities, duct work, ceiling and flooring materials were revised.

The structural concrete slab is covered with 6-cm concrete fill. A flexible membrane of rubber reinforced with fabric (Dex-O-Tex, Cincinnati Floor Co., according to specifications S-607A) (Knepfle, 1970) covers the concrete and forms the traffic surface. A drop ceiling of mineral fibers treated with antidust and antistatic coatings (Particle-Gard, Johns-Manville) (Knepfle, 1970) is placed 2.82 meters above the floor. All partitions are covered with 6-mm soft plywood treated with a boiled linseed oil-turpentine (1:1) mixture. The three interior walls are of glazed, ceramic tile. The wall common to the three animal rooms is an exterior wall; it is covered with polystyrene insulation (Dow Styrofoam FR, Dow Chemical Co.). This insulation is covered with the same plywood as the partitions.

Air Control System. Conditioned air is supplied to the animal rooms from the central air-conditioning system at the Kettering Laboratory at the rate of 81.7 m<sup>3</sup>/min. It is then passed through glass asbestos filters (Cambridge Filter Corp., Models 1J-725-2 or 1J-600-2), which remove 99.97% of all particles of 0.3  $\mu$  or greater, and is delivered to the animal rooms through stainless steel ducts. Filters are changed periodically on demonstration that their resistance to airflow has increased.

The animal rooms are exhausted via the central corridor and diet preparation room. The energy for this movement of the air is supplied by individual fans for each room. Temperature is controlled to  $24^\circ \pm 0.5^\circ C$  by a series of thermostats and dampers.

Diet Preparation Room. Airborne exposures, technically more difficult to control, are small compared to dietary exposures to most metallic elements. Consequently, animals are fed only purified diets. The diet room contains equipment necessary for the mixing of purified diets and for the storage of both diets and dietary components without contamination or spoilage. A detailed floor plan is shown in Figure 2. All vessels used in preparation of diets are either borosilicate glass or stainless steel. The blade of the mixer and shelves of the drying oven are also of stainless steel. Diets are stored in polyethylene-lined containers. Because the amount of metallic elements found in various dietary components varies from

<sup>&</sup>lt;sup>1</sup> Present address: Kettering Laboratory, Eden Ave., Cincinnati, Ohio 45219. To whom correspondence should be addressed.



Figure 1. Floor plan of the laboratory



Figure 2. Floor plan of the diet preparation room and preparation room

batch to batch, only components that have been analyzed for impurities under study are used.

Water given to the animals has been freed of metallic cations by either glass distillation or passage over ion-exchange resins. Only silicone stoppers (Ronthor Reiss Corp.) are used in the water bottles as traces of zinc can be eluted continuously from rubber stoppers. Water bottles are of soft glass and have spouts of stainless steel.

Animal Rooms. Rats are housed in individual cages of 11mm mesh measuring  $17.5 \times 17.7 \times 24.2$  cm containing a glass food dish and with access to the spout of the water bottle. These stainless steel cages are hung from stainless steel stands that provide a solid ceiling and are arranged in a variety of combinations depending on the room configuration. Typically the stands have five layers of six cages. Urine and most feces fall from the cages and are collected on brown paper 3.5 cm below the cage, minimizing coprophagy.

Beagles are housed in stainless steel cages measuring  $71 \times 72.5 \times 81$  cm with floors and door made of 22-mm stainless steel mesh. Food containers are of stainless steel. Urine and feces are collected in stainless steel trays 8 cm below the cage floor.

			, -0/1000			
)r	Fe	Mn	Cu	Zn	Cd	Pb
(7) 149	90(1020)			630(570)	6(5)	1080(550)
1	1100	32		210	4	1500
(0.4) 11	.4(6.7) (	).6(0.5)	1.2(1.2)	3.4(2.2)	0.1(0.0)	1.2(1.3)
	-r 7) 14 7 ((0.4) 11	7) 1490(1020) 7 1100 (0.4) 11.4(6.7) (	л Ре мп 7) 1490(1020) 7 1100 32 ((0.4) 11.4(6.7) 0.6(0.5) :	r Fé Min Cu 7) 1490(1020) 7 1100 32 (0.4) 11.4(6.7) 0.6(0.5) 1.2(1.2)	r       Fe       Mn       Cu       Zn         7)       1490(1020)       630(570) $r$ 7       1100       32       210 $r(0.4)$ 11.4(6.7)       0.6(0.5)       1.2(1.2)       3.4(2.2) <sup>b</sup>	r $re$ Mn $Cu$ $Zn$ $Ca$ 7)       1490(1020)       630(570)       6(5)         7       1100       32       210       4 $(0.4)$ 11.4(6.7)       0.6(0.5)       1.2(1.2)       3.4(2.2) <sup>b</sup> 0.1(0.0)

<sup>b</sup> A single value of 46.8 was omitted from these calculations. Numbers in parentheses are standard deviations.

Both rat and dog cages are on wheels and can be removed for washing and autoclaving.

The fluorescent lights (F 40 CW) (Doyle, 1970) are automatically turned on for 12 hr at 7:00 a.m.

Preparation Room. This small room is designed to provide space for storage of small pieces of equipment and for performance of certain manipulations on the animals. So far it has been used when rectal temperatures, body weights, blood pressures, and close-up photographs have been obtained.

General Precautions. Insect infestation is minimized by immediate removal of spilled feed by vacuum cleaner, bucket and mop, by storage of diet and dietary components in sealed containers, and by occasional use of insecticide (Lethalaire V-23, Virginia Chemicals, Inc.).

Attendants and visitors wear gowns provided at the entrance to the interior corridor and put on disposable polyethylene boots to avoid tracking in offensive materials.

Air Analysis. Air samples were taken (USPHS, 1965) for seven consecutive days. Samples were taken simultaneously 61 cm from the floor and ceiling of each animal room, metallic elements were measured by atomic absorption spectrophotometry following digestion in nitric and perchloric acids. Air was sampled in the empty animal rooms following remodeling, after empty cages were placed into the rooms, and after completion of an animal experiment in each room (60 rats or six dogs for 90 days). Light intensity in the animal rooms was measured at bench height (94 cm) above the floor with a Model 614 foot-candle meter (Weston Instruments Division, Daystrom, Inc.). Noise was measured with a Type 1565-A sound-level meter (General Radio Co.), which used the As scale, 1 meter above the floor.

# Regults

All stainless steel items mentioned in this text are made of stainless steel no. 304, which has the following composition: chromium, 18 to 20%; nickel, 8 to 12%; manganese, 2% maximum; silicon, 1% maximum; and carbon, 0.08% maximum (Phelps, 1970).

Due to the scarcity of sampling equipment, the air samples were taken sequentially in order of animal room number. Large, highly significant correlation coefficients were obtained between samples collected simultaneously at the floor and ceiling. Consequently, it was assumed that variations were due more to sampling error than to differences in air composition.

The data were then subjected to analysis of variance (Snedecor, 1956). No differences due to season, animal room, or interaction were demonstrable. A highly significant difference due to metal was noted (F = 18.2, p < 0.005 for 6, 62 df) as expected.

Consequently, the values for each metal shown in Table I represent the combination of all values in all rooms at all sampling times. Data on the outside yearly averages and on room air before remodeling are given for comparison. Further samples will be collected to test the effect of the animal population on the composition of air.

The composition of one of the purified diets currently in use is shown in Table II. Diets are made in sufficient quantity to reduce component weighing error to less than 1%. This diet is designed to permit study of the effect of environmental agents, such as cadmium on the metabolic utilization of zinc and copper. If the components are selected with care, the zinc, copper, and cadmium contents of the diet can be held below 2, 1, and 0.1 µg/gram of diet, respectively. This diet is extremely deficient in the essential nutrients, zinc and copper. Only if zinc and copper are supplied in the drinking water at about 10 to 20 µg/ml and 1 to 2 µg/ml, respectively, will normal growth and physiology result.

Light and sound intensities in the animal rooms were 70 ft-c and 55 dB, respectively.

Certain construction parameters have been rounded off on conversion to the metric system.

#### Discussion

A unique laboratory for complete control of the exposure of animals to metallic elements has been described. While the facility operated in Brattleboro, Vt. (Schroeder et al., 1963) is of unimpeachable quality, the urban environment of

623.5
30.0
40.0
1.5
200.0
5.0
10.0
90.0

a Jack Frost brand.

Whatman CF11, w&R Balston, Ltd.
 Specially prepared by Nutritional Biochemical Corp.
 General Biochemicals.

<sup>6</sup> The vitamin mix consists of the following components in mg: thiamine hydrochloride, 400; riboflavin, 800; pyridoxine hydrochloride, 400; calcium pantothenate, 2500; niacinamide, 4000; folic acid, 100; menadione, 10; biotin, 20; cyancobalamine, 15. These were mixed with

Menatorie, 10, activity for the following: calciferol, 5.70 mg.; f The vitamin ADE mix consists of the following: calciferol, 5.70 mg.;  $\alpha$ -tocopherol, 10 grams, vitamin A palmitate, 2 grams. These were  $\alpha$ -tocopherol, 10 grams, vitam mixed with 1000 grams corn oil.  $\varphi$  Mazola brand.

Cincinnati, Ohio, placed certain constraints on our laboratory design. The problems of the urban environment have been solved by extensive air filtration and the use of purified diets. The Biotron at the University of Wisconsin is used to control only conditions of climate such as temperature, humidity, light and sound intensity, and barometric pressure (Senn, 1970).

We have placed great reliance on the fact that the stainless steel used in certain materials in the laboratory will not contaminate the environment and vitiate current experimental results.

If future experiments demand study of, for example, chromium as a variable, additional precautions may be needed. If chromium from cages and mixers should be found to alter significantly chromium intake, plastic cages and mixers coated with tetrafluoroethylene may have to be used.

Currently the animal population of the laboratory is small enough so each experiment can be housed in a separate animal room. In the future if two apparently incompatible experiments need be housed in a single animal room, we plan to use isolettes similar to those used in gnotobiotic studies. The isolettes will then protect against metallic element contamination rather than bacterial contamination.

# Conclusions

The construction of a laboratory for study of the effects of metallic element exposure on small mammals has been described. Absolute exposure control is obtained by careful attention to structural materials, air filtration, and purification of animal diets.

A diet has been described for use in experiments on the effect of environmental agents on the utilization of zinc and copper by rats. Supplementary methods for study of other variables were discussed.

#### Literature Cited

- Doyle, U. L., Whiteway Mfg. Co., Cincinnati, Ohio, private communication, 1970.
- Harding, W. B., "Metallic Coatings," in "Kirk-Othmer Encyclopedia of Chemical Technology," 2nd ed., H. F. Mark, J. J. McKetta, Jr., D. F. Othmer, and A. Standen, Eds., Vol. 13, Wiley, New York, N. Y., 1967, pp 255-7.
- Kehoe, R. A., J. Roy. Inst. Pub. Health 24 (4), 81 (1961).
- Knepfle, J. H., Fosdick, and Hilmer, Cincinnati, Ohio, private communication, 1970.
- Morgan, J. J., ENVIRON. SCI. TECHNOL. 1 (1), 5 (1967).
- Phelps, N., Allegheny Ludlum Steel Corp., Cincinnati, Ohio, private communication, 1970.
- Schroeder, H. A., Vinton, W. H., Jr., Balassa, J. J., J. Nutr. 80, 39-47 (1963).
- Senn, H. A., University of Wisconsin, Madison, Wis., private communication, 1970. Snedecor, G. W., "Statistical Methods," 5th ed., The Iowa
- State University Press, Ames, Iowa, 1956, pp 360-2.
- U.S. Public Health Service, Cincinnati, Ohio, "Survey of Lead in the Atmosphere of Three Urban Communities, Public Health Service Publication no. 999-AP-12: 20 (1965).

Received for review Nov. 6, 1970. Accepted April 25, 1971. Upon completion of the construction, this work received support from Public Health Service Grant No. 5 P10 ES 00159.

# Lead Contamination of Some Agricultural Soils in Western Canada

# Matt K. John

Canada Dept. of Agriculture, Agassiz, B.C., Canada

 Nitric acid soluble lead in 700 samples mostly from agricultural soils in British Columbia was related to proximity to industrial and population centers. The soluble lead was found to be immobilized in surface horizons. Soils taken near a battery smelter were found to be highly contaminated with lead and the extent of contamination decreased with distance from the smelter. 14

he Environmental Pollution Panel of the President's Science Advisory Committee (1965) has emphasized the health hazards associated with heavy metals entering the food cycle from the soil. While most contamination of food products may be the result of the surface deposition of particulate matter (Cannon and Bowles, 1962; Lagerwerff and Specht, 1970; Motto et al., 1970; Warren and Delavault, 1962), translocation from soil has been reported by various workers (Jones and Hatch, 1945; Mitchell and Reith, 1966).

The major sources of soil contamination with lead are combustion products of leaded gasoline, lead arsenate pesticides, phosphate fertilizers, and wastes from metal-smelting. In 1965, it was estimated that the annual motor vehicle exhaust of lead in North America was about 240,000 tons (Patterson, 1965).

The concentration of lead in soils near highways has been related to density of traffic and to distance from the road (Cannon and Bowles, 1962; Dunn and Bloxam, 1933; Kleinman, 1968; Kloke and Riebartsch, 1964; Leh, 1966). Motto et al. (1970) showed that most of the lead accumulation was within 100 ft of highways. Studies on lead contamination of agricultural soils have been confined to soils of apple orchards where lead arsenate sprays were used in earlier days for insect control (Chisholm and Bishop, 1967; Jones and Hatch, 1945). However, no systematic evaluation of lead contamination of agricultural soils has been reported in the literature.

Brewer (1966), in his review of lead in soils, reports a general range of 0.05 to 5 ppm of weak acid soluble lead. Swaine (1955) estimated the average amount of lead extracted with acetic acid or acetate solutions from Scottish soils to

				Trea	tment and in	ncubation pe	riod			
-	Control		3 Days			30 Days			360 Days	
Soil type	Lead, ppm	Lead, ppm	Lead recov, ppm	% Recov <sup>a</sup>	Lead, ppm	Lead recov, ppm	% Recov	Lead, ppm	Lead recov, ppm	% Recov
					40	Ppm lead ad	lded			
Marble Hill, SiL	9.2	46.5	37.3	93.3	43.4	34.2	85.6	39.8	30.6	76.5
Fairfield, VFSL	7.9	48.9	41.0	102.5	49.7	41.8	104.5	47.7	39.8	99.5
Hazelwood, SiCL	12.2	50.9	38.7	96.8	51.7	39.5	98.8	50.1	37.9	94.8
Glenmore, CL	11.2	46.5	35.3	88.3	50.1	38.9	97.3	43.0	31.8	79.5
Annis, muck	12.2	53.6	41.4	103.5	55.6	43.4	108.5	51.3	39.1	97.8
Mean % recov				96.9			98.9			89.6
					160	Ppm lead a	dded			
Marble Hill, SiL	9.2	167.4	158.2	98.9	173.9	164.7	102.9	160.5	151.3	94.6
Fairfield, VFSL	7.9	176.0	168.1	105.1	173.1	165.2	103.3	172.3	164.4	102.8
Hazelwood, SiCl	12.2	165.0	152.8	95.5	184.9	172.7	107.9	171.1	158.9	99.3
Glenmore, CL	11.2	168.2	157.0	98.1	165.8	154.6	96.7	166.2	155.0	96.9
Annis, muck	12.2	198.4	186.2	116.4	197.2	185.0	115.6	190.2	178.0	111.3
Mean % recov				102.8			105.3			101.0
<sup>a</sup> % Recovery is ca	lculated as	(ppm lead ex	stracted from	treated soil	– ppm lead	extracted fror	n control)/pr	m lead adde	d.	

Table I. Recovery of Added Lead Extracted with 1N Nitric Acid

be less than 1 ppm. Mitchell and Reith (1966) studied translocation of lead from root to shoot for various herbage species grown in soils containing native lead. Jones and Hatch (1945) grew eight different plant species in orchard soils at four different locations in Oregon and found that lead in plants from soils sprayed with lead arsenate and unsprayed soils differed by a factor of 1.6 and 3.1 for edible portions and roots, respectively. Keaton (1937) found a high degree of fixation of lead in soils and suggested that lead uptake by plants will be in negligible amounts. However, the potential hazard to humans of minute amounts of lead in plants may be important when edible plant materials are passed through the consumption chain or through biological magnification. The otherwise harmless concentrations of lead may increase to harmful levels. Thus, a study was undertaken to determine the levels of lead in agricultural soils through a large area in British Columbia.

# Experimental

Extraction of Lead From Soils. Five British Columbia soils varying in organic matter and texture were selected. Samples were incubated at near field capacity after addition of 0, 40, and 160 ppm of lead as lead nitrate. A sample of each soil was analyzed after 3, 30, and 360 days. Several solutions were used to extract the added lead. Of these, neutral normal ammonium acetate, normal ammonium acetate adjusted to pH 4.8, and normal acetic acid solutions extracted only trace amounts of lead. Since the solubility of lead nitrate is appreciably high, nitric acid was selected as extractant. Several normalities of nitric acid, extracting times, and soil to solution ratios were investigated. Satisfactory recovery of added lead was obtained when 2 grams of soil was extracted with 10 ml of normal nitric acid, shaking for 30 min. The lead content of soil extracts was determined by atomic absorption spectrophotometry at 2833 Å.

Nitric Acid Extractable Lead in 700 Farmland Soils. Most of the samples were taken from sites throughout British Columbia, but a few samples were included from other parts of Canada, New Zealand, and U.S. The soils included random samples of surface and subsurface horizons from agricultural land. The surface horizons generally represent a plow depth of 0 to 8 in., whereas the depth of subsurface horizons varied with soil profile development, but are subdivisions between a depth of 8 and 80 in. To characterize the soils, pH of a 1/1 soil to water ratio was measured. Available phosphorus was extracted by Bray P<sub>1</sub> solution (Jackson, 1958) and color developed by the method described by John (1970). Oxidizable organic matter, cation-exchange capacity, exchangeable cations, and free iron content of the samples were also determined according to procedures described by Jackson (1958). The results of analysis were grouped according to regions and depth, and various statistical analyses were performed with an IBM 360/system computer.

Total Lead in Selected Soil Samples. This study involved the determination of total lead in about 200 selected soil samples. Two grams of air dry soil was placed in a Teflon beaker and 5 ml of concentrated nitric acid was added. These were heated in a sand bath to  $80^{\circ}$ C until the nitric acid was evaporated. Ten milliliters of hydrofluoric acid was then added and samples taken to dryness. The samples were further treated with 72% perchloric acid and boiled at 220°C for 30 min. Samples were transferred to a volumetric flask with 10 ml of normal hydrochloric acid and brought to volume. Lead was determined with atomic absorption. Total lead content thus obtained was used in calculating the various soil lead fractions.

Nitric Acid Soluble Lead in Soils Adjacent to a Battery Smelter. The fourth part of the study involved the determination of nitric acid soluble lead on soil samples taken from near a battery smelter and in random directions.

# Results and Discussion

Extraction of Lead from Soils. The extraction of lead with normal nitric acid proved to be a satisfactory method for measuring lead contamination in soils (Table I). The recovery of added lead averaged 99.1% with a standard deviation of  $\pm 7.3\%$ . Due to the presence of various anions in soils, it is assumed that the applied lead has been transformed into

# Table II. Distribution of Nitric Acid Soluble Lead in Surface and Subsurface Soil Samples

	from		<b>a c</b>						
	Van-		Surface	horizons	D		Secon	d horizons	
Location	miles	Obsda	Mean, ppm	sD,º ppm	ppm	Obsd	Mean, ppm	sD, ppm	Range, ppm
Delta	13	60	15.8	24.3	1.5-134.9	19	9.4	20.2	1.8-92.4
Surrey	17	33	12.2	8.9	1.1-34.6				2000 000 0000000000
Pitt	20	23	20.4	35.4	6.4-180.4	10	6.8	3.8	2.9-16.4
Langley	25	80	6.5	3.6	0.6-13.3	2	5.5	2.1	4.0-7.0
Matsqui	35	54	11.8	7.4	2.6-36.1	5	7.9	2.9	5.2-12.5
Mission	40	3	9.3	4.5	5.7-14.4				
Sumas	45	16	8.5	3.2	2.8-13.2				
Chilliwack	55	38	6.3	2.4	1.1-12.1	2	6.1	1.3	5.2-7.0
Kent	65	34	7.3	4.0	1.1-21.8	2	5.9	1.0	5.2-6.6
Ashcroft-Savona	135	24	6.5	1.8	2.9- 9.9	21	5.3	2.1	0.8-8.7
Similkameen	140	22	8.5	2.5	2.2-11.4	20	6.8	2.3	3.8-12.1
North Okanagan	170	27	8.5	3.5	2.6-14.7	21	7.2	2.2	3.4-13.7
Shuswap Lake	210	8	7.3	2.2	4.8-10.3	6	5.3	1.2	3.8-6.4
Kettle-Creston	250	7	24.3	22.9	10.3-75.0	7	12.9	3.1	8.7-17.2
Kootenay-Elk	350	12	10.5	2.9	5.9-16.9	12	11.1	2.7	7.6-16.6
Other Canadian districts		4	12.2	7.8	7.0-25.7				
California, U.S.		2	72.1	49.1	23.0-121.2				
New Zealand		6	6.4	1.3	5.2- 8.5				
All soils		453	10.6	13.2	0.6-180.4	127	7.7	8.2	0.8-92.4
	Distance		De	ener horiz	one			All horizor	10
	Vancouver.		Mean.	sD	Range.	-		Mean.	SD.
Location	miles	Obsd	ppm	pp	m ppm		Obsd	ppm	ppm
Delta	13	69	4.8	2.	7 1.8-17.3		148	9.9	17.1
Surrey	17						33	12.2	8.9
Pitt	20	39	5.4	1.	5 3.2-10.7		72	10.4	20.1
Langley	25						82	6.5	3.6
Matsqui	35	11	7.5	3.	0 4.4-15.1		70	10.9	6.7
Mission	40						3	9.3	4:5
Sumas	45						16	8.5	3.2
Chilliwack	55	2	5.7	0.	8 5.2-6.3		42	6.2	2.3
Kent	65						36	7.2	4.0
Ashcroft-Savona	135						45	5.9	2.0
Similkameen	140						42	7.7	2.4
North Okanagan	170						48	7.9	3.0
Shuswap Lake	210						14	6.4	1.8
Kettle-Creston	250						14	18.6	16.3
Kootenay-Elk	350						24	10.8	2.8
Other Canadian districts							4	12.2	7.8
California, U.S.							2	72.1	49.1
New Zealand							6	6.4	1.2
All soils		121	5.3	2.	5 1.8–17.3		701	9.1	11.3
<sup>a</sup> Obsd = number of obse h  sp =  standard deviation	rvations.								

<sup>c</sup> Districts in British Columbia unless otherwise stated.

D' ....

lead compounds, primarily carbonates, chlorides, and sulfates. The normal nitric acid was able to extract all these forms. The recovery of lead was not influenced by the incubation period or the rate of treatment. Soils in this study varied widely in texture and organic matter content with no apparent effect on lead recovery. Use of normal nitric acid was therefore chosen as a method of measuring lead contamination in soils.

Extractable Lead in 700 Farmland Soils. Extraction of lead from about 700 farmland soils, primarily from British

Columbia and some from other parts of Canada, New Zealand, and the U.S., showed that lead contamination varied with geographic region, depth of sampling, and proximity to industrial and population centers (Table II). The average nitric acid soluble lead content of soils was 9.1 ppm with a range of 0.6 to 180.4 ppm. The greatest concentrations of lead occurred in surface horizons with lower amounts detected at deeper horizons. Compared to the surface horizons, the samples from deeper horizons were less variable, ranging between 1.9 and 17.3 ppm. While there were differ-



Figure 1. Vertical distribution of nitric acid soluble lead (ppm) in some selected soil profiles

ences in geological source of parent material, the contribution of lower horizons to nitric acid soluble lead appeared to be uniform.

Lead originating from contamination or from decayed plant material is immobilized in the topsoil. This is expected because of fixation of lead in soils by precipitation with various anions. Wright et al. (1955) reported that lead content of the first horizon was 3.2 times that in the second horizon for the Armadale soil series. The surface accumulation of lead is apparent in the profiles in Figure 1. A more than tenfold increase in the surface horizon was observed in the Seaview and Wigden series. However, no lead accumulation was apparent in the surface horizon of Grevell series, a recent Fraser River flood plain soil, or in Triggs series, a recently reclaimed peat.

In an attempt to predict any association between soil

properties and lead content, a regression analysis was performed on 380 surface samples. While exchangeable iron was found to be related to nitric acid soluble lead (r = 0.203, P = 0.05) the relationship was interpreted as coincidental, because of the occurrence of high soluble iron in the humid coastal area, which also happens to be the industrial area, where the lead content is also high. No meaningful relationship was found between lead and organic matter, available phosphorus, pH, or any of the other exchangeable cations. It seems safe, therefore, to conclude that the variation of lead reported in Table II is due mostly to pollution. Potatoes are occasionally grown in the coastal area of British Columbia and a few cases of high soil lead content could therefore be ascribed to the residual effect of lead arsenate sprays used on potatoes in earlier days. However, the majority of the samples was taken from nonpotato growing areas. The high concentration of soil lead near Vancouver, B.C., the only densely populated center of Canadian sites sampled (Delta, Pitt Meadows, and Surrey), could be related to fallout from automobile exhaust or other sources, since the soluble lead content decreases with increased distance from that center, and therefore decreased traffic density. The soluble lead content of the sparsely populated areas of the interior was low, except for the Kettle-Creston area. The higher soluble lead in this region is ascribed to inclusion of two samples taken 8 miles from the plant of Consolidated Mining and Smelting Co., the leading lead-producing smelter in the world.

Fractionation of Soil Lead. The third part of the study involved the fractionation of soil lead into soluble and native lead (Table III). The native lead, henceforth called the  $\Delta$  lead, is calculated by subtracting the nitric acid soluble lead from the total lead content of the soil samples. The average total lead content of the 201 samples was 51.9 ppm with a coefficient of variation of 25.4%. The soluble lead of these samples averaged 10.2 ppm with a coefficient of variation of 99.0%. The smallest coefficient of variation of 19.2% was obtained with native lead ( $\Delta$ ), indicating the trend of uniformity in distribution of  $\Delta$  lead.

The fractionation method was found suitable in distinguishing between lead pollution in soil and the presence of natural lead. The effects of region and depth are clear when lead is fractionated into the three forms. The soils listed in Table III did not vary significantly in  $\Delta$  lead with region or depth, but the variation of soluble lead between surface and subsurface samples or between thinly and heavily populated areas is more distinguishable by the soluble lead fraction.

Nitric Acid Soluble Lead in Soils Adjacent to a Battery Smelter. The fourth part of the study involved determination

140	ie m. Distrib	ution of Leau	ractions in C	ertani Geograf	mear Regions		
		Total	lead	Nitric acid s	soluble lead	Native	lead
Region	Obsda	Mean, ppm	sD, <sup>b</sup> ppm	Mean, ppm	sD, ppm	Mean, ppm	sD, ppm
Coastal B.C. surface	63	51.3	19.3	11.3	13.5	40.0	10.0
B.C. interior surface	102	51.1	7.7	9.3	7.5	41.9	7.4
New Zealand surface	6	41.1	14.4	6.4	1.3	34.6	3.1
Other Canadian surface	4	60.7	12.0	12.2	7.8	48.5	6.3
California surface	2	125.9	54.0	72.1	49.1	53.8	4.9
Coastal B.C. subsurface	24	51.8	5.0	7.0	2.5	44.7	4.8
All soils	201	51.9	13.2	10.2	10.1	41.7	8.0

Table III Distribution of Load Erections in Contain Coographical Degions

<sup>a</sup> Obsd = number of observations.
 <sup>b</sup> sD = standard deviation.

of lead contamination in soil samples near a battery smelter. Soils close to the battery smelter were highly contaminated with lead (Table IV). The soluble lead content ranged from 106 to 59,580 ppm. While the extent of contamination decreased with distance from the smelter, considerable variation was observed in various directions at short distances from the smelter. These anomalies were not explainable by wind direction.

# Summary and Conclusion

The content of nitric acid soluble lead among 700 soil samples, mostly from agricultural soils in British Columbia, was related to proximity to industrial and population centers. Soluble lead was found to be immobilized in surface horizons and ranged from 0.5 to 180.4 ppm in the agricultural soils. The soluble lead content in surface samples collected near a battery smelter was found to be as high as 59,580 ppm. Fractionation of lead into total, native, and soluble forms was found to be useful in assessing the degree of soil pollution. Since plant availability of lead may depend on many factors other than soil lead content, it is difficult to conclude whether some of the high levels of lead present in these soils could result in excessive accumulation in plants. However, the extent of soil contamination has been assessed and the problem areas delineated for further study.

# Acknowledgment

The author tenders his grateful thanks to all individuals who assisted in the investigation, particularly Cornelis Van Laerhoven for critical review of procedures and statistical analysis, Ron Mankau of the University of California, and Jim Raiside of Soil Bureau, New Zealand, for providing some of the soil samples.

#### Literature Cited

Brewer, R. F., "Diagnostic criteria for plants and soils," H. D. Champman, Ed., University of California, Division of Agricultural Sciences, Riverside, Calif., 1966.

Cannon, H. L., Bowles, J. M., Science, 137, 765 (1962)

Chisholm, D., Bishop, R. F., Phytoprotection 48, 78 (1967).

Dunn, J. T., Bloxam, H. C. L., J. Soc. Chem. Ind. London 52, 189T (1933).

Table IV.	Nitric Acid Soluble Lead of Surface Samples in	n
	the Vicinity of a Battery Smelter	

from battery smelter flume, ft	Obsd <sup>a</sup>	Mean, ppm	$SD^b$	Range, ppm
50	5	24,136	19,885	3,081-59,581
100	4	430	227	138-680
200	1	3,081		
300	3	1,075	743	329-2,089
400	1	414		
600	1	229		
1,000	1	106		
Overall	16	8,019	15,516	106-59,581
<sup>a</sup> Obsd = n	umber of	observations		

<sup>b</sup> SD = standard deviation.

- Environmental Pollution Panel of the President's Science "Restoring the Quality of our Advisory Committee, "Restoring the Quality of our Environment," The White House, Washington, D.C., 1965.
- Jackson, M. L., "Soil Chemical An New York, N.Y., 1958, pp 134–182. John, M. K., Soil Sci. 109, 214 (1970). "Soil Chemical Analysis," Prentice Hall,
- Jones, J. S., Hatch, H. B., *ibid*. **60**, 277 (1945). Keaton, C. M., *ibid*., **43**, 401 (1937).
- Kleinman, A., Pestic. Monit. J. 1, 8 (1968).
- Kloke, A., Riebartsch, K., Naturwiss. 51, 367 (1964). Lagerwerff, J. V., Specht, A. W., ENVIRON. SCI. TECHNOL. 4, 583 (1970).
- Leh, H. O., Gesunde Pflanzen 18, 21 (1966).
- Mitchell, R. L., Reith, J. W. S., J. Sci. Food Agr. 17, 437 (1966).
- Motto, H. L., Daines, R. H., Chilko, D. M., Motto, C. K., ENVIRON. SCI. TECHNOL. 4, 231 (1970).
- Patterson, C. C., Arch. Environ. Health 11, 344 (1965).
- Swaine, D. J., Commonw. Bur. Soil Sci. Tech. Comm. 48, 1955.
- Warren, H. V., Delavault, R. E., J. Sci. Food Agr. 13, 96 (1962)
- Wright, J. R., Levick, R., Atkinson, H. J., Soil Sci. Soc. Amer. Proc. 19, 340 (1955).

Received for review December 8, 1970. Accepted April 12, 1971.

# Selenium in Lake Sediments—Analytical Procedure and Preliminary Results

# James H. Wiersma<sup>1</sup> and G. Fred Lee<sup>2</sup>

University of Wisconsin, Water Chemistry Program, Madison, Wis. 53706

A fluorometric analytical procedure for the determination of selenium in lake sediments is presented. The sample is digested in nitric and perchloric acids. The selenium is reduced and coprecipitated by arsenic and hypophosphorous acid. The precipitate is dissolved in HNO<sub>3</sub>, allowed to react with DAN reagent, and extracted with cyclohexane with the fluorescence being measured on the extract. Selenium content of sediments from 11 Wisconsin lakes and one South Dakota reservoir range from about 1 to 3 µg Se/g dry weight.

elenium is an unusual element because of its nutritional properties. In animals, selenium exhibits toxic properties when present in food sources at the parts per million level, but if selenium is at low levels in the diet of animals, seleniumdeficient diseases appear. Although the cycling of selenium has been investigated for soil-plant-animal systems (Muth, 1967),

<sup>&</sup>lt;sup>1</sup> Present address: University of Wisconsin-Green Bay, Green Bay, Wis. 54301.

<sup>&</sup>lt;sup>2</sup> To whom correspondence should be addressed.

Table	I.	Survey	of	Selenium	in	Lake	Sediments
	_		~ ~				

Lake	Location	Date sampled	Depth, m	Ppm Se <sup>a</sup>	No. detn.
Mendota <sup>b</sup>	Dane Co., Wis.	11/2/67	24	1.9	10
Weber	Vilas Co., Wis.	9/24/67	16	2.7	4
Big Muskel- lunge	Vilas Co., Wis.	7/28/67	20	2.0	2
Trout	Vilas Co., Wis.	7/27/67	28	3.1	2
Monona	Dane Co., Wis.	7/21/67	15	2.2	2
Waubesa	Dane Co., Wis.	8/15/67	5	2.2	2
Crystal	Vilas Co., Wis.	7/24/67	15	3.5	2
Little John	Vilas Co., Wis.	7/22/67	6	1.9	2
Minocqua	Oneida Co., Wis.	7/21/67	18	1.3	2
Sparkling	Vilas Co., Wis.	7/26/67	19	1.8	1
Belle Fourche Reservoir <sup>c</sup>	Butte Co., S.D.	6/27/68	15	1.5	8
Kegonsa	Dane Co., Wis.	8/15/67	7	1.8	2

 $b_{c}$  Standard deviations = 0.16 and 0.15 ppm, respectively.

Table II. Variation of Selenium Concentration with Location in Lake Mendota, Dane County, Wis.

Station no. <sup>a</sup>	Depth, m	Ppm Se found <sup>a</sup>
3	15	1.5
2	19	1.2
23	20	1.3
32	24	1.5
12	10	0.5
24	21	1.7
32	24	1.8
		weeks and the second of

<sup>a</sup> Locations of stations reported previously by Delfino et al., 1969.

little is known about the role selenium plays in aquatic ecosystems. Oelschläger and Menke (1969) have shown that significant concentrations of selenium exist in both fresh- and saltwater fish. Apparently selenium cycles through the aquatic ecosystem and accumulates in the higher forms of life, namely fish. This investigation was conducted to ascertain the concentration of selenium in lake sediments, a likely reservoir of selenium for the aquatic ecosystem. An additional question to be answered was whether man's activities are significantly raising the selenium concentrations in lake sediments.

Reported in this paper are the results of the analysis of lake sediment samples from 11 Wisconsin lakes and a South Dakota reservoir. The variation of selenium with depth in a given lake, the variation of selenium from lakes of different trophic levels, and the variation of selenium concentrations in a sediment core are also reported. A sensitive fluorometric procedure for the determination of selenium in lake sediments is described.

# Experimental

Reagents and Apparatus. All reagents used were analytical grade unless otherwise specified.

Standard selenium solutions were prepared by dissolving an appropriate amount of 99.99% pure selenium metal in a minimum of 1:1 mixture of nitric and hydrochloric acids.

DAN solution, 2,3-diaminonaphthalene, (Aldrich Chemical Co., Milwaukee, Wis.) was prepared daily by dissolving a sufficient quantity to give a 0.1% solution in 0.1M HCl. Just prior to use, 50 ml of the solution was extracted twice with

20 ml portions of cyclohexane to remove residual fluorescent materials.

Digestion reagent was prepared by mixing four parts of concentrated nitric acid with one part of 60% perchloric acid.

Arsenic solution was prepared by dissolving 0.315 gram of As<sub>2</sub>O<sub>3</sub> and 10 NaOH pellets in 50 ml of distilled water.

Arsenic reducing solution was prepared by mixing three parts of concentrated HCl, one part 50% H<sub>3</sub>PO<sub>2</sub>. To remove any traces of selenium impurities in this reagent, 8 ml of arsenic solution was added per liter, the solution was boiled for 5 min, and the precipitated arsenic filtered with a Gooch crucible and glass-fiber mat. The resulting solution was used as the arsenic reducing solution.

Spectroanalyzed cyclohexane (Fisher Scientific Co.) was used as the extracting agent.

Separatory funnels equipped with Teflon stopcocks were used to prevent contamination from grease.

A Turner Model 111 fluorometer was used to make fluorescence measurements.

Analytical Procedures. Approximately 1-gram samples were weighed accurately and transferred to 100-ml beakers. Two 10-ml portions of digestion reagent were added, allowing effervescence to cease before the second portion was added. Samples were digested for one to 1.5 hr on a hot plate in a fume hood until a thick paste remained. The samples were then removed from the hot plate and allowed to cool before 10 ml of 6M HCl was added and the solution brought to a boil and allowed to cool. Each sample was then filtered through Gooch crucibles with glass-fiber mats to remove the undigested sediment. Each beaker was washed with a 10 and 5 ml washing of 6M HCl. The washings were also passed through the undigested sediment in the Gooch crucible. To the filtrates an additional 20 ml of concentrated HCl was added followed by 5 ml of arsenic reducing solution and 10 ml of 50% hypophosphorous acid. Solutions were heated until all the arsenic precipitated. The arsenic and coprecipitated selenium were then collected by filtration on glass-fiber mats in a Gooch crucible. The arsenic metal and the fiber mats were transferred to a 100-ml beaker. Any arsenic on the Gooch crucible was transferred to the beaker by washing with 2 ml concentrated HNO3 and then with distilled water. The arsenic and selenium were redissolved by heating the contents at boiling temperatures for 2-3 min. After cooling, 2.5 ml of formic acid and 1.0 ml of 0.5M EDTA were added. At this point, a series of standard samples were added containing 0-3.5 µg selenium as selenous acid. The pH of the samples was adjusted to 1.5  $\pm$ 0.1 with dilute aqueous ammonia solution or dilute HCl. Samples were then transferred to 125-ml separatory funnels and the volume adjusted to a total of 40 ml. DAN reagent, 5 ml. was added to each sample, the solution shaken briefly, and then placed in the dark at room temperature for 1 to 1.5 hr. After this time the solutions were extracted by shaking with exactly 10 ml cyclohexane for 75 sec. The aqueous layer was removed and the cyclohexane layer washed with 15 ml of 0.1M HCl by shaking for 30 sec. The aqueous layer was again discarded. The cyclohexane layer was then passed through cotton plugs inserted into the separatory funnel stems and collected in matched cuvets. Fluorescence readings were made with a Corning 7-60 primary filter and a Turner 23A secondary filter.

**Sample Collection.** Sediment samples were collected with an Eckman dredge, returned to the laboratory, and then airdried. Sediment core samples were obtained by using a 3.5-in. diam piston-type core barrel. Sections 5 cm in length were then removed from the core barrel and air-dried. After drying,

the sediment was powdered in a mortar and pestle until it would pass through a 100-mesh sieve. The ground samples were stored in glass bottles until analyzed.

# **Results and Discussion**

Analytical Method. Lane (1966) has reported a method for the determination of selenium in soil samples. This method, however, could not be used for lake sediment samples because low results were obtained. As a consequence, the filtrates were analyzed by a procedure similar to the procedure described by Allaway and Cary (1964) with minor modifications such as the purification of the arsenic precipitating reagent to ensure lower values for blank determinations. The shorter procedure described by Lane (1966) yielded low results because during pH adjustment of the sample from strongly acidic to a pH of 1.5 with aqueous ammonia, a heavy precipitate of Fe(OH)<sub>3</sub> formed which redissolved slowly at this pH. During the formation of Fe(OH)3 some of the selenite ion coprecipitates, making it unavailable to react with DAN, hence, the lower results. For this reason the longer, but more reliable procedure was used.

The addition of standard amounts of selenium equivalent to the concentration in Lake Mendota sediments resulted in 115% recovery of the added selenium. Standard deviations for eight Belle Fourche Reservoir samples and 10 Lake Mendota samples (Table I) were 0.15 and 0.16 ppm Se, respectively.

Field Studies. The results of the analysis of the sediments from 11 Wisconsin lakes and a South Dakota reservoir are given in Table I. Compared to concentrations found in nontoxic soils (Lakin and Davidson, 1967) and soils from low Se regions (Cary et al., 1967) of the U.S., lake sediments contain considerably higher concentrations of Se indicating that sediments are probably a reservoir for selenium. Sediments from Belle Fourche Reservoir, S.D., a region of high Se soil content, however, were among the lowest concentrations found in lake sediments. Perhaps the best explanation of this observation is that the Se entering the reservoir is diluted by a high rate of sediment formation taking place within the reservoir.

To study the variation of Se concentration in lake sediments, Eckman dredge samples were taken from various locations and depths from Lake Mendota and analyzed for Se content. In addition, sections of a sediment core from the deepest part of Lake Mendota were also analyzed for Se content. The results of these analyses are presented in Tables II and III. These results combined with the previous analysis by Delfino et al. (1969) of the dredge samples and Bortleson (1967) analysis of the core sections, allow the calculation of correlation coefficients for Se and several parameters. These results presented in Table IV show a high correlation between Se and depth as well as with Fe, Mn, and P. Cary et al. (1967) have shown that the soil chemistry of Se is related to the chemical form of Se present. It is quite possible that the Se found in lake sediments is associated with the finer-grained sediments as are Mn, Fe, and P as suggested by Delfino et al. (1969). The high correlation of Se with these elements is possible due to sorption characteristics of the sediment rather than to interrelated chemical reactions such as the possible coprecipitation of Se with Fe(OH)<sub>3</sub>. Support is given to the sorption argument because studies which involve the Se-75labeled selenite ion indicate that selenite is sorbed to lake sediments. The mechanism of selenite coprecipitating with Fe(OH)3, however, should not be completely ruled out as it may be significant during spring and fall turnover.

Despite the fact that increased amount of selenite is entering the atmosphere through the combustion of fossil fuels and trash, no Se buildup in the sediments of the lakes studied was recognized. In fact, core analyses (Table III) show that at some time in the past the Se concentrations were higher. It is also of interest that most of the sediments from the northern Wisconsin lakes, a sparsely populated area of little industrial activity, contained higher levels of Se than did the sediments from the three Dane County lakes, an area of much higher population density and industrial activity. Furthermore, Lake Minocqua is considered the most eutrophic of the Vilas and Oneida County lakes studied, yet it was found to have a lower Se content than all of the other lakes studied. The higher concentrations of Se in the northern Wisconsin lakes is the result of the fact that these lakes are soft water lakes with no CaCO<sub>3</sub> precipitation. On the other hand, the lakes located near Madison, Wis., are hard water lakes with large amounts of CaCO3 accumulating in the sediments. The CaCO3 deposition tends to dilute the Se concentration in the sediments.

Although this study shows that lake sediments contain significant quantities of Se, no attempt was made to ascertain the mechanism whereby Se cycles through the aquatic ecosystem. Further studies will be required to determine the mobility of the chemical forms of Se in lake sediments and the quantity of Se directly available to the benthic organisms. The significance of the presence of Se in the aquatic ecosystem remains unknown.

# Table III. Selenium Concentration in Mendota Core (AAA-43-89-63) Depth, cm Ppm Se

Depth, cm	Ppm Se
5-10	1.8
10-15	2.3
15-20	2.0
20-25	1.9
25-30	2.2
30-35	2.2
35-40	2.4
40-45	2.3
45-50	1.9
50-55	2.2
55-60	2.2
60-65	1.1
65-70	1.0
70-75	1.1
75-80	1.4
80-85	0.8
85-90	1.3
90-95	1.2

Table IV.	Correlation of Se with Other Parameters in
	Lake Mendota Sediments

Parameter	r <sup>a</sup> (samples from various locations)	r (sections from core)
Fe	0.81	0.78
Mn	0.49	0.71
Р	0.58	0.64
Depth	0.85	
$a r = \frac{\Sigma}{\left\{ \left( \Sigma X^2 - \frac{(\Sigma X)^2}{2} \right)^2 \right\}^2}$	$\frac{XY - \frac{\Sigma X\Sigma Y}{N}}{\frac{X)^2}{N} \left(\Sigma Y^2 - \frac{(\Sigma Y)^2}{N}\right)^{1/2}}$	

# Acknowledgment

We wish to acknowledge the assistance of Larry Van Ray, Fisheries Research Biology, S.D., Dept. of Fish, Game and Parks, Rapid City, S.D., in collecting the samples from Belle Fourche Reservoir.

# Literature Cited

- Allaway, W. H., Cary, E. E., Anal. Chem. 36, 1459 (1964). Bortleson, G. C., MS Thesis, Water Chemistry Dept., Uni-
- versity of Wisconsin, Madison, Wis., 1967. Cary, E. E., Wieczorek, G. A., Allaway, W. H., Soil Sci. Soc. Amer. Proc. 31, 21 (1967).
- Delfino, J. J., Bortleson, G. C., Lee, G. F., ENVIRON. SCI. TECHNOL. 3, 1189–92 (1969).

Lakin, H. W., Davidson, D. F., "Selenium in Biomedicine," First International Symposium, O. H. Muth, Ed., Avi Publ., Westport, Conn., 1967.

Lane, J. C., Ir. J. Agr. Res. 5, 177 (1966). Muth, O. H., Ed., "Selenium in Biomedicine," First International Symposium, Avi Pub., Westport, Conn., 1967. Oelschläger, V. W., Menke, K. H., Z. Ernahrungswiss. 9,

Received for review March 15, 1971. Accepted July 23, 1971. This investigation was supported by training grant number 5Tl-WP-22 from the Federal Water Quality Administration. In addition, support was derived from the University of Wisconsin Dept. of Civil Engineering and the Engineering Experiment Station.

# An Empirical Method for Determining the Concentration of Solids in Suspension

# John W. Liskowitz<sup>1</sup>

American Standard Inc., P.O. Box 2003, New Brunswick, N. J. 08903

The degree of depolarization of back-scattered polarized radiation by model hydrosol systems has been investigated. A resulting empirical method for determining suspended solids concentrations has been established. Results show that the degree of depolarization is related to the volume concentration of suspended solids. The degree of depolarization increases with the refractive index ratio of the solid to the dispersing medium at values below 1.38 and remains constant in the 1.38 to 1.82 range. The degree of depolarization increases with the optical path length, but this increase is limited by the concentration of the solids and refractive index ratio of the suspension. The degree of depolarization is a single valued function with respect to concentration and is unaffected by such factors as particle shape, optical activity, and the solid deposits on the optical windows. This approach responds to a greater concentration range of particles and is less dependent on particle size than the commonly used transmission and light-scattering techniques.

n optical method for measuring the mass concentration of suspended solids in hydrosols would be extremely useful in monitoring water pollution because such an approach could offer rapid and continuous operation. Available optical techniques such as light absorption and light scattering intensity measurements have limited applications for a number of reasons. Measurements from these techniques are affected by variation in particle size, shape, and color; light source fluctuations can cause variations in the intensity of the transmitted and scattered radiation.

As an empirical method of measuring the concentration of suspended solids, the depolarization of back-scattered polarized radiation was investigated. This optical approach

is based on the well known effect that the depolarization of scattered light resulting from multiple scattering increases with the concentration of scattering particles. Although many investigators-Napper and Ottewill (1964); Kraut and Dandliker (1955); Doty and Stein (1948); Doty and Kaufman (1945); Kerker and Matijevic (1960); Renau et al. (1967); Oster (1948); Kratohvil and Smart (1965); Wallace and Kratohvil (1967); Smart et al. (1965); Woodward (1964); Walsh (1968); Graessley and Zufall (1964); Tabibian and Heller (1958); Querfield (1969); Heller (1963); Hodkinson (1963)-studied depolarization of scattered radiation and multiple scattering, the use of depolarization of back-scattered polarized radiation as a means of measuring the concentration of solids in suspension appears to have been overlooked.

The purpose of this paper is to bring attention to the apparently unexpected results obtained by measuring the depolarization of back-scattered radiation exhibited by particles of various shapes and sizes. A study of the effect of particle size, shape, refractive index, and optical path length on the empirical relationship between the degree of depolarization of back-scattered polarized radiation and the concentration of suspended particles in hydrosols was carried out. Also, the results obtained with the depolarization method were compared with those obtained by the transmission and light scattering methods (Black and Hannah, 1965; Downing et al., 1965) presently used for monitoring the amount of suspended solids in streams, waste water, and sewage. This involved the determination of the range of suspended solid concentrations that can be determined with these optical methods. The effect of such factors as solids buildup on optical windows of the cuvette and variations in particle size on the results obtained with the depolarization method was also studied because these factors influence the intensity of the transmitted and scattered radiation. In addition the effect of optical activity on the degree of depolarization was investigated because optically active compounds are present in streams, waste water, and sewage, and these compounds can rotate the plane of the polarized incident and scattered radiation.

<sup>216 (1969).</sup> 

<sup>&</sup>lt;sup>1</sup> Present address: Dept. of Civil and Environmental Engineering, Newark College of Engineering, Newark, N. J. 07102.

Table I. Refi	active	Index	Ratio
---------------	--------	-------	-------

Dispersing media	Poly- styrene <sup>a</sup>	Poly- vinyl toluene	Al <sub>2</sub> O <sub>3<sup>b</sup></sub>	SiO <sub>2</sub>	Dia- mond
H₂O	1.199	1.188	1.341	1.162	1.820
13% Glycol-H2O	1.188				
25% Glycol-H <sub>2</sub> O	1.171	1.166			
35% Glycol-H2O					1.767
50% Glycol-H2O	1.155		1.295	1.120	
75% Glycol-H <sub>2</sub> O	1.135				
85% Glycol-H <sub>2</sub> O					1.715
95% Glycol-H <sub>2</sub> O	1.120	1.110	1.255	1.088	
Benzene			1.190	1.031	1.550
Bromobenzene					1.610
Methylene					
iodide					1.373
a D I walnue for	nolucturo	a and not	winyl tob	ana latar	narticles

<sup>a</sup> R.I. values for polystyrene and polyvinyl toluene latex particles were those used by Heller and Tabibian (1962).
<sup>b</sup> R.I. values for Al<sub>2</sub>O<sub>3</sub> (corundum), SiO<sub>2</sub> (natural), and diamond were obtained from the International Critical Tables (1930).

# Experimental

**Reagents.** The materials used in this investigation were Dow polystyrene latex particles (density = 1.058 grams/cc) with diameters of 0.088, 0.234, 0.357, 0.557, 0.796, and  $1.305\mu$ and Dow polyvinyl toluene latex particles (density = 1.027grams/cc) with diameters of 1.90 and 2.68 $\mu$ .

The alumina and natural quartz in the size range  $1-2.5\mu$ and  $0.5-1.75\mu$ , respectively, were obtained from A-2 fine alumina (Alcoa) and  $5\mu$  Min-U-Sil quartz (Pennsylvania Pulverizing Co.) by sedimentation. The particle size distributions in the alumina and quartz sample were determined by microscopy. DeBeers natural diamond dust in the particle size range of  $1-2\mu$  was obtained from Warren Diamond Powder Co., College Point, N. Y.

A series of suspensions in which the ratios of refractive index of suspended solids to refractive index of liquid were varied was prepared (Table I). The volume concentration of the particles below a refractive index of 1.341 was maintained at  $4.74 \times 10^{-2}$  cc in 100 ml of suspension. For higher relative refractive index ratios, the volume concentration of the particles was reduced to  $1.36 \times 10^{-3}$  cc in 100 ml of suspension to avoid complete depolarization of back-scattered polarized radiation.

The effect of sludge deposition on the degree of depolarization was determined by coating a 36-mm i.d. cylindrical cuvette with  $MnO_2$ . The  $MnO_2$  deposit was formed as a result of the reduction of  $KMnO_4$  by an organic coating on the surface of the cuvette. The  $MnO_2$  was selected because it is insoluble in water and its color is similar to the color of suspended matter in streams, waste water, and sewage.

For study of the influence of optical activity on the degree of depolarization, a polystyrene latex suspension (200 ppm) containing 0.209 gram/cc of optically active sucrose was used. This amount of sucrose exhibited a positive optical rotation of  $6.0^{\circ}$  in a 3.6-cm cuvette.

# Procedure

All depolarization measurements by use of a scattering angle  $\leq 150^{\circ}$  with respect to the incident beam were carried out with a modified Brice Phoenix light-scattering photometer (Model 1000-D), by use of either polychromatic incident radiation from a type AH-3 mercury source or monochro-

matic incident radiation of a wavelength of 546 mµ. The limiting slits (15  $\times$  15 mm) and (12  $\times$  15 mm) generally found in the incident beam of the Brice Phoenix instrument were replaced with slits whose dimensions were  $4 \times 15$  mm and  $1.5 \times 15$  mm, respectively. The size of the latter slit permitted the receiver to be positioned at a scattering angle of 150°. The incident beam was polarized in a vertical direction and the degree of depolarization was obtained from the ratio of the intensities of scattered radiation passing through the analyzer with its axis in a horizontal  $(E_{\perp})$  and vertical position ( $E_{\parallel}$ ). A correction had to be made for the preferential response of the photomultiplier to horizontal radiation  $(E_{\perp})$ . This was accomplished by inserting in front of the analyzer a plate which completely depolarized the scattered radiation. The intensity of radiation that passed through the analyzer with its axis in a horizontal and then in a vertical position was then measured.

A schematic of the experimental setup designed to perform depolarization measurements at a scattering angle of 170° is shown in Figure 1. Most of the components in this instrument were taken from a Brice Phoenix light scattering photometer. The complete source unit consisting of a type A-H3 mercury lamp, the 546 m $\mu$  monochromatic filter, the iris diaphragm, the cylindrical lens, and the Polaroid polarizer was mounted on an optical bench designed to support a sample cuvette at one end. The receiver unit was positioned on a detector support which could be rotated to obtain backscattering angles of 150° and 170°. A partition was placed between the source unit and receiver unit to prevent stray source radiation from interfering with the depolarization measurements. The detector was directed at a point along the incident beam which corresponds to the center of the cylindrical sample cuvette. The width and height of the incident beam image at this point were  $3 \times 22$  mm. The axis of the analyzer was again manually positioned to obtain  $E_{\perp}$ and  $E_{\parallel}$ . All measurements which made use of this experimental setup were carried out in a darkened room to prevent any stray radiation from entering the receiver unit.

Elimination of the reflections from the back of the sample cell which was significant at a back-scattering angle of 170° was accomplished with a light trap and coating the back surface of the sample cell with 3M black velvet paint. The radiation reflected off the front surface of the sample cell was con-



Figure 1. Schematic of the instrumental arrangement for depolarization measurements at 170  $^\circ$ 



Figure 2. Degree of depolarization as a function of scattering angle using polystyrene latex particles



Figure 3. Degree of depolarization depending on polystyrene particle sizes as a function of scattering angle

Concentration	=	200 ppm
<b>Refractive index ratio</b>	=	1.199
Sample cuvette	=	36 mm i.d
Incident wavelength	=	546 mµ
□ 0.557 µ parti	cle	diam
△ 1.305µ parti	cle	diam

sidered by first carrying out the depolarization measurements with only clear liquid in the sample cell. The values  $(E_{\parallel})$  obtained from these measurements were then subtracted from those obtained when the sample cell contained the suspension. No depolarization of the radiation reflected from the front surface of the sample cell was observed. A linear response of the photomultipliers was maintained for all measurements by regulation of the power supply.

# Results

The results of depolarization measurements at a backscattering angle of  $150^{\circ}$  were found to respond to a greater range of particle concentration than those performed at forward scattering angle of  $30^{\circ}$  (Figure 2). A measurable degree of depolarization is exhibited by polystyrene particle concentrations of 10 ppm by weight when measured at  $150^{\circ}$ , whereas, a particle concentration of 50 ppm at a scattering angle of  $30^{\circ}$  is required to obtain this degree of depolarization. For high concentrations, the scattered radiation measured at an angle of  $30^{\circ}$  is completely depolarized by a particle concentration of 300 ppm. In comparison, the measurements on the same concentration of particles at  $150^{\circ}$  still indicate a measurable depolarization.

The effect of variations in particle size on the degree of depolarization was investigated by performing depolarization



Figure 4. Degree of depolarization as a function of particle diameter for a given scattering angle using polystyrene and polyvinyltoluene latex particles



Table II. Dependency of the Degree of Depolarization Upon Bulk Volume, Total Surface Area, and Total Number of Particles

Degree of de- polariza- tion $\langle = 150$ $\lambda =$ 546 m $\mu$	Particle size, µ	Total bulk volume, cc/ml	Total surface area, cm²/ ml	Total no. of particles, ml
0.295	0.557	$4.73 \times 10^{-5}$	5.08	$5.22  imes 10^8$
0.295	0.796	$4.73 \times 10^{-5}$	3.53	$1.78 imes10^8$
0.290	1.305	$4.73 \times 10^{-5}$	2.17	$4.05 \times 10^{7}$
0.295	0.557	$4.73 \times 10^{-5}$	5.08	$5.22  imes 10^8$
0.405	0.796	$6.80 \times 10^{-5}$	5.08	$2.56 \times 10^{8}$
0.540	1.305	$11.02 \times 10^{-5}$	5.08	$9.45 \times 10^{7}$
0.295	0.557	$4.73 \times 10^{-5}$	5.08	$5.22  imes 10^8$
0.605	0.796	$13.86 \times 10^{-5}$	10.4	$5.22  imes 10^8$
0.900	1.305	$61.0 \times 10^{-5}$	28.0	$5.22  imes 10^8$

measurements on two aqueous suspensions prepared with the same weight concentration (200 ppm) of polystyrene particles of different diameters. The results indicate that the effect of particle size on the degree of depolarization decreased with an increase in the back-scattering angle (Figure 3). At scattering angles of 0° and 90°, the degree of depolarization exhibited by both suspensions was different, whereas, the degree of depolarization when measured at 150° with respect to the direction of the incident beam was the same for both suspensions.

The degree of depolarization of back-scattered polarized radiation at a scattering angle of 150° appears to be dependent on the volume concentration of suspended particles. Depolarization measurements on a series of polystyrene latex suspensions in which the volume concentrations were held constant indicate no change in the degree of depolarization (Table II), even though the diameters of the particles in suspension were different. In comparison, when the surface area and number of particles in the suspension were held constant with an accompanying increase in the volume concentration, the degree of depolarization also increased. However, when the diameter of the particles is smaller than 0.4µ or the backscattering angle is decreased from 150° to 135°, the degree of depolarization becomes dependent on the diameter of particles in suspensions containing the same volume concentration of particles (Figure 4).



REFRACTIVE INDEX RATIO (R. L. MEDIUM)

Figure 5. Degree of depolarization as a function of the refractive index ratio

Concentration of particles =  $4.74 \times 10^{-2}$  cc/100 ml of suspension for refractive index ratio < 1.34

Concentration of particles =  $1.36 \times 10^{-3}$  cc/100 ml of suspension for refractive index ratio > 1.34

> Incident wavelength = 546  $m_{\mu}$ = 47 mm i.d. Sample cuvette 0 Polystyrene spherical latex particles Δ Polyvinyl toluene spherical latex particles Al<sub>2</sub>O<sub>3</sub> (corundum) S SiO<sub>2</sub> (natural quartz) Diamond 150° Scattering angle 170° Scattering angle

The effect of variations in the ratio of refractive index of particles to that of the dispersing media on the degree of depolarization measured at a scattering angle of 150° was examined in the ranges from 1.02 to 1.82. In the range between 1.02 and 1.38, the degree of depolarization increases with refractive index ratio (Figure 5). However, between 1.38 and 1.82, the degree of depolarization remains relatively constant with further increases in the refractive index ratio. These results also hold for the depolarization measurements performed at a back-scattering angle of 170°.

In comparison, the total back-scattered radiation increases in a regular manner with the refractive index ratio (Figure 6). The measurements carried out at 170° appear to exhibit a greater change in intensity with the refractive index ratio than those carried out at 150°.

The presence of spherical or irregularly shaped particles such as quartz and alumina does not influence the results of the depolarization measurements. Suspensions prepared with polystyrene and polyvinyl toluene spherical latex particles or alumina and quartz exhibit similar degrees of depolarization at a scattering angle of 150° provided that the volume concentration and the refractive index ratio are the same (Figure 5).

The degree of depolarization can be related to the concentration of particles in suspension either in terms of the volume or weight concentration provided that the density of the particle remains constant. An increase in the weight concentration of polystyrene latex particles results in a continuous increase in the degree of depolarization (Figure 7). The degree of depolarization approaches a value of zero for low concentrations and a value of one for high concentrations of suspended particles.

The sensitivity of the depolarization measurements in determining low particles concentrations can be enhanced by increasing the optical path length. However, the degree of depolarization is independent of the optical path length at polystyrene latex concentrations above 300 ppm (Figure 7). For alumina suspended in water and benzene, the degree of depolarization was independent of optical path length at concentrations of 1100 and 1500 ppm, respectively (Figure 8).

The results of coating a sample cuvette with MnO<sub>2</sub> in



Figure 6. Total back-scattered radiation exhibited by Al<sub>2</sub>O<sub>3</sub> and diamond suspensions as a function of refractive index ratio

Concentration of particles =  $1.36 \times 10^{-3}$  cc/100 ml of suspension Sample cuvette = 47 mm i.d. 150° Scattering angle П

170° Scattering angle 0





Figure 7. Effect of optical path length on the degree of depolarization using polystyrene latex particles





Figure 8. Effect of optical path length on degree of depolarization using Al<sub>2</sub>O<sub>3</sub>

150° Scattering angle Incident wavelength (546 mµ) Δ 25 mm i.d. cuvette ō 36 mm i.d. cuvette 47 mm i.d. cuvette

amounts sufficient to reduce the transmission of the incident radiation down to 0.6% were found to have little effect on the measurement of the degree of depolarization. A small and nearly constant difference of the order of 5% was observed between the result obtained with the fouled and unfouled surfaces. A comparison of the values obtained for  $E_{\perp}$  and  $E_{\parallel}$ revealed the same fractional loss due to scattering by deposited MnO<sub>2</sub>.

On the other hand, the ratio of the intensity of scattered light measured at right angles with respect to the incident



Figure 9. Degree of depolarization as a function of polystyrene particle concentration

Incident radiation—white (polychromatic) light Sample cuvette = 36 mm i.d. Scattering angle =  $150^{\circ}$ Refractive index ratio = 1.199  $\Box$  0.557 $\mu$  particle diam 1.305 $\mu$  particle diam

beam and the intensity of the transmitted light was strongly influenced by the presence of matter on the optical surface of the sample cuvette. The fouled and unfouled surfaces gave differences in results of as much as 30 to 100%. This unequal attenuation of the scattered radiation and transmitted radiation is due to the nonuniform accumulation of the solid matter on the optical surface of the cuvette.

The effect of the optical activity in a sample equivalent to a  $+6.0^{\circ}$  rotation in a 3.6-cm cuvette on the degree of depolarization was found to be significant at an angle of observation of 0°. A 19% enhancement in the degree of depolarization was observed. However, as the angle was increased in a direction opposite to that of the incident beam, the effect of optical activity was decreased. At an angle of 150°, the degree of depolarization was not influenced to any significant extent by the optical activity.

The results of depolarization measurements on two suspensions containing 0.557 and  $1.305\mu$  polystyrene latex particles indicate that a concentration range from 3 to 1000 ppm by weight could be measured by use of this approach (Figure 9). The relationship between the degree of depolarization and concentration was found to be a single value function that approached zero at 3 ppm and becomes one at 1000 ppm. The size of the particles in the two suspensions did not affect this relationship.

In comparison, a concentration range from only 50 to 1000 ppm by weight could be determined by measuring the ratio of the intensity of light scattered at right angles to the incident beam and that transmitted through the suspensions (Figure 10). The effect of size on the results of these measurements was quite pronounced. A suspension containing 200 ppm of  $0.557\mu$  particles exhibited the same ratio as a 400 ppm of the  $1.305\mu$  particles.

The results of transmission measurement on the polystyrene latex suspension indicated that the relationship between optical density and concentration was linear up to about 40 ppm (Figure 11). However, these relationships differed for the suspensions prepared with 0.557 and  $1.305\mu$ particles.

Scattering measurements at right angles to the incident beam indicate that the relationship between the intensity of scattered radiation and concentration is not a single value function. The intensity of the scattered radiation reached a maximum around 100 ppm and then fell off nonlinearly to about 20–40% of its peak value by 1000 ppm.



Figure 10. Ratio of the intensity of light scattered at right angles to the incident beam to the intensity of transmitted light as a function of polystyrene particle concentration

Incident radiation—white (polychromatic) light Refractive index ratio = 1.199 Sample cuvette = 36 mm i.d.  $\Box$  0.557 $\mu$  particle diam  $\triangle$  1.305 $\mu$  particle diam



Figure 11. Optical density as a function of polystyrene particle concentration

Incident radiation—white (polychromatic) light Sample cuvette = 36 mm i.d. Refractive index ratio = 1.199 □ 0.557µ particle diam △ 1.305µ particle diam

#### Discussion

The results of this investigation indicate that the measurement of the depolarization of back-scattered polarized radiation shows promise as a method for determining the concentration of particles in suspension. Advantages of the method are that the degree of depolarization is dependent on the volume or mass concentration at a fixed density and independent of whether the particles are spherical or irregular in shape. In addition the effect of particle size on the relationship between the degree of depolarization and concentration of suspended solids in the limited range of sizes examined can be minimized. This is achieved by increasing the backscattering angles ( $\geq 150^{\circ}$ ) used for the depolarization measurements and selecting a specific wavelength (546 m $\mu$ ) of the incident radiation so that the range of particle diameters (0.4 to  $2.68\mu$ ) is comparable or larger than this wavelength. Fouled optical surfaces also do not significantly influence the results obtained with depolarization measurements. The radiation scattered by the deposited matter apparently does not affect the degree of depolarization because the depolarization method is independent of variations in the intensity of the back-scattered radiations and responds only to that radiation which passes through the deposited solids at one location

Variations in the refractive index ratio were found to have a marked effect on the degree of depolarization of backscattered polarized radiation below 1.38. However, in the 1.38-1.82 range, the degree of depolarization remained constant with an increase in the refractive index ratio. These results were unexpected because the intensity of the backscattered radiation measured at the same (back-scattering) angle showed a linear increase with the refractive index ratio. The reason for the degree of depolarization becoming independent of the refractive index ratio is not clear at the present time.

The sensitivity of depolarization measurements in monitoring low concentrations of suspended solids can be increased by increasing the optical path length. However, above a given concentration of particles of suspension, the degree of depolarization becomes independent of the optical path length. This occurs when the incident beam is completely scattered by the suspension prior to the point along the incident beam at which the detectors are directed. The concentration of particles at which this occurs depends on the refractive index ratio. For polystyrene water suspension (1.199), the degree of depolarization becomes independent of its optical path length at a volume concentration of  $2.84 \times 10^{-4}$  cc/ml. For alumina-water (1.341) and alumina-benzene (1.190) suspensions, this occurs at volume concentrations of 2.75  $\times$  10<sup>-4</sup> cc/ml and  $3.76 \times 10^{-4}$  cc/ml, respectively.

# Acknowledgment

The author thanks Richard E. Gellner, Jr. for his assistance in carrying out the depolarization measurements and wishes to acknowledge the many helpful discussions with Horst Casper and William Hodes during the course of this investigation.

#### Literature Cited

- Black A. P., Hannah, S. A., J. Amer. Water Works Ass. 57, 901 (1965).
- Doty, P., Kaufman, H. S., J. Phys. Chem. 49, 583 (1945). Doty, P., Stein, S. J., J. Polym. Sci. 3, 763 (1948).
- Downing, A. L., Eden, G. E., Briggs, R., Inst. Sew. Purif. J. Proc. I, 75 (1965).
- Graessley, W. W., Zufall, J. H., J. Colloid Sci. 19, 516-524 (1964). Heller, W., "Electromagnetic Scattering," M. Kerker, Ed.,
- MacMillan, New York, N.Y., 1963, pp 101-20
- Heller, W., Tabibian, R. J., J. Phys. Chem. 66, 2059 (1962).
- Hodkinson, R. J., "Electromagnetic Scattering," M. Kerker,
- Ed., MacMillan, New York, N.Y., 1963, pp 87-100. "International Critical Tables of Numerical Data, Physics, Chemistry and Technology," VII, 18, 22; VI, 341, McGraw-Hill, New York, N.Y., 1930.
- Kerker, M., Matijevic, E., J. Opt. Soc. Amer. 50, 722 (1960). Kratohvil, J. P., Smart, C., J. Colloid Sci. 20, 875 (1965).
- Kraut, J., Dandliker, W. B., J. Polymer Sci. 18, 563 (1955)
- Napper, D. H., Ottewill, R. H., J. Colloid Sci. 19, 72 (1964).
- Oster, G., Chem. Rev. 43, 344 (1948)
- Querfield, C. W., Ph.D. Thesis, Clarkson College of Technology, Potsdam, N.Y., 1969. Renau, J., Cleo, P. K., Cooper, H. G., J. Opt. Soc. Amer.
- 57, 459 (1967).
- Smart, C., Jacobsen, R., Kerker, M., Kratahvil, J. P., Mati-jevic, E., J. Opt. Soc. Amer. 55, 957 (1965).
- Tabibian, R. M., Heller, W. J., J. Colloid Sci. 31, 6 (1958)
- Wallace, T. P., Kratohvil, J. P., Polym. Lett. 5, 1139 (1967).
- Walsh, D. H., Appl. Optics 7, 1213 (1968). Woodward, D. H., J. Opt. Soc. Amer. 54, 1325 (1964).

Received for review April 17, 1970. Accepted April 18, 1971.

# Spark Replica Technique for Measurement of Sulfuric Acid Nuclei

# Janet E. Stickney and Jimmie E. Quon<sup>1</sup>

Environmental Health Engineering, Technological Institute, Northwestern University, Evanston, Ill. 60201

Application of a spark replica technique for the measurement of sulfuric acid nuclei was explored. The technique involves exposure of a polycarbonate film to an acid aerosol and counting the number of defects or holes developed in the film with a spark replica counter. The defects in the film may be enlarged by etching in sodium hydroxide. The film, after etching and drying, is used as the dielectric material of a capacitor. Impressing a voltage across this capacitor gives rise to sparking through the holes. The number of sparks corresponds to the number of holes sufficiently large to permit sparking at the operating voltage. Operational parameters such as sampling time, flow rate, etching time, and operating voltage of the counter were investigated. Sulfuric acid nuclei were generated by photooxidation of sulfur dioxide in air. The concentration of nuclei is an exponential function of the number of counts (holes) recorded. The minimum detectable concentration by this technique is 104 nuclei/cm3. For aerosol concentrations of approximately 105 nuclei/cm3, the average and standard deviation of nine replicated measurements were found to be 75 and 9 spark counts, respectively.

ulfuric acid aerosols may be formed by the photooxidation of sulfur dioxide and subsequent hydration of the trioxide; the hydration of the trioxide resulting from the combustion of fuel; and the surface-catalyzed oxidation of the dioxide. A mass median diameter of  $\leq 0.5 \mu$  has been reported for the acid aerosol (Waller et al., 1963; Waller, 1963). Sulfuric acid aerosol concentrations of 678  $\mu$ g/m<sup>3</sup> have been observed during periods of atmospheric stagnation (Stern, 1968).

The spark replica counting technique has been used for the measurement of nuclear particles (Cross and Tammasino, 1969; Johnson et al., 1970; Kastner, 1970). The adaptation of the spark replica technique to the measurement of sulfuric acid aerosol offers the potential of counting the reaction spots or damage sites of submicron particles without the aid of an electron microscope.

The spark replica method involves exposure of a thin plastic film to a sulfuric acid aerosol and counting the number of defects (holes) in the film. In most applications, the damage

<sup>&</sup>lt;sup>1</sup> To whom correspondence should be addressed.

sites need to be enlarged by etching the plastic film in a solution of sodium hydroxide for ease of detection. A spark replica counter is used for determining the number of damage sites.

The spark replica counter consists of two charged parallel plates separated by a plastic film. One of these plates is an aluminized Mylar sheet. The damage sites on the film function as small capacitors. An impressed electric field of sufficient strength causes the small capacitors to discharge or spark. Each spark may be recorded with a scaler unit similar to those used in connection with a Geiger counter. Each spark causes evaporation of the aluminum film on the Mylar adjacent to the damage site. Consequently, each damage site gives rise to only one spark.

The feasibility of adapting the spark replica counting technique for the measurement of sulfuric acid aerosols was evaluated. A simple spark replica counter was developed, and the use of this counter in connection with a sampling system utilizing a polycarbonate plastic film was investigated.

Procedures for the enlargement of damage sites on the plastic film to facilitate counting and different sampling procedures were evaluated. The test sulfuric acid aerosols used for this study were generated by the photooxidation of sulfur dioxide in air. The concentration of the aerosol was measured with a condensation nuclei counter. A relationship between nuclei concentration and spark count was established.

# Experimental Apparatus and Procedures

Sulfuric acid aerosols were generated by irradiating plastic bags containing a mixture of sulfur dioxide in air with blacklights having a peak spectral emission at 350 m $\mu$  (Quon et al., 1970). Gas mixtures of different concentrations of sulfur dioxide were prepared, with the appropriate airflow rates through a mixing chamber containing a sulfur dioxide permeation tube. The temperature of the mixing chamber was maintained at 23° ± 0.1°C.

The concentration of the acid aerosol generated was measured with a Wilson-type condensation nuclei meter (Quon, 1964). The concentration of an aerosol was measured at least three times within a short time period, generally within a 3-min period, and the average of the group of measurements was used to represent the concentration of the sample. Each sample removed from the plastic bag does not cause a dilution of the remaining contents. Coagulation and wall losses occur continually, of course.

A spark replica counter consists of the spark chamber, the high voltage power supply, the scaler unit, and the electrical



Figure 1. Electric circuit diagram of spark replica counter

circuit connecting the spark chamber with the scaler. Picker Compact Scalers (Model 60010) were used for the power supply and the scaler unit. One conducting plate of the spark chamber was a sheet of aluminized Mylar, and the other plate was a flat smooth surface of a block of brass. The dimensions of the brass block were  $4 \times 1 \times 1$  in. As a safety precaution, the brass block was covered with Lucite on four of its six faces. A standard post was drilled into one exposed end and tapped to provide an electrical connection. The remaining exposed surface served as one of the two electrodes of the spark chamber. The counting surface area was approximately 25.8 cm<sup>2</sup>. The circuit diagram for the counter was established empirically and is shown in Figure 1. The sizes of the resistors and capacitors were varied until the amplitude of the spark and the time constant of the system were such that each spark was recorded separately by the scaler unit. The amplitude of the output pulse depends on the applied voltage and was approximately 200 mV at an applied voltage of 550 V. The time constant was about 0.2 µsec. This basic arrangement was patterned after the spark replica counter design used by the Argonne National Laboratory (Kastner, 1970).

A plastic film placed between the aluminized Mylar and the brass block will act as an insulator. If there are damage sites on the film, each site or hole acts as a small capacitor and will discharge or spark, if a sufficiently high electric field is im-

Film	Etching medium, NaOH (N)	Etching period, hr	Remarks
Cellophane, coated with	0.5	0.5	Sloughing of outer layer; film
cellulose nitrate and	1.0	0.5	shrinks and shrivels on drying
various plasticizers	0.5	1.0	
	1.0	1.0	Film becomes brittle
Cellulose acetate butyrate, 0.188 in.	6.25	12.0	Film curls after etching and is still much too thick to be useful
Polycarbonate (Kimfol), 8 and 10 µ	6.25	12.0	A flat smooth film results; etching is uniform if film is kept sub- merged in the etching solution throughout the 12 hr; 8-µ film gives much greater spark counts than the 10-µ film after exposu- to sulfuric acid aerosol

pressed across the two parallel plate electrodes. An operating voltage of 550 V in the Geiger plateau region was selected for the counter to minimize the dependence of the number of sparks or counts recorded on the operating voltage.

The suitability of a plastic film for use in conjunction with the spark replica counter for the measurement of sulfuric acid aerosol concentrations depends on the susceptibility of the film to damage by the acid aerosol and on the etching characteristics of the film. Etching the film in a strong solution of sodium hydroxide is necessary to enlarge the damage sites on the film. It is desirable for the thickness of the film to remain uniform and for the film not to buckle after a prolonged etching period. Table I contains a list of several plastic films and a summary of their etching characteristics. Both the 8- and  $10-\mu$ polycarbonate film (Kimfol) were found to possess good etching characteristics.

Etching the film gives rise to some damage sites on the film. The etching conditions for the polycarbonate film were selected on the basis of convenience and acceptable damage to the film. Figure 2 shows the spark count or number of damage sites on  $8-\mu$  thick polycarbonate films, without previous exposure to an acid aersosol, for different etching periods. The solution of sodium hydroxide used was 6.25*N*, and the solution was stirred gently at room temperature. Figure 3 is similar to Figure 2, but the etching solution was not stirred. After etching, the film was rinsed generously, but gently, in cold water and then rinsed with distilled water. The film was sandwiched between two paper towels and dried in an oven at 100°C for 20 to 30 min.

Figures 2 and 3 also show the spark count for polycarbonate films exposed, on a batch basis, to a sulfuric acid aerosol concentration of the order of  $10^5/\text{cm}^3$  for 30 min. The ratio of spark count for the exposed film to the background count

does not increase significantly with an increase in etching time in excess of 12 hr. An etching time of 12 hr was selected to keep the background spark count below 10. The variations in the etching period used were kept within 0.5 hr. The  $8_{-\mu}$ film was reduced to 6.35  $\mu$  on the average for this etching period. The decrease of 1.65  $\mu$  in thickness may be expected to enlarge the damage sites by the same amount (Fleischer and Price, 1964).

One side of the polycarbonate film appears duller than the other and this distinction in appearance remained after etching. As a matter of procedure, the dull side of the film was used for exposure to the acid aerosol and was placed facing the brass block of the spark chamber for counting.

Preparation of the film for counting included etching, washing, drying, and subjecting the film to a high electric field (1000 V per  $6.35 \mu$ ) for a period of 30 min. The latter procedure was to develop fully any partially etched holes. The actual counting used an operating voltage of 550 V. This procedure allowed the counting at 550 V to be completed in a reasonable length of time.

The method of sampling involved the use of a rectangular diffusion chamber and laminar flow through the chamber. The dimensions of the chamber used were 40.0 cm in length, 5.08 cm in height, and 0.159 cm in width. One wall of the chamber was lined with the polycarbonate film, and the aerosol was drawn through the chamber by means of a vacuum pump. Flow rate was measured with a rotameter.

For laminar flow in a rectangular channel, the reduction in concentration of an aerosol is a function of the volumetric flow rate, the diffusion coefficient of the particles, and the dimensions of the channel. In addition to these factors, the number of particles deposited on the channel walls will depend on the sampling period.



Figure 2. Spark count as a function of etching time, with stirring Kimfol film (8  $\mu$ ) etched in 6.25N NaOH;  $\bigcirc$  = film exposed to sulfuric acid aerosol;  $\triangle$  unexposed film



Figure 3. Spark count as a function of etching time, without stirring Kimfol film (8  $\mu$ ) etched in 6.25N NaOH;  $\bigcirc$  = film exposed to sulfuric acid aerosol;  $\triangle$  unexposed film





Total volume of sample is constant and equal to 1.5 liters. Flow rates:  $\triangle = 250 \text{ cm}^3/\text{min}; \bigcirc = 200 \text{ cm}^3/\text{min}; \square = 150 \text{ cm}^3/\text{min}$ 

Table II. Sulfuric Acid Nuclei Concentration vs. Spark Count

			Grou	p average
	Spark	Nuclei concen-	Spark	Nuclei
Run	count, no.	tration, no./cm <sup>3</sup>	count, no.	no./cm <sup>3</sup>
23	28	$8.9  imes 10^3$	26.2	$1.0 imes10^4$
28	18	$9.0 imes10^{3}$		
24	33	$1.2 imes10^4$		
30	42	$2.3  imes 10^4$	41.7	$2.6 imes10^4$
38	41	$2.9  imes 10^4$		
25	43	$3.6 imes10^4$	56	$4.0 \times 10^{4}$
47	56	$3.7 imes10^4$		
48	57	$3.8 imes10^4$		
35	68	$4.7  imes 10^4$		
44	62	$6.9 imes10^4$	75.5	$1.2 imes10^{5}$
33	71	$7.9 imes10^4$		
26	70	$9.5 imes10^4$		
27	78	$1.0 imes10^5$	$(\sigma = 8.6)$	
31	78	$1.2 imes10^{5}$		
42	71	$1.5 imes10^5$		
41	73	$1.5 imes10^5$		
43	89	$1.6 imes10^5$		
37	87	$1.9 imes10^5$		
46	96	$2.1 imes10^5$	97	$2.4 imes10^5$
36	90	$2.4 imes10^5$		
34	105	$2.8 imes10^5$		
40	113	$3.8 imes10^5$	109	$3.9 imes10^5$
29	104	$4.0 imes10^5$		
45	148	${\sim}2 imes10^{6}$	148	${\sim}2 imes10^{6}$
19	148	$\sim$ 1–2 $ imes$ 10 $^{6}$		



Flow rate: 150 cm<sup>3</sup>/min; sample volume =  $\Box$  450 cm<sup>3</sup>;  $\Delta$  = 750 cm<sup>3</sup>;

A centrally located portion of the exposed film, approximately 25.8 cm<sup>2</sup> (1  $\times$  4 in.), was used for counting. Each film was counted at least six separate times. Generally, the counts can be replicated within 1%.

Figure 4 shows the number of spark counts obtained for different acid nuclei concentrations, by use of several sample flow rates. The total sample volume used was kept constant at 1.5 liters by varying the sampling period. Coagulation and wall losses were not considered in these measurements since the purposes of these measurements were to determine suitable sampling rates and periods and to assess the approximate spark count to be expected. Coagulation and wall losses were considered in subsequent measurements used to establish the relationship between nuclei concentration and spark count. Figure 5 shows the spark count for different nuclei concentrations, using several sampling periods and a sampling rate of 150 cm<sup>3</sup>/min. A 3-min sampling period at 150 cm<sup>3</sup>/min was found to be adequate for detecting an acid aerosol concentration of greater than 10<sup>4</sup> per cm<sup>3</sup>.

# Results and Discussion

O = 1500 cm<sup>3</sup>

By using the sampling and counting procedures discussed in the previous section, we developed a systematic relationship between sulfuric acid nuclei concentration and spark count. Each point in Figure 6 represents the average values of nuclei concentration and spark count for a group of measurements. The spark counts were obtained using a 3-min sampling period and a sampling rate of  $150 \text{ cm}^3/\text{min}$ . Each measurement was assigned to a particular group on the basis of the nuclei concentration associated with the measurement. In a few cases, the assignment was not defined sharply. The empirical relation illustrated in Figure 6 is represented by the equation

$$\ln \frac{c}{b} = ms \tag{1}$$



where c = sulfuric acid nuclei concentration, nuclei/cm<sup>3</sup>;  $b = a \text{ constant}, \text{ nuclei/cm}^3; m = a \text{ constant}, \text{ per spark}; and$ s = spark count, sparks. The values for b and m are  $3.4 \times 10^3$ nuclei/cm3 and 0.044 per spark, respectively. A tabulation of the spark count obtained for each nuclei concentration and the aggregation of these measurements into groups is given in Table II.

The acid aerosol concentration changes during the sampling period because of coagulation and wall losses. A mean concentration was computed from measurements of nuclei concentration at the beginning and end of each sampling period. Empirically, it was observed that the change in concentration over a short period of time is described by a first-order equation with respect to concentration. The concentration corresponding to the middle of the sampling period was defined as the mean concentration.

The reproducibility of the spark count obtained at a nuclei concentration of 105/cm3 may be estimated from the standard deviation of the nine separate measurements made at this concentration. The standard deviation was found to be 8.6 sparks and is the same magnitude as the background count. Hence, a nuclei concentration of approximately 104/cm3, corresponding to a spark count of 17 to 25, is the minimum concentration detectable by the spark replica counter and procedures described here. The sensitivity of the spark replica method for measuring sulfuric acid nuclei was found to be dependent on concentration. For an acid concentration of 105/cm3, a change in concentration by a factor of two may be differentiated on the basis of the spark counts while for a concentration of 104/cm3, a change in concentration by a factor of three is necessary for detection.

The number of sparks in relation to the number of acid

particles deposited on the film is surprisingly small. As implied by the information presented in Figure 6, the ratio is in the order of 10<sup>-3</sup>. One plausible reason for this low ratio is that the formation of a damage site which is sufficiently large, after etching, to cause a spark requires the coincident deposition of two or more acid particles on the same site. It is also possible that only acid particles greater than a certain size are effective in damaging the polycarbonate film. Since the acid particles formed by photooxidation are in the order of 10 Å (Quon, 1964), it is unlikely that deposition of several particles at the same location on the film occurs frequently enough to account for the ratio of sparks to acid particles.

The development of the spark replica technique for the determination of ambient sulfuric acid concentration requires further information on the specificity of the method and the selection of suitable sampling procedures. Changes in ambient acid aerosol concentration over a sampling period of less than 10 min are not significant, although such changes may be large in a laboratory situation. Hence, for atmospheric measurements, the sampling procedures need not be concerned with coagulation. Wall losses in the sampling probe leading to the collector are easily minimized by the use of relatively large diameter probes and a relatively short length of probe.

The specificity of the spark replica method for the determination of sulfuric acid aerosol concentration depends on the resistance of the polycarbonate film to damage by other acids or substances which may be present in a given sample. The determination of the degree of susceptibility of the film to damage by hydrochloric acid, nitric acid, and various oxidants is pertinent, but was not within the scope of this initial effort.

#### Acknowledgment

The advice of Jacob Kastner of the Argonne National Laboratory is gratefully acknowledged.

# Literature Cited

- Cross, W. G., Tammasino, L., "Spark Replica Technique for Measuring Neutron Doses with Damage Track Dosim-14th Annual Hlth. Physics Soc. Meet., Pittsburgh, eters. Pa., June 8-12, 1969
- Fleischer, R. L., Price, P. B., Science, 143, 249-50 (1964).
- Johnson, D. R., Boyett, R. H., Becker, K., Health Phys., 18, 424-7 (1970).
- Kastner, J., Argonne National Laboratory, Argonne, Ill. private communication, February 1970.
- Quon, J. E., Amer. Ind. Hyg. Ass. J., 25, 15-24, (1964). Quon, J. E., Siegel, R. P., Hulburt, H. M., "Particle Formation From Photooxidation of Sulfur Dioxide in Air, Second International Clean Air Congress, International Union of Air Pollution Prevention Association, Washington, D.C., December 6-11, 1970.
- Stern, Arthur C., Ed., "Air Pollution," Vol. I, 2nd ed., p 76, Academic Press, New York, N.Y., 1968
- Waller, R. E., Int. J. Air Water Pollut., 7, 773-8 (1963).
- Waller, R. E., Brooks, A. G. F., Cartwright, J., ibid., pp 779-86.

Received for review March 31, 1971. Accepted July 28, 1971. Work was supported, in part, by funds awarded to Northwestern University under a research grant (AP-00039) from the Air Pollution Control Office, EPA, and under a traineeship grant from the Bureau of Health Professions Education and Manpower Training, NIH. Paper was presented at the Kendall Award Symposium, 161st National Meeting of the ACS in Los Angeles, March 28-April 2, 1971.

# Characterization of Four Major Components in a Technical Polychlorinated Biphenyl Mixture

# Albert C. Tas1 and Rudolf H. de Vos

Central Institute for Nutrition and Food Research TNO, Utrechtseweg, 48 Zeist, The Netherlands

Polychlorinated biphenyls (PCB's) have recently been recognized as contaminants of the environment. Technical PCB preparations are complicated mixtures of compounds with different structures and degrees of chlorine substitutions. The exact structures of some major constituents (two hexachlorobiphenyls) and two heptachlorobiphenyls) of a commercial PCB preparation have been determined by synthesis. The pure compounds may be useful for toxicity studies.

olychlorinated biphenyls (PCB's) have a wide spectrum of industrial application. The compounds are used as plasticizers, insulation fluids, and as additives to hydraulic fluids, lubricants, paints, protective coatings, and adhesives. PCB's are quite stable and chemically inert compounds. Their widespread use has been found to give rise to environmental pollution (Gustafson, 1970). PCB residues in wildlife samples were first reported in Sweden (Jensen, 1966) and afterward in several European countries and in North America. PCB's have a tendency to accumulate in fatty animal tissues like some of the persistent organochlorine pesticides. PCB residues have been detected by gas chromatography in sludge from sewage purification works (Holden, 1970); in fish, mussels, and birds (Bagley et al., 1970; Holmes et ai., 1967; Koeman et al., 1969); seals and porpoises (Holden and Marsden, 1967); in food (Bailey et al., 1970; Westöö et al., 1970); and in human milk (Acker and Schulte, 1970; Westöö et al., 1970). The compounds are industrially prepared by chlorination of biphenyl. Several fractions of different degrees of chlorination are manufactured. Gas chromatograms of PCB residues found in Dutch birds and fish (Koeman et al., 1969) show a pattern comparable to that of a commercial PCB mixture containing about 60% of chlorine (corresponding to an average number of six chlorine atoms per molecule).

In the technical chlorination process, many chlorinated biphenyls are formed with different arrangements of the chlorine atoms in the molecule. Molecular weight and numbers of chlorine atoms per molecule have been determined for several components from PCB mixtures by gas chromatography combined with mass spectrometry (Bagley et al., 1970; Koeman et al., 1969).

To our knowledge, however, the actual structure of one or more of these compounds has not been reported so far. The knowledge of the structure may be important for toxicity studies. It has been found that the evaluation of animal tests on PCB is made difficult by the presence of traces of toxic chlorinated dibenzofurans in some commercial PCB preparations (Vos et al., 1970). For the evaluation of the actual PCB toxicity, it is necessary to have pure compounds of known structures available.

In this paper, the structure is reported of four major compounds of a commercial PCB preparation named Phenochlor DP 6 (Figure 1*A*). This French product (manufactured by Prodelec) is comparable to Clophen A 60 (Bayer, Ger.; Figure 1*B*), and Aroclor 1260 (Monsanto, U.S.; Figure 1*C*).

# Experimental

The technical mixture was fractionated by preparative glc, and the purity of the fractions corresponding to the numbered peaks (Figure 1) was further tested by electron capture glc and by a tlc system with improved resolution under published conditions (de Vos and Peet, 1971). Fractions 6, 8, 11, and 12 proved to contain essentially one component and were further investigated by nmr spectroscopy, giving evidence on the positions of the chlorine atoms in the aromatic nuclei.

The compounds having the inferred structures were synthesized by the Ullmann reaction with activated copper powder at 215–225°C and 2.5 hr reaction time ("Organic Reactions," 1944) with the appropriate polychloroiodobenzenes as the starting materials. When two different polychloroiodobenzenes were used, the two symmetrical PCB's were also formed. The reaction products were then isolated by glc.

The polychloroiodobenzenes were prepared from the corresponding amino compounds by diazotation and reaction with KI.

By comparing nmr and ir spectra, the retention times on two different analytical glc columns and the  $R_f$  values in tlc of both the fractions mentioned above and the synthesized PCB's, the identity of the following components could be ascertained.

Peak 6: 2,2',4,4',5,5'-hexachlorobiphenyl Peak 8: 2,2',3,4,4',5'-hexachlorobiphenyl Peak 11: 2,2',3,4,4',5,5'-heptachlorobiphenyl Peak 12: 2,2',3,3',4,4',5-heptachlorobiphenyl

# Instrumental and Other Data

Preparative glc was performed with an Aerograph Model 705; column: aluminum, 5 meters  $\times$  6 mm i.d., packed with 20% SF 96 on Chromosorb W/AW, temp 225°C, flow 75 ml N<sub>2</sub>/ min.

Control glc was effected by using a Carlo Erba Fractovap GV; columns: (a) glass, 1.9 meters  $\times$  3 mm i.d., packed with 3% OV-1 on gaschrom Q, 80–100 mesh, temp 190°C, flow 80 ml N<sub>2</sub>/min, and (b) a column of identical size packed with 1.8% OV-1 and 2.7% QF-1 on gaschrom Q, 80–100 mesh,

<sup>&</sup>lt;sup>1</sup> To whom correspondence should be addressed.

under the same conditions. Retention times were calculated relative to aldrin.

Ir spectra were recorded either with a Perkin-Elmer 13 or with a Hilger and Watts H-1200 apparatus. The samples were supplied either as a thin layer on NaCl tablets or mulled and pressed in KBr tablets. Absorptions are given at  $cm^{-1}$  values.

Nmr spectra were recorded with a Jeol A-60 apparatus, TMS being the internal standard and CDCl<sub>3</sub> the solvent.

Mass spectra were recorded with an Atlas CH4 apparatus. 2,4,5-Trichloroiodobenzene was prepared, using 2,4,5-trichloroaniline (obtained from Fluka, Switz.) as base.

Mol wt: 306; three Cl atoms (from mass spectrum); mp: 106-107°C; bp: 97-100°C/0.5 mm; ir spectrum: Figure 2A.

2,3,4-Trichloroiodobenzene was prepared from 2,3,4-trichloroaniline, which was synthesized from 1,2,3-trichlorobenzene (obtained from BDH, Eng.) by nitration and catalytic reduction (PtO<sub>2</sub> in ethanol). Mol wt: 306; three Cl atoms (from mass spectrum); mp: 65–66 °C; bp: 97–98 °C/0.5 mm; ir spectrum: Figure 2B.

2,3,4,5-Tetrachloroiodobenzene was prepared from 2,3,4,5tetrachloroaniline as base. The latter compound was prepared from 2,3,4,5-tetrachloronitrobenzene (obtained from Fluka, Switz.) by catalytic reduction (PtO<sub>2</sub> in ethanol). Mol wt: 340; four Cl atoms (from mass spectrum); mp: 89–90°C; bp: 115– 118°C/0.5 mm; ir spectrum: Figure 2C.

2,2',4,4',5,5'-Hexachlorobiphenyl was prepared from 2,4,5trichloroiodobenzene. Mp: 102–103 °C.  $R_t$  value of 2,2',4,4',-



Figure 1. Gas chromatograms of A: Phenochlor DP 6 (Prodelec, Fr), B: Clophen (Bayer, Ger.), C: Aroclor 1260 (Monsanto, U.S.)

Column: glass, 1.9 meters  $\times$  3 mm i.d. packed with 3% OV-1 on gaschrom Q, 80–100 mesh, temp 180°C, flow 60 ml  $N_2/min.$  Detection: electron capture



Figure 2. Infrared spectra of A: 2,4,5-trichloroiodobenzene (in KBr), B: 2,3,4-trichloroiodobenzene (supercooled liquid), C: 2,3,4,5tetrachloroiodobenzene (in KBr)



Figure 3. Infrared spectra of A: 2,2',4,4',5,5'-hexachlorobiphenyl (in KBr), B: 2,2',3,4,4',5'-hexachlorobiphenyl (supercooled liquid), C: 2,2',3,4,4',5,5'-heptachlorobiphenyl (supercooled liquid), D: 2,2',3,4,4',5-heptachlorobiphenyl (in KBr)

5,5'-hexachlorobiphenyl on (a) 3.18; on (b) 3.21. Rt value of peak 6 on (a) 3.19; on (b) 3.22. Ir spectrum: Figure 3A. Nmr spectrum: 2H (d),  $\delta = 7.61$ ,  $J \simeq 0.3$  cps; 2H (d),  $\delta = 7.36$ ,  $J \simeq 0.3$  cps.

2,2',3,4,4',5'-Hexachlorobiphenyl was prepared from an equimolecular amount of 2,4,5-trichloroiodobenzene and 2,3,4-trichloroiodobenzene. Mp: 78.5-80°C. Rt value of 2,2',3,4,4',5'-hexachlorobiphenyl on (a) 3.75; on (b) 3.88.  $R_t$  value of peak 8 on (a) 3.77; on (b) 3.90. Ir spectrum: Figure 3B. Nmr spectrum: 1H (d),  $\delta = 7.62, J \sim 0.3$  cps; 1H (d),  $\delta = 7.50, J = 8.25 \text{ cps}; 1 \text{ H} (\text{d}), \delta = 7.35, J \sim 0.3 \text{ cps}; 1 \text{ H} (\text{d}),$  $\delta = 7.10, J = 8.25$  cps.

By-products: 2,2',4,4',5,5'-hexachlorobiphenyl and 2,2',-3,3',4,4'-hexachlorobiphenyl. Mp: 145.5-146.5°C. Rt value: on (a) 4.44; on (b) 4.69. Ir spectrum (KBr): strong 1430, 1353, 1185, 792; medium 1370, 1168, 881, 830, 819, 751. Nmr spectrum: 2H (d),  $\delta = 7.50$ , J = 8.25 cps; 2H (d),  $\delta =$ 7.10, J = 8.25 cps.

2,2',3,4,4',5,5'-Heptachlorobiphenyl was prepared from an equimolecular amount of 2,4,5-trichloroiodobenzene and 2,3,4,5-tetrachloroiodobenzene. Mp: 109-110°C. Rt value of 2,2',3,4,4',5,5'-heptachlorobiphenyl on (a) 6.48; on (b) 6.52.  $R_t$  value of peak 11 on (a) 6.49; on (b) 6.53. Ir spectrum: Figure 3C. Nmr spectrum: 1H (d),  $\delta = 7.64$ ,  $J \sim 0.3$  cps; 1H (d),  $\delta = 7.35$ ,  $J \sim 0.3$  cps; 1H (s),  $\delta = 7.30$ .

By-products: 2,2',4,4',5,5'-hexachlorobiphenyl and 2,2',-3,3',4,4',5,5'-octachlorobiphenyl. Mp: 152-153°C. Rt value of 2,2',3,3',4,4',5,5'-octachlorobiphenyl on (a) 13.18; on (b) 13.18. Ir spectrum: strong 1401, 1341; medium 1181, 1097, 880, 848, 831, 782, 686. Nmr spectrum: 2H (s),  $\delta = 7.31$ .

2,2',3,3',4,4',5-Heptachlorobiphenyl was prepared with an equimolecular amount of 2,3,4-trichloroiodobenzene and 2,3,4,5-tetrachloroiodobenzene. Mp: 134.5-135.5°C. Rt value of 2,2',3,3',4,4',5-heptachlorobiphenyl on (a) 7.73; on (b) 7.92. Rt value of peak 12 on (a) 7.68; on (b) 7.89. Ir spectrum: Figure 3D. Nmr spectrum: 1H (d),  $\delta = 7.51$ , J = 8.25 cps; 1H (s),  $\delta = 7.32$ ; 1H (d),  $\delta = 7.09$ , J = 8.25 cps.

By-products: 2,2',3,3',4,4'-hexachlorobiphenyl and 2,2',-3,3',4,4',5,5'-octachlorobiphenyl.

# **Results** and Discussion

From the obtained nmr, ir, and glc data, it can be concluded that the two hexachlorobiphenyls and two heptachlorobiphenyls are major constituents of the investigated Phenochlor DP 6 chlorinated biphenyl mixture. Moreover, the melting points of the isolated fractions showed no depression when mixed with the corresponding synthetic material. The symmetric compound 2,2',4,4',5,5'-hexachlorobiphenyl can be obtained in a pure form by a relatively simple synthesis and will be used for toxicity studies. The identification study has been restricted to the Phenochlor mixture. As far as the gas chromatograms are concerned, comparable products of other manufacturers have been found similar (Koeman et al., 1969; Figure 1).

#### Acknowledgment

We thank R. J. Belz and R. J. C. Kleipool for their valuable advice.

#### Literature Cited

- Acker, L., Schulte, E., Naturwissenschaften 57, 497 (1970).
- Bagley, G. E., Reichel, W. L., Cromartie, E., J. Ass. Offic. Anal. Chem. 53, 251 (1970).
- Bailey, S., Bunyan, P. J., Fishwick, F. B., Chem. Ind., (London) 705 (1970).

- Gustafson, C. G., ENVIRON. SCI. TECHNOL. 4, 814 (1970).
  Holden, A. V., Nature 228, 1220 (1970).
  Holden, A. V., Marsden, K., *ibid.* 216, 1274 (1967).
  Holmes, D. C., Simmons, J. H., Tatton, J. O. G., *ibid.* p 227.
- Jensen, S., *New Sci.* **32**, 612 (1966). Koeman, J. H., Noever de Brauw, M. C. ten, Vos, R. H. de, Nature 221, 1126 (1969).
- "Organic Reactions," Vol II, p 243, Wiley, New York, N.Y., 1944
- Vos, J. G., Koeman, J. H., Maas, H. L. van der, Noever de Brauw, M. C. ten, Vos, R. H. de, Food. Cosmet. Toxicol. 8, 625 (1970).
- Vos, R. H. de, Peet, E. W., Bull. Environ. Contam. Toxicol. 6, 164 (1971).
- Westöö, G., Norén, K., Andersson, M., Var Foeda 22, 11 (1970).

Received for review March 8, 1971. Accepted July 12, 1971.

# A Smog Chamber Study Comparing Blacklight Fluorescent Lamps with Natural Sunlight

# John L. Laity

Emeryville Research Center, Shell Development Co., Emeryville, Calif. 94608

Photochemical smog is commonly studied in irradiation chambers by using blacklight fluorescent lighting, which differs in several respects from natural sunlight. A direct comparison of the effects of artificial and natural sunlight has been obtained in a glass chamber. Since only slight discrepancies are observed in comparable experiments with blacklight or sunlight irradiation, the differences between blacklight lamps and natural sunlight do not dramatically influence photochemical smog formation with the systems investigated. This finding justifies the conventional use of blacklight irradiation in laboratory investigations of photochemical smog.

uch of the present knowledge about photochemical smog comes from studies conducted in irradiation chambers with either fluorescent lamps (Altshuller, 1966; Altshuller and Bufalini, 1965, 1971; Heuss and Glasson, 1968; Katz, 1970) or actual sunlight (Altshuller et al., 1970). Artificial sunlight obtained from fluorescent lamps differs appreciably from natural sunlight, and these differences in the light source conceivably could affect photochemical smog formation. One comparison of the effects of artificial and natural sunlight was presented by Stephens et al. (1967), who used gas-liquid chromatography (glc) to follow hydrocarbon disappearance with a sample of urban air in two glass vessels. One vessel was exposed to the sun for an entire day, and the



other was irradiated with blacklight fluorescent lamps for the same period one day later. In these experiments, the olefins (especially propylene) disappeared somewhat more rapidly with actual solar irradiation. Yet, a difference in the light source was not the only disparity between the two experiments.

The spectral distribution (centered at 3550 Å) of blacklight lamps is somewhat different from the uv portion of natural sunlight (Tuesday, 1961). Moreover, unlike sunlight, the fluorescent lamps used in many smog chamber studies have a rapid stroboscopic effect and do not give a constant output of light. An oscillogram (Figure 1) of the light modulation at 120 Hz (with 60 Hz power) of a blacklight fluorescent lamp indicates substantial, repetitive variations in the light intensity. The modulation of the alternating-current lamps is dependent on a number of factors including the ballasts, phasing of the current, and the phosphorescence qualities of the lamps. However, actual solar irradiation does not feature the rapid fluctuations of light intensity that are characteristic of ac fluorescent lamps. As many others have noted, intermittent illumination may influence light-induced reactions, especially chain processes, by affecting the concentrations of reactive intermediates (Calvert and Pitts, 1966).

# Experimental

The vessel used for these studies is a 22-l. borosilicate glass spherical flask fitted with a glass cap (which has three sampling ports) and a magnetically driven, all-glass stirrer. (Grasley et al., 1969). The chamber was cleaned between experiments by overnight evacuation while warming the walls to  $\sim 50$  °C.

Indoors, the vessel was irradiated at 23 °C with three blacklight lamps (Rayonet 3500 Å, with each lamp approximately 12.5 W) in a commercially available Rayonet reactor (Southern New England Ultraviolet Co., Middletown, Conn.). Outdoor studies were conducted in the San Francisco Bay area at Emeryville, Calif., from 11 A.M. to 3 P.M. on several clear, sunny days in September 1970. Since the objective of these experiments was a comparison of the effects of natural and artificial sunlight, all other variables (temperature, chamber dilution rate, etc.) were matched and held as constant as possible. The indoor and average outdoor light intensities gave about the same rate ( $K_d$ ) of photolytic decomposition of NO<sub>2</sub> (2 ppm) in nitrogen. The results of several outdoor  $K_d$ 



determinations ranged from 0.15–0.3 min<sup>-1</sup>, depending on the day and time, but the average value  $(\pm \sigma)$  was 0.22  $\pm$  0.05 min<sup>-1</sup>; the indoor  $K_d$  was 0.22  $\pm$  0.02 min<sup>-1</sup>.

The experiments were followed by conventional experimental techniques (Grasley et al., 1969). Hydrocarbons were analyzed by glc with a flame ionization detector, peroxyacetyl nitrate was monitored by glc with an electron capture detector (Darley et al., 1963; Stephens, 1969), and hourly readings of total oxidant were measured coulometrically with a commercial ozone meter (Mast Development Co., Davenport, Iowa). The response of the meter to nitrogen dioxide was subtracted to give the oxidant values. Nitrogen dioxide was determined colorimetrically with 250-ml grab bottles and Saltzman's reagent (Saltzman, 1954, 1965). The formaldehyde level was determined at the end of each run by the chromotropic acid method (Altshuller et al., 1961; Sleva, 1965; West and Sen, 1956). During sampling, pure air was added to maintain constant pressure, and the analytical determinations were corrected for the resultant dilution.

High-purity air (Air Products and Chemicals ultrapure air containing <2 ppm methane as the only detectable hydrocarbon impurity) and chemicals (Matheson and Phillips) were used. As judged by glc, no impurities were present in the hydrocarbons. The water used to obtain 60% relative humidity was double distilled from potassium permanganate and barium hydroxide.

# **Results and Discussion**

Under the same experimental conditions, the results obtained in the smog chamber indoors with blacklight irradiation are very similar to those observed outdoors with actual solar irradiation. With toluene (2 ppm) and nitrogen oxides (0.6 ppm, initially composed of 17% NO<sub>2</sub> and 83% ppm NO), Figure 2 shows that hydrocarbon disappearance and NO<sub>2</sub> formation are essentially the same for indoor and outdoor runs. Disappearance of NO<sub>2</sub> is somewhat faster with sunlight, but this may be due in part to an increase in the light intensity in the early afternoon. The indoor and outdoor maxima for oxidant (0.08 vs. 0.10 ppm), peroxyacetyl nitrate (0.15 ppm in both cases), and formaldehyde (0.18 vs. 0.21 ppm) are also virtually equal within the limits of experimental uncertainty.

A series of experiments with propylene (1 ppm), *n*-butane (1 ppm), and nitrogen oxides (1 ppm) in the smog chamber gave the results shown in Figures 3 and 4. Propylene reacts much more rapidly than butane (Figure 3), and the disappearance of each hydrocarbon is the same with either blacklight or sunlight. As in the toluene runs, the production of NO<sub>2</sub> (Figure 4) is much the same for indoor and outdoor runs, but NO<sub>2</sub> disappearance may be somewhat faster with sunlight. The maximum oxidant value attained during the four hours of irradiation is slightly higher with sunlight (0.23 ppm) than with blacklight (0.18 ppm), but the maxima for peroxyacetyl nitrate (0.30 ppm) and formaldehyde (0.65 ppm) are the same for indoor and outdoor experiments.

Differences in light intensity certainly affect the results obtained in a smog chamber (Glasson and Tuesday, 1970; Tuesday, 1961). Substantial difficulties are involved in exactly matching indoor and outdoor values for light intensity and the many other relevant variables (concentrations of reactants, temperature, etc.) in these smog chamber studies. Small variations in the controlled variables could account for the slight differences observed in comparable experiments with blacklight or sunlight irradiation. Thus, although blacklight lamps (with their stroboscopic effect and spectral distribution) differ from natural sunlight, these differences do not dramatically influence the photochemical smog-forming tendencies of the



Figure 3. Disappearance of propylene and n-butane with nitrogen oxides in air



Figure 4. Formation and disappearance of nitrogen dioxide with propylene and *n*-butane in air

systems investigated. This finding justifies the conventional use of blacklight irradiation in laboratory investigations of photochemical smog and also has interesting implications about the photochemistry of smog formation. However, the borosilicate glass walls of the chamber transmit only a portion of low wavelength ( $\lambda < 3200$  Å) ultraviolet light (Koller, 1965), which is somewhat more prevalent in sunlight than in blacklight irradiation (Tuesday, 1961). The possible importance of the small amount of low-wavelength ultraviolet light in the atmosphere and, in particular, the substantial surface effects and other constraints encountered in smog chambers (Grasley et al., 1969; Laity and Maynard, 1971) still make it difficult to extend chamber results directly to an actual urban atmosphere.

# Acknowledgment

The oscillogram of the blacklight lamps used in the Rayonet reactor for this study was obtained by D. W. Frew at Shell Development Co. General Electric Co. provided the oscillogram of a 40-W (F 40 BL) blacklight lamp used in other smog

chamber studies (Grasley et al., 1969). I. G. Burstain originally assembled the vessel used in this investigation, and R. W. Franklin and R. A. Hurst provided valuable experimental assistance.

# Literature Cited

- Altshuller, A. P., J. Air Pollut. Contr. Ass., 16, 257 (1966).
- Altshuller, A. P., Bufalini, J. J., ENVIRON. SCI. TECHNOL., 5, 39 (1971).
- Altshuller, A. P., Bufalini, J. J., Photochem. Photobiol., 4, 97 (1965).
- Altshuller, A. P., Kopczynski, S. L., Lonneman, W. A., Sutterfield, F. D., ENVIRON. SCI. TECHNOL., 4, 503 (1970).
- Altshuller, A. P., Miller, D. L., Sleva, S. F., Anal. Chem., 33, 621 (1961).
- Calvert, J. G., Pitts, J. N., Jr., "Photochemistry," pp 651-9, Wiley, New York, N.Y., 1966.
- Darley, E. F., Kettner, K. A., Stephens, E. R., Anal. Chem., 35, 589 (1963).
- Glasson, W. A., Tuesday, C. S., J. Air Pollut. Contr. Ass., 20, 239 (1970).
- Grasley, M. H., Appel, B. R., Burstain, I. G., Laity, J. L., Richards, H. F., Amer. Chem. Soc. Div. Org. Coatings Plast. Chem. Pap., 29(2), 422-6; 158th National Meeting, Acs, New York, N.Y., September 1969.
- Heuss, J. M., Glasson, W. A., ENVIRON. SCI. TECHNOL., 2, 1109 (1968).
- Katz, M., Can. J. Chem. Eng., 48, 3 (1970).
  Koller, L. R., "Ultraviolet Radiation," 2nd ed., p 160, Wiley, New York, N.Y., 1965.
- Laity, J. L., Maynard, J. B., 64th Annual Meeting, Air Pollution Control Association, Atlantic City, N.J., June 1971.
- Saltzman, B. E., Anal. Chem., 26, 1949 (1954).
- Saltzman, B. E., in "Selected Methods for the Measurement of Air Pollutants," M. Storlazzi and S. Hochheiser, Eds., U.S. Dept. of Health, Education and Welfare, Public Health Service Publication No. 999-AP-11, pp Cl-7, Cincinnati, Ohio, 1965
- Sleva, S. F., in "Selected Methods for the Measurement of Air Pollutants," M. Storlazzi and S. Hochheiser, Eds., U.S. Dept. of Health, Education and Welfare, Public Health Service Publication No. 999-AP-11, pp HI-5, Cincinnati, Ohio, 1965.
- Stephens, E. R., in "Advances in Environmental Sciences," Vol 1, pp 119-146, Wiley-Interscience, New York, N.Y., 1969.
- Stephens, E. R., Darley, E. F., Burleson, F. R., Proc. Amer. Petrol. Inst. Div. Refining, 47, 466 (1967).
   Tuesday, C. S., in "Chemical Reactions in the Lower and
- Upper Atmosphere," pp 15-49, Interscience, New York, N.Ŷ., 1961.

West, P. W., Sen, B., Z. Anal. Chem., 153, 177 (1956).

Received for review March 12, 1971. Accepted June 4, 1971.

# High-Speed Collection of Organic Vapors from the Atmosphere

Andrew Dravnieks,<sup>1</sup> Boguslaw K. Krotoszynski, Joyce Whitfield, Anne O'Donnell, and Theodore Burgwald IIT Research Institute, Chicago, Ill. 60616

In odorous pollution studies, gas chromatographic analysis of air for organic compounds requires a sensitivity to 10<sup>-10</sup> g/l. and usually needs sample preconcentration. A process was developed for the extraction of organic species from air at a rate of 4 l./min by adsorption on a high-surfacearea styrene-divinyl copolymer (Chromosorb 102) and an essentially contamination-free transfer of the sample to a gas chromatograph. Air moisture was not collected in amounts sufficient to interfere with the process.

he need to analyze air for extremely small amounts of many organic contaminants arises in the studies of odorous pollution: some odorants produce odors at concentrations as low as 10-10 g/l. of air.

Water Problem. Since water constitutes several percent of atmosphere, preconcentration of a sample by cryogenic collection is small. Gas chromatographs typically accept 10-3 gram of condensate water per injection, equivalent to, for example, 30 ml of air; hydrogen flame ionization detectors, sensitive to

<sup>&</sup>lt;sup>1</sup> To whom correspondence should be addressed.



Figure 1. High-speed organic vapor collector

Figure 2. Transfer of sample from collector to injector

 $10^{-9}$  gram would miss those species which were below concentrations of  $3.10^{-8}$  g/l. of air. Water separation is possible by extraction, desiccants, freeze-thaw cycles, zone refining, etc. In practice, these procedures easily introduce contaminants and losses.

Organic absorbents such as low-volatility liquids and greases, and polymeric adsorbents, if devoid of polar groups, collect little water while adequately collecting many organic substances.

**Polymeric Adsorbent.** Chromosorb 102, (Johns-Manville, 1967), is a highly porous styrene-divinylbenzene polymer. Collection efficiency is conveniently compared through ambient partition coefficients. For 60/80 mesh Chromosorb 102, they exceeded those of methylsilicone SF-96-coated (40%) 110/120 mesh Anakrom ABs by a factor of 50 to 100. The pores actually are channels which range up to 30 Å in diameter. Thus, all organic molecules analyzable by gas chromatography do not suffer from size exclusion effects.

Adsorbents as collectors are free from liquid diffusion delay problems. To collect in a liquid or grease film, the molecules must diffuse into the inner layers of the film material—e.g., 30 min is necessary to reach the final concentration in 10% Apiezon L on Teflon powder. With adsorbents, this diffusion into the film is not required. However, a slight diffusion into the matrix of the polymer may occur.

**Collection Modes.** The maximum amount of a substance that can be accumulated by a fixed amount of the collector phase from air containing an organic vapor depends on the respective partition coefficient.

Two collection modes are possible. In a fluidized bed mode (Dravnieks and Krotoszynski, 1968), vapors simultaneously reach every particle and the maximum collectable amount of each component is rapidly accumulated. Chromosorb 102 spontaneously acquired electrostatic charges and exhibited poor floating characteristics.

In the other mode, a fixed air volume is passed through a packed collector. For the less adsorbable substances (with lesser retention volumes), equilibration is soon reached and they begin to pass through, while the collected amounts remain proportional to concentrations in air. More adsorbable substances are fully extracted provided the air sample does not exceed their respective retention volumes. The analytical interpretation of samples collected by the fixed-volume procedure is difficult if many components begin to break through the collector. The Chromosorb 102 collectors exhibited large retention volumes.

Collector. The collector, shown in Figure 1, is made of

stainless steel and contains 5 grams of 60/80 mesh Chromosorb 102, with a total surface area of 1500 m<sup>2</sup>.

The collector is preconditioned at 220 °C with nitrogen gas for 24 hr, then conditioned at 120 °C with a pure (zero) helium flow of 60 ml/min overnight. A properly closed conditioned collector can be stored at ambient temperatures for several weeks. After long storage, a few hours of reconditioning are recommended to remove trace contaminants which somehow accumulate in the collector.

In sampling, air is drawn through the collector. At 2 psi (0.14 atm) pressure drop, the sampling rate reaches 4 l./min, so that pollution surges lasting a few minutes can be documented. Most organic species are completely collected from a 10-liter air sample, since the retention volumes at 25 °C were; in 1: methanol, 2.7; ethanol, 14; pentane, 12; hexane, 30. Since gas chromatographs with FID detectors detect  $10^{-9}$  gram of an organic species, an analytical sensitivity of  $10^{-10}$  g/l. air is possible.

Sample Transfer. The sample is analyzed at the earliest possible convenience. Internal distillation can occur in the collector if it is stored in a temperature gradient. However, diesel exhaust samples, stored in closed collectors in the laboratory for weeks, yielded essentially the same data as the samples analyzed immediately.

Sample transfer to a special injector needle is shown in Figure 2, which is self-explanatory. A copper side tube connects the boiling liquid nitrogen to the covered groove which holds the injector. Nitrogen boils in this tube, continuously purges the groove, and prevents accumulation of frost which otherwise thermally insulates the injector. The collector and the injector are connected by Teflon tubing. Occasionally, if the sample is large or contains excessive moisture, a plug may form in the front section of the injector. A drop in the flow rate indicates such difficulty; the plug is dissipated by a slight warming of the upstream portion of the injector for a few seconds. The elution of the sample from the collector is in a direction opposite to the direction of sampling into the collector. The transfer for practical reasons is limited to 1 hr. Approximately 90 to 95% of the sample is transferred. Losses remain reproducible, and the procedure is acceptable under routine conditions. The device shown in Figure 3 serves to inject the sample into a gas chromatograph. The injection port is modified by silverbrazing a stainless steel fitting containing a reusable Teflon compression plug sealing element (Conax fitting, Conax Co.) with a 1/16-in. hole which accepts the small end of the injector onto the port. The seal is accomplished by tightening the nut. Silicone septums sealed capriciously and



produced ghost peaks in the programmed temperature analysis. Between analyses, the hole in the plug is sealed by a metal rod. Before the injector attachment, the U-tube between the cross and the injector attachment end is heated under helium flush to remove impurities, and then kept immersed in liquid nitrogen to block off any impurities that cannot be removed from the bellows-manometer system. The bellows system is maintained in the back-flush mode between analyses.

For analysis, the injector needle is transferred to the chromatograph and clamped between the copper blocks, cooled by



Figure 4. Blank analysis (A) and analysis of air (B) from an urban expressway

Column: 100 ft, support-coated Carbowax 20M column programmed 60–180  $^{\circ}C$  at 2  $^{\circ}C/min$ 

sidebars immersed in liquid nitrogen. One end is inserted in the septum, the other connects to the bellows system. The backflush helium line is removed and the corresponding opening at the cross-fitting is sealed with a nut. The manometer serves to detect leaks in the system and to monitor for pressure stabilization.

The eccentric cam is operated to withdraw 1 ml of helium from the gas chromatograph into the bellows. The sample injection is effected by twisting the injection device's knob and actuating the bellows motor. This moves the cold copper blocks away from the injector while the preheated (to 250°C) copper blocks move vertically to clamp the injector for 10 sec. The bellows movement returns the 1 ml of helium through the injector, carrying the vaporized sample into the chromatograph. The injector is then reclamped between the cold blocks.

An important feature of the injector is a restriction at its downstream end. When the injector is flash-heated to inject the sample into the chromatograph, only a negligible fraction of the sample can travel through the restricted end. The injection of the sample into the gc port is 95 to 98% complete.

The entire procedure of sampling and sample transfer is quite reproducible. In sampling from synthetic mixtures of nine components in air, the reproducibility of the gc peak areas was within  $\pm 3\%$ . A blank and an air analysis are shown in Figure 4.

# Literature Cited

- Dravnieks, A., Krotoszynski, B. K., J. Gas Chromat. 6, 144 (1968).
- Johns-Manville Celite Division, Sales Bull. FF-157B, "Chromosorb 102," New York, N.Y., 1967.

Received for review July 20, 1970. Accepted June 25, 1971.

# Correction

Floyd D. Sutterfield points out that in the Altshuller et al. paper [Es&T, 5, 1009 (1971)], his first name appears incorrectly as Frank.

# industry trends

**Research-Cottrell, Inc.** will supply an electrostatic precipitator for a lignite-fueled boiler of the Otter Tail Power Co. in Ortonville, Minn. The unit is sized at 133,000 cfm and will reduce emissions at rated conditions to 0.012  $gr/ft^3$ .

**Combustion Equipment Associates** has received a contract from Nevada Power and Light Co. to design and construct a \$5.25 million air pollution control facility. The system will meet stringent codes of Clark County, Nev. for control of sulfur dioxide and particulate matter. Construction is to be completed by mid 1973.

Swindell-Dressler Co. will design, engineer, and build a cold mill waste treatment system for the Great Lakes Division of National Steel Corp. at Ecorse, Mich. The unit will contain an oil skimmer, a flash mix tank for treating waste water with pickle liquor, an activated sludge module, and a clarifier.

Waste Management, Inc., an Illinois firm, has extended its operations in Florida by agreeing to acquire five additional companies. Details of the transaction were not disclosed, but the company will buy Dump-All, Inc., and Dump-All Disposal Service, Inc. (Orlando and Pensacola), Nichols Sanitation Service, Inc. (West Palm Beach), and Refuse Service, Inc. (Jacksonville). Waste Management will also acquire a substantial minority interest in Industrial Trash Service, Inc. (Jacksonville).

Peabody Galion Corp. has acquired Gordon & Piatt, Inc. (Winfield, Kan.) for 212,500 shares of Peabody Stock. Gordon & Piatt is an international manufacturer of combustion equipment, including forced-draft oil and gas-fired burners.

Chemetron (Holland, Mich.) has begun construction of its secondary treatment plant designed to reduce BOD of its pigment plant effluent to acceptable levels under Michigan standards. The plant is basically a compressed air feed aerobic oxidation unit.

Research-Cottrell, Inc. has received its first commercial scale order for its combined flyash-sulfur oxide removal system. The first contract calls for a turnkey system for Arizona Public Service Co., at its Cholla generating plant in Joseph City, Ariz. Value of the contract is in excess of \$4 million.

Solar Corp. (San Diego, Calif.) has received contracts from the Environmental Protection Agency totaling \$417,000 to research methods of building a low-emission engine. A \$177,000 contract calls for demonstration of a combustor for a gas turbine engine that will meet the 1976 emission limits. A second \$240,000 contract is for development of a combustor vapor generator and controls for a Rankine-type engine.

Browning-Ferris Industries, Inc. has acquired two solid waste management businesses—Active Disposal Co. (Detroit, Mich.) and Nelson Industrial Services, Inc., and Disposal Systems, Inc., (Lake Charles, La.) The two businesses have combined revenues of about \$2.7 million annually.

Prenco Mfg. Co. (Royal Oak, Mich.) has licensed Shinko-Pfaudler Co. Ltd., of Kobe, Japan to manufacture and market Prenco's proprietary Pyro-Decomposition liquid waste disposal system in Japan, Korea, Okinawa and Taiwan.

Resources Conservation Co. (RCC) has received a \$100,000 contract from the Office of Saline Water for conceptual design and cost analysis of a 2.5-million gpd desalination plant using RCC's evaporative process. RCC is a joint venture in the water reclamation field of Reading and Bates Offshore Drilling Co., El Paso Natural Gas Co., and the Boeing Co. Wastewater Analysis Guide



Hach Chemical has prepared a new, 16 page guide to assist municipal and industrial wastewater treatment plants in conducting the many water quality tests now required by pollution control authorities.

The guide lists each test, recommended methods and the chemicals, apparatus and glassware necessary.

For your free copy of the Hach Wastewater Analysis Guide, write:



Chemical Company P.O. Box 907 • Ames, Iowa 50010 (515) 232-2533 "First in Water Analysis"

Circle No. 6 on Readers' Service Card

# new products

# **Trace oven**

New oven provides a relatively inexpensive way to analyze for metal particulate matter in air samples. Sample on paper tape has reagent added and dissolved contaminants concentrate in a ring. Paper is dried and cut into sectors for analysis. Arthur H. Thomas Co. **61** 

# **Salinity measurement**

Type 102 refractometer/salinometer can measure salinity to an accuracy of  $\pm 0.1$  ppt over a range of 0-45 ppt. The hand-held instrument does not use electronic circuitry and is ruggedly built for field use. Environmental Devices Corp. 62

# Wet scrubber

New self-contained venturi eductor wet scrubber is claimed to operate at up to 98% efficiency. Applications are in service where vapors or fumes to be scrubbed contain water soluble materials or materials that can be sublimed by water. Brighton Corp. **63** 

# Shredder/Compactor

Model 915 shredder/compactor offers combination of low initial cost and low operating costs. Mil-Pac unit shreds and compacts to an 8:1 ratio and boasts fully automatic waste processing. Mil-Pac Systems, Inc. 64

# **Mercury analyzer**







# Condensers

New line of high-performance mufflercondensers suppress noise from exhaust of pneumatic equipment and air lines and remove particulate matter, condensing oil, and water mist from airstream. Bendix Corporation. **66** 

#### **Smoke monitor**

Solid state smoke density monitor has large digital display reading from 0 to 5 Ringlemann units. Green, yellow, and red signal units can be illuminated in sequence as smoke increases in optical density. Thumb wheels set densities at which lights are activated. Initial calibration is simplified. Photomation, Inc. **67** 

# **Thiocyanate electrode**

Specific ion electrode rapidly determines thiocyanate concentrations from 0.3-58,000 ppm over a pH range of 2-10 and at temperatures from 0-95°C. Chloride does not interfere in concentrations up to 20 times the thiocyanate concentration. Orion Research, Inc. **68** 

# **Exhaust purifier**

Replaceable, throw-away catalytic cartridge is key feature of exhaust purifier designed for internal combustion engines and all fuels. Emissions are oxidized to  $CO_2$  and water. Unit is claimed to achieve 95% or more reduction in CO, hydrocarbons, smoke, and odors. Granlin Corp. **69** 



#### **Electronic filter**

Electro-Filter systems utilize new technology—nonionizing, electrostatic removal of entrained or dissolved fluids or particulate matter from dielectric fluids and gases. Permanent filter elements can be flushed clean in the forward direction. Electro-Filter Systems. 70

# Aerator pump

Lagoon aerator pump provides aerating and circulating action that supplements natural wave and sunlight action to reduce odors and improve clarity of water in lagoons. The pump is designed for year-round service in all sorts of weather conditions. Waukesha Foundry Co. 71


#### **Microbe tester**

QuiMIQ (Quick Microbial Identifier and Quantifier) rapidly measures and identifies microorganisms in liquid. Uv sensor evaluates reactions between antibodies and antigens, allowing a determination to be made in a few hours, while comparable results require several days with conventional methods. Offshore/Sea Development Corp. 72

#### Ir analyzer

Low-cost nondispersive infrared analyzer can measure concentrations of such gases as CO,  $CO_2$ . Model 5500 is easy to use and portable; it weighs just 18 lb. Can be used by service station personnel to measure CO in automobile exhaust. Ecologic Instruments Corp. 73

#### Asphalt melting control

Emission control device eliminates visible vapors and nuisance odors from portable asphalt melting kettles widely used in roofing and highway maintenance work. Model EE afterburner will fit equipment already in the field. Aeroil Products Co., Inc. **74** 

#### Acid neutralizer

New system neutralizes acid liquor wastes from processing equipment and comprises a neutralizing chamber, control unit, recorders, and flow accessories. The unit uses anhydrous ammonia for neutralization, and pH of the effluent is kept between 5 and 9. Vistatype Corp. **75** 

#### Water test kits

New series of water quality test kits for diverse applications ranging from plant effluent monitoring to student experiments in limnology or oceanography boasts rugged weatherproof carrying case and step-by-step instructions. Ecologic Instruments Corp. **76** 

Need more information about any items? If so, just circle the appropriate numbers on one of the reader service cards bound into the back of this issue and mail in the card. No stamp is necessary.



## New Sulfur Dioxide Recorder Continuous sampling, Ultra portable, Under \$1,000

New from Mast, the air monitoring specialist. Measures  $SO_2$  within EPA-specified ambient ranges. New selective electrode permits direct and immediate readings of  $SO_2$  in air with no significant interferences. Range is continuously variable from 0 to 0.2 ppm/vol. to 0 to 5 ppm/vol. Sensitivity is .005 ppm/vol. Integral strip chart recorder provides permanent data. For full details, send for Bulletin S-1. Ask about Mast low cost, portable Oxidant Monitors, too. The instruments with more than 12 years of field experience.



# new literature

Pickle liquor. Brochure details systems for recovering acid wastes associated with steel pickling. Conservall, Inc. 91

**Dust collectors.** Bulletin describes availability of custom-designed fabric collectors and baghouses for industrial air pollution control. Includes data sheets on operating conditions and lists accessories. American Air Filter Co., Inc. **92** 

Flue sampling. Four-page publication describes Model 743 flue gas sampling system. System conditions flue gases for oxygen analysis where natural gas, fuel oil, or other clean low-sulfur fuels are burned. Beckman Instruments, Inc. 93

Temperature controls. Thirty-two-page catalog features complete listing of temperature and pressure controls, recorders, and measuring devices. United Electric Controls Co. 94

Mining wastes. Technical reprint details treatment methods for liquid wastes from mining and mineral-processing operations. Tables give cost of various acceptable treatment methods and lists chemicals commonly used. Nalco Chemical Co. 95

Water treatment. Aeration, degasification, and deaeration water treatment equipment and processes are described in 4-page brochure just released. Bulletin contains plan drawings, dimensions and capacities, as well as process summaries. Permutit Co. 96

Water quality. Catalog lists available equipment for water quality measurement including differential electrode probes and other various sensing, recording, and control equipment. Great Lakes Instruments, Inc. 97

Demineralizer. Flyer describes CE's condensate demineralizer, a water purification system for use in once-through steam generating systems for fossil- and nuclear-fueled power stations. Combustion Engineering, Inc. 98

Pulverizers. Bulletin 1125 details process-matched refuse pulverizing systems from single pieces of equipment to complete plants. Jeffrey Manufacturing Co. 99

Activated carbon. Use of activated carbon for purifying beverage water for industrial use is subject of bulletin 4635. Bulletin also gives information on packaged bottling plants. Permutit Co. 100

Accessories. New 12-page catalog lists complete line of mechanical accessories used for industrial waste treatment systems. Includes new line of noncorrosive air filter mufflers. Engineered Products 101

Magnetic treatment. "How 278 Processing Problems Were Solved with an Assist from Magnetic Forces" is title of 54-page booklet listing problem solutions in alphabetical order by materials treated. Erie Magnetics 102

Planning. Bulletin lists four key steps to solving pollution problems "with a minimum of expensive mistakes." Midwest Applied Science Corp. 103

Scrubbers. New bulletin lists line of equipment for removing air pollutants. Details are provided on both standard and custom-built fume scrubbers using proprietary packings. Norton Co. 104

Test papers. Fourth edition of "MN" Indicator and Test Paper brochure is now available. Book covers over 100 test papers for pH determination, anion and cation detection, and a variety of reagent test papers for detection of many substances. Gallard-Schlesinger Chemical Mfg. Corp. **105** 

Trace element detection. Six separate data sheets describe the application of electrochemical and atomic absorption techniques to the measurement of trace elements in water. Included is information on mercury analysis. Beckman Instruments, Inc. 106

**BOD** analyzer. Illustrated brochure describes new Arthur BOD Analyzer. Instrument provides results within 2–

10 hr and allows continuous charting of oxygen demand during the test period. Undiluted 1–4-liter samples are used in the test. Arthur Bros., Inc. **107** 

Case studies. Case studies outline performance history of Mogul nonchromate, nonphosphate cooling water treatments. Gives concise summaries of five different industrial and nonindustrial applications. Mogul Corp. 108

**Coagulants.** Two brochures describe cationic polymers for liquid/solid separation. Bulletin 12-59 describes WT-2570 and WT-2580 dry cationic polyelectrolytes, and Bulletin 12-58 describes WT-2640 liquid cationic polyelectrolyte. All three ionics are water soluble and effective over a wide solids and pH range. Calgon Corp. **109** 

Environmental services. Illustrated brochure describes the broad capabilities of the company in engineering, design, and construction of air and water pollution controls and in waste disposal systems. Projects already carried out in several different industries are described. Jacobs Engineering Co. 110

Environmental films. 154 different titles of environmental films are available "on a nominal service charge basis" from a newly established film service. Films will be loaned to schools, conservation organizations, etc. Free catalog is available. The National Association of Conservation Districts, P.O. Box 855, League City, Tex. 77573 (Write direct)

**Open dumps.** Report details strategy for closing open dumps and includes appendix on alternative solid waste disposal methods. Report SW-61ts is available from the Environmental Protection Agency, Washington, D.C. (Write direct)

Need more information about any items? If so, just circle the appropriate numbers on one of the reader service cards bound into the back of this issue and mail in the card. No stamp is necessary.

# bookshelf

Controlled Test Atmospheres: Principles & Techniques. Gary O. Nelson. xii + 247 pages. Ann Arbor Science Publishers, Inc., P.O. Box 1425, Ann Arbor, Mich. 48106. 1971. \$17.50, hard cover.

Recommended for analytical chemists, air pollution control engineers and scientists, industrial hygienists, and animal toxicologists. Describes useful methods for synthesizing artificial test environments.

Industrial Pollution Control Handbook. Herbert F. Lund, Ed. McGraw-Hill Book Co., 330 W. 42nd St., New York, N.Y. 10036. 1971. \$29.50, hard cover.

Book focuses on major industries where pollution has proved to be a difficult problem—steel, foundry, metal fabrication, plating, chemical, pharmaceutical, textile finishing, food processing, electronics, and pulp and paper. Divides subject areas into evolution of industrial pollution control, pollution control by industry problem, and pollution control equipment and operation.

Methods for Emission Spectrochemical Analysis. xviii + 1094 pages. American Society for Testing & Materials, 1916 Race St., Philadelphia, Pa. 19103. 1971. \$30, hard cover.

Gives current information regarding practices and methods that can be used in an analytical laboratory. Covers metallic and nonmetallic metals.

Environmental Aspects of Nuclear Power Stations. 970 pages. Unipub, Inc., P.O. Box 433, New York, N.Y. 10016. 1971. \$25, paper.

Proceedings from a symposium at which all activities in the production of nuclear power which might have an impact on the environment could be discussed and compared. Participants from 25 countries and nine international organizations attended.

Environment: Resources, Pollution & Society. William W. Murdoch, Ed. vii + 440 pages. Sinauer Associates, Inc., 20 Second St., Stamford, Conn. 06905. 1971. \$5.95, paper.

Intended for undergraduates taking courses that deal with the interaction between man and environment. Authors try to distinguish truly alarming situations from those that are simply serious.

Chemistry of Pesticides. N. N. Melnikov. ix + 480 pages. Springer-Verlag New York, Inc., 175 Fifth Ave., New York, N.Y. 10010. 1971. \$19.80, hard cover.

Translated from the Russian language, this book is a summary of the basic principles of practical pest control by chemical means. Offers the beginner a comprehensive survey of diverse chemicals for adequate production of food and fiber, as well as public health protection.

Agricultural Chemicals Manufacture. Marshall Sittig. xi + 263 pages. Noyles Data Corp., Park Ridge, N.J. 07656. 1971. \$35, paper.

Reviewing processes to produce insecticides, herbicides, fungicides, nematocides, and plant growth regulators, the book supplies detailed technical information and can be used as a guide to the U.S. patent literature in the field.

Study of the Pollution Control Equipment & Services Industry. William G. McLoughlin, Ed. McLoughlin Research Associates, Inc., 10516 Estate Lane, Dallas, Tex. 75238. 1971. \$100.

Written for companies in the pollution control industry, companies considering entering the pollution industry, "polluters" facing the challenge of pollution abatement, and banking and investment institutions. Limited subscription—will be sold to only 50 industrial firms and 10 banking or investment houses.

The Town that Launders Its Water: How a California Town Learned to Reclaim and Reuse Its Water. Leonard A. Stevens. 122 pages. Coward, Mc-Cann & Geoghegan, Inc., 200 Madison Ave., New York, N.Y. 10016. 1971. \$4.49, hard cover.

In an area with only 10 in. of rainfall per year, there are eight freshwater lakes—all made from reclaimed sewage water. Book describes the facts behind the scene.

Fabric Filter Systems Study, Vols I–IV. 1185 pages. National Technical Information Service, U.S. Dept. of Commerce, Springfield, Va. 22151. 1971. \$18, paper.

Covers investigations in major air pollution control areas which could be amenable to control by fabric filtration. Includes evaluations of tested devices.

Plants, How They Improve Our Environment. 16 pages. Soil Conservation Society of America, 7515 Northeast Ankeny Road, Ankeny, Iowa 50021. 1971. 25 cents, paper.

Educational cartoon booklet helps young people to understand the function of plants in the environment. Explains how vegetation improves environmental quality by producing oxygen, preventing air pollution, reducing noise, and guarding against soil erosion.

Environmental Economics. Thomas D. Crocker, A. J. Rogers III. vii + 150 pages. Gallery Direct, 403 W. Galena Blvd., Aurora, Ill. 60506. 1971. \$6.95, hard cover.

Deals with economic aspects of pollution. Covers natural vs. economic man,

## BOD and DO ASSEMBLY SPECIAL OFFER

(This month only)

Whether you now have an equipped laboratory or not, this special BOD and DO assembly is your best buy for a permanent set-up.

Don't dilly dally—go directly to this standard accepted chemical procedure. A BOD test can be run in about 5 minutes actual working time (5 days reaction). This special offer includes instructions for improved accuracy and greatly simplified calculations. Assembly includes sample bottles, reagent bottles, BOD bottles, all necessary lab glassware, double beam balance, demineralizer, and many other major pieces. Sufficient bulk reagents are supplied for 700 tests. No incubator is supplied—you may not need one.

This special assembly is selling for only \$249 this month. Don't wait. (Regularly \$325). This assembly will be shipped to you any place in the continental USA prepaid if remittance accompanies the order. Municipalities and firms with favorable Dun and Bradstreet rating terms net 30 days.

ACT NOW. Order BOD and DO assembly from Seymour Specialty Supplies 2841 Parkwood Dr. Brunswick, Georgia 31520

## PESTICIDAL FORMULATIONS RESEARCH

### ADVANCES IN CHEMISTRY SERIES NO. 86

Fifteen papers from a symposium sponsored by the ACS Divisions of Agricultural and Food Chemistry and Colloid and Surface Chemistry chaired by J. W. Van Valkenburg.

The physical and colloidal chemical aspects discussed include physicochemical principles, the role played by these principles in the formulation and functioning of pesticides and herbicides, and related phenomena. Several studies on specific pests and pesticides are included.

212 pages with index	Cloth	(1969)	\$9.50
		(/	+

Free set of L. C. cards with library orders upon request

Postpaid in U.S. and Canada; plus 30 cents in PUAS and elsewhere.

Order from:

SPECIAL ISSUES SALES AMERICAN CHEMICAL SOCIETY 1155 SIXTEENTH ST., N.W. WASHINGTON, D.C. 20036 materials balance, central vs. individual control, and cooperative efforts among industries.

Fundamentals of Ecology, 3rd ed. Eugene P. Odum. xiv + 574 pages. W. S. Saunders Co., W. Washington Sq., Philadelphia, Pa. 19105. 1971. \$11.75, hard cover.

Involves ecology as it relates to human affairs, can be used for an undergraduate course in ecology, and is a comprehensive reference work on principles, environments, and ecological technology. "...It is three books in one, each of which can serve a different purpose," says the author.

Proceedings of the Conference on the Beneficial Uses of Thermal Discharges. Satyendra P. Mathur and Ronald Stewart, Eds. 227 pages. Office of Recovery, Recycling, & Reuse, New York State Department of Environmental Conservation, Albany, N.Y. 12201. 1971. \$10, paper.

Conference brought together national and international experts to present papers on the various beneficial uses that waste heat in water can be and is put to. Shows that this heat resource can be an asset.

Elements of Water Supply and Wastewater Disposal, 2nd Ed. Gordon Maskew Fair, John Charles Geyer, Daniel Alexander Okum. viii + 752 pages. John Wiley & Sons, Inc., 605 Third Ave., New York, N.Y. 10016. 1971. \$15.95, hard cover.

Book is directed to the needs of undergraduate students and others seeking fundamental principles in this field. Covers all elements of water supply and waste water disposal.

Documentation of the Threshold Limit Values for Substances in Workroom Air, 3rd ed. iv + 286 pages. American Conference of Governmental Industrial Hygienists, P.O. Box 1937, Cincinnati, Ohio 45201. 1971. \$15, hard cover.

Documents exposure levels for over 475 substances. Includes such materials as asbestos, beryllium, and cadmium.

#### December 15-17 **Institute of Electrical and Electronics Engineers**, Inc.

1971 IEEE Conference on Decision and Control

Miami Beach, Fla.

Special session on applying systems analysis to the problems of air, water, and land environmental pollution. Contact: H. S. Rao, c/o S. K. Miller, Rm. 35-229, Massachusetts Institute of Technology, Cambridge, Mass. 02139

#### December 26-31 **American Association for the Advancement of Science**

138th Annual Meeting Philadelphia, Pa.

Write: D. W. Thornhill, AAAS, 1515 Massachusetts Ave., N.W., Washington, D.C. 20005

#### January 9-14

#### **Engineering Foundation**

Mercury in the Industrial Environment Conference

Pacific Grove, Calif.

Attendance limited to 100 persons. Fee: \$175. Contact: Engineering Founda-tion, 345 E. 47th St., New York, N.Y., 10017

#### January 10-13 **Louisiana State University**

LSU Symposium on Air Pollution Baton Rouge, La.

Contact: J. W. Robinson, Department of Chemistry, Louisiana State University, Baton Rouge, La. 70803

#### January 17-21 **American Society for Testing and** Materials

**ASTM Committee Meeting** 

Ft. Lauderdale, Fla.

Session on water. Contact: Hank Hamil-ton, ASTM, 1916 Race St., Philadelphia, Pa.19103

#### January 24-27 Clapp & Poliak, Inc.

23rd Annual Plant Engineering Maintenance Conference and Show & Philadelphia, Pa.

Exhibits and papers will cover air, wa-ter, and noise pollution, as well as solid waste. Contact: Clapp & Poliak, Inc., 245 Park Ave., New York, N.Y. 10017

#### January 25-27 American Society of Mechanical **Engineers and others**

Annual Reliability and Maintainability Symposium

San Francisco, Calif.

Merged meeting with the Institute of Environmental Sciences and others. Write: C. M. Bird, Publicity Chairman, IBM Corp., Dept. 942, 8600 N. Astronaut Blvd., Cape Kennedy, Fla. 32920

#### January 31-February 1 Southern California Chapter of the American Statistical Association and others

Statistics and the Environment Symposium

Los Angeles, Calif.

Discussions center around using an interdisciplinary approach to solve environmental problems. Contact: Max Astrachan, Dept. of Management Science, San Fernando Valley State College, Northridge, Calif. 91324

#### January 31-February 2 **Cornell University**

Agricultural Waste Management Conference

Svracuse, N.Y.

Emphasizing land disposal, legal and enforcement regulations, nutrient control, treatment and disposal, and man-agement principles. Write: Raymond C. Loehr, Program Chairman, 207 Riley Robb, Cornell University, Ithaca, N.Y. 14850

#### February 5-7 Water Resources Congress

1972 Annual Meeting of the Water Resources Congress

St. Louis, Mo.

Held in conjunction with the U.S. Marine Exposition. Contact: Water Resources Congress, 1130 17th St., N.W., Washington, D.C. 20036

#### February 9-10 III. EPA and Dept. of Civil Engineering, Univ. of III.

14th Water Quality Conference Urbana, IlÌ.

"Groundwater Quality and Treatment" is conference title. Write: V. L. Snoeyink, Assistant Professor of Sanitary Engineer-ing, 3230 Civil Engineering Bldg., Univ. of III., Urbana, III. 61801

# meeting guide

#### February 14-15 **MTS Coastal Zone Management** Committee

Tools for Coastal Zone Management Conference Washington, D.C. Contact: Marine Technology Society, 1730 M St., N.W., Washington, D.C. 20036

### February 14-16

#### **Technical Association of the Pulp and** Paper Industry

57th Annual Meeting New York, N.Y. Write: M. J. Williams, TAPPI, 360 Lexington Ave., New York, N.Y. 10017

## February 20-23

#### American Institute of Chemical Engineers

AIChE 71st National Meeting Dallas, Tex.

Many sessions on various phases of pollution control. Contact: R. S. Schechter, Dept. of Chem. Eng., Univ. of Texas, Austin, Tex. 78712

#### February 21-22 **Environmental Protection Agency** and Clemson University

Coastal Zone Pollution Management Symposium

Charleston, S.C.

Focuses attention of regional, state, and local agencies on water quality problems in the coastal zone. Write: Billy L. Edge, Co-Director, Coastal Zone Pollution Management, Rhodes Engineering Research Center, Clemson Univ., Clemson, S.C. 29631

#### March 5-9

#### Society of Toxicology

1972 Annual Scientific Meeting Williamsburg, Va.

For additional information, Robert A. Scala, Esso Research and Engineering Co., P.O. Box 45, Linden, N.J. 07036

#### MEETING GUIDE (continued)



# SOLID WASTES

A new publication of the American Chemical Society puts the nation's solid waste problems in perspective.

A 96-page book entitled "SOLID WASTES" contains 26 articles that first appeared in Environmental Science & Technology.

Among the topics covered are:

- Incineration
- Pyrolysis of plastics
- · Electricity from waste
- Federal government programs
- Fly ash utilization
- Auto hulk disposal

#### and many others

The book can only be obtained from the Society and is not available in any bookstore. It costs just \$2.00.

#### Order from:

Special Issues Sales – E American Chemical Society 1155 16th St., N. W. Washington, D. C. 20036

#### March 14-15

#### American Gas Association and others GATE-SwRI Energy Conservation Forum

San Antonio, Tex.

Will consider conservation and ways of producing more energy. Write: Jack Wolfe, GATE Information Center, Southwest Research Institute, 8500 Culebra Rd., San Antonio, Tex. 78284

#### March 14-16 U.S. Bureau of Mines and IIT Research Institute

Third Mineral Waste Utilization Symposium

Chicago, III.

Registration accepted on an as-received basis. For details: Murray A. Schwartz, Symposium Chairman, IIT Research Institute, 10 W. 35 St., Chicago, III. 60616

## March 20-24

#### **Ohio State University**

Midwest Workshop in Environmental Science

Columbus, Ohio

Contact: John Lindamood, Dept. of Food Science and Nutrition, Ohio State University, Columbus, Ohio 43210

#### March 21-23 Environmental

#### Environmental Protection Agency and University of Houston

National Conference on Control of Hazardous Material Spills

Houston, Tex.

Write: H. Nugent Myrick, Associate Professor of Civil and Environmental Engineering, University of Houston, 3801 Cullen Bivd., Houston, Tex. 77004

#### Courses

#### January 10-11 George Washington University

Air Pollution Control Short Course Washington, D.C.

Fee: \$125. For details: J. E. Mansfield, Director of Continuing Engineering Education Program, The George Washington University, Washington D.C. 20006

#### January 24–25 George Washington University

Solid Waste Management for Hospitals Washington, D.C.

Fee: \$125. For details: J. E. Mansfield, Director of Continuing Engineering Education Program, The George Washington University, Washington, D.C. 20006

#### **Air Pollution Training Courses**

New catalog of air pollution training and university training courses is now available. Lists courses from July 1971 through June 1972. Write: Registrar, Institute for Air Pollution Training, Research Triangle Park, N.C. 27711

#### **Harvard School of Public Health**

Environmental Health Graduate Training Boston, Mass.

Opportunities for master's and doctoral degrees in environmental health sciences and engineering. Limited number of fellowships available for the 1972–73 year. Write: Dade W. Moeller, Associate Director, Kresge Center for Environmental Health, Harvard School of Public Health, 655 Huntington Ave., Boston, Mass. 02115

#### March 6-7

#### **USDA Graduate School**

Policy Issue Seminar on the Quality of the Environment

Washington, D.C.

Will discuss environmental degradation and why it occurs or can occur in the future. Nominations due before Feb. 21. Fee: \$95. Write: Dee W. Henderson, Suite 265, National Press Bldg., 529 14th St., N.W., Washington, D.C. 20004

#### **Texas A&M University**

Rd., Dallas, Tex. 75216

Training Program in Chemical-Physical Process-Control AWT Techniques Dallas, Tex.

Courses on the operation, maintenance, and control of the chemical-physical advanced waste treatment facilities. Travel and per diem will be paid. Enrollment limited. Write: Harold W. Wolf, Professor and Director, Dallas Water Reclamation Research Center, 1020 Sargent

#### **Call for papers**

#### December 15 deadline International Association for Great Lakes Research

Fifteenth Conference on Great Lakes Research

Madison, Wis.

Write: Gregory D. Hedden, Director, University Extension Sea Grant Program, 610 Langdon St., Madison, Wis. 53706

# professional consulting services directory



# professional consulting services directory





Syracuse N.Y. Dover Del. Charlotte N.C.



by combustion

METALS

? PROBLEMS ?

and affiliate

HOME OFFICE

60

## CLASSIFIED SECTION

#### MISCELLANEOUS

managers, engineers, salesme why work for someone else

START YOUR OWN BUSINESS

START YOUR OWN BUSINESS if you have experience in environmental areas: refuse waste compactors, air precipitators, paper reclamation & baling, paper recycling, solid waste disposable systems, garbage recycling, water purify. Opportunity to make contacts, form a balanced management team, and get financing. List with no obligation by submitting re-sume in confidence to: ENTREPRENEUR SEARCH, PO Box 756, 340W42, N.Y., N.Y. 10036

#### POSITIONS OPEN

PROJECT COORDINATOR The Tahoe-Truckee Sanitation Agency needs a Co-ordinator for the 325,000,000 Regional Sever-age Project, which includes a culture for the sever-nations include: a college degree in engineering, business administration, public administration or some equivalent training or experience in engi-neering or construction management, business management position. Starting sate years are of a management position. Starting sate years of the severation of the severation of the severation of resume, by December 31, 1971, to the FIVE DIS-TRICT COMMITTEE, Drawer E, Tahoe City, California 95730. PROJECT COORDINATOR

ENVIRONMENTAL PROTECTION ENGINEER

If you have a BS degree in Science or Engin ering. and a minimum of 4 years working background in pe-troleum refining or petrochemical operations, including responsibilities in environmental protection and conser-vation, then our position should be of interest to you.

At our Midwestern Refinery, you will be afforded the opportunity to work with the most modern environ-mental equipment available to our industry.

This position, reporting to our Environmental Engi-neering Manager, will assist in the implementation and coordination of all refinery activities relating to environmental control.

If you possess the above requirements, and are inter-ested in a challenging position with a major refining operation, then submit your resume, including salary history and requirements to P.O. Box 12-71-1, E.S.&T., Easton, Pa. 18042

AN EQUAL OPPORTUNITY EMPLOYER

#### **ENGINEERS MS/PhD**

**Air Quality** 

**Conservation** 

Engineering

#### TISERS IN THIS ISSUE

INDEX TO ADV	ERTI
Atlas Electric Devices Company Sprinkle, Green, Beham & Petersen Advertising, Inc.	IBC
Baron Blakeslee Inc	1160
Beckman Instruments, Inc., Process Industries Div	OBC
Inc. The Bendix Corporation, Process In- struments Div D'Arcy-MacManus-Intermarco, Inc.	1158
Cen-Trific-Air Producs, Inc	IFC
Environmental Research Corporation.	1189
Environment/One Corporation Evans Garber Ligas & Paige	1166
Hach Chemical Co	1223
Mast Development Company	1225
Metrodata Systems, Inc Robert V. Freeland & Associates	1173
Millipore Corp	1190
Monitor Laboratories, Inc Spectra Advertising	1173
Nupro Co Falls Advertising Co.	1183
Olin Keenan Keane & McLaughlin Inc.	1162
Research Appliance Company W. F. Minnick & Associates	1164
Seymour Specialty Supplies Spraying Systems Co	$1228 \\ 1173$
Technicon.	1157
Mediad, Inc. Trapelo/West Cerrito Graphic Arts Advertising	1225
TRW Systems Group The Bowes Company	1183
PROFESSIONAL CONSULTING SER- VICES DIRECTORY1231-1232	2-1233
CLASSIFIED SECTION	1234

CENTURY COMMUNICATIONS CORPORATION Edward P. Blanchard, President, Thomas N. J. Koerwer, Executive Vice President, 142 East Avenue, Norwalk, Connecticut 06851 (Area Code 203) 853-4488

Advertising management for the

American Chemical Society Publications

ADVERTISING SALES MANAGER Thomas N. J. Koerwer

SALES REPRESENTATIVES

- Chicago 60601 . . . Gilbert C. Mueller, Cen-tury Communications Corp., 307 North Michigan Avenue, (Area Code 312) 641-0890
- Dallas 75207 . . . Parker Harris, George Thompson, Roy MacDonald Assoc., 714 Stemmons Tower West, (Area Code 214) 637-2444
- Denver 80203 . . Robert H. Heidersbach, Bud Foster, Roy McDonald Assoc., Inc., 846 Lincoln Street (Area Code 303) 825-3325
- Houston 77006 . . . Frank N. Vickrey, Rich-ard Clothier, Roy MacDonald Assoc., Inc., 3130 Southwest Freeway, (Area Code 713) 529-6711
- Los Angeles 90045 . . . Clay S. Holden, Con-necticut Century Communications Corp., Airport Arcade Bldg., 8820 S. Sepulveda Blvd., Suite 215, (Area Code 213) 776-0552
- Norwalk 06851 . . . Anthony J. Giamanco Century Communications Corp., 142 East Avenue, (Area Code 203) 853-4488
- Great Britain and Western Europe . . . Bray-ton Nichols, The American Magazine Group, 27 Maddox Street, London, W. 1, England, Telephone-499-0180 Japan . . . Sumio Oka, International Media Representatives, Ltd., 1, hiracho, Minatoku, Tokyo

PRODUCTION DIRECTOR Joseph P. Stenza

Esso Research and Engineering Company, the principal technical affiliate of the Standard Oil Company (N.J.), is expanding its program in air quality conservation and is offering unique opportunities for qualified individuals with at least three years experience in air pollution abatement research and engineering activities. Candidates should have experience in at least one of the following areas:

- Application of air pollution control technology theory and hardware to stationary sources.
- Capabilities, limitations and applications of air pollution diffusion calculations and complex source modeling.
- Air pollution abatement, instrumentation, field sampling techniques and test methods.

Our Engineering Center is located in north central New Jersey at Florham Park (near Morristown). This provides an opportunity to live in suburban New Jersey . . . yet New York City is just one hour away.

Interested engineers with advanced degrees in environmental science should submit their resumes in confidence to:



ESSO RESEARCH AND ENGINEERING COMPANY Professional Recruitment, Dept. EE226 P.O. Box 101 Florham Park, New Jersey 07932

#### Environmental Science & Technology

Volume 5. Number 12

December 1971

### NAMES INDEX

January1-90	July
February	August
March	September
April	October
May	November
June467–568	December1153-1242

Refer to the above listing to determine the issue in which an entry appears.

This year's Names and Subject indexes, like last year's, leave something to be desired in the way of completeness. The ES&T staff recognizes this, but we need feedback from users of the indexes to determine how best to arrange entries. Please direct your comments to the managing editor.

All parts of ES&T have been indexed, with the exception of Industry trends, New products, New literature, Bookshelf, and Meeting guide. A more complete guide to products, services, books, and meetings will be found in the Pollution Control Directory, published in 1971 as part of the September issue. The names index contains the full titles of all current research papers listed under the senior author's name.

#### A

Abate, Joe, 24 Abel, I. W., 659 Ackerman, David, 506, 979 Adams, Timothy J., 750 Adams, William R., 123 Adler, Cyrus, 380 Afghan, Badar K., and Goulden, Peter D. Determination of trace quantities of nitrilotriacetic acid by differential cathode-ray po-larography, 601 Agee, James L., 13 Aiken, George D., 102 Albert, A. William, 124, 485 Alcorn, David S., 490 Alexander, Martin, 186 Alexander, Robert H., 677 Altshuller, Aubrey P., 394, 1073 Altshuller, Aubrey P., and Bufa-lini, Joseph J. Photochemical aspects of air pollution: A re-view, 39 View, 33 Altshuller, Aubrey P., Lonneman, William A., Sutterfield, Floyd D., and Kopczynski, Stanley L. Hydrocarbon composition of the atmosphere of the Los Angeles Basin–1967, 1222 Anderegg, James A., 122 Anderson, R. A., 396 Anderson, Thomas G., 586 Anderson, Vaughn, 122 Anduze, Roy A., 124 Armstrong, David E. See Wil-liams, Julian D. H., 1113 Atkeson, Timothy, 587 Attrep, Moses, Enochs, John A., and Broz, Larry D. Atmospheric technetium-99, 344 Axelrod, Herman D., Bonelli, Joseph E., and Lodge, James P., Jr. Fluorometric determina-tion of bromine: Application to measurement of bromine aero-sols, 420 See also Toshichi, Okita, 532 Axsom, Jim, 204

#### В

Bache, Carl A. See McKone, Colin E., 1138 Badalich, John P., 123 Balile, R. C., 656 Baird, Ralph W. See Swoboda, Allen R., 141 Baker, Howard H., Jr., 505 Ballou, E. Vernon, Wydeven, Theodore, and Leban, Mark I.

Ballou, E. Vernon, Wydeven, Theodore, and Leban, Mark I. Solute rejection by porous glass membranes. I. Hyperfiltration of sodium chloride and urea feed solutions, 1032 Barnes, Gerald J., 579

Barney, James E., II. See Stan-ley, Charles W., 430 Barth, Delbert, 503, 584 Bartok, William, 320 Bassemir, Robert W., 1087 Bauer, Elmer J. See Hermance, Harold W., 781 Baum, Harry, 470 Beasley, Thomas M., Mercury in selected fish protein concen-trates, 634 Becht, Charles, 752 Beck, Arthur N., 122 Beeckmans, John M., and Ng, Park C. Pyrolyzed sewage sludge: Its production and pos-sible utility, 69 Begeman, Charles R. Colucci, Joseph M., 145 See Behlke, James P., 124 Bell, Herbert E., 1176 Berg, Karl H., 1174 Berkshire, David C. See Miller, Ronald F., 127 Bernardin, Frederick E., Jr., 1080 Bickerstaff, Henry, 95 Bingley, W. McLean, 121 Blaser, William L., 1163 Blyholder, George D., and Cagle, Gordon W. Infrared spectra of H<sub>2</sub>S, CS<sub>2</sub>, SO<sub>2</sub>, CH<sub>3</sub>SH, and C<sub>2</sub>H<sub>3</sub>SH adsorbed on Fe and Ni. 158 Bober, Thomas W., 1084 Bohn, Hinrich, 573, 1069 Bolton, R. P., 1070 Bonelli, Joseph E. See Axelrod, Herman D., 420 Bortner, M. H. See Kummler, R. H., 1140 Bove, John L. See Magyar, Mar-tha, 358 Bowen, D. H. Michael, 9, 97, 191, 291, 383, 473, 657, 739, 1071, 1073, 1159 Bowne, Norman E. See Hilst, Glenn R., 327 Bramer, Henry C., 1004 Brief, Richard S. See Eckard, R. E., 548 See also Morrow, Norman L., 786 Brinck, Claiborne W., 123 Brisco, G. J., 654 Brokaw, Newton A., 282 Broz, Larry D. See Attrep, Moses, 344 Bryson, John C., 122 Bufalini, Joseph J., 394 Bufalini, Joseph J., Gay, Bruce W., Jr., and Kopczynski, Stanley L. Oxidation of *n*-bu-tane by the photolysis of NO<sub>2</sub>, 333 See also Altshuller, Aubrey P., 39; Gay, Bruce W., Jr., 422

Bufalini, Marijon. Oxidation of sulfur dioxide in polluted atmospheres: A Review, 685 Burd, Robert S., 670 Burg, William R. See Saltzman, Bernard E., 1121 Burgwald, Theodore. See Dravnieks, Andrew, 1220 Burmann, Franz J., 678, 978, 1070 Burns, Donald E., 1080 Burton, Robert S., III, 656 Busterud, John A., 1177 Byers, R. Lee, Davis, John W., White, Eugene W., and Mc-Millan, Ralph E. A computerization of atmospheric aerosols by the scanning electron microscope, 517

#### С

Cabrera, Benedicto E. See Steph-enson, Marvin E., 799 Cadle, Richard D., 105 Cady, Foster B. See Swoboda, Allen R., 141 Cagle, Gordon W. See Blyholder, George D., 158 Cahill, William T., 196, 578 Caldwell, Lynton K., 575 Camin, Kathleen Q., 590 Campbell, Angus, 661 Cannon, Joseph E., 124 Carl, Charles E., 124 Carotti, Arrigo A., 665, 668 Carroll, Thomas E., 483 Casberg, Thomas, 1177 Castellani, E. W., 583 Chafee, John H., 295 Chan, Raymond K. See Murthi, Kotturi S., 776 Chass, Robert, 395 Cheng, Shang-I, Pitlick, Harris, and Siegel, Robert. Removal of lead from automobile exhausts by molten salts, 72 Cholak, Jacob. See Yeager, David W., 1020 Christman, Russell F., ES&T Advisory Board member, 83 Clarke, F. J., 1161 Cleary, Edward J., 22 Clesceri, Lenore S. See Hardt, Frederick W., 345 Clusen, Ruth, 741 Collins, A. Gene. See Davis, James W., 1039 Colón-Yordán, Ernesto, 124 Colucci, Joseph M., and Bege-man, Charles R. Carcinogenic air pollutants in relation to automotive traffic in New York, 145

Conner, J. R., 281 Converse, Alvin O. See Fagan, Robert D., 545 Convery, John, 500 Corey, John C. See Horton, J. Henry, 338 Corn, Morton, Montgomery, Thomas L., and Esmen, Nurtan A. Suspended particulate mat-ter: Seasonal variation in speci-fic surface areas and densities, 155 Cort, Steward S., 16 Coshow, William R. See Haque, Rizwanul, 139 Coulehan, Barbara A., and Lang, Helen W. Rapid determination of nitrogen oxides with use of phenoldisulfonic acid, 163 Coulson, J. M., 1090 Coulter, James B., 123 Crosby, Donald G., and Tucker Richard K., Accumulation of DDT by daphnia magna, 714 of Cross, Bert S., 195, 1083 Cummings, John, 999 Cunningham, Bob, 204 Curry, John J., 122 Cywin, Allen, 760

#### D

Dash, Daniel P., 287 Davies, S. L., 122 Davis, James W., and Collins, A. Gene. Solubility of barium and strontium sulfates in strong electrolyte solutions, 1039 Davis, John W. See Byers, R. Lee, 517 Dean, Charles W., 289 Dean, Robert B., 1069 Dean, Robert B., Williams, Robert T., and Wise, Robert H. Disposal of mercury wastes from water laboratories, 1044 DeFalco, Paul, Jr., 13 Dell'Omo, John, 21 DeLong, Lewis. See Goldberg, Marvin C., 161 Denbo, Robert T., 1098 de Seversky, Alexander P., 588 DeSista, James E., 483 de Vos, Rudolph H. See Tas, Albert C., 1216 Diamond, Henry L., 388 Dimitriades, Basil, and Seizin-ger, Donald E. A procedure for routine use in chromato-graphic analysis of automotive hydrocarbon emissions, 223 Dimitriades, Basil, and Whisman, Marvin. Carbon monoxide in lower atmosphere reactions, 219, 1141

- Dingell, John D., 587
- DiNunno, Joseph J., 737
- D'Itri, Frank, 113. See Stephen-son, Marvin E., 799
- Doerner, William, 1165 Doerner, William, 1165 Domalski, Eugene S. Thermo-chemical properties of peroxy-acetyl (PAN) and peroxyben-zoyl nitrate (PBN), 443
- Dominick, David D., 13, 21, 303, 483
- Yood State Strain St
- Drowley, W. B., 665 Dubois, Donald P., 13
- Duce, Robert A. See Hoffman, Gerald L., 1134 Duke, Richard, 202

#### F

- Eagle, George H., 124 Eagleton, Thomas F., 483 Ebers, Earle S., 301 Eckardt, R. E., Scala, R. A., and Brief, R. S. Short-term effects of air pollution on mortality in New York City, 548 Egan, Thomas F. See Hermance, Harold W., 781
- Eggers, Alfred J., Jr., 295, 992 Eichelberger, James W., and Lichtenberg, James J. Per-sistence of pesticides in river water, 541
- Eisenbud, Merril, 1168
- Elish, Herbert, 1169
- Ellis, Ronald D., Glater, Julius, and McCutchan, Joseph W. Alkaline scale abatement by carbon dioxide injection, 350
- Enochs, John A. See Attrep, Moses, 344 Erickson, Frederick K., 314
- Esmen, Nurtan, A. See Corn, Morton, 155
- Evans, R. T., Jr., 109
- Everett, W., 210

#### F

- Fagan, Robert D., Grethlein, Hans E., Converse, Alvin O., and Porteous, Andrew. Kine-tics of acid hydrolysis of cellu-lose found in paper refuse, 545
- Farrell, Joseph B. Sludge de-watering by high-rate freezing at small temperature differ-ences, 716 Feldman, Maurice, 1169
- Ferguson, John F., and McCarty, Perry L. Effects of carbonate and magnesium on calcium phosphate precipitation, 534
- Ferrand, Edward F., See Magyar, Martha. 358 Fetterolf, Carlos, 1171 Files, John, 306
- Filip, T. A., 123 Floyd, John, 757
- Foerster, John W., 6
- Fontijn, Arthur, 573
- Ford, Gerald, 587
- Ford, Henry, II, 105 Forrestal, Dan, 491
- Fowler, James, 661
- Frangos, Thomas G., 125
- Freeman, David, 743 Friberg, Lars, 755

#### G

- Gakner, Alexander, 743 Gallatin, Albert, 581 Galston, John W., 308 Garber, Morris J. See Ordin, Lawrence, 621, 1047 Garthe, Edmund C., 122
- Gay, Bruce W., Jr., and Bufalini, Joseph J. Nitric acid and the nitrogen balance of irradiated hydrocarbons in the presence of oxides of nitrogen, 422 See also Bufalini, Joseph J., 333
- Gebhard, Lloyd, 13
- Gentry, James W. Evaluation of rat eradication programs, 704

1236 Environmental Science & Technology

Gerlach, Arch, 677 Gigliotti, M. F. X., 669 Gilbertson, Wesley E., 124 Ginter, J. Lyell, 211 Ginzton, E. L., 983 Glasson, William A., and Tues-day, Charles S. Reactivity re-lationships of hydrocarbon mix-tures in atmospheric photoxida-tion, 151 Glater, Julius. See Ellis, Ronald D., 350 Glenn, Thomas R., Jr., 125 Goldberg, Marvin C., DeLong, Lewis, and Kahn, Lloyd. Con-tinuous extraction of organic materials from water, 161 organic Goodsel, Arthur J. See Low, M. J. D., 1191 Goodsell, L. J., 125 Goolsby, Alvin D., Continuous monitoring of water surfaces for oil films by reflectance measurements, 356 Gorelick, Sam, 1177 Goren, S. L. See Spielman, L. A. 254 Gorin, Everett. See Struck, Robert T., 626 Goswami, Kishore P., and Green, Richard E. Microbial degrada-tion of the herbicide atrazine and its 2-hydroxy analog in sub-merged soils, 426 Gould, Matthew, 301 Goulden, Peter D. See Afghan, Badar K., 601 Gowdy, Fred W., 1098 Graber, Ralph C., 314 Gray, Melville W., 123 Green, Fitzhugh, 751 Green, Richard E. See Goswami, Kishore P., 426 Greene, Alexander J., 498 Greenfield, Stanley M., 195, 393, 483, 505, 990 Gregory, Ernest G., 123 Grethlein, Hans E. See Fagan, Robert D., 545 Greve, L. Carl. See Ordin, Law-rence, 621, 1047 Gribbs, Roman S., 14, 196 Griffith, Harry A., 582

Gerbacia, William, 186

Gross, Frederick, 1175 Grundy, Richard, 1184

#### н

- Haagen-Smit, Arie Jan, 198, 394 Habibian, Mohammad T. See Yao, Kuan-Mu, 1105 Hack, Fred C., 309 Hadjimarkos, D. M. Levels of antimony, cadmium, chro-mium, cobalt, manganese, and zinc in institutional total diets, 1048
- Hale, Samuel, Jr., 1077 Hall, Homer, J., 320 Hamilton, Walter, 1082 Hansen, Robert E., 758 Hansler, Gerald M., 13
- Haque, Rizwanul, and Coshow, William R. Adsorption of isocil and bromacil from aqueous so-lution onto some mineral sur-faces, 139 Harding, Ralph L., Jr., 667
- Hardt, Frederick W., Young, John C., Clesceri, Lenore S., and Washington, Donald R. Ultra-filtration for the control of re-cycled solids in a biological sys-tem, 345 Harris, Robin F. See Williams, Julian D. H., 1113
- Harrison, Douglas. See Murthi, Kotturi S.,776 Hart, Philip, 28, 587 Harvey, G. J., 381 Haskell, Elizabeth H., 1092 Hasler, Arthur, 198
- Hayes, Dora K., 198 Healy, William A., 123 Hechman, Jerome H., 669
  - Heilig, Louis F., 989
  - Heller, Austin, 1169
- Helton, Michael R., See Stanley, Charles W., 430

- Henderson, Ethel W. See Yeager, David W., 1020 Henry, Edgar N., 124 Hensel, Earl G. See Thompson, C. Ray, 1017 Hermance, Harold W., Russell, Charles A., Bauer, Elmer J., Egan, Thomas F., and Wadlow, Harold V. Relation of airborne nitrate to telephone equipment damage, 781 Herter, Christian, 750 Hester, B. D., 592 Hidy, George M., ES&T Advisory Board member, 83 Higgins, Irwin, 25 Hilst, Glenn R., and Bowne, Nor-man E. Diffusion of aerosols re-leased upwind of an urban com-plex, 327 Hirsch, Michael, 1090 Hochheiser, Seymour, 678, 978, 1070 Hodgson, Thomas A., Jr. Short-term effects of air pollution on mortality in New York City, 548
- Hoffman, Gerald L., and Duce, Robert A. Copper contamina-tion of atmospheric particulate samples collected with Gelman Hurricane air samplers, 1134 Hood, Donald W. See Miller, Ronald F., 127
- Hope, Malcolm C., 122
- Horton, J. Henry, Corey, John C., and Wallace, Richard M. Tritium loss from water exposed to the atmosphere, 338
- Horton, Robert J. M., 755
- Horton, Robert K., 22, 125
- Howard, R. S., 122
- Hu, John Nan-Hai. An improved impactor for aerosol studies— modified Andersen sampler, 251
- Hubbard, E. C., 124
- Humphrey, Clifford C., 1158 I

## Idol, James, 669

- J
- Jackson, Henry M., 387 Jaffe, L. S. See Kummler, R. H., 1140
- Jeffries, Harvey. See Ripperton, Lyman A., 246
- Jennings, Burgess H., 1170
- Jewell, William J., 287
- Jewell, William J., 28/ Perry L. Aerobic decomposition of algae, 1023
- John, Matt K. Lead contamina-tion of some agricultural soils in western Canada, 1199
- Johnson, Carol J., 125
- Johnson, David L. Simultaneous determination of arsenate and phosphate in natural waters, 411
- Johnson, Harry R., 30, 289, 573
- Johnson, Lyndon B., 120, 297
- Johnson, Raymond E., 13, 398 Jones, James H., Kummer, Joseph T., Otto, Klaus, Sheld, Mordecai, and Weaver, E. Eugene. Selective catalytic re-action of hydrogen with nitric oxide in the presence of oxygen, 790
- Jones, John D. See Rottschafer, J. Mark, 336 Jones, Robert E., 20
- Jones, S. Leary, 124

#### κ

- Kahn, Lloyd. Marvin C., 161 See Goldberg,
- Kaim, Fred J., 979
- Kaiser, Elmer, 665, 668
- Kapoor, Inder P. See Metcalf, Robert L., 709
- Kashiwa, Shiro, 303, 994
- Kats, Gerrit. See Thompson, C. Ray, 1017
- Kawahara, Fred K., Gas chroma-tographic analysis of mer-captans, phenols, and organic acids in surface waters with use of pentafluorobenzyl deriva-tives, 235

- Kelley, John J. See Miller, Ronald F., 127 Kenahan, Charles B., 594 Kennedy, David, 673 Kindinger, Juanita I. See Ordin, Lawrence, 621, 1047 Klaff, Jerome L., 1161 Klashman, Lester, 13 Klassen, C. W., 122 Klein, Carl, 97 Klevay, L. M., Petering, Harold, and Stemmer, K. L. A control-led environment for trace metal experiments on animals, 1196 Klimisch, Richard L., 579 Knapp, Carol, 399 Knight, Earl W., 1000 Knight, R. W. See Thruston, Alfred D., 64 Knipling, Edward F., 399 Knisel, Walter G. See Swoboda, Allen R., 141 Kopczynski, Stanley L. See Bufa-lini, Joseph J., 333; Altshuller, Aubrey P., 1009 Kortschak, Hugo P., 1158 Kotin, Paul. 28 Kramer, Harry P., 198, 203 Kretchmer, Jerome, 744, 1169
- Krotinger, Nathan J., 287
- Krotoszynski, Boguslaw K. See Dravnieks, Andrew, 1220
- Kulik, Metro D. See Struck, Robert T., 626
- Kummer, Joseph T. See Jones, James H., 790 Kummer, W. A., Pitts, J. N., Jr., and Steer, R. P. Chemilumines-centreactions of ozone with ole-fins and sulfides, 1045
- Kummler, R. H., Bortner, M. H., and Jaffe, L. S. Carbon mon-oxide in lower atmosphere re-actions, 1140

#### L

- Lacy, William J., 760
- Lafleur, R. A., 123
- La Graff, Michael, 748 Laird, Melvin R., 295
- Laity, John L. A smog chamber study comparing black-light fluorescent lamps with natural sunlight, 1218
- Lang, Helen W. See Coulehan, Barbara A., 163

Larson, Thurston E. See Sollo, Frank W., 240

Laseter, John L., and Valle, Ri-cardo. Organics associated with the outer surface of airborne urediospores, 631

Leban, Mark I. See Ballou, E. Vernon, 1032

Lee, G. Fred. See Veith, Gilman D., 230; Weimer, W. C., 1136; Wiersma, James H., 1203

Leeds, J. V. See Naden, Rex A., 522

Leich, Harold, 9, 11, 188, 281, 282, 283, 287

Lichtenberg, James J. See Eichelberger, James W., 541

Lisk, Donald J. See McKone, Colin E., 1138

Liskowitz, John W. An empirical method for determining the concentration of solids in sus-pension, 1206

Lloyd, William G., and Rowe, Donald R. Homogeneous cata-lytic oxidation of carbon monox-ide, 1133

Lodge, James P., Jr. See Axelrod, Herman D., 420; Toshiichi, Okita, 532

Lieberman, Joseph A., 13, 483

Lang, Martin, 1001, 1169 Lapp, Ralph E., 656 Larsen, Robert G., 301

Laureate, Willard F., 197

Lehr, William E., 512

Leininger, Kurt, 94

Lewis, Jesse L., 20

Levadie, Benjamin, 978

Levin, Gilbert, 15, 288

Lindsay, John V., 1168

Lombardo, Pio, 6 Lonneman, William A. See Alt-shuller, Aubrey P., 1009 Low, M. J. D., Goodsel, Arthur J., and Takezawa, Nobotsune. Reactions of gaseous pollu-tants with solids. I. Infrared study of the sorption of SO<sub>2</sub> on CaO, 1191 Lowry, H. H., 978 Luce, Charles F., 191, 193, 470 Lyles, G. R. See West, P. W., 550

#### Mc

- McCabe, Lee J., 754
- McCabe, Louis, 394
- McCaldin, Roy O. See Stephens, N. Thomas, 615
- McCarty, Perry L., ES&T Ad-visory Board member, 83. See also Ferguson, John F., 534; Jewell, William J., 1023
- McClindon, Dean, 583
- McCoy, Charles B., 390
- McCutchan, Joseph W. See Ellis, Ronald D., 350
- Notatu D., 330 McEachern, Peter, Myers, Wil-lard G., and White, Frederick A. Uranium concentrations in surface air at rural and urban localities within New York State, 700
- McElroy, William, 505
- McFarland, Bill V., 13
- McGinty, Richard T., 202
- McGovern, George, 587
- McGurk, Florence F. See Sollo, Frank W., 240
- McKee, Paul W., 123
- McKone, Colin E., Young, Roger G., Bache, Carl A., and Lisk, Donald J. Rapid uptake of mercuric ion by goldfish, 1138 of McLaren, Richard W., 1082
- McMahon, Thomas C., 123
- McMillan, Ralph E. See Byers, R. Lee, 517
- McMullin, Rod J., 1170
- McNair, Robert, 308

MacGregor, lan, 750 Mackenzie, John D., 1165 Magyar, Martha, Bove, John L., Magyar, Martha, Bove, John L., Nathanson, Benjamin, Sieben-berg, Stanley, and Forran Edward F. Analysis of barium sulfate by atomic absorption, 358 Marienthal, George, 1176 Mark, Harry B., Jr. See Rott-schafer, J. Mark, 336; Mattson, James S., 415 Marland, Sidney P., Jr., 1161 Marsland, David B., 289 Mason, Craig C., 583

- Massell,Sam, 14, 196
- Matrone, John, 211
- Mattson, James S., Mark, Harry B., Jr., Prostak, Arnold, and Schutt, Clarence E. Potential application of an infrared spec-troradiometer for remote de-tection and identification of oil slicks on water, 415
- Mayo, Francis T., 13
- Meloy, Thomas P., 389, 978 Menden, Edward E. See Michael, Leslie W., 249
- Metcalf, C. W., 121

- Metcali, C. W., 111 Metcali, Robert L., Sangha, Gurcharan K., and Kapoor, Inder P. Model ecosystem for the evaluation of pesticide bio-degradability and ecological magnification, 709
- Metzler, Dwight F., 121
- Meyers, Alvin F., 1177
- Michael, Leslie W., Menden, Edward E., and Petering, Har-old G. Copper-binding activity of tobacco smoke condensate, 249
- Middleton, John T., 13, 483
- Miller, J. L. See West, P. W., 550
- Miller, R. L., and Winefordner, J. D. Calculation of excess air for combustion processes using O<sub>2</sub>-to-N<sub>2</sub> ratio, 444

Miller, Ronald F., Berkshire, David C., Kelley, John J., and Hood, Donald W. Method for determination of reaction rates of carbon dioxide with water and hydroxyl ion in seawater, 127 Miller, Stanton S., 120, 391, 398, Mills, G. Alex, 9, 30, 289, 573, 1178 Moeller, Dade W., 745 Moeller, Griswold, 1168 Montgomery, Thomas L. See Corn, Morton, 155 Moore, Arch, 387 Morgan, George B., 678, 978, 1070 Morgan, James J., 83 Morrow, Norman L., and Brief, Richard S., Elemental composi-tion of suspended particulate matter in metropolitan New York, 786 Morgan, P. E. D., 197 Mosiman, Donald M., 483 Moulik, Satya P. Physical aspects of electrofiltration, 771 Mulligan, Kerry W., 121, 744 Murthi, Kotturi S., Harrison, Douglas, and Chan, Raymond K. Reaction of sulfur dioxide with calcined limestones and dolomites, 776 Murthy, Gopala K. Levels of antimony, cadimium, chro-mium, cobalt, manganese, and zinc in institutional total diets, 1048

Murthy, Gopala K., Rhea, Ulysses, and Peeler, James T. Levels of antimony, cadmium, chromium, cobalt, manganese, chromium, cobalt, manganese, and zinc in institutional total diets, 436

Muskie, Edmund S., 302, 492, 1073 Myers, Willard G. See McEach-ern, Peter, 700

#### N

Naden, Rex A., and Leeds, J. V. Signal processing techniques for estimating parameters of certain biological models, 522 Nagey, T. F., 103 Nalesnik, Richard, 749, 1171 Nance, Paul, 756 Natarajan, O. V., 122 Nathanson, Benjamin, See Mag-yar, Martha, 358 Neff, N. Thomas, 998 Newill, Vaun A., 198, 992 Ng, Park C. See Beeckmans, John M., 69 Niessen, Walter R., 7 Nixon, Richard M., 13, 97, 101, 191, 195, 201, 303, 391, 575, 577, 581, 661, 743, 751, 1075, 1082, 1176 Nordberg, Gunnar, 755

Noznesky, Harry J., 304

#### 0

- Obr, Joseph E., 121 Odendahl, James P., 1073 O'Donnell, Anne. See Drav-nieks, Andrew, 1220 Oglesby, Sabert, Jr., 766 Okita, Toshiichi, Lodge, James P., Jr., and Axelrod, Herman D. Filter method for the mea-surement of atmospheric hy-drogen sulfide, 532 Okun, Daniel A., 281 O'Melia, Charles R. See Yao, Kuan-Mu, 1105
- Ordin, Lawrence, Garber, Morris J., Kindinger, Juanita I., Whit-more, Sherry A., Greve, L. Carl, and Taylor, O. Clifton. Effect of peroxyacetyl nitrate (PAN) in vivo on tobacco leaf polysac-charide synthetic pathway en-zymes, 621, 1047 (correction) Orr, W. J., 209
- Otto, Klaus. See Jones, James H., 790

#### P

Pack, Merrill R. Effects of hydro-gen fluoride on production and organic reserves of bean seed, 1128

Packwood, Bob, 399 Paessler, A. H., 121 Parsons, William B., 314 Patton, Vincent D., 122 Paul, Ronald, 505 Peck, Charles E., 489 Peeler, James T. See Murthy, Gopala K., 436 Peloquin, Alfred E., 125 Perry, Harry, 30, 289, 573 Petering, Harold G., 755. See also Michael, Leslie W., 249; Klevay, Leslie M., 1196 Peterson, E. K., 380 Peterson, Russell W., 479, 662 Pickard, Ralph C., 123 Pierrard, John M., 663 Piland, V. M., 1172 Filang, V. M., 11/2 Pillay, K. K. Suvasankara, Thomas, Charles C., Jr., and Sondel, James A. Activation analysis of airborne selenium as a possible indicator of atmospheric sulfur pollutants, 74 Piscator, Magnus, 755 Pitlick, Harris. See Shang-I, 72 Cheng, Pitts, James N., Jr., 198 See also Kummer, W. A., 1045 Poliskin, J. S., 979 Poole, Blucher A., 122 Porteous, Andrew. See Fagan, Robert D., 545 Potenza, Edward E., 282 Price, A. Roy, 306 Printz, Bert, 749 Prostak, Arnold. See Mattson, James S., 415 Proxmire, William, 28 Puckorius, Paul, 206 Pummill, Llovd F., 124 Purdy, Ralph W., 123

#### Q

Quarles, John R., Jr., 483, 743, 994 Quon, Jimmie E. See Stickney, Janet E., 1211

#### R

- Rademacher, John M., 13 Ragone, David V., 387 Raleigh, Michael, 743 Ramaswamy, Gopalakrishnan. See Saltzman, Bernard E., 1121 Reagan, Ronald, 395 Rebhun, Menahem, and Manka, Josepha. Classification of or-ganics in secondary effluents, 606 Redmond, John, 1177 Reed, F. Everett, 385, 736 Reed, Richard C., 7 Rees, L. W., 211 Reuss, Henry D., 20 Rey, George, 760 Rhea, Ulysses. Gopala K., 436 See Murthy, Rhoads, F. M., 281 Riccardelli, Michael F., 752 Rickles, Robert, 1169 Ripperton, Lyman A., Jeffries, Harvey, and Worth, James J. B. Natural synthesis of ozone in the troposphere, 246 Rockefeller, Nelson, 303 Roddis, Louis H., Jr., 1167 Rosain, Robert M., 736 Ross, Richard D., 1087 Rottschafer, J. Mark, Jones, John D., and Mark, Harry B., Jr. A simple, rapid method for determining trace mercury in fish via neutron activation analysis, 336 Rowe, Donald R. See Lloyd, Wil-liam G., 1133 Rozich, Frank, 121
- Ruckelshaus, William D., 13, 14, 101, 102, 105, 200, 302, 388, 391, 473, 492, 503, 577, 578, 580, 661. 739, 995, 1077, 1167, 1171, 1172, 1174
- Russell, Charles A. S mance, Harold W., 781 See Her-

#### S

Salisbury, T. E., 1167 Saltzman, Bernard E., Burg, William R., and Ramaswamy, Gopalakrishnan. Performance of permeation tubes as stan-dard gas sources, 1121 Sandhu, S. S., 95, 380 Sangha, Gurcharan K. See Met-calf, Robert L., 709 Sax, Joseph L., 586 Sayers, William T., 114 Scala, R. A. See Eckardt, R. E., 548 Schlesinger, James, 983 Schlesinger, Martin D., 310 Schliekelman, R. J., 123 Schmidt, Richard, 979 Schoenberg, Ted, 18 Schork, John, 390, 1081 Schueneman, Jean J., 198 Schutt, Clarence E. See Mattson, James S., 415 Schuyler, William E., Jr., 295 Seizinger, Donald E. See Dimi-triades, Basil, 223 Shapiro, Joseph, 288 Shapp, Milton J., 744 Sharp, Charles R., 584 Sharp, Mitchell, 578 Shaw, Warren C., 186 Shea, William, 305 Sheehy, Edward J., 390 Shelef, Mordecai. See Jones, James H., 790 Shell, Gerry, 1080 Shukla, Surendra S. See Wil-liams, Julian D. H., 1113 Siebenberg, Stanley. See Mag-yar, Martha, 358 Siegel, Robert. See Cheng, Shang-I, 72 Smith, Jack K., 121 Smith, Raymond, 501 Snow, Curtis M., 311, 656 Snow, Joel A., 99 Sollo, Frank W., Larson, Thur-ston, E., McGurk, Florence F. Colorimetric methods for bro-mine, 240 Sondel, James, A. See Pillay, K. K. Sivasankara, 74 Soneda, Shinji, 122 Spaid, Richard E., 750 Speer, Edgar B., 6 Sphannaus, Warren R., 102 Spielman, L. A., and Goren, S. L. Capture of small particles by London forces from low-speed liquid flows, 254 (correction) Spies, Kenneth H., 124 Spinrad, Bernard I., 470 Spinfad, Bernard I., 470 Spofford, Walter, Jr., 94, 95 Stanley, Charles W., Barney, James E., II, Helton, Michael R., and Yobs, Anne R. Measure-ment of atmospheric levels of pesticides, 430 Stans, Maurice H., 580, 1082 Steer, R. P. See Kummer, W. A., 1045 Steinfeld, Jesse L., 747 Steinkraus, Keith H., 282 Stemmer, Klaus L. See Klevay, Leslie M., 1196 Stephan, David, 500 Stephens, N. Thomas, and Mc-Caldin, Roy O. Attenuation of power station plumes as de-termined by instrumented air-craft, 615 Stephenson, Marvin E., Cabrera, Benedicto E., and D'Itri, Frank M. Wet combustion procedure for determination of carbon con-tent in municipal refuse, 799 Sternglass, Ernest J., 745 Stewart, William H., 583 Steyn, Herbert A., 674 Stickney, Janet E., and Quon, Jimmie E. Spark replica tech-nique for measurement of sul-furic acid nuclei, 1211 Stinson, George A., 664 Stokes, Carl, 14 Story, William S., 489 Struck, Robert T., Kulik, Metro D. and Gorin, Everett. Removal of sulfur dioxide from stack gases by a modified Claus process, 626

Sullivan, Richard J., 123, 388, 485 Sutterfield, Floyd D. See Alt-shuller, Aubrey P., 1009

- Swoboda, Allen R., Thomas, Grant W., Cady, Foster B., Baird, Ralph W., and Knisel, Walter G. Distribution of DDT and toxaphene in Houston black clay on three watersheds, 141
- Syers, John K. See Williams, Julian D. H., 1113

#### т

- Takezawa, Nobotsune. See Low, M. J. D., 1191
- Talty, John, 499
- Tancig, W. J., 380
- Tanner, Howard, 112
- Tas, Albert C., and de Vos, Rudolf H. Characterization of four major components in a tech-nical polychlorinated biphenyl mixture, 1216
- Taylor, O. Clifton. See Ordin, Lawrence, 621, 1047 Teller, Joe, 121
- Thatcher, Lynn M., 124
- Thoman, John R., 13
- Thomas, Charles C., Jr. See Pillay, K. K. Sivasankara, 74
- Thomas, Grant W. See Swoboda, Allen R., 141
- Thompson, C. Ray, Kats, Gerrit, and Hensel, Earl G. Effects of ambient levels of NO<sub>2</sub> on navel oranges, 1017
- Thruston, Alfred D., Jr., and Knight, R. W. Characterization of crude and residual-type oils by fluorescence spectroscopy, 64
- Train, Russell, 303, 578, 1075, 1082 Tribus, Myron C., 577

Truman, Harry S., 22 Tsivoglou, Ernest C., 404, 654

- Tucker, Richard, 1172
- Tucker, Richard K. See Crosby, Donald G., 714
- Tuesday, Charles S., 987. See also Glasson, William A., 151

#### U

Udail, Stewart L., 123 Upholt, William M., 483

#### V

- Vaccaro, Ralph F. Estimation of adsorbable solutes in sea-water with <sup>14</sup>C-labeled phenol and activated carbon, 134 Valle, Ricardo. See Laseter, John L., 631
- Van Heuvelen, W., 124
- Varro, Stephen, Jr., 1088
- Vaughan, D. A., 396 Vaughan, Richard D., 13, 293, 483, 998
- Vaux, Walter, 987
- Veith, Gilman D., and Lee, G., Fred. Water chemistry of toxa-phene—role of lake sediments, 230
- Vikin, Joe, 573 Vollmer, Howard M., 506, 979
  - W
- Wadlow, Harold V. See Her-mance, Harold W., 781 Wakelin, James H., Jr., 577 Wallace, Richard M. See Horton, J. Henry, 338 Walsh, Robert, 748 Warren, Robert, 1079

enforcement of air quality standards, 387 given instrument by Ford, 15 ir pollution damage PAN effects on tobacco leaves, 621.

Air pollution mortality short term effects in New York City, 548

Air quality control regions National capital region formed, 985

automatic instruments, 978 carbon monoxide levels, 212 EPA views, 992 GM mobile laboratory, 987 instrument reliability, 1070 laser for NO., 745 laser light, 389 markets for instruments, 301 NCAR initiates global system, 105 particulate matter monitor, 664

105 particulate matter monitor, 664 Philadelphia computer-based system, 1079 power plant plumes, 609 remote surveillance, 676 review of instrumentation, 678 southwest power plant area, 1161 Utah system, 196

Air quality standards become effective, 387 national ambient standards proposed, 195 national standards announced, 503

awarded WQO grant, 13

Alaska Lumber and Pulp Co. cited for water pollution, 578

Aldrin EPA announcement expected, 13

Algae see also eutrophication aerobic decomposition and nu-trient balance in lakes, 1023 decomposition effects on water quality, 1023

Allied Chemical Corp. reduces coke oven emissions,

Alaska

Air quality monitoring astronomical data, 579 automatic instruments, 97

Washington, Donald R. Hardt, Frederick W., 345 See Weaver, E. Eugene. See Jones, James H., 790

- Webb, H. J., 124
- Weimer, W. C., and Lee, G. Fred. Method for the storage of sam-ples for dissolved gas analyses, 1136
- Weinberg, Alvin, 505
- West, Lloyd E., 1084
- West, P. W., Lyles, G. R., Miller, J. L. Spectrophotometric de-termination of atmospheric fluorides, 550 (correction) Wheelis, Reuben E., 583 Whisman, Marvin. See Dimi-triades, Basil, 219, 1141
- White, Eugene W. See Byers, R. Lee, 517
- White, Frederick A. See Mc-Eachern, Peter, 700
- Whitfield, Joyce. See Drav-nieks, Andrew, 1220
- Whitmore, Sherry A. See Ordin, Lawrence, 621, 1047
- Wiersma, James H., and Lee, G. Fred. Selenium in lake sedi-ments—Analytical procedure and preliminary results, 1203
- Wilber, Richard L., 1177
- Willa, Jim, 204
- Williams, Harold S., 758
- Williams, ratou 5,750 Williams, Julian D. H., Syers, John K., Shukla, Surendra S., Harris, Robin F., and Arm-strong, David E. Levels of in-organic and total phosphorus in lake sediments as related to other sediment parameters, 1113 other 1113
- Williams, Louis G., 188
- Williams, Robert T. See Dean, Robert B., 1044
- Williamson, Arthur E., 125

Williamson, Peter, 997 Wilson, Donald L. Method for macrodetermination of carbon

Alpine Geophysical Associates,

protein from sewage sludge, 299

American Chemical Society EPA response to research recommendations, 991

American Institute of Chemical Engineers (AIChE) solvent emissions forum, 1086

American Smelting and Refining **Co.** SO₂ removal process, 1165

hydrocarbons from automobile

by gc technique, 223 ir for CO levels, 212 odorous compounds in water by gc technique, 235 sewage by body fluids analyzer, 103

Andersen sampler modifications for improved aerosol sampling, 251

Antimony in food and water values in 28 institutional diets, 436

auto exhaust testing program, 1079 water pollution control status, 120

new environmental depart-ment, 1092

Armco Steel Co. prosecution for water pollution, 101

Arsenic analysis colorimetric technique for water samples, 411

markets for air pollution in-struments, 301

Atlanta air pollution warning from Georgia, 297

Arctic environment

Arthur D. Little, Inc.

insulated pipeline, 579

American Standard improved precipitator, 665

The Aluminum Association refuse recycling plant, 109

and hydrogen in solid wastes,

- Winefordner, J. D. See Miller, R. L., 444
- Wirth, George, 20 Wirth, Lou, 25
- Wise, Robert H. See Dean, Robert B., 1044
- Wolf, Philip C., 212
  - Wolfner, Jacques P., 381
- Wolman, Abel, 981
- Wood, Glen, Jr., 123
- Worth, James J. B. See Ripper-ton, Lyman A., 246
- Wortreich, Herb, 1087
- Wright, James F., 125, 997
- Wright, John R., 123
- Wydeven, Theodore. See Ballou, E. Vernon, 1032

#### Y

Yang, John, 380

- Yantis, Hugh C., 124
- Yao, Kuan-Mu, Habibian, Mo-hammad T., and O'Melia, Charles R. Water and waste water filtration: Concepts and applications, 1105
- Applications, 1109 Yeager, David W., Cholak, Jacob, and Henderson, Ethel W. De-termination of lead in biological and related material by atomic absorption spectrophotometry, 1020
- Yobs, Anne R. Charles W., 430 See Stanley.
- Young, John C. Frederick W., 345 See Hardt,
- Young, Roger G. See McKone, Colin E., 1138

#### Z

cannot meet EPA deadline, 196 given 180-day warning by EPA, 14

Atlantic Council of the U.S. international conference, 198

Atmospheric pollutants beryllium, 584 effects on citrus production, 1017

hydrocarbons, role from auto-mobiles, 145

Atomic absorption technique atmospheric barium analysis, 358 lead in biological samples, 1020

Atomic Energy Commission (AEC) asked to enforce thermal pol-

environmental impact of nu-clear power, 983 nuclear power plant monitoring, 985

role

ole in nuclear power contro-versy, 404

Austin Tool Co. low-emission vehicle contracts, 663

Auto hulks BuMines recycling programs, 597

Arizona eyes compulsory auto inspection, 1079 auto mechanic training grants, 1077

California assembly line test,

Commerce Department report on fuels, 387 CO monitoring near highways, 212

212 contribution to air pollution, 34 contribution to Los Angeles smog, 394 philadelphia, New Jersey, North Carolina, 985 emission control catalyst, 197 GM mobile test laboratory, 103 GM spending for control, 580 lead removal from by molten salts, 72

salts, 72 low-emission vehicle contracts, 663

Automotive emissions

Zall, Robert R., 396

## SUBJECT INDEX

Ínc.

Analysis

Arizona

Arkansas

### A

Abcor Inc.

- membranes for whey treat-
- membranes for whey treat-ment, 396 Acid mine drainage treatment of contaminated water supply, 24 use of limestone for neutraliza-tion, 1165

Aerosols

- counting method for H<sub>2</sub>SO<sub>4</sub>, 1211 diffusion over an urban com-plex, 327
- size measurements by scan-ning electron microscope, 517

- Aerosol sampler improved impactor—m Andersen sampler, 251 impactor-modified
- Aerospace companies eye pollution control business, 105
- Agency for International De-velopment sets up environmental watch-dog, 661
- Agriculture Department, U.S. pest control programs, 399

Air pollution

more specific listings

- Air pollution control electrostatic precipitator main-tenance, 489 electrostatic precipitator oper-ation, 765 EPA performance standards, 748
- 748 improved coke oven charging method, 665 innovative precipitator, 665 innovative precipitator, 588 lead smetting plant, 304 Michigan foundry, 1080 new federal law, 106 performance standards, 1077 solventless coating method, 299 steel industry, 1004
- (APCO), formerly NAPCA see also Environmental Pro-tection Agency APEX training game, 202 Air

1238 Environmental Science & Technology

NAS committee on controls, 983 983 new concept vehicles, 197 1975-76 regulations, 661 NO<sub>2</sub> formation, 579 particulate matter from un-leaded gasoline, 663 program in meeting standards, 492 substitute for lead antiknocks, 487 Avco Corp. granular bed filter study, 18 oil spill clean-up, 15 AWT Systems, Inc. sewage treatment process, 756

### B

Barium analysis atomic absorption technique for Hi-Vol samples, 358 Barium sulfate solubility in strong electrolyte solutions, 1039 Barringer Research Ltd. correlation spectrometer, 677 Battelle Memorial Institute international pollution ference, 198 con-Beatrice Foods Co. coating system, 299 Bell Laboratories NO<sub>x</sub> laser monitor, 745 Beryllium air pollutant, 584 **Biodegradability** pesticides by ecosystem model, 709 **Biological waste treatment facil**ities ultrafiltration use in, 345 Biospherics, Inc. phosphate removal process, 15 Black Clawson Co. Franklin, Ohio recycling system, 998 Boeing Co. waste recycling project, 747 Bromacil

adsorption, on five minera surfaces, 139 heat of adsorption, 139 for

Bromine colorimetric analysis for, 240 fluorometric technique atmospheric samples, 420

Bromine in the atmosphere automobiles, 420 Bureau of Solid Waste Manage-ment (BSWM) see Solid Wastes Office, EPA

n-Butane oxidation by photolysis of NO<sub>2</sub>, 333

role in oxidants formation, 333

#### С

Cadmium in environment, 754 in food and water, values from 28 institutional diets, 436

Calgon Corp. cvanide removal process, 1080

California denied waivers on auto testing,

denied waivers on auto testing, 661 new environmental depart-ment, 1092 open-burning ban, 388 urges repeal of 1899 Act, 744 water pollution control status, 120

water reclamation in Orange County, 1079

Carbon analysis wet method refuse, 799 for municipal

Carbon and hydrogen analysis macromethod for solid wastes characterization, 609

Carbon dioxide from fuel combustion, 380 use to control scale in heat transfer equipment, 350

transfer equipment, 350 Carbon monoxide air quality standards, 195 analytical instrumentation, 678 catalytical oxidation of, 1133 conversion to CO: in the atmo-sphere, 1140 hazards and monitoring, 212 national air quality standard, 503

removal from stack gases, 1133 role in lower atmospheric reac-tions, 1140 role in photochemical smoo

role in photochemical smog formation, 219

Carcinogenic air pollutants New York, 145

Cellulose conversion to sugar by acid hydrolysis, 545 Cement plants air emission standards, 748

Chattanooga reduces sewage load to lake,

662 Chemical Construction Co. auto exhaust catalytic muffler, 663

Chemical industry supported over environment, 580

Chemical Separations, Inc. ion exchange process, 24

Chem Systems, Inc. solid waste market study, 16

Chicago fuel oil, detergent restrictions, 196 industrial waste treatment sur-charges, 1000 noise control ordinance, 662 steam-raising incinerator, 207

Chromium in food and water values from 28 instituti diets, 436 institutiona

Citizen action environmental law, 586

Cleveland given 180-day warning by EPA, 14

receives sewage funds from EPA, 1163 Coal

oal gasification processes, 1178 gasification proposal in Con-gress, 743 low-sulfur oil produced from, 745

Cobalt in food and water values from 28 institutional diets, 436

Colorado clamps down on open burning, 1079

water pollution control status, 120

Colors in water supplies classification scheme for, 606 Columbia Processors Coopera-

waste recycling project, 747 Combustion Equipment Assoc. incinerator smoke controls, 1081

**Combustion processes** calculation of air necessary for incineration, 444

Commerce Department, U.S. encourages U.S. pollution encourages U.S. pollution firms 16 impact statement publication, 577

noise and auto fuel reports,

sponsorship of NIPCC, 1082

Commerce, Tex. atmospheric technetium-99 concentration at, 344

Composting status of current projects, 1088

Computer application size characterization spheric aerosols, 517 of atmo-

The Conference Board, Inc. tudy of pollution groups, 301 study control

Connecticut

new department of environ-mental protection, 985 new shredder/landfill opera-tion, 297 water pollution control status, 120

Consolidated Edison, Inc. power plant permits, 1167

Cooling towers see also thermal pollution role in water reuse, 204

Copper industry SO<sub>2</sub> control expenditures, 489 Corps of Engineers, U.S. Army enforcement of refuse act, 302 EPA views on permit program, 392

Tennessee-Tombigbee project, 581

waste discharge permit pro-gram, 101, 483, 1161

Council Environmental ouncil on Environmental Quality (CEQ) cooperation with NIPCC, 1082 Great Lakes water quality, 578 new guidelines for impact statements, 295 revises environmental impact guidelines, 483 second anual report 743 on

second annual report, 743 sulfur tax study, 195

Crowley Milk Co. cheese whey treatment, 396

D DDT accumulation by food chain link, Dephne magne, 714 banned in New York state, 102 Envirogenics removal unit, 747 fate of in Houston watersheds, 141 Deep well disposal Hercules will phase out sites, 664 Defense Department, U.S. pollution control at facilities, 1176 suspends ocean dumping by U.S. Navy, 295 Delaware legislation barring industry from coast, 662 new environmental depart-ment, 1092 Recip Com-Delaware River Basin Com-mission organization and programs, 996 Denver to reuse treated waste water, 1163 103 Detergents Chicago controls phosphate content, 196 NIPCC report, 13 NTA as phosphate substitute, 747 NTA health effects, 983 phosphate limits, 1184 recycling laundry wash water, Sears-Roebuck phosphate-free Sears-Roebuck phosphate-free product, 664 Detroit given 180-day warning by EPA, 14 receives federal funds for sewage treatment, 985 short on money for water cleanup, 196 tests pure oxygen for sewage treatment, 1079 Deuterium Corp. heavy water plant in Georgia, 102 Dieldrin EPA announcement expected, 13 Diets trace elements content from 28 institutional diets, 436 Disinfectants for potable water bromine consideration for, 240 Dow Chemical Co. Arctic pipeline, 579 exchanges know-how with Rol-lins-Purle, 390 ion exchange resin, 24 Dun & Bradstreet, Inc. industrial pollution survey, 1081 control Du Pont Co. Kastone cyanide removal pro-cess, 496 pledges \$300 million for controls, 390 Rankine cycle engine, 1165 views on WQO inventory, 21 Ε Eastman Kodak Co.

photoprocessing waste control, 1084

Ecology, Inc. Brooklyn composting plant, 1088

Ecosystem model for pesticide evaluation, 709

for pesticide evaluation, 709 Editorials asking childish questions, 9 crunch time for air quality, 473 discharge permit program, 657 effluents as drinking water, 97 end of an era, 1159 government spending, 191 handout time in the nation's capital, 1071 planning for land use, 291 pollution is a two-edged sword, 383 slow cleanup progress 730

slow cleanup progress, 739

Electrofiltration development in waste water treatment, 771

for 10 elements in particulate matter samples, 786

Energy conservation through proper design, 489 President proposes clean-fuel research, 577

Energy Systems, Inc. nuclear sewage treatment, 197

Enforcement views of EPA administrator, 391

Engineers, Inc. wave basin for oil pollution studies, 579

Envirogenics Co. DDT removal unit, 747

Environment see more specific entries

Environmental law citizen action under, 586

citizen action under, 586 Environmental Protection baseline data projects, 1161 budget authority, 200 challenges Union Carbide on abatement schedule, 105 cracks down on sugar process-ors, 1170 demonstration grant program, discharge permit program, 101, 657, 983 657, 983

657,983 early activities, 101 effluent requirements, 743 enforcement actions, 302, 578, 994 industrial emission guidelines,

748 initial organization, 13 interview with administrator, 391

issues 180-day warning to three

cities, 14 lead poisoning, 580 low-emission vehicle contracts, 663

meets air pollution deadlines, 295

295 national air quality standard, 1975-76 auto exhaust regula-tions, 661 180-day notices, 1163 organizational changes, 483 regulations for state imple-mentation plans, 983 research programs and prior-ities, 990 responsibilities under federal

responsibilities under federal air law, 106 role in tax incentive procedure, 672

treatment plant construction regulations, 577 turnkey sewage plant proposal, 1077

urges sugar industry cleanup, 1167

Environmental Science & Technology Pollution Control Directory, 813

Envirotech Corp. phosphorus removal process, 1080

Ethyl Corp. environmental public relations, 490

European Common Market opportunity for U.S. pollution firms, 16

phosphorus role in, 1113 strategies for control, 1184

Executive orders federal facility cleanup, 1176 penalties for air polluters, 661

Extraction equipment removing pesticides from water samples, 161

F

Federal Power Commission (FPC) report on power plant controls, 743

Federal Water Quality Admin-istration (FWQA) see Water Quality Office, EPA

The Firestone Tire & Rubber Co. industrial waste treatment, 1167

mercury content, 336 mercury content in protein con-centrates, 631

demonstration sanitary land-fill, 297 open-burning restrictions, 744 water pollution control status, 120

Florida Power and Light Co. settles thermal pollution suit, 983

Florida State University microbial oil spill study, 389

Volume 5, Number 12, December 1971 1239

Federal budget, 200

Filtration model for, 1105

Fish

Florida

Eutrophication

- Fluorides in the atmosphere spectrophotometric technique for, 550
- Fluorimetry for selenium analysis, 1203 Food chain

DDT concentration by animal link in aquatic food chain, 714 Food protein

- mercury content of fish con-centrates, 634
- Food wastes new blanching process, 389 treatment of cheese whey, 396
- Ford Motor Co. donates instrument to EPA
- pledges clean plants and prod-ucts, 105 pollution-free paint curing, 103
- Fort Wayne, Ind. aerosol diffusion study over, 327 The Franklin Institute
- incinerator ash project, 197 to develop trash separator, 15
- Frost & Sullivan, Inc. solid waste market study, 16
- Fuels and energy coal gasification processes, 1178 environmental impacts, 30
- Fungal spores found in particulate matter samples, 631

#### G

- GAF Corp. fined for water pollution, 485
- Garrett Research and Develop-ment Co. pyrolysis process, 487
- Gas analysis storage of samples for, 1136
- Gas chromatography separation of isomeric PCB's,
- separa 1216
- General Battery Corp. air pollution control at smelter, 304
- General Motors Corp. mobile auto emissions test lab, 103, 987 pollution control spending, 580
- Georgia acts on disposal sites, 485 municipality plans joint in-dustry-local plant, 102 warns Atlanta over incinerator emissions, 297 water pollution control status, 120

- Georgia-Pacific Corp. criticism of federal role, 301
- Geothermal energy western states formed, 662 compact
- **Gillette Research Institute** recycling cellulosic wastes, 299
- Granular beds for SO<sub>2</sub> and fly ash removal, 18
- Great Lakes see also names of specific lakes water quality goals, 578

Groundwater organic materials, extraction from, 161 Gulf Oil Co.

environmental improvement at Philadelphia refinery, 1081 **Gulton Industries** 

pollution 388 warning from N.J.,

#### н

- Hawaii pollution from sugar process-ing, 1170 Hazardous materials federal controls proposed, 195 Health effects of cadmium, 754
- Heat transfer equipment scale control by CO<sub>2</sub> injection, 350 Herbicides
- Atrazine-degradation in the soil, 426
- Hercules, Inc. forms environmental marketing unit, 390 phases out injection wells, 664
- Hilton Head Island master plan for development, 308
- Hi-vol samplers odor contaminants, 1220 precautions against copper con-tamination, 1134

- Humble Oil Co. pollution control at Baton Rouge refinery, 1098 Hydrocarbon reactions nitrogen balance with oxides of nitrogen, 422 oxides of nitrogen, 422

Hydrocarbons air quality standards, 195 analytical instrumentation, 678 national air quality standard, 503

Hydrocarbons in atmosphere Los Angeles Basin data for 1967, 1009

Hydrocarbons emissions separation of automobile fuels into 165 species, 223 status of control efforts, 1086

Hydrocarbons reactivity role in atmospheric phot oxidations, 145 role in air pollution studies, 39

Hydrogen analysis wet method for municipal

Hydrogen sulfide in the atmo-sphere light attenuation technique for, 532

I

controls smoke emissions, 578

open-burning regulations, 1079 pollution-based shutdowns, 1163

Incineration air emission standards, 748 calculation of air needed for efficient combustion, 444

erricient combustion, 444 gaseous emissions study, 665 junked autos, 987 letters on emissions, 6, 7 liquid industrial wastes, 989 odorous emissions, 1087 reclamation of silver, 389 refuse recycling plant, use in, 109

109 smoke controls for fire-fighting demos, 1081 steam-raising plants, 207 Wanaque, N.J. facility, 753 Incinerator Engineering Co. scrap film incinerator, 389

Industrial Gas Cleaning In-

Industrial waste control EPA discharge survey, 1077 EPA guidelines and standards, 748

748 Firestone rubber plant, 1167 Oregon recycling project, 747 photoprocessing wastes, 1084 problems around the states, 125

to measure ozone and NOz, 15

International Joint Commission bilateral cooperation, 750 International pollution cooperative efforts, 750

Interviews Stanley Greenfield, 990 William Ruckelshaus, 391

lon exchange for acid water treatment, 24

lonics, Inc. hypochlorite generator for in-sewer service, 1080

water pollution control status, 120

adsorption on five mineral surfaces, 139 heat of adsorption, 139

ITT Levitt & Sons, Inc. residential sewage treatment process, 756

Jones & Laughlin Steel Co. prosecution for water pollution, 101

Iowa Beef Processors, Inc. packing waste treatment, 590

precipitator survey, 489 Industrial wastes treatment charges in municipal systems, 1000 WQO inventory, 20

role of water reuse, 760 Infrared technique oil slicks monitoring, 415 stack gas SO<sub>2</sub>, 1191

Instrumentation

lowa

Isocil

stitute

water pollution fine, 485

Improved Machinery, Inc. aerobic digester, 989

Illinois

wet method refuse, 799 Hydrogen fluoride effects on beam plants, 1128

photo-

- Justice Department, U.S. antipollution program, 994 settles thermal pollution suit, 983

J. T. Baker Chemical Co. environmental public relations, 490

### κ

- Kentucky air pollution regulations, 1163 Kinetics
  - inetics cellulose by acid hydrolysis, 454 experimental methods for mea-suring reaction rates, 127 reaction rates of CO<sub>2</sub> with water and OH<sup>-</sup> in seawater, 127
- Koppers Co. coke oven emissions, 105

#### L

Lake Champlain Vermont seeks legal aid for cleanup, 102 Lake Erie activities of special congress, 758 Lake Huron mercury content of fish taken from, 336 Lake St. Clair, Mich. mercury content of fish taken from, 336 Lake Superior enforcement conference, 387 Land use planning federal interest, 195 Hilton Head Island plan, 308 Lead ead antiknock substitute, 487 in Canadian soil samples, 1199 grain alcohol as substitute in gasoline, 578 particulate matter in auto ex-haust, 663 removal from automobile ex-haust by molten salts, 72 report on poisoning, 580 tax on, in gasoline, 195 ead analusie Lead analysis extract-atomic absorption spec-trophotometric method, 1020 in biological samples, 1020 Lead Industries Assoc. Lead plosoning, 580 Lead poisoning, 580 Legislation, federal amendments to water law, 302 California urges repeal of 1899 Act, 744 Canada Air Act, 665 Clean Air Act amendments, 106 106 committee on environ-ment established, 387 National Air Quality Standards Act passes, 13 pesticide laws proposed, 400 Presidential proposals, 195 progress in the 91st Congress, 200 proposed marine arctiti 106 26 proposed marine protection act, 387 Public Domain Lands Act, 387 Toxic Substances Control Act, 483 water pollution control in pri-ority, 195 Legislation, state and local Chicago antinoise ordinance, 662 662 Delaware bars coastal develop-ment, 662 N.J. ocean dumping law, 578 N.J. Wetlands Act, 196, 485 N.Y. City regulations, 1168 revamped governmental units, 299 sewage treatment surcharge ordinances, 1000 state environmental agencies, 1092 Letters to the editor, 6, 94, 186, 281, 380, 470, 573, 654, 736, 978, 1069, 1158 Light attenuation technique hydrogen sulfide atmospheric determinations, 532 Little Miami River, Ohio fate of 28 pesticides in waters of, 541 London fog disaster mathematical modeling for, 522 London Forces role in filtration, 254

Los Angeles fight against smog, 394

- Los Angeles County Air Pollution Control District programs and progress, 394 Rule 66 and solvent emissions, 1086
- Louisiana State University air pollution symposium, 198 Luria Brothers & Co., Inc. junked auto incinerator, 987

M ew environmental depart-ment, 1092 Maine new Manganese in food and water values from 28 institutional diets, 436 Manpower air pollution training game, 202 estimates of future needs, 314 Manpower and training NSF teacher grants, 101 waste water operator training, 101 White House awards program, 1161 Maryland new environmental depart-ment, 1092 water pollution control status, 120 Massachusetts new environmental depart-ment, 1092 water pollution control status, 120 Mathematical analysis for rat eradication strategies, 704 Mathematical modeling air pollution disaster incidents, 522 signal processing technique for biological events, 522 Meloy Laboratories oil tagging, 389 Mercury disposal from analytical lab-oratories, 1044 in fish protein concentrates, 634 634 mercuric ion uptake by gold-fish, 1138 North Carolina bans trickling filter seals, 1079 Mercury analysis neutron activation technique, 336 Merichem Co. products from wastes, 306 Michigan phosphorus removal require-ment, 297 regulates discharge from boats, 388 waste quality standards, 985 Michigan State University sewage treatment project, 112 Ninnesota new air pollution rules, 1163 new environmental depart-ment, 1092 takes radioactive discharge case to Supreme Court, 102 water pollution control status, 120 Missouri Monitoring for nuclear industry activities, 700 Monsanto Co. clean-burning plastic, 669 environmental public relations, 490 tests with NTA, 747 Monsanto Enviro-Chem Systems, Landgard pyrolysis process, 310 Montreal steam-raising incinerator, 207 Mortality air pollution effects in New York City, 548 Ν National Academy of Sciences automotive exhaust control, 983 Ational Aeronautics & Space Administration remote sensing project, 676 National Air Pollution Control Administration (NAPCA) see Air Pollution Control Office, EPA

- National Center for Atmospheric
- initiates global air monitoring system, 105

1240 Environmental Science & Technology

- National Center for Solid Waste Disposal, Inc. refuse recycling plant, 109 National Commission on terials Policy recycling study, 1161 Ma National environmental laboratory congressional hearings, 505 congressional nearings, 305 National Industrial Pollution Control Council issues three reports, 13 meeting planned, 101 organization and accomplish-ments, 1082 plastics incineration, 667 report to the President, 195 National Institute of Ecology formation, 198 National Oceanic and spheric Administration pollution alerts, 1077 Atmo-National Science Foundation air pollution data from astron-omy, 579 grants for precollege teachers, 101 quality of life study, 661 summer grant program, 295 Odors Nebraska gasoline tax, 578 New England River Basins Com-mission report of progress, 297 Ohio New Hampshire water pollution control status, 120 New Jersey antipollution moves, 1163 diesel, auto exhaust controls, 985 halts waterfront development, 485 485 new environmental depart-ment, 1092 odor control regulation, 1086 pollution warnings, 388 solid waste as public utility, 752 waste dumping law, 578 water quality standards, 985 Wetlands Act, 196 New Mexico water pollution control status, 120 New York City air pollution effects on mortal-ity, 548 carcinogenic pollutants and automotive traffic, 145 drops superincinerator plans, 744 industrial waste treatment sur-charges, 1000 progress and style of city EPA, 1168 Oklahoma updates air pollution codes, 14 updates air poliution codes, 14 New York State atmospheric uranium concen-trations for, 700 bars persistent pesticides, 102 new environmental depart-ment, 1092 nuclear power plant moni-toring, 985 performance bonds, 388 water pollution control status, 120 Oregon New York Testing Laboratories, 621 Nitrates, atmospheric effect on telephone equipment, 781 Nitric acid plants air emission standards, 748 auto exhaust controls, 790 catalytic reactions, 790 Nitrilotriacetic acid (NTA) as detergent constituent, 983 determination in water samples by polarography, 601 in detergents, 747 Nitrogen dioxide analytical instrumentation, 678 effects on orange trees, 1017 Nitrogen oxides air quality standards, 195 formation in auto exhaust, 579 instrument for measurement, national air quality standard, 503 rapid analysis with phenol-disulfonic acid, 163 reduction from stationary sources, 320, 987 Noise pollution Chicago enacts ordinance, 662 Commerce Department report, 387 EPA office established, 483 federal control proposed, 195 Pa. regulations in force, 1163 organic content of atmospheric samples, 631

North Carolina bans mercury trickling filter seals, 1079 diesel exhaust control, 985 water pollution control status, 120

- Nuclear power Atomic Energy Commission's responsibilities for impact, 983
- 983 benefits and risks, 404 monitoring around plants, 985 thermal discharges, 388
- Nutrient removal see also phosphate removal PhoStrip process, 15

0 Oak Ridge National Laboratory develops body fluids analyzer for sewage, 103 Ocean dumping DOD orders Navy to stop, 295 federal prohibition proposed, 195 and solvent emissions, 1086 atmospheric sampling and identification techniques, 1220 Odors in water supplies classification scheme for, 606 water pollution control status, 120 Ohio River Valley Water Sanitafunction and organization, 22 letter, 186 Cil refining pollution control at Gulf refin-ery, 1081 pollution control at Humble re-finery, 1098 Oil slicks monitoring infrared spectroradiometer technique, 415 reflectance technique, 356 reflectance technique, 356 Oil spills beach cleaner, 978 Coast Guard programs, 512 magnetic mop-up methods, 674 review of clean-up methods, 674 Senate ratifies IMCO conven-tion, 1077 tagging of oil with micro-spheres, 389 use of absorbent garbage, 987 use of microbes, 389 wave basin studies, 579 Oil spille characterization **Oil spills characterization** fluorescence spectroscopy, 64 Optical methods suspended solids in hydrosols, 1206 new environmental depart-ment, 1092 water pollution control status, 120 Organic carbon cycle role of phenolic condensates in herbicides, 134 Oxidants PAN effects on tobacco leaves, Oxidants formation role of n-butane in, 333 Oxy-Catalyst, Inc. acquired by Research-Cottrell, 1081 Cone Chemiluminescent detector for, 1045 chemiluminescent reactions with olefins and sulfur-con-taining compounds, 1045 instrument for measurement, natural formation in tropo-sphere, 246 P PAN effects on tobacco leaves, 621 Paper refuse conversion to sugar by hy-drolysis of, 545 Particulate matter articulate matter air quality standards, 195 analytical instrumentation, 678 computerized method for size characterization, 517 elemental composition, 786 fungal spore content of, 631 national air quality standard, 500 in constant of characteristic

removal by electrostatic precipi-tation, 765 removal from gas streams, 18 seasonal variations in Pitts-burgh, 155 10 elements found in N.Y. sam-ples, 786 Particulate matter monitoring power plant plumes by aircraft technique, 615 Particulate matter samples precautions against contamination, 1134 copper PCB's identification of isomers, 1216 Peabody-Galion Corp. liquid waste incinerator, 989 Pennsylvania awarded WQO grant, 13 mine drainage control con-tracts, 744 uacts, /44 new environmental depart-ment, 1092 new environmental quality board, 985 noise regulations, 1163 program for mine drainage con-trol, 24 requires permits for waste la-goons, 14 Permeation tubes for NO<sub>2</sub> and hydrocarbons, 1121 methods for sealing, 1121 use in calibration of monitoring instruments, 1121 Perry Oceanographers, Inc. pollution control submarine, 663 pollution control submarine, 663 Pesticides see also more specific entries alternatives control method, 198 DDT removal unit, 747 ecosystem model for evaluation of biodegradability, 709 extraction from water, 158 fate of 28 materials in river water, 541 monitoring program in Virginia, new registration procedures Pesticides in atmosphere levels for 19 compounds in nine U.S. locations, 430 Pesticides Office, EPA regulatory programs, 398 Petro-Electric Motors hybrid vehicle contract, 663 Petroleum industry antipollution expenditures, 16 Phenolic condensates Philadelphia Philco-Ford Corp. reverse osmosis modules, 989 Philip Carey Corp. deadline from N.J., 388 Phosphate analysis colorimetric technique for water samples, 411 Phosphate removal carbonate and magnesium ef-fects on, 534 conditions for optimum re-Phosphorus see also eutrophication, nutri-ent'removal levels in 14 Wisconsin lakes, 1113 Photochemical oxidants analytical instrumentation, 678 national air quality standard, 503 resulting from atmospheric hy-drocarbons, 1009 **Photochemical reactions** carbon monoxide role in, 219 literature review, 39 nitrogen balance in, 422 SO<sub>2</sub> to particulate sulfur com-pounds, 685 Photochemical smog oxidants, air quality standards Pittsburgh particulate matter seasonal variations, 155 Plant siting of nuclear power plants, 410 Plastic wastes incineration problems, 667

Princeton Aqua Science BOD monitor, 487 Procter and Gamble Co. tests with NTA, 747 Pyrolysis Garrett process, 487 Landgard, BuMines processes, 310 Radiation exposure 985 new registration procedures proposed, 195 persistence in river waters, 541 persistence of DDT-Toxaphene in Houston watersheds, 141 pyrethrins as insecticide, 745 trends in regulation, 398 Radioactive discharges tritium losses from water ex-posed to atmosphere, 338 TVA starts monitoring, 485 Rat eradication programs mathematical modeling for, 704 Recycling see also more specific listings use of cooling towers, 204 Research-Cottrell, Inc. acquires Oxy-Catalyst Co., 1081 demand for air control devices, 390 air monitoring systems, 1079 air pollution regulations, 388 pollution inspectors denied ac-cess, 196 smoky exhaust control, 985 removal from waste water, 1080 strategies for control of eutro-phication, 1184

# Reserve Mining Co. pollution abatement plan, 101 taconite tailings, 387 Resource Control, Inc. Pennsylvania mine drainage contract, 744

Reverse osmosis experimental data with porous glass membrane, 1032 Philco-Ford units, 989

electrostatic precipitator order, 989

R

controversy over low-level effects, 745 letters, 654, 736 reduction by lake management, 338

Rex Chainbelt, Inc. combined sewer overflow solu-tions, 1080

Rollins-Purle exchanges know-how with Dow, 390

#### ς

Sand filters use in waste water treatment, 1105 Sanitary landfill leachate control by membrane, 663

Scientific Incineration Devices, Inc. N.J. facility, 752

- Sears, Roebuck & Co. phosphate free detergent, 664
- Secondary effluents scheme for classification of odors, tastes, and color, 606 Securities and Exchange Com-mission
- environmental stock listings, 210 Selenium
- detection in lake sediments, 1203 in Wis. lake sediments, 1203 indicator of sulfur pollutants, 74
- Seversky Electronatom Corp. air pollution control system, 305 electrostatic precipitator, 586

Sewage sludge conversion to animal food, 299 pyrolysis, 69

used in making tiles, 1165 waste water treatment use, 69

## mits, 1167 execs meet with EPA on stan-dards, 1161 FPC report on controls, 743 heated water discharges, 1170 power plant use of precipita-tos, 765 Presidential and orders energy message, 577 Preston County Coal and Coke Co. required by W.Va. to phase out operations, 662

- role in organic carbon cycle, 134

- moval from waste waters, 534

- Inc. letter, 381

Nitric oxide

- Polarography differential cathode-ray tech-nique for NTA analysis, 601
  - Pollution control business aerospace companies eye pros-pects, 105 CEQ report optimistic, 743 expenditure survey, 1081 markets for air instruments, 301 new firms registered with SEC, 210

announcements

Pollution control expenditures tax incentives, 577, 672

Power generation air emission standards, 748 atmospheric fate of plumes, 615 construction and operating per-mits, 1167

- Sewage treatment AWT process, 756 Detroit tests pure oxygen, 1079 flush toilet challenged, 11 garmar ardiation, use of, 197 in-flow treatment in combined sewers, 1080 letters on the flush toilet, 281 oxygenation in aerobic digester, phosphate removal processes phosphate removal processes, 15, 288 15, 288 phosphorus removal costs, 1184 shipboard systems, 514 sludge handling, 670 Thiokol process, 756 turnkey proposal by EPA, 1077 use of fish, aquatic plants, and irrigation, 112 Sewers solutions to overflow problem, 1080 Skidmore, Owings & Merrill Hilton Head Island plan, 308 Sludge treatment and handling, 670 high rate freezing at small tem-perature differences, 716 problems in developing practi-cal methods, 716 Smog chambers black light justification, 1218 hydrocarbon photochemical re-activities, 1086 Society of the Plastic Industry, Inc comments on plastics incinera-tion, 667 Soil microbial degradation of herbi-cides in, 426 Solid Waste Management Office, EPA (formerly BSWM) see Environmental Protection Agency Solid wastes BuMines 594 research programs, Lightes research programs, carbon, hydrogen analysis by wet method, 799 ceramics from sludge and glass, 1165 control to be big market, 16 feasibility of recycling, 1161 Franklin, Ohio, recycling sys-tem, 998 incineration of plastics, 667 incineration of scrap film, 389 incineration ash, use as aggre-gate, 197 macroanalysis technique for

gate, 197 macroanalysis technique for carbon and hydrogen, 609 markets for recycled products, 489

489 methane from animal waste, 573, 1069 methods for carbon and hydro-gen analysis, 609 open burning at dumps, 1079 Oregon recycling project, 747 produced in steel industry, 1004

protein from sewage sludge, 299 public utility concept, 752 pyrolysis processes, 310, 487, 654

recycling of cellulose, 299 refuse recycling plant, 109 resource recovery demo grants, 1077

10/7 status of composting, 1088 steam-raising incinerators, 207 steel can recycling, 664 trash separator development,

Wisconsin acts on violating sites, 1079 wood made from scrap, 747

Solubility data sulfates in strong electrolyte so-lutions, 1039

South Dakota water pollution control status, 120

Special reports pest control, 398

Spectra

infrared-sulfur compounds ad-sorbed on Fe and Ni, 155

Spectrophotometric analysis arsenate and phosphate by dif-ference colorimetry, 411 atmospheric fluorides, 550 fluorescence technique for oil spills, 64

Spills, u+ Stack gases CO removal from, 1133 removal of NO., 320 SO<sub>2</sub> removal by modified Claus process, 626 SO<sub>2</sub> removal process, 776, 1191

State Department, U.S. environmental affairs, 750

State government organization of ecology depart-ment, 506

1242 Environmental Science & Technology

States role in water pollution control, 120

Steam Engine Systems Corp. external combustion engine, 197

Steel industry Japanese pollution control, 1167 plans for can recycling, 664 pollution and pollution control, 1004

- Strontium sulfate solubility in strong electrolyte solutions, 1039
- Sugar industry cleanup agreement with EPA, 1167 pollution problems in Hawaii, 1170
- Sulfur
- in coal 978
- Sulfur compounds removal by Fe and Ni, 158
- Sulfur dioxide analytical instrumentation, 678 control in the copper industry, 489
  - national air quality standard, 503
  - 503 oxidation in polluted atmo-spheres, 685 reaction with calcium oxide in stack gases, 1191 reaction with limestone and dolomites, 776 removal by modified Claus pro-cess, 626 removal from smelter gases, 1165

  - 1165
  - review of reactions with other air pollutants, 685

Sulfur dioxide monitoring power plant plumes by aircraft technique, 615

- Sulfur oxides air quality standards, 195 removal from gas streams, 18 removal from stack gases, 37 tax on sulfur content of fuel, 195
- Sulfuric acid plants air emission standards, 748
- Suspended solids analysis empirical method for suspen-sions, 1206
- Swift & Co. electrochemical particle removal, 103

#### т

- Tastes in water supplies classification scheme for, 606
- Tax credits for pollution control letter, 6 steel exec's views, 16
- Taxes on electricity bills, 193, 470
- Technetium-99 role of thyroid system, 344
- Telephone equipment damage effect of atmospheric nitrates on, 781
- Tennessee changes in water law sug-gested, 297
- reopens lake to recreation, 662
- Tennessee-Tombigbee waterway description of project, 581
- Tennessee Valley Authority Johnson City composting plant, 1088
- radiation monitoring, 485 Texas
- water pollution control status, 120
- Thermal pollution Florida case settled out of court, 983
- from om energy sources, 33 generation sources, 33 nuclear power plants, 388, 408 status of effects and regula-tions, 1170 use of heat for irrigation, 580
- Thermodynamic properties peroxyacetyl nitrate (PAN), 443 peroxybenzoyl nitrate (PBN), 443
- Thermo-Systems, Inc. particulate matter monitor, 664
- Thiokol Chemical Corp. sewage treatment process, 756
- Tobacco leaves effects of PAN, 621
- chemical activity of, 249 copper binding activities of, 249
- Toxaphene concentrations in three Wiscon-sin lakes, 230
  - sin lakes, 230 fate of in Houston watersheds,

Trace analysis NTA determination by polarog-raphy, 601

W

Mashington state new environmental depart-ment, 1992 state ecology department, 506 water pollution control status, 1200

Waste discharge permits see also Corps of Engineers, U.S. Army state requirements, 122

Waste lagoons Pennsylvania requires permits, 14

Waste treatment control of recycled solids by ul-trafiltration, 345

Water supplies scheme for classifying odors, tastes, and colors, 606

Western States Geothermal Council

establishment and member-

Westinghouse Corp. wood from plastic and paper scrap, 747

Westinghouse Research Labo-ratories

West Virginia air pollution regulation, 665 cracks down on coke o emissions, 662

Wilson Certified Foods, Inc. packing waste treatment, 590

wisconsin issues abatement orders, 14 legal action on solid waste sites, 1079 new environmental depart-ment, 1092 toxanheae contamination of

toxaphene contamination of lakes in, 230

water pollution control status, 120

z

Zinc in food and water values from 28 institutional diets, 436

Zurn Industries, Inc. enters thermal pollution con-trol field, 1081

W. R. Grace Co. tests with NTA, 747

Wyoming

garbage soaks up oil spills, 987

oven

cooling tower needs, 206

Water treatment

ship, 662

Weather pollution alerts, 1077

Warner Co. membrane for landfills, 663

- Trace elements from human diets, 1047 lab equipment design, 1196 levels for six materials in insti-tutional diets, 436 levels in institutional diets, 1047
- Treasury Department, U.S. tax breaks for control expendi-tures, 672

- Tritium loss from water exposed to at-mosphere, 338
- Tyco Labs, Inc. NO<sub>x</sub> scrubbing process, 324

#### U

electrochemical particle re-moval, 103 in meat packing industry, 590 Ultrafiltration use in biological waste treat-ment facilities, 345 Water pollution see more specific entries Union Carbide Corp. air pollution abatement, 105 Water pollution control amendments to federal law, 302 cyanide removal technique, 1080 Uniroyal Development Co. support for uniform standards, 301 Delaware Valley, 996 electrofiltration development, United States government see name of specific agency electrollitration development, 771 EPA effluent guidelines, 748 federal legal actions, 994 federal legislation priority, 195 in the steel industry, 1004 oil-water separation, 487 President establishes dis-charge permit program, 101 role of the states, 120 role of water reuse, 760 /eter quality University consortia New England air pollution group established, 14 University of Utah Center for Environmental Stud-ies, 301 by mass spectrometric and mis-sion track analysis, 700 monitoring by combination of analytical techniques, 700 Water quality in Great Lakes, 578 Water quality monitoring coastal water project, 1161 EPA views, 992 federal/state network, 114 pollution patrol submarine, 663 reflectance instrument for oil slicks, 356 Urban atmospheres diffusion of aerosols over. 327 U.S. Bureau of Mines oil from coal, 745 pyrolysis process, 310 solid waste programs, 594 U.S. Coast Guard pollution control activities, 512 Water Quality Office, EPA (for-merly FWQA) see also Environmental Protec-U.S. Forest Service pyrethrin insecticide, 745 tion Agency approves state programs, 13 industrial waste inventory, 20 support for cheese whey proj-ect, 396 U.S. Geological Survey national water monitoring net-work, 116 remote sensing project, 676 ect, 350 Water quality standards effluent guidelines, 743, 748 EPA temperature requirements, 170 in New Jersey, Michigan, 985 unresolved issues, 123 U.S. Patent Office results of environmental prior-ity program, 295 U.S. Plywood Co. prosecution for water pollu-tion, 101

- Utah
- air surveillance system, 196 water pollution control status, 120

#### v

- Vegetation hydrogen fluoride effects on, 1128
- Vermont
- erfluent permit system, 485 new environmental depart-ment, 1092 seeks legal aid to clean up Lake Champlain, 102

- Champlain, 102 Viewpoint a challenge to the environmen-tal pro, 11 CEQ: environmental voice at the top, 105 environmental partnership, 74 environmental partnership, 74 no quick and easy solution, 981 presidential reorganization pro-posal, 575 sonke vs. jobs, 659 solid waste management, 293 taxes to support environmental R&D, 193 why must water be barren, 385

- why must water be barren, 385 Vineland Chemical Co. pollution warning from N.J., 388
- Virgin Islands receives WQO grant, 13

air pollution in coal industry, 662 pesticide monitoring program, 985

water pollution control status, 120

Virginia Electric and Power Co. orders electrostatic precipita-tors, 989

Vistron Corp. clean-burning plastic, 669

Virginia

# **ENVIRONMENTAL SCIENCE & TECHNOLOGY READER SERVIC**

If you would like to receive any of the material made available by advertisers in this issue, circle the numbers on one of the attached cards corresponding to the number shown beneath each advertisement. The New Product and New Literature Digests also have corresponding numbers for each item. This is a free service provided by ES&T.

Government

□ Academic

BUSINESS: Other

Volume	5.	Number	12.	December	1971	1243
v orunne	э,	rammer	14,	December	13/1	1243

# ENVIRONMENTAL SCIENCE & TECHNOLOGY READER SERVICE



If you would like to receive any of the material made available by advertisers in this issue, circle the numbers on one of the attached cards corresponding to the number shown beneath each advertisement. The New Product and New Literature Digests also have corresponding numbers for each item. This is a free service provided by ES&T.

1244 Environmental Science & Technology

# Our new gas analyzers practically take man out of the picture

The fewer man-hours spent servicing and operating a gas analyzer, the more money you save. Because man is money.

Which is why our new "simply better" automatic systems save you so much. They practically take man out of the picture. So much so that most systems only require chart paper and pump tubing changed once a month; and more reagent added a few times a year.

Everything else happens

without man. Including automatic calibration up to 12 times a day. Automatic water makeup. And automatic reagent regeneration and recirculation.

You spend little or no time on maintenance either. Because of fewer but better components. And separate chemical and power packs that simply plug together, so you can change or replace either in seconds. The chemical packs come in models for O<sub>3</sub>/SO<sub>2</sub>, SO<sub>2</sub>/Aldehydes, NO/NO<sub>2</sub>/NO<sub>3</sub>; and operate from either an automatic or manual power pack.

All use fast, proven chemical measurement methods, such as our patented Schulze nitrogen-dioxide analysis.

Expensive? Hardly. Automatic systems start at \$3200. Manual at \$1775.

For the facts on these new "simply better" gas analyzer systems, call or write. Find out how you can practically take man out of your picture.

#### the simply better gas analyzers from





4114 N. Ravenswood Ave., Chicago, III. 60613 Phone: 312-327-4520 / Cable ATELDECO Circle No. 1 on Readers' Service Card

# Polluted air isn't new.

# But our chromatograph is – and it meets the new standards for measuring some big dangers.

The miner's canary gave way long ago to more accurate monitoring devices. And today, even some modern methods face the same outmoding.

Why? The new Federal ambient air quality standards. They're explicit and stringent. And traditional techniques

explicit and stringent. And traditional techniques just can't do what our new Model 6800 Air Quality Chromatograph does—namely, make accurate interference-free measurements of CO, methane, and total hydrocarbons, including optional measurements for ethylene and acetylene. From 0-1 ppm full scale for each pollutant.

This new instrument, using an advanced method developed at NAPCA, actually exceeds Federal selectivity and sensitivity standards. Its CO detection range reaches limits that infrared analyzers can't. And it identifies reactive hydrocarbons – not possible with previously established techniques.

Its measurements are totally free of interference from water vapor or other atmospheric pollutants.



What's more, you'll appreciate the long-term, unattended operation. The instrument automatically monitors, zero-calibrates, infroduces calibration standard, and provides signal output to recorders and/or data acquisition equipment. Such unattended

operation is a Beckman feature in chromatography, field-proven by thousands of our industrial chromatographs in plants around the world.

And the new 6800 is just one more result of our 15 years of air quality monitoring experience and leadership in industrial process chromatography. Learn more about this exceptional instrument. Write for Data File AP-3-172



HELPING SCIENCE AND INDUSTRY IMPROVE THE QUALITY OF LIFE. Circle No. 21 on Readers' Service Card

