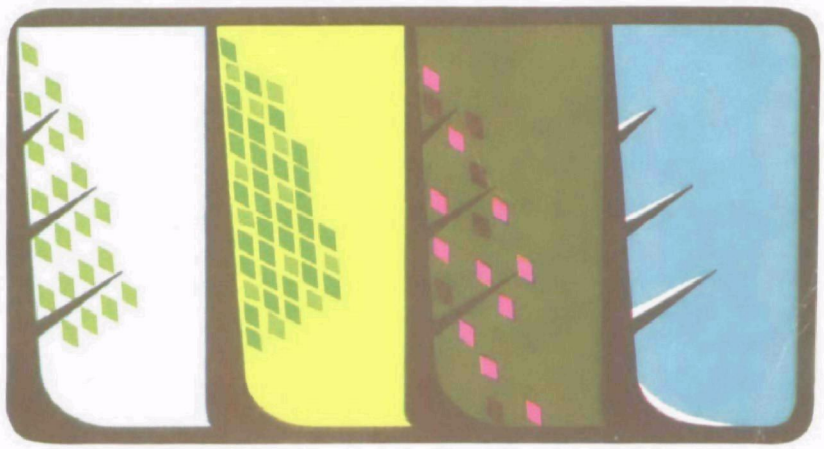
ENVIRONMENTAL RESEARCH IN 1973

ANNUAL REPORT



U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL ENVIRONMENTAL RESEARCH CENTER
CINCINNATI, OHIO 45268

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ENVIRONMENTAL RESEARCH IN 1973

Annual Report

National Environmental Research Center
Cincinnati, Ohio

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
National Environmental Research Center
Cincinnati, Ohio 45268

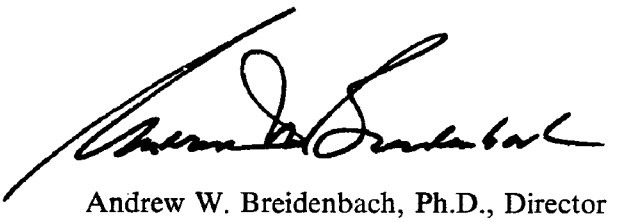
REVIEW NOTICE

This report has been reviewed by the National Environmental Research Center, Cincinnati, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The research program of the National Environmental Research Center in Cincinnati, Ohio, is directed toward solving major environmental problems in wastewater management and treatment, drinking water, solid wastes, toxicants from automobile exhaust and other sources, industrial and hazardous waste management and control, radioactivity emissions from nuclear power plants, and methods development and quality assurance. The work of the Center is principally governed by legislative mandates.

In this, the Second Annual Report of the National Environmental Research Center, the programs are described and progress during 1973 is delineated. Articles on various specific projects provide some detailed results of research progress. Interrelationships of programs within NERC-Cincinnati and the other three NERC's are coordinated to ensure maximum usage of results. Contacts with scientists and grant projects in foreign countries assure that the research program is of international significance. Hopefully, the information presented here will contribute to bettering our environment.



Andrew W. Breidenbach, Ph.D., Director
National Environmental Research Center
Cincinnati, Ohio

OFFICE OF THE DIRECTOR

IMMEDIATE OFFICE OF THE DIRECTOR

During 1973, the Office of the Director undertook the accomplishment of a vigorous set of goals which, when accomplished, were designed to strengthen the National Environmental Research Center-Cincinnati (NERC-Cincinnati) both administratively and technically. Accomplishing the goals called for numerous scheduled events or milestones to be completed. These accomplishments are grouped here in several broad categories.

Improvement of the Personnel Management Program

In this area, several significant achievements were made during the year. Because funding and positions in the Solid Waste Research Laboratory and in other areas were reduced or reallocated, a significant overage of positions had accumulated. During the year, this entire overage situation was eliminated by the outplacement or reassignment of the individuals involved, without resorting to reductions in force or other more drastic measures.

Grade ceilings for clerical and secretarial personnel were established, a policy was developed for the use of temporary and all other nonpermanent full-time personnel, and an executive development training program was established for all supervisory personnel. To establish a vigorous training program for the Center, the Director appointed a task group to recommend a viable training program. This program has been adopted, and its implementation is now underway.

Achievement of Interim/Optimum Use of Facilities

To obtain more economical use of facilities and personnel, several small outlying laboratories were consolidated into the Cincinnati complex. The personnel and functions of the Water Supply Research Laboratories in Gig Harbor, Washington; Dauphin Island, Alabama; and Narragansett, Rhode Island, were transferred to Cincinnati, Ohio, and the vacated facilities released for United States Environmental Protection Agency (EPA) or other Federal use. A considerable savings in manpower, especially in the support areas, was realized by this move.

During this period, a task group appointed by the Director examined the use of our presently occupied space, and as a result, numerous changes in space assignments took place. Space assignment will be under continuous surveillance to ensure we are making optimum use of laboratories, offices, and other space. With completion of the new research facility at the University of Cincinnati now only 2 years away, proposed space assignments in it are being studied and evaluated to ensure the best use of the new space as well as that of the Robert A. Taft Research Laboratory after occupancy of the new building.

Expansion of Working Relationships with the University of Cincinnati

To achieve a closer working relationship with the University of Cincinnati (U.C.) and to bring about a savings in resources, the services common to both institutions are constantly being examined for possible sharing. During 1973, the University and NERC-Cincinnati entered into a computer software service contract. Under it, the University provides NERC-Cincinnati with scientific computer programming, data processing, consulting service, and aid in laboratory automation projects.

To provide an instrument through which common interests of professional personnel of the two institutions could be beneficially explored, symposium INTERACT took place on December 11 and 12, 1972, on the campus of the University of Cincinnati. This symposium was planned by a joint subcommittee of the NERC/U.C. Linking Pin Committee appointed by the Director of NERC and the President of U.C. The symposium brought together professionals from a wide variety of disciplines. Each presented his own interest and sometimes those of departments or programs with which he was associated.

During the fall of 1973, a series of graduate seminars in science and engineering was presented by NERC-Cincinnati and the College of Engineering. Subjects covered during this series were: Pollution in the Environment; Effluent Standards Strategy — Rejuvenation of an Old Game Plan; Advanced Waste

Treatment; Asbestos in the Environment; Allergenic Pollutants in the Air and Water Environments; Processing and Disposal of Sludges; New Atmospheric Pollutants from Automobile Catalytic Converters; Barriers to the Enforcement of Water Pollution Laws at the Local and National Level; and Management of Oil and Hazardous Material Spills.

During two 2-week periods in midsummer, June 17-30 and July 8-21, NERC-Cincinnati and the University, in cooperation with the Cincinnati Federal Executive Board and the Cincinnati Public Schools, sponsored a Summer Institute in Environmental Education. This Institute was designed to assist junior and senior high school science teachers develop environmental studies curricula. Each of the two sessions was limited to 30 secondary science teachers from Ohio, Kentucky, Indiana, West Virginia, Southern Illinois, and Western Pennsylvania. The Institute was funded by a grant from EPA to the University's Department of Civil and Environmental Engineering.

Strengthening of Staff Offices in the Office of the Director and Providing for Additional Services to Operating Research Laboratories

One of the prime goals of the Director's Office during 1973 was to prepare and have accepted a viable reorganization plan. A task force, appointed by the Director, submitted a reorganization proposal, and after several revisions, the plan was submitted to EPA Headquarters for approval. The plan was approved on September 14, 1973, and its implementation is now underway. A more detailed explanation of this reorganization is in the discussion of the Program Coordination Office.

Another major NERC-Cincinnati goal accomplished during 1973 was establishing a closer relationship with the EPA Regional Offices. During the year, the Director and persons from his staff and from the various NERC-Cincinnati laboratories planned and carried out a series of visits to each Region. The visits were designed to increase communication with the Regions and to build stronger and more responsive working relationships.

During the year, the Director's Office procured two valuable research "tools" for the use of all laboratories. The first was a closed-circuit, color television system capable of creating live or taped-on-site video presentations. The unit will be used for surveillance of laboratory research projects and for creating technical and nontechnical presentations for distribution throughout the country. The second is the purchase of a JEOL Model JEM 100B electron microscope. This microscope, which is equipped for scanning or transmission work, also allows for the use of energy dispersive techniques. Acquiring these items gives the NERC-Cincinnati researchers the very latest state-of-the-art tools to conduct their research. Purchasing these items would have been too costly for individual laboratories; their purchase by the Director's Office allows for more uniform use and availability to all laboratories regardless of their financial resources.

PROGRAM COORDINATION OFFICE

Two themes dominated the Program Coordination Office (PCO) efforts in 1973: reorganization and research program coordination. A summary of each is described below:

Reorganization

In March 1972, Dr. Breidenbach formed an Organizational Task Force composed primarily of key EPA Office of Research and Development (OR&D) personnel and outside consultants to recommend a new NERC-Cincinnati organization. The PCO was the staff arm of the Task Force. After review and modification, Dr. Breidenbach submitted an organizational plan to the Assistant Administrator for Research and Development that carefully preserved strengths of the current organization and recommended new organizational approaches to the dynamic OR&D program. The new organization:

- creates an Industrial Waste Treatment Research Laboratory, using the present Edison Water Quality Research Laboratory as a base, supplemented by transfer of the Mine Drainage Program;
- forms a Methods Development and Quality Assurance Research Laboratory that combines the present Analytical Quality Control Laboratory, Radiochemistry and Nuclear Engineering Research Laboratory, and present virology functions of the Advanced Waste Treatment Research Laboratory;
- consolidates all municipal treatment water research activities by reassigning the Edison-based Storm and Combined Sewer Branch to the Advanced Waste Treatment Research Laboratory;
- retains the Environmental Toxicology Research Laboratory, the Solid and Hazardous Waste Research Laboratory, and the Water Supply Research Laboratory with only internal changes;
- directs significant internal branch changes within the laboratories to consolidate like responsibilities and efforts and to eliminate overlaps.

Major advantages of the new organization, which was activated in October 1973, are a unification of industrial waste research efforts, consolidation of analytical methods and monitoring from three laboratories into one, increased interaction of the Program Area Managers and the Program Element Di-

rectors through eliminating multi-laboratory program element responsibilities, and an overall improvement of intralaboratory organization.

Research Program Coordination

Significant strides were made to improve and refine NERC-Cincinnati research efforts: intensive Research Objectives Achievement Program (ROAP) examinations enabled PCO to recommend specific actions to reduce duplication and coordinate interfaces; management reporting system was designed and implemented during the fiscal year; research project report was compiled and distributed to provide all levels of management with an effective ready reference for the hundreds of ongoing tasks at NERC-Cincinnati; rational system for prioritizing research needs was designed and successfully applied to almost 500 NERC-Cincinnati generated needs; monthly resources capsule report has been initiated to provide the NERC-Cincinnati Director with critical data extracted from a variety of information sources. PCO has responded to a number of requests for information including potential research to be funded by foreign currency programs, FY-75 legislative needs, equipment inventory evaluation, OR&D overhead review, and many other items. Budgeting figures and expenditures are channelled through this office (Tables 1 and 2; Figures 1-3).

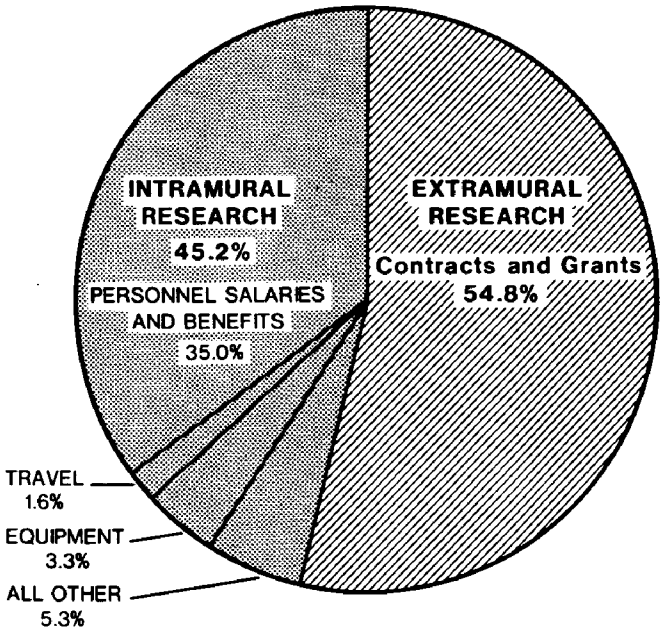


FIGURE 1. WHERE THE NERC-CINCINNATI DOLLAR GOES. PERCENTAGES ARE BASED ON THE FY 1973 NERC-CINCINNATI RESEARCH BUDGET.

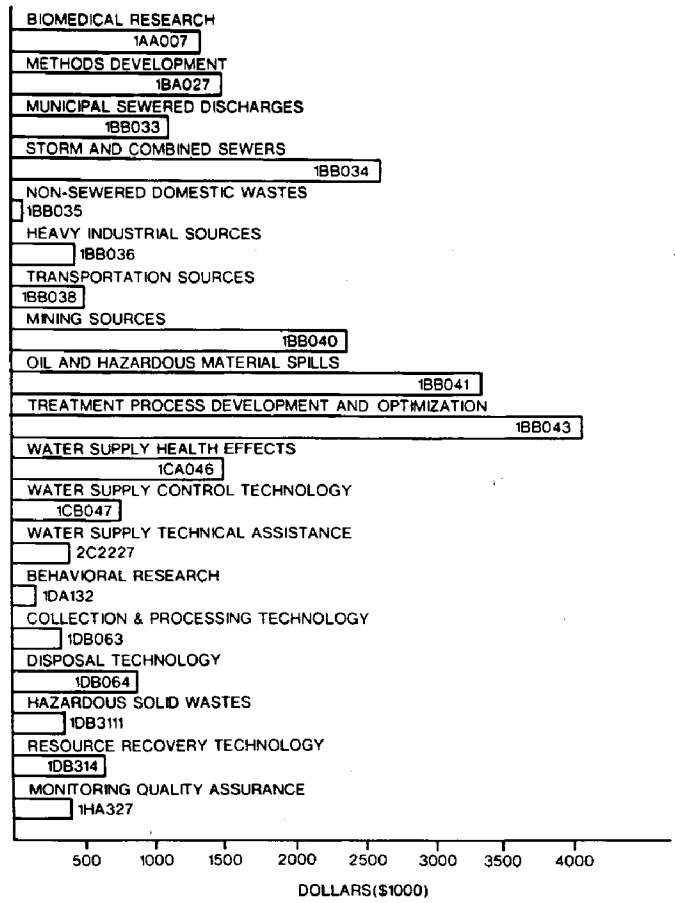


FIGURE 2. NERC-CINCINNATI FY 1973 LEVELS OF EFFORT (IN $1000) BY PROGRAM ELEMENT.

PUBLIC AFFAIRS OFFICE

New Facility

The Public Affairs Office (PAO) continued to keep the NERC-Cincinnati employees informed as to the progress of the new facility near the University of Cincinnati through Progress Report bulletins. The mailing list for these bulletins included not only regional and national media but also interested members of both Houses of Congress. The President's scheduling office was informed and acknowledged receipt of a June 1975 completion date.

Open House

During Earth Week, NERC-Cincinnati sponsored an extremely successful Open House at the Taft Laboratory, which featured guided tours, literature displays, exhibits, movies, and slides. It was decided that the Open House, which was attended by over 700 individuals of all ages, will be continued on at least a semiannual basis. It provides an excellent vehicle through which to acquaint high school students with environmental problems and their solutions. Media coverage for the event was excellent.

TABLE 1. NERC-CINCINNATI BUDGET FOR FY 1973 (in $1000)

Laboratory/Office	Intramural	Extramural	Total
OFFICE OF THE DIRECTOR	$ 771	$ —	$ 771
ADVANCED WASTE TREATMENT RESEARCH LABORATORY			
Treatment process development	1,980	2,028	4,008
Mining sources of pollution	416	1,898	2,314
Municipal sewered discharges	294	814	1,108
Methods development	222	275	497
Nonsewered domestic wastes	42	—	42
Total	2,954	5,015	7,969
ANALYTICAL QUALITY CONTROL LABORATORY			
Methods development	917	64	981
Methods standardization	263	—	263
Total	1,180	64	1,244
EDISON WATER QUALITY RESEARCH LABORATORY			
Oil and hazardous material spills	525	2,781	3,306
Storm and combined sewers	161	2,408	2,569
Transportation sources of pollution	84	417	501
Heavy industrial sources of pollution	96	311	407
Total	866	5,917	6,783
ENVIRONMENTAL TOXICOLOGY RESEARCH LABORATORY			
Biomedical research	1,120	225	1,345
RADIOCHEMISTRY & NUCLEAR ENGINEERING RESEARCH LABORATORY			
Radiochemical measurements	136	—	136
SOLID WASTE RESEARCH LABORATORY			
Disposal technology	464	397	861
Resource recovery	264	356	620
Hazardous solid wastes	94	284	378
Collection/processing technology	146	170	316
Behavioral research	135	—	135
Total	1,103	1,207	2,310
WATER SUPPLY RESEARCH LABORATORY			
Health effects	1,316	178	1,494
Control technology	634	110	744
Technical assistance	393	—	393
Total	2,343	288	2,631
Total NERC-Cincinnati	10,473	12,716	23,189

TABLE 2. NERC-CINCINNATI BUDGET FOR FY 1974 (in $1000)

Laboratory/Office	Intramural	Extramural	Total
OFFICE OF THE DIRECTOR	$ 769	$ —	$ 769
ADVANCED WASTE TREATMENT RESEARCH LABORATORY			
Treatment process development	2,435	2,210	4,645
Storm and combined sewers	163	1,734	1,897
Municipal sewered discharges	315	360	675
Nonsewered domestic wastes	63	300	363
Total	2,976	4,604	7,580
ENVIRONMENTAL TOXICOLOGY RESEARCH LABORATORY			
Biomedical research	1,185	125	1,310
INDUSTRIAL WASTE TREATMENT RESEARCH LABORATORY			
Oil and hazardous material spills	1,007	2,157	3,164
Mining sources of pollution	488	1,540	2,028
Heavy industrial sources	204	505	709
Transportation sources	32	19	51
Total	1,731	4,221	5,952
METHODS DEVELOPMENT AND QUALITY ASSURANCE RESEARCH LABORATORY			
Methods development	1,150	365	1,515
Monitoring quality assurance	384	—	384
Total	1,534	365	1,899
SOLID AND HAZARDOUS WASTE RESEARCH LABORATORY			
Disposal technology	299	663	962
Collection/processing technology	89	385	474
Hazardous solid wastes	85	210	295
Behavioral research	65	—	65
Total	538	1,258	1,796
WATER SUPPLY RESEARCH LABORATORY			
Health effects	1,529	379	1,908
Control technology	440	140	580
Technical assistance	403	—	403
Total	2,372	519	2,891
Total NERC-Cincinnati	11,105	11,092	22,197

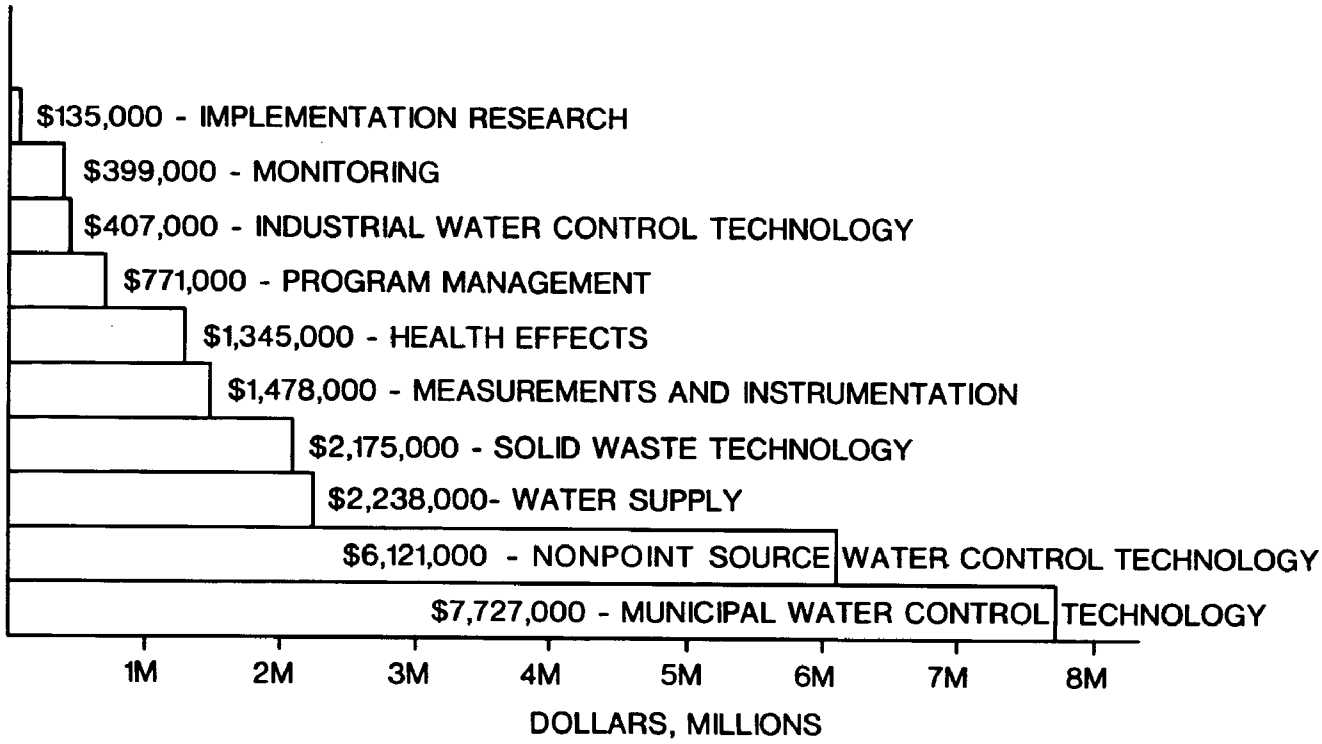


FIGURE 3. EXPENDITURES BY PROGRAM AREA AT NERC-CINCINNATI IN FY 1973.

Foreign Visitors

PAO increased its participation in the handling, scheduling, and media exposure of important visitors to the NERC-Cincinnati facilities. Of particular note were the Japanese teams for Mission on Environmental Issues, the German Ministry of Interior, the Water Conservation Delegation from the Peoples Republic of China, and two groups of scientists from the Soviet Union. (The section on International Activities discusses the foreign visitors in detail.)

Federal Executive Board

In 1973, the Director of PAO took on the additional duties of the Public Affairs Officer for the Cincinnati Federal Executive Board (FEB). Highlights of these FEB activities included a Consumer Fair at Tri-County Shopping Center, Federal Employees' Day at Kings Island, and support given the Cost of Living Council regional meeting. As PAO of NERC-Cincinnati and of the FEB, the PAO also assisted with the Summer Institute in Environmental Education at the University of Cincinnati; the teachers who attended the sessions have been contacted and offered assistance so that effective courses in environmental education can be made available in their classes.

Liaison

The PAO, by maintaining and developing contacts in EPA offices in Washington and the Regions, has been able to keep Dr. Breidenbach informed on current issues. The contacts and liaison developed with the Cincinnati Chamber of Commerce, local officials, Congressional delegation, and the White House have been continued throughout 1973.

CIVIL RIGHTS AND URBAN AFFAIRS OFFICE

During 1973, the Civil Rights and Urban Affairs Office (CRUAO), in cooperation with the Personnel Management Division, conducted an Equal Employment Opportunity (EEO) Seminar for managers and supervisors acquainting the participants with the primary objectives of the equal employment opportunity objectives of NERC-Cincinnati. Most managers and supervisors attended the seminar. This initial EEO Seminar launched a management training program that, by year's end, had exposed all of NERC-Cincinnati management and many of its supervisory personnel to specific management training in many diverse areas. The overall result has been an intensified effort to amplify management's commitment to equal opportunity in several areas: recruitment and placement of minorities and women in University of Cincinnati co-op positions at NERC-Cincinnati and greater participation in special program areas such as Summer Aid Program (62 students) and Stay-In-School Program (10 students). These programs provide part-time employment for college students and disadvantaged

high school youth whose education might otherwise be curtailed without the funds provided by these jobs. Similarly, valuable on-the-job training aids in the maturing process of the young people.

CRUAO participated in Wilberforce University's 2nd Annual Career Symposium by providing a workshop acquainting co-op students with the role of the Federal government as an employer, career opportunities with EPA, and their responsibilities in the community and in the world of work.

CRUAO assisted EPA's Mobile Source Pollution Control Laboratory (MSPCL), Ann Arbor, Michigan, in establishing an EEO Program. The MSPCL management staff was very receptive to the objectives of the EEO team conducting the initial training sessions.

As the initial phase of the NERC-Cincinnati Upward Mobility Program, a Skills Inventory Survey was conducted among employees in grades GS-1 through 7 and WG-1 through 5 to assess the under-utilized skills available in the workforce. The second phase involved career counseling of the participating employees to obtain more specific information about their aspirations and goals. During FY 1974, the third phase will take place — discussions between career counselors and supervisors to ascertain the feasibility of training employees or the type of training that will enable employees who qualify to participate in phase four. With the approval of the U.S. Civil Service Commission, phase four will establish the Upward Mobility Program that will set-up "bridge positions" and "career ladders" to enhance promotional opportunities at NERC-Cincinnati.

OFFICE OF ADMINISTRATION*

The Office of Administration (OA), with 133 employees, provides support services to the NERC-Cincinnati, other EPA organizations located in Cincinnati, and various installations not in Cincinnati. The services include personnel, contracting, facilities management, safety, library, financial management, and computer services and systems.

In addition to the day-to-day support services listed above, the OA is active in efforts to develop EPA's relationship with other sectors of the scientific community and the local universities. An example of our continuing effort to work as a part of the Cincinnati community is our sponsorship of a Junior Achievement Company during the past year. This company, Terramco, was composed of local youth and was given support and advice by a four-person EPA team of volunteers.

During the year, the relationship between EPA and U.C. has strengthened and grown — to the mutual benefit of both organizations. A specific example of a joint activity sponsored by both organizations (through the Linking Pin Committee whose formation the OA had spearheaded) would be the INTERACT symposium. This symposium was held to encourage personnel from both organizations to become better acquainted; this, in turn, will lead to increased sharing of scientific knowledge.

Other U.C.-EPA joint activities involving the OA include hiring of U.C. students through a Cooperative Agreement and a College Work-Study Agreement; the University's use of noted EPA scientists as Adjunct Professors to teach at U.C.; and the EPA-funded - U.C.-sponsored Summer Environmental Education Institute.

In addition to the nonroutine accomplishments of the Office highlighted above, each Division in Administration has made headway in significant areas during the year. These accomplishments are presented in the following narrative.

Personnel Management

The Personnel Management office made many breakthroughs in 1973 that are helping EPA in Cincinnati to operate more smoothly and productively. Our new Suggestion System has resulted in a 100 percent increase in the number of suggestions. A suggestion to modify lighting fixture panels at the Ridge facility netted us a $39,000 savings in replacement costs of the fixtures. The Personnel office facilitated the hiring, during the summer, of 100 high school students to work in our various laboratories. A new use was made of the Intergovernmental Personnel Act: employees were temporarily assigned from a Federal agency to State and local governments. In the past, the Act has only been used to assign personnel from State and local governments to Federal agencies. The advantage of these assignments is that talents of high quality, skilled employees may be shared.

Computer Services and Systems

The Computer Services and Systems division operates the EPA-Cincinnati Computer Center, which provides a full range of computer services. A significant project, initiated by the division, is a long-range plan to develop a total, computerized, laboratory automation system for EPA laboratories in Cincinnati. This system will improve both the quantity and quality of work in the labs as well as provide new and improved research capabilities.

*The organizational relationship of the Office of Administration to Headquarters is through the Deputy Assistant Administrator for Administration, Assistant Administrator for Planning and Management, U. S. Environmental Protection Agency.

This developmental effort is expected to have general application throughout EPA, and as part of this project, a continuing education program on laboratory automation topics is being coordinated by the division.

Financial Management

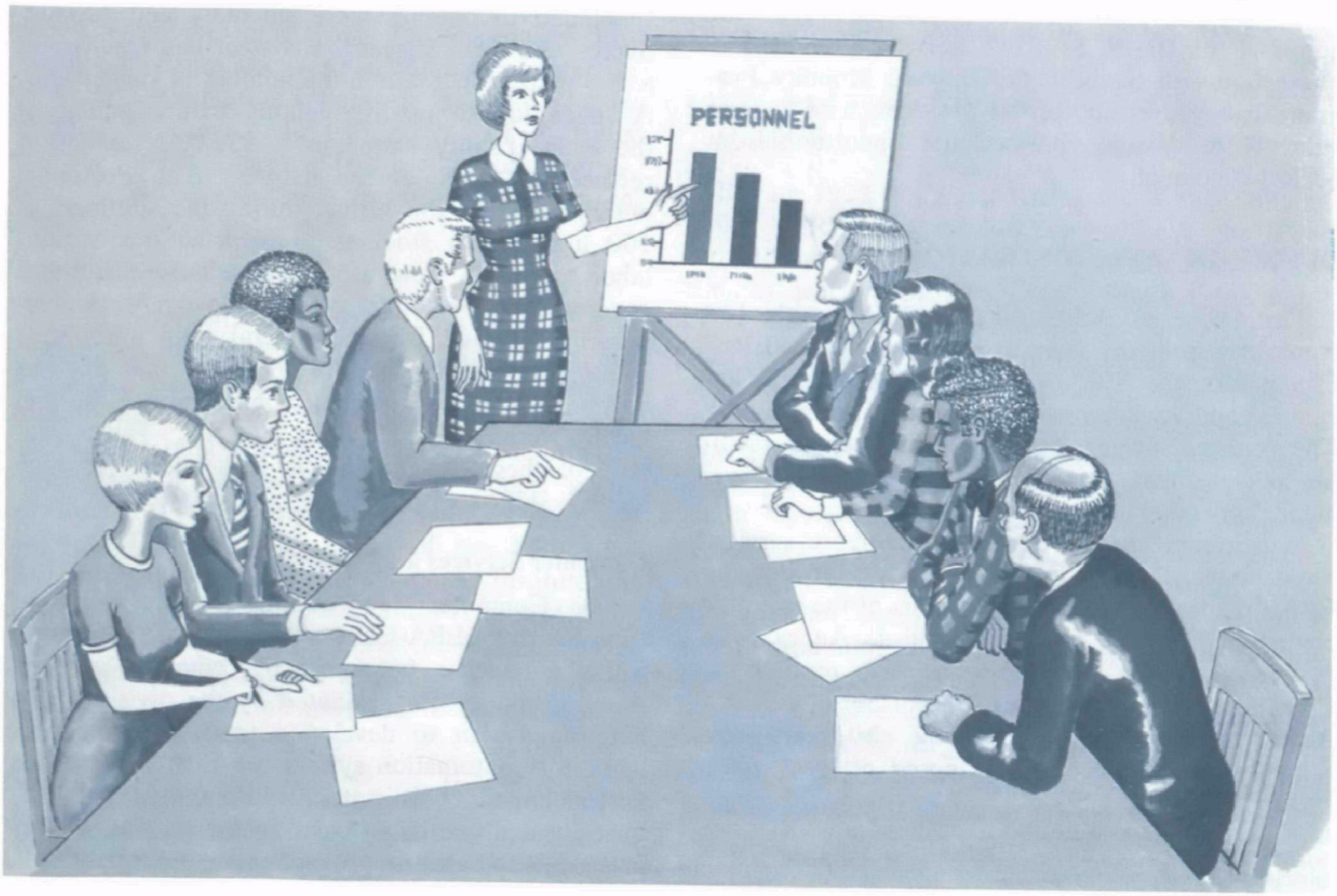
Our Financial Management branch has been able, in the past year, to sort through the bushels of financial data coming to them daily and still have the initiative to institute new and more efficient systems to control funds and pay the Agency's bills. The branch developed a reporting system for travel advances to employees that allows outstanding individual travel advances to be reported in a number of different formats. The improved reporting has enabled a closer review of fund control on advances and has permitted the EPA research programs to have access to this hitherto unavailable information. Another major improvement in the finance area, which added new responsibilities to the branch, resulted from the Agency's integration of record keeping, financial reporting, and fund control processes. The new system, which was successfully put into operation in Cincinnati, made mechanized record keeping accessible to the research programs and, thereby, made possible more accuracy and savings in the manhours spent on record keeping.

Library

This year the Library has automated many of its operations — the book catalog, original cataloging, the circulation system, and various mailing and file records. The advantage of automation is that accuracy is increased and labor costs are reduced. In fact, even with a two-position decrease in personnel, the services to the Cincinnati and to the other EPA laboratories across the country supported by the NERC-Cincinnati Library have increased. Perhaps the most important service that has been automated is searching literature for document titles. Through this service, the time normally spent by researchers hunting through journals for information needed to perform their work is significantly reduced. Over 2,000 computerized searches were performed by the Library last year — more than was performed by any other Federal agency.

Contracts Management

The Contracts Management division provides support to EPA laboratories in Las Vegas, Nevada; Corvallis, Oregon; and Ann Arbor, Michigan, in addition to EPA-Cincinnati. The workload of the other-than-Cincinnati labs has largely been taken on without a proportionate increase in personnel. Because of this, the Division has been highly re-



sourceful this year in finding and implementing mechanisms to decrease the workload without decreasing the quality of work. Two of these mechanisms are of most importance: intensive training courses for contracts personnel and development of the oral purchase order procedure. The training courses serve to increase each employee's productivity without increasing the hours worked. The oral purchase order procedure, for low-dollar-value purchases, serves four functions, all of which save time and money: vendor response is immediate; typing of orders and purchasing agent reviews are eliminated; mailing orders to vendors is eliminated; and clerical efforts can be diverted to other needed areas. The procedure has already saved at least 2 man-years of effort at NERC-Cincinnati. All other major purchasing offices in EPA are now using the procedure, to a similar benefit.

The New NERC-Cincinnati Facility

The estimated completion date of the new EPA facility, located adjacent to the U.C. campus, is still projected for July of 1975.

All EPA personnel in the Ridge facility, Laidlaw facility, Broadway facility, Federal Office Building, and the Virginia Avenue and the Center Hill facilities will relocate to either the Robert A. Taft Laboratory or the new facility.

The new facility is a 10-story structure, rising 8 stories above grade, in the southeast sector of an almost rectangular 20-acre tract in the Corryville section of Cincinnati, Ohio. The site, which is bounded by Nixon, Vine, and St. Clair Streets, and the rear property line of houses on Bishop Street is strategically located between the main campus of the University of Cincinnati on the southwest and the hospital-medical complex, dominated by the Cincinnati General Hospital, on the northeast. The site straddles a ridge that extends diagonally through the site in a northwesterly direction toward the Mill Creek Valley.

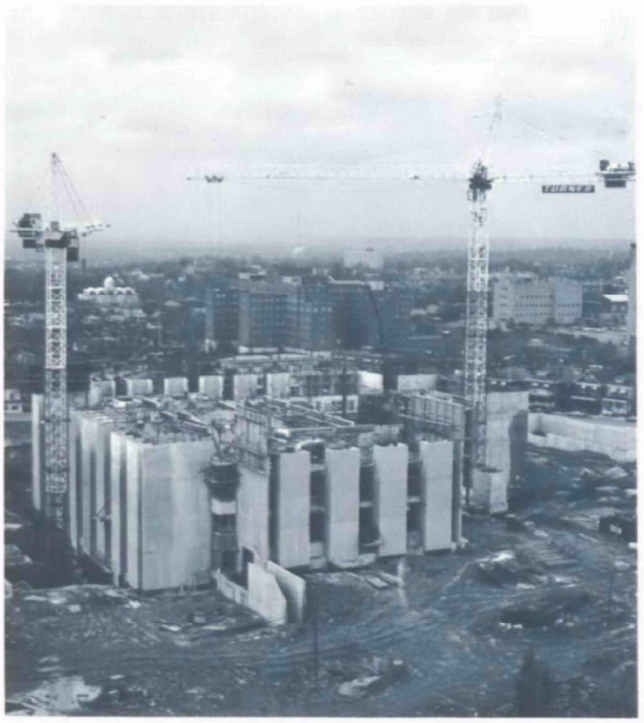
The building will be located on the ridge at the highest point of the site to take advantage of the view afforded in all directions. The apex of the L-shaped high-rise section is close to the center of the site, with the wings extending to the east and south. In this location, the building will serve as a focal point for motorists going northward along Jefferson Avenue. The main entrance road will extend northward from St. Clair Street opposite Jefferson Avenue, at the south boundary of the site.

The needed parking space will be separated into five areas, two of which, at the west side of the site, can be enlarged to accompany future expansion of the facility. Access to the main employees' entrance will be across a paved terrace outside the

October

November

December



January, 1974

apex of the buildings. Pedestrian walkways extend from this terrace to the parking areas, and westward toward adjacent Burnet Woods.

The main L-shaped building is based upon the concept of a 10-foot by 23-foot module. Certain special functional spaces between the wings of the main building, such as the computer room and the library, are based on a 5-foot-square module.

Each module is adjacent to a central service core or to an exterior vertical chase. All exhaust ducts, all service piping for liquids and gases, and all electrical feeders for service to laboratory furniture and equipment are located in the cores and chases, which will be sized and arranged for required maintenance, additions, and modifications to the piping and ductwork and to the electrical system. Supply air to laboratory modules is from main ducts in circulation corridors. A separate air supply from ducts in the service cores and vertical chases is provided for auxiliary air-type fume hoods. In addition, vertical chases contain laboratory waste and vent lines, and piping for cold water, hot water, natural gas, vacuuming, compressed air, and (in some chases) steam and condensate. Similar facilities, plus distilled water, are provided in the central service cores where additional space will be available for unforeseen additions and changes to piping, duct, and electrical systems.

Future expansion is planned as two 4-story buildings located to the north and west of the main building, as indicated on the site plan. These buildings will provide an additional 50 percent or more space. Placement of the expansion buildings parallel to and approximately 65 feet away from the main building will minimize disturbance to the main building during their construction. Their location will define the paved entry court that will provide the access for all three building units. The expansion units would also have entrances from adjacent parking areas and would be linked to the main building by bridges at an upper floor. The space between the main building and the expansion units would be treated as courtyard space.

During the early months of construction in 1973 (January, February, March, and April), an unusual amount of rain slowed the progress of the new facility considerably. In the last 4 months, the weather has cooperated and almost unbelievable progress has been made. The building is well out of the ground. The floor slabs for the first four floors have been completed.

The Program of Requirements for the unassigned space in this facility has been completed. This study identifies the needs of each program as to the amount

of space (laboratory, office, and special purpose), configuration of the space, and also the type of laboratory furniture required. The architect/engineer is now in the process of revising the construction drawings to agree with the new Program of Requirements. These drawings are scheduled for completion in January 1974, and at that time, everyone will be able to see exactly where he or she will be located in the new building.

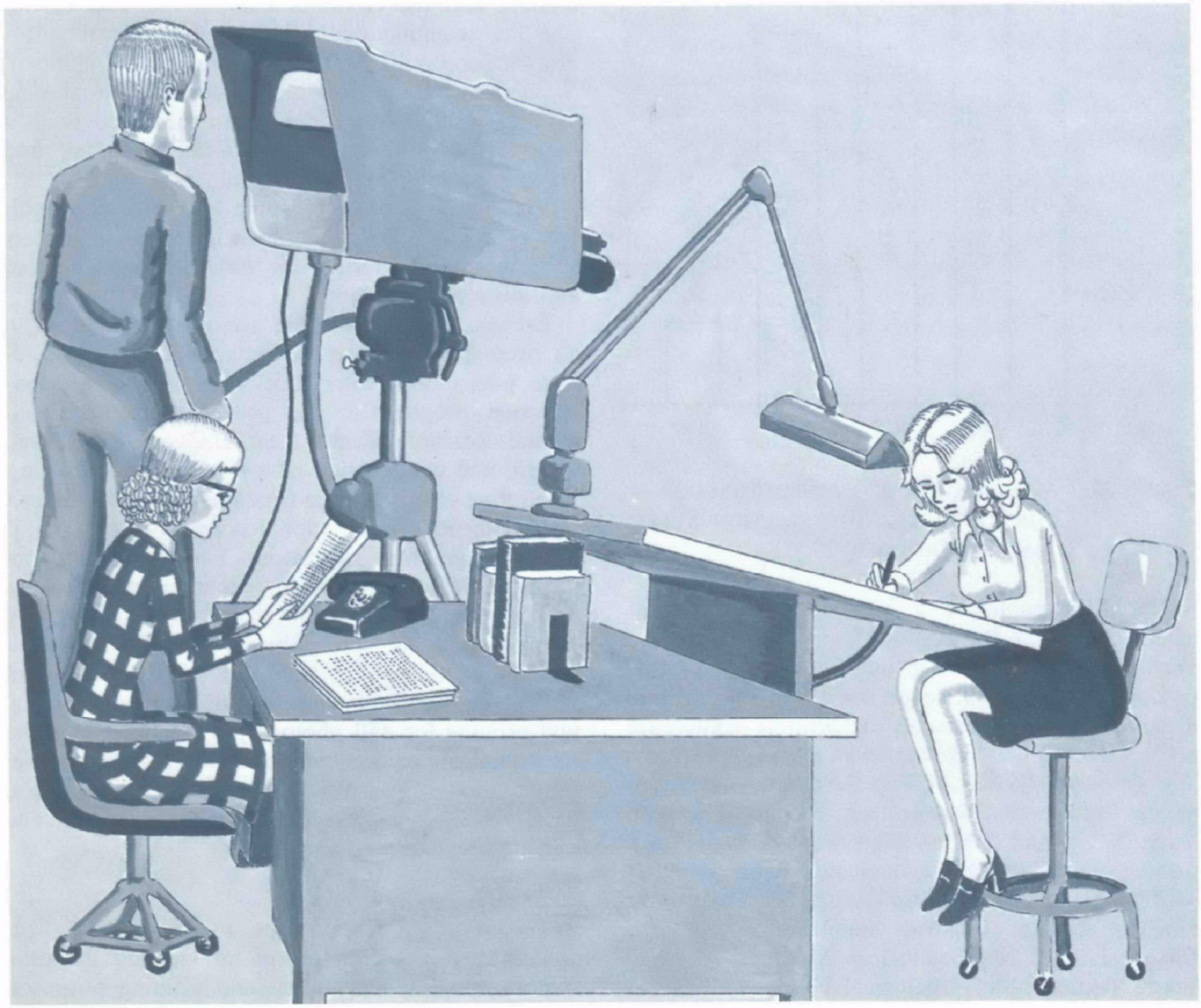
TECHNICAL INFORMATION OFFICE

Research without communication is like bottling the product and then not distributing it. The aim of the Technical Information Office (TIO) of NERC-Cincinnati is to aid this communication process through its three continuing services — editorial, graphics, and television. The TIO seeks to inform the technical and scientific communities of industry, government, and education of the research performed at NERC-Cincinnati in its programs related to advanced waste treatment, environmental toxicology (air), industrial waste treatment, methods development and quality assurance, solid and hazardous waste, and water supply.

Editorial and Publications

The editorial staff is responsible for editing and evaluating manuscripts intended as reports, symposia proceedings, and journal articles. It coordinates the issuance of the reports from the inception phase to the printing process and through to the final production. It provides policy guidelines and coordinates final clearance for all NERC-Cincinnati publications.

During the year, the TIO has edited and cleared 245 publications resulting from contracts, grants, and in-house studies (Figure 4). Close liaison was maintained with the Printing Specialist (Facilities Management & Services Division) who arranged for



the prompt and effective composition and printing of research publications.

In May 1973, "News of Environmental Research in Cincinnati," a pertinent fact sheet of the environmental research being conducted in Cincinnati, was started. Fourteen issues have been published; each outlines various research efforts of the NERC-Cincinnati laboratories and describes how they are being handled. The reception given this publication has been gratifying, as individual requests have continued to increase since its inception. These requests and mailing lists for mass mailings are handled from the Publications Distribution Unit of the TIO.

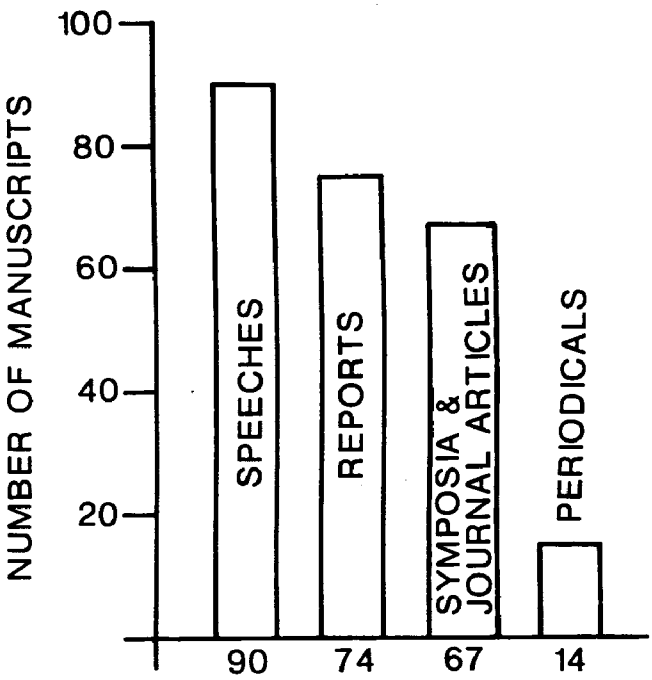


FIGURE 4. MANUSCRIPTS PROCESSED THROUGH THE TECHNICAL INFORMATION STAFF, JANUARY-OCTOBER 1973.

The TIO published a bibliography, "Environmental Research Publications," listing reports and publications of NERC-Cincinnati. It compiled and prepared the "Annual Report for 1972" and assisted in compiling and preparing for printing conference proceedings on the "Cycling and Control of Metals"; "Symposium INTERACT"; "National Environmental Information Symposium, Summary Report, Volume 1"; and "Proceedings Second U.S.-Japan Conference on Sewage Technology." Three manuals — "Procedures for the Radiochemical Analysis of Nuclear Reactor Aqueous Solutions"; "Physical, Chemical, and Microbiological Methods of Solid Waste Testing"; and "Biological Field and Laboratory Methods for Measuring Water Quality" — were edited and published.

Editorial and graphics assistance was given to the EPA's Office of Planning and Evaluation for the "Clean Water - Report to Congress, 1973," a report transmitted to the U.S. Congress as required by Section 516(a) of the Federal Water Pollution Control Act.

Most reporting at NERC-Cincinnati is in the form of professional journal articles rather than as technical reports. Distribution of these reprints, both internally and in response to requests, is an important function in the Office. In addition to updating a mailing list of 7,000, nearly 5,000 requests were received and 20,000 pieces of technical literature were sent to the technical community and concerned citizens in 1973.

Graphic Arts

Visual communication plays an important role in communicating the research efforts of NERC-Cincinnati, and the Graphics Unit in the TIO carries out the scientific and administrative visual information aspects of all EPA programs in Cincinnati. Services include providing illustrations, photographic services, visual aids, slides, and exhibits covering a wide variety of complex technical, scientific, and specialized information material.

The members of the graphic arts staff work with the program officials, writer-editors, and printers in developing materials for publication, television, and slide presentations.

During 1973, advice and assistance was given to all programs for many projects, such as an up-to-date photo and color-slide presentation of construction progress of the new National Environmental Research Center near U.C., or the layout, design, and construction of a 4- x 8-foot, full-color, illustrative display for the Cincinnati Public Library's Environmental Information Room.

Major graphics operations have included preparing 1,700 drawings for technical publications and presentations; 3,600 black and white and colored slides for special seminars, training, television productions, and technical presentations; and 100 photographic assignments (filming, developing, and printing for 450 photographs) for technical and nontechnical reports, news releases, and special presentations. Over 500 miscellaneous charts, forms, paste-ups, full-color television visuals, signs, and name tags were produced.

Television

Television productions are used at NERC-Cincinnati to orient and inform foreign and domestic visitors and for educational and training purposes.

All productions are recorded on tape for repeated showings.

The TIO and National Training Center are cooperating to produce tapes to be used by employees of NERC-Cincinnati as well as by trainees. Twelve tapes have been produced for the different laboratories describing laboratory techniques and how to operate specific pieces of equipment. Two tapes on oil identification and spills were made and television production consultation was given to the Edison Water Quality Research Laboratory. Six tapes were made for the Office of Administration on the themes of preparing travel authorization, employee retirement, and the research library's skills and services.

Present plans include exploring work accomplishments of the specific laboratories at the Center, and a TV tape is now being produced that will introduce NERC-Cincinnati and its laboratory directors and explain its mission.

The Television Unit offers complete production services in color or black and white. This capability includes tapes for film segments, slides, and studio taping; these can readily be adapted to create a production tape.

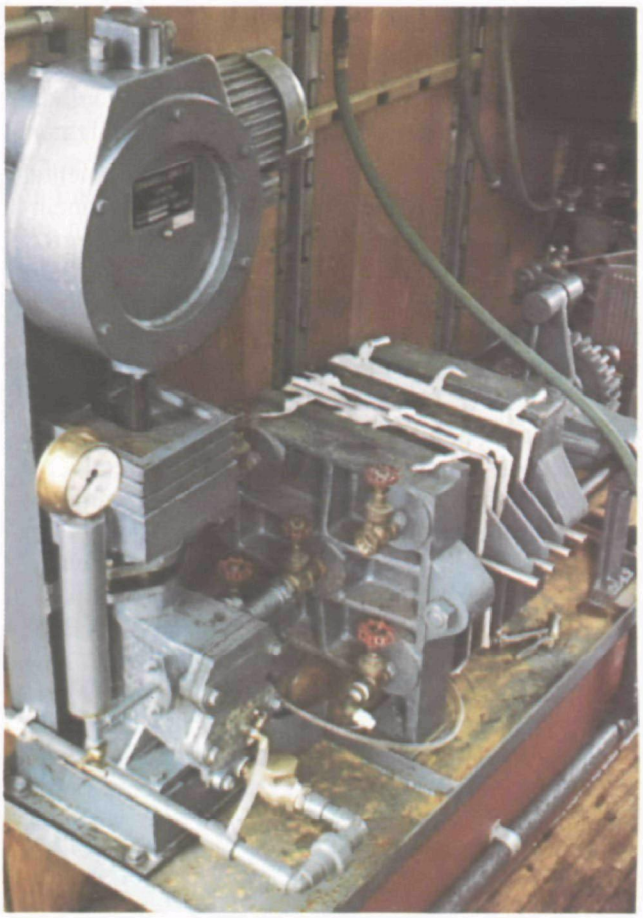
Production requires script writing, editing, and technical expertise in recording and sound. The editorial and graphics staff members of the TIO cooperate with each other to assist the Television Unit in taping their productions.

NERC Relationships

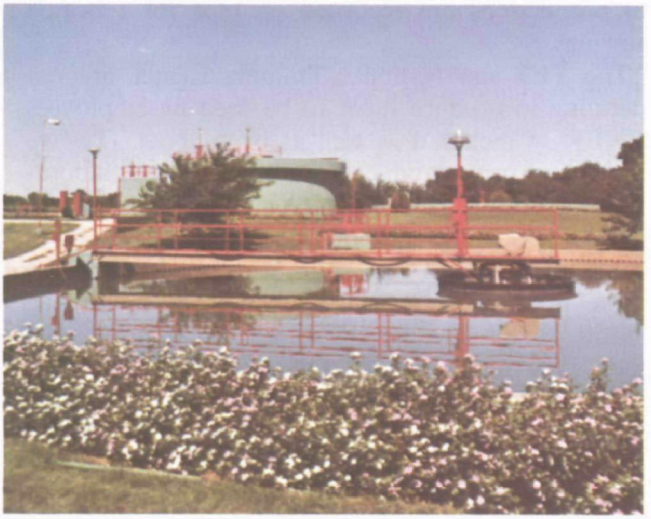
Nonresearch components of the Environmental Protection Agency also have activities in Cincinnati, Ohio: the National Field Investigations Center, a Division of the Office of Enforcement and General Counsel; and the National Training Center under the Water Programs Operations Office. The Office of the Director of the National Environmental Research Center furnishes these organizations with administrative and other support services through the Office of Administration. Program direction is provided from the cognizant Assistant Administrators' offices in Headquarters.

Over 200 foreign visitors have visited this Center. A small number of foreign scientists have also received training at the Cincinnati facility. NERC staff have been called upon for consultation and assistance on international matters. The World Health Organization sought and received assistance in furthering environmental activities in Poland.

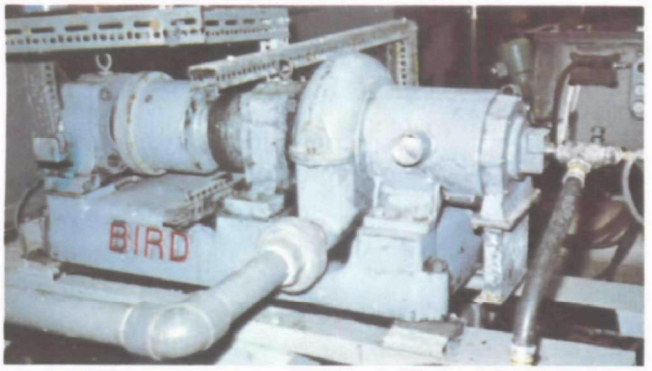
NERC-Cincinnati staff maintains a continuous communication and information exchange with the other three NERC's.



Dewatering of wastewater sludges using a filter press.



Upgrading trickling filter - Richardson, Texas.



Centrifugation of wastewater sludges.

Ozone treatment of wastewater.

Use of wastewater sludge on land.

ADVANCED WASTE TREATMENT RESEARCH LABORATORY

The advanced waste treatment program was initiated in Cincinnati in 1960 in response to the Federal Water Pollution Control Act. Until EPA was established in December 1970, research had been conducted under the auspicies of the U. S. Public Health Service and, later, the Department of the Interior.

The Advanced Waste Treatment Research Laboratory (AWTRL) develops new methods and improves existing methods for wastewater treatment and reuse. Most of the studies are centered on municipal wastewater treatment; however, much of the methodology is also adaptable to treatment systems for industrial and agricultural wastewaters. For most of 1973, the Mine Drainage Pollution Control activities, which will be discussed in more detail later, have been included under AWTRL.

MUNICIPAL POLLUTION CONTROL RESEARCH

Areas of interest to AWTRL include removing oxygen-demanding materials and algal nutrient such as phosphorus and ammonia and nitrate nitrogen from municipal wastewater, destroying pathogens including viruses, improving techniques for handling and removing sludge, and renovating and reusing wastewater. Included in the area of technology development is the instrumentation and automated control that are needed for dependable operation. Cost effectiveness is an important factor in all technology development, and the economic feasibility of technology is investigated on a continuing basis to ensure that practicable treatment methods will result.

Extramural and intramural efforts are combined to carry out the program. Research contracts and grants are utilized in the earlier stages of development; demonstration grants are available for evaluation of processes and systems at full scale. Intramural work includes initial feasibility studies, special analytical studies, and pilot-plant investigations. In addition to pilot facilities at the Cincinnati laboratory, pilot plants are operated in cooperation with municipalities at Washington, D. C.; Lebanon, Ohio; and Pomona, California. Although the intramural staff was recently reassigned from the Pomona facility, plant operation will continue under contract with the Los Angeles County Sanitation Districts. Some of the work at the District of Columbia-EPA pilot plant is carried out under contract with the District of Columbia.

Biological Treatment Technology

Work was continued on a number of projects aimed at improving the cost effectiveness of biological treatment methods to remove organics. In addition, study was begun to determine how to increase the effectiveness of treatment lagoons.

Lagoon Upgrading

Of all conventional secondary treatment processes, lagoons will have the most difficulty in routinely producing an effluent that will meet the newly promulgated secondary treatment standards. Seasonal algal blooms can drastically increase suspended solids and organic carbon concentrations in lagoon effluents. Algae removal presents a challenging task because of the unicellular nature of many algae species. The first projects of an intensive multiphase lagoon upgrading research and development program were begun in 1973. In these studies, an attempt will be made to reduce algae and other suspended solids in lagoon effluents to satisfactorily low levels. The upgrading techniques initially being evaluated include an intermittent, slow sand filter (Utah State University); a slow rock filter (University of Kansas); and spreading lagoon effluent on land (Utah State University). These techniques were selected because they offer potential for cost-effective solutions compatible with the limited resources of small rural communities. Future planned projects will examine year-round performance of several lagoon configurations in different climates, methods of improving organic removal during cold weather, nutrient control, and disinfection requirements.

New Development in Activated Sludge Separation

A novel proprietary device of the FMC Corporation has been tested as a substitute for or as an aid to the conventional gravity clarifier that separates activated sludge from mixed liquor. The device is

a rotating drum strainer equipped with an ultrasonic cleaner. The primary-stage strainer is immersed vertically in the aeration tank with 6 to 18 inches of head. Rotational speed can vary from 30 to 120 rpm. Direction of flow is from outside to inside with strained activated sludge solids being retained in the aeration tank. On a recent contract project, the strainer was tested over a range of mixed liquor suspended solids (MLSS) concentrations from 3,000 to 12,000 mg/liter. With a 10-micron stainless steel fabric, the primary strainer produced effluent concentrations of 20 to 30 mg/liter at a surface loading of 0.122 cubic meter per day per square meter (3 gpm per square foot) and 50 to 100 mg/liter at a surface loading of 0.41 to 0.49 cubic meter per day per square foot (10 to 12 gpm per square foot). Directing the primary strainer effluent through a second-stage strainer located outside the aerator in a small receiver tank approximately halved the remaining suspended solids. A follow-on contract will investigate other second-stage polishing techniques for removing residual solids from the primary strainer effluent including direct settling, coagulation/sedimentation, direct filtration, and coagulation/filtration. Potential applications for the mixed-liquor strainer include using it: as a replacement of the first-stage clarifier in a two-stage nitrification system; to reduce mass loading on overloaded secondary clarifiers; to upgrade overloaded aerators by permitting maintenance of higher MLSS levels without attendant increase in clarifier mass loading; and as a direct replacement for final clarifiers when operated at conservative surface loadings.

Oxygen Aeration Demonstrations

Full-scale, covered-tank, oxygen activated sludge demonstrations are nearing completion in New York City and Las Virgenes, California. Operation over a wide range of loading conditions has verified the high-rate capabilities of the process. On the Union Carbide multistage, gas recycle system at the Newtown Creek plant in Brooklyn, efficient secondary treatment has been achieved at nominal aeration detention times of 50 to 60 minutes in the summer and 80 to 90 minutes in the winter. Similar results have been experienced with the Cordon International single-stage, gas-recycle system at Las Virgenes with aeration detention times as low as 2 hours (minimum detention time possible with available plant flow). Preliminary data from the FMC open-tank pilot-plant oxygenation study recently begun in Denver, Colorado, indicate this unique process will soon be ready for full-scale implementation and, thereby, expand oxygen-activated sludge alternatives available to the design engineer.

Tube Settler Study

In a 1-year, full-scale demonstration of tube settlers at the 1.1 mgd Lebanon, Ohio, wastewater treatment plant, the effluent suspended solids were 50 percent less than those from a conventional clarifier operated under the same loading conditions.

Physical-Chemical Treatment

Physical-chemical methods for treating wastewater have been investigated throughout the history of the advanced waste treatment program. Initially, however, strong emphasis was placed on utilizing these treatment methods following conventional biological treatment to upgrade effluent quality. More recently, the concept of completely replacing the biological system with physical-chemical methods has evolved, because biological systems are susceptible to upset — especially when industrial wastes that are toxic to microorganisms occur in the raw sewage. The past year has seen significant strides made in the acceptance of physical-chemical systems as a substitute for biological systems. Some 22 plants, planned or under construction, will employ processes developed under the advanced waste treatment program. One of the plants (Rocky River, near Cleveland, Ohio) is nearing completion. This plant, supported by EPA research and construction grant funds, will be one of the first large-scale demonstrations of physical-chemical treatment of municipal wastewaters. On a smaller scale, at Freehold, New Jersey, a physical-chemical system has been used to treat wastewater from a housing development. The plant is in a house located near and similar to others in the development. Full-scale evaluation has been underway since July 1973. Typical effluent characteristics are: BOD, < 2 mg/liter; suspended solids, 1 mg/liter; COD, 20 mg/liter; phosphorus, 1 mg/liter; MPN, $< 1/100$ milliliter. This project will evaluate the feasibility of this system treatment in semi-rural areas far from a centralized sewer system.

A major demonstration facility nearing completion in Rosemount, Minnesota, will exclusively employ physical-chemical methods to reduce solids, organics, phosphorus, and ammonia to very low levels. Ammonia will be removed by the selective ion exchange or clinoptilolite process.

A technical feasibility study on the use of powdered rather than granular carbon is nearing conclusion at Salt Lake City. Previous work had shown that powdered carbon in reasonable dosages could treat chemically pretreated wastewater using countercurrent slurry contacting. It has now also been shown that powdered carbon can be regen-

erated with the use of a fluidized-bed type of furnace, whose development had been supported by the advanced waste treatment program from inception of design to prototype operation.

An environmental first in physical-chemical treatment was achieved this year at Pomona when the exhausted carbon from a physical-chemical system treating raw sewage was successfully regenerated after 20 months of continuous operation. Total carbon loading at the time of regeneration was over four times that previously obtained with tertiary carbon adsorption.

A new, short-contact time, single-stage, low-pH, lime clarification system was successfully operated at the Blue Plains pilot plant. A 30 percent savings in capital and operating costs is projected for this system over that of a two-stage, lime precipitation system. Operation of a single-stage system has proved difficult on low alkalinity water.

Three 5-gpm physical-chemical systems have been constructed at the Cincinnati facility and will serve to study: the removal of metals and nonmetallic contaminants from wastewater, the effect of pH on carbon adsorption, and the capability of the system to remove hazardous synthetic organic chemicals. The production of 138 billion pounds of synthetic organics in the United States in 1970 lends urgency to this study.

Nutrient Removal

Processes to control nitrogen and phosphorus in municipal wastewater effluents were operated at both pilot-plant and full-scale facilities during 1973.

Pilot work, conducted at experimental sites in Cincinnati, Blue Plains (D.C.), and Pomona, California, covered such techniques as control of phosphorus in extended-aeration plants, oxygen aeration and nitrification in suspended growth reactors, use of attached growths in columns for nitrification of both biological and physical/chemical effluents, and combined nitrification and denitrification in a single sludge process. The latter process is of interest because it eliminates the need for methanol, which must be added when denitrification is carried out as a separate process.

Full-scale facilities that have been evaluated include Hatfield Township, Pennsylvania, and El Lago, Texas. Hatfield Township is a 14,000 cubic meter per day (3.6 mgd) plant that employs lime addition to the primary clarifier and tertiary alum coagulation, followed by multi-media filtration for phosphorus control. Residual phosphorus in the plant effluent is 0.1 to 0.2 mg/liter.

The El Lago plant is a 1,900 cubic meter per day (0.5 mgd) system that controls both nitrogen and phosphorus. Phosphorus is precipitated in the primary clarifier by ferric iron and polymer; nitrification is accomplished in a second-stage suspended growth reactor. Nitrogen removal is by biological denitrification on packed columns. The effluent is filtered before discharge. The total residual nitrogen content of the effluent is about 2 mg/liter.

A recent survey of EPA regional construction grant activity revealed that 55 plants are in the design or construction phase for nitrogen control processes. Of this total, 45 are employing biological systems and 10 are utilizing some type of physical-chemical process such as breakpoint chlorination or ion-exchange.

A national survey of phosphorus control implementation shows that 112 plants are being constructed for chemical supplementation to provide for phosphorus removal. Sixty-six plants are operational.

Ultimate Disposal

Ultimate disposal is concerned with the handling, processing, transporting, and disposing of sludges and brines removed from wastewater treatment processes. The emphasis has been on sludge disposal. Brine disposal is presently of less interest because large-scale implementation of brine-producing demineralization methods is not anticipated to occur in the near future.

Although sludge is often mistakenly considered to be solid waste, it actually contains far more water than solids. Removing this water, or devising a new way to bypass the water removal step, is one of the most important problems in sludge disposal. For final disposal, the primary methods are incineration, landfill including "permanent" lagoons, and land spreading. Sludge disposed to landfill or to the land must be stabilized to reduce its infection potential and its tendency to decompose quickly. New technology, particularly physical-chemical treatment, is producing sludges for which new processing techniques are sometimes required. The program has devoted major effort towards finding new approaches to these problems, but it is also providing information that will improve reliability of existing procedures and design methods.

Sludge Treatment

An improved dewatering method in which a vacuum filter is modified to operate in a top-feed mode has been investigated on a pilot scale at Milwaukee, Wisconsin. The Milwaukee Sewerage Commission has been granted funds to evaluate the performance of a top-feed filter on full scale. Westinghouse has completed experimental work on their

capillary suction filter, which shows great promise for dewatering waste-activated sludge at a high rate. Pilot studies have indicated dewatering rates of 6 pounds per hour per square foot or greater and dewatered sludge with at least 16 percent solids. Conditioning chemical requirements are less than for vacuum filtration of the sludge. A grant has been awarded to the City of St. Charles, Illinois, to demonstrate the use of this device at full scale. A grant to Cedar Rapids, Iowa, has demonstrated that incinerator ash may be used as a filter aid for pressure filtration of sewage sludge. The resulting cake is so dry that no supplementary fuel is required to incinerate it.

Very effective use of limited resources resulted when AWTRL funded the publication of two reports on valuable research supported by sources other than EPA. In these cases, the researchers had not intended to make their results generally available. One funded report described the extensive investigation Los Angeles County made of alternative schemes for dewatering digested sludges. The other report described innovative work by Brown and Caldwell Engineers for Contra Costa County, California, on the successful use of centrifuges to separate recoverable calcium carbonate from a primary-lime sludge and then to dewater the waste sludge. In both of these cases, work that was destined for very limited distribution, but pertinent to the goals of the program, was made generally available to municipalities and the engineering profession.

A Task Force Report on Sludge Disposal, prepared by staff in EPA's Offices of Research and Development and Air and Water Programs, was distributed widely in FY 1973. It was prepared to aid EPA in planning an overall research program and in identifying major EPA policy issues with regard to sludge disposal. The sludge analysis work, which was begun to provide the Task Force with basic information on the substances found in sludge, has been continued and benchmark data on heavy metal, polychlorinated biphenyl, and insecticide concentrations in sewage sludge has also been collected.

Progress has been made in developing information on processes to stabilize sludge, other than the sensitive process of anaerobic digestion. Aerobic stabilization investigations conducted on a plant scale at Denver, Colorado, have provided valuable information on cost and effect of process variables. Stabilization of sludges by lime addition has been investigated by contract with Battelle-Northwest. The reports of these contracts, which are due in FY 1974, will provide information of great value for process design.

Many wastewater treatment plants, particularly those in the Great Lakes region, are being required to add chemicals that precipitate phosphate and remove it from the wastewater. The mass of sludge is increased and its dewatering properties are drastically changed. Accurate predictions of sludge quantities and dewatering rates are important so that correctly sized equipment of the most suitable type will be selected. The Eimco Corporation at Salt Lake City, Utah, and in-house personnel at Lebanon, Ohio, and Washington, D. C., are attempting to supply this information, which will be made available to municipalities and consulting engineers through reports and through the EPA Technology Transfer Program.

Sludge Disposal

Although incineration and deposition in landfills are common methods for disposal of dewatered sludge, they are costly because 85 to 95 percent of the water must first be removed. Disposal by applying wet sludge to land for soil improvement is often an economical and ecologically advantageous alternative to incineration or landfill. Although many various-sized communities have used this procedure, Chicago is the first large city to preface the direct land application of wet sludge to cropland with large research and demonstration projects to determine long-term effects. These continuing pilot studies have also served to develop design criteria for pretreating, transporting, storing, and applying sludge on cropland or on marginal land needing reclamation. Soil management techniques to ensure safe application and utilization of the sludge are being studied. The soil-renovating quality of liquid sludge has been demonstrated on the ashes of a burned dump, infertile sand dredged from a lake, a strongly alkaline silica waste, and very acid strip mine spoil. Chicago now ships liquid sludge almost 200 miles to renovate strip-mined land. Their chosen disposal method for all of their sludge in the foreseeable future is spreading wet sludge for soil improvement. AWTRL has provided a portion of Chicago's funding needs and supports their long-term studies of crop yields being conducted at the University of Illinois.

Several coastal communities considering land disposal as an alternative to ocean dumping have submitted research proposals; with EPA support, Ocean County, New Jersey, is demonstrating the use of sludge to increase the productivity of sandy, infertile soils.

Many community officials and consultants considering alternate methods of sludge disposal lack sufficient information concerning the state of the

art of spreading sewage sludge or effluents on land. A symposium at Rutgers University, cosponsored by EPA and Rutgers, was designed to supply as much of the needed information as is available. The proceedings are being published.

Pathogen Removal

Disinfection

The sole objective of disinfecting wastewater is to prevent transmission of disease. Until recently, this consisted of applying a sufficient amount of chlorine to reduce the coliform content of effluents to specified regulatory levels. Increasingly, evidence indicates that proof of destruction of coliform organisms does not necessarily ensure that all viruses are killed. In addition, there is growing concern regarding the low virucidal potency of chloramines, toxicity of chlorine to receiving water biota, and the possibility of producing undesirable organic-chlorine reaction products. As a result, the emphasis in disinfection research is shifting to alternatives for chlorine or to methods of neutralizing its residual effects; to a practical method for quantitatively recovering viruses from disinfected wastewater; and to an improved biological indicator of wastewater disinfection efficiency.

In October 1970, when concern was expressed regarding the toxicity imparted to receiving waters by chlorinated effluents, an EPA grant was developed with the City of Wyoming, Michigan, to evaluate the disinfection efficiency of chlorine, ozone, and bromine chloride. These disinfectants are being applied to parallel streams of secondary effluent from both an activated sludge plant and a trickling filter plant. A stream of chlorinated effluent from each plant is being dechlorinated with sulfur dioxide. All disinfected streams, the dechlorinated streams, and a control stream are being subjected to continuous short-term and long-term evaluation for possible unfavorable effects on receiving water biota. Data obtained in this study will provide a basis for establishing which treatment system will combine the desired level of disinfection with the lowest toxic effect on biota tested.

In work on an EPA grant at the University of Illinois, potential indicator organisms that are much more resistant to chlorine than are coliform bacteria have been isolated from wastewater. A yeast and two different acid-fast bacilli have been found that are resistant to chlorine at levels considered necessary for inactivation of pathogens, including viruses. A draft of proposed methods for detection and enumeration of these organisms has been prepared.

In a completed study to determine the effect of combining gamma radiation with chloramine to destroy *Escherichia coli,* researchers found that combining the two germicidal agents in any manner (simultaneously or sequentially) did not produce a synergistic effect. The bactericidal effect was additive to less than additive. It was further observed that chloramine was destroyed faster than the organisms during the simultaneous exposures. Since an increase in the bactericidal effectiveness of either disinfectant (by prior or simultaneous treatment of the cells with the other disinfectant) was not achieved in buffered distilled water, it was concluded that disinfection of wastewater effluents by combining ionizing radiation with chloramine would not be economically feasible.

Virus Studies

More than 100 different viruses excreted by man may be discharged into waterways as a result of inadequate waste treatment practices. Since the importance of viruses resides not in their number, but in their infectivity, a high degree of removal of viruses from effluents is desirable. AWTRL is charged with developing methods to concentrate, recover, and identify viruses in waste, renovated, and other waters; assessing treatment processes for their capacity to remove viruses and other pathogens; and accumulating data on viral hazards in support of enforcement efforts.

Prospects of increased water reuse have further intensified concern over the degree of virus removal by waste treatment processes. One major effort, directed toward the viral aspects of present-day treatment practices, has involved seeding a three-stage activated sludge system at the Washington, D. C., pilot plant with a bacterial virus, coliphage f2. Data collected from a process-by-process evaluation of the system showed varying degrees of viral removal efficiency. Collectively, however, the multi-stage system achieved removal of greater than 99 percent without disinfection. More recently, a study was instituted to determine the removal of virus in a solids-contact clarifier at the Dallas, Texas, demonstration plant.

Developing relatively simple and inexpensive methods to detect one virus in 100 gallons of water is the objective of current research to recover low concentrations of viruses from water. Clearly, such recoveries require novel concentration methods, and a number are under study. Which will prove the most efficient and utilitarian is not known — if, in fact, any one does become universal in all of the applications for which such methodology is needed.

The basic kinetics and chemistry of virus inactivation by chlorine, iodine, and their compounds

and by ozone are being carried out as comparative studies that include both in-house and extramural efforts on virus disinfection in waste, renovated, and other waters. It is obvious from these studies that in a water in which hypochlorous acid can be maintained there is no need to consider another agent for disinfection. In nature, however, it often is impossible to maintain such conditions. To ensure reliable virus destruction, disinfectants need to be chosen to meet particular needs. To determine which disinfectant species are best suited to satisfy each specific situation, controlled and standardized laboratory experiments are being conducted at the University of Cincinnati, Hebrew University in Israel, and AWTRL.

Viruses have been readily isolated from solids in sewage and surface waters. In the past few years, it has been learned that more viruses adsorb to these solids than are found in the waters themselves. It is possible to recover viruses from river solids, while failing to demonstrate their presence in 50-gallon water samples. Modest progress has been made in increasing the level of virus recovery from solids. Although recovery efficiency is low, data accumulated by the program clearly point to solids in sewage and surface waters as major viral reservoirs.

Studies on the Wabash River (Indiana) were made in support of a Region V enforcement action, and more recently, studies on viral survival and disinfection on samples collected from Lake Superior were carried out.

Instrumentation and Control

Better instrumentation and automated control of waste treatment plants is an important need in improving effluent quality. A state-of-the-art report on instrumentation and control, now being completed, includes a compilation of abstracts from a literature survey and the results of a plant survey.

A digital computer program capable of simulating operation of the activated sludge process under various control schemes has been completed. Control of dissolved oxygen, based on a continuous dissolved oxygen measurement, is included in the program. Sludge wasting can be accomplished based on a waste stream of constant volume, on a waste stream with a volume directly proportional to the influent flow, or on a waste volume that keeps sludge retention time fixed; the wasting can also be based on not allowing the sludge blanket in the final settler to exceed some value. Sludge storage can be simulated in the final settler or in a separate sludge storage tank in the return line. Sludge storage can be used to fix mixed liquor suspended solids in the aerator or to fix the food to microorganisms ratio. Cost effectiveness of these strategies is being evaluated.

A grant at Palo Alto, California, provides for operating an activated sludge plant under various control schemes to evaluate the effectiveness of each scheme. At this time, data have been received only for the baseline 30-day period and for the 30-day period in which dissolved oxygen control was carried out. The electrical power savings associated with dissolved oxygen control appear to be in the range of 10 to 20 percent. The data, which are also being used to validate the computer program, show distinct diurnal trends with a minimum of scatter and will, therefore, be of great value in understanding the time-dependent behavior of the activated sludge process.

At the Blue Plains pilot plant, several treatment systems were automated. A physical-chemical system consisting of two-stage lime treatment, filtration, breakpoint chlorination, and carbon treatment was operated with both digital and analog computer control. Flow rate was varied by making step changes. In the lime treatment, lime feed, carbon dioxide, and solid ferric chloride rates were controlled. The control of the breakpoint chlorination was based on inlet ammonia concentration, effluent chlorine concentration, and pH. Step changes could be easily compensated for manually, and because of this, there was not a significant difference in effluent quality between manual and automated control. Planned testing of a typical diurnal variation in flow is expected to show greater difference between manual and automated control.

Automated control was also tested on a three-stage biological treatment system. Controlled parameters included dissolved oxygen, pH in the nitrifying stage, and methanol in the denitrifying stage based on inlet nitrate concentration and flow rate. A polishing dose of alum in the denitrifying stage was also controlled to maintain good phosphorus removal. The principal alum addition, which took place in the first stage, was not automatically controlled.

Treatment Cost Studies

Design and cost estimating relationships for most conventional sludge handling processes were developed and inserted in an existing Executive Program for waste treatment processes. The processes for which subroutines were developed are gravity thickening, air flotation thickening, centrifugation, second-stage anaerobic digestion, aerobic digestion, vacuum filtration, filter presses, sand drying beds, multiple hearth sludge incinerators, and land spreading of liquid sludges. By considering conventional

sludge-handling processes, 185 different treatment systems have been enumerated to dispose of treatment plant sludge, and preliminary computations of the cost of these systems have been made. In terms of dollars per ton of dry sludge, costs range from a minimum of $7.29 for land disposal after lime treatment to $66.73 for digestion, vacuum filtration, and multiple hearth incineration.

The consumption of electrical power and the cost of the power as compared with total treatment cost or as compared with residential usage was estimated for all conventional and advanced processes and for complete plants. In this work (published in report No. EPA-R2-73-281, July 1973, "Electrical Power Consumption for Municipal Wastewater Treatment" by R. Smith, available from NTIS as PB 223 360/9 WE), it was shown that for secondary treatment using the activated sludge process, the amount of electrical power consumed on a per capita basis equals about one 15-watt light bulb burning 24 hours per day in each household.

The potential cost-effectiveness of equalization basins upstream from treatment plants was studied. Diurnal dry weather flow patterns were collected from 15 plants, and these data were integrated to find the necessary equalization basin volume. Analysis of the data showed that allowing 25 percent excess capacity, the basin capacity should equal 15 percent of the daily influent volume flow. The cost of equalization basins with this volume and the cost for sufficient mixing to prevent settling of solids were computed and compared with the cost saving that would result from designing the primary and final settlers on the average flow instead of on the peak diurnal flow. Installing equalization basins just to provide for better solids settling is not justified; there are, however, other possible benefits of equalization that need to be considered before drawing a final conclusion.

Major Demonstration Projects

Three new demonstration projects were initiated in 1973. A project for the full-scale demonstration of flow equalization was initiated at Ypsilanti Township in Southern Michigan. This 3-year project will document the advantages of equalized flow, as compared with unequalized flow, on the performance of two parallel 4.5-mgd activated sludge plants.

At Rosemount, Minnesota, a new project was initiated to completely evaluate a 600,000-gpd physical-chemical treatment plant. Processes to be evaluated include chemical coagulation, dual-media filtration, granular carbon adsorption, and ion-exchange for ammonia nitrogen removal. This plant has been constructed, and the 2-year plant-scale evaluation is scheduled to begin on January 1, 1974.

At Escondido, California, a 150,000-gpd reverse osmosis unit of the spiral-wound configuration will be demonstrated. The unit will utilize sand-filtered secondary effluent for feed. This project represents the culmination of over 8 years of bench scale and pilot plant research on reverse osmosis treatment (Figure 5).

Progress continued on major demonstration projects at Ely, Minnesota; Piscataway, Maryland; and Rocky River, near Cleveland, Ohio. The tertiary treatment plant at Ely has operated successfully and produced effluent with residuals of 0.05 mg total phosphorus per liter. It is hoped that this low phosphorus water, which discharges into Lake Shagawa, will significantly reduce the eutrophication of that lake. The 5-mgd advanced waste treatment plant at Piscataway, Maryland, which utilizes secondary effluent for feed, has operated on a flow scheme of two-stage lime clarification, dual-media filtration, and granular carbon adsorption to produce an effluent of less than 2.0 mg total organic carbon and less than 0.1 mg of total phosphorus per liter. The Rocky River project was mentioned earlier under the Physical-Chemical Treatment discussion.

Other Research

Pressure-Sewer Demonstrations

Two pressure-sewer demonstration projects have been completed. The utility of these systems in areas where conventional sewers are prohibitively expensive and septic-tank — soil-absorption systems are not feasible has been demonstrated. In addition to their technical feasibility, these pressure-sewer systems have demonstrated such advantages as no infiltration, ability to convey wastewater up steep inclines, and ease of installation.

Water Conservation in the Home

Household water conservation was demonstrated in a project with the Electric Boat Division of General Dynamics using eight test homes. The study evaluated the water savings potential for reduced-flow toilets and shower heads and for pilot recycle systems that reused laundry and bath water for toilet flushing and lawn watering.

Estimates, based on cost of water saved, indicate that dual-flush modification of toilets and reduced-flow shower heads are cost effective. The shallow-trap toilet should be considered for new installations or when malfunctioning toilets need replacing; its relatively high initial and installation costs, however, do not justify using it to replace workable toilets. Wash-water recycle systems can be justified for homes in areas of relatively high water and sewerage charges and where a recycle

FIGURE 5. REVERSE OSMOSIS PILOT UNIT TREATING WASTEWATER AT POMONA, CALIFORNIA.

system could eliminate the need for modification of a septic tank system. These factors indicate that more experimental work on recycle systems for single homes is justified, and recycle systems for multiple dwellings should be even more attractive. With home recycling, however, there is need for concern from the aesthetic and particularly the public health standpoints. The systems must be reliable and provide adequate disinfection.

Technology Transfer

In addition to their work on technology development, staff members have made significant contributions to the program of the Office of Technology Transfer. Since the inception of that program, the AWTRL staff has participated in 21 Municipal Design Seminars and 10 Infiltration/Inflow Seminars. Within the last year, staff members have also aided in the revision of four design manuals and in the preparation of four new manuals, two technical brochures, and one television tape.

MINE DRAINAGE POLLUTION CONTROL

Activities in the area of mine drainage pollution control involve research, development, and demonstrations on the control of environmental problems from mining operations on a nationwide scale. The studies are divided into five areas: treatment of mine drainage, surface mining, underground mining, new mining methods, and demonstrations of economical and practical control methods. Approximately one half of the budgeted funds are expended in the last area.

Major strides have been made in developing methods for analyzing overburden from surface mines as a technique for preplanning the mining operation. Several states have adopted these procedures as prerequisites to obtaining a surface mining permit. The methods were developed in the Appalachian region and are currently being tested for western coal-mining-area development and in noncoal situations. Core borings or rock chips of the overburden are collected at the proposed mining

site and are then analyzed to determine potential acid or other problems.

A feasibility study was completed showing that longwall mining technology, which is used in underground mines, can be adapted to the surface mining situation. The use of the longwall method should minimize the surface disturbance and reduce water pollution. A surface mine is being developed to test the method. Longwall mining is a system by which the seam is removed in one operation by means of a long working-face or wall. The workings advance in a continuous line, which may be several hundred feet in length. The space from which the coal has been removed is allowed to collapse (Figure 6). The longwall system should resolve many of the environmental problems encountered in contour mining.

The mine drainage pollution control field site for research on mine drainage treatment was completed near Morgantown, West Virginia. The facility, known as the Crown Field Site, is equipped for studies on neutralization, reverse osmosis, and ion exchange. In addition, lagoons, drying beds, thickeners, and irrigation systems are available for evaluating methods of disposing of the sludges from the above systems.

Two coal by-products (coal-mine refuse and fly ash) are being utilized for the first time as a highway base material in an experimental parking lot at the Crown Field Site (Figure 7). The base material is composed of 75 percent coal refuse and 25 percent fly ash and is covered with a 3-inch bituminous mix. The durability of the material will be evaluated, and in addition, drainage from the area will be monitored to determine if acid mine drainage is formed.

Several additional grants were awarded under the Section 107 Mine Drainage Demonstration Program, a program to demonstrate economically feasible and practical techniques for the abatement of mine drainage. Two of the projects deal with the reclamation

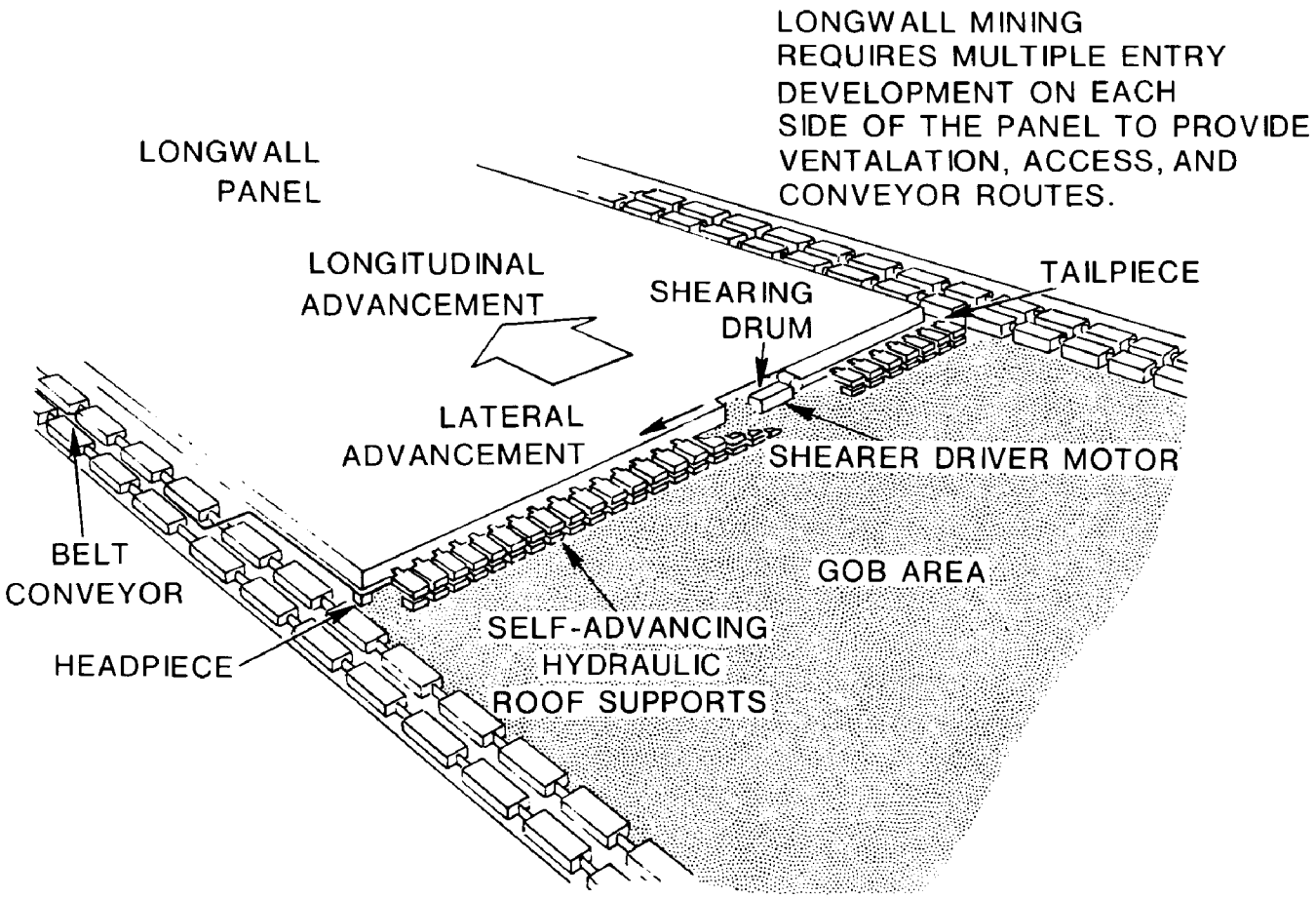


FIGURE 6. ILLUSTRATION OF LONGWALL MINING TECHNIQUE.

FIGURE 7. COAL-REFUSE — FLY-ASH HIGHWAY BASE MATERIAL BEING LAID.

of coal refuse piles. In the first, spoil material will be used to cover a refuse pile and, thus, eliminate the refuse and spoil problem. At the second pile, hydrologic isolation will be used. In another project, abandoned surface mines will be reclaimed with fly ash. Control of erosion from surface mines and haul roads will be demonstrated on two other projects. In Ohio, a massive sand erosion control project was undertaken, and in Kentucky, the proper methods of constructing and maintaining a haul road to prevent erosion will be demonstrated. Two feasibility studies were initiated for the control of acid mine drainage and heavy metals from "hard rock" mines.

ANALYTICAL QUALITY CONTROL LABORATORY (METHODS DEVELOPMENT AND QUALITY ASSURANCE RESEARCH LABORATORY)

PHYSICAL-CHEMICAL METHODS DEVELOPMENT

The physics and chemistry studies of the Analytical Quality Control Laboratory (AQCL) are subdivided into five functional areas, each with specific assignments for analytical methods developments in a particular area of expertise: trace metals measurements, pesticides and other trace organics, oil identification, organics instrumentation, and general inorganics. The activities and achievements in these areas during the calendar year 1973 are indicated below.

Trace Metals

Pursuant to Section 304(g) of the Federal Water Pollution Control Act amendments of 1972, test procedures for the determination of trace metals have been provided to EPA and industrial water laboratories. During the investigation, a variety of industrial waste samples were examined to establish detection limits, sensitivity, and optimum concentration range. Investigations of various digestion procedures to ensure conversion of organically bound metals to an inorganic form were also initiated.

The direct reading emission spectograph was successfully interfaced with the Wang 720B programmable calculator. With the use of a logarithmic variation of a parabolic second order equation, a program has been written that will record the scaler count, recall the coefficients of the equation, and print the corresponding concentrations on a hard copy report form. Significant savings in time are achieved, but more importantly, a concentration printout is available after the sample has been analyzed. Quality control techniques are incorporated that alert the analyst immediately to out-of-control limits of precision and accuracy.

Acquisition of the P&E 503 Atomic Absorption Spectrophotometer including the HGA 2000 Graphite Furnace has resulted in a system capable of measuring total concentrations of a variety of metals without sample pretreatment. With the use of programmed sequence, a sample is dried, charred, and subsequently atomized. The technique has been successfully applied to various industrial wastes for metals such as chromium, nickel, vanadium, and selenium. Other metals are being investigated as time permits.

Pesticides and Other Trace Organics

AQCL develops methods for the detection and quantitative measurement of trace amounts of toxic organic materials in the water-related environment. In 1973, methods for chlorinated hydrocarbon pesticides and other chlorinated organic pollutants in industrial effluents were prepared and distributed. Each method could be applied to a series of chemically related toxic substances.

Gas chromatographic (GC) methods were prepared for detecting both chlorinated and organophosphorus insecticides after they are simultaneously extracted from wastewaters. The methods employ cleanup procedures to separate the insecticides from the complex mixture of organic materials that may exist in a sample. The method also serves as a springboard for detecting a family of widespread environmental pollutants, the polychlorinated biphenyls (PCB). A sophisticated but easy-to-use analytical scheme was devised that employs gas chromatography to quantitate these materials in a variety of samples and in the presence of gross interferences.

GC also serves as the basic approach for another method reviewed by the group. The phenoxyacetic acid herbicides (2,4-D; 2,4,5-T) and their various esters and salts are detected after they are first converted to a volatile form suitable for a GC analysis. Once again, cleanup procedures are supplied to make the method applicable to wastewaters.

Insecticides and herbicides based on carbon-nitrogen structures have become popular because they weather rapidly in the environment. This very characteristic makes the analysis of many of these materials relatively difficult. A GC method was produced for triazines (Atrazine), but methods produced for

both aromatic carbamates (Sevin) and aromatic ureas relied on thin-layer chromatography (TLC) for detection.

A method was developed for the quantitative determination of common chlorinated solvents in effluent samples. This method relies on direct aqueous injection of the water sample into a GC for solvent levels of 1 ppm or higher. Several methods for extracting PCB's and pesticides from bottom samples have been evaluated; air drying — soxhlet extraction was found to be the most effective.

Another very promising method consists of a sparging device in which certain classes of organics may be removed from a sample and trapped directly on an adsorbing column. The trap is then heated in the inlet of a GC, and the trace organics are separated and measured. The sensitivity of the system lends itself to analysis of relatively clean waters, i.e., drinking waters. Preliminary findings with the use of this technique on some surface waters, ground waters, and drinking waters have revealed the presence of some unexpected materials, such as chlorinated aliphatic materials.

Several methods for the determination of oil and grease were also evaluated. Extraction with Freon followed by a gravimetric determination was found to be an effective quantitative measurement for oil and grease in industrial effluents.

Oil Identification

The development and testing of a new concept of oil analysis this past year has made possible the successful application of GC — electron capture (EC) detector to the analysis and identification of lubricating oils, residual fuel oils, and asphalts. Using organic minor components in petroleum to serve as fingerprints for identification is relatively new and has not been applied toward the identification of petroleum products. Much of petroleum products, especially those derived from straight run distillates such as No. 1 fuel oil and No. 2 fuel oil, appears similar with respect to flame ionization detector (FID) GC. Five detailed investigations may be necessary to effect differences in these straight-run fuels for enforcement purposes. Moreover, no FID GC technique has been found suitable for identification purposes when dealing with SAE 20, 30, 40, 50 lube oils and asphalts. (At times, the latter product may be diluted with a light cutter stock. Under these circumstances, the asphalt may be studied with FID GC for identification purposes.)

The conversion of weak acids to the pentafluorobenzyl derivatives and the EC detector GC analysis of asphalts have provided technical support in enforcement cases, e.g., tracing phenols found in the City of Wheeling drinking water samples. The procedure, developed at AQCL, made possible the tracing of minute quantities of phenols in the city water to its source 20 miles upstream.

The recently developed ratio of infrared absorbance technique was used to identify asphalt from a spill on May 8, 1972, near Aliquippa, Pennsylvania. Previously, the only "tools" or "handles" available for enforcement in asphalt cases would have been nickel-vanadium ratios and sulfur values. The infrared ratio method is successful for identifying heavier petroleum products, and GC analysis of derivatives of minor components is successful for identifying pollutant asphalts to the source. Results by elemental metals analysis and infrared computer analysis also confirmed these initial findings.

The pentafluorobenzyl derivative analysis by EC GC demonstrated that source and pollutant lube oil found in the Allegheny River oil spill of April 18, 1972, were alike. The GC results confirmed the infrared identification of the two lube oils. Further confirmation was gained through metals analysis (8 metals) and by elemental analysis.

Further research work was undertaken to determine optimum conditions for the isolation of the weak acids from petroleum products and the separation of their respective derivatives on the GC column. A superior extracting solvent and a superior liquid phase for gas chromatographic separations of the pentafluorobenzyl derivatives were found.

Organic Instrumentation

During 1973, the efforts devoted to organic instrumentation were divided among GC/MS research (approximately 90 percent), nuclear magnetic resonance research (5 percent), and laboratory automation plans (5 percent).

Work was completed on a GC/MS method for PCB's in the presence of chlorinated pesticides. The method eliminates the need for elaborate cleanup on most samples and permits a significant increase in sensitivity. This method was summarized at the May 1973 meeting of the American Society for Mass Spectrometry, and a manuscript describing the method has been accepted for publication in "Analytical Chemistry."

Work was completed on a procedure to evaluate the performance of a computerized GC/MS with the use of standard reference material. The procedure and a sample of the reference compound were distributed to all EPA laboratories with GC/MS capability that requested it.

All EPA personnel (regional, National Field Investigation Center, NERC, and others) using computerized GC/MS to characterize organic environmental pollutants were encouraged, through meet-

ings and newsletters, to participate in the EPA Mass Spectrometer Users Group. Two meetings were held to informally exchange information and several newsletters were compiled and distributed for the same purpose.

General Inorganics

Studies were completed on the evaluation and development of an automated colorimetric procedure for the simultaneous determination of total phosphorus and total Kjeldahl nitrogen. The technique can be used to measure concurrently these constituents in surface waters and in domestic and industrial wastes with applicable working ranges of 0.10 to 10 mg nitrogen/liter and 0.02 to 1.0 mg phosphorus/liter. The results of this study will be published as an EPA Environmental Monitoring Series Report.

The Technicon procedure for phenols was evaluated, including the automatic preliminary screening and distillation of the sample. Results obtained for both the AA-I manifold system and AA-II cartridge system were compared with the manual 4-aminoantipyrine procedure on a variety of surface waters, sewage samples, and industrial wastes. A working range of 2 to 200 μg/liter was developed for those samples containing minimal amounts of phenol.

In the continuing assignment to develop uniform methodology, methods writeups were prepared for both AA-I and AA-II systems for phosphate, ammonia, and nitrate-nitrite. These writeups were done in EPA, Standard Methods, and ASTM format, so they may be considered concurrently by all three official groups.

Studies were completed on an evaluation of a forward-scatter-type turbidimeter, the Monitek 150. Data were collected on standards, water, waste, and sewage samples by comparing the Monitek unit with the Hack 2100, Hellige unit, Jackson Candle measurements, and suspended solids determinations. Results indicated that the forward-scatter-type concept offered no advantages over side-scatter-measuring units and, as a general trend, gave higher apparent results on most sample types. These results were presented at the 2nd Joint Conference on the Sensing of Environmental Pollutants.

The Beckman Model 915 Total Carbon unit was updated to new Beckman specifications, including modification of the combustion train of both the total and inorganic carbon channels. Routine use on a variety of water and waste samples showed this modified system to be similar to the original design.

A comparative study on techniques for calibrating dissolved oxygen meters was completed. By comparing standard solutions and various water and waste samples at different dissolved oxygen levels, it was shown that a Winkler titration was still more reliable than either air calibration or bottle (water-saturated air) calibration.

As part of an on-going research contract, a computer program was developed for potential applicability on all instrumental techniques that will (a) identify replicate, spiked, and standard samples, (b) compute control limits for both CuSum and Shewhart quality control charts and determine if system is "in" or "out" of control, (c) sound alarm (buzzer) when something is amiss, and (d) compensate for baseline drift.

Quality assurance techniques proposed for use by both EPA and state laboratories in compliance monitoring were developed. Items covered were: (a) sampling and preservation, (b) laboratory analysis, (c) quality control (intralaboratory), (d) laboratory review, and (e) special sampling cases.

The ammonia selective electrode was evaluated in a variety of surface waters, sewage samples, and saline waters. It compared very favorably with the indophenol blue method, as done on the Technicon Auto Analyzer. Both direct measurement and known addition techniques were acceptable, with the electrode having a minimum detectable limit of 0.03 mg nitrogen/liter on actual samples. In addition to being inexpensive, the ammonia electrode offers the advantage of minimal sample and reagent preparation prior to analysis, wide concentration range, precision and accuracy comparable to accepted methods, and speed (maximum of 5 minutes per sample).

The fluoroborate electrode was evaluated in conjunction with monitoring for total fluoride. In addition to determining the response of the fluoroborate and fluoride electrodes before and after the preliminary distillation step for breaking down complex fluorides, studies were also made on water and waste samples over a time period to determine the feasibility of tracing fluoroborate activity in the respective samples. Results showed that, because of the formation of various complexes under acid or basic conditions, it is not practical to use the fluoroborate electrode to monitor fluoroborate as an indicator of fluoride discharge.

The chloride ion selective electrode was evaluated as a potential tool for measuring chloride in industrial waste samples that are too colored or turbid to be titrated. The results of direct measurement of industrial waste and riverwater samples were higher than those obtained with mercuric nitrate titration. The electrode was also used to sense the endpoint when titrating with silver nitrate, and the results

from this method were in closer agreement with those of the approved method than were the results from the direct measurement technique.

Laboratory analyses were made on a variety of industrial wastes to determine the applicability of proposed test procedures for compliance monitoring. Such procedures are used to analyze samples collected from plant source and nonpoint source and ambient samples for monitoring and enforcement purposes. In addition to checking procedures for minerals, nutrient, demand, and physical-analysis-type measurements, special emphasis was placed on the evaluation of methods for measuring cyanides, nitrates, phenols, and bromides. Test procedures for the analyses of approximately 70 pollutants were published in the Federal Register.

MICROBIOLOGICAL METHODS ACTIVITIES

Microbiological methods are used to determine the sanitary quality of water and wastewater, the sources of microbial pollution, the adequacy of treatment, and the effectiveness of control measures. The methods presently available are not applicable in all environmental situations nor to all types of samples. Acceptable methodology does not exist for many potential indicator organisms or for most waterborne pathogens. New, improved, and more rapid procedures must be developed and continuously evaluated using the best available methods as reference standards. The precision and reliability of these methods must be determined.

One of the most persistent problems in microbiological analyses is the lack of a method for preservation and the need to examine samples as soon as possible after collection. A delayed-incubation membrane filter (MF) procedure for the examination of fecal coliforms was developed, evaluated in field tests by comparison with the immediate MF technique, and recently published. The procedure will be useful under survey, monitoring, and emergency conditions where the time and temperature requirements for sample transport and storage cannot be met.

The laboratory is conducting replicate analyses and statistical studies on the total and fecal coliform MF techniques to determine, in more depth, their precision, reproducibility, and performance variation.

Laboratory and field investigations encounter various technical problems in the use of presently available tests. Erratic results have been reported when MF techniques for coliforms were applied to chlorinated wastewaters. These erratic results are particularly pertinent to the establishment and enforcement of effluent standards and to wastewater monitoring. A detailed investigation was carried out on chlorinated wastewaters from representative sewage treatment plants in the Cincinnati area. The MF results were not in agreement with the MPN based upon the percentage of MF data that did not fall with the 95 percent confidence limits of the MPN. The MF levels were consistently low. Various alternative enrichment and temperature acclimation procedures that were investigated show promise for increasing MF coliform recovery and yielding results more consistent with the MPN values.

A more rapid test for fecal streptococci has frequently been sought. Newer, improved MF media have been evaluated with representative, known cultures and natural samples. The quantitative results with these media compare favorably with the standard method results but clean-cut differentiation of colonies does not result. Identification of streptococcal species recovered by the respective procedures is being carried out. Modifications of the indicator system and the technique are being made to produce an acceptable 24-hour procedure.

Uniform procedures for the evaluation of microbiological methods and performance are essential to ensure reliable and valid data. Continuing studies are being conducted on the evaluation of media and materials used in commonly applied tests. Proposed screening procedures and abbreviated test materials and equipment are given special attention.

Many different procedures have been proposed for the isolation and identification of enteric pathogens from water and wastewater, with no general concensus on methodology. An evaluation of enrichment and selective media for *Salmonella* has been carried out on high-and-low-density natural samples. A follow-up study is evaluating several commercially available, multitest systems for the identification of Enterobacteraceae isolated from water.

Field surveys frequently experience the need to test for microorganisms other than the conventional pollution indicators. For example, it would be useful to differentiate easily between fecal coliforms and *Klebsiella* in special areas such as paper and pulp mill wastes, food processing plants, and recreational waters. A research plan has been completed for the development of a laboratory procedure to identify *Klebsiella* species in wastewater that will include appropriate field studies.

INSTRUMENTATION DEVELOPMENT

As one of the five activities within AQCL, instrumentation development is concerned with developing and demonstrating new monitoring instruments for

environmental media; developing guidelines and programs for use of such instrumentation; and evaluating water samplers, measurement systems, and data transmission and handling functions. Specifications are developed for procurement application by other Federal and state agencies and, frequently, consultation is provided to these agencies in the matter of automatic water quality monitoring.

An EPCO Model 6130 velocity probe was evaluated during calendar year 1973, and a first draft of the evaluation report was prepared. Results show instrument drift under AC operation and instability occurring on the low range when full-scale output was exceeded by 30 percent. On battery power, drift was less significant and the meter was accurate. Resolution would be improved by changing to a mirror-backed meter that is directly readable on all ranges. Through the generosity of the University of Cincinnati, the flume in the Civil Engineering Department was temporarily modified by EPA personnel for these tests.

An automatic chlorination system for controlling biological growth in the pump systems that are used with automatic instrumentation was designed and tested. Results show that proper intake system design with high-flow velocity should be completed first and the inlet strainer should be kept clean and raised from the river-bottom sediment. If DO still changes after proper system design, some form of cleaning would be required. These tests show that intermittent automatic chlorination at low concentration is a satisfactory method for minimizing sample change that results from biological growth within the pumping system. Components used for automation are given in the report.

A survey of automatic compositors, listing the advantages and faults of these devices, was initiated with the intention of purchasing the three most desirable for evaluation. A seminar was attended in Region VII, sampling installations were inspected, and reports and other information on the compositors from Region VII, Department of the Army, and manufacturers were collected. Information obtained to date indicates need to determine sampler accuracy for parameters such as suspended solids and totally automatic composite flow. Sampler evaluation for endurance and ease of operation is also required.

A survey on rapid instrumental techniques for measurement of specific and gross pollution indicator organisms indicated that chlorophyll, ATP, and nitrates were most amenable to instrumental field measurement. Chlorophyll, however, is the only one that had been measured successfully on a continuous basis with the measurements primarily restricted to large, "stable" bodies of water. Two chlorophyll measurement systems, a Turner and Amico, were tested. The former displayed reasonably consistent output for the total system under temperature variations, but the latter displayed a drift of approximately 10 percent for the same conditions. The effects of turbidity were investigated by employing a clear sample of reasonably high chlorophyll concentration and adding fuller's earth. The fluorescence of the sample was greatly affected.

A survey of the application of instrumental techniques for measuring selected ions to field use revealed that sample preconditioning was of paramount importance before an ion selective sensor could be employed. Sample preparation is not only unique to the measurement, but the reagents are a function of the interferences so that this type of measurement is somewhat specific rather than general. The draft report summarizes sensor manufacturers, sensor impedance, interference, temperature range, pH range, and design philosophy. The solid state sensor appears more amenable to field service than does the liquid membrane sensors.

A draft report on "BOD Literature Survey and Recommended Approach to Waste Treatment Plant Control" has been completed, and it includes information on the BOD obtained through the use of differential measurements (ΔTOC, ΔTOD, ΔCOD). The differential measurements are taken across the treatment plant and across a sample processed further biologically. Theoretically a good estimate of the ultimate BOD can be obtained with further processing of an effluent sample, e.g., biofiltration.

An evaluation of the American Limnetics dissolved oxygen meter has been completed. The draft report discusses drift, instability, and temperature characteristics. The instability and long-term drift of the thallium-mercury alloy electrode indicates that this sensor is not satisfactory for the controlling function intended.

A draft report entitled, "Comparison Program for Water Quality Transmission Modes" has been completed; it compares the automatic reduction of data between transmissions via NASA facilities and those via existing EPA facilities. The program utilizes the PDP-8/S, which controls the station interrogation/data storage and the teletype output device. The report describes the segmentation of the program and includes simplified flow charts and a complete program listing.

As an integral part of a project for a recommended monitoring intake system, a Goulds 2-hp centrifugal pump was tested at the Great Miami River research facility. This pump consisted of five impeller stages driven on a hexagonal shaft by

a 2-hp, submersible Franklin electric motor. To date, the testing of the pump for flow characteristics and mechanical wear over long-term continuous conditions indicates that the motor bearings are the weakest link in the system. If these parts can be strengthened or protected, pump life could be lengthened to perhaps 8 to 12 months.

A prototype, sample preconditioning flow cell, intended for intermittent determination of oxygen decay and selected ions, was fabricated by the Schneider Instrument Company in accordance with EPA specifications. The device includes two retaining vessels: the first raises the sample temperature with simultaneous aeration and stirring, and the second, which contains a lesser volume, provides for the sample measurement held at a constant temperature. External means for pH control are available. An auxiliary window wiper for dissolved oxygen removes bubble formation at the sensor. The sample is first accumulated in the primary reservoir, treated, and transferred to the second for measurement.

On numerous occasions, the AQCL has been contacted for consultation on a variety of problems including developing plans for effluent and background water quality monitoring. An opinion on water quality instrumentation was provided to the State of California, Department of Water Resources, Delta Branch, for the Sacramento and San Joaquin Rivers. On request, the New England District of the Corps of Engineers were provided specifications, addenda, and an evaluation of Invitation for Bid. Additionally, two water quality monitors — one manufactured by the Schneider Instrument Company and the other by the Ecologic Instrument Company — were evaluated in the AQCL for the Corps of Engineers.

Periodically, intralaboratory assistance is provided between activities. On one such occasion, an electronic inverter/converter was designed to improve the scanning capability of the nuclear magnetic resonator. The inverter/converter provides a discontinuous voltage input to a voltage-controlled oscillator whose frequency varies between 0 and 10 KHz. A 100-MHz carrier within the nuclear magnetic resonator is modulated by this frequency. The inverter/converter is provided with offset so that the frequency sweep can be minimized or maximized depending on the tests performed.

METHOD AND PERFORMANCE EVALUATION

A preliminary comparison study on methods of analyses for total mercury in water was completed by AQCL and distributed as a formal report. In this comparative study of the EPA method and other methods of choice, completed by 42 private and governmental laboratories, it was shown that samples containing organic mercury require a vigorous digestion step, such as that in the EPA method, to obtain good recovery.

In "EPA Method Study 7, Trace Metals," three sets of paired samples, each containing 10 metals, were analyzed by 164 analysts in both governmental and private laboratories. Data were returned by 109 analysts and are being evaluated for a report.

A joint "ASTM-EPA Method Study 8, Total Mercury in Water" was conducted with 170 analysts in a variety of laboratories. Sample pairs containing inorganic and organic mercury were tested at four concentrations. The laboratory phase has been completed, and the data from 94 laboratories have been evaluated and a formal report is in final preparation. Statistical data were provided to the Task Group on Mercury for consideration and acceptance by Committee D-19, ASTM.

In a two-phase study, "EPA Method Study 9, Chlorophyll," samples were prepared and distributed to 124 analysts in a full range of laboratories. In each phase, six chlorophyll samples were analyzed spectrophotometrically and six fluorometrically. At the final cut-off date, 68 laboratories had returned data. An evaluation is now completed, and a final report is in preparation.

Special nutrient, mineral, trace metal, mercury, and demand samples were prepared and forwarded to 27 laboratories participating as contract laboratories for the Effluent Guidelines Division (EGD), EPA. When requested by project officer, data were returned to AQCL for evaluation and interpretation and subsequent reporting back to EGD.

In continuation of the cooperative effort between The Soap and Detergent Association and EPA, a new reference standard of linear alkylate sulfonate (LAS) was prepared and analyzed and is being distributed by AQCL on a sole source basis. The standard is required for use in the Methylene-Blue-Active Substance Test, and in the Shake Flask and Activated Sludge Biodegradation Tests. A new series of nitrilotriacetic acid (NTA) reference samples has been prepared and is now being distributed to laboratories doing phosphate-substitute evaluations.

In a special study conducted on request from IFYGL, nine Canadian and U.S. laboratories analyzed Lake Ontario-like water samples for 15 parameters in each of similar, yet different, sample pairs. Under a confidential code known only to the IFYGL Coordinator, data from each laboratory were evaluated and indicated *Acceptable* or *Non-Acceptable*.

On an emergency basis, a special series of 1400 ampuls containing cadmium, mercury, PCB (Arochlor 1242), or toxaphene at each of three levels was prepared, analyzed, and shipped to a laboratory doing bioassays on contract to EPA.

Exact chemical solutions were prepared in ultrapure water and furnished to the Benthos Group, AQCL, for use in special fish bioassays.

In continuing support of analytical quality control in water laboratories, a total of 13,000 ampuls containing reference samples for LAS, NTA, mercury, minerals, nutrients, trace metals, and demand parameters were prepared and shipped to approximately 4300 analysts.

DEVELOPMENT OF BIOLOGICAL METHODS

The ultimate proof that the Nation's surface waters are adequately protected by the Federal and State pollution control programs can be obtained only by periodically examining the indigenous communities of aquatic organisms. Water quality is reflected in the species composition and diversity, population density, and physiological condition of native populations of aquatic organisms. Biological methods employed in water pollution control, therefore, deal primarily with the collection, counting, and identification of these organisms, biomass measurements, measurement of the toxicity, bioaccumulation and biomagnification of pollutants, and biological data processing and interpretation. AQCL conducts research in all areas of biological methodology used in both marine and fresh waters in routine field and laboratory work arising during short-term enforcement studies, long-term water quality monitoring, and effluent testing. Methods evaluation and development are accomplished through grants, contracts, and in-house research.

Because of the broad scope of the biological methodology involved in the EPA program, a national advisory committee of senior biologists was selected from EPA enforcement laboratories and from regional surveillance and analysis and national research programs. The committee meets at least once a year to review the biological methods research program and to select methods for Agency use.

Biological Methods Manual

The first EPA biological methods manual was completed in 1973 and distributed to Federal and State agencies and other interested programs. The manual was prepared jointly by the Biological Advisory Committee and the AQCL Biology staff; it contains field and laboratory methodology for sampling and identifying plankton, periphyton, macrophyton, macroinvertebrates, fish, and bioassays, and has a chapter on biometrics. The manual will be reviewed periodically by the Advisory Committee, and existing methods will be revised and new methods will be added as the need arises.

Sample Collection and Preparation

Projects underway in this area in 1973 included studies of the effect of substrate depth on the abundance and species composition of periphyton, the effect of artificial substrate sampler geometry on macroinvertebrate collections, and the comparability of bottom grab samplers. A preliminary report on the performance of the Ekman, Petersen, and Ponar bottom grabs was completed and submitted for publication in a technical journal. A preliminary study was completed on the recovery and selectivity of various sieves used in processing macroinvertebrate samples, and a report is in preparation.

The feasibility of developing an automatic sample sorting and counting device for processing macroinvertebrate samples was also explored in-house and through discussions with consulting firms. Macroinvertebrate field samples currently require 4 or more hours for manual sorting. Mechanization of this operation would result in a significant savings in man-hours in Federal and State water pollution control programs. The possibility of using automatic, bacteria plate counters to speed the counting of hand-sorted organisms was examined and showed sufficient promise to warrant purchase of an instrument (AMINCO PETRI-SCAN) for further studies.

Methods of Organism Identification

Keys for the identification of the diatoms and midges, both of which are important water indicator organisms, were reprinted because of the continued high demand for these publications. Revisions of both keys are underway and will be completed in 1974 or 1975. Work also continued on a key to the *Stenonema* mayflies, which will go to press early in 1974.

A small, scanning electron microscope was purchased to aid in preparing the revision of the identification guides and in the preparation of new publications.

Measurements of Biomass and Metabolic Rates

The concentration and relative abundance of chlorophyll *a*, *b*, and *c*, and chlorophyll degradation products are widely used to estimate phytoplankton density, taxonomic composition, and physiological condition. Chlorophyll methodology, however, has not been rigorously evaluated.

Long-term studies of the stability of chlorophyll extracts completed early in 1973 demonstrated that chlorophyll solutions stored in the dark at freezer

temperatures (-20°C) were stable for at least 12 months. The results indicated that it would be feasible to use such extracts in a formal interlaboratory study of chlorophyll analytical methodology, and such a study was carried out (see the section on interlaboratory methods studies, below). A high-resolution research spectrophotometer (BECKMAN ACTA V) was purchased to provide more accurate data from laboratory analyses. A grant was awarded to the Department of Biological Sciences, University of Cincinnati, to develop gas chromatographic methods for chlorophyll identification and quantification.

A study of the potential usefulness of macroinvertebrate biomass data in determining water quality was completed and a report was prepared for publication.

An evaluation of methods of measuring plankton biomass, begun in 1972, was continued in 1973. Parameters being examined include cell count, cell volume, dry weight, ash-free weight, and chlorophyll and adenosine triphosphate content.

Bioassay, Bioaccumulation, and Biomonitoring

An evaluation of bioassay methods was initiated in 1973 with a review of the bioassay literature and a laboratory evaluation of current standard methods for conducting static fish toxicity tests. During the tests, numerous instances were noted where changes in equipment and techniques would result in significant improvements in the tests. A preliminary report was prepared and further studies are planned for 1974.

A grant was awarded to the Department of Botany, Ohio State University, Columbus, to develop a rapid, algal bioassay technique.

Data Processing and Evaluation

A project was initiated in April 1973 to develop a computerized biological data storage and retrieval system within the Agency's data storage and retrieval facility (STORET) capable of handling the hierarchical structure of taxonomic nomenclature. A contract was awarded to the General Electric Company, Beltsville, Maryland, to determine the system requirements and design, and to develop the master files for species, parameters, and stations. An initial, minimal system was planned to handle the data from the Lake Ontario study conducted by the International Field Year for the Great Lakes (a joint U.S.-Canadian project), the Ocean Disposal Program, the National Eutrophication Survey, and the EPA and State water pollution surveillance programs. Completion of this project has been delayed temporarily because of lack of funds.

Grants were awarded to the Department of Botany, Bowling Green State University, Bowling Green, Ohio, to review the literature and compile the published data on the environmental requirements of the common diatoms collected in water quality studies, and to Florida State University, Tallahassee, to carry out a similar project for the midges. These grants, the first in a series to be awarded to compile ecological data on all of the common aquatic organisms, will assist Federal and other water pollution biologists to evaluate data collected in enforcement and water quality monitoring studies.

Interlaboratory Biological Methods Studies

A formal interlaboratory study of chlorophyll methodology was carried out in May and June 1973. The reference sample was prepared and distributed to approximately 100 laboratories. The results indicated good precision for the method for chlorophyll *a*, but data for the other chlorophylls and pheophytin *a* showed considerable scatter. A final report on the study is in preparation.

Preparations for a formal interlaboratory study of macroinvertebrate identification methods were initiated early in 1973. More than 100 laboratories responded to the announcement of the study contained in the July AQCL Newsletter. Work is continuing on the project, and the reference samples will be distributed in January 1974.

Plans were also initiated for a formal interlaboratory study of a plankton counting and identification methods to be carried out during the first half of 1974.

EDISON WATER QUALITY RESEARCH LABORATORY (INDUSTRIAL WASTE TREATMENT RESEARCH LABORATORY)

At the Edison Water Quality Research Laboratory (EWQRL), new process technology for abating water pollution is developed — from concept through demonstrated hardware and processes. At this major satellite facility of NERC-Cincinnati, the R&D efforts are grouped in four areas: managing oil and hazardous material spills, controlling industrial effluents, managing storm and combined sanitary sewer overflows, and abating pollution from recreational and transportation sources. There is useful cross-fertilization among the areas within the laboratory; e.g., the work of the industrial pollution control program provides useful information to the hazardous spill program and the spill control programs can and do use technology developed by the others. Related efforts at the other three NERC's, in industry, and at universities is also closely coordinated with EWQRL research.

The EWQRL serves as the center of oil and hazardous spill control research in the Nation. It has, since 1969, gained and continues to enjoy, a worldwide reputation in this area. The prime emphasis of the team, supported by in-house engineering, chemistry, and biology efforts, is to develop new hardware concepts to detect, contain, and remove pollutants that leak or spill into the environment accidentally.

The industrial pollution research effort of NERC-Cincinnati is centered at EWQRL. The program in the past focused on waste problems of the electroplating and nonferrous metals industries. Much of the effort has been geared to supporting the demonstration of pollution control technology at the pilot or semi-works scale. The program has also supported the standard-setting efforts of the Effluent Guidelines Division of the Office of Water Programs. This year, additional Edison R&D efforts covered the inorganic and miscellaneous chemicals area, as well as the manufacture of synthetics, plastics, and rubber.

The storm and combined sewer overflow program develops abatement concepts, at pilot and full scale, to mitigate pollution resulting from water runoff occuring in urban areas at times of heavy rain or melting snow. These wet-weather flows can cause over 50 percent of the pollution load in a stream. The program not only demonstrates control technology, but sponsors work to minimize urban runoff and urban runoff pollutant levels.

Waste management for small boats has been the main thrust of the transportation program. This 3-year effort has demonstrated successful solutions for controlling pollution from small and medium size boats. Some of these solutions can be applied to problems encountered at remote recreational facilities; EWQRL has a minor effort in the area this year.

The EWQRL has a fully equipped scientific laboratory for chemical and biological analysis to support the technology development work. Outdoor and indoor test facilities include a 100-foot indoor test tank. The laboratory shares facilities with Region II's Surveillance and Analysis Division — enjoying the Region's support for routine work while supporting the Region with its area of expertise.

OIL SPILL RESEARCH

The prime responsibility of the oil spill research is to develop systems that will prevent, contain, control, identify, and clean up spills of crude oil and petroleum products. Current efforts include work in managing waste oil, developing booms and skimmers, utilizing total response systems during spills of opportunity, identifying pollutants, and demonstrating oil/water separation systems. A major effort this past year has been devoted to constructing the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) which will be operational in spring 1974.

Waste Oil Management

A study has been underway since 1972 to develop a nonpolluting waste oil-refining process. The full scale demonstration is being carried out by the National Oil Recovery Corporation (NORCO). The process utilizes vacuum distillation to produce marketable lube stocks and No. 2 and No. 4 fuel oils.

Additional tasks incorporated in the contract include:

- studies to determine a pretreatment process for feedstock
- design and development of specifications for a bottoms incinerator
- product outlets for high-solids-content bottoms
- product quality studies
- plant runs to obtain system design and operating data

At present, a post-distillation process, hydrotreating, appears to be more attractive than pretreatment. Hydrotreating should be demonstrated in 1974. Process studies indicate that, if done at a sufficient scale, re-refining can be economically attractive.

A grant was awarded to Maryland Environmental Service to survey the waste oil problems in Maryland, as a typical state. The study will provide a management program for collecting and recycling waste oils; the plan will provide an example for other states to follow. Preliminary evaluation of the study results indicate that collection costs over an entire state will be as high as $0.05 per gallon. An amendment was awarded in June 1973 to investigate technology for disposal of high-solids residues. A report "Waste Oil Recovery Practices, State-of-the-Art (1972)" has been published.

The EWQRL personnel helped prepare the report "Waste Oil Study - Preliminary Report to the Congress, April 1973," required 6 months after enactment of Section 104(m)(3) of WPCA Amendments of 1972. As part of the EPA working group for Section 104(m), they are preparing major sections of the final Report to Congress to be submitted by April 1974.

Booms and Skimmers

Conventional oil retention booms fail to contain oil in currents above 1 to 2 knots. A streamlined boom was designed to operate in currents in excess of 2 knots under varying wave-current conditions. The initial boom design consisted of an airfoil-shaped (hydrofoil) leading-edge section designed to move near the water surface and permit oil and water to flow over the top of the leading edge into a flexible sump. Tests indicated that although the flow associated with the leading-edge hydrofoil section appeared promising, it would be difficult to control the flexible sump shape, especially in currents greater than about 2 knots. A modified streamlined boom was then designed with a rigid sump formed by the interior of the streamlined shape. The boom consists of an airfoil-shaped section resembling a hydrofoil, operating at the water surface (Figure 8). Motion of the boom through the water (or flow of water past the boom) caused a bow wave that swept oil and water over the top of the leading edge of the boom into a sump. Tests indicated that the streamlined boom has a drag profile less than one-third that of conventional boom shapes of equivalent depth. Measurements of oil collection efficiency indicated that at a speed of 3 knots, collection efficiencies can exceed 65 to 75 percent.

In a series of laboratory and tow-tank tests, Consultec, Inc. studied the feasibility of using a woven hydrophilic fabric boom to contain oil floating on water. A 46-inch-wide model did not leak when towed through calm water at 1.5 knots. An

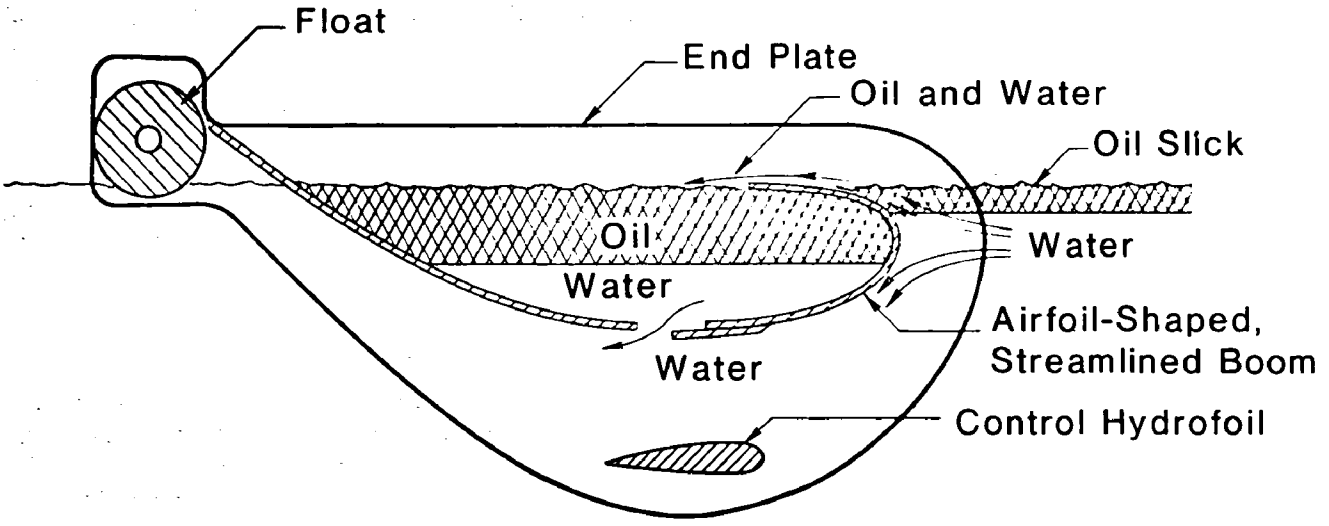


FIGURE 8. STREAMLINED BOOM DESIGN WITH RIGID SUMP AS AN INTEGRAL PART OF THE SHAPE.

adaption of this technique may contribute to solving the problem of retaining spilled oil in rivers and estuarine areas where water speeds reach 5 knots.

Oil Identification

A method was developed and evaluated by Esso Research and Engineering Company to identify sources of oil pollution by comparison of certain stable chemical indices present in unweathered oil from suspect pollution sources and the weathered pollution sample. Several compound indices were found to be stable after laboratory simulated weathering and showed the ability to help discriminate between pairs of oils used in the study. These indices provided a means of clearly distinguishing among the oils used in the study with a high degree of statistical confidence.

An assessment of the utility of ultraviolet fluorescence spectrophotometry for characterizing and identifying oils found as slicks and shore-line residues was completed. An intramural effort made significant progress towards developing novel and more efficient methods for characterizing and quantitating oil by fluorescent techniques. A broad variety of severely weathered (simulated) oils were successfully matched with their corresponding unweathered counterparts. A preliminary fluorescence method was completed for quantitating oil directly in water. Intramural efforts in this area will continue through 1974.

To provide a much needed instrument for automatically measuring the concentration of oil in water, NUCOR Corporation is developing an "Oil Contamination Meter." This meter, based on flame emission spectroscopy, will measure from 5 to 500 ppm of oil in marine, brackish, or fresh water. The burner system will respond to 4 ppm benzene and 10 ppm of No. 2 fuel oil in fresh water and to 30 ppm of No. 2 fuel oil in brackish water. A prototype unit should be tested and delivered to EWQRL by December 1973.

The State of Maine Department of Environmental Protection (D.E.P.) evaluated an EPA high-resolution, gas chromatographic (GC) analysis method to be used in the enforcement of their state Oil Conveyance Law. To help identify "mystery oil spills," the law requires portions of all oils transported through Maine to be stored for 15 days. The Woods Hole Oceanographic Institution developed the GC method for EWQRL; The Research Institute of the Gulf of Maine (TRIGOM) conducted extensive oil weathering experiments using large outdoor tanks with continuously recirculating Casco Bay water; and Bowdoin College conducted the GC analysis. (TRIGOM and Bowdoin College are under the immediate direction of D.E.P.).

When oil films of controlled thickness (up to 3000 panometers) were formed upon water surfaces in the EWQRL laboratory, an inherent and orderly thickness – appearance relationship was confirmed, a relationship independent of oil type and water type. These relationship studies also investigated the effects of viewing conditions on the ease with which the film could be seen. The EWQRL out-of-doors observations and work reported by other sources correspond with the laboratory results. The visibility of a thin oil film depends not only on its inherent thickness – dependent appearance, but also on conditions external to the film: the nature of illumination and sky conditions, sun angle, color and depth of water, color of bottom, and viewing angle (Figure 9). A very thin film can be detected under favorable conditions (Figure 10).

Oil and Water Separation

A chemically assisted, backwashable coalescer with a backwash solids treater is being developed by Pollution Abatement Research. This system, which will agglomorate submicron oil droplets, is aimed at the water treatment problems encountered

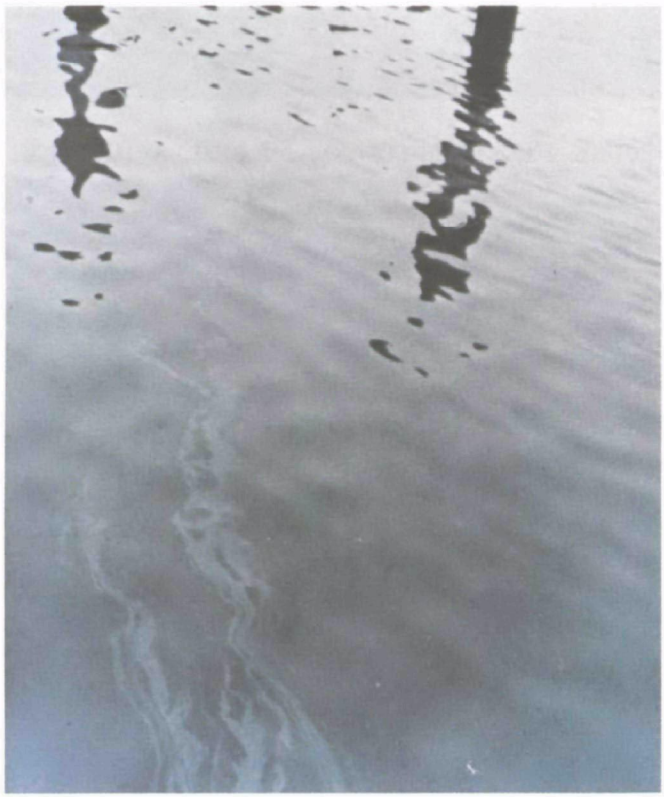


FIGURE 9. VISIBILITY OF OIL SLICK ON WATER DEPENDS ON MANY VARIABLES. THE OIL SLICK COVERS THE ENTIRE AREA BUT IS ONLY SEEN IN THE RELATIVELY CALM AREA WHERE THE VIEWING AND SUN ANGLE ARE FAVORABLE.

FIGURE 10. VISIBILITY OF 50 GPM, A 100 PPM OIL-WATER DISCHARGE, FROM THE AIR.

on offshore oil production platforms. Preliminary testing of the system with a 50 gpm coalescer operating on actual wastewater from an offshore oil production platform shows considerable promise. Benefits of the system will be its small size, continuous backflushing to cleanse the backwashed solids, and the resulting high quality water and solids effluents. The backwash solids treater will be tested further, and the system will be used on an oil production site for an extended time period.

The Ben Holt Company is investigating adsorptive techniques to remove chemically emulsified and dissolved oils from water. Preliminary investigations with a solvent-regenerated, carbon adsorption system pointed to solvent efficiency problems. Further investigations have been aimed at various thermally regenerable adsorptive surfaces with oily water contact being in the form of a spray or mist. Data produced thus far indicate considerable promise. With a single pass at the adsorptive surface and a contact time on the order of 1 second, recoveries of 69 percent have been achieved (100 ppm "in," 31 ppm "out").

Oil Spill Response

Under an EPA grant monitored at EWQRL, the New York City Fire Department produced a film and training manual aimed at promoting the response of fire departments to oil spills. Fire departments, trained and equipped to respond to a community emergency, can provide a valuable "first aid" action at an oil spill to limit spreading (Figure 11). Cleanup would be by a trained cleanup crew, not the fire department. Copies of the film and training manual were distributed nationwide to the major city fire departments. Response to these materials has been good, and a major oil company is reproducing the film for international distribution to its affiliates.

OHMSETT (Oil and Hazardous Materials Simulated Environmental Test Tank)

EWQRL continues to provide technical supervision during the construction of OHMSETT, the 670-foot-long, 65-foot-wide, 11-foot-deep wave tank being constructed at Leonardo, New Jersey (Figure 12). This $3 million facility for developing, test-

ing, refining, and evaluating oil and hazardous materials spill cleanup equipment is scheduled to be turned over to EPA by the contractor April 1, 1974. The concrete work has been completed; the three-story control building is ready for occupancy. The large mechanical equipment is being installed. A 250-HP electrohydraulic system will power the generator to produce waves up to 2 feet in height and 16 feet in length. A 2000-gpm diatomaceous earth filter system will help maintain the water clarity needed for underwater photography and videotape recordings that will constitute the bulk of the data record. The foundation for the 7000-square-foot, prefabricated, support-facilities building is complete, and the building was completed in late 1973. The completed OHMSETT facility will provide a much-needed, environmentally safe transition between laboratory work and actual river and harbor spill conditions.

Conference: Prevention and Control of Oil Spills

Eighty-seven papers were presented to over 1500 attendees at the 1973 Conference on Prevention and Control of Oil Spills sponsored by EPA, the American Petroleum Institute, and the U.S. Coast Guard. This was the third such sesquiannual interchange and assessment of technology within the last 4 years. The exhibits, representing the best of more than 75 companies, demonstrated the dramatic advances in the state-of-the-art in oil spill control and cleanup made since the first conference in December 1969.

Fifty foreign delegates to the Conference accepted invitations to visit EWQRL and OHMSETT on the day following the Conference.

HAZARDOUS MATERIALS SPILLS RESEARCH

Within EWQRL, hazardous materials spills research develop technology and systems for preventing, detecting, identifying, containing, monitoring, controlling, and cleaning up in the water environment spills of hazardous substances that dissolve in or react with water or that sink, float, or volatilize. Some examples of hazardous materials are: phenol, alcohol, nitric acid, chlorosulfonic acid, acetone cyanohydrin, toluene diisocyanate, organophosphate pesticides (Diazinon, parathion), chlordane, perchloroethylene, creosote, carbon disulfide, styrene, iso-octane, formaldehyde, and chlorine.

During 1973, significant progress continued to be made in the area of containing hazardous material spills on land and in water. Spill alarm and treatment devices were developed and new concepts introduced. A manual of guidelines for disposing of small-lots of spilled or unused pesticides, with extensive tables of chemical properties and a review

FIGURE 11. FIRE BOAT HERDS SIMULATED OIL SLICK WITH ITS MAIN FIRE RESPONSE SYSTEM. THE OIL IS SIMULATED BY THE WHITE PAPER SQUARE.

FIGURE 12. OHMSETT (LOOKING DOWN THE TANK TO THE CONTROL HOUSE) AS IT APPEARED IN SEPTEMBER 1973, ABOUT 75 PERCENT COMPLETE.

FIGURE 13. QUICK SETTING FOAM PLUG APPLIED TO LEAKING BENZENE CONTAINER.

of relevant disposal chemistry, will soon be submitted for printing.

Containment

Following a demonstration (Figure 13) of the feasibility of using foamed-in-place plastic for plugging leaks in ruptured containers, a one-man-operated device is now being built.

A foam-dike backpack unit (cost about $150 per unit) has been constructed and is on stand-by for actual field use in confining spills on land and preventing their entry into nearby watercourses or storm drains (Figure 14).

Characterization of a "universal" gelling agent for increasing the viscosity of spilled hazardous materials is underway and a contract will be awarded for producing a field-use application system. Based on the preliminary evaluation, the cost of gelling hazardous materials ranges from 30 to 60 cents per gallon of spilled material. In field demonstrations (Figure 15), the flow of cyclohexane spilled on land (and on water) was halted by applying the gelling agent. In a preliminary study, the treatment of land with plastic sealants to make the ground impervious to percolation of spilled hazardous materials shows promise. The work is expected to be continued.

A sealed boom (water curtain) for confining a spill by isolating a water column 70 feet in diameter and up to 25 feet high has been constructed and is scheduled for testing in a stream flowing at 2 knots.

The readily transportable, field-use, battery-powered pump and self-deploying 7000-gallon containment bag system for collecting spilling or spilled hazardous materials is being readied for an early demonstration. The unit weighs less than 1000 pounds, costs between $2,500 and $3,000, and is stowed on a 4- by 4-foot reinforced plastic pallet, which can easily be moved to a spill site with a small pick-up truck.

Removal

The 5-gpm "Dynactor"/separator was successfully demonstrated for removing hazardous materials dissolved in or associated with water. A scaled-up, 250-gpm, trailer-mounted "Dynactor"/separator system is presently being constructed under contract. The system utilizes a dynamic, thin-film contactor/reactor ("Dynactor") coupled with special, high-

FIGURE 14. PLASTIC FOAM DAM USED TO SEAL STORM DRAIN.

FIGURE 15. DEMONSTRATION ON THE USE OF "UNIVERSAL GEL" TO SOLIDIFY SPILLED CHEMICAL IN DITCH.

filtration-rate separators to treat water with any or a combination of activated carbon, precipitating agents, neutralizing reagents, or ozone.

A commercial 17½-minute, color, sound film, "Once A River," has been produced to document a successful cleanup of hazardous materials in the Little Menomonee River in Milwaukee, Wisconsin. The 5-gpm "Dynactor"/separator and the 200-gpm, mobile, physical/chemical separation system (which consists of chemical reaction vessels and activated carbon and mixed media filter columns) were each successfully used, along with other EPA-developed equipment, to clean up settled creosote from separate 500-foot lengths of the river. The entire 2½-mile contaminated length of the river is now being cleaned, as a demonstration, at an estimated cost of $70,000 per mile. Tests show that creosote continually oozes from the banks and is redeposited in the cleaned sections of the river. The creosote-containing earth is first removed. Next, the creosote that lies in pools or is dispersed in mud on the river bottom is sucked up by a specially constructed, maneuverable vacuum frame. The collected creosote/mud and water are separated by primary sedimentation. The clarified water is then freed of dissolved creosote with the 200-gpm mobile physical/chemical treatment trailer (Figure 16) and returned to the river. This treatment system can probably be reproduced for $100,000.

As an add-on to an on-going project on hydrological modification, Hittman Associates is assessing the suitability of the "Mudcat" dredge and a physical, water-sediment separation system for removing spilled hazardous materials, especially solids, from watercourses and returning clean water to the spill site. The feasibility of adapting this moderate scale (1500 gpm) system to separating insoluble, or slightly soluble, spilled, hazardous fluids from water will be evaluated.

A cleanup system using floatable mass-transfer media — activated carbon to remove "Diazinon" and an ion exchange resin to remove sulfuric acid — was successfully demonstrated in a large, concrete-lined water pond. In the process, the adsorption media are introduced to the bottom of a waterbody in weighted containers, which can be dropped from a helicopter or other aircraft (Figure 17). The media self-release from the containers, float to the surface of the water, and collect dissolved hazardous material as they rise. The spent carbon or ion exchange resin is then harvested. Work is now in progress on adapting the method for use in flowing streams.

When activated carbon "tea bags" (Figure 18) were tested in a static pool of water with phenol as

FIGURE 16. 200 GPM MOBILE PHYSICAL/CHEMICAL TREATMENT SYSTEM CLEANS UP SPILLS ON THE SPOT.

FIGURE 17. DROPPED CONTAINERS RELEASE FLOATABLE MEDIA FROM POND BOTTOM. MEDIA DECONTAMINATES SPILLED MATERIAL AS THEY RISE TO SURFACE.

the pollutant, the rate of phenol adsorption was prohibitively slow unless the water was agitated or became turbulent. It was determined that, under calm conditions in an actual hazardous material spill situation, a small number of outboard boats could adequately produce the needed agitation.

A grant has been awarded to determine the feasibility of biological countermeasures for mitigating the effects of hazardous material spills.

Identification

CAM-1 (Figure 19), the organophosphate pesticide alarm device featured in the "1972 Annual Report" and "News of Environmental Research in Cincinnati" (7-1-73), has had more laboratory testing and is now being characterized and evaluated for actual field use. An inexpensive (about $500) portable version is planned, and similarly favorable test results with a laboratory system that responds to low levels of heavy metals in water, the cyclic colorimeter, have led to the award of a contract for developing and testing a more rugged field-use model.

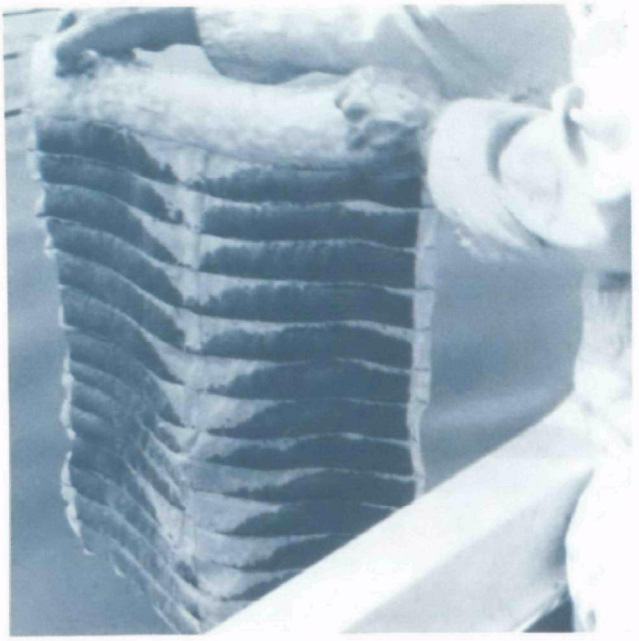


FIGURE 18. CARBON "TEA BAGS" USED TO ADSORB SPILLED CHEMICALS.

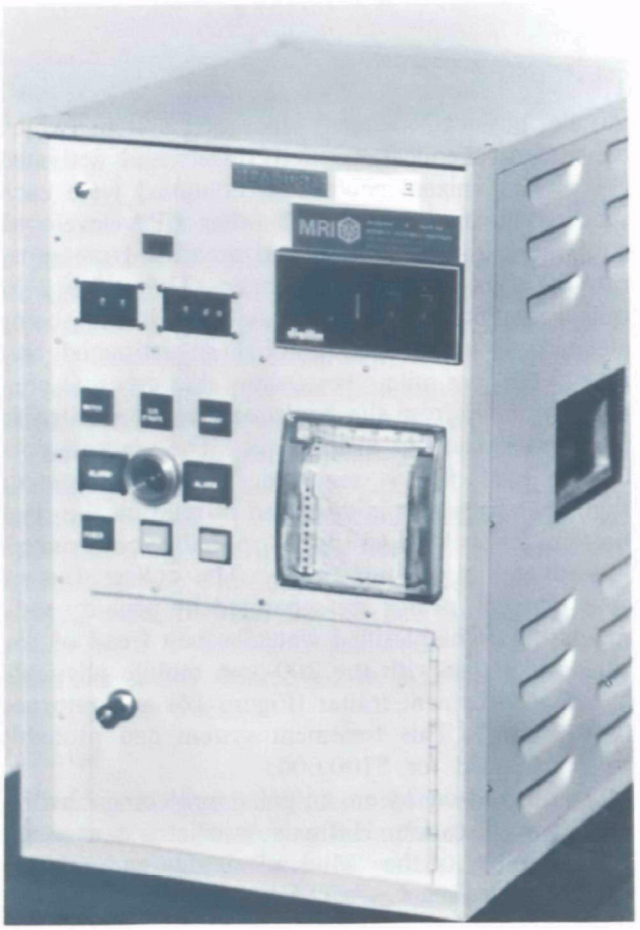


FIGURE 19. CAM-1 DEVICE WARNS OF PESTICIDE SPILLS.

Prevention

The problem of providing an alarm when an earthen dike approaches failure is being tackled through a grant to develop an acoustical-emission sensing device, which responds to the interparticle shear energy release of a dangerously stressed dike.

One goal of a model contingency plan that is being prepared for handling spills of hazardous materials in metropolitan areas is to keep the spill from entering the sewer system. For spills that do arrive at a sewage treatment plant, pilot-scale studies of corrective measures are being tested. Specific literature references on the effects of hazardous materials and on preventive measures in secondary treatment systems have been collected and critically evaluated. Publication of these references is planned for early 1974.

The hazards to aquatic food chains and to water quality are being assessed in a project concerning the spillage and release of thallium and related heavy metals (copper, lead, zinc) from ore smelting and refining operations. State agencies in Montana, Idaho, Missouri, and Arizona have cooperated extensively, and in one instance, between samplings, a major smelter instituted certain on-site treatment practices that improved water quality downstream.

Insurance and casualty loss records, a new source of documentation on the causes of hazardous material spills, are being examined — along with the usually available data sources — to set realistic priorities for developing up-coming hazardous material spill prevention and control systems.

The need remains for a captive test site on which to conduct the full-scale hazardous material spills that are essential to proper testing of prevention, control, and removal equipment, since it now appears that the NASA Mississippi Test Facility may not be suitable "as is" without extensive modification.

The American Institute of Chemical Engineers (AIChE) has been awarded a grant to sponsor, jointly with EPA, the 2nd National Conference on the Prevention and Control of Hazardous Material Spills. This 3-day meeting is scheduled to be held at San Francisco in August 1974.

INDUSTRIAL WASTE TECHNOLOGY

The activity concerned with industrial waste technology is responsible for developing and demonstrating new and improved technology for the prevention, control, treatment, recovery, and reuse of wastes in the metal finishing, nonferrous metals, rubber and plastics, inorganic chemicals, paint and pigment, pharmaceutical, soap and detergent, and miscellaneous chemicals industries.

During the past year, a number of significant EWQRL extramural developmental demonstration studies were completed. Major advances have been made in the demonstration of closed-loop-type waste abatement technology; technical assistance has been provided to the Effluent Guidelines, Refuse Act Permit, and Technology Transfer Programs; and in addition, the staff has prepared overview papers on pollution problems and on present and potential waste abatement technology for the industries in the program, and presented this information at annual as well as numerous local meetings.

Surveys

State-of-the-art surveys of the ethical pharmaceutical industry and of the paint and pigment industry have been completed. The nature and extent of their major pollution problems have been identified, with information on the sources, characteristics, and significance of specific wastes, current water management practices, waste treatment and recovery procedures obtained directly from these industries. This material will provide a basis for defining research needs and for planning broadly applicable pollution abatement development and demonstration efforts in cooperation with the individual industries. In addition, these surveys will serve as "pathfinder" studies for development of effluent guidelines for these industries.

Nonferrous and Electroplating Industries

Chemical rinsing of electroplated parts and batch chemical treatment of spent processing solutions have been demonstrated to be practical approaches for abating pollution in a small captive metal finishing facility. A full-scale treatment system reduced the amount of chromium, nickel, zinc, copper, and other heavy metals in the waste to a level where substantial quantities of water could be reused. The waste treatment costs were estimated to be 1.5 percent of product value and 6 percent of value added.

A study has been completed that demonstrated the feasibility of using electrodialysis to treat copper cyanide rinsewaters. A prototype electrodialysis system was used to show that the chemicals could be concentrated to a level that would permit their return to the bath as well as allow reuse of the treated wastewater in the rinsing operations. The study also identified certain improvements that should be made to currently available equipment.

The feasibility of using presently available reverse osmosis membranes to treat various metal finishing rinsewaters was demonstrated in a comprehensive pilot plant program. This technique purifies

the rinsewater for reuse and concentrates the chemicals for return to the processing bath. The most promising applications of reverse osmosis were identified, as were those rinse wastes that cannot be effectively treated with existing membranes and must await the development of new and improved membranes capable of withstanding more severe operating conditions. In addition to alleviating the sludge problems produced by the commonly used chemical treatment methods, reverse osmosis is attractive because of low capital and operating costs, simplicity of operation, and modular construction requiring a minimum of space.

Using an ion exchange process to recover chromate from wastewaters containing high concentrations of chromate (2700 ppm) was successfully demonstrated. In the treatment process, washwater from the production of zinc-yellow pigment is equalized, acidified, and filtered before passing through the exchange bed. The exchange bed effluent, which contains less than 0.1 percent of its original chromate content, is neutralized with sodium carbonate before conventional treatment of the remaining chromate. The resultant zinc carbonate is recovered and sold as a byproduct. Regeneration of the exchange bed with an alkaline solution recovers the chromate, which is then used in the preparation of the succeeding batch of pigment. This economically advantageous process recovers over 99.9 percent of the expensive chromate, allows formation of a saleable zinc carbonate byproduct, and substantially lowers the chromate loading to the plant's conventional chemical treatment and sedimentation facility.

Rubber Industry

A full-scale facility costing $1.5 million (exclusive of another $0.5 million for stormwater segregation) has been evaluated for the treatment of 3.5 mgd wastewater from a synthetic rubber manufacturing plant. The system consists of neutralization, chemical coagulation, primary and secondary solids removal by dissolved air flotation, and biological treatment in a completely mixed aerated lagoon; it removed just under 85 percent of the BOD, COD, and suspended solids (SS) during the start-up and demonstration period. Improvements made during the final months of the study and others that can be made to overcome recognized problems suggest that higher levels of pollutant removal are achievable. Average operating cost of treatment during the study period was $0.50 per 1000 gallons of wastewater treated — exclusive of sludge disposal.

Optimization of a full-scale storage pond system for stabilization and storage of secondary, treated, sanitary wastewater and cooling waters is an effective means of increasing the reuse ratio of water supplies from 6 to 15 times, a technique useful during periods of drought and in water-short areas. The system, which shows some similarities to an oxidation pond, includes optimization of biological activities in shallow areas and control of thermal stratification; it also allows the most effective use to be made of the pond system, including potential for total water recycle during critical, low-stream-flow periods.

STORM AND COMBINED SEWER TECHNOLOGY

Studies are being conducted at EWQRL to develop and demonstrate technology for controlling urban storm-generated runoff pollution. The major sources of this pollution are combined sewer overflows, storm sewer discharges, and nonsewered urban runoff.

Treatment

Conventional treatment processes apply basically to the nearly steady-state conditions of sanitary wastewater, whereas combined sewer overflows occur on an intermittent and random basis. Consequently, it has been difficult to adapt existing treatment methods directly to storm-generated overflows, especially the microorganism-dependent biological processes. Adverse flow conditions and unpredictable shock loadings make it advisable to consider the newer chemical and physical treatment techniques.

The applicability of the Swirl Concentrator (Figure 20) to regulate combined sewer overflow was demonstrated on a pilot scale level. This device requires no moving parts and can control the rate of flow to the interceptor and at the same time significantly reduce the amount of settleable solids in the overflow. Tankage requirements and associated costs are far less than those for conventional sedimentation. The estimated cost (1972) for a 165 cfs, 36-foot-diameter unit to be installed at Lancaster, Pennsylvania, is $100,000, or $700 per acre. Another 12.5-foot-diameter prototype with a capacity of 15.5 cfs was shop-fabricated out of carbon steel for installation in Onondaga County, Syracuse, New York. The cost of this prototype, including installation, appurtenances, and pumping, was approximately $30,000.

Based on design criteria developed from a project by the American Public Works Association for a swirl degritter, a full-scale degritter unit, which is now operating successfully without prescreening, was installed in Denver, Colorado. Actual sampling has substantiated that its performance is equal to or better than anticipated.

A physical-chemical process utilizing powdered activated carbon for the treatment of sanitary and combined sewage was successfully demonstrated in Syracuse, New York, on a 100,000 gpd scale. For combined sewage, average removals exceeded 94 percent for COD, 94 percent for BOD, and 99 percent for SS.

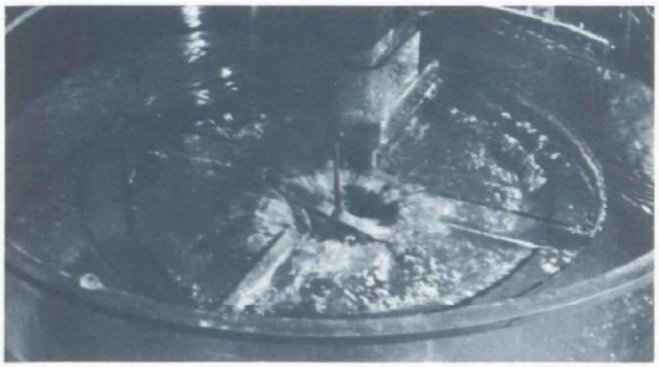


FIGURE 20. PLAN VIEW OF SWIRL FLOW REGULATOR/SOLIDS SEPARATOR DEVICE DEPICTING FLUID ACTION; PILOT STUDY FOR LANCASTER, PENNSYLVANIA, AT LASALLE, P.Q.

The Philadelphia Water Department completed the second phase of work conducted to confirm the performance of a microstraining unit (Figure 21) and the effectiveness of disinfection at high rate with chlorine. The SS in combined sewer overflow was reduced from 700 to 45 mg per liter while flowing through the microstrainer (with a 23-micron screen aperture operating at flow rates of 35 gpm per ft^2). Disinfection with 5 mg chlorine per liter in a specially built, high-rate contact chamber for only 2 minutes contact time reduced the coliform concentrations by four, or more, orders of magnitude. The cost of installing this microstrainer — special chlorine contact chamber is $6,750 per cfs of peak flow rate capacity, less land and engineering. On the design basis of 2 cfs instantaneous overflow per acre, this is $13,500 per acre.

Control

An 8.66-acre-feet, paved, asphalt detention basin was constructed at Chippewa Falls, Wisconsin, to store overflow from a 90-acre drainage area. Treatment was provided at the wastewater treatment plant when precipitation subsided. During the 2-year study period, 59 of the 62 overflow events were captured in the basin. This means that 93.7 percent of the total overflow volume was withheld for subsequent treatment before release to the river. This represented 98.2 percent of the BOD and 95.8 percent of the SS in the overflow. The estimated cost of operating and maintaining the basin and associated facilities was $7,300 per year for the 2-year period. Capital costs were $6,780 per acre of drainage area.

The importance of surface and sewer system "housekeeping" was examined in work conducted by the URS Research Company. Materials that commonly reside on street surfaces were found to contribute substantially to urban pollution when washed into receiving water by storm runoff, and in fact, the runoff is similar in many respects to sanitary sewage. Characterization studies also revealed a significant amount of exotic pollutants in the runoff — pollutants that included heavy metals (lead, zinc, cadmium, mercury, copper, chromium), pesticides and PCB's, nutrients, chemical deicers, and nonbiodegradable and refractory organics. Increasing street cleaning efficiency and limiting the use of chemicals are ways to reduce these pollutants, but specific stormwater treatment methods are also needed.

Sewer Design

University of Illinois evaluated the British Road Research Laboratory (RRL) method of storm sewer design. They found that the RRL method provides an accurate means of computing runoff from the paved area portion of an urban basin and adequately represents the runoff from actual urban basins when the basin area is less than 5 square miles, the directly connected paved area is at least 15 percent of the basin area, and the frequency of the storm event being considered is not greater than 20 years.

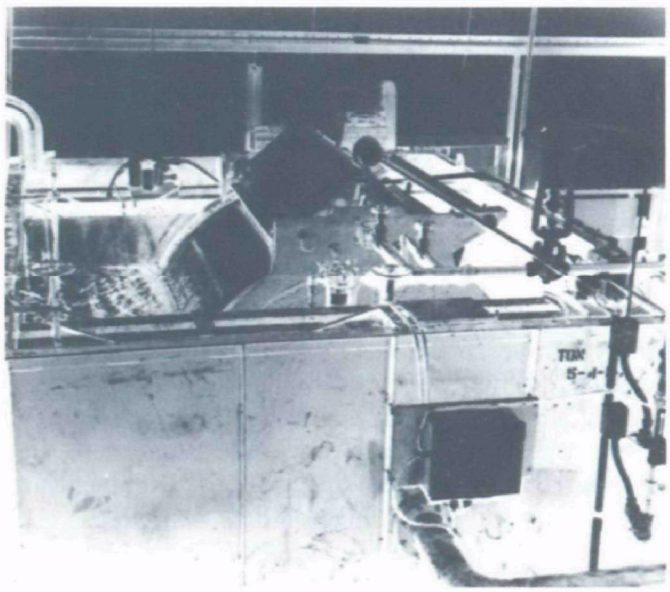


FIGURE 21. MICROSTRAINER SYSTEM USED FOR STUDY TO EVALUATE ITS USE IN TREATING COMBINED SEWER OVERFLOWS, PHILADELPHIA, PENNSYLVANIA.

The effectiveness of small, nonmetallic pipe (sewer) to transport wastewater from a macerator device under pressure was successfully demonstrated by the New York State Department of Environmental Conservation in Albany. When compared with conventional wastewater, the pressure sewer waste was 100 percent stronger. The pressure sewer system is designed to serve as an adjunct to conventional gravity sewers and to offer a new degree of freedom in providing sewer service. Use of a pressure system to collect and convey sanitary wastewater can reduce the waste volume generated, reduce conduit sizes, eliminate infiltration, minimize associated installation and treatment costs, and also alleviate overflows. In an average household, the power cost for a macerator was only $0.34 per person for a year; the unit cost was less than $1,000.

If there is insufficient carrying capacity in sewers, adding polymers may measurably reduce fluid friction. In the Columbia Research Corporation study of the effect of these additives on open channel flows, the changes in flow characteristics produced by polymer additives were reflected as either a water surface level decrease at constant flow rates or a flow rate increase at constant static heads. Such additives could increase the flow capacity of sewer lines, especially older ones, and accordingly reduce overflows from combined as well as sanitary sewers. A preliminary cost comparison for a 15-inch sewer in Garland, Texas, indicated that using polymers to control overflow and surcharge in pipes would cost one-fourth as much relief sewer construction. Additional cost verification is necessary for other locations, however.

Instrumentation

Geophysical Survey Systems, Inc., studied a unique radar system that produces a continuous profile of subsurface conditions — the depth and location of geological formations and buried utilities. This underground mapping will yield better cost estimates for designing sewage collection systems.

Hydrospace-Challenger, Inc., evaluated the suitability of over 60 models of automatic samplers to measure the flow of storm and/or combined sewers. Design guides for a new and improved device for storm and combined sewer application were developed. The assessment and guide development are applicable to all disciplines of flow sampling.

Deicer Effects

The Storm and Combined Sewer Technology Branch recently completed a state-of-the-art review of highway deicing practices and associated environmental effects entitled "Water Pollution and Associated Effects from Street Salting."

In a related project conducted by Abt Associates, Inc., several approaches were identified (both new and existing) aimed at the problems of snow removal and ice control. They concluded that more information is required on deicing, both in defining the problem and in evaluating the alternatives. The study recommended developing a hydrophobic/icephobic (water/ice repellent) substance as an alternative to the commonly used highway deicer — salt.

Beneficial Use of Stormwater

Hittman Associates, Inc., in a project at Columbia, Maryland, determined that the use of local storage and treatment represents a feasible and economic method of for urban runoff pollution control and, further, that the use of the treated water can supply a large portion of the fresh water demands of a typical urban residential community.

In Mount Clemens, Michigan, a series of three "lakelets" has been incorporated into a park development. Treatment is being provided so that these lakes are aesthetically pleasing and so their waters can be used for recreation and reused for irrigation. The Mount Clemens design has won the ASCE Conceptor Award in the state. Another project, conducted by Roy F. Weston, Inc., in the Washington, D.C. area, has also shown the feasibility of reclaiming stormwater.

Because of their value in urban planning, more demonstrations of the beneficial use of stormwater are needed. Another 1973 EPA project, part of a planned community being developed near Houston, Texas, will focus on how a "natural drainage system" can be integrated into a reuse scheme for recreational and aesthetic purposes. In this new community development, the concept of urban runoff as a benefit, rather than as wastewater, to be blended into and enhance the environment rather than upset it, will be employed and thoroughly evaluated for the first time. Hopefully, it will be shown that man and the natural environment can coexist.

TRANSPORTATION AND RECREATIONAL-AREA WASTE TECHNOLOGY

Watercraft Waste Technology

The research concerning transportation wastes involves developing the technology for the economic treatment of wastewater (including bilge and ballast discharges) from watercraft, for handling galley wastes and litter from boats, and for minimizing engine emissions.

Research on systems for managing wastes on commercial and recreational watercraft continued with

emphasis placed on recirculating waste treatment technology. To date, seven wastewater treatment systems that employ scrceening, filtration, centrifugation, carbon adsorption, incineration, and disinfection have been evaluated onboard operating watercraft. Development and laboratory testing of five other systems under simulated field conditions was also completed. Treatment effectiveness, operational and maintenance requirements, safety aspects, and costs were documented for each system evaluated. Table 3 summarizes these projects.

A physical-chemical, low-volume flush, recirculating waste treatment system was demonstrated over a 5-month period on a 50-man Corps of Engineer's dredge. The system consists of a unique, moving-paper filtration process. The demonstration showed

TABLE 3. MARINE SANITATION PROGRAMS

Contractor (subcontractor)	System type	Capacity crew size	Major equipment	Installation
Ametek	Flow thru (physical-chemical)	4-6	Surge tanks; chemical addition; sand filter; carbon adsorption; disinfection	Recreational charter boat
AWT, Inc.	Flow thru/ recirculation; (physical-chemical)	4-10	Filter incinerator; carbon adsorption; disinfection	Recreational vessel
Cleveland Cliffs Iron Co. (Thiokol Chemical)	Flow thru (physical-chemical)	30 (3000 gpd)	Primary tanks; chemical addition; centrifuge; holding tank; catalyst column; incinerator	Cliffs Victory ore carrier
Delaware River & Bay Authority (Marland Environmental Inc.)	Flow thru/ recirculation; (physical-chemical)	— (5000 gpd)	Vibro-separator; collection tank; centrifuge; carbon adsorption; disinfection; solids holding tank	Cape May - Lewes Ferry
Fairbanks-Morse	Recirculation; (physical-chemical)	25	Rotary strainer; surge tank; chemical feed; paper filter; collection tank; carbon adsorption; incinerator	Corps of Engineers dredge "MacKenzie"
General American Transportation Corp.	Flow thru (physical-chemical)	20 (700 gpd)	Primary tanks; chemical addition; rotary feed valve; moving screen filter; carbon adsorption; disinfection	Corps of Engineers dredge "Ros"
General Electric	Flow thru (electro-chemical)	35	Pump grinder; electrocoagulation cells; upflow clarifier and concentrator; carbon adsorption; disinfection; incinerator	Corps of Engineers dredge "Gerig"
Gulf & Western	Flow thru (physical-chemical)	15 man-days	Carbon injection; mixing tube; filter; disinfection	Recreational vessel
Ocean Science & Engineering	Recirculation; (chemical)	50	Chemical addition; mixing and settling tanks; sludge tank; hydraulic accumulator	Alcoa Seaprobe research vessel
Ocean Systems	Incinerating toilet	4	Oil burner; combustion chamber; afterburner	Recreational vessel
Thiokol Chemical Corp.	Flow thru/ recirculation (physical-chemical)	4-10	Holding tank; filter incinerator; catalyst tank; disinfection	Houseboat
Westinghouse	Recirculating toilet	4-5	Traveling spring screen; in-line filter; carbon adsorption; electric incinerator	Westinghouse research craft "NorthStar"

that the system can reduce SS and BOD by 99 and 95 percent, respectively. The quality of the flush water throughout the test remained generally clear and odorless with only a slight ammonia odor and bluish color occasionally detectable. Shipboard operation indicated problems that required some additional developmental work and also the need for routine maintenance to ensure unnecessary system breakdown. The unit cost is estimated between $27,000 and $39,000 and operating costs at about $3 per day.

A 5000 gpd physical-chemical treatment system was installed and evaluated onboard a ferry operating in Delaware Bay. The shipboard demonstration was conducted during the 1972 peak summer season with the system operating in the flow-through (overboard discharge) and the recirculating modes. Performance data for overboard discharge showed that SS in the effluent were always less than 50 mg per liter. Effluent BOD ranged from 98 to 150 mg per liter. The BOD and ammonia nitrogen, which increased rapidly in the treated recycle water, caused serious deterioration of the flush media. The system costs about $40,000, and operating expenses can be $200 per month during peak periods.

A wastewater treatment system with a novel filter-incinerator and catalytic oxidation process, used as flow through or recycle operation, was developed for recreational watercraft. Typical results shown during extensive laboratory testing illustrate that significant reduction in BOD and SS, generally greater than 90 percent, can be achieved by the system. Tests performed in the laboratory indicate that the system is capable of maintaining an aesthetically acceptable flush liquid, i.e., containing no color, slight cloudy appearance, and no objectionable odor. The analytical data collected during these tests indicated a gradual buildup of BOD to concentrations between 1000 and 1500 mg per liter. SS were generally maintained around 100 mg per liter. The system will be tested on a houseboat to generate operating data; the hardware cost is estimated between $500 and $1000.

Laboratory and on-ship evaluation of a small recirculating waste-treatment device for recreational watercraft indicated that human waste can be effectively treated to provide an aesthetically acceptable recirculating flush media. The device (Figure 22), which provides liquid-solids separation, disinfection, and electric incineration, will cost about $500 and can handle 46 man-days of usage without discharge to shoreside support facilities.

Treating vessel-retained waste, which is extremely high in organics and often contains toxic, deodorizing chemicals, presents a serious shoreside problem. Projects were initiated to characterize this unique waste, perform treatability and toxicity studies, and demonstrate promising systems to document treatment effectiveness, reliability, cost, and sludge disposal needs. The waste characterization program showed that pumpout waste can obtain BOD and SS in excess of 1000 mg per liter; the treatability and toxicity studies indicated that, at small dilution ratios, these wastes can adversely affect conventional treatment processes. Initial evaluation of one of these projects at the Lake Mead Marina indicates that a physical-chemical system can effectively reduce BOD and SS by greater than 90 percent (design objective). An evaporator-incinerator system to treat pumpout waste is also under development and evaluation. Laboratory investigations have been conducted to establish and verify heat transfer coefficients, continuous sludge feed technique, ash removal, and optimum cool-down cycle. The ability of the materials to withstand the corrosive effects of

FIGURE 22. WESTINGHOUSE COMPACT RECIRCULATING TREATMENT TOILET FOR FOUR-MAN CREW VESSEL.

the process will also be investigated. The concept, thus far, appears feasible although some material problems have been indicated. A field evaluation, scheduled at a marina on the Great Lakes for summer 1974, will define the ability of the system to effectively and economically treat pumpout waste under normal operating conditions. Waste input, evaporator effluent, exhaust streams, and ash residual will be monitored over the 90-day test period.

Research was initiated to advance the technology for collecting, handling, and treating all vessel-generated waste at port facilities. Emphasis has been placed on the Great Lakes where a waste characterization program is underway at Duluth-Superior Harbor. Useful quantitative and qualitative data on the character and generation of various waste sources offloaded from both domestic and foreign craft will result.

Research continued through 1973 to investigate the extent of pollution from outboard engine exhaust and its impact on the aquatic environment. The collection of chemical, physical, and biological data is complete, and the complex evaluation underway will provide a scientifically based assessment of the outboard engine exhaust problem.

Recreational-Area Waste Treatment

Treating wastes generated at recreational areas is a major problem because of the short-duration and high load factor and the need to provide a high level of treatment to protect the water quality of the recreational area. The installation and demonstration of a nonaqueous, recirculating waste treatment system at Mt. Rushmore, South Dakota, was successfully completed. The evaluation showed the concept to be feasible and effective for areas where water supplies are limited. Continued support was given projects to demonstrate a recirculating, catalytic oxidation waste treatment system for a ski resort and urea formaldehyde foam for a flora-filter waste treatment system at two Ohio State parks.

A Federal Interagency Committee on Recreational Waste Management Research was established to coordinate, accelerate, and enhance the research, development, and demonstration efforts of the agencies involved with recreational waste management. The Committee will identify mutual, immediate, and long-term research needs, set priorities, provide a technical exchange forum, and promote cooperative research projects among Federal agencies.

Edison Water Quality Research Laboratory, Edison, New Jersey.

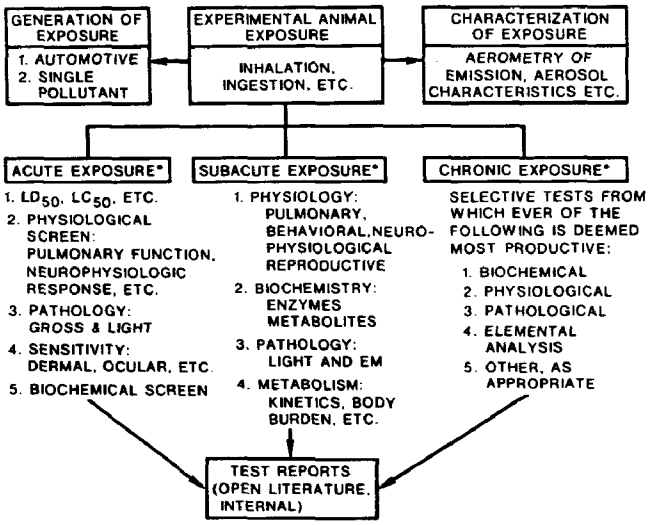
ENVIRONMENTAL TOXICOLOGY RESEARCH LABORATORY

The Environmental Toxicology Research Laboratory was charged to test, evaluate and define potential harmful effects of environmental pollutants from mobile and stationary sources. The data obtained in experimental biological models, particularly in mammalian species, provide necessary input for the development of criteria documents, which in turn serve to establish realistic environmental standards.

A major effort during 1973 was the evaluation of biological effects of fuel and fuel additive emissions from automobiles and of engine models equipped with catalytic converter control systems.

The definitive toxicological investigations conducted in this laboratory are particularly related to air pollutants, and the route of animal exposure is, primarily, inhalation. In many instances, however, the pollutants studied are found in various environmental media, and to provide relevant information on the public health impact of such pollutants, the different routes of entry must be studied. In addition, using judicious selection, several appropriate animal species of different ages (from embryonic to aged models) are being used to optimize the probability of reproducing human response.

The protocol followed in the process of toxicologic investigation is summarized in Figure 23. Whether this matrix is followed in part or in full depends on the theoretical prediction of potential toxicity and the amount of knowledge presently available on the pollutant in question.



*THE APPROACH FOR ANY GIVEN POLLUTANT(S) WILL VARY SOMEWHAT FROM THIS GENERAL SCHEME, DEPENDING ON WHAT IS CURRENTLY KNOWN ABOUT THE POLLUTANT AND THE TYPE OF INFORMATION NEEDED TO FIT THE GAPS.

FIGURE 23. DEFINITIVE TOXICOLOGICAL MATRIX FOR INDIVIDUAL POLLUTANTS AND EMISSIONS FROM MOBILE SOURCES.

ANIMAL EXPOSURE STUDIES

During 1973, animal exposure studies were conducted to assess the relative health hazard of whole exhaust emissions coming from gasoline engines equipped with catalytic converters. The auto exhaust generating facilities were extensively modified before the beginning of TAME* G study. Additional modifications including installation of two 1975 prototype engines were made after its completion. The addition of an air dilution tube for the immediate mixing of the entire raw exhaust emissions with filtered and temperature controlled air was used for the first time beginning with study G. This dilution tube eliminated the necessity of a heat exchanger, which had been attributed to loss of particulate in the former exhaust dilution system, and the raw exhaust now entered a large volume mixing chamber from the dilution tube. Because the engine cycle produces varying amounts of exhaust and the gaseous components are in different proportions, this mixing chamber provides a degree of integration of the flow and concentration. A bleed line to the outside atmosphere, with a motorized damper, is controlled by sensing downstream pressure from the mixing chamber. The supply source for both raw and irradiated exhaust gas to the animal chambers must be as identical as practicable.

After the completion of TAME G, the laboratory acquired, free of charge, 1975 prototype engines equipped with catalytic converters from General Motors Company and the Ford Motor Company. The 1972 Chevrolet engines were removed from the dynamometer test stand and the following engine systems were installed:

*Toxicity Assessment Mobile Emissions (TAME)

FORD — 400 C.I.D., R-6 engine with R-14 calibration and the following controls:

(1) EGR (exhaust gas recirculation)
(2) Air pump
(3) Fluidic spark delay valve
(4) Various temperature sensing triggers
(5) Catalytic converter of monolith, noble metal oxidation type. *Two* converters of this type are required, one for each bank of cylinders. (Catalyst by Matthey-Bishop Co.)

GENERAL MOTORS — 350 C.I.D.

(1) EGR
(2) Air pump
(3) Catalytic converter, pelletized type, noble metal oxidation catalyst. One converter after Y pipe. (Catalyst by W. R. Grace & Co.)

During studies H, I, J, and K, the 1975 prototype Chevrolet engine was operated continuously on the California Cycle for 7 days without interruption. Although the exact average gaseous pollutants in the animal exposure chambers are not available at this time, the approximate chamber concentrations and other control criteria are given in Table 4.

Under similar operating conditions on the dynamometer test stand, the 1975 prototype Chevrolet engine consumed 28 percent more fuel than the 1972 Chevrolet used in study G. The average speed calculated for the California Cycle was 20 miles per hour, which resulted in 17.2 miles per gallon for the 1972 engine compared with 13.4 miles per gallon for the 1975 prototype. These figures are not absolute for road vehicles; they were compiled from many weeks of engine operation and are accurate for comparison between road vehicles. The principal reason for the extra fuel consumption is the exhaust gas recirculation system added to the later model engine.

Catalysts are designed to lower the exhaust emissions of carbon monoxide, hydrocarbons, and oxides of nitrogen, the three pollutants specifically listed in the Federal Clean Air Act of 1970. The regulations also require that no pollution control device shall emit "noxious or toxic" substances. Two possible

TABLE 4. COMPARISON OF EMISSION COMPONENTS AND CONTROL CRITERIA IN TAME STUDIES

Measurement	TAME G*	TAME H†	TAME I‡	TAME J	TAME K§
Dates	4/13 — 6/15	9/10 — 17	10/10 — 17	10/24 — 31	11/14 — 21
Fuel	Ref. + MMT	Ref. Only	Ref. Only	Ref. Only	Ref. + Sulfur
Engine	72 Chev	75 Chev w/Cat.	75 Chev No Cat.	75 Chev w/Cat.	75 Chev w/Cat.
Engine hours	A 348- 723 B 2161-2353	62-230	255-425	444-615	675-841
Study hours	509	168	170	171	166
Engine miles	—	4608	8504	12,292	16,812
Cumulative catalyst hours	—	244	244	465	632
Catalyst miles	—	4608	4608	9308	12,636
Total fuel, lb.	3614	1533	1545	1601	1493
Fuel, lb./hr.	7.1	9.10	9.08	9.40	9.02
Exhaust oxygen, percent	1.6	4.9	N.A.	4.2	4.7
Air/fuel ratio	15.3	—	14.4 cycle 12.4 idle	—	—
Dilution ratio	25/1	8.0/1	9.6/1	8.7/1	9.5/1
Exposure chamber concentrations					
Carbon monoxide, ppm	135	7	560	40	30
Total hydrocarbon, ppm	78	12	120	20	17
Nitrogen oxides, ppm	21.75	11	12	15	12

*8 hour/day, 7 days/week interrupted exposure. MMT added, 0.25g as manganese per gallon ref. fuel.
†Studies H, J, K were continuous (24 hour/day) 7-day runs. Factory tuned, carburetor "limiters" in place. No adjustments.
‡Study I, no changes except for removal of catalyst.
§Thiophene added to produce 0.10% by weight sulfur in reference fuel (Indolene "clear").
// Air/fuel ratio determined with air pump disabled. (Cycling and at idle).

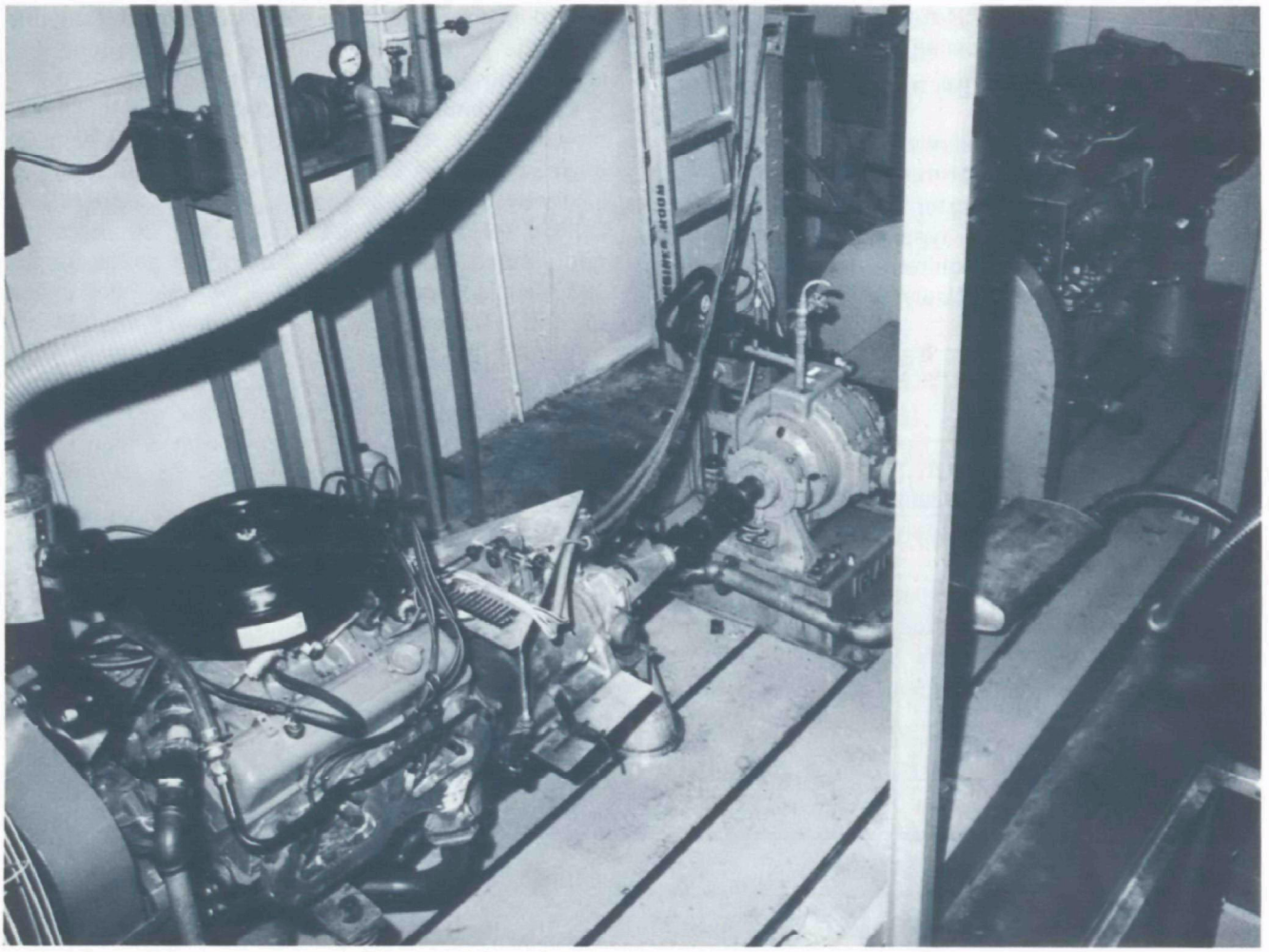


FIGURE 24. ENGINE DYNAMOMETER ROOM.

problems could create these noxious or toxic substances. One could arise as the hot catalysts promote the oxidation of carbon monoxide and hydrocarbons in automotive exhaust, converting them to carbon dioxide and water. At the same time, the catalysts would convert small amounts of organic sulfur compounds present in all gasoline into sulfuric acid mist. The second problem could arise from the metal used in the device, such as platinum and palladium, which may be emitted from the exhaust pipe in very fine particles and be suspended in the air.

Sulfur compounds present in gasoline are mainly in the form of polysulfides and of thiophene compounds with, possibly, an insignificant amount of hydrogen sulfide dissolved in the gasoline. To produce a high-sulfur content gasoline free of other undesirable substances such as lead, thiophene was added to produce a sulfur content of 1000 ppm in the Indolene for TAME K. With the use of the Catalytic Converter Control System, the higher sulfur gasoline produced almost the same exhaust chemistry with the additional expected sulfur dioxide plus sulfur trioxide compounds.

It was reported and confirmed in our laboratory that installation of oxidation catalysts in the automotive exhaust system causes an increase in the emitted particulate material, which consists mainly of hydrated sulfuric acid droplets resulting from the oxidation of organic sulfur compounds in gasoline. Recent averages of the sulfur content run between 210 and 260 ppm for premium gasoline, and between 390 and 440 ppm for regular gasoline. The "Indolene" motor fuel used at the ETRL facility had a sulfur content of 0.4 percent by weight or 400 ppm. It is hypothesized that the internal combustion process causes the organic sulfur compounds to become sulfur dioxide, which is oxidized by the emission catalyst to sulfur trioxide, which then reacts with water vapor in the exhaust to form sulfuric acid droplets. Among measures considered to decrease formation of the sulfuric acid are: lower sulfur content in the gasoline, low excess oxygen supply to the catalytic converter, and optimization of catalyst temperature.

The best current estimate of the resulting increase in suspended acid aerosol emissions and particulate

sulfates is about 0.05 gram per mile measured as sulfate with a range of 0.02 gram per mile to 0.10 gram per mile.

TAME studies H, I, J, and K were conducted at this laboratory to substantiate these estimates based on rather limited data. Initial measurements indicate that particulates are increased 2½ to 3 times in animal exposure chambers (Figure 25), and the relative acidity of the emissions is increased approximately 65 times with the use of the catalyst and reference fuel — Indolene.

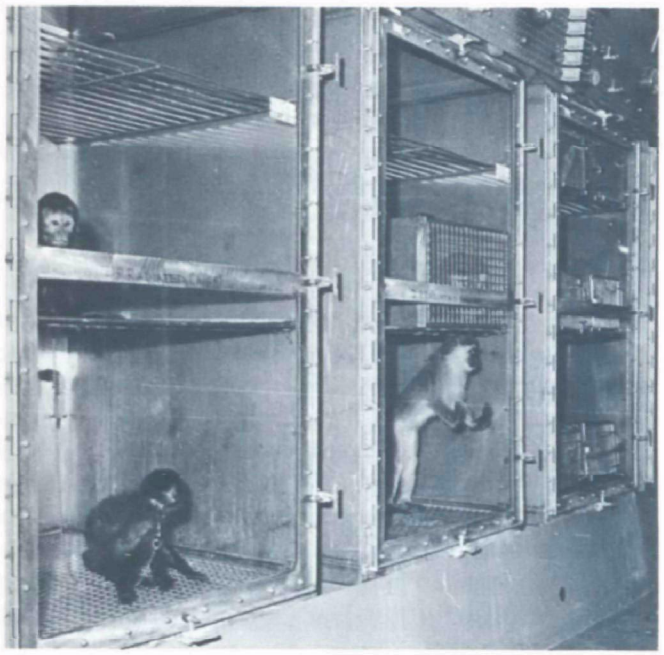


FIGURE 25. ANIMAL EXPOSURE CHAMBER.

EXPERIMENTAL PHYSIOLOGY

Toxicity of Pollutants as Determined by Cardiopulmonary Response

Although most of the respiration, cardiovascular function, and other physiological studies have been done on anesthetized animals, it is recognized that anesthesia in many cases alters physiological response. The cardiovascular and respiratory systems are among those that are highly sensitive to anesthesia. During 1973, the physiology laboratory at ETRL developed three separate studies in which unanesthetized animals are discretely monitored for cardiovascular or respiratory system response during actual pollutant exposure.

Telemetric Measurement of Respiration Rate and Volume in Dogs

If rate and depth of breathing in a conscious dog are measured while the dog is in a controlled atmosphere, then the problem of measuring a dose of any fixed atmospheric pollutant administered to the dog is a matter of simple arithmetic. This method, therefore, greatly increases the precision in determining the amount of inhaled compound. Known doses of any pollutant can then be more easily correlated with other physiological or behavioral effects or pathological tissue changes.

The study was projected in two steps: (1) The design and building of a workable implantable strain gage sensor for monitoring respiration; the design and assembly of equipment required for transmitting, receiving, and recording respiratory signals; and development and execution of a method (closed TV) for viewing the animal indirectly. (2) Implantation and calibration of the strain gage - transmitter unit; control measurements; exposure to a pollutant agent (sulfates); and data collection, reduction, and interpretation. At the present time, step 1 has been completed and the first phases of step 2 have begun. The sensor, which consists of a semiconductor strain gage deposited on a small plate, has been surgically attached to the ninth rib with bone screws. Stress on the rib, generated by intercostal muscle pull during breathing, produces a measurable voltage output by the strain gage. The calibrated signal from the gage reflects respiratory rate and volume. The strain gage output modulates an FM transmitter via an impedance transformer. The transmitted signal is received by a commercial receiver, and the output from a discriminator is fed to a chart recorder. The surgically prepared and calibrated dogs are located in atmospherically controlled chambers, and the respiratory signals are being recorded in an adjoining room as the animal's behavior is being monitored on a television screen.

Cardiovascular Response to Pollutants as Measured in an Unanesthetized Rat: A Screening Technique

A study is presently underway that utilizes a systematic method for screening pollutant effects on the heart and blood vessels in the unanesthetized rat. Parameters measured are ECG, heart rate, ventricular contractility, blood pressure, and breathing rate and depth. Initial work includes using a number of platinum and palladium compounds, which are of interest because of their use in the catalytic converter. Measurements will assess effects of subacute dosages of different agents when administered intravenously, intraperitoneally, or orally.

Physiologic Responses of the Respiratory Tract During Pollutant Aerosol Exposure

Guinea pigs have been used extensively to study pollutant effects on the respiratory system. Much information can be gained to evaluate effects of particulate irritants on health when a system is used that combines aerosol generation and exposure with

simultaneous animal physiological measurements. Such a system is presently being developed at ETRL. The goal of this task was to establish a routine procedure to screen a large number of pollutants for subacute toxic effects. Platinum and palladium compounds, as well as sulfates, are of primary concern and are to be tested first. For the exposure, particulate size, concentration, and exposure time are controlled. Guinea pigs are measured for total respiratory flow resistance, respiratory frequency, minute volume, arterial oxygen tension, body temperature, and ECG.

Neurotoxicity Index of Metals from Mobile or Stationary Sources

The rat visual-evoked potential is being utilized as a screening technique to test the relative short-term effects of various metal pollutants on central nervous system function.

Over 120 rats have been exposed via intravenous injection to several toxicologic agents in the past year. The resultant change in the visual-evoked potential has been analyzed using various methods including computer averaging techniques. The preliminary results have indicated that the rat visual-evoked potential may be important in assessing the significant acute effects of various pollutants on central nervous system function. In Table 5 are the threshold doses of tested cations that elicited a reproducible effect in the visual-evoked potential.

TABLE 5. VISUAL-EVOKED POTENTIAL SCREEN

Metal compounds	Reproducible dose-effect threshold (mg/kg)
Cobalt	0.010
Cadmium	0.10
Chromium	0.40
Palladium	0.40
Barium	2.0
Manganese	2.0
Platinum	Minimal effect

Therefore, the relative short-term effect of the intravenous administration of these metals on the rat visual-evoked potential was ranked as follows:

Cobalt>Cadmium, Chromium, Palladium>Barium, Manganese>Platinum

Further work is currently underway in order to determine the dose-response of these and other toxicologic agents.

Behavioral Toxicity of Automotive Emissions in Mice

Experiments indicated that the voluntary wheel running activity of mice was suppressed during exposure to raw and irradiated automotive exhaust in direct proportion to the atmospheric concentration. Further observations have shown that the level of activity suppression was not changed by the introduction of a manganese fuel additive into the gasoline. When mice were exposed to exhaust emissions for only 8 hours per day, their wheel running was suppressed during those 8 hours but returned to control levels during the remainder of each day, throughout the 8-week study. When the exhaust was passed through a catalytic converter before entering the exposure chambers, wheel running decreased for only the first day of exposure and thereafter returned to control (normal) levels for the duration of the experiment.

Lead and Mercury Contract Study

Heavy metals, particularly lead and mercury, have been implicated in various disturbances of central nervous system function. Due to inherent technical difficulties, there have been very few electrophysiological studies of specific neural circuits that will elucidate the mechanism of action of these metals on the central nervous system function. Results from the experiments outlined here should provide definitive conclusions regarding the effects and the site and mode of action of lead and mercury on spinal reflex transmission.

Thus far, experiments have been performed to examine the effects of lead injected directly into the cat spinal cord. Preliminary data have shown that lead reduces the rate of transmission between cells in the spinal cord. Since information of this type may have important consequences, further experiments are underway in an attempt to ascertain the precise site and mode of action of lead and other heavy metals.

METABOLISM AND KINETICS

Pulmonary Cytologic Defense System

Methods were adapted to assess the effects of inhalation and intratracheal exposure to test pollutants on lavage-recoverable free cells of the pulmonary tree. Following experimental pollutant exposure, test animals were anesthetized and polystyrene latex spheres were administered intratracheally. After 30 minutes the lungs were lavaged with normal saline. Lavage suspension cell count and cell size were determined as well as cell character and phagocytic activity. Also noted on each animal was body weight and total and differential WBC counts. Test ex-

posures to evaluate pulmonary cellular responses have included the mobile emission tests to examine 1-week inhalation toxicity of automotive exhaust associated with the use of a prototype catalytic converter system and with fuel of low and high sulfur content. Other tests included brief inhalation exposure to respirable titanium dioxide dust (used in studies or "inert" dust lung clearance) and intratracheal instillations of two palladium compounds.

Preliminary analysis of TAME H data suggests an exhaust exposure effect in terms of altered cell size and of distribution of phagocytic activity (numbers of latex spheres phagocytized). Male hamsters exposed to irradiated exhaust without the converter showed signs of illness and weight loss, whereas in a study with a converter, exposed animals did not lose appreciable weight and were not grossly ill.

Dermal Irritancy and Cellular Toxicity Testing

As a component of a broad toxicologic evaluation of substances possibly associated with the use of automotive catalytic emission control systems and fuel additives, several chemicals were tested with respect to severity of response when applied directly to the intact (irritancy) and abraded (cellular toxicity) skin of rabbits. Three palladium compounds and one platinum compound were assessed as probably unsafe for human skin contact, either intact or abraded; three additional palladium compounds were assessed as safe for intact skin, but unsafe for unprotected abraded skin contact. The other palladium and platinum compounds, two lead compounds, and an organic manganese fuel additive (MMT) appeared safe for skin contact.

Tests for dermal sensitization are in preparation; they may have a greater environmental health significance since the dermal irritancy is relevant primarily to industrial exposures.

PHARMACOLOGIC METABOLISM

Microsomal Enzyme Effects of Auto Exhaust

Several compounds in automotive exhaust are known to affect the microsomal enzyme system. Since the system is responsible for the biotransformation of xenobiotic and numerous endogenous compounds, its integrity is of paramount importance to the organism.

Lung microsomal metabolism as reflected by aryl hydrocarbon hydroxylase (AHH) activity was determined in hamsters following exposure to auto exhaust. Using interrupted exposure (TAME G, 8 hours per day for 8 weeks), average AHH activity was depressed 22 percent by nonirradiated and 31 percent by irradiated exhaust. The reduction was significant following 8 hours' exposure and remained depressed for at least 15 days. After 8 weeks' exposure, AHH activity was still depressed, although the difference was not statistically significant.

The effectiveness of exhaust catalytic devices was evaluated by comparing the AHH activity after 5 days' continuous exposure with and without the catalyst (TAME I and TAME J, respectively). Without the catalyst, AHH activity was reduced by 56 and 57 percent in irradiated and raw atmosphere, respectively. Introducing the catalyst resulted in 26 percent and 9 percent reduction, respectively, in the irradiated and raw atmosphere at the same exhaust dilution ratio. The reduction in AHH activity following exposure to irradiated exhaust was statistically significant in both studies and the reduction following exposure to raw (nonirradiated) exhaust was significant in TAME J (without catalyst).

Biotransformation of Manganese Fuel Additive

The metabolism and biotransformation of MMT was investigated using *in vivo* and *in vitro* techniques. Following intravenous administration of radioactive labeled MMT and manganese chloride in adult rats, 0.23 percent of the manganese chloride was excreted in the urine and 17.0 percent in the feces; 15.8 percent of the manganese from MMT was excreted in the urine and 22 percent in the feces. In both experiments, the manganese was not organic extractable, which indicates that inorganic manganese was being excreted. Since inorganic manganese is not readily excreted in the urine but does appear in the feces, *in vitro* metabolism studies were undertaken. The results showed that for a concentration of 5μg MMT per ml tissue homogenate, the rates of metabolism for liver, kidney, lung, and brain were 1.24, 0.07, 0.0317 and 0.03 percent per minute, respectively. The results indicate that (1) MMT is metabolized by the microsomal system; (2) the ability to metabolize MMT was found in liver > lung > kidney > brain in decreasing order; (3) some volatile form of manganese may be produced by metabolism; and (4) metabolism by the kidney occurs at some point distal to the site of manganese reabsorption in the nephron.

Acute Toxicity Studies with Palladium Chloride

The acute single dose toxicity in rats of palladium chloride following administration by the intravenous route was 5 mg per kg; the intraperitoneal route, 75 mg per kg; and the oral route, greater than 200 mg per kg. A similar response was noted in the rabbit after intravenous administration. Toxicometric effects observed were decreased food and water intake, loss of body weight, renal effects as manifested by proteinuria, increased urine output with constant decreased specific gravity, elevated urinary ketone

bodies, exitus due to respiratory arrest without cyanosis (and convulsion — both clonic and tonic). Additional studies are in progress.

Protein Binding Studies

Because of the rather sharp threshold for acute intravenous toxicity, which suggests some compartmental saturation phenomena, protein binding studies were performed with palladium and platinum chlorides. At concentrations up to 200 mg palladium chloride per ml, binding to protein was greater than 99 percent as measured by the Toribara technique. Temperature, pH, and type of protein were not found to affect binding. Similar results were noted with platinum.

PATHOLOGICAL AND BIOCHEMICAL EFFECTS OF POLLUTANTS

These studies have been directed toward delineating some of the pathological and biochemical changes in animals that result from exposure to environmental pollutants. During 1973, the major emphasis has been placed on determining the biological fate and toxicity of: (1) methylcyclopentadienyl manganese tricarbonyl (MMT), a fuel additive combustion improver; (2) lead pollutants, bound in environmental dust; (3) methylmercury, essentially completed in 1973; (4) automobile exhaust whole emission products; and (5) catalytic converter components initiated in mid-1973.

Methylcyclopentadienyl Manganese Tricarbonyl (MMT)

Federal regulations require that an unleaded grade of gasoline be made generally available to permit the use of emission control devices on 1975 light duty vehicles. This mandate has stimulated renewed consideration of MMT as a primary antiknock agent. In this grade of gasoline, MMT would not be competing with tetraethyl lead. MMT contains approximately 25 percent manganese by weight, and the maximum concentration recommended by the producer is 0.125 gram manganese per gallon of gasoline. Generally, following combustion, only manganese oxides are present in exhaust emissions.

In ascertaining the environmental impact of MMT, it is important to determine if its usage will cause a significant increase in manganese concentrations in urban ambient air and whether or not an increase in the air concentration of manganese will produce biological effects or affect other atmospheric pollutants.

We reported last year on the toxicity of MMT and on its ability to produce damage to lungs, liver, and kidneys. This year, we were able to demonstrate that capillary permeability in the lungs may be altered by oral doses of MMT as low as 15 mg per kg. Lung lavage techniques, utilizing radioiodinated albumin as a tracer, have shown that maximum response occurs within 24 hours.

In an 8-week whole emission study, animals were exposed in our chamber facility to exhaust products from an engine fueled with Indolene containing MMT. No lesions attributable to MMT or manganese oxides could be found in any of the animals. Microscopic examination of the lungs showed minimal changes related to the exhaust emissions. There appeared to be an increase in the concentration of manganese in tissues taken from the exposed rats (Table 6) when compared with control rats (clean air); both groups of rats were fed a specially formulated diet low in manganese. Similar changes were noted in rats maintained on a regular diet containing normal amounts of manganese.

Environmental Lead

Tetraethyl lead is the most effective and commonly used primary antiknock agent in gasoline. Following combustion, lead is emitted in auto exhaust and consequently contaminates the environment. The concentration of lead in street dust and surface soil has been shown to correlate with the amount of traffic and distance from the highway. This environmental lead dust has been incriminated as one source of human exposure, especially in children .that have

TABLE 6. MANGANESE CONCENTRATION IN DIFFERENT RAT ORGANS AFTER EXPOSURE TO AUTOMOTIVE EMISSIONS, μg per gram dry weight

Organ	Treatment			
	Clean air, regular diet	Irradiated exhaust, regular diet	Clean air, special diet	Irradiated exhaust, special diet
Brain	5.06	9.44	3.54	5.16
Heart	3.80	3.08	4.23	4.37
Kidney	5.63	5.80	3.34	4.03
Liver	4.37	7.39	1.77	3.14
Lung	1.36	2.07	1.81	2.94

pica. In these studies, laboratory animals were used to show that, following ingestion, lead was absorbed from lead-contaminated street dust at a rate similar to that found for elemental lead.

Studies this year have shown that the chemical form in which lead is found is not significant from the standpoint of physiological availability. Tracer studies that employed radioactive lead oxide, acetate, and chlorbromide showed similar absorption and distribution curves following oral ingestion in rats. Another study demonstrated that lead would cross the placenta and could be found in the unborn fetus. A 5-month rat study in which lead oxide, tetraoxide, acetate, or chlorbromide was added to the diet has shown no difference in blood levels that are attributable to the chemical form of lead. There were significant increases in blood lead levels when compared with controls, however. Organ concentrations of lead are not yet available as the study is continuing.

Mercury

High concentrations of mercury in certain foodstuffs, especially seafood, are a major international problem and have resulted in banning the use of certain types of aquatic animals for food. Our studies have been concerned with developing methods for the detection of early biohemical changes associated with mercury toxicity.

From radiorespirometric investigations of the metabolic effects of methyl mercury chloride, a mathematical model was developed that permits metabolic effects to be predicted over a longer time period by examining the carbon-14 labeled carbon dioxide excretion over a 30- to 60-minute period. In addition, the dose:response can be predicted over a wide range of toxicant concentrations by data simulation on an analog computer and interpolation following a small number of strategic experiments.

Gaseous Emissions (Nitrogen Dioxide)

A study was completed in which hamsters were continuously exposed for up to 5 days to 5, 10, and 20 ppm nitrogen dioxide. Lesions were confined to the lungs and were localized at the level of the terminal bronchioles. The severity of the lesions correlated well with dosage and had similar chronological stages. These stages consisted initially (the first 48 to 72 hours) of an exudative stage in which macrophages and inflammatory cells predominated. Subsequently, a proliferative stage developed and the predominant features were alveolar septal thickening and extension of cuboidal respiratory epithelium more distally into the lungs. These lesions appeared identical to those seen in the whole auto exhaust emission studies; this suggests nitrogen dioxide as a major causative agent for the pulmonary morphologic changes noted thus far.

Catalytic Converter Components (Platinum and Palladium)

Automotive manufacturers have indicated that platinum and palladium will be used in catalytic converters, which are designed to reduce the concentrations of carbon monoxide and hydrocarbons in the exhaust stream by oxidizing them to carbon dioxide and water. This use of platinum and palladium in automotive catalytic converters creates the possibility that some amount of these elements will be emitted into the atmosphere or enter other segments of the biosphere following degradation during driving or disposal of worn-out converters.

Current studies involve exposing animals to platinum and palladium and determining the biological fate of these metals. Radioactive platinum and palladium have been given orally, intravenously, and intratracheally to young, adult, male rats. Data indicate that these metals are not readily absorbed from the gastrointestinal tract and that the whole body retention time is rather short. Both metals will cross the placental barrier. One study with palladium has been completed; it indicates transfer of the metal to suckling rats in milk from mothers given palladium intravenously. Biochemical studies have demonstrated that compounds of platinum and palladium have an inhibitory effect on certain serum enzymes *in vitro*. In on-going but not completed studies concerned with the fate and toxicity of inhaled platinum and palladium, the Lovelace Chamber (Figure 26) is being used; this permits exposure to high concentrations of respirable materials with minimal contamination of the animal's body.

Acute (7 day) studies comparing the biologic effects of exhaust emissions from engines with and without catalytic converters have been completed. Use of the catalytic converter markedly reduced carbon monoxide and hydrocarbon levels, and essentially, no lesions were detectable in exposed animals. In the exposure without the converter, extensive lesions were noted as well as high infant-rat mortality (Figure 27), body weight loss, and changes in blood components in exposed animals.

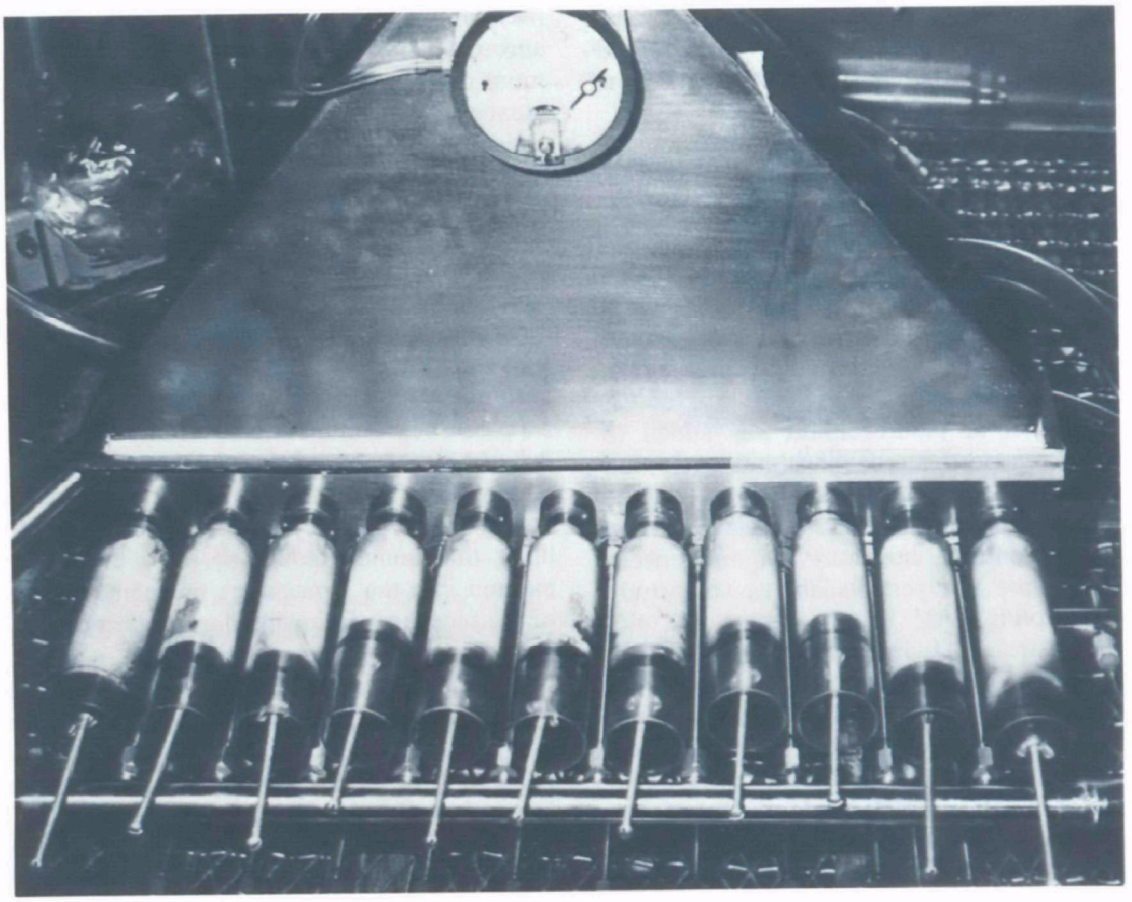


FIGURE 26. LOVELACE CHAMBER.

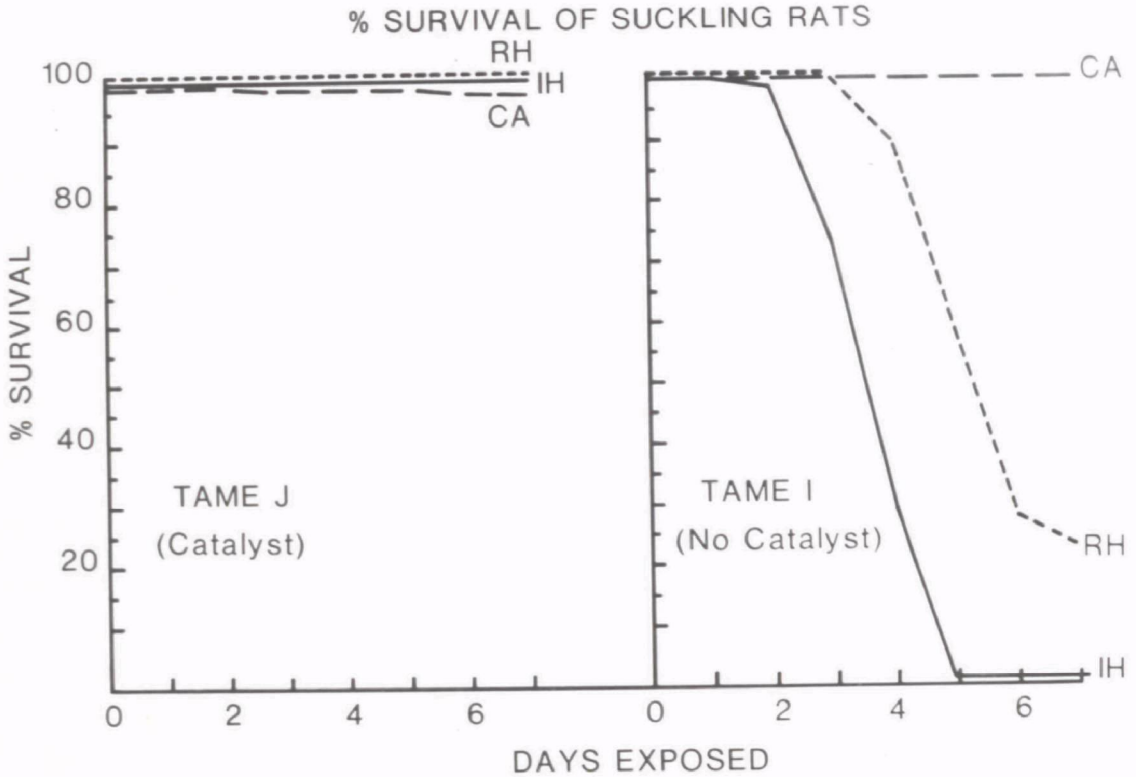


FIGURE 27. PERCENT SURVIVAL OF SUCKLING RATS.

RADIOCHEMISTRY AND NUCLEAR ENGINEERING BRANCH AND FACILITY*

In the field of radiochemistry and nuclear engineering, NERC-Cincinnati undertakes studies at commercially operated nuclear power facilities to provide guidance for radiological surveillance. These studies are jointly supported by the Office of Radiation Programs and the Office of Research and Development. For the former, reports are prepared that provide information on population and environmental radiation exposure during routine operation of the station, with emphasis on the validation of radiation exposure models; for the latter, manuals of procedures are written for measuring radionuclides and radiation at these facilities and in the environment.

A 6-year program of generic radiological surveillance studies at four nuclear power stations — two boiling water reactors and two pressurized water reactors — was completed. Reports of two of the studies were published in previous years, and the report of the third study was prepared this year in draft form and is being circulated for review; in the fourth study, all sample collection and measurements were finished. Publication of the third and fourth reports is planned for next year. The reports describe in detail, where possible, movement of radionuclides from their formation in the reactor to points of discharge at the facility and through the environment to points of population radiation exposure. Data are provided on the concentrations of the radionuclides in effluents and environmental samples, and radiation exposures are calculated.

A generic study at a nuclear fuel reprocessing plant was planned to begin during the summer of 1973, but the plant has not yet started operating. This commercial plant, the only one of its kind in the United States, will process all fuel for nuclear power stations in the immediate future. The study is being postponed until the plant will be in routine operation, possibly in the middle of 1974. Of particular interest will be the amounts of ^{3}H, ^{85}Kr, ^{129}I, and transuranium elements discharged to the environment.

*The Radiochemistry and Nuclear Engineering Facility is part of the Technology Assessment Division, Office of Radiation Programs, U. S. Environmental Protection Agency. Following the NERC-Cincinnati internal reorganization in the latter part of 1973, the Radiochemistry and Nuclear Engineering Branch became part of the Methods Development and Quality Assurance Research Laboratory.

A special study was undertaken in cooperation with the U. S. Atomic Energy Commission to evaluate the model for ^{131}I exposure by the air-milk pathway. The study had particular urgency because the EPA and AEC, in preparing to publish guides for population radiation exposure, observed that this may be the critical pathway after the application of waste treatment processes to reach "lowest practicable" exposures. The complex of three Dresden nuclear power stations at Morris, Illinois, was used as sources, and measurements were focused on a dairy herd located (for the purpose of the study) approximately 1 km distant. Iodine-131 was measured at the points of discharge (two chimneys and a stack), in ground-level air, in deposition and grass, and in the cows' milk. The chemical forms of the ^{131}I were identified by the AEC at the points of discharge. The values measured in the environmental samples were compared with values predicted from models of atmospheric dispersion, deposition, and the cows' metabolism. Of particular interest were the observations that most discharged ^{131}I was in the form of CH_3I, not I_2; that most of the ^{131}I in milk apparently reached the ground in rain rather than as dry deposition, as commonly assumed; and that the main sources of ^{131}I for the nearby cows may have been the relatively low-level effluent from the stack and possibly other low-lying sources, rather than the chimneys. The report of this 2-month study was published, and a more detailed study may be planned.

In response to a request by the state of Vermont, a demonstration program of environmental radiation exposure measurements was undertaken in cooperation with the EPA Eastern Environmental Radiation Facility at the Vermont Yankee nuclear power stations. A network of radiation detection instruments was located in Vermont, New Hampshire, and Massachusetts, and in the immediate vicinity of the station. Radiation exposure was measured with thermoluminescent dosimeters for 4 months. Results during periods of station operation and station shutdown were compared to compute, by difference, the radiation exposure attributable to the station. Variations in the natural radiation background — due to

snow covering the ground, for example — exceeded those from station operation. Brief direct measurements were also undertaken to relate exposures in the environment to radiation from the plume of gaseous stack effluent and from on-site radionuclides. A report of this activity (in preparation) includes descriptions of measurement capabilities for environmental radiation exposure and recommendations for an exposure monitoring program.

A manual of analytical procedures for measuring radionuclides in aqueous solutions at nuclear power stations was published after several years of preparation. These methods are directed mainly toward solutions that contain numerous radionuclides at readily detectable levels, and emphasize use of chemical separation to purify radionuclides for radiation detection. Concurrently, methods were tested and modified for determining radionuclides in surface and marine waters. Radionuclides in these samples are usually fewer in number but at extremely low levels, so that an initial concentrating step is needed. Concentration steps for surface water had been described in a paper published earlier; methods for concentrating radionuclides in seawater are described in a paper submitted for publication this year.

In gases, analysis of the radionuclides ^{3}H, ^{14}C, and ^{85}Kr from nuclear power stations requires distinctly different methods than analyses for most other important radionuclides, which can be measured by gamma-ray spectral analysis. Methods for concentrating the three radionuclides and for purifying for their subsequent analysis are being prepared and should be complete for publication next year. As a concurrent project, procedures will be tested for separating the various forms of ^{3}H and ^{14}C in air — e.g., water vapor, H_2, CH_4, CO, and CO_2 — so that radionuclide concentrations in these various forms can be distinguished.

SOLID AND HAZARDOUS WASTE RESEARCH LABORATORY

LABORATORY FUNCTION

The Solid and Hazardous Waste Research Laboratory (SHWRL) plans, conducts, and evaluates research to develop improved methods of dealing with solid wastes from all sources. Efforts are directed primarily toward determining means of recovering materials and energy from solid wastes, toward determining the public's attitude on resource recovery and waste reduction at the source, and toward developing suitable techniques for the disposal of all forms of nonrecyclable solid wastes — including extremely hazardous wastes.

Analytical and pilot-plant facilities are maintained to conduct and support research studies designed to develop new waste handling or processing methods and to develop resource recovery procedures and appropriate ultimate disposal methods for solid wastes.

BACKGROUND

The problems of solid waste disposal are interrelated with those of air and water pollution. Incineration, grinding, and the use of water for either transportation of solids or as solid waste sinks impinge upon the concurrent attempts to purify the air and water environments. Additionally, the elimination of impurities from air or water effluents at the sources of pollution results in the generation of solids wastes by such processes as separation, drying, or compaction — solids that in turn require disposal. Measures to reduce pollution, or dispose of waste material, must therefore be taken with full consideration of the effect upon the overall environment — air, water, and land.

The solid waste problem is concentrated in densely populated urban areas. In some cases, entire neighborhoods are being degenerated, blighting much of the inner cities. Refuse storage, collection, transportation, and processing directly and intimately affect some 80 percent of the population. The costs of waste handling, already severe, are rising. The loss of billions of tons of material to unreclaimed waste each year indirectly affects each consumer. The aesthetic and real values of certain areas are being degraded by inadequate solid waste disposal.

Only in the last decade have serious thought and effort been addressed nationally to the problems of solid waste disposal. From an initial concentration on pollution control and the attempt to regulate the flow of waste from its sources, a realization has grown that our real concern should be for the overall quality of the environment.

PROJECTS

Land Disposal

Sanitary landfilling and land burial are the only low-cost methods presently available for disposal of solid and hazardous waste onto the land. Landfills for disposal of solid wastes can be designed to produce little or no impact on the environment; however, additional technical information is needed on decomposition rates and leachate and gas production to allow efficient rational design of sanitary landfills and to select suitable landfill site locations. Also, much information is needed regarding the disposal of sludge and industrial liquid waste materials into a landfill environment. Disposal of these high-moisture content and potentially hazardous materials into a landfill can cause environmental and health effects problems if not properly controlled. The land burial of hazardous wastes has caused much concern because of the pollution potential, especially to ground and surface waters. Consequently, much technical information is needed regarding documentation of past incidences, effects, and migration phenomena and criteria development to produce standards for enforcement and regulation. The SHWRL has an integrated program of grants, contracts, and in-house research to develop the needed information.

In-house activities have emphasized the collection of field-scale data from two experimental landfills located in Walton, Kentucky. Also, the construction of a third experimental landfill has been completed at a research site located at Center Hill in Cincinnati, Ohio. Leachate production rates have been determined twice a week. A total of 75,000 gallons of leachate has been collected from experimental cell 1. This cell was constructed in June 1971 with 435 tons of municipal-type solid waste deposited. From cell 2, constructed in June 1972, 7,500 gallons of

leachate was collected — leachate generated from 126 tons of municipal-type refuse. Gas samples to date have numbered 700, and analyses for nitrogen, oxygen, carbon dioxide, and methane indicated varying concentrations of these gases being produced. Experimental cell 3 consisting of fifteen 6-foot-diameter steel pipes provides the capability of analyzing pollutant production under a variety of climatic conditions for various waste materials. These simulated cells will be used to evaluate a large number of variables without the great expense of quality-controlled field cells.

Under a grant to the Georgia Institute of Technology, the feasibility of modifying traditional sanitary landfill operational procedures is being studied. Leachate produced in laboratory-scale simulated landfills is recycled through the compacted waste. The objective is to achieve a high rate of anaerobic decomposition by creating a natural buffer system conducive to methane formation.

Data have been collected over a period of 780 days for the initial two simulated sanitary landfills, and for about 480 days on two additional test simulations. These data continue to indicate the beneficial effect of leachate recycle and pH control on the initiation of rapid decomposition. In general, the changes recorded by the test parameters continued to follow a trend predictable by the recognized sequence of events occasioned by an initial acid fermentation followed by methane generation.

An in-house project relating to spray irrigation of landfill leachate has also been undertaken. The data obtained indicate that both organic and inorganic contaminants carried in leachate are retained within the grass cover and the soil or are converted to gaseous products. Study of leachate characteristics applied with percolate and surface runoff characteristics generally indicated greater than 90 percent reduction in all contaminants except for nitrate, which showed greater than 300 percent increase. This large increase is due to the oxidation of the large quantities of ammonia and organic nitrogen.

The University of Arizona and the Illinois State Geological Survey are investigating the leachate pollution attenuation in soils. This contract will identify the attenuation mechanisms; evaluate pollutant attenuation of soils by column studies; and develop simulation for models for the prediction of solute changes as a result of water flow through soils. Nine specific soil types have been collected and characterized for column studies. Equilibrium studies and soil-column acid-leaching studies are presently being performed. Specifically, the effect of H^+ on movement of native soil constituents is being investigated. The model for solute movement has been characterized by three mechanisms for solute transport: convective flow, diffusion-like process into a stagnant region, and the dispersion effect. Also, basic pure-clay minerals kaolinite, illite, and montmorillonite have been obtained and separated prior to admixing with various sands and silts. Six preliminary columns have been set up to study hydrologic equilibria and column design in general. Microbial activity at the soil leachate interface has caused separation of the soil particles. To determine the effects of this microbial activity, it is anticipated that two sets of columns, one sterile and one active, will be constructed and evaluated to determine effects of microbial activity on pollutant attentuation.

An extensive study to develop treatment methodology for landfill leachates is being performed under a research grant with the University of Illinois. This three-phase project is (a) characterizing leachates; (b) determining various unit processes applicable for treating of leachates; (c) evaluating these individual processes or specific combinations of processes for best performance in leachate treatment. The characterization effort establishes the first comprehensive data on the organic and heavy metal content of landfill leachate.

Michigan State University has been evaluating the landfilling of high-ash papermill sludges for the laboratory. The first annual report indicated that soil mechanics theory can be used to accurately model the sludge consolidation behavior for different loading conditions. The second annual report indicates that soil mechanics theory can be used to predict the stability of slopes excavated in a sludge landfill. Also, data indicate that reasonable estimates can be obtained from the theory equations for ultimate primary settlement and pore pressure.

Under a research contract with Arthur D. Little, Inc., the design of a detailed, practical, systematic classification system has been developed. This system is applicable to all solid wastes generated by industries in all divisions of the Standard Industrial Codes (SIC). The project involved the use of an extensive literature search of past classification efforts and personal interviews with government agencies, trade associations, and university personnel. Also, site visits were conducted at selected industries for observing and testing of the classification scheme. Information of interest included waste generation (quantities and properties), present handling procedures with emphasis on salvage operators (present and potential), and environmental impact (hazardous nature if any).

Hazardous Wastes

The SHWRL has been engaged in a series of contracts designed to gather information needed to prepare a report to Congress on National Disposal Sites

(NDS) for hazardous wastes in compliance with Section 212 of Public Law 91-512. Three contracts were awarded during FY-72 and FY-73. Their respective purposes were to: (1) develop an inventory of hazardous waste materials; describe their effects on man and his environment; and determine presently used methods for their disposal; (2) provide recommended methods of reduction, neutralization, recovery, and disposal of all hazardous waste; and (3) determine public and private attitudes of persons near proposed regionally located disposal sites towards disposal of hazardous wastes.

A list of over 500 hazardous materials known to be components of industrial waste streams was completed under the first contract effort, performed by Booz-Allen Applied Research, Inc. The three-volume final report, delivered in June of 1972 (available from NTIS as PB 221 464), also summarized waste disposal practices in industries handling the designated materials. The final report further pointed out that current literature did not provide sufficient information on the forms of hazardous materials found in the waste streams, the quantities of the wastes, and their distribution within the United States; nor was such information readily available from other sources such as trade associations.

The second contract effort, performed by TRW Systems, was completed in June 1973. The final 16-volume report has been received (available from NTIS as PB 224 579 SET/AS), and the title headings are:

Volume	*Title*
1	Executive Summary
2	Toxicologic Summary
3	Incineration, Pyrolysis
4	Biological Processes
5	Pesticide and Cyanide
6	Mercury, Arsenic, Chromium, Cadmium
7	Propellants, Explosives
8	Miscellaneous Organic and Inorganic Compounds
9	Nuclear
10 & 11	Categories 2 and 3 Organics
12 & 13	Categories 2 and 3 Inorganics
14	Form and Quantities
15	Research and Development Plans
16	References

These volumes contain profile reports summarizing the definition of adequate waste management and evaluation of waste management practices for over 500 hazardous materials. These reports also serve to designate a material as a candidate for NDS, and they describe current acceptable disposal methods for non-NDS candidates. The reports also discuss and list recommended research and development activities to develop adequate waste management practices for hazardous waste disposal. Specific information obtained from these report volumes has been incorporated in the "Reports to Congress on Hazardous Waste Disposal" dated June 30, 1973.

The third contract conducted by HumRRO and completed in June 1973 (available from NTIS as PB 223-638) presents results obtained from a national survey. The data indicate that most respondents have positive attitudes toward NDS, would accept one in their county, and believe an NDS would be beneficial to their area. About 50 percent of the respondents wanted information before agreeing to a nearby NDS. Most respondents named the mass media (TV and local newspapers) as the greatest sources of influence on their environmental and ecological attitudes. Specific information obtained in this report was also included in the "Reports to Congress on Hazardous Waste Disposal."

An extramural study of hospital solid waste handling systems was completed. A model was developed for estimating hospital solid waste generation as a function of location, bed capacity, and use of disposable items. Other extramural studies were also implemented to forecast household solid wastes and the effects of air and water pollution controls on total solid waste generation. These efforts are needed to predict the magnitude of future solid waste flows and to develop appropriate and timely strategies. Also, a research grant has been awarded to the University of Florida to determine the types and quantities of toxic and hazardous materials (nonindustrial) in municipal wastes. An interim report from this grant has been developed that discusses and summarizes nonindustrial toxic and hazardous wastes related to biological, business, agriculture, and household waste streams.

Collection and Transport

The SHWRL has continued several studies in an effort to define and evaluate more efficient collection and transportation systems. A grant to Dr. J. C. Liebman at the University of Illinois has been completed. This research involves conventional packer trucks and describes a new set of techniques that determine near-optimum districts and routes for the collection vehicles. These techniques emphasize new, mathematical solutions to both single and multiple truck routing problems for various kinds of street and traffic situations. At the Massachusetts Institute of Technology, Cambridge, Massachusetts, Dr. D. H. Marks completed a similar investigation of computerized districting and routing techniques with emphasis on methods for dividing a municipality into equal-effort collection districts. Both the Liebman and Marks studies are primarily paper studies devoted

to technology advancements through applications and solutions of heuristics and classical urban decision theory. However, Dr. Marks also demonstrated the practical application of his programs to the solid waste generation, districting, and routing problems within the nearby town of Brookline, Massachusetts.

To ensure that the foregoing theoretical developments will meet the needs of local governments, a research grant to Public Technology Incorporated of Washington, D. C., is in progress. The grantee is evaluating the results of the available computer programs and will demonstrate certain case study applications in addition to providing practical instruction documents. Finally, through a contract with Messer Associates, Inc., Silver Springs, Maryland, "effectiveness measures" for solid waste storage, collection, and transportation are being developed. The intent of this study is to provide a system of universal ratings whereby storage, collection, and transportation effectiveness in a given local area can be compared with a national standard.

Research continued on ways to improve the efficiency of collections. Using wage incentives to increase collection crew productivity is being investigated. Further research in this area involves the evaluation of collection, processing (including recycling) and disposal systems, and the location and design of facilities. Particular emphasis in this study is being placed on the feasibility of transfer stations.

In the area of potential future use of sanitary sewerlines as transport lines for solid waste, an initial technical feasibility study by Foster-Miller Associates, indicated positive and encouraging results for the concept. A further study by Curran Associates was begun into the economic and political impacts of sewerline transport of combined sewage and ground solid waste. The Curran study, now nearly completed, has brought to the foreground several discouraging aspects about the concept including (1) high overall system costs, (2) increased sewer network maintenance, and (3) a greater awareness of the treatment plant problems. It now appears that this concept, although still viable, will require several years of additional research in various pilot plant phases before any full-scale application can be considered.

Processing

SHWRL has continued to obtain basic performance requirements of refuse size-reduction equipment. Dr. G. Trezek at the University of California at Berkeley has completed his first year's effort in this area. Tests made thus far include an evaluation of the effects of refuse moisture content, grinder shaft speed, grate opening, grinder materials, and other variables. The ultimate goal is to provide guidelines for mechanical equipment and process design that will lead to significantly lower solid waste processing costs and improved safety of operation.

Separation

The design phase of an in-house pilot plant study of mechanized, dry sorting and separation of municipal refuse has been completed. All major equipment items have been received. Actual setup and operation of the pilot plant has been delayed.

A Massachusetts Institute of Technology study on automatic "sensing" separation is essentially completed. This study provides an assortment of futuristic, albeit potentially very functional, coding and sensing devices and techniques for solid waste separation. The mechanisms for sensing component materials are based on real, identifiable physical properties including electrical conductivity, infrared properties, and reaction to impact.

Incineration

Research is continuing at Battelle of Columbus, Ohio, to establish the extent of and the mechanism whereby corrosion of metallic incinerator components occurs. The main thrust of this research is determining the corrosive effects from the incineration of PVC plastics. However, other factors such as moisture, sulfur, sodium, and phosphorus, and contents of the refuse and their interactions are included. Actual corrosion tests in operating incinerators with simulated boiler-tube configurations have already provided a wealth of materials compatibility data.

An in-house incinerator was operated for a series of brief shakedown runs under a range of conditions including stack testing. This research evaluation has been suspended, however, due to limited funds.

Recycling: Resource Recovery

A major resource recovery process developed under contract by the Combustion Power Company in Menlo Park, California, is the CPU-400. The process involves the high-pressure combustion of municipal solid waste and the direct conversion of the energy contained in hot gas effluent to electricity. Following successful low-pressure operation of the 100-ton-per-day pilot plant, the turbine was integrated into the system. Initial tests on the fully integrated system indicate its ability to burn solid waste efficiently and to generate full power output (1000 kw) under complete automatic control. Recent tests, however, have demonstrated that extensive deposits of alumina and silica develop on the first stage turbine stator blades after operating only a few hours. Since the inefficiency of the inertial separators to remove extremely fine particulate matter is believed to be the predominant cause, adding

another particulate removal stage to the system is being investigated.

Extramural and in-house research on recycling of solid waste has focused on the transformation of selected refuse items into useful products. Protein production studies at Louisiana State University have been completed. Under this research grant, the basic information on the conversion of municipal cellulosic wastes and agricultural crop residues into a protein for animal feed has been obtained. This information was used by a private company, Bechtel, in determining the economic feasibility of this process. Results from a rainbow trout feeding trial showed conclusively that microbial protein produced from organic wastes can be substituted for conventional protein sources in fish diets. A chick feeding trial has been initiated, and this study is expected to confirm the value of microbial protein as a protein supplement.

Gillette Research Institute has demonstrated that the degree of polymerization of cellulose is significantly reduced by a sensitized photochemical process. This technique is expected to improve the cost factors of processes that utilize waste cellulose to produce various forms of animal feed. A final report describing this work is now being prepared.

A completed research grant with the University of Montana indicates that a low-pressure hydrogenation process offers potential for converting cellulosic waste into a high-grade fuel. The process is technically feasible but is not presently economically attractive. In a research study entitled "Chemical Conversion of Wood and Cellulosic Wastes," three fractions were isolated from the pyrolysis of cellulosic material. These fractions contain products that could be used as fuels.

A research grant with the University of Utah indicates that waste glass recovered from the solid waste stream can be converted into a product of commercial quality. By processing waste glass with calcium carbonate, foamed glass can be produced with uniform cell size, good insulating capacities, and negligible solubility in water. The investigators found that this foamed glass could be used as a premium grade insulation for industrial and commercial uses and that foamed-glass pellets could be used as loose-fill insulation or lightweight aggregate.

Two research grants were awarded to the National Center for Resource Recovery during the year to develop statistical sampling plans for use in maintaining quality control at resource recovery processing plants and to establish specifications for the products of separation. Specifications were developed for steel in tin cans, steel for iron precipitations, aluminum, glass, inorganic fines, and mixed organics. In addition, a mobile air classifier was tested and provided an acceptable split between aluminum and paper. Data were generated describing recovery systems.

The role of transportation in resource recovery was investigated through a research grant. The results indicated that in recent years transportation rates for selected secondary materials (ferrous scrap and waste paper) have increased nearly three to five times faster than rates for the competing virgin materials. On a direct comparison basis for the competing raw materials, the ICC-regulated rates favor the movement of virgin materials over that of ferrous scrap and waste paper. Because comparisons for waste paper and ferrous scrap with the equivalent virgin components were complicated by the kind of virgin material and the distance of haul, conclusions are uncertain without further research. Other efforts in the resource recovery area included implementation of a study to determine the kind and level of incentives needed to encourage recycling of secondary fiber. The impact of incentives involves complex corporate decisions on alternative papermaking processes, long-run capital investments, and location factors. The opportunity for federal procurement policies and practices to provide incentives for recycling was also investigated. Results of the study are incomplete, but preliminary indications suggest a major opportunity area — one where the government can influence recycling through its purchasing power — is that of using paper and paperboard as packaging material. Extramural research was also directed towards evaluating the administrative efficiency and political feasibility of regional solid waste management systems. A model framework for description, analysis, and selection of alternative systems is being developed, and recycling activities in a regional setting will be evaluated.

Systems and Behavioral

Systems and behavioral activities were directed towards evaluating various economic alternatives available to improve the efficiency of managing solid wastes. A study was initiated to investigate the applicability of material balance models for attaining economic efficiency in solid waste management. General equilibrium models incorporating this concept have been developed for waste residuals in general. The contractor will develop models designed especially to provide information on policy alternatives related to solid waste flows. Another study is investigating the economic implications of various pricing mechanisms for solid waste management. The theoretical efficiency and effectiveness of pricing mechanisms for allocating efficiency resources in a market economy are well known, but the particular applicability to the solid waste management

problem has not been determined. Incremental user charges for collection and disposal are being considered as an operational pricing mechanism. User charges may influence consumer behavior in a socially desirable manner and thereby reduce solid waste management costs. A recent study completed for NERC-Cincinnati by the University of Chicago, Center for Urban Studies, suggests that the amount of household refuse generated is strongly influenced by the level of household income. The relative influence of this variable on total household refuse collected was observed to vary with the season of the year. The overall quantity of household refuse was sensitive to normal seasonal changes.

In-house activities were concentrated on evaluating the potential for recovering the resource value of selected waste materials. The state-of-the-art for associated reclamation technology was examined and the market potential for reclaimed materials was assessed. It was concluded that uncertainty over scrape prices deters increased recovery of both aluminum and ferrous scrap from the solid waste stream. The use of ferrous scrap in steelmaking also involves the risk of contamination, which further deters its increased use. Potential resource value of waste materials also includes its conversion to other useful products. The economic feasibility of marketing microbially converted cellulosic waste (bagasse) as a human or animal protein supplement was evaluated. Preliminary results suggests that the production costs associated with the presently known technology will make it difficult for the end product to compete with normal supply and demand for the conventional forms of proteins.

WATER SUPPLY RESEARCH LABORATORY

The Water Supply Research Laboratory (WSRL)

- performs health-effects studies necessary to establish standards for drinking and recreational waters,
- develops the microbiological, chemical, and engineering technology necessary to ensure the attainment of drinking water standards and the maintenance of satisfactory quality throughout the distribution system, and
- provides analytical and technical services to EPA Regional Offices and the Office of Air and Water Programs.

STANDARDS ATTAINMENT STUDIES

Water Treatment Research

Inorganic Contaminant Removal

In 1973, laboratory tests for removal of inorganic contaminants were continued for mercury. In addition, barium, selenium^{IV} (selenite), selenium^{VI} (selenate), and arsenic^{V} (arsenate) were studied. Contaminant levels generally ranged from Drinking Water Standards limits to 10 times the limits. Jar test results indicate that the most effective removal processes are: excess lime softening to pH 10.6 for 90+ percent removal of barium and arsenic^{V}, 60 percent removal of inorganic mercury; and coagulation with ferric sulfate for 90+ percent removal of arsenic^{V}, and 60+ percent removal of selenium^{IV}. Both inorganic mercury, as $HgCl_2$, and organic mercury, as CH_3HgCl, were removed in the 60 to 90 percent range by activated carbon. No conventional process effectively removed Se^{VI} (selenate).

Particulate Removal

Construction of a fully instrumented water treatment pilot plant capable of treating two parallel streams at about 0.5 cubic meter per hour was completed and put into operation. The plant is designed to permit studies of various water treatment processes including direct filtration, coagulation with tube settling, conventional coagulation, softening with secondary coagulation, and excess lime softening with recarbonation for pH control. Filtration through conventional sand media, sand-anthracite media, sand-anthracite-garnet media, or granular carbon media is possible. Early studies are concerned with particulate removal, with the production of a minimum of sludge.

A bench-scale study of nitrate removal with anion exchange resin was performed. These studies showed that:

- Nitrates can be removed from water by anion exchange resins.
- Other anions present will reduce nitrate removal.
- Silicate will not foul the resin so as to prevent the removal of nitrates although it will reduce removal when present.
- Iron can cause caking and fouling of the resin.
- Concentrated solutions of anions cannot be used to determine or estimate removal performance with regard to specific ions in a weaker solution.
- Each individual water to receive anion exchange treatment will have to be tested if an accurate estimate of the performance of the resin with this water is desired.

Disinfection

The disinfection studies performed this year had two purposes: one, to determine if natural virus (directly from infected hosts) had the same inactivation rates when disinfected with chlorine as their "cousins" that had been transferred many times in the laboratory; and two, to determine if the presence of turbidity interferes with viral inactivation by chlorine. Results from the first study are confusing at the moment as some tests indicated similarity between "natural" and "laboratory" virus types of the same strain and others showed dissimilarity. Differing degrees of clumping will be investigated as a possible explanation of these differences. Results from the second study showed that the presence of alum floc does not interfere with inactivation of virus with chlorine.

Organic Contaminant Removal

During 1973, experimentation was begun on the removal of organic compounds from drinking water with the use of ozone. Organic compounds, which are measured by the organics-carbon adsorbable (O-CA) method in water prior to ozone treatment, may be changed through ozonation to other compounds not measured by this method. This would

result in a "reduction" in O-CA levels, when, in fact, little or no organics had been removed. To ensure that the reductions are real, total organic carbon (TOC) measurements are needed, but work on this task has been temporarily halted until a sensitive, low-level TOC instrument is obtained.

A project funded by the National Science Foundation was begun to perform laboratory verification testing of small ozone water treatment devices. Purpose of the project is "to provide verification testing of a technical innovation by an independent, scientifically recognized organization in order to assess the impact of such testing on the future economic development and marketing potential of the innovation."

The most common adsorbant used in treating drinking water is powdered activated carbon. The use of granular activated carbon is, however, steadily rising. During 1973, a number of water purveyors were queried by the WSRL on the use of granular activated carbon. These experiences showed that design and operation of carbon beds is largely trial and error because of difficulties in monitoring for organics and the differences in properties and sorptive characteristics between commercially available activated carbons. The general organics sampler developed by the WSRL and used as a field monitor has repeatedly shown that granular activated carbon, although effective for many months for taste and odor control, rapidly (within a few weeks) becomes exhausted for general organics removal.

Adsorption studies are underway that will evaluate the performance of granular activated carbon subjected to a variety of: loading rates; backwash rates; and activated carbon types, sizes, depths, and reactivation frequencies. An obstacle in developing and evaluating any treatment process is the ability to measure and identify the parameters of interest. There are a number of organic monitoring methods either adapted for use or about to be refined for use by the WSRL in this problem area.

Bench- and pilot-scale studies on the removal of trace organics and taste and odor compounds from water through the use of various oxidants and/or adsorbants are beginning. In support of this work on organic contaminant control technology development, a strong capability to measure pertinent physical and chemical parameters has been developed. In addition to providing general analytical support to the organic removal experiments, specific accomplishments include: 1) developing optimum conditions for gas phase chromatography of carbon chloroform extract (CCE) and carbon alcohol extract (CAE) fractions, which has resulted in the resolution of 101 and 83 peaks in selected CCE and CAE fractions, respectively; 2) developing proficiency in the use of phenol and iodine tests to evaluate adsorption characteristics of activated carbon samples; 3) establishing an inventory of refractory industrial wastes and other synthetic organic compounds known to cause taste and odor problems in water supplies. These compounds and samples of the natural products, geosmin and methyl isoborneol (taste and odor causing compounds), procured through award of a research grant, will be used as standards in organics removal experiments.

Ongoing studies include:

- Evaluation of analytical procedures for the determination of organic content of water as related to the need for a monitor of water treatment unit processes, including the O-CA minisampler technique (and characterization of CCE and CAE), TOC adsorption, and fluorescence-spectrophotometry;
- Development of procedures for assessing the status of activated carbon filter beds with regard to their ability to remove tastes and odors in addition to general organics; and
- Investigation of the phenomenon of "bed unloading" as evidenced by negative CAE removal values that have been found during the field monitoring of granular activated carbon beds.

Water Quality in Distribution Systems

Microbiological Quality

At present, the most promising MF technique for standard plate count populations results in a 70 to 75 percent bacterial detection when compared with the standard pour plate procedure. Various commercial media, prepared formulations, and specially prepared membranes were evaluated.

Research on the radiometric method for coliform detection indicates that relatively high background counts of experimental controls continue to interfere with test sensitivity. Modification of incubator chamber design is completed, and further testing may show increased test sensitivity.

For the disinfection of newly laid water mains, laboratory studies showed chlorine to be a much better disinfectant than potassium permanganate. Field studies at Charleston, West Virginia, demonstrated that thoroughly flushed or cleaned new mains can be satisfactorily disinfected by low, free-residual chlorine. Chlorine was also a better disinfectant than potassium permanganate in these field studies.

Chemical Quality

A study was made of the Seattle, Oregon, water obtained from two sources, the Cedar River and the south fork of the Tolt River. The hardness, alkalinity, salinity, and trace metal content of these waters are quite low, but they have aggressive corrosion tenden-

cies. Standing and running samples were taken from various locations within the city and analyzed for various chemical parameters. A report was issued to the Seattle Water Department for correlation with their pipe materials in the distribution system. Further studies were interrupted by the transfer of WSRL laboratory facilities and personnel to Cincinnati.

The Mobile Water Quality Monitoring Laboratory, which was built under contract by the National Sanitation Foundation, was delivered to WSRL on October 1, 1973. Before delivery, it was field tested in Chicago for 1 month and in Philadelphia for 1 month. An on-board computer was installed just before the Philadelphia test to operate and collect data from each of the analyzer systems. The computer obtains data from each of the 17 different monitoring systems once or twice every 13 minutes and also can activate a sampler to collect samples with a preset frequency or whenever any of the 17 parameters shows an anomaly. The results are punched out on paper tape for later computer processing and analysis. During the testing in Philadelphia, each of the WSRL personnel to be involved in the laboratory operation received a week's training. Further testing and evaluation will now be done by WSRL personnel.

Bottled Water

The bottled water study was completed June 1, 1973, and final analysis of data is complete. The study indicated that coliforms are observed infrequently in bottled water; however, the general bacterial population often exceeds 1,000 organisms per 1 ml. This condition may reflect contamination during bottling and storage or unsanitary practices associated with water cooler dispensers. The lack of a systematic surveillance of bottled waters is a matter of growing concern. These sources of drinking water should be analyzed at the same bacteriological sampling frequency per month that the Interstate Drinking Water Standards require for public water sampling, including repeat sampling and a follow-up sanitary survey when data indicate unsatisfactory quality.

Quality of Raw Stored Water

Commercial manufacture of the bottom sampler was completed and each sampler was satisfactorily field tested (Figure 28). These bottom samplers will be sent to collaborating American Water Works Association Quality in Reservoir Committee members who will participate in gathering bacteriological data pertaining to water quality and the impact of stratification on reservoirs.

Preliminary data obtained from a study conducted in March 1973 on the Big Creek Reservoir, Mobile, Alabama, indicate that variations of bacterial population densities, pH, temperature, and turbidity were attributed directly to run-off after heavy rains rather than to stratification. Transferring of laboratory capabilities from the study area near Mobile, Alabama, to NERC-Cincinnati interrupted reservoir studies and necessitated locating alternative study areas in the Cincinnati area.

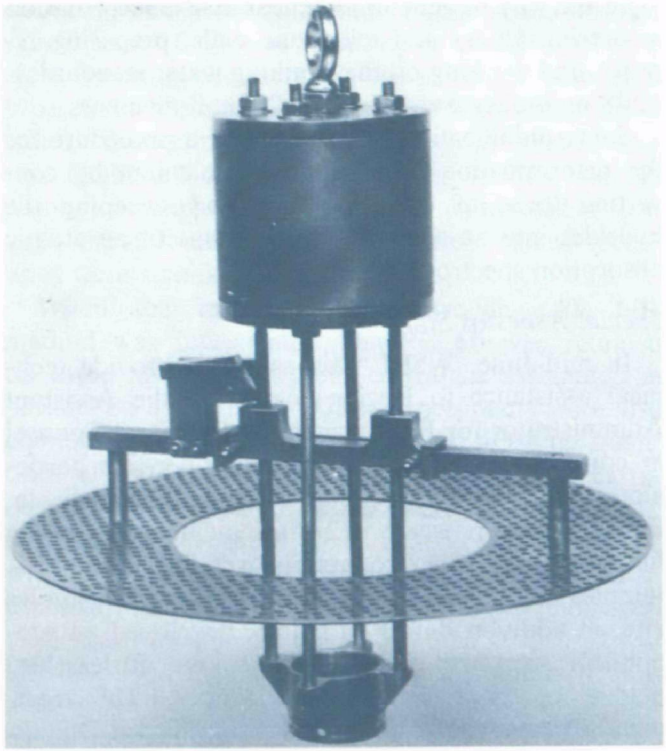


FIGURE 28. SAMPLER USED FOR COLLECTING BOTTOM MUD FROM RESERVOIRS TO BE USED FOR BACTERIOLOGICAL ANALYSIS.

Technical Assistance

Twenty-seven state bacteriological laboratories were surveyed in 1973, a 30 percent increase in laboratory evaluations over 1972. In addition, three water chemistry laboratories were surveyed.

For the surveillance of Interstate Carrier Water Supplies (ICWS), the evaluation of State water supplies, Federal water supplies, and in special studies the following number of samples were analyzed:

Analysis for	Trace metals	Other chemical parameters	Pesticides	O-CA Test
ICWS	129	125	50	79
State evaluation	391	174	78	23
Federal study	325	37		

An additional 393 samples were examined for bacteria, 253 for asbestos, and 101 for such miscellaneous substances as silica, barium, fluorides, selenium, and nitrates.

In the way of general technical assistance (that is: answering letters and telephone calls, preparing reports, and working on the drinking water standards), 1248 man-days were spent by 25 staff members.

Some modifications were made of a procedure for the determination of arsenic and selenium by converting them to their hydrides and sweeping the hydrides into an argon-hydrogen flame of an atomic absorption spectrophotometer.

Special Asbestos Study

In mid-June, WSRL was asked to provide technical assistance to Region V and to the Assistant Administrator for Enforcement and General Counsel in connection with the findings of fiber-like particulates in the drinking water of Duluth, Minnesota. For the next 6 weeks, 12 staff members, working full time, made fiber counts on over 50 Duluth area samples and over 200 treatment research samples and, in addition during this time, developed an economical treatment method to remove at least 90 percent of these fiber-like particulates. This treatment process will be tested in a pilot plant at Duluth.

HEALTH EFFECTS STUDIES

Organic Contaminants

Suspicion exists that the organic compounds in drinking water produce, or at least contribute to, chronic diseases in man. A research program is being implemented to determine the potential or actual hazard to human health from ingesting these organics.

The evaluation of the health effects of organic materials in drinking water has made significant progress in the areas of (1) concentration and extraction of organics, (2) characterization of fractions and identification of specific compounds, and (3) toxicity testing of the organic concentrates and fractions.

The application of reverse osmosis (RO) membrane technology to the concentration of organics has proven successful. Cellulose acetate membrane can recover 30 to 40 percent of the organics from drinking water, a substantial increase over other concentration methods. An important advantage to this method is that the compounds are not altered chemically. Still to be determined is whether the molar ratios of the compounds are altered during concentration. A nylon membrane and aqueous concentrator are presently being tested in sequence with the cellulose acetate membrane to determine if they will significantly increase the yield of organics. Preliminary results with the use of the two membranes are encouraging. The development of new membrane materials for the concentration of organics is being pursued extramurally. Several macroreticular resins are being evaluated for their ability to concentrate organic material in water; however, their usefulness appears to be more limited than that of the membranes.

Gross chemical characterization of the organic concentrates and fractions has been undertaken to establish similarities and differences between water samples, concentrates, and partitions that will permit further comparison with results of toxicity tests. Evaluation of gas chromatographic retention times as well as infrared and ultraviolet spectra indicates a large number of similarities between samples taken from the same water supply but at different sampling times. Such evaluations also demonstrate substantial differences between the different fractions of the same concentrate. Mass and nuclear magnetic resonance spectra indicate that many different compounds are present in the concentrates and that the fractionation procedures are successful in segregating specific types of compounds. Only a relatively small number of compounds in these concentrates have been identified. Because our laboratory capabilities are expanding and because the need exists to determine which specific compounds are responsible for the observed toxicity, increased emphasis will be placed on the identification of specific compounds from those concentrates and partitions that are most toxic.

Total organic carbon analysis (TOC) is being evaluated as a monitoring system for organic loading of drinking water. A study is being initiated to determine the variability of the organic loading in potable water systems and to ascertain whether a correlation exists between the level of TOC and the toxicity of the concentrates.

The toxicity of the concentrates and partitions is being tested in experimental animals. The RO concentrates of organics from drinking water are highly toxic when administered in a single dose. The hydrophilic fraction, corresponding to "natural" rather than "synthetic" organics, appears to be substantially less toxic than does the whole concentrate. With a few concentrates, the materials were administered repeatedly to experimental animals, and the results indicate that some of the fractions have potential for cumulative toxicity.

The compounds identified in the concentrates and fractions serve as models for further studies. As a result of the identification of halo ethers in drinking water, a subchronic toxicity study is being initiated on a homologous series of these agents. The potential for interaction of specific agents added in known amounts to the concentrates will also be determined. A literature search will be made of the identified compounds to learn of their toxic properties.

The long-range goal is to identify the relative toxicity of the concentrates after repeated exposures.

Dose-response data from such studies will permit the calculation of a margin of safety for man and will provide a basis for conducting epidemiologic investigations to determine the validity of the margin of safety.

Biological Contaminants of Water Supplies

Improving Methods to Detect Viruses in Water

The potential occurrence of enteric viruses in potable waters is of major concern to environmental health officials. The enigma of the virus-in-water problem is related directly to the lack of a sensitive method for detecting viruses that occur at very low levels. A need, therefore, exists for a reliable method for concentrating and recovering low levels of virus from large quantities of water. This is particularly relevant if viral surveillance of potable water supplies is to be implemented successfully.

Another major activity of WSRL is concerned with the improvement of virus detection methods, methods adapted to concentrating and detecting enteric viruses in water samples of 400 liters or more. The emphasis during 1973 was placed on three basic methods that had shown promise for satisfying the established criteria: (1) the flow-through gauze pad sampler technique, (2) the membrane virus-adsorption technique, and (3) the insoluble polyelectrolyte (PE 60) method.

To investigate the flow-through gauze pad sampler technique, a number of experiments employing poliovirus type 1 and reovirus type 3 as test viruses were conducted and completed. Adding various cations as salts to the test water before sampling was found to increase virus recovery about fourfold when compared with that recovered from control samples. Recovery of reovirus type 3 paralleled that of poliovirus type 1. A number of experiments were also conducted using a fiberglass filter as a virus adsorbent; recoveries using poliovirus type 1 as the test virus were good-to-excellent when input levels were high in 114 liter-size water samples.

Earlier investigations of the membrane virus-adsorption technique coupled with the two-phase aqueous polymer separation technique indicated good virus recoveries from 400-liter potable water samples at low virus input levels. A recognized limitation of this technique, however, concerns the premature clogging of the filter surfaces when the test waters contain suspended particulate matter. Consequently, efforts in 1973 were oriented toward ameliorative measures to permit recovering virus from large quantities of turbid water. At the outset, a number of experiments were conducted with poliovirus type 1 and 400-liter quantities of water. A membrane filter was compared with a microfilter composed of microsized glass and asbestos fibers bound in epoxy saturant; both filters had controlled porosities of 0.45 μm. Recoveries of the test virus were found to be essentially the same for both filter types when virus input levels were high using turbid water. Processing 400-liter volumes of turbid water was facilitated by adding Celite as a filter aid. A number of experiments were also conducted at low virus input levels using turbid water. Virus recoveries were significantly lower.

When the insoluble polyelectrolyte (PE 60) method was investigated, the PE 60 was retained on three fiberglass element cartridges assembled in parallel on a manifold. These experiments were also conducted with poliovirus type 1 and 400-liter quantities of water. In low virus input studies, virus recoveries from potable water were moderate. No significant difference in virus recovery was observed when experiments were performed with tap water at a pH of 5.5 or at 8.0. In deionized water, however, virus recovery was greater at 5.5 than at 8.0. It was also observed that adding sodium thiosulfate to potable water before sampling produced no noticeable effect on virus recovery.

The virus recovery studies described above were performed at three satellite laboratories of WSRL: Northeast at Narragansett, Rhode Island; Gulf Coast at Dauphin Island, Alabama; and Northwest at Gig Harbor, Washington. The virology function of these satellite laboratories has been recently consolidated at Cincinnati. Program needs concerning methodology are now being integrated to further test and evaluate not only the three virus concentrating methods but also a recently developed virus-concentrator device. These tests will be conducted under simultaneous experimental conditions, and poliovirus type 1 and 400 liters or more of test water will be used as the sample size. The superior efficiency of any of the methods should become manifest during the course of experimentation. A number of bench-type experiments are also planned for the purpose of optimizing or refining many of the procedural steps involved in virus concentration.

Viruses in Finished Water

A study was begun at the three satellite facilities with the following objectives:

- to determine if viruses could be detected in finished drinking water,
- to evaluate and compare, under actual field conditions, the efficacy of three different virus concentrating techniques, and
- to relate the presence or absence of viruses in finished drinking water to treatment processes, water source and protection, total and fecal coliform densities, standard plate count, and zoomicrobe population.

Of the 84 virus study samples collected from 10 water treatment plants in 6 states and the District of Columbia, 80 have been examined for viruses. Sample volumes varied from 19 to 950 liters because of the techniques used and the quality of the water sample. Additionally, 12 positive controls (known virus deliberately added) were processed as a continual check on the sensitivity and recovery efficiency of the techniques used. Data indicated that the three techniques had a sensitivity of detecting about one virus unit per 3.8 liters for enteroviruses.

No viruses were recovered in 45 study samples examined at the Gulf Coast laboratory, nor were any viruses detected in 12 study samples collected by the Northwest laboratory.

Of the 29 samples of water collected from 6 communities and processed in the Northeast laboratory, 3 were positive controls (poliovirus added) and 3 were negative controls (heated or autoclaved virus-free water). Virus (poliovirus type 3) were detected in two samples, one collected at Billerica, Massachusetts, on August 15, 1972, and one negative control sample (60°C tap water that should not have contained viable virus), which was processed on August 24, 1972. It is our professional opinion that the virus found in the Billerica water sample was probably the result of laboratory contamination and that it was not present in the original water sample, particularly since this water sample had a free chlorine residual of 1.0 mg per liter (total chlorine 1.1 mg per liter) and a turbidity recorded as zero. This belief was reinforced when the same virus type was isolated in a negative control water sample processed 1 week later.

Cytopathic effects (CPE's) were observed in five other study samples collected by the Northeast laboratory. The occurrence of CPE in cell culture does not necessarily mean a virus is present; CPE can be caused by a number of substances or conditions, including enteric viruses. These five samples were submitted to the National Center for Disease Control, Atlanta, Georgia (NCDC) for confirmatory test, and no viruses were isolated from any of the samples. CPE's were also observed in cell cultures that received each of three positive controls and in two additional study samples. All five of these samples are now being processed to determine whether or not the CPE is of viral etiology.

Coliform organisms were found in only four samples of finished water in the entire study and these were well within the limit of 1 coliform per 100 ml allowed by the U. S. PHS Drinking Water Standards. No *Salmonella, Shigella,* or coliform organisms were detected in the water samples that had been concentrated for viral analyses.

From a bacteriological standpoint, source waters for each of the treatment plants were generally better than had been anticipated from background data that had been obtained from State and local sources.

Zoomicrobes (nematodes and amoebae) were found in essentially all finished water samples tested.

It seems safe to state that the drinking water from these 10 selected systems was rarely, if ever, polluted with sufficient numbers of virus to be an important vehicle for the transmission of human enteric viruses. Whether these 10 selected systems produce a finished product representative, from a viral standpoint, of the drinking water in this country remains to be determined.

Even though the main objectives of this study have not been fully realized because all tests have not been completed, much background data have been obtained and many of the areas of difficulty in conducting such a study have been uncovered.

As a result of the consolidation of field laboratory personnel into the Cincinnati Center, sampling sites for the coming year will be selected water supplies in the midwest.

Epidemiological Studies

An integral part of studies on biological contaminants in water supplies is designing and carrying out epidemiological studies of those contaminants whose transmission by drinking water is suspected, but not definitely proven.

During 1973, two types of such studies were begun. The first is an intensive literature search relating to the minimal infective dose of enteroviruses and data collection on recovery of poliovirus from stools, sewage, streams, etc. The objective of this study is to attempt to determine the "real world" significance of the experimental observation that one virus particle is sufficient to infect some completely susceptible persons. It is important to attempt to do this in order to be able to evaluate the true health significance of viruses in drinking water, should they be found there. Such a study is very complex and involves statistical probability, infectivity of the organism, host susceptibility, etc.

The second study has the objective of determining at what age children become infected with enteroviruses, particularly when there are siblings in the family. Such a study, if it can be accomplished, would show the role of drinking and recreational water in the transmission of virus disease or infection as contrasted with the role of person-to-person spread of these viruses.

Waterborne Disease Surveillance

A WSRL tabulation on waterborne-disease outbreaks is maintained (Figure 29). In cooperation

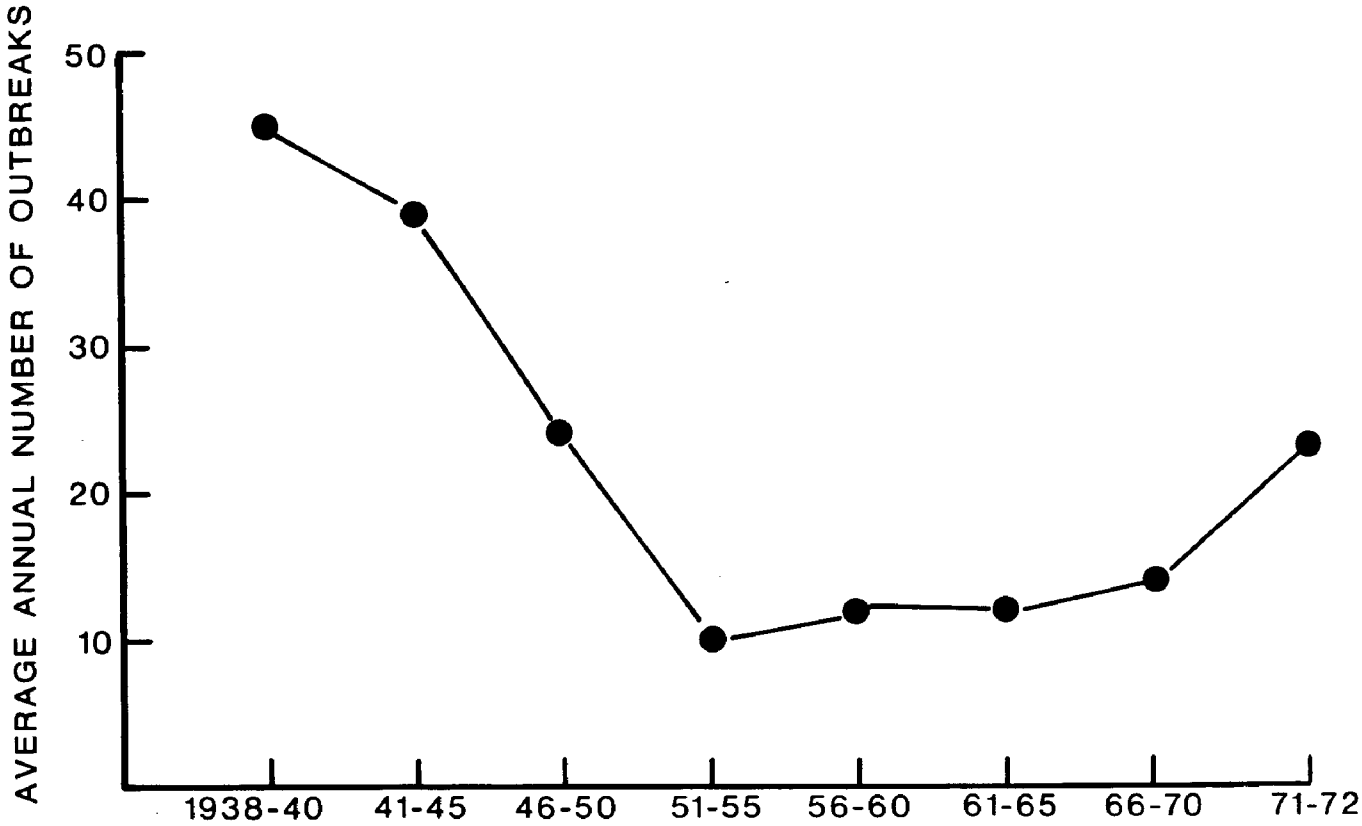


FIGURE 29. OUTBREAKS OF WATERBORNE DISEASE IN THE UNITED STATES, 1938-1972.

with NCDC, investigative assistance is available to States and localities to determine the cause of the outbreaks.

In the last 2 years, 47 waterborne outbreaks, resulting in 6817 illnesses, are known to have occurred in the United States. During the period 1951-1970, waterborne outbreaks occurred, on the average, at a rate of about one per month; in the past 2 years, the rate has increased to about two per month. This increase occurred primarily in semi-public and individual water systems and probably results from greater awareness and better reporting. Most of the outbreaks were in the semi-public systems and involved travelers, campers, and restaurant patrons. Outbreaks associated with municipal systems, however, were responsible for the greatest number of illnesses; the largest outbreak, 3500 cases, occurred in Pico Rivera, California, in 1971.

Safe Recreational Water Quality Criteria

Central to the program concerned with safe recreational waters is a series of epidemiological — microbiological surveys to be conducted at appropriate salt and fresh water bathing beaches. The objective is to relate some microbial, chemical, or physical measure(s) of water quality at the beaches to the incidence and nature of illnesses among the swimmers using them. Concurrently, microbiological and epidemiological methods are being refined and developed. Salt water beaches at Coney Island and the Rockaway in New York City were chosen as the test and control beaches for the first survey.

The first phase of the survey, whose objective was to pretest the methodology and determine the suitability of the test sites, was completed in 1973. Information on swimming activity and on the incidence, nature, and severity of illnesses among swimmers and nonswimming controls was obtained from about 700 individuals at each beach during the course of 8 trials. A preliminary analysis of the data — the first such data to become available since the 1950's — indicates that the epidemiological methodology will be satisfactory for the Phase 2 of the study scheduled for the summer of 1974. In addition, there was a suggestion that the rate of gastrointestinal disturbances among swimmers, when corrected for that among nonswimmers, was higher at the test than at the control beach. An additional pair of demographically comparable beaches (one test and one control) was sought and located in Nassau County, New York.

Development and laboratory evaluations were completed on membrane filter and enumerative methods for fecal streptococci (mSD); for *Aeromonas hydrophila* (mA); and for total coliforms, fecal coliforms,

and the component members of the coliform population *(Klebsiella, Escherichia, Enterobacter,* and *Citrobacter)* (mC). A high-volume (about 50 liters of water) method for *Salmonella* was developed. These methods, along with that developed for *Pseudomonas aeruginosa,* were successfully used during the summer trials of 1973. Unique data comparing the densities of these organisms were developed during these trials.

Environmental isolates of *Klebsiella* species, *A. hydrophila, V. parahemolyticus,* and *P. aeruginosa* have been collected. Their pathogenicity, growth, and biochemical and serological characteristics are being or have been compared with those of chemical isolates.

In conjunction with the National Lake Eutrophication Study, water samples were examined for the presence of amoeba, especially pathogenic *Naegleria.* Small, free-living amoeba were isolated from a number of the samples, and there was a suggestion that in certain regions their densities were correlated to the trophic state of the lake. Pathogenic *Naegleria* sp. were not isolated from any of the samples. A number of additional clinical isolates of *Naegleria* species were examined to confirm the correlation of cytopathogenicity in tissue culture to mouse pathogenicity. In addition, *P. aeruginosa, A. hydrophila,* and *Klebsiella* densities in a large number of the lakes were examined to determine if the levels of these pathogens could be correlated to the trophic state.

Screening of Known Chemicals for Specific Toxic Effects

Controlled studies on experimental animals were conducted during the year (1) to determine the lowest dose of methyl mercury in drinking water that would produce biochemical changes in the central nervous system and (2) to ascertain whether methyl mercury in drinking water would produce synergistic/antagonistic toxicity of other environmental chemicals. Results indicate that measurable changes occur in the biochemistry and physiology of brain slices taken from animals exposed to levels of methyl mercury much below those required for the development of overt symptoms. A significant slowing of the rate of pyridine nucleotide reoxidation was noted at dosage levels as low as 0.01 mg per kg per day in water at both 90 and 180 days of exposure. To determine whether subacute exposure to methyl mercury produces synergistic/antagonistic toxicity of other chemicals, a study of the effects on hepatic detoxification enzymes (EPN detoxification System and p-Nitroanisole O-Demethylase) of adult male rats was conducted. In long-term experiments, animals were exposed to methyl mercury in drinking water at concentrations of 0, 0.01, 0.1, 1.0, and 10.0 mg per liter for up to 180 days. At 90 days, the activity of the EPN Detoxification System was inhibited by 32 percent in the highest dose group and activity of O-Demethylase was depressed by 14 percent at the 10 mg per liter level; no inhibition occurred at lower dose levels. After 180 days exposure, there was no statistically significant effect on the enzyme activities at any exposure level. Additional studies could not explain the magnitude of inhibition observed at 90 days of exposure.

Controlled animal experiments begun in 1973 include (1) studies of the effects of lead on the metabolic integrity of the central nervous system, (2) study of the effects of cadmium on hepatic detoxification enzymes, (3) a study of the effects of cadmium on renovascular function, particularly its effect on the renin-angiotensin system and renal hypertension, and (4) studies to determine the absorption, distribution, and excretion and the toxic effects of subchronic ingestion of soluble barium. The barium study is in response to a need for health effects data to support the present limit of 1.0 mg per liter in drinking water, which is exceeded by several water supplies in Illinois.

An appreciation of the current knowledge on the health effects of asbestos, especially ingestion via food or water, was obtained through an extensive literature review and personal communication with leading scientists in the field. Meetings were held with other Federal agencies and interested parties to discuss limitations and difficulties of previous research and to plan studies for obtaining a better assessment of the possible risk to the population from asbestos in drinking water, whether it originates at the source of supply or from the use of asbestos-cement pipe in distribution systems. Important factors that must be considered in any animal experiment or epidemiologic study include type of fiber, fiber size, amount, exposure period, type of exposure, type of experimental animal, and feeding to minimize inhalation. It is planned to determine the extent of absorption and distribution of asbestos in the gastrointestinal tract after ingestion by rats. To accomplish this task, a radioactive label must be incorporated into the crystalline mass of the asbestos fiber so as to require dissolution of the fiber before the label will be lost. If additional resources are obtained, long-term animal studies and epidemiologic studies of the effects of asbestos ingestion will be initiated before July 1974.

Quantitative *in vitro* mammalian cell methodology was evaluated as a screening device for use in studies concerned with the genetic toxicity of chemicals. Emphasis was on the induction, isolation, and characterization of nonlethal genetic damage. Stan-

dardization of the BUdR-visible light technique for determining mutant mammalian cells is planned with application of the technique as a bioassay system, the goal for 1975. A study of the mutagenic/carcinogenic potential of raw and finished drinking water from the lower Mississippi River using cultured mammalian cells and *in vivo* techniques was also initiated.

Studies of trace-metal body burden and environment exposure were expanded to include four New Jersey communities near New York City; Birmingham, Alabama; and Charlotte, North Carolina. Tap water has been collected and analyzed for trace metals found in scalp hair. Other variables, particularly exposure to trace metals via inhalation, will be assessed by NERC-RTP as part of the Community Health and Environmental Surveillance Studies.

During the past year, Boston was identified as having a significant problem with lead in tap water. Results of a survey in the Beacon Hill area showed lead concentrations above the Drinking Water Standards limit in over half of the homes sampled with some samples being five to six times the limit. Since lead in this concentration is not present in the raw or finished water, these concentrations can be attributed to the "aggressiveness" of the water on lead distribution piping. An epidemiologic study is planned to determine if a correlation exists between blood lead levels and the lead concentration in tap water when all other variables are controlled.

A cooperative study with the National Institute of Heart and Lung Disease was initiated to better define the role of water quality in chronic disease mortality (cardio-vascular).

INTERNATIONAL ACTIVITIES

AT HOME

Foreign Visitors

During 1973, NERC-Cincinnati received 222 foreign visitors who represented national and local governments and industry from 27 different countries. Much interest is expressed by these visitors in our major water programs, Advanced Waste Treatment and Water Supply Research, and in our solid waste program. Our industrial waste activities at Edison, New Jersey, are also at times visited by foreign scientists. The countries represented by these visitors (and their numbers) in 1973 were: Japan, 131; Germany, 16; Poland, 11; China, 10; U.S.S.R., 8; Australia, 6; South Africa, Italy, and the Netherlands, 4 each; and England, Sweden, Singapore, and Hungary, 3 each. An additional 16 visitors came from 14 other countries: Switzerland, Norway, France, Finland, Czechoslovakia, Spain, Surinam, Ghana, Iran, Liberia, Mexico, Taiwan, Chile, and Brazil.

Foreign Scientists Receiving Research Training

Although NERC-Cincinnati has no formal research training program for visiting scientists, several requests are made each year by foreign governments and scientists to come here for work experience in special fields. The scientists are supported by NATO and WHO scholarships or by their employer.

During 1973 the following scientists conducted research and obtained training here.

Shinichiro Uchida	Chief Sanitary and Planning Engineer Sewerage Bureau Osaka Municipal Government Osaka, Japan	Physical-Chemical Treatment Program, AWTRL	March-July 1973
Dr. Hubert J. Kastenhuber	On a fellowship from the German Academic Exchange Service	Physical-Chemical Treatment Program, AWTRL	April 1973 March 1974
Tokuyi Annaka	Research Engineer Sewage Works Section Public Works Research Institute Ministry of Construction Tokyo, Japan	Biological Treatment Program, AWTRL	September 1973 August 1974
Dr. Susanna Deak	WHO Fellow and Senior Research Worker National Institute of Public Health Budapest, Hungary	Microbiology Group WSRL and Waste Identification and Analysis Section, AWTRL	November 1973 January 1974
Akio Yutani	Sanitary Engineer City of Osaka Osaka, Japan	Ultimate Disposal Program, AWTRL	November 1973 March 1974

While at NERC-Cincinnati, Mr. Uchida worked on a research proposal involving a laboratory investigation of a novel process to remove ammonia from wastewater. In the process, a suitable exchanger is treated with a solution containing a metal ion that forms a complex with ammonia. The exchanger removes ammonia from aqueous solution by ligand exchange. The exhausted exchanger is regenerated thermally using low pressure steam. Technical feasibility of the process was demonstrated with the use of actual municipal wastewater.

Dr. Kastenhuber is engaged in a pilot-plant study of the removal of ammonia from a physical-chemical treatment plant effluent by partial chlorination followed by dechlorination by activated carbon. The influence of variations in pH, chlorine to ammonia-N ratio, and contact time on the chemistry of the chlorine-ammonia reactions is being determined. Also being evaluated, in terms of ammonia removal, are the reaction products of the carbon-chlorine and carbon-chloramine reactions.

Mr. Annaka is studying integrated chemical and biological nitrification for the control of phosphorus and nitrogen with the use of 800-liter-per-day pilot plants. Small 20-liter-per-day bench scale units are used to determine kinetic rates of nitrification. Discussions with AWTRL staff, review of publications, and field-site visits to operating facilities will be employed in the general evaluation Mr. Annaka is making of advanced treatment processes.

Dr. Deak is to study radiometric determination of coliform bacteria in water with the use of carbon-14 sodium formate and also to work on a project attempting to recover viruses from a potable water using large samples.

Mr. Yutani's research will center mainly upon the classification of filtrates and centrates that result during vacuum filtration and centrifugal dewatering of phosphorus-laden chemical sludges. Results of the research will provide a better insight into the best method of ultimately disposing of these liquid side streams.

ABROAD

Public Law 480 Projects

Under P.L. 480, U. S. counterpart funds in foreign countries are being used to finance projects designed to advance scientific and technical research in the particular country, as well as in the United States. From NERC-Cincinnati, Project Officers supervise investigations relating to the identification and solution of environmental problems.

"Development of Methods and Techniques for Final Treatment of Combined Municipal and Textile Wastewaters Including Sludge," Water Economy Research Institute, Katowice, Poland (Investigator: J. Suschka; EPA Project Officer: R. L. Bunch)

Various combinations of waste treatment processes will be investigated to effectively treat a combination of domestic and textile wastewater. Special emphasis will be placed on color elimination. Consideration will also be given to pretreatment of textile wastewater before combining with municipal wastewater. Sludge disposal from best processes will be considered.

Dr. Suschka, the project officer, visited this country in the middle of November 1973 and reported that the literature has been reviewed for analytical methodology on dyes used in textile processing. Various methods have been tested and modified to meet the requirements of the study. Samples of dye work wastes are being characterized as to their physical and chemical properties.

"Epidemiological Study of Methemoglobinemia in Croatia," Institute of Public Health in Croatia, Zagreb, Yugoslavia (Investigator: B. Plese; EPA Project Officer: L. J. McCabe)

Continued investigations were conducted on rural water supplies. Staffing and transportation difficulties have impeded progress on the annual report.

"Factors Influencing Lead Absorption from the Intestine," Institute for Medical Research, Zagreb, Yugoslavia (Investigator: Dr. K. Kostial; EPA Project Officer: Dr. J. F. Stara)

This project is designed to investigate in experimental animals the different factors (age, pregnancy, lactation, and selected dietary additives) that might influence the absorption and metabolism of ingested lead. The data will provide additional necessary information on the metabolism of lead and calcium in the very young and on dietary additives that could be used to decrease physiological availability of lead for absorption. The project has been in progress since July 1972, and manuscripts dealing with the effect of lead ions on calcium transport through the intestine, the effect of milk additives on intestinal lead absorption, lead absorption from the intestine in lactation, and comparative metabolism of lead and calcium in young and adult rats have been prepared. The senior investigator is internationally recognized as an expert in this area of research.

"Health Effects of Nitrates in Drinking Water," Hebrew University, Jerusalem, Israel (Investigator: H. Shuval; EPA Project Officer: L. J. McCabe)

Methemoglobinemia in infants (blue baby) is the cause of concern for nitrates in drinking water. A final report was completed that presents the results of a series of field and laboratory studies designed to evaluate the health effects of nitrates in drinking

water. The results of the epidemiological and toxicological studies do not provide a basis for a liberalization of the current drinking water standard for nitrates. If anything, evidence is presented that may raise some questions as whether the current standard provides a sufficient margin of safety below the detectable effect level.

"Neutralization and Utilization of Post-Coagulation Sludge," Institute of Municipal Economy, Warszawa, Poland (Investigator: J. Salbut; EPA Project Officer: R. B. Dean)

This project is concerned with treatment of sludges from the purification of river water by coagulation with alum. Recovery of alum is believed to be economically viable. Basic studies on chemical recovery and concentration by freezing have been initiated. There is a good possibility that the Warsaw project may be able to demonstrate disposal of alum sludges in the new municipal sewage treatment plant at minimal cost.

"The Role of Silicates in the Etiopathogenesis of Endemic Nephropathy," Belgrade University Medical School, Belgrade, Yugoslavia (Investigator: A. Bata; EPA Project Officer: L. J. McCabe)

The first annual progress report covering the literature review and initiation of the research was received. Two animal experiments are currently in progress. Water obtained from a well epidemiologically associated with several cases of endemic nephropathy is concentrated and fed to rats. This group is to be compared with a control group exposed to Belgrade water and another exposed to filtered water from the same well. A second experiment consists of feeding rats concentrations of 25, 50, and 100 mg quartz per liter and 50 and 100 mg granite per liter suspended in drinking water. Physiological and biochemical variables are monitored, and pathohistological investigations are planned.

"Sludge Utilization in Physico-Chemical Treatment of Combined Municipal/Steel Industry Wastewater," Environmental Protection Center, Katowice, Poland (Investigator: Dr. Jan Suschka; EPA Project Officer: Dr. H. S. Skovronek)

A process is being developed to use available, iron-rich sludge from primary treatment as the coagulant for physico-chemical treatment of combined industrial and municipal wastewaters. The effectiveness and dependability of such a procedure, even under adverse climatic conditions, will be compared with that achievable by biological treatment in similar circumstances.

The initial work has demonstrated that the wastewater generated in the highly industrialized Katowice region of Poland can be treated effectively with conventional coagulants. Experiments are now under way to establish the effectiveness of the iron-rich sludge, both as is and after physical and/or chemical modifications. Simultaneously, pilot-plant equipment has been modified to allow evaluation of the physico-chemical treatment process on a larger scale and to establish more fully the effectiveness of the sludge or the selected derivatives, or both, relative to commercial coagulants. For comparison, data have been collected over the past several months to establish the best results which can be expected from biological treatment. In the future, the investigators will attempt to identify and optimize the major parameters influencing the efficiency of coagulation and pollutant removal.

"Solid Waste in India," Central Public Health Engineering Research Institute, Nagpur, India (Investigator: A. D. Bhide; EPA Project Officer: L. W. Lefke)

A survey has been conducted of the solid waste problems in India, with regard to the generation, storage, collection, processing, disposal or recycling of wastes generated in urban communities. The development of solid waste technology, as well as of nontechnological systems, is dependent on a complete understanding of the composition and properties of waste materials.

The information obtained on composition and quantity of solid waste is of value to Indian and United States researchers concerned with the proper management of solid residues. A final report prepared for this project is now undergoing review.

"Utilization of Sewage Sludges from Combined Treatment Plant/Textile and Tannery Wastes and Sanitary Sewage/in Combination with Municipal Wastes," Institute of Meteorology and Water Economy, Wroclaw, Poland (Investigator: H. Manczak; EPA Project Officer: R. B. Dean)

This project is concerned with sludge disposal in an industrialized mountainous region above a water supply reservoir. Composting with municipal solid waste to produce a useful product is being investigated. The properties of industrial and municipal sewage sludge combinations, including biological stabilization and dewatering by filtration, can be measured at their field laboratory.

International Organizations, Working Agreements, and Conferences

International Joint Commission

Throughout the year, Mr. D. G. Ballinger served as Chairman of the Standing Committee on Analytical Sampling and Measurement Methods, Research

Advisory Board, International Joint Commission. At regular meetings of the Committee, held in Canada and the United States, reports and recommendations on research needs, on-going research in both countries, and a joint Canadian-U.S. research information system were prepared and forwarded to the Board.

International Standards Organization

In September 1973, Mr. Ballinger again headed the U. S. delegation to Technical Committee 147 — Water Quality of the International Standards Organization. The biannual meeting was held in Washington, D. C.

International Conference on Pollution Control in the Marine Industries

In 1973, this international conference was co-sponsored by the Edison Water Quality Research Laboratory. The conference, held in Canada, covered all aspects of marine pollution control including legislation, enforcement, development, and research. The presentations at the meeting are available in a Proceedings.

Committee on Challenges to Modern Society

The project activities of this NATO environmental coordinating committee are expanding and progressing rapidly. The United Kingdom, pilot country for the project, has announced that construction of the Physical-Chemical Pilot Plant at Coleshill has been initiated and completion is scheduled for the spring of 1975.

Development of a study plan and common basis of analytical methods and data exchange has been initiated.

Dr. R. L. Bunch participated in a project-related workshop at Wuppertal, Germany, on oxygen aeration technology. The proceedings of this workshop have been printed.

The U. S. delegate to the October plenary, Mr. John Barnum, announced the start up of the first full-scale independent physical-chemical treatment plant in this country. Performance evaluation of this 0.6 mgd facility in Rosemount, Minnesota, is being supported by an Office of Research and Development (EPA) grant. The process sequence includes: chemical coagulation, sedimentation, filtration, granular activated carbon, second-stage filtration, nitrogen removal using ion exchange with an ammonia selective resin (clinoptilolite), and chlorination.

Interest in the AWT project is expanding, with NATO delegates from Canada and Italy indicating an interest in active participation.

Canada

In May 1973, Dr. A. J. Klee presented a paper "An Overview of Environmental Plastics Legislation in the United States" and served as one of the U. S. representatives on a panel entitled "The Environmental Impact of Plastics" at the 31st Annual Technical Conference of the Society of Plastics Engineers, Inc., held in Montreal, Canada. The international conference was jointly sponsored by the American Society of Plastics Engineers, Inc., and the Plastic Institute of Great Britian. The technical session provided the forum for scientists to discuss the status of research throughout the world on the environmental effects of plastics.

Israel

At the request of the Water Commissioner's Office, Ministry of Agriculture, Israel, Mr. N. B. Schomaker visited several existing and proposed sites within the Dan Region and the Northern District of the Ministry of Health, January 1-12, 1973, to review and study Israeli groundwater pollution abatement techniques as applied to landfill leachate control and to discuss technology regarding solid waste disposal. These existing sites were located specifically in Tel Aviv and Jerusalem. Technical institutions in Haifa and Jerusalem were also visited.

Mr. Schomaker presented lectures on solid waste management practices relating American technology to current and potential solid waste management problems in Israel. Mechanisms were set up for the further exchange of information of interest to Israel. The Water Commissioner expressed an interest in further developing an exchange program between his office and EPA.

Europe

Dr. J. M. Symons visited France, Germany, The Netherlands, and the United Kingdom in March 1973 to discuss water supply practices and research programs as they exist in Europe and the United States. Dr. Symons also participated in a Water Research Association conference and presented a paper on activated carbon experience in the United States.

EVALUATION OF ASBESTOS-LIKE FIBER PROBLEM IN DRINKING WATER FROM LAKE SUPERIOR*

In June 1973, an apparent problem with fiber-like particulates in the drinking water of Duluth, Minnesota, and surrounding communities was revealed by the National Water Quality Laboratory, NERC-Corvallis. The Water Supply Research Laboratory (WSRL), NERC-Cincinnati, staff was asked two questions: Could we help evaluate the relative fiber-like content of various waters in the Duluth area? What treatment processes, if any, would remove these particulates?

Samples sent us from the Duluth area were analyzed using the optical microscope method originally developed by the National Institute of Occupational Safety and Health for air sampling and modified for water samples. This showed the extent of the problem — that all drinking water supplies using water from western Lake Superior contained high numbers of extremely small, fiber-like particulates (Figure 30).

Treatment research was also conducted along with the fiber count determinations of various raw water sources. Because Lake Superior water was of high quality except for the small particulates, a simple form of treatment by direct granular filtration was tried first. By adding a small amount of coagulant and a polymer to the water, the small particulates were agglomerated sufficiently to remove most of them in the filter. Preliminary tests showed this process very promising and about 4 weeks after the problem was first surfaced, the final, confirming, small-scale, pilot-plant treatment run was performed.

*J. M. Symons, Water Supply Research Laboratory.

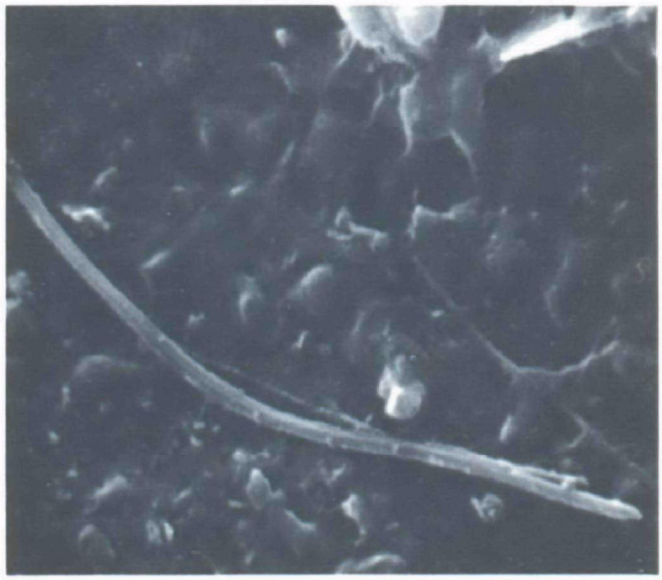


FIGURE 30. ELECTRON PHOTOMICROGRAPH OF AN ASBESTOS FIBER (CENTER) AT 10,000X MAGNIFICATION.

Large-scale pilot plant work on site is now being planned that will yield final design criteria for the needed treatment plants in the area.

In a companion effort, the epidemiologist and toxicologists, along with the engineers of WSRL assisted the Office of Air and Water Programs in developing an EPA guideline document for interim measures to be taken by water utilities using western Lake Superior as a source.

IMPROVED TECHNIQUES TO IDENTIFY SPILLED ASPHALTS*

The primary goal of the U.S. Environmental Protection Agency is the preservation and improvement of the environment. The National Environmental Research Center - Cincinnati, one of the four EPA research centers, is dedicated to solving research and engineering problems related to restoration of the quality of our environment. Among the many efforts for upgrading the environment studied at the Cincinnati center are the control of stack emissions, the wide use of pesticides, reduction of pollutants in automotive exhausts, efficient management of solid wastes, and the improvement of water quality. One of the serious and continuing water problems is the discharge of oils into surface waters. Thus, analytical procedures for the identification of discharged petroleum products and the successful application of these techniques are significant contributions to enforcement and environmental improvement.

Asphaltic materials cannot be readily identified to a source because they are not, by their very high molecular weights, complexity, and physical nature, usually amenable to analysis by gas chromatography with flame ionization detector. The limiting difficulty is the inability to vaporize and to separate the high molecular weight components in the gas chromatographic column. One feasible approach leading to identification, however, is the use of electron capture gas chromatography to separate the passively-labeled perfluoro phenolic ethers and thioether derivatives of the weak acids present in discharged heavier petroleum products. The identification is corroborated by results obtained by infrared spectrophotometry, metals analysis, elemental analysis, and statistical linear discriminate function analysis.

The measurements of major components, minor components, trace metals, spectral properties, and physical properties are illustrated in an enforcement case brought by the U.S. Coast Guard against an asphalt plant in 1971. The action involved an asphalt-like material spilled on the Ohio River at Aliquippa, Pennsylvania, and the Coast Guard requested the help of AQCL to identify the substances and company involved.

*F. K. Kawahara, Anlytical Quality Control Laboratory.

PREPARATION OF SAMPLE

The black, tacky material was completely extracted with chloroform, washed, and dried. Solvent was removed under reduced pressure. The source sample taken from the company asphalt pipeline and the river sample were treated similarly.

ASPHALTENE CONTENT

The two dried samples collected from the source and the river were subjected to asphaltene determination described by Abraham (1). The asphaltene contents were as follows: source sample, 21.1 percent; river sample, 22.6 percent.

INFRARED ANALYSIS

Spectra of the source and river samples were obtained with use of the Perkin-Elmer 137 Infrared Spectrophotometer. Spectra were characteristically similar throughout the range from 4000 cm^{-1} to 660 cm^{-1}. Examination of six infrared absorbance ratios for the source and river samples demonstrates the similarity of the ratios and of the samples.

CARBON AND HYDROGEN ANALYSIS

The carbon determinations for the source asphalt and river samples were 85.57 and 86.07 percent, respectively, and the hydrogen determinations were 10.86 and 11.16 percent. Values are averages of seven determinations per sample, and each determination was made on the Hewlett-Packard 185B. This agreement of the carbon and hydrogen content of the pipeline sample with the river sample suggests similarity between the two.

GAS CHROMATOGRAPHIC ANALYSIS

To demonstrate the similarity of the Ohio River sample and the source sample taken from the asphalt pipeline, the weak acid components (phenols and mercaptans) of the asphalts taken from the source and from the river were compared. Each asphalt mixture is treated with pentafluorobenzyl

bromide and potassium carbonate in an acetone-chloroform mixture. Each reaction mixture is then fractionated into six fractions with the use of solvent mixtures of varying polarity to effect a separation on silica gel column. The third eluate fraction yielded the revealing electron capture detector gas chromatograms. The retention distances of the 14 resolved peaks taken from the electron capture gas chromatographic analysis of the pentafluorobenzyl derivatives of the asphalt pollutant from the Ohio River are compared with those from resolved peaks of the derivative asphaltic material that was taken from the asphalt pipeline. Fourteen peaks (phenols and mercaptans) of the source sample match the 14 peaks (phenols and mercaptans) of the pollutant Ohio River sample. When a scatter diagram was made of 28 retention times, a 45° diagonal line showed an excellent fit to the points. (Three components of the 14 peaks found in the source sample are larger in amount than those in the river sample; three components may have been lost as a result of solubilization, etc., in the river sample.) The two asphalts are the same. This specific class analysis that determines phenols and mercaptans as ethers and thioethers (3,4) provides prima facie legal evidence.

NICKEL AND VANADIUM RESULTS

The residue of asphalt resulting from the digestion in concentrated nitric acid was dissolved in dilute nitric acid and analyzed by atomic absorption. The nickel and vanadium contents in the source sample were 81 and 30 mg per gram, and these values in the river sample were 49 and 28 mg per gram, respectively. The nickel in the river sample appears to be somewhat lower than expected, whereas the vanadium results agree well.

DATA TREATMENT AND STATISTICAL ANALYSIS

Infrared spectrophotometry has been a useful technique for the characterization and identification of these materials. With the use of a combination of infrared spectrophotometry, data treatment, data transformation, and discriminant function analysis with computer assistance, a precise method of classification has been derived. From among 20-plus samples of commercial asphalts, the unknown river sample was coupled to the commercial source via good agreement of mathematical values from the corresponding linear discriminant functions (5).

ENFORCEMENT ACTION

The Coast Guard won its case. All results pointed to the conclusion that the pipeline asphalt was the source of the pollutant river asphalt.

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ION-SELECTIVE ELECTRODES IN WATER ANALYSIS*

Since their introduction a few years ago, ion selective electrodes have found application in a variety of chemistry-related fields. In bio-medicine, clinical laboratories have employed electrodes in blood and urine analysis. In analytical chemistry research, the kinetics and mechanisms of certain reactions can be followed in solution by ion selective electrodes. In water analysis, these electrodes show great promise as analytical tools in the laboratory and in continuous monitoring equipment. This last area has been the main impetus behind the research and marketing of a variety of ion selective electrodes.

In simple terms, ion selective electrodes are electrochemical, potentiometric sensors that contain an internal phase and a membrane, which separates the internal and external (sample) phases. The type of membrane and the nature of the internal solution determine the electrode responsivity to a particular ion. When the ion is sensed, a potential is developed across the membrane, and the potential generated is compared with a reference potential. The difference is amplified by an electrometer. The electrometer output varies with the logarithm of the activity of the ion, not the concentration. In addition, the activity is greatly affected by the amount and type of background ions in a sample. For this reason, the application of electrodes to *in situ* water quality monitoring is severely limited.

At the Methods Development and Quality Assurance Research Laboratory (MDQARL), a number of electrodes and their associated methodology have been evaluated for usage with waters of all types. There are four basic electrode methods: direct, ionic strength adjustment, known addition, and potentiometric titrations. With the direct method, the response for a sample is compared with a previously calibrated standard curve, with the limitation that the standards and sample must have the same ionic (background) strength. This method is applicable only to pure solutions of the ion sought and, therefore, cannot be employed in water analysis. The ionic strength adjustment technique circumvents the limitation of the direct method by adding a sufficient amount of a noninterfering ionic compound to both the standards and the samples. In this way, any differences in ionic strength will be effectively "swamped out" and made constant. The known addition method requires the analyst to determine sample concentration by adding a known amount of standard to the sample. A simple calculation is made or a set of tables consulted to obtain the original concentration, without resorting to a standard curve. Finally, electrodes can be utilized as end-point detectors in potentiometric titrations, providing, of course, that a titration procedure is available for the ion in question.

Electrodes incorporating a solid crystal membrane, such as fluoride, chloride, and cyanide probes, have been evaluated by the MDQARL staff. Electrode maintenance is a major factor in constructing continuous monitoring apparatus; with this type of electrode, the amount of maintenance is limited. There is no need to replace the membrane or to replenish the filling solution.

Of the ion selective electrodes, the fluoride electrode (Figure 31) has enjoyed the widest popularity

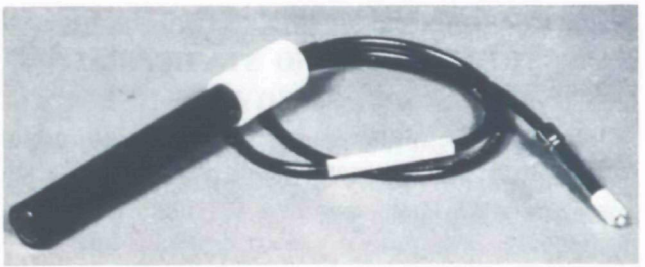

FIGURE 31. FLUORIDE SELECTIVE ELECTRODE.

because it has performed satisfactorily in a variety of sample media. Adding an ionic strength adjustor/buffer to the water sample is the only modification necessary for uncomplexed fluoride analysis. For total fluoride analysis, however, a preliminary distillation must be performed. The chloride electrode is an excellent end-point detector in the potentiometric titration of a water sample with silver nitrate. When used in this manner, it has correlated well with an approved manual titration. So far, this is

*R. F. Thomas, Analytical Quality Control Laboratory.

the only mode in which the chloride electrode may be used. If the electrode is standardized in a sample-matching matrix and this matrix remains constant, it may find additional application. The cyanide electrode cannot be used directly on a sample. Presently, this electrode is being evaluated on water samples that have previously undergone a distillation to ensure the dissolution of all metal-cyanide complexes.

The filling solutions of the nitrate and fluoroborate electrodes are high molecular weight organic compounds that serve as ion-exchange media. The filling solution is separated from the sample solution by a small porous membrane. Because these liquid membrane electrodes require a great deal of upkeep to work properly, their adaptation to continuous monitoring is difficult. The nitrate electrode has been extensively investigated with various waters and found to be useful, with limitations. Extreme care must be taken to nullify the effect of the sample ionic strength by adding an ionic strength adjustor. However, the proper adjustor and the appropriate amount to be added have not as yet been determined. In addition, many of the ions normally found in water samples interfere with the nitrate electrode. The fluoroborate electrode suffers from the same limitations as the nitrate electrode, since it is a part of the same electrode family. As a matter of fact, the presence of nitrate in a sample greatly interferes with the results of the fluoroborate electrode.

Finally, MDQARL has thoroughly investigated the ammonia electrode (Figure 32). It utilizes a unique gas-sensing approach. The sample is pretreated with a strong base so that all the ammonia is converted to the gaseous form. The ammonia then passes through the membrane, which is solely gas permeable, and is measured by the electrode. This concept eliminates any problems resulting from background ionic strength and interferences. In this laboratory and in others, results with the electrode were comparable to accepted methods when employed on a wide variety of water samples.

The development and utilization of ion selective electrodes for measuring inorganic ions in water will continue to be of utmost concern to the water chemist. Current research includes a promising sulfate electrode, and even development of a phosphate electrode is in the distant future. There are electrodes available for measuring certain metal cations, but this measurement is much more easily accomplished by means of atomic absorption spectroscopy. By the same token, present methodologies must be refined to achieve the optimum performance from each electrode. In short, the electrode surface is just being scratched.

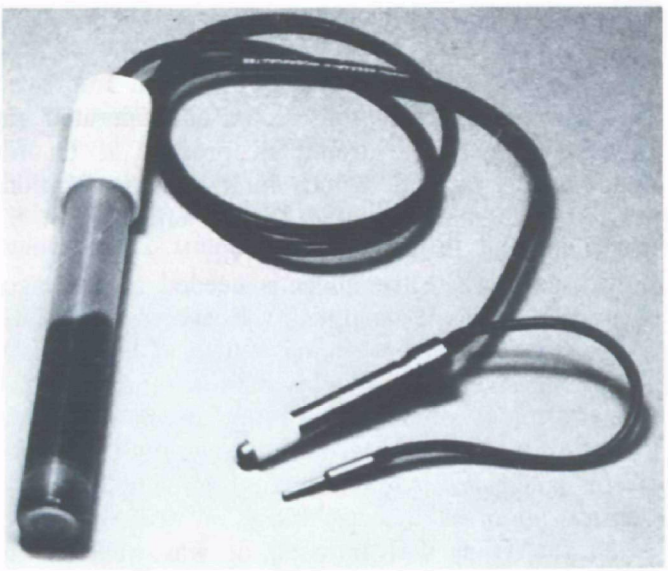

FIGURE 32. AMMONIA SELECTIVE ELECTRODE.

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Analytical Quality Control Laboratory, "Methods for Chemical Analysis of Water and Wastes," U.S. Environmental Protection Agency, National Environmental Research Center, Cincinnati, Ohio, 1971.

Thomas, R.F., and Booth, R.L., "Selective Electrode Measurement of Ammonia in Water and Wastes," Environ. Sci. Tech. 7(6): 523-526, 1973.

NUTRIENT CONTROL AT EL LAGO, TEXAS*

The Harris County Water Control and Improvement District #50 has constructed and operated an advanced wastewater treatment process at its El Lago, Texas, facility. Funds for the demonstration project were shared by the District and the U. S. Environmental Protection Agency.

Advanced waste treatment is needed at El Lago because of Texas Water Quality Board requirements designed to protect receiving waters (Clear Lake) from excessive pollution by organic carbon, suspended solids, ammonia nitrogen oxygen demand, and phosphorus. Nitrate removal, although not part of the Clear Lake requirements, is included as a demonstration of the capability of denitrification. When the grant was initiated, it was not known whether the Texas Water Quality Board would require nitrogen removal or elect to establish nitrogen control on a total oxygen demand basis.

All existing facilities of the nominal 1,135 cubic meter per day (0.3-mgd) plant were utilized in the advanced waste treatment design. The processes in the operation were:

- phosphorus control by metallic salt addition to the primary settler
- carbonaceous removal by trickling filters
- nitrogenous oxygen demand control by suspended-growth, second-stage activated sludge
- nitrogen removal via attached-growth-column denitrification
- tertiary solids removal by granular media filtration

These processes are operated in series. The construction and installation of the capital equipment for nitrogen control started February 1972. The phosphorus removal, nitrification and tertiary filtration facilities are designed for a maximum dry weather flow of 1,892 cubic meters per day (0.5 mgd). Design for denitrification is for average dry weather flow of 1,135 cubic meters per day (0.3 mgd) since there was no established nitrogen removal standard.

The main thrust of the demonstration is the comparison of two types of attached-growth denitrification processes. One process uses 3- to 4-mm sand particles and the other, 15- by 15-mm plastic cylinders as surfaces for attachment of active organisms. Each type medium is contained in a steel tower with suitable piping and valving. Figure 33 is a view of the El Lago plant. Shown in sequence from front to back are the intermediate clarifier, centrifugal air compressors, nitrification reactor, and denitrification towers. The two smaller towers contain the sand media; the size and shape of this media is shown in Figure 34. The larger towers contain the plastic media. Figure 35 shows various sized cylinders; the size used in this demonstration is the one on the extreme right of the photograph.

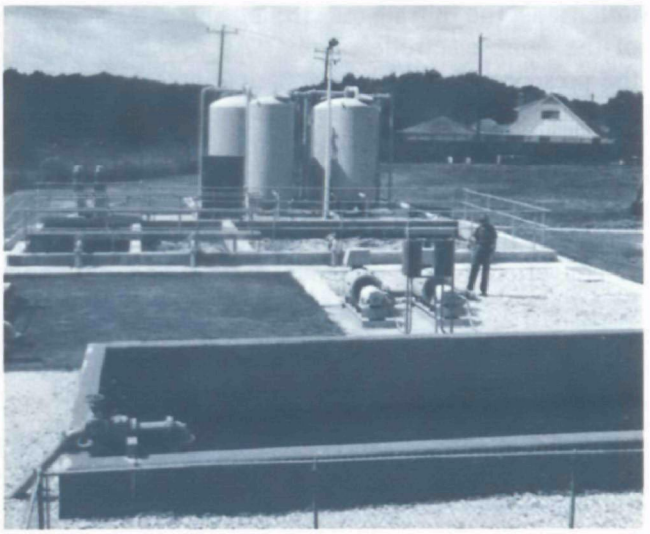


FIGURE 33. DENITRIFICATION TOWERS.

Each set of denitrification towers was operated initially for a 6-week period. The two processes are about equal in nitrogen removal capability but differ in operation. The small-media towers are operated downflow and have a void volume of about 40 percent. This void volume tends to be blocked by the growth of organisms resulting from the injection of methyl alcohol that is used to control the denitrification reaction. These towers must be back-washed once each 24 hours to maintain unrestricted flow through the system.

*E. F. Barth, Advanced Waste Treatment Research Laboratory.

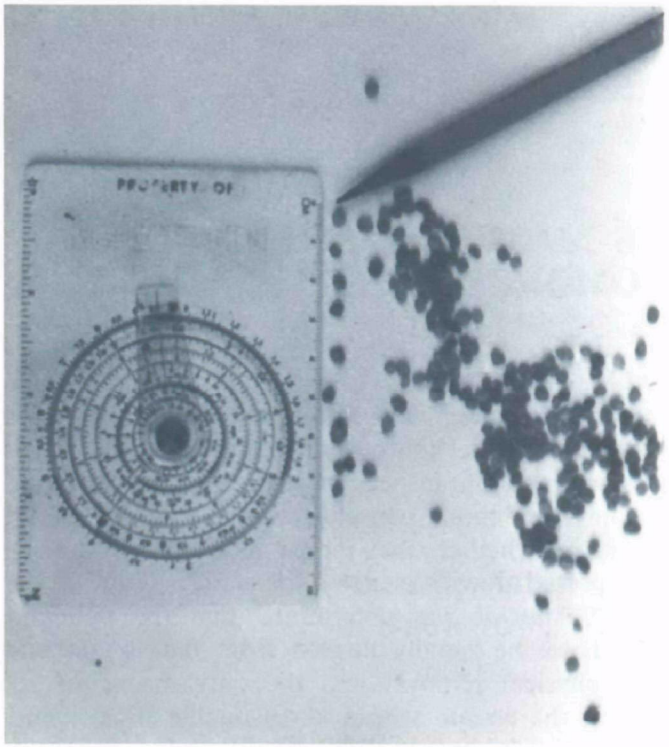


FIGURE 34. SMALL SAND MEDIA.

The plastic-media towers are operated upflow and have a void volume of 92 percent. Growth of organisms in this system does not impede the flow to any appreciable extent, and these towers only require back-washing once a month.

The El Lago plant is the first full-scale application of attached-growth biological denitrification technology, and initial evaluation of the efficiency of the various plant processes, as given in Table 7, shows a high-quality effluent can be produced. The data contained in this table were collected during operation of the plastic media towers in July and August 1973. The values are the residual concentrations of the pollutants in each major process stream; thus, the final effluent being discharged to Clear Lake has a low suspended solids, total nitrogen, and oxygen demand.

The cost of chemicals for controlling nitrogen and phosphorus during the demonstration was 2.6 cents per cubic meter (9.6 cents per 1,000 gallons) which, on a population basis for El Lago, figures to 1 cent per day per person.

In a 6-month evaluation program, now in progress, slight modifications in operational control are being made to produce lower effluent residuals and to determine the operational reliability and variability experienced in daily operation of this advance waste treatment system.

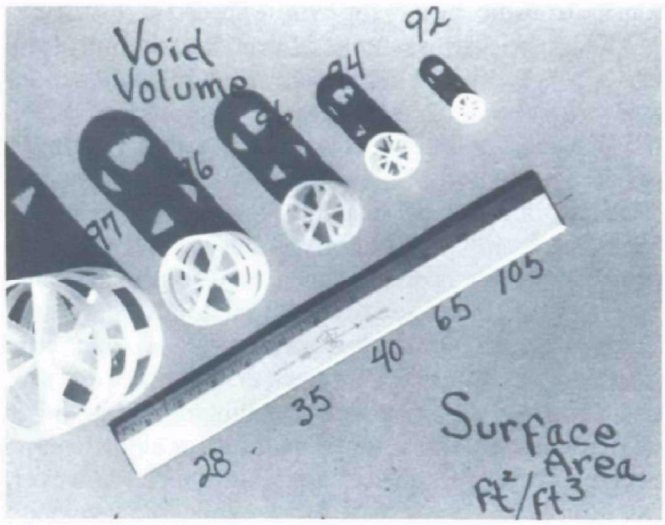


FIGURE 35. LARGE PLASTIC MEDIA.

TABLE 7. EVALUATION OF LARGE-MEDIA (PLASTIC CYLINDER) DENITRIFICATION TOWERS, JULY 8 - AUGUST 31, 1973*

Item	Raw wastewater	Primary influent	Primary effluent	Nitrified effluent	Denitrified effluent	Final effluent
Total phosphorus	12.3	13.1	6.7	-	-	0.9
Soluble phosphorus	10.3	3.1	2.4	-	-	0.7
Suspended solids	102	231	63	43	19	4.5
Ammonia nitrogen	16.3	14.6	14.4	0.9	1.2	0.9
Total Kjeldehl nitrogen	29.7	31.8	26.7	2.6	2.5	1.7
Nitrate nitrogen	-	-	-	13.6	0.9	0.6
Biochemical oxygen demand	143	156	87	43†	15	8
Chemical oxygen demand	248	336	167	107†	52	38
Methanol dose	-	-	-	34	-	-

*All values are averaged and in mg/l.

†Includes demand due to added methanol.

RESEARCH TACKLES A HAZARDOUS MATERIAL SPILL PROBLEM IN THE LITTLE MENOMONEE RIVER*

Hazardous material spills adversely affect the community and its facilities. Effective cleanup techniques, directed by the Edison Water Quality Research Laboratory (EWQRL) demonstrated that these effects need only be temporary. Such a pilot demonstration has been going on in Milwaukee, Wisconsin, for the past year with successful results.

The scene was a sunny afternoon early in June 1971. A group of Milwaukee junior-high school students rolled up their sleeves and undertook to reclaim a debris-littered stream in one of the county's parks. By the end of the afternoon, several teenagers required out-patient hospital care for "chemical" burns on their hands, arms, and legs; and one was retained in the hospital for a week with systemic effects, including a kidney malfunction.

The stream they had set out to clean up, the Little Menomonee River, had once been a pleasant site, full of fish and suitable for wading and the other recreational activities associated with a small watercourse. Years of neglect and ignorance, however, caused it to become a hidden public menace with a toxic, oily substance, creosote, lurking beneath its innocent-looking waters. The material had been deposited there over the previous three decades by a number of spills from a railroad-tie treating operation.

Within days of the "cleanup" incident, the State of Wisconsin, the County Parks Commission, and the Federal Government ordered that the creosoting plant stop all discharges to the river. The Company rapidly complied with the abatement orders, but the problem of how to remove the remaining pollutant from the bottom muds was still to be solved.

By chance, at approximately the same time that these events were transpiring in Milwaukee, the Hazardous Material Spills Research Branch of the EWQRL was seeking a site to demonstrate and evaluate methods to physically remove spilled, heavier-than-water material from the bottoms of watercourses. Upon learning of the problem in the Little Menomonee River, the Branch initiated contact with the appropriate State and local agencies. Several site inspection visits were made during the next few months to characterize the stream and ascertain whether the settled creosote would be transported downstream by the natural flow of the river. After it was determined that the pollutant would not be rapidly flushed from the stream and that physical removal was the only means of restoring the stream within a reasonable time frame, EWQRL initiated an RFP (Request for Proposal) seeking methods and devices to remove the creosote from the Little Menomonee River. The intent of the RFP was to demonstrate at least two methods that would not permanently damage the stream bottom or banks or stir up the bottom to a point where the creosote would be resuspended and, in turn, become a threat to downstream waters. In addition to the engineering demonstrations, each contractor was required to conduct a detailed sampling and analysis program before, during, and after cleanup operations to determine the efficiency of the removal methods and their environmental impact.

As a result of the RFP, both Rexnord Corporation, Milwaukee, Wisconsin, and Industrial Bio-Test Laboratories, Inc., Northbrook, Illinois, were selected to demonstrate their cleanup systems on separate 500-foot segments of the river, during a designated 10-day period (Phase I). The more cost-effective of the two systems would later be chosen to remove creosote from the entire (2½ mile) contaminated section of the river bottom (Phase II).

Both contractors initiated laboratory, design, and fabrication work in June 1972, and the field demonstrations were conducted during October and November.

REXNORD SYSTEM

Rexnord Corporation used a system (Figure 36) consisting of: a "river sweeper" to physically remove the creosote-soaked mud from the river bottom; the EPA "beach cleaner" to separate the creosote

*J. P. Lafornara and I. Wilder, Edison Water Quality Research Laboratory.

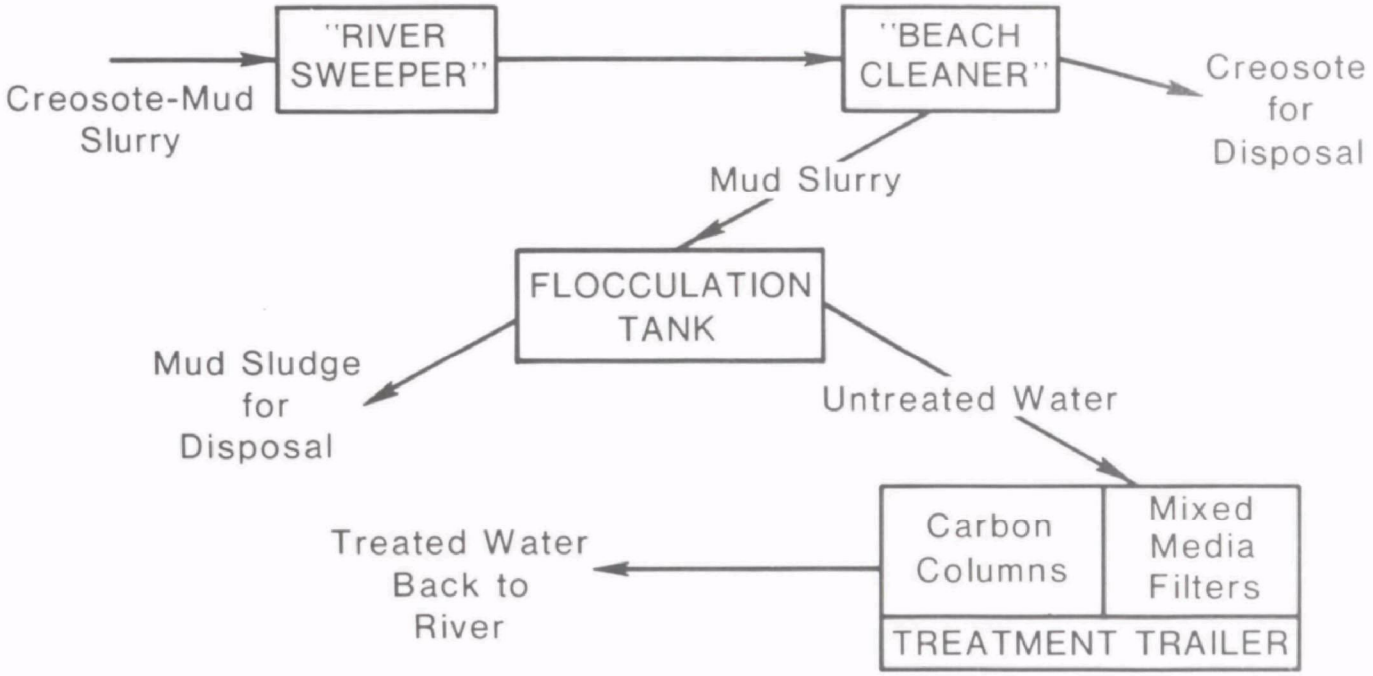


FIGURE 36. FLOW DIAGRAM OF CREOSOTE REMOVAL SYSTEM USED BY REXNORD CORPORATION.

from the mud and water; a flocculation tank to settle the mud; and the EPA "mobile spills treatment trailer" to remove any residual dissolved and colloidal creosote from the water. The "river sweeper" (Figure 37) consisted of a pontoon-mounted device with a suction head joined to the end of a hydraulically operated mast that moved in three dimensions. During removal operations, the mast was lowered into place so that the suction head was touching the river bottom where it could vacuum up the mud, creosote, and associated water. When the contaminated mud was completely removed from any particular location in the river, the mast and head were raised from the bottom and moved forward or back, or to the left or right as was appropriate, and the mast was again lowered into another position to pump up more creosote, mud, and water.

From the "river sweeper," this mixture entered the EPA "beach cleaner" (Figure 38), a device previously developed under contract for EWQRL to remove oil from beach sand. The creosote-mud slurry was pumped directly into the beach cleaner's froth flotation cells (Figure 39). Air was blown through diffusers into the slurry causing the creosote to become separated from the mud and to rise to the surface with the air bubbles. The resulting froth was skimmed from the surface and disposed of at a state-approved sanitary landfill.

The remaining mud and water was pumped to a portable flocculation tank (Figure 40) where ferric chloride was added to hasten settling of the mud. This tank is an integral part of EPA's "mobile spills treatment trailer" (Figure 41), a device previously designed and fabricated for EWQRL by Rexnord Corp. The settled sludge was removed from the flucculation tank periodically and deposited in the approved landfill. The supernatant water from the

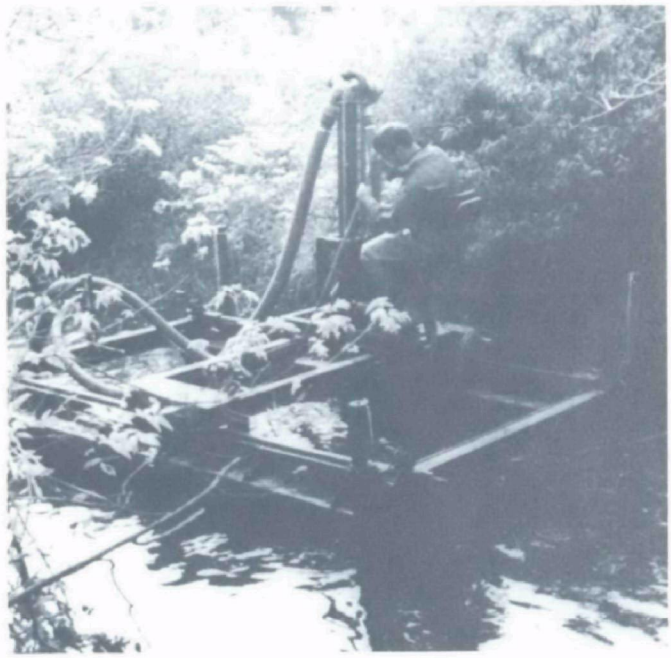


FIGURE 37. "RIVER SWEEPER" PICKS UP CREOSOTE-MUD SLURRY FROM THE RIVER BOTTOM.

FIGURE 38. "BEACH CLEANER" SEPARATES CREOSOTE FROM THE MUD SLURRY.

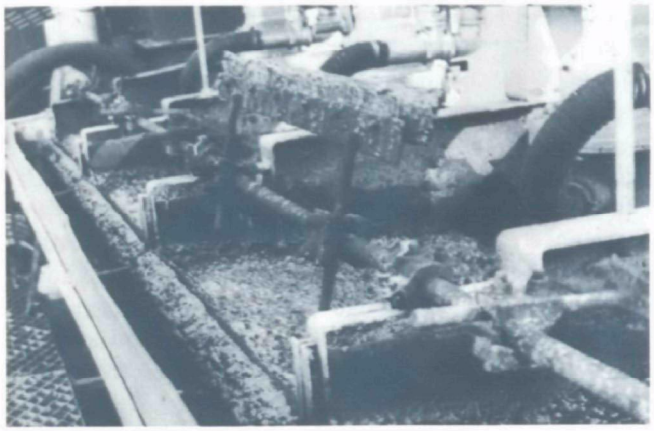


FIGURE 39. FORMATION OF CREOSOTE FROTH IN "BEACH CLEANER'S" FLOTATION CELLS.

FIGURE 40. FLOCCULATION TANK SEPARATES MUD FROM THE WATER.

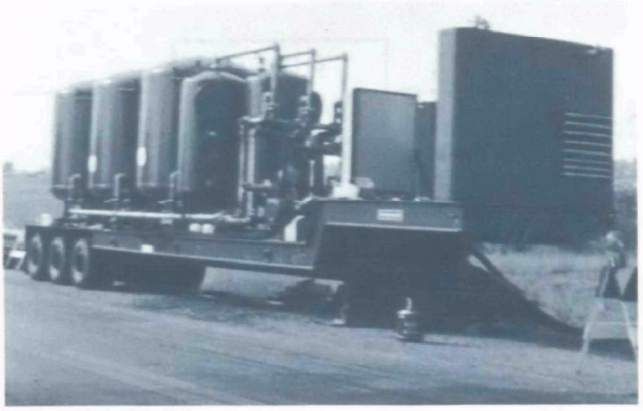


FIGURE 41. "MOBILE SPILLS TREATMENT TRAILER" FILTERS SUSPENDED PARTICLES AND REMOVES DISSOLVED CREOSOTE BY CARBON ADSORPTION.

tank was processed through the "mobile spills treatment trailer" where suspended particles were removed by mixed filters and dissolved creosote was removed by carbon adsorption columns.

The processed water from the carbon columns was returned to the river. The creosote concentration of this water (as determined by the "hexane" extractables method) varied from 1 to 3 ppm as compared with a background creosote concentration in the river water of between 10 and 15 ppm.

INDUSTRIAL BIO-TEST SYSTEM

In contrast to the rather large equipment used by Rexnord, the Industrial Bio-Test system utilized relatively small-scale devices of novel design. The system (Figure 42), which was designed, built, and operated under a subcontract to RP Industries, Marlboro, Massachusetts, was automated to the maximum extent possible and could be operated by only two men. Its main components were a hand-held vacuum nozzle, an in-line grass filter, a primary settling column, a "Dynactor," a secondary settling column, a magnetic separator, and a final sand filter. The creosote-mud slurry entered the system through a nozzle that was designed in much the same manner as a vacuum cleaner nozzle, so that there were no constrictions where clogging could take place. The slurry then passed through a grass filter that was needed to protect the rest of the system from fouling caused by aquatic weeds and other debris from the river bottom.

From the filter, the slurry was pumped to the primary settling column (Figure 43) where a flocculant was added and the mud and creosote were separated from the water. The mud-creosote sludge was drained from the bottom of the settler and disposed of at the approved landfill. The supernatant

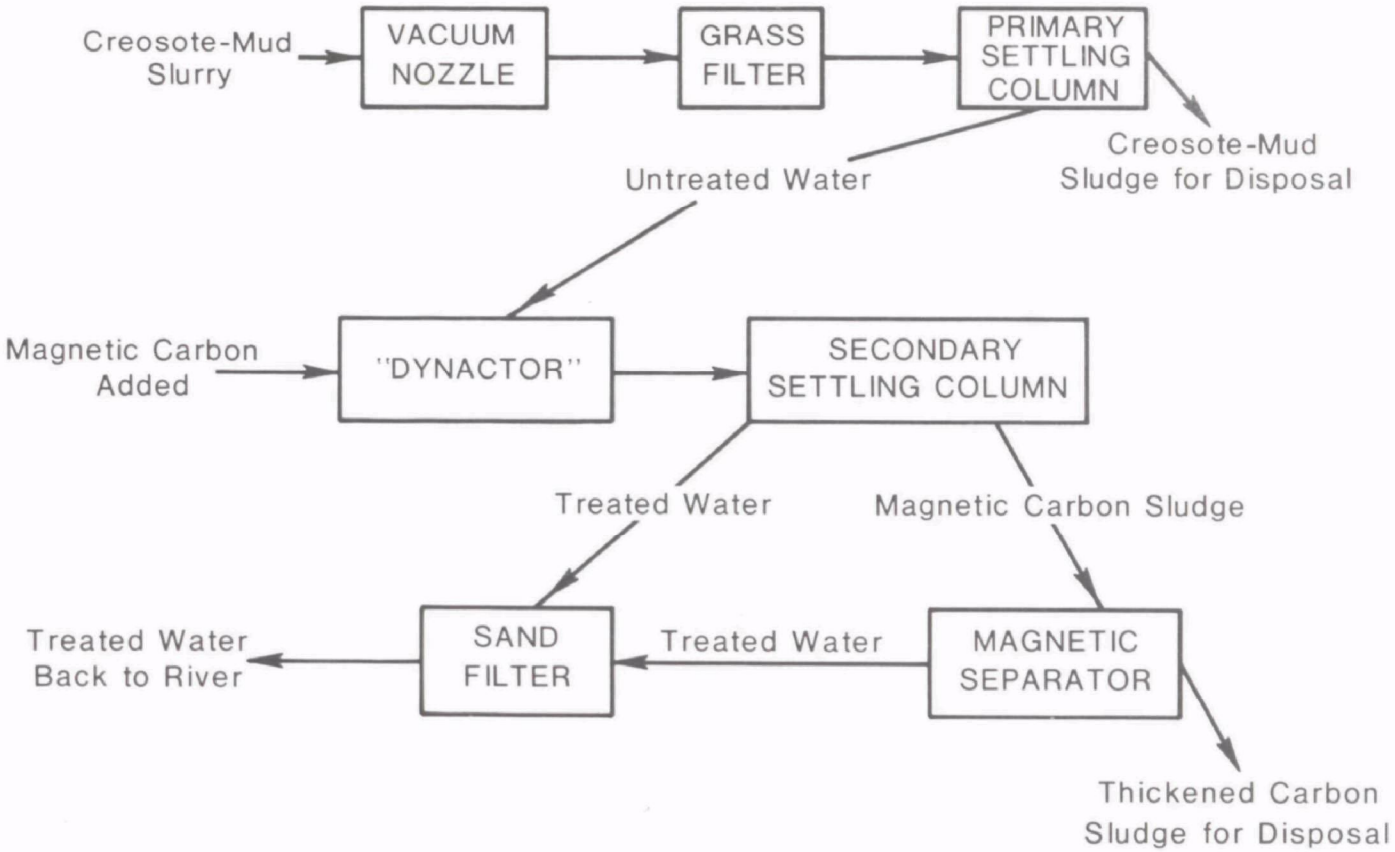


FIGURE 42. FLOW DIAGRAM OF CREOSOTE REMOVAL SYSTEM USED BY INDUSTRIAL BIO-TEST LABORATORIES AND RP INDUSTRIES.

water was pumped through the "Dynactor" where a blend of activated carbon and a magnetic oxide was introduced to remove the residual dissolved carbon creosote from the water. The resulting carbon slurry from the "Dynactor" entered a secondary settling column (Figure 43) where another flocculant was added to aid the settling of the carbon. The carbon sludge was dewatered in a "magnetic separator," and both the supernatant water from the secondary settler and the water that was removed from the carbon sludge by the "magnetic separator" were passed through a final sand filter. The effluent from the filter was then returned to the river. The creosote concentration (hexane extractables) of the processed water was always significantly lower than the background creosote concentration in the stream.

EVALUATION AND AWARD OF PHASE II

After both contractors completed their demonstrations and sampling and analysis programs, final reports were submitted to EPA. The data presented indicated that each contractor performed well enough in Phase I to qualify to conduct the full-scale clean-up (Phase II). Observations during Phase I showed that not only was the river bottom contaminated

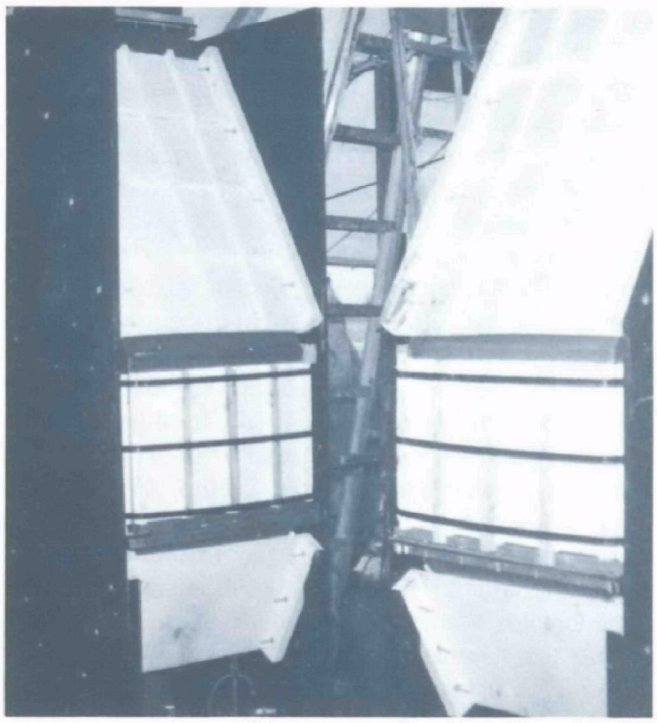


FIGURE 43. PRIMARY AND SECONDARY SETTLERS REMOVE MUD AND CARBON, RESPECTIVELY, FROM THE WATER.

with creosote but the river banks were also soaked with this coal tar substance.

A revised Work Scope that included some toxicological studies and bank cleanup, as well as the full-scale stream bottom removal, was prepared by EWQRL. Both contractors were invited to resubmit bids for the Phase II work. The low bidder, Rexnord Corporation, was awarded the contract and proceeded with the cleanup operations in July 1973.

PROGRESS TO DATE

Rexnord made minor modifications to its Phase I system to increase its cost effectiveness: two river sweepers were deployed in the river instead of one and the "beach cleaner" was replaced by a presettling column. To clean up the river bank creosote, manual labor using a rototiller, and picks and shovels removed the contaminated soil for ultimate disposal to the approved landfill and, thereby, ensured that irreparable damage would not be done to the trees and brush along the river by heavy earth-moving equipment. The bank cleanup has already been completed and about 1.5 miles of stream bottom have been decontaminated. The remaining creosote laden portion of the stream was expected to be cleaned up in December 1973. Fish and aquatic plant life have already begun to return to the cleaned section of the river, and the prognosis for a complete biological recovery is good.

After this project is complete, the Little Menomonee River, which flows through county park land for nearly all its length, will be restored for the beneficial use of the people of Metropolitan Milwaukee. A giant step has been taken to demonstrate that Research and Development does not have to remain in its "ivory tower" but can be utilized to solve some of the environmental problems of the real world.

SANITARY LANDFILL LEACHATE RESEARCH*

The sanitary landfill method of solid waste disposal is advocated by the U.S. Environmental Protection Agency (EPA) when raw solid waste is disposed of on land.† The method of disposal, practiced to a limited extent since 1940, is an engineered alternative to burning and to open or intermittently covered dumps. Approximately 10 percent of the Nation's solid waste is disposed of in this manner. The major objections to dumping solid waste are the unacceptable aesthetic appearance and the threat to public health. Although the sanitary landfill method was developed to alleviate these problems, it does not inherently prevent contamination of surface or groundwater. Careful site selection and design can minimize and, under optimum conditions, eliminate the potential for water contamination. Because rain isn't controlled, water percolates into the landfilled solid waste and carries off dissolved and finely suspended solids called leachates. In essence, rainwater has leached waterborne contaminants from the decomposing landfilled solid waste.

Sufficient moisture is available within the disposed solid waste to allow a vigorous growth of aerobic microorganisms; this initial growth is followed by a slower, more prolonged growth of anaerobic and facultative organisms. These microorganisms utilize the innumerable constituents of solid waste and produce waste products such as carbon dioxide, methane, organic acids, and humic substances. These are the waste products, along with the soluble fraction of raw solid waste, that are of primary interest in evaluating the impact of the sanitary landfill method on the specific environment in which it is located.

The Boone County Field Site (BCFS) was established to realistically evaluate, by field-scale studies, the potential impact of sanitary landfilling on the environment. Previous sanitary landfill research was lab-scale oriented or was aimed at measuring the effects of a specific, full-scale, operating landfill without appropriate control of variables.. Leachate studies represent only one portion of the total Boone County effort. Studies on settlement, landfill gas production and migration, and detection and survival of pathogens have been part of the original planned research activities. The 3.6 hectare (9-acre) ridge-top site, leased from a privately operated solid waste management firm, is located on McCoy's Fork Road, Walton, Kentucky. A storage shed, converted trailer/office, portable scale, front-end loader/back-hoe, and a trailer-mounted, 3.8-cubic meter (1000-gallon) water tank are available at the site. All leachate and gas analyses (except pH, temperature, specific conductivity, and dissolved oxygen) are performed in Cincinnati.

In June 1971, the best available sanitary landfilling techniques were used to dispose of 394 metric tons (435 tons) of municipal solid waste by the trench method (Figures 44 and 45). The objectives for leachate research were to determine the composition and flow rates of leachate from this waste. Two drains and an impermeable liner were installed to evaluate the ability of the indigenous clay soil to act as a liner for leachate collection. Other studies included viral and pathogen survival (Figure 46), settlement, temperature, gas, and moisture movement. Random samples were obtained for subsequent physical categorization (paper, metals, etc.) and chemical composition. After 0.6 meter (2 feet) of the indigenous clay soil was placed on top (Figure 47) of the 594 kg per cubic meter (1000 pounds per cubic yard) of compacted solid waste, the site was graded to encourage surface runoff in accordance with best practices.

As a result of channeling rainwater through the compacted solid waste, leachate first appeared in August 1971, only 2 months after placing the solid waste and after 403 mm (16.12 inches) of rain. Typical composition of leachate and the range in values reported since August 1971 are shown in Table 8. The leachate composition depicted indicates degradation of the solid waste is still active. Since a finite mass of 394 metric tons (435 tons) of solid waste is being leached, the quality of the leachate should improve with time.

Leachate volumes are small when compared with domestic wastewater volumes from an equivalent

*D. R. Brunner, Solid and Hazardous Waste Research Laboratory.

†Federal Register, "Solid Waste Disposal; Proposed Guidelines for Thermal Processing and Land Disposal of Solid Wastes," 38(81):10544-10553, Part II, April 27, 1973.

FIGURE 44. MUNICIPAL SOLID WASTE BEING DEPOSITED IN SANITARY LANDFILL.

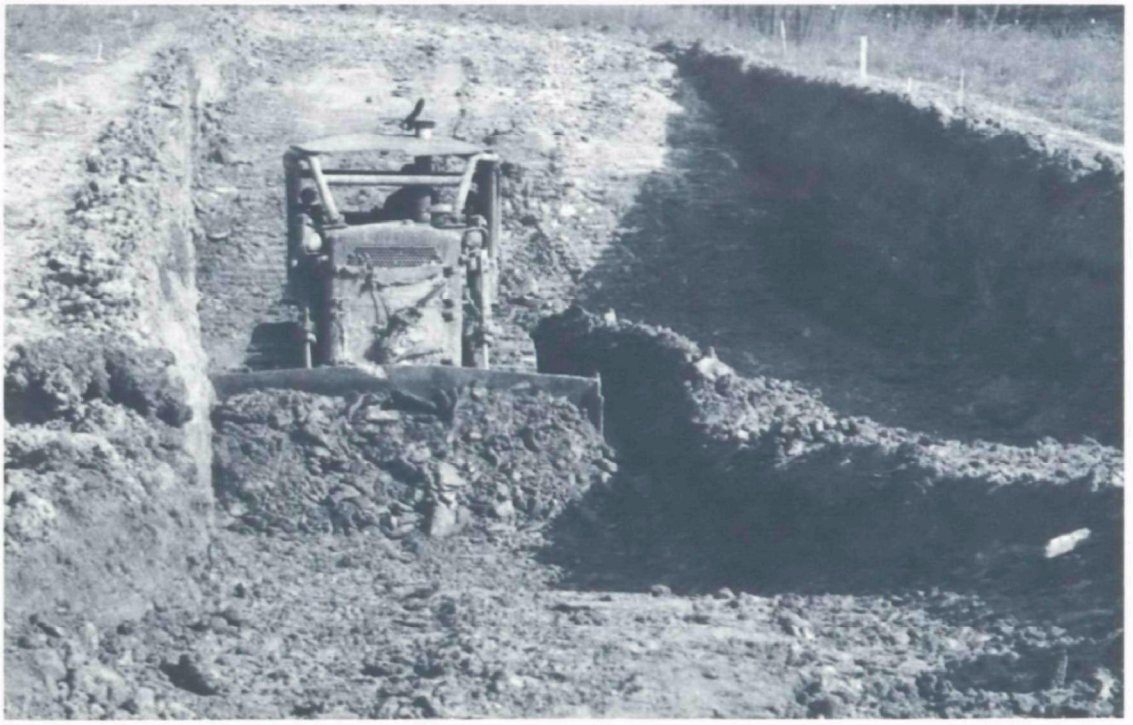


FIGURE 45. MUNICIPAL SOLID WASTE BEING SPREAD IN SANITARY LANDFILL.

FIGURE 46. PREPARATION OF VIRAL AND BACTERIAL INNOCULUM.

FIGURE 47. SPREADING AND COMPACTING SOIL OVER MUNICIPAL WASTE IN SANITARY LANDFILL.

TABLE 8. COMPOSITION OF LEACHATE FROM UPPER COLLECTION PIPE AT BOONE COUNTY FIELD SITE LANDFILL

Parameter	Range	Typical
pH	5.2-6.4	5.7
Specific conductance (μmho/cm)	6000-12200	10200
Total solids (mg/l)	10000-23600	20700
Suspended solid (mg/l)	30-1840	49
Dissolved solids (mg/l)	10000-23400	20700
Volatile solids (mg/l)	5000-13000	11100
Fixed solids (mg/l)	4500-11300	9580
Chloride (mg/l)	600-1560	1270
Sulfate (mg/l)	400-1200	1040
Calcium (mg/l)	900-2320	1882
Magnesium (mg/l)	160-374	291
Iron (mg/l)	210-548	518
Manganese (mg/l)	75-125	93
Zinc (mg/l)	10-30	26.5
Potassium (mg/l)	295-737	658
Sodium (mg/l)	450-1040	858
Hardness as $CaCO_3$ (mg/l)	3500-7500	5680
Alkalinity as $CaCO_3$ (mg/l)	800-8040	7460
Acidity as $CaCO_3$ (mg/l)	1500-3700	3100
Chemical oxygen demand (mg/l)	16000-37500	32000
Biochemical oxygen demand (mg/l)	7500-18500	15700
Total inorganic phosphate (mg/l)	25-65.7	29.3
Orthophosphate (mg/l)	23-33	26.0
Nitrite-N (mg/l)	0.02-0.05	0.04
Nitrite-N + Nitrate-N (mg/l)	0.2-0.8	0.05

population of 450,000. Over a 781-day period, 295.6 cubic meters (78,089 gallons) of leachate have been collected. Although the volume is small, leachate contains high concentrations of organic and inorganic matter, most of which are present in the dissolved form. The impact of this highly contaminated small flow must be carefully evaluated for each sanitary landfill site.

Collection, treatment, and disposal of leachate may be required in some particularly sensitive locations such as a site with sand overlying a good-quality aquifer that is being used for drinking water. Spray irrigation of the collected leachate is being evaluated at the BCFS on a small test-bin basis. Leachate collected from Test Series No. 1 is applied at three different loading rates to (a) a clay soil indigenous to the site, (b) a sandy clay, and (c) two control bins, where hydraulic loading and composition of the percolate are being evaluated. Results, to date, indicate significant organic removals after 2 years of intermittent leachate (greater than 80 percent) application. Significant removals of inorganic contaminants such as iron were noted in the first year; these were not monitored in the second. Nitrates, however, increased by more than 300 percent the first year because of oxidation of the high ammonia and organic nitrogen concentrations. Additional leachate treatment work is being conducted by contract and grant.

Test Series 2 was installed in August 1972. The major purpose of this cell was to evaluate the in-

FIGURE 48. PLACEMENT OF SMALL-SCALE LYSIMETER AS PART OF TEST SERIES 2. THESE CONTAIN SAND AND GRAVEL UNDERDRAINS, COMPACTED MUNICIPAL SOLID WASTE, AND COMPACTED SOIL FOR COVER MATERIAL.

herent variability of small-scale, 1.8-meter (6-foot) diameter lysimeters (Figure 48) and also to gather some indication of scaling factors between large-scale lysimeters (more than 90.7 metric tons, 100 tons) and the small-scale ones (1.8 metric tons, 2 tons). Results so far indicate that temperatures within the two, different-sized landfill cells are significantly different. Peak temperatures observed during the initial short-term aerobic biodegradation were identical, but the small-scale lysimeters approached ambient soil temperature at a faster rate than did the large-scale cell. No significant temperature difference between the three small-scale cells was observed. The secondary purpose of Test Series 2 was to obtain leachate volume and composition for landfilled solid waste receiving a net infiltration rate of 500 mm (20 inches) per year, as compared with the estimated 150 mm (6 inches) per year that Test Series 1 receives in the Greater Cincinnati area. Data obtained to date are insufficient to draw any trends or conclusions.

A third series of 17 cells, designed around the 1.8-meter (6-foot) diameter scale, is planned. With these cells, the influence of different rainfall patterns will be evaluated. Other tests will be made to determine what effect adding raw and digested domestic wastewater has on leachate and gas generation, as well as the effect of adding surplus nitrogen and phosphorus, adding lime to control pH, and adding water at the same time municipal solid waste is placed in the cell. Several of the lysimeters will be used to evaluate the leachate from hazardous waste that has been disposed of by sanitary landfilling with municipal solid waste.

This leachate research performed by various members of the Solid and Hazardous Waste Research Laboratory is planned to provide criteria on which to rationally design sanitary landfills. When this information is combined with that from projects being performed by grantees and contractors, a planned approach to a full evaluation of leachate and the sanitary landfill method can be made.

TOXICOLOGY OF ATMOSPHERIC POLLUTANTS ASSOCIATED WITH THE USE OF AUTOMOBILE CATALYTIC CONVERTERS*

Based on 1970 Clean Air Act legislation, the level of gaseous emissions from mobile sources, namely, carbon monoxide, total hydrocarbons, and nitrogen oxides, must be reduced by 90+ percent by 1976. The automotive industry plans to achieve compliance with the legal requirements by installing catalytic converter systems to control carbon monoxide and total hydrocarbon emissions (nitrogen oxide control to be implemented at a later date) from the internal combustion engines. In the case of cars to be sold in California, catalytic converters will be used at an earlier date in order to comply with interim standards set by this state. Based on these guidelines, General Motors plans to install the catalysts on most of their 1975 models for the U.S. market as well as on cars designated to the California market. Ford and Chrysler also plan to install the catalytic systems on cars sold in California. As a result, it is estimated that between 6 and 10 million new automobiles will be built and marketed with catalytic converters in 1975.

These future plans of the auto manufacturers make it mandatory to evaluate, as rapidly as possible, emissions from vehicles equipped with the catalyst from the standpoint of chemical assessment for possible new pollutants or for changes in the levels of existing pollutants and their potential harmful effects on public health. During initial chemical assessment of the emissions, it was determined that the oxidizing and reducing types of catalysts have the capability of controlling the three major gaseous emissions; however, during this process, other potentially hazardous pollutants were measured. There was an increase in sulfuric acid and sulfate emissions in the exhaust because of the catalyst reaction with the organic sulfur in gasoline. In addition, new atmospheric pollutants, specifically platinum and palladium compounds, may be introduced into the environment with the use of the noble metal catalyst.

*J. F. Stara, M. Moore, and R. Hinners, Environmental Toxicology Research Laboratory.

Basically, the automotive catalytic converter is a device containing catalytic material capable of decreasing the concentration of emitted gases by increasing the rate of chemical reaction during passage through the device. The automotive and ancillary industries have developed and tested literally hundreds of catalytic converter prototypes. Currently, there are three basic catalytic systems under consideration:

1. single-bed oxidation catalysts that remove hydrocarbons and carbon monoxide,
2. dual-bed device having one oxidation catalyst bed to remove hydrocarbons and carbon monoxide and a separate reduction catalyst bed to remove nitrogen oxides, and
3. tricomponent single-bed catalytic device that removes hydrocarbons, carbon monoxide, and nitrogen oxides, simultaneously.

Testing the different types of devices has met with varying degrees of success. By far, the greatest effort has gone into developing catalysts that oxidize hydrocarbons and carbon monoxide into carbon dioxide and water. Secondary air is added to the engine exhausts to supply the hydrocarbons/carbon monoxide oxidation catalysts the excess oxygen (air) they need.

Catalytic converters are further classified based on the metal(s) used for catalytic action:

1. Base metal catalyst uses base metals from transitional group (e.g., vanadium, chromium, manganese, iron, cobalt, nickel, copper, and zinc). The structural support consists of alumina (Al_2O_3), and/or silica (SiO_2), or both.
2. Noble metal catalyst uses precious metals, platinum and palladium (0.1 to 0.6% by weight). The structural support here consists of alumina or silica.
3. Bulk metal catalyst uses homogeneous metals in different shapes such as pellets, wires, and honeycomb structures (e.g., copper, stainless steel, and copper-coated stainless steel).

The noble metal catalysts seem to be the most efficient and, at present, are the systems of choice. Some of the specific structural and chemical formulations are considered trade secrets.

The performance and life of the catalyst depend on engine operating conditions and other emission control components. In turn, the performance and characteristics of the catalytic converter affect the complete system. Some of the major causes of catalyst degradation are: (1) lead coating, (2) thermal effects, (3) ignition failure, (4) vigorous vibration. In addition to lead — phosphorus, chlorine, bromine, and sulfur in the fuel also have detrimental effects.

In July 1973, the Environmental Toxicology Research Laboratory was assigned the mission of evaluating the potential toxic effects of the pollutants related to the catalyst emission. With the cooperation of the General Motors and Ford companies, we obtained prototypes of 1975 GM and Ford engines, including the noble-metal catalytic converters. (Figure 49 shows the GM prototype engine system, which is currently being operated.)

A major concern in the use of catalysts is the presence of increased concentrations of certain types of sulfur compounds in the exhaust emissions. Aerometric measurements of exhaust emissions that have passed through the catalyst have shown an increase in particulate matter by 2.5 to 3.0 times, as well as a major increase in acid particulates indicating the presence of sulfuric acid droplets in the catalyst emissions and formation of sulfates. Biological effect studies with these compounds have been initiated.

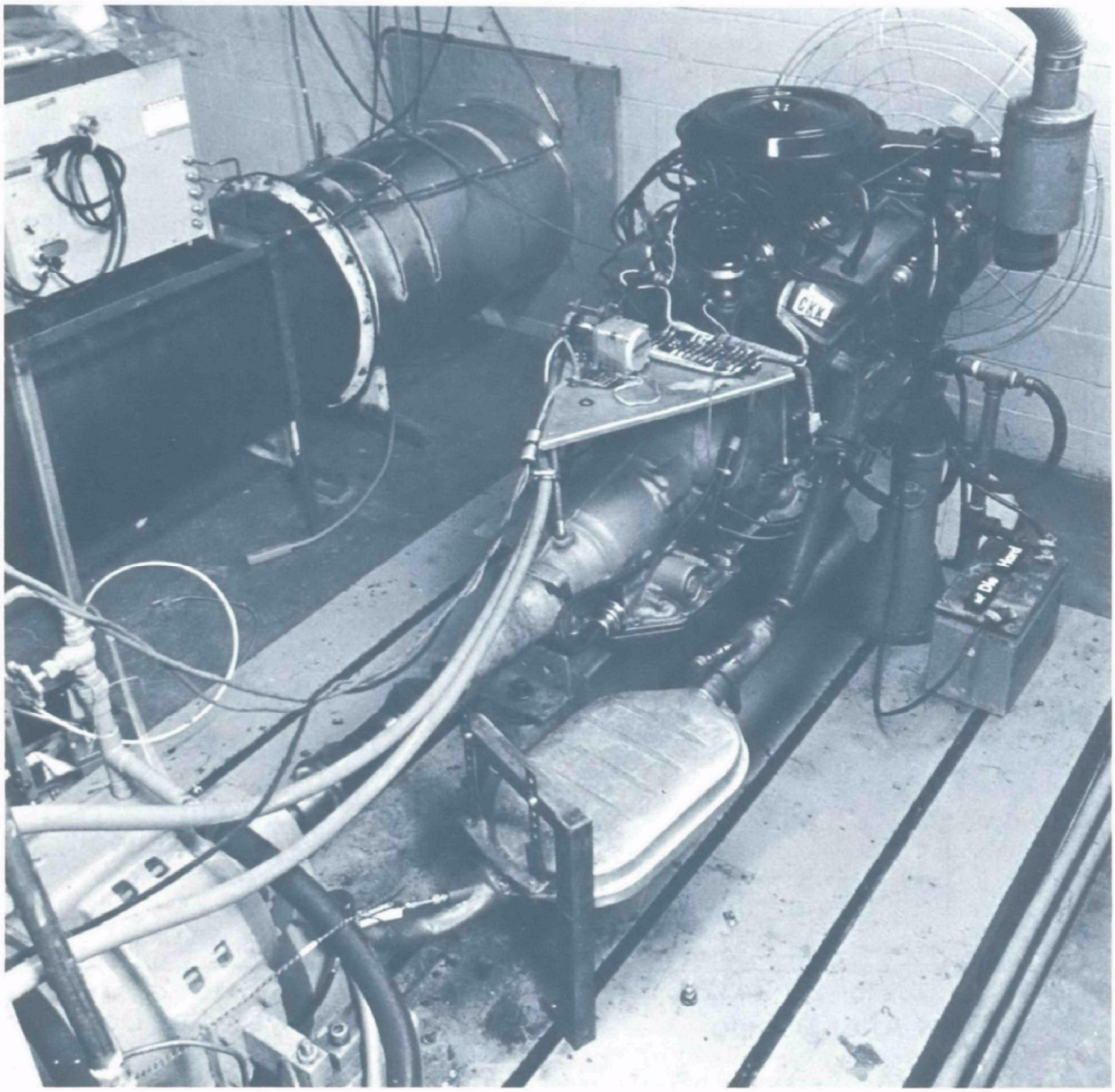


FIGURE 49. GENERAL MOTORS PROTOTYPE ENGINE UNIT WITH CATALYTIC CONVERTER.

With the almost exclusive use of the noble metal catalyst as the system of choice to control carbon monoxide and hydrocarbon emissions, the possibility exists that some amounts of platinum and palladium will be emitted into the atmosphere or enter into other parts of the biosphere following degradation during driving or disposal of worn-out converters. Because of the paucity of data on toxic effects of these elements, particularly after their deposition into the respiratory system, current studies at ETRL involve exposing animals to platinum and palladium by different routes of administration and determining the biological fate of the two metals. Data indicate that these metals are not readily absorbed from the gastrointestinal tract and that following oral administration, the whole body retention times for these metals were rather short. A much greater percent of the dose was retained in the body after intratracheal administration of the compounds (Figure 50). In both instances and for both metals, the pattern of distribution was similar. Among the organs with greatest concentrations were the kidneys, liver, lung, spleen, and bone.

Acute toxicity studies demonstrated that the lethal dose (LD_{50}) of palladium chloride ($PdC1_2$) was 5 mg/kg after intravenous dose, 70 mg/kg after intraperitoneal dose, and more than 200 mg/kg following oral administration. These results support the kinetic data. Biochemical data have shown that compounds of platinum and palladium have an inhibitory effect on certain enzymes *in vitro*. Skin irritancy tests demonstrated various levels of effects

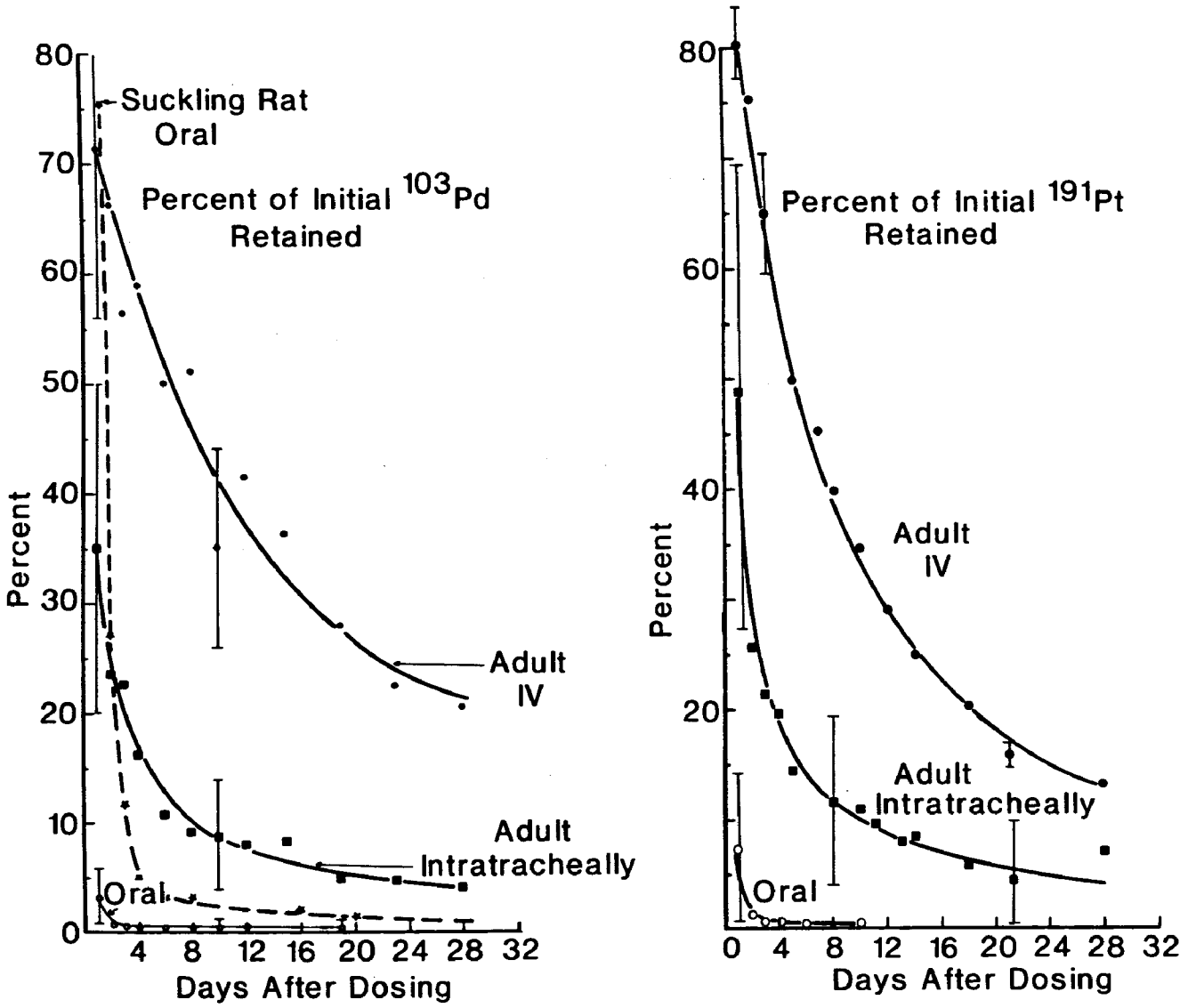


FIGURE 50. RETENTION OF PALLADIUM AND PLATINUM CHLORIDES IN RATS FOLLOWING DIFFERENT ROUTES OF ADMINISTRATION.

TABLE 9. DERMAL TOXICITY OF PALLADIUM AND PLATINUM COMPOUNDS IN RABBITS*

Treatment	Intact skin*	Abraded skin*
Deionized water (Negative Control)	0	0
Palladium monoxide (PdO)	0	0
Palladium dichloride ($PdCl_2$)	0 (0.1)*	0.6 (1.0)*
Ammonium hexachloro-palladate [$(NH_4)_2PdCl_6$]	2.8 (4.0)*	3.2 (4.0)*
Platinum dioxide (PtO_2)	0	0
Platinum dichloride ($PtCl_2$)	0.2	0.6
Platinum tetrachloride ($PtCl_4$)	1.8 (2.7)*	2.6 (3.8)*
2-Methylcyclopentadienyl manganese tricarbonyl (MMT)	0.1	0.8
Glacial acetic acid	2.6	3.2

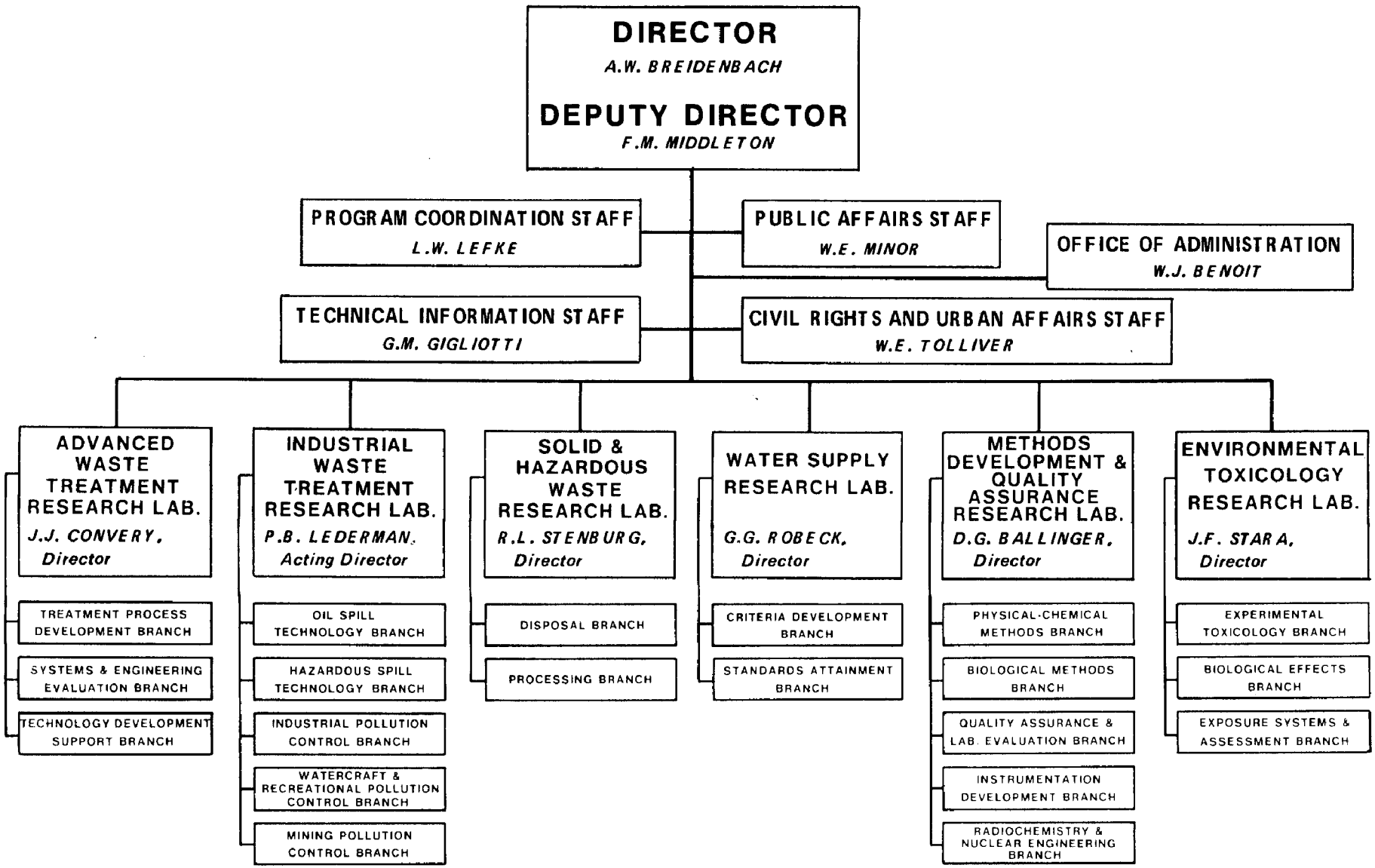
*0 — no irritation; 1 — erythema; 2 — erythema and edema confined to test area; 3 — erythema and edema extending beyond test area; 4 — Eschar (deep reaction involving dermis). Rating in the parentheses indicates the most severe test result where tested more than once; those without parantheses indicate a single test rating or average of 2 or 3 test ratings.

both on intact and abraded skin ranging from no effect for palladium monoxide and platinum dioxide to severe effects for ammonium hexachloropalladate and platinum tetrachloride compounds (Table 9).

Screening tests for potential neuro-toxic effects conducted on several metals of environmental significance indicated that palladium was potentially neuro-toxic whereas platinum produced a minimal effect under the conditions of these investigations.

In a different series of automotive emission studies with catalysts, no significant amounts of platinum or palladium were found in tissues of animals exposed continuously. The converter reduced markedly the carbon monoxide and hydrocarbon levels, and no significant pathologic lesions were found in animals exposed to the exhaust. However, in the control study in which the engine operating conditions were identical except the converter was removed, extensive lesions were found in adult animals exposed to the exhaust and a significant mortality rate was observed in exposed suckling animals. This effect was not due to the carbon monoxide levels. The greatest mortality rate in the suckling animals occurred in the chambers with the irradiated exhaust. All these studies are rather acute and in some respects, preliminary, since the program began only 2 months ago. A detailed set of data using longer periods of exposure will be available in April 1974.

This 1973 Annual Report was prepared by the Technical Information Staff of NERC-Cincinnati: G. M. Gigliotti planned, gathered, and assembled the material; Mrs. M. Curry edited the report; D. W. Dietrich prepared the drawings, artwork, and layout; Mrs. E. Cole proofed, typed, and generally assisted. The perspective, comments, and assistance of M. E. Folkers, Printing Specialist, are gratefully acknowledged.



Organization of NERC-Cincinnati, effective September 14, 1973.