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United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/9-80-014
June 1980

Research and Development

EPA

Report of Progress

MERL 79

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FOREWORD

The chief aim and primary purpose of our laboratory is to develop technology, systems, processes and improved management practices to prevent, control and treat pollutants that affect communities and municipalities. We develop and demonstrate cost-effective methods in the areas of sewage and wastewaters, solid and hazardous wastes, and public drinking water supplies.

We recognize our responsibility to help establish and maintain communications with our user community. We are also aware that every effort must be made to reduce the time it takes to move research findings from the laboratory to the user. This publication is one way for us to share with you our research results. It briefly outlines our progress during 1979. Should you have any comments about this publication, or suggestions for its improvement, please take the time to write to me.

Francis T. Mayo
Director
Municipal Environmental Research Laboratory

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OFFICE OF THE DIRECTOR

MANAGEMENT

The Municipal Environmental Research Laboratory is composed of the Office of the Director and three operating divisions. In 1980 it has a budget of almost $26,000,000 and a permanent staff of 160 scientists, engineers and support personnel. The Office of the Director (O.D.) has three major purposes, the most important of which is to provide direction and leadership to the operating divisions. Program planning and review, resources management, the timely execution of projects and programs, management reporting, and information management are some of the major functions performed within the O.D. In 1979, the office developed procedures for implementing a new output planning procedure, began work on a highly visible and intensive system of peer review, implemented a highly successful final report mailing list system, and mechanized their word processing function.

COORDINATION

The second major purpose of the Office of the Director is to establish effective communications between the Laboratory and its user community. The Director has devoted much of the office's effort to strengthening ties between the MERL and the EPA Program Offices and Regional Offices. Additionally, a mid-year reorganization moved the laboratory from the Office of Air, Land and Water Use to the Office of Environmental Engineering and Technology, and new channels of communication were quickly developed to expedite the exchange of information and ideas between and among the ORD Headquarters Office and our new sister Industrial Laboratories in Cincinnati and RTP. Another area of increased effort is with the research committees that provide an effective planning forum for ORD, the Program and Regional offices.

TABLE 1. MERL BUDGET FOR FY 1979 (In $1000's)

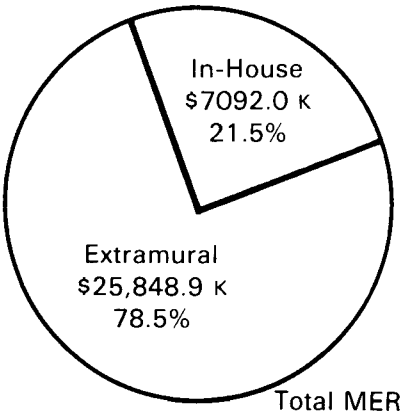
PE#	AREA OF WORK	PFTE POSNS.*	IN-HOUSE $	XM $	TOTAL
1BC821	Urban Systems, Toxics & Residuals Mgmt.	52	$2,170.9	$ 3,989.1	$ 6,160.0
1BC822	Wastewater Systems Control Technology	45	1,940.1	11,060.0	13,000.1
1CC824	Drinking Water Treatment	47	1,925.2	5,360.1	7,285.3
1DC818	Solid Wastes Control Technology	16	1,055.8	4,638.4	5,694.2
1NE827	Environmental Impact of Energy Systems	—	—	265.0	265.0
1AD712	Carbon Fiber Research	—	—	350.0	350.0
XM1627	Reimbursable Agreements	—	—	186.3	186.3
	Total MERL	160	$7,092.0	$25,848.9	$32,940.9

*PFTE stands for Permanent Full-Time Equivalent

ADMINISTRATION

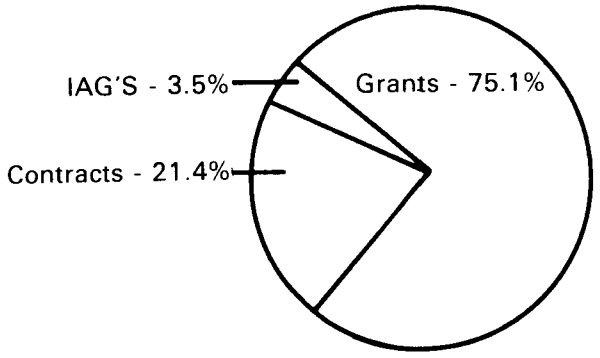
The third major purpose of the O.D. is to provide our line managers and supervisors with the resources they need to accomplish their mission. At the MERL, this translates into the nuts and bolts of moving the paper necessary to recruit personnel, purchase supplies and materials, maintain commitment records of expenditure, provide for adequate space, provide editorial and publications support for reports and technical information, processing research contracts, cooperative agreements and grants, and all of the other chores necessary to keep a laboratory on the move.

Where The MERL Dollars Were Spent in FY-79



Total MERL FY-79
Expenditures
$32,940 K

Extramural Costs



In-House Costs

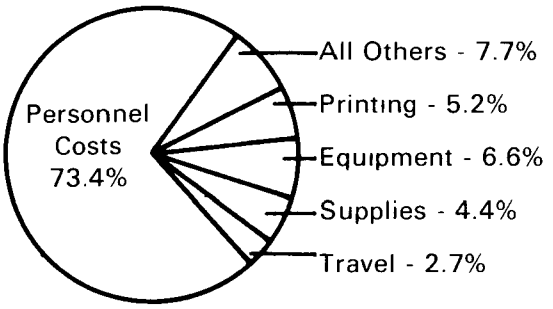
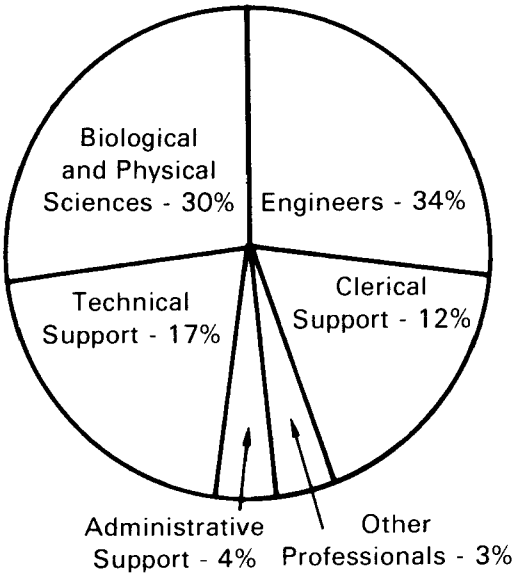


TABLE 2. MERL BUDGET FOR FY 1980 (In $1000's)

PE#	AREA OF WORK	PFTE POSNS.*	IN-HOUSE $	XM $	TOTAL
36B1C	Urban Systems, Toxics & Residuals Mgmt.	55.1	$2,438.8	$ 4,825.3	$ 7.264.1
35B1C	Wastewater Systems Control Technology	41.0	1,690.0	3,966.2	5,656.2
61C1C	Drinking Water Treatment & Groundwater Prot.	47.0	1,981.1	4,648.8	6,629.9
73D1C	Solid Wastes Control Technology	16.0	1,025.9	4,565.0	5,590.9
07A1D	Carbon Fiber Research	—	—	600.0	600.0
1MH1E	Acid-Rain Anticipatory R&D	—	—	100.0	100.0
	Total MERL	159.1	$7,135.8	$18,705.3	$25,841.1

*PFTE stands for Permanent Full-Time Equivalent

COMPOSITION OF MERL WORKFORCE BY DISCIPLINE



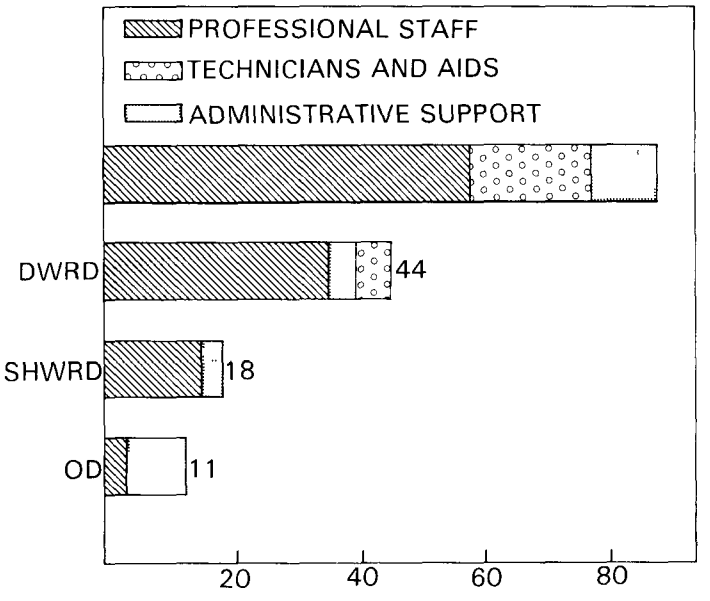
PROFESSIONAL POSITIONS

Chemical Engineer	8
Environmental Engineer	45
Mechanical Engineer	1
Microbiologist	10
Soil Scientist	3
Chemist	29
Environmental Scientist	2
Physical Scientist	5
Economist	1
Operations Research Analyst	3
Systems Analyst	1
	Totals 108

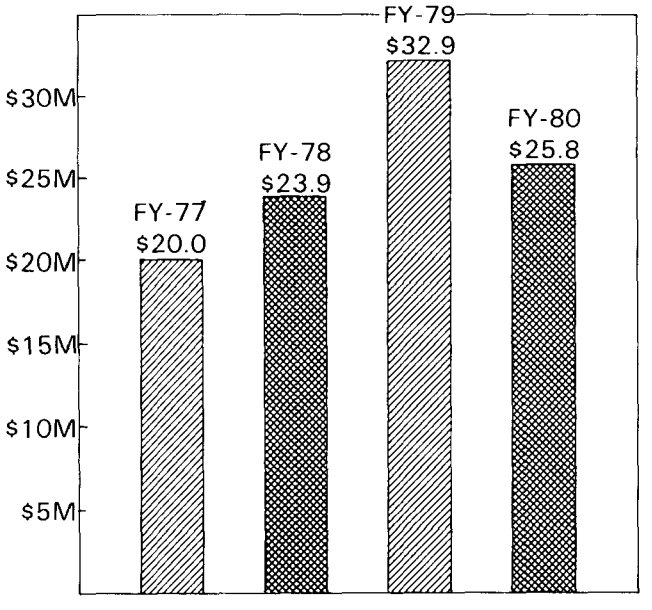
SUPPORT POSITIONS

Secretary	20
Biological Aid/Tech.	4
Engineering Aid/Tech.	7
Equipment Mechanic	1
Physical Sci. Aid/Tech.	15
Administrative Officer	1
Administrative Tech.	1
Program Analyst	1
Management Analyst	1
Editorial Assistant	1
Extramural Assistant	1
	Totals 53

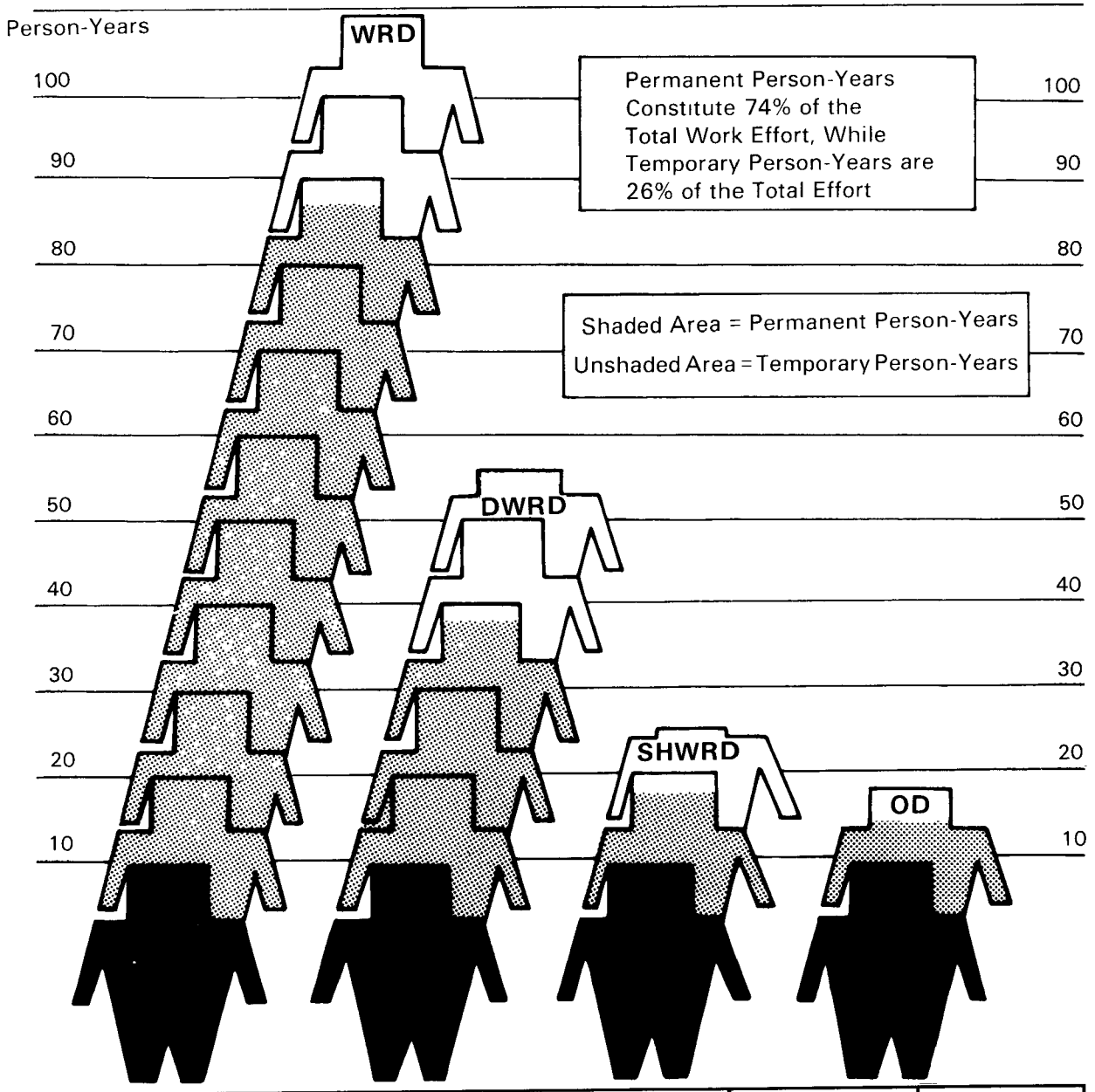
Composition and Size of MERL Workforce by Organization (December 1979)



MERL Resource Trends



PERSON YEARS OF EFFORT FOR MERL IN FY 79



	WRD	DWRD	SHWRD	OD	MERL
PERM P.Y.	86 2	42 4	17.2	11 0	156 8
TEMP. P.Y	24.7	16.1	7.9	4 7	53 4
TOTAL P.Y.	110.9	58.5	25.1	15.7	210.2

SOLID AND HAZARDOUS WASTE RESEARCH DIVISION

The Solid and Hazardous Waste Research Division (SHWRD) conducts research in three major functional areas: disposal technology, hazardous wastes, and resource recovery. In the past, solid waste research was concentrated on problems associated with municipal solid waste. With present efforts directed primarily toward the environmental effects of hazardous waste disposed onto or into the land, research has concentrated on disposal or treatment technologies that will minimize or prevent harmful effects.

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

The solid waste problem is concentrated in densely populated urban areas. 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 affect each consumer.

Even more threatening in terms of public health and environmental effects are the present disposal practices for hazardous wastes. Current estimates indicate that 30 to 35 million tons of hazardous wastes are disposed of to the ground with no controls, no records as to location, and quantity and composition. At the present time, proven techniques for large-scale disposal of most, if not all, hazardous wastes are not available and generators of these wastes have little incentive to expend resources for adequate managment.

Municipalities and other governmental agencies need new and improved systems for storage, collection, and transportation of solid waste; improved technology or methodology for waste reduction; and criteria for site selection, design, and operation of landfills.

WASTE DISPOSAL

Increasing amounts of waste residuals are being directed to the land for disposal by landfilling. The waste disposal program of SHWRD has been designed to document and evaluate the potentially adverse environmental and public health effects that could result if precautions are not taken for handling the environmental degradation produced in the course of landfilling. The SHWRD research – encompassing state-of-the-art documents, laboratory analysis, bench and pilot studies, and full-scale field verification studies – will result in research reports, criteria, guidance documents for user communities, and in a criteria data base for the development of standards mandated by the recently enacted "Resource Conservation and Recovery Act of 1976." The current research activities classified and discussed here are:

1. Waste Characterization/Decomposition
2. Pollutant Transport
3. Pollutant Control
4. Co-disposal
5. Pollutant Treatment
6. Environmental Assessment
7. Remedial Action for Inoperative Sites
8. Landfill Alternatives
9. Economic Analysis

Waste Characterization/Decomposition

Studies in this area involve collecting composition data on municipal and hazardous wastes from individual waste residuals and landfill disposal sites. The study objectives are to (1) quantify the gas and leachate production from current best-practice sanitary landfilling and (2) modify the landfill method to reduce the environmental impact of gas and leachate production in a positive and predictable manner. These objectives are to be achieved by construction and long-term

monitoring of typical and simulated landfill cells and investigation, development, and optimization of those factors that control gas and leachate production. Results are expected only after long-term monitoring, due to the extremely slow reaction rates.

Standard Techniques

Procedures for analyzing contaminants in leachate samples are being developed, both specific to the wastes being studied and for general use. In studying the potential environmental impact of contaminants, a standard test is being planned to assess contaminants leached from a waste by water and other solvents, both initially and over time.

Waste Leachability

The leachability of municipal refuse has been the subject of several studies. One involves the determination of long-term gas and leachate generation characteristics by leaching 395 Mkg (thousands of kilograms) of municipal refuse and comparing the results to those from monitoring 106 Mkg and 2.7 Mkg experimental landfills at the Boone County Field Site (BCFS) of USEPA. The volume of leachate collected from the 395 Mkg landfill has been 15 percent greater than predicted using the USEPA water balance method. Composition of the leachate seems to have reached a stable rate of contaminant release (Figure 1 – total dissolved solids or chemical oxygen demand vs. time). Gas composition, at 50 percent CH_4 and 50 percent CO_2 indicates the refuse is well into the methane fermentation stage of decomposition. Settlement over the last eight years has been less than 5 percent; the refuse was initially placed at a field density of 600 kg/m³ (exclusive of cover). Analysis of the data indicates the leachate composition is described better when compared to the volume of leachate than time (Figure 2).

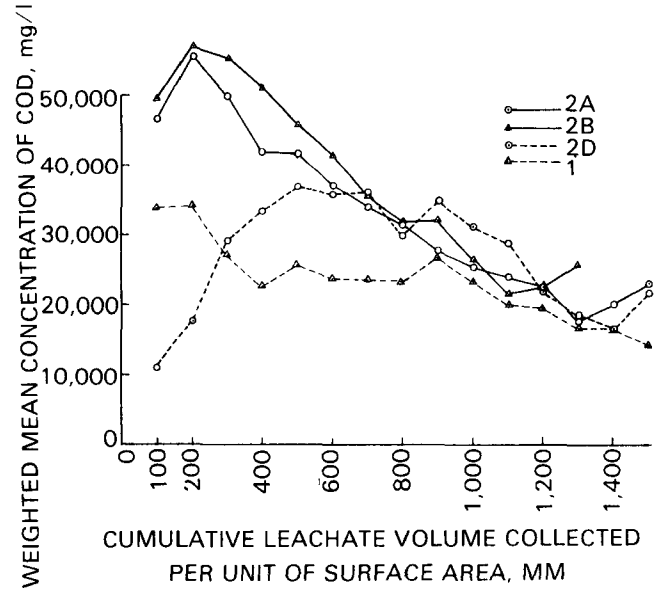


Figure 1. Total dissolved solids or chemical oxygen demand vs. time.

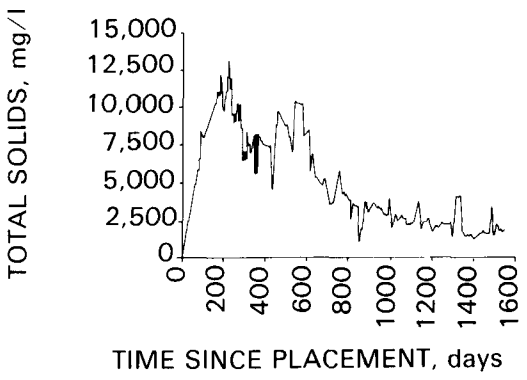


Figure 2. Release of total solids from Boone County Field Site Test Cell 1.

The smaller experimental landfills at BCFS responded in a similar manner to the 395 Mkg landfill, although they have not reached a stable discharge of contaminants. The release of chemical oxygen demand (COD) was described by the empirical equation shown in Figure 3. Although this is a preliminary it offers the possibility of putting landfill design and evaluation on a rational, predictive basis. Estimates of leachate composition over the life of the landfill can help in scheduling when and what type of leachate treatment facility should be constructed, how long it should be operated, and the magnitude of long-term maintenance and environmental control operating costs.

Comparison of leaching results from several 2.7 Mkg experimental landfills at the Center Hill Facility indicates a surprising insensitivity to additives of special wastes and rates of leaching. The results shown in Figure 4 indicate very similar responses over the range of water addition studied (400 mm/yr to 800 mm/yr) and special wastes added (3 to 35 percent of dry refuse solids).

A new project to obtain gas volume production information was initiated at the Center Hill Facility in cooperation with the Department of Energy's Urban Wastes Program. A number of 0.4 Mkg experimental landfills will be constructed and operated to evaluate the effect of nutrient additions, buffer additions, and leachate recyc-

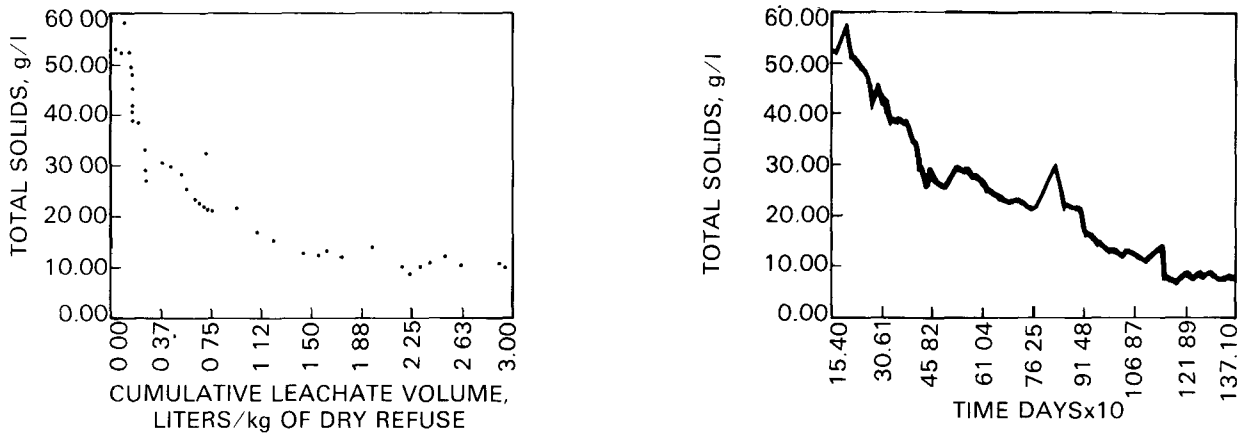


Figure 3. Total solids concentration from experimental refuse landfill leached at 813 mm/yr.

ling, on enhanced methane production. In addition, several landfills will be used to indicate how methane may be enhanced at old sites where the refuse is partially decomposed.

Another ongoing leachability study deals with inorganic industrial waste in which there is no appreciable biological activity. Consequently, the chief mode of decomposition and pollutant release is solubilization and other strictly chemical/physical changes rather than the biological decomposition that takes place as the waste is leached with water. Accordingly, the testing program is designed to evaluate leaching and pollutant release through time under a variety of leaching conditions encountered in one or more disposal situations.

Results to date are consistent with findings from other projects that leachability of inorganic wastes is a function not only of the constituent of interest, but also the surface area per unit weight of waste and the stability of the compounds formed during waste treatment. The variability in degree of buffering against solvent-induced changes indicates that the time dependent leachability also be considered.

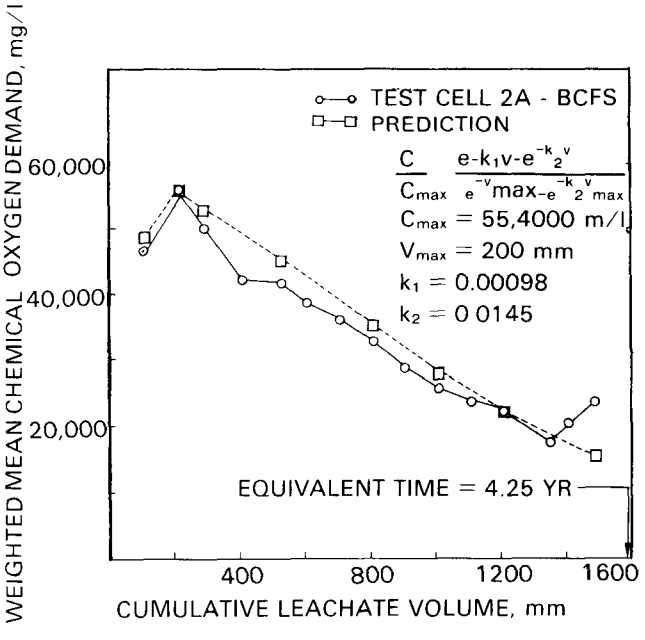


Figure 4. Empirical curve fit by wigh for Boone County Field Site Test Cell 2A.

Waste Decomposition

The several research projects underway are intended to document the rates and gaseous and liquid releases of decomposing refuse and to control these processes so they may occur in a predictable and desireable manner. One technique to accelerate the rate of decompsotion which has been under development by the SHWRD is leachate recycle. Pilot scale evaluation of a batch operated recycle system was recently completed and indicated that stabilization of readily available organic materials in shredded refuse and transferred to recycled leachate was essentially completed within six months. Daily gas production during the period of rapid stabilization was as high as 50.5 ml/kg of dry refuse which then dropped to 0.79 ml/kg of dry refuse after stabilization. The total quantity of gas collected was approaching 3.0 l/kg dry refuse, with approximately 2.76 l/kg dry refuse produced in a six month period (Figure 5). Additional work is intended to resolve the long-term environmental effect if the stabilized waste is allowed to leach in a traditional manner.

Processing of refuse has also been viewed as a means of controlling waste decomposition rates.

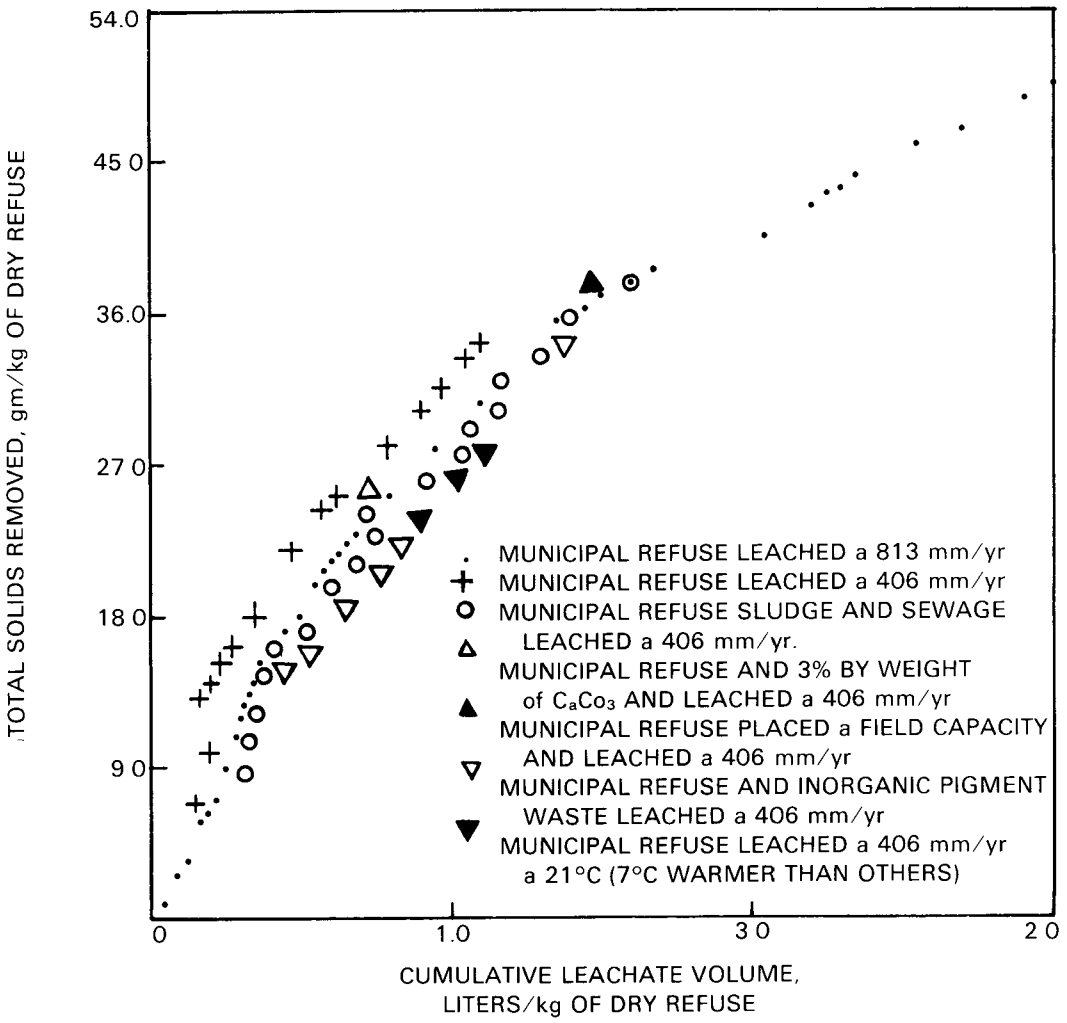


Figure 5. Total solids removed from different experimental landfills.

The effect of baling on refuse leachability and gas production was the object of a contractual study located in Franklin, Ohio. The treatments were placed in pilot scale (10 Mkg) experimental landfills and were subjected to seasonal rainfall application of 600 mm/year. Interim results indicate that baled refuse still is microbiologically active and yields gas composition typical of unprocessed refuse: 50 percent CH_4 and 50 percent CO_2. Thus gas migration, which is driven by diffusional rather than total pressure differentials, presents as much of a hazard at balefill as at a traditional landfill. Comparison of leachate composition and production, however, indicates that baled refuse may release less of a contaminant to the environment than unprocessed refuse (Figure 6) over a four year period. It appears that the bulk of the refuse is not subjected to the surface leaching of each bale of refuse in an above the ground water table balefill, however, when the bales are allowed to saturate, then there is very little difference in leaching characteristics of the baled and unprocessed refuse (Figure 7). It is uncertain how long the internal volume of each bale will remain isolated from the percolating water of an above the ground water table balefill.

Pollutant Transport

Recent pollutant transport studies have focused on organic compounds that present disposal/toxicity problems. Work has been completed on polychlorinated biphenyls (PCB), is under way on polybrominated biphenyls (PBB), hexachlorobenzene (HCB), and hexachlorocyclopentadiene (HCCPD).

A recent publication entitled "Attenuation of Water-Soluble Polychlorinated Biphenyls by Earth Materials" (EPA-600/2-80-027) reported the results of a laboratory study of the aqueous sol-

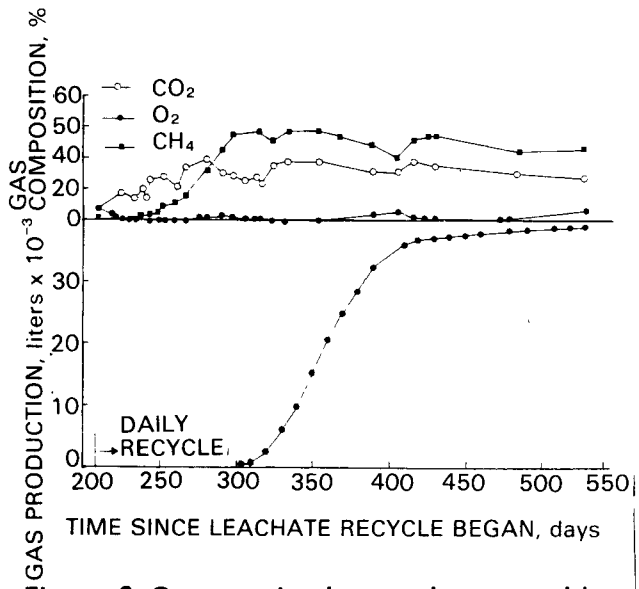


Figure 6. Gas production and composition from the sealed pilot-scale landfill cell operated in a leachate recycle mode.

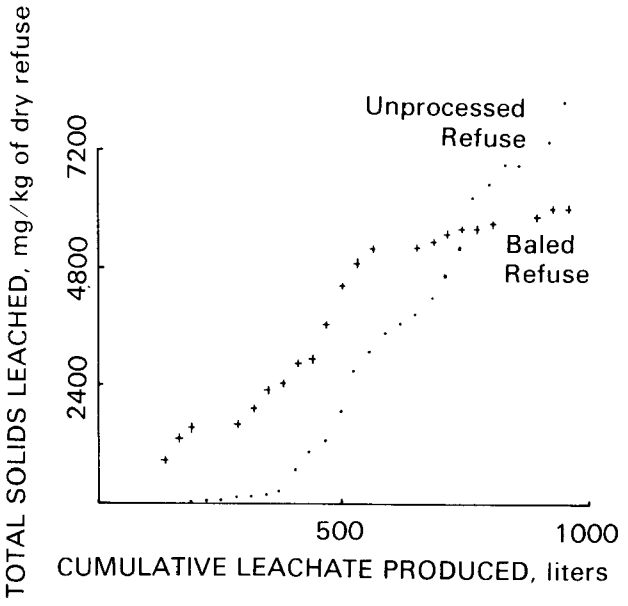


Figure 7. Flux of total solids leached from experimental landfills.

ubility, adsorption, mobility, microbial degradation, and volatility of polychlorinated biphenyls. Generally, the water-soluble fractions of the PCB fluids were richer in the lower chlorinated isomers than in the original mixture of isomers in the fluid. The solubilities of Aroclor 1016, 1221, 1242, and 1254 were 906 ppb, 3516 ppb, 703 ppb, and ~70 ppb, respectively.

A simple linear relation described the adsorption of water-soluble PCBs by five earth materials and their low-temperature ashes. The absorption was strongly correlated to the total organic carbon (TOC) content and surface area of the earth materials. TOC was the dominant of these two earth material properties by a ratio greater than three to one.

PCBs in silica-gel, silica sand, seven soils, and a coal char were immobile when leached with water or landfill leachate, but were intensely mobile when leached with organic solvents using soil thin-layer chromatography. The mobilities were strongly relaued to the solubilities of the PCBs in the leaching solvent; the mobilities of PCBs in soils leached with carbon tetrachloride were highly related to the TOC content.

The rates of degradation by mixed cultures of soil microorganisms ranged from the monochloro isomers,
which degraded 100 percent within 6 hours, to the tetrachloro isomers, which averaged 42 percent degradation after 15 days. The predominant organisms found in the mixed cultures were *Alkaligenes odorans, Alkaligenes denitrificans,* and an unidentified bacterium. The volatilization of PCBs from pure water agreed with theoretical predictions that the half-life of Aroclor 1242 stripped from water would be about 6 hours. Adsorption of PCBs by soil and humic acid reduced the total amounts of PCBs volatilized. Higher chlorinated PCB isomers were found to be less soluble in water preferentially adsorbed by soil materials, less mobile in soil, less degradable by microorganisms, and less volatile from water than lower chlorinated isomers. Thus, higher chlorinated isomers would be less mobile and more persistent in the environment than lower chlorinated isomers.

A laboratory study of the aqueous solubility, adsorption, mobility, and microbial degradation of polybrominated biphenyls (PBBs) and hexachlorobenzene (HCB) is underway by the same group. PBBs are more than 200 times and HCB more than 2.5 times more soluble in landfill leachate than in distilled water. The solubilities of PBBs and HCB were higher in creek water and landfill leachates than in purified waters; this was directly correlated with the level of dissolved organics in the waters.

HCB show a greater tendency for adsorption by soils and Ambersorb XE-348 carbonaceous adsorbent than did PBBs. There was a high direct correlation between the total organic carbon (TOC) content of soils and the amount adsorbed. No measureable adsorption of either PBBs or HCB by soils occurred from organic solvents; however, they were strongly adsorbed from the

solvents by the Ambersorb.

PBBs and HCB remain immobile in soils when leached with water or landfill leachate but are high mobile when leached with organic solvents. Mobility is directly proportional to the solubility of the compounds in the leaching solvents and to the soil organic matter content.

PBBs and HCB are resistant to microbial degradation. Both compounds presisted in soils in experiments lasting 6 months and in solution culture experiments lasting for 4 weeks with no measurable degradation.

Pollutant Control

The pollutant control studies determine the ability of in-situ soils, ranging from sands to clays, and natural soil processes to limit the transport of leachate contaminants as the leachate migrates from landfill sites through the soil. The studies also determine how various synthetic and admixed materials can be utilized as liners to prevent leachate migration. The overall objective is to enable minimization of sub-surface pollution, particularly of groundwater.

Liners/Membranes/Admixtures

The test program is evaluating, in a landfill environment, the chemical resistance and durability of liner materials over 12-, 24-, and 52-month exposure periods to leachates derived from hazardous wastes, SO_x wastes, and municipal solid wastes. The liner materials being investigated for municipal solid wastes include six admixed materials.

2 asphalt concretes (varying in permeability),
1 soil asphalt,
2 asphalt membrances (one based on an emulsified asphalt and the other on catalytically-blown asphalt),
1 soil cement;

and six flexible membranes:

butyl rubber,
ethylene propylene rubber (EPDM),
chlorinated polyetheylene (CPE),
chlorosulfonated polyethylene (HYPALON),
polyethylene (PE), and
polyvinyl chloride (PVC).

Results of the first 12 month's exposure to municipal solid wastes produced only minor changes on the physical properties of the liner materials exposed to landfill leachate. Subexperiments within this project have started producing results. In an experiment designed to investigate accelerated testing, samples that were exposed on both sides in immersion tanks produced one year exposure results in approximately eight months. Results of the testing indicated minor changes in the physical properties. Results of the ASTM E-96, Method BW water vapor permeability has been reported (X). These results rank polyvinyl chloride as having the highest permeability to water vapor and butyl rubber and elasticized polyolefin the lowest. There was some indication that permeability increased with test time, probably due to the membranes swelling caused by the water. An osmotic bag test was developed which shows promise of assessing membranes under a variety of exposure conditions. The advantage of using this test is its small size, ease of handling and potential for producing results on a timely basis.

The dismantling of the exposure cells containing hazardous wastes and various liner material candidates was delayed so that a longer exposure data base could be developed. However, monitoring of the cells continued in order to detect any failures that may have occurred. No failures or leakages occurred during this time period. Sub-experiments of the project were performed to increase the potential cause and effect of liner failures. The effect of immersion is shown in Table 3, which presents the increase in weight during the exposure period. As with the results from the first year's data the effects vary considerably with liner type and waste. In addition, significant variation in effects occurs between liners made of the same polymer. This is particularly true among, the three PVC liners.

Hanging the samples in the wastes allows the various phases of the waste to contact the specimens. The effects of this exposure on the top and bottom sections of the samples are shown in Table 4.

Water Adsorption of Polymeric Liners

Results of the water adsorption tests run on the same polymeric membrane liners at room temperature and at 70°C are presented in Table 5. The immersion time for this experiment was 308 days. These results show a great difference in ultimate swelling of these lining materials by water. Of particular interest is the low water swell of the elasticized polyolefin membrane of the PVC membranes at room temperature.

Membrane Bags Containing Water

This test of the liner membranes which ran up to 337 days, showed them to be very impermeable. A slight increase occurred in the conductivity of the deionized water outside the bags, indicating that some ions do pass through the mem-

TABLE 3. SWELLING OF MEMBRANE LINING MATERIALS ON IMMERSION IN WASTES

	Liner No.	Vulcanized	Acidic Wastes HP	Acidic Wastes HNO_3	Alkaline Wastes Slop-water	Alkaline Wastes Spent caustic	Lead Waste	Oily Wastes Aromatic	Oily Wastes Pond 104	Oily Wastes Weed	Pesticide/ Herbicide
Immersion time, days	—	—	**250**	**193**	**193**	**238**	**236**	**257**	**248**	**252**	**242**
Butyl rubber	44	Yes	2.7	1.4	2.0	0.4	20.1	32.3	96.5	70.8	0.8
Chlorinated polyethylene	77	No	9.4	9.3	1.5	0.6	70.9	59.5	31.6	116.7	9.6
Chlorosulfonated polyethylene	6-R	No	6.8	10.3	3.8	3.3	83.0	51.1	75.1	202.3	13.1
	55	No	5.4	7.5	3.8	2.2	69.6	53.2	58.4	210.5	12.3
Elasticized polyolefin	36	No	0.3	2.7	17.3	0.5	18.2	21.3	33.5	44.2	0.0
Ethylene propylene rubber	83	Yes	3.1	2.6	2.7	1.3	23.0	15.8	35.4	73.4	3.7
	91	?	16.1	18.3	3.1	0.2	29.3	35.3	80.1	79.4	8.1
Neoprene	90	Yes	9.6	10.9	0.4	0.8	45.6	60.7	25.3	94.8	3.5
Polyester Elastonar	75	No	0.6	4.2	35.1	0.6	7.6	17.1	7.9	16.3	2.4
Polyvinyl Chloride	11	No	10.2	16.8	13.5	0.1	4.4	10.7	-7.7	10.0	4.0
	59	No	2.3	-2.8	-6.4	-3.0	8.8	11.3	-1.5	33.4	0.5
	88	No	7.5	19.8	-13.5	0.1	2.2	7.2	-10.3	18.1	2.9

TABLE 4. RETENTION OF TENSILE STRENGTH OF MEMBRANE LINER MATERIALS ON IMMERSION IN "WEED OIL"[a] (Percent of original value)

Polymer	Liner No.	Original Value, psi	Retention Top of specimen	Retention Bottom of specimen
Butyl rubber	44	1520	16	55
Chlorinated polyethylene	77	2235	(b)	4
Chlorosulfonated polyethylene	6-R	1730	7	43
	55	1715	(b)	45
Elasticized polyolefin	36	2595	26	32
Ethylene propylene rubber	83	970	(b)	39
	91	1865	30	40
Neoprene	90	1940	18	32
Polyester elastomer	75	6770	90	81
Polyvinyl chloride	11	2955	72	84
	59	2555	50	42
	88	3155	63	68

a Immersion time, 252 days.
(b) Too soft to test
R = Fabric reinforced

branes. On the other hand, the bags have generally increased in weight, showing that the water has moved into the bags as a result of osmotic pressure. Table 6 illustrates this effect for the bags containing strong acid.

Chemical Stabilization

Chemical stabilization is achieved by incorporating the solid and liquid phases of the waste in a relatively inert matrix that protects the components of the waste from dissolution by rainfall

TABLE 5. SWELLING OF POLYMERIC MEMBRANE LINERS IN WATER[a]
(Percent weight increase)

Polymer	Liner No.	Room Temp.	70°C
Butyl rubber	57-R	4.5	53.9
Chlorinated polvethylene	77	10.2	140.0
Chlorosulfonated polyethylene	6-R	10.9	245.6
Elasticized polyolefin	36	0	0.6
Ethylene propylene rubber	8	1.6	10.8
	26	1.5	11.2
Neoprene	43	37.8	240.0
	82	18.5	191.4
Polyester elastomer	75	10.2	140.0
Polyvinyl chloride	10	0.7	39.2
	59	2.4	24.0

a Immersion time 308 days.
R = Fabric reinforced.

TABLE 6. SEALED BAGS CONTAINING STRONG ACID WASTE IMMERSED IN DEIONIZED WATER[a]

Polymer	Liner No.	Deionized water		Increase in weight of bag containing waste g.
		pH	Conductivity μ mho	
Chlorinated polyethylene	86	4.0	132	6.1
Chlorosulfonated polyethylene	85	7.7	306	8.9
Elasticized polyolefin	36	5.9	25	0.5
Polybutylene	98	3.1	296	0.6
Polyvinyl chloride	19	2.5	1970	5.0
	88	2.4	2285	11.3
	—	4.9	7	—

[a]Immersion time, 337 days.

or other water in the soil.

If this slows the rate of contaminant leaching sufficiently to render the waste essentially harmless, then restrictions on disposal site location can be minimal. The test program consists of investigating five industrial wastes, in both the raw and fixed states. Each waste was treated in five separate fixation processes and subjected to physical testing for leachability. Results to date indicate that leaching of fixed wastes is a function of physical, chemical, and biological mechanisms and principally occurs in the following two ways:

1. External leaching which occurs primarily as surface washing and/or as diffusion into surface flow.
2. Internal leaching which is primarily a function of the solubility of the material.

Since most fixed wastes are characterized as being highly impermeable; then in a field disposal situation the internal leaching contributes an insignificant mass of contaminants to the environment. External leaching is the predominant mechanisms for contaminant mobility stated, this external leaching is a combination of surface washing and/or diffusion to surface flow.

Fixation of sludges will generally result in an improvement in leachate quality because of the inherent physical and chemical properties of the fixed wastes as compared to the raw sludges. The

primary factor contributing to improvement in leachate quality from fixed wastes is the reduction in raw waste surface exposed to leaching. This fact generally results, not only in lower leachate concentrations, but also in a significant improvement in the total mass of contaminants released to the environment.

Co-disposal of the fixed waste with municipal refuse is also being investigated. Chemically stabilized industrial sludges have been loaded into large lysimeters with municipal solid waste. These lysimeter systems will simulate landfill conditions. Differences in leachate quality between untreated sludges, stabilized sludges, and MSW without sludges are being determined.

Pollutant Treatment

The treatability of landfill leachate has been evaluated in the laboratory; a summary of the pertinent processes and results was prepared by Chian and DeWalle. A critical problem impeding the full scale implementation of leachate treatment is the flow and compositional variation. The long-term trend toward decreasing concentration (Figure 8) has caused at least one treatment facility to be grossly over-designed. The composition had decreased between field sampling/pilot-scale testing and completion of the treatment facility. One means of dealing with large flow and composition variation is to use a large equalization pond and bleed directly into a municipal sewerage system. Toward this end, and as a follow-up of laboratory studies, the co-treatment of leachate and municipal wastewater at an activated sludge facility will be performed at the MERL Test & Evaluation Facility.

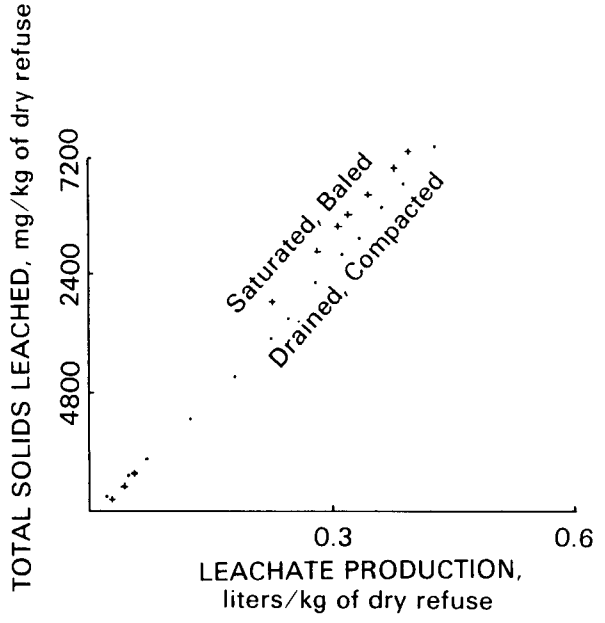


Figure 8. Flux of total solids from experimental landfills.

Co-disposal

Wastewater treatment plant sludges and industrial wastes are often co-disposed with municipal refuse at landfills, but there is very little quantitative information available concerning the environmental effects of such practices. The addition of municipal or industrial sludges may affect the rate and amount of contaminants leached from refuse by modifying the type and/or duration of bacterial activity within the refuse. The introduction of industrial wastes may also yield new contaminants not usually found in significant concentrations in leachate from refuse. The ability of the landfill and the surrounding environment to accept increases in types and quantities of contaminants is not understood. It was also considered plausible that the rate and amount of contaminants leached from refuse may be reduced.

Interim results from a project started in 1975 at our Center Hill Facility to evaluate the leaching characteristics of several selected wastes co-disposed with municipal refuse have not provided consistent conclusions. The addition of refinery sludge has generally reduced the leaching of contaminants; copper and lead release, however, has been greater than the municipal refuse control. Addition of sewage sludge has not significantly affected the leaching characteristics of municipal refuse, even at per capita production rates. Large differences in the contaminant release rates were not noticable for inorganic pigment wastes. Heavy metal and salt flux were noticeably greater when chlorine production brine sludge was added to refuse. Despite the initial alkaline nature of the electroplating sludge, an increase in the heavy metals, organics, and chloride was noticed when disposed with municipal refuse. The addition of battery production waste showed a similar response. The addition of organic pigment sludge indicated a general suppression of metal release and an enhancement of the leading of other materials such as COD, total solids, and alkalinity. Those results fail to show any consistent trend but instead indicate that the landfill response to co-disposal of specific wastes is unique.

Another project designed to assess the potential effects of co-disposal involves the leaching of industrial wastes with municipal landfill leachate

as well as water. Leachate from a municipal solid waste (MSW) landfill was used to extract the five industrial wastes and to study movement of their components in the soil columns. MSW leachate dissolved much greater amounts of substances from the wastes and apparently increased the mobility of these substances in the soil columns relative to the dissolution and mobility observed when deionized water was used as a leaching solution. The municipal landfill leachate is a highly odorous material containing many organic acids and is strongly buffered at a pH of about 5. Consequently, it has proved to be a very effective solvent. A sequential batch leaching and soil adsorption procedure has been developed that provides information comparable to that from soil column studies but in a much shorter time.

Another experimental landfill project involves a study of the effects of co-disposal of chemically stabilized sludges in a municipal refuse landfill. The stability, weatherability, pollutant leachability, and leaching rate of raw and fixed sludges will be determined. Test results show that fixing can cause significant changes in the properties of sludge, that fixed sludges are similar to soil, soil-cement, or low strength concrete, and that properties are process dependent.

Environmental Assessment

Disposal of municipal solid waste to the land is a common practice and is likely to be the predominant disposal mode for most communities for many years in the future. This research area is concerned with the impacts on the environment due to this landfilling of solid wastes.

The impacts of different disposal practices are assessed along with the response of vegetation to landfill environments. Studies on the effects of land application of waste on vegetation have also been conducted. Economic analyses will be performed on both municipal solid waste and flue gas cleaning sludge disposal.

During the past dozen years, many attempts to revegetate completed sanitary landfills have been undertaken throughout the United States, with varying degrees of success. This has been evaluated in a recent nationwide field survey of vegetation growth on completed sanitary landfills. Based on the results of this survey, literature reviews and other field experiences, a study was undertaken to determine which species, if any, can maintain themselves in a landfill environment; to investigate the feasibility of preventing landfill gas from penetrating the root zone of selected species by using gas barrier techniques; and to identify the factors which are most important in maintaining adequate plant growth on completed sanitary landfills. Ten replicates of nineteen woody species were planted on a ten-year old completed sanitary landfill and five gas barrier systems were constructed. The experiment was replicated on nearby old forest land to act as a control. Of the nineteen species planted on the landfill for the past two years, certain species have tolerated the landfill conditions better than others. Where the gas barrier technique kept landfill gases from the root zone the trees grew best.

A research program to determine effects of milled refuse particle size on landfilled solid waste has also been initiated. Four experimental test plots were constructed using four different particle size distributions. Each pit representing a specific milled refuse particle size will be evaluated in an attempt to correlate particle size with different parameters. The parameters under study are: wind displacement of milled refuse, differential settlement of compacted milled refuse, and attraction of vectors, rodents, birds and wildlife to the milled refuse. Monitoring of the test pits has just been initiated so preliminary results are not available to date.

Remedial Action for Waste Disposal Sites

A recent House Commerce Investigative Subcommittee report on the waste disposal practices of 53 of the nation's largest chemical manufacturers identified 3,383 sites that were used for disposal operations since 1950. Of the 3,383 sites identified 1,099 are no longer in use. The report states that among these closed sites a substantial portion, have probably been abandoned with no company or person identifiable as responsible for cleaning up the areas. These abandoned sites contain an estimated 100 million tons of chemical wastes. The members of the House Subcommittee cautioned that the study only addressed the 53 largest chemical manufacturers, while smaller companies with less resources for proper disposal are still unidentified.

The EPA has estimated that 379 million tons of waste were generated in 1977 by all industry not just chemical manufacturers. There are an estimated 50,000 hazardous waste sites in the U.S., over 34,000 of which may pose potential environmental problems and 2000 of which may pose very serious environmental problems.

In 1976 SHWRD was requested by the Office of Solid Waste to initiate a definitive research and development program in the area of remedial action. Subsequent to this request the Resource Conservation and Recovery Act (RCRA), Public Law 94-580, Section 4005, Part C designated the

SHWRD to assist in solving the Army Creek (Llangollen) hazardous waste landfill problem.

As a result of these mandates SHWRD awarded its first contract in remedial action research during October of 1976. This initial award resulted in a full-scale remedial action research project as a municipal landfill in Windham, Connecticut. This municipal landfill remedial action will soon be monitored to determine its effectiveness in reducing the discharge of contaminants into a drinking water reservoir. An interim report of the potential remedial actions that were studied in preparation for this field verification is available as an EPA publication (EPA-600/2-78-142) entitled "Guidance Manual for Minimizing Pollution from Waste Disposal Sites." Work is expected to be completed by the Spring of 1980.

During the period of 1976 to the present, SHWRD has been called upon to provide funding, task force support and technical advice on remedial action sites located throughout the United States from Iowa to Rhode Island. Some of these sites include:

Love Canal, New York
Saltvill, Virginia (Chloroalkali plant site)
Army Creek Landfill, Deleware
Kin Buck Landfill, New Jersey
La Bounty Landfill, Iowa
Earthline Corporation Landfill, Illinois
Clermont Environmental, Ohio
Stringfellow Landfill, California
Rollins Environmental, Texas
Mesita del Buey Landfill, New Mexico
Li Pari Landfill, New Jersey
Valley of the Drums, Kentucky
Candy Box Farm, Rhode Island

At the present time SHWRD is in the process of issuing two new contracts in remedial action technology. One will be for remedial action at a hazardous waste disposal site and the other for remedial action at a surface impoundment. The purpose of the remedial action programs being conducted by SHWRD is to provide a data base for other federal agencies, state agencies, local communities and private industries in solving their needs for the selection of viable, economical and environmentally protective remedial actions at any type of polluting waste disposal site.

Landfill Alternatives

The promulgation of air and water pollution control regulations has resulted in more effective removal of contaminants from waste streams, especially the hazardous constituents in many industrial effluent streams. These cleanup activities have resulted in an increased quantity of concentrated hazardous wastes that must be disposed of. Growing concern over possible degradation of the environment from current disposal methods has led government to seek more acceptable ways for industry to dispose of its hazardous wastes.

Many disposal techniques have been utilized or proposed, none of which is problem free. Problem areas encountered have included adverse enviromental impacts, excessively high costs and a scarcity of acceptable sites. Current research activities on landfill alternatives concern such methods as deep-well injection, land cultivation, and disposal in saline/marshland environments. Some of these methods are currently being practiced in the United States.

Deep-Well Injection

Available information has been compiled on the injection of industrial hazardous wastes into deep wells. The planning and operation of a deep well system is a multi-disciplinary effort involving geological, engineering, chemical, biological and legal expertise.

Deep-well injection systems for nearly all types of non-hazardous and hazardous industrial waste are a safe method of handling if the systems are properly located, designed, operated, maintained and regulated.

Land Cultivation

The disposal technique of land cultivation, whereby specific waste residues have been directly applied or admixed into soils, has been an alternate disposal option for many years by pharmaceutical, tannery, food processing, paper and pulp, and oil refinery industries. To assess this concept, various research efforts have been initiated.

Land cultivation practices were observed at six sites disposing of industrial residuals. The sites were selected to permit identification and verification of parameters that contribute to the environmental acceptability of land cultivation for a variety of industrial wastes under markedly different hydrogeological, meteorological, and land use conditions. Landfarming at each site investigated was characterized as a physical/chemical/biological waste treatment process. Accordingly, information was obtained on the physical and chemical composition of the waste fed to the surficial soil treatment system; characteristics of the treatment system; operational procedures; effectiveness of treatment; potential environmental impacts; and costs. To assess the effectiveness of treatment, samples of waste, soil and waste-soil mixtures were collected and analyzed for organic compound classes; pH; SO_4 and Cl;

electrical conductivity; cation exchange capacity; total Kjeldahl nitrogen; As, B, Ca, Cd, Cr, Cu, K, Mg, Mo, Na, Ni, P, Se, V, and Zn. To access the extent of uptake of inorganic waste constituents, vegetation was collected at most sites, and elemental analysis was carried out. Waste inputs to a landfarming system can be characterized quite precisely; output stream can be determined in principle by comparing the composition of waste application areas with the composition of suitably chosen control areas. Treatment processes occurring in the soil system for particular wastes in particular locations can, at the present time, only be inferred from observed compositional changes. This points up the need for long-range research on fundamental mechanisms of waste treatment in soil systems; and short-range research on monitoring protocol for landfarming operations.

Preliminary studies of the effects of amending soils with API oil-water separator sludge on the germination and yield of ryegrass were initiated to generate data on acceptable sludge loading rates and to elicit mechanisms which affect plant responses.

A petrochemical and refinery waste were utilized and each waste was mixed with each of four soils in varying ratios by volume. The mixtures were planted with ryegrass, and emergence and dry matter yields were determined. Eight plant harvest cycles were completed over a 17 month test period. Soil wettability was also determined periodically.

Concentrations of petroleum hydrocarbons as low as 2 percent by volume depressed ryegrass emergence and yields, apparently through at least two mechanisms. Phytotoxic waste constituents initially acted to severly diminish plant response. Long term yield reductions largely resulted from impaired water, air, and nutrient relations associated with recalcitrant hydrophobic hydrocarbons.

The petrochemical sludge suppressed the emergence and yield over a longer period of time. The suppression was proportional to the amount of each waste applied.

Economic Analysis

The use of scrap futures markets as a means for encouraging resource recovery from solid waste was investigated. As a result of a preliminary feasibility study, the Solid and Hazardous Waste Research Division sponsored a symposium in May 1979 in New Orleans, Louisiana for persons interested in implementation of futures markets for ferrous scrap and wastepaper. A follow-up symposium, limited to discussions on futures markets for wastepaper, was held in November 1979 in Washington, D.C. These symposiums provided forums for informal discussions among persons in industry, government, and research on the potential advantages and disadvantages of scrap futures markets in private industry. As a result of these meetings, a major stock exchange has developed plans to submit model trading contracts to the Commodity Futures Trading Commission for approval.

A number of case studies were undertaken to identify and quantify the economical, technological, and other impediments which affect the successful operation of resource recovery facilities receiving municipal solid waste. Preliminary results at the end of the year indicated that none of the eight selected facilities had been able to achieve a breakeven financial record in recent years. The financial analyses were based primarily on actual operating data in contrast to past studies which relied mainly on engineering estimates, and other preliminary or hypothetical data. The study indicated that a significant impediment to successful operation of the facilities (i.e. revenues equal to or in excess of costs) was the competitive advantage held by landfilling of municipal solid waste.

RESOURCE RECOVERY

SHWRD is charged with the responsibility for (1) resource recovery research and development (including materials and energy recovery), (2) waste reduction, and (3) hazardous materials treatment and processing. The multifaceted resource recovery programs involve research to determine and develop the best techniques for the recovery and reuse of the material and energy values contained in municipal solid waste. Currently, the program involves research in seven basic areas:

1. Refuse derived fuels
2. Evaluation of resource recovery facilities
3. Technology assessment
4. Process equipment evaluations
5. Economic and institutional studies
6. Environmental impacts
7. Special studies under the Resource Conservation and Recovery Act (PL 92-580).

Refuse Derived Fuel

This research involves extracting the combustible organic fraction of municipal solid waste, processing it into an easily handled form, and investigating its combustion characteristics in industrial, institutional, and utility boilers. Research priorities include co-firing of refuse derived fuels (RDF) and coal; investigating chemical

and thermal processes for improving RDF fuel quality; onsite combustion tests to determine environmental emissions, plant modifications, and equipment requirements, development of standard sampling and testing procedures, and specifications for standardized RDF and d-RDF (densified). With increasing experience the knowledge the marketability and acceptability of RDF should improve, making it a promising resource recovery alternative.

SHWRD is cooperating with others to help increase the acceptability of the concept. Joint projects were implemented with the Industrial Environmental Research Laboratory (IERL) in Cincinnati to evaluate special aspects of the Madison and Milwaukee, Wisconsin resource recovery systems dealing with the use of RDF. Additionally, IERL and SHWRD are cooperating with the State of Maryland in a project to use RDF as a fuel in cement kilns. The State of Maryland was involved in the first combustion test of densified refuse derived fuels in the Maryland Correctional Institute's stoker boiler located near Hagertown, Maryland. Industry is also participating in the second phase tests of d-RDF in an industrial boiler located in Erie, Pennsylvania. SHWRD provided 60 tons of d-RDF to be tested at a state boiler in New York. Approximately 2000 tons of d-RDF were burned in the GE Boiler at Erie, Pennsylvania. Test data are still being analyzed, but tests were successful. Much valuable information was obtained on the combustion and boiler operating characteristics, emissions characteristics, and the storage, handling, and transportation of d-RDF.

Resource Recovery Facilities

Several research projects are directly concerned with the design, implementation, testing, and evaluation of planned or existing resource recovery facilities.

The City of Ames, Iowa, received a grant from SHWRD to evaluate the city resource recovery system. Research includes statistically designed experiments to investigate air emissions from RDF combustion boiler corrosion, burnouts, and boiler and plant operations.

The project is providing the first long-term data available on the effects of RDF on the corrosion of boiler tubes. Tubes placed in situ have been removed after 1,000 hours and one year of exposure to the combined combustion of RDF and coal. Analyses have indicated virtually no corrosion for the 1,000 hour samples for the year-exposed samples. Based upon the detailed analysis of these samples, the investigators concluded that burning RDF with coal does not alter the basic mechanism of corrosion found to exist on superheater and waterwall tubes when coal is burned alone. There is no evidence to suggest that the presence of RDF causes an acceleration of the rate of attack. This work will provide significant information to the industry and should help to reduce concerns that RDF will corrode boiler tubes.

SHWRD has conducted several projects to develop facility design and operating data, including alternative disposal systems and methods for predicting waste composition and quantity. A study of the Palos Verdes, California landfill involved optimizing methane production from the landfill and testing biodegradation processes and rates.

An additional study further defined the state-of-the-art of methane recovery from landfills and assessed the technical and economic feasibility of the concept. The concept is technically feasible, but economically dependent on local market conditions. Off-site sales of raw (low BTU) gas to industrial customers in profitable under current market conditions if a minimum production volume can be guaranteed. Sales of cleaned gas (medium to high BTU) to utilities is economical only in specific cases. With the deregulation of natural gas, however, this concept will likely be attractive in most cases.

A current study involves the evaluation of different molecular sieves for gas cleanup. The object is to improve the BTU yield by increased $CO_{2_{(g)}}$ removal.

Technology Assessments

In addition to the data being generated from evaluation of available resource recovery facilities, studies are being conducted to assess the feasibility of alternative technologies for resource recovery.

The biological conversion of cellulosic wastes to methane studies have been completed at three commercially constructed, intermediate-sized digesters. Materials handling presented the greatest obstacle to satisfactory operation of farm-scale anaerobic digesters. Converstion of biogas to electricity via standard engine-generator sets is capital and maintenance intensive. Combining wastes from several forms and/or communities could provide economics of sale provided management and social barriers are overcome.

Research was continued on optimization of acid hydrolysis technology for industrial-scale conversion of waste cellulose to glucose. This one ton/day plant utilizes hydropulped refuse and sawdust as feedstock. The Werner & Pfleiderer is used as the reactor devise for contin-

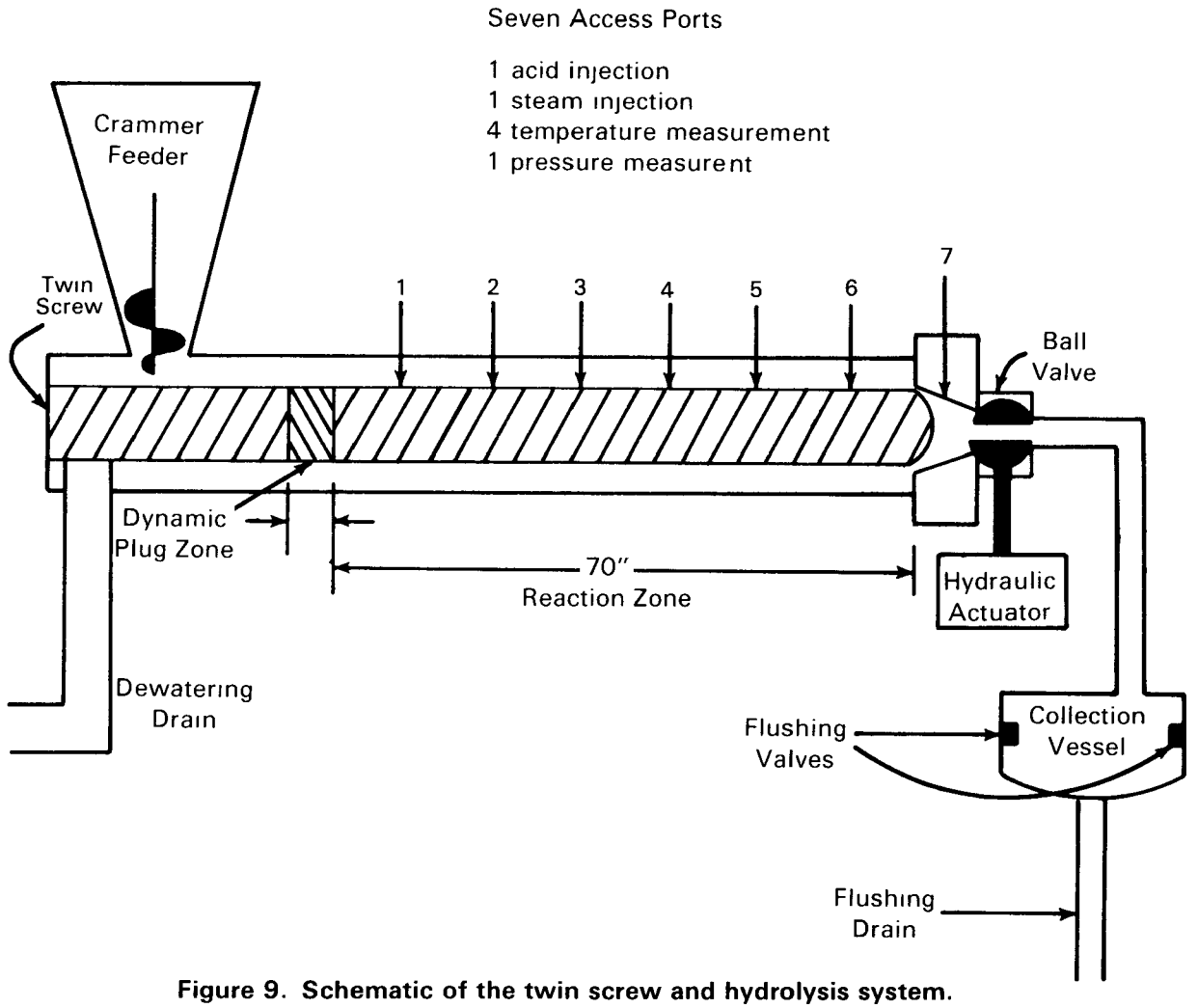


Figure 9. Schematic of the twin screw and hydrolysis system.

uously reacting cellulose in dry or aqueous slurry at suitability evaluated temperatures. Figure 9 is a schematic of the Werner & Pfleiderer twin-screw extruder (reactor), selected because of its capacity for conveying and mixing the feedstocks. This equipment allows accurate control of temperatures, pressure and resident time and temperature during intensive mixing. Currently, plans are being developed for a cellulose-glucose pilot plant capable of producing 10-50 tons/day of glucose.

Three techniques have been developed and evaluated on the pilot scale for utilization and stabilization of pyrolytic oils produced from municipal solid waste. Physical and chemical processing steps are being investigated to maximize the value of the oils produced and to maintain their consistency during storage. Evaluations of three processes are continuing for the 50 pounds/day continuous process selection.

Related studies have identified and verified chemical treatments for cellulose embrittlement. As a result, the basic requirements were defined for producing a fine powdered RDF from the organic fraction of municipal solid waste. This work is continuing to further evaluate the combustion characteristics of powder fuel obtained from processed MSW. Additionally, work will evaluate techniques for preparing stabilized mixtures of the powder RDF and oil, and to determine the mixtures' combustion characteristics.

Process Equipment Evaluations

Several projects are being conducted to evaluate the operating performance of selected types of resource recovery process equipment. Nine shredders at several large-scale solid waste processing facilities were evaluated to determine their performance characteristics as well as to verify basic theoretical relationships developed in laboratory research on the size reduction of solid waste.

Seven horizontal hammermills, one vertical hammermill, and one vertical ring shredder were evaluated. Also, two stage-size reduction and single-stage size reduction were studied. The work has resulted in the development of analytical relationships among the size reduction parameters and established levels of shredder performance with respect to energy consumption and hammer wear.

Another study is evaluating the operating performance of large-scale air classifiers (AC). Primary emphasis is placed upon parameters that can be determined from the testing of air classifiers operating the field. Parameters such as the air/solids ratios, light fraction quality, fuel quality index, and operation efficiency will be determined. Seven air classifiers with operation ranges of 5 to 50 tons per hour will be tested.

Other evaluations at Recovery I in New Orleans are continuing on the use of froth flotation for gas recovery and the use of the trommel rotary screen to separate MSW prior to shredding. In conjunction with this, SHWRD is providing technical assistance to the Department of Energy's large research and development study on the use of trommel screens for resource recovery.

A more basic research project in investigating the densification of solid waste to produce d-RDF. Attempts are being made to develop the basis data required to design proper equipment and processes for the production of d-RDF. Preliminary results have shown a relationship between pellet quality and temperature, moisture, die taper, and the level of compaction of the light MSW prior to entering the pelletizer chamber. The effect of temperature is unclear and the effect of moisture content is counter to observations made during the actual production of d-RDF for the field combustion tests.

Explosions in resource recovery facilities have been a problem. While many have gone unreported, there is documentation for well over a hundred in only a few years. Some have caused very extensive facility damage and some have caused personnel injury. In an effort to minimize this problem, SHWRD initiated a project to provide the data necessary to design explosion venting systems for solid waste shredders, the one piece of equipment causing the most explosions. The project will adopt information available for explosion venting of other industrial equipment through conduct of actual explosions in a mock-up full-scale shredder.

Economic and Institutional Studies

An economic analysis has shown the feasibility of employing scrap futures markets for ferrous and waste paper. Establishment of the concept could aid the trading of these secondary materials and encourage the flow of capital to the scrap industry. The results of this study were presented at a symposium on scrap futures in New Orleans. As a result of this symposium, COMEX decided to recommend the establishment of a futures market for ferrous scrap. Another symposium is being conducted to provide the latest information on futures markets to the paper industry.

A study of user charges for solid waste management was inconclusive regarding the relationships of user charges' effects on the quantity, composition, and rate of resource recovery of solid waste. Additional work is required to establish these relationships. Results did show, however, that there was a significant relationship between the user charges and the frequency of solid waste pick up service demanded.

Environmental Impact

Several continuing projects involve investigations of the emissions and needed controls to make resource recovery systems environmentally acceptable. One study involves emissions from preprocessing and bioconversion systems. Investigators are characterizing pollutants, developing assessment criteria and pollution measurement techniques, and performing a trade-off analysis of cost and performance of pollution control equipment. Another study involves selection and on-site testing of various air pollution control devices, with a determination of unit acceptability and needed improvements. This work is being conducted in cooperation with IERL-Cincinnati.

Potential methods available for removing lead and other metals from solid waste are being investigated. The presence of lead in solid waste has resulted in potentially unacceptable levels of lead in the emissions from facilities combusting RDF with coal. Emphasis is being placed on potential lead emissions to the air from current and planned incinerators and RDF plants over the next several years.

A study to assess the environmental impact of resource recovery was completed. It showed that the net environmental impact of RR from MSW will be primarily beneficial. Emissions from most air pollutants will be reduced. Discharge of some pollutants to surface waters will increase. Less landfill capacity will be required for disposal of MSW. Energy savings will be realized from energy conservation in materials production and energy recovery from MSW. The analysis is based on specific scenarios selected from MSW

disposal in 1990 with and without resource recovery.

Special Studies

SHWRD is responding to mandates of RCRA by conducting several special studies. These studies are designed to provide status reports to the Congress on various aspects of resource recovery. Studies include assessments of selected small-scale, low technology resource recovery methods, evaluation of the compatability of source separation with centralized resource recovery facilities, and techniques for forecasting the quality and composition of municipal solid waste. In other special studies, research priorities for resource recovery are being assessed as are the impediments to the economical operation of resource recovery facilities. The status of glass and plastics resource recovery, and the impediments to passenger tire recycling are the subjects of other special studies.

The study of forecasting the quantity and composition of MSW showed that, based on the model assumptions, per capita generation of waste will increase at a rate less than the rate of increase projected for the GNP through 1990. This is largely accounted for by the projected substitution of light materials (plastics, aluminum, etc.) for glass and steel. The study of economic impediments to resource recovery facilities indicates that large MSW to RDF plants are uneconomical from a market point-of-view. Modular incinerators with heat recovery appear to hold promise. These are preliminary findings only.

In the assessment of small-scale and low technology, the study showed that modular incineration with heat recovery and source separation were the most feasible at this time. Scaled downed versions of other technologies or systems appear unacceptable.

Results of the study to determine the compatibility of source separation and centralized processing (high technology) are still being reviewed, however, they tend to show that neither source separation and centralized processing (high technology) are still being reviewed, however, they tend to show that neither source separation nor mixed-waste processing alone would provide maximum benefits to the Nation and to the hypothetical community analyzed. A combination was judged to provide the greatest benefits. The study identified various combinations and their relative value for providing maximum benefit to a community from resource recovery.

TOXIC AND HAZARDOUS WASTE TREATMENT

Under the mandates of the Resource Conservation and Recovery Act and the Toxic Substances Control Act, the EPA is in the process of identifying hazardous and toxic materials manufactured or generated by industrial operations which, if not properly controlled, pose significant environment and public health problems. Municipal waste disposal facilities are generally not capable of treating and managing such materials and their release in certain instances from unacceptable disposal sites has led to highly undesirable environmental contamination. Accordingly, SHWRD's research program is concerned with the identification/assessment of effective techniques for treatment and control of toxic and hazardous waste materials.

These techniques involve biological processes, incineration, and chemical/physical treatment, as well as the corresponding economic and environmental impacts of such activities. The program is designed to eliminate or reduce the hazardous nature of wastes and to protect the environment. The research program includes:

1. Techno-economic assessments
2. Environmental impacts
3. Treatment technologies

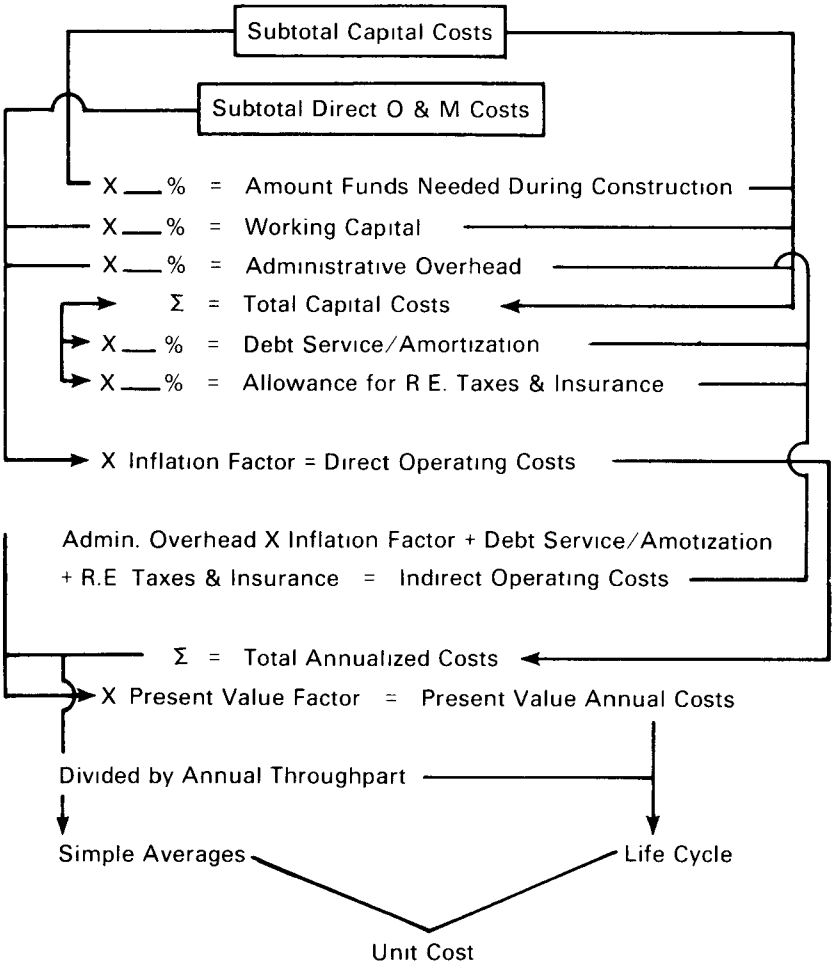
Techno-Economic Assessment

A study has been completed which quantified the amount of industrial hazardous waste disposed of in public sector facilities. This analysis determined industrial waste types and disposal method of generators' Standard Industrial Classification (SIC) Code. Five SIC codes were examined. These were chemicals and allied products, petroleum refining and related industries, rubber and miscellaneous plastic products, leather and leather products, and electrical and electronic machinery, equipment and supplies. These five codes were found to account for 50 percent of the hazardous waste generated in the country; with approximately 10 percent of this waste entering the municipal sector.

Other assessments being performed involve the relevancy and adequacy of existing and developing processing techniques for selected hazardous wastes. Processes examined include chlorinolysis, deep-well injection, catalysis, concentration techniques for heavy metal waste, assessment of techniques for treatment of selected hazardous waste, biodegradation treatment processes, and state-of-the-art processes for pesticide disposal.

Economic evaluations of the interrelationships between control costs and regulations for haz-

Figure 10. Unit Cost Calculator.



ardous waste treatment and disposal are being conducted. For example, a study to evaluate the cost-effectiveness of available treatment and disposal alternatives for hazardous wastes to meet proposed RCRA regulations is underway. Some 16 treatment and 5 disposal unit processes applicable to selected industries are being evaluated for life cycle and simple average costs (Figure 10. Unit Cost Calculator) using a computer-assisted cost/performance program. Preliminary indications are the flotation, filtration, and hydrolysis rank among the more cost-effective treatment options, while encapsulation and land disposal are most cost-effective among the disposal options.

Environmental Impact

Pollution levels associated with the processing of hazardous waste are being studied to determine the environmental impacts. One project is evaluating both toxicity of by-products and the associated health and environmental hazards of air emissions from selected hazardous waste management facilities. Sampling and analysis are underway at several locations. Thus far, no hazardous levels of emissions have been detected at any of the test sites.

A second newly initiated project will assess the nature and magnitude of hazardous pollutants discharged into the environment from the barrel/drum reconditioning industry. To date, there is little information on the nature and extent of air, land, and water pollution caused by improper reconditioning of barrels and drums.

Treatment Technologies

To effectively process the diverse hazardous wastes generated, many treatment technologies have been evaluated. A study to assess new hazardous waste treatment technologies is ongoing. The objective of this study is to identify and evaluate technologies that are more cost-effective

than the treatment method now being used.

Microwave plasma detoxification of various forms of hazardous wastes was successfully tested at 5-7 pounds per hour in the laboratory. A larger 15 kilowatt, 10-12 pounds per hour unit effectively destroyed several complex chlorinated gases, but liquids and solids were incompletely treated because of undeveloped evaporation techniques. Two to five years of additional research and development may be needed to perfect the technology for wide ranges of materials at larger scales. Meanwhile, tests with real nerve gases (U.S. Army) and PCB's (Canadian Electrical Association) are continuing. The U.S. Environmental Protection Agency plans to demonstrate a new pesticide laboratory unit around 1982.

BIOLOGICAL/CHEMICAL/PHYSICAL TREATMENT

A specially constructed pesticide pit has been evaluated for three years and has proven to be an effective method for containment of excess pesticides and rinse waters generated by farmers and applicators. Monitoring of air and water in the surrounding area has shown no pesticide contamination. Study of the pit content has revealed that microorganisms are present and capable of destroying many of the pesticides discharged into the pit. In areas where pesticide pit disposal will have limited application, filtration/adsorption techniques are being developed. Identification of filtration/adsorption for effective treatment of pesticide waste water will provide for pesticide removal and safe discharge of treated water to sewers.

Treatment of hazardous wastes by concentration of technologies is being evaluated. Individual unit processes under going evaluation are chemical coagulation and precipitation, biological treatment of activated sludge, activated carbon adsorption, resin adsorption, reverse osmosis, ultrafiltration, and air or steam stripping. Using the above unit processes and developed process trains, bench and pilot scale treatability studies will be performed on hazardous wastes and leachates. The leachate from Love Canal is a prime example. The objective of the study is to develop concentration technologies for the removal of hazardous constituents and enable the majority of the waste to be discharged to existing municipal treatment plants. As a result, the concentrated wastes can be cost-effectively treated, incinerated or disposed of in secure landfills.

Techniques to control inorganic chemical wastes, especially heavy metals, have been identified and evaluated. Three techniques that have broad application for hazardous inorganic constituents are high gradient magnetic separation, solvent extraction, and chemical precipitation. Demonstration and verification of these selected techniques for treatment of inorganic pollutants from municipal landfills, surface impoundments, and hazardous waste treatment facilities are ongoing.

A chemical method is being developed and evaluated for detoxification of halogenated hazardous chemical wastes. The active reagent is for treatment of molten sodium and polyethylene glycol. Thus far, the method has proven effective for decomposition of hexachlorocyclohexane, tricholorobenzene, Kepon, DDT, and more importantly, PCB-contained dielectric fluids. Fields verifications are planned at the conclusion of laboratory studies.

Encapsulation techniques have been developed for safe storage and/or disposal of hazardous waste. This project has researched and/or evaluated the use of cement for encapsulating small containers of waste; the use of large cement containers, i.e., culverts, missile silos, etc. for the disposal of waste; and the four polymeric techniques which include encapsulation of 55-gallon drums or other containers. Encapsulating materials formed with the polymeric techniques are unique in their capabilities to resist physical

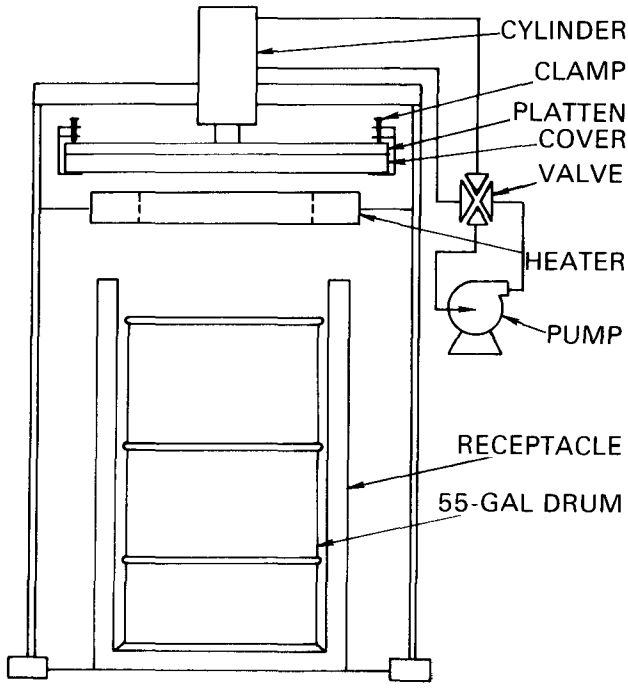


Figure 11. Apparatus for encapsulating 55- gallon drums holding hazardous wastes.

and chemical stresses. They are tough, flexible coatings which prevent leaching of materials into or from the matrix. Process development and product evaluations have been conducted on a laboratory scale for three processes, while full-scale work is proceeding for the fuse welding process for encapsulating 55-gallon containers. (Figure 11)

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WASTEWATER RESEARCH DIVISION

The Wastewater Research Division (WRD) was formed in July of 1975 from the Advanced Waste Treatment Research Laboratory which had been initiated in Cincinnati in 1960. Advanced waste treatment work had been carried out under both the U.S. Public Health Service and the Department of the Interior before the establishment of the U.S. Environmental Protection Agency in 1970. With the passage of Public Law 92-500 in 1972, with changes in the national perception of municipal research problems, and with a consolidation of USEPA municipal wastewater pollution research within MERL, the range of topics expanded beyond those formerly addressed. Wastewater Research Division had become a more accurate description of the program.

Following the special topics is a description of the work and of important accomplishments in the Division.

SPECIAL TOPICS

Urban and Rural Communities Cooperate In Land Utilization of Sludge

When a municipality decides that land application of sludge is economically and environmentally desirable, it is generally faced with the need to convince the potential recipients or the community at large that sludge reuse is a good thing. Strategic plans are laid to choose the optimum sites, keep the community informed, and establish a "climate of trust."

The "climate of trust" is often very hard to establish. If the proposed recipient is a farmer, he is asked to stake his farm and his livelihood on the claims of "honest-looking" municipal officials, who clearly have their own reasons for encouraging sludge use on land, that sludge is safe for his crops, is not hazardous to his family's health, and is a profitable replacement for much of his fertilizer needs. The farmer knows that his farm must still be profitably producing crops long after municipal authorities have left office, engineering firms have gone on to other jobs, and those sewage treatment operators who were so reassuring have transferred to some other treatment plant. The farmer often concludes that his safest course is to reject the sludge option.

Another approach, hard at first, but more profitable in the long run, is for the municipality to surrender to the agricultural community some of the decision-making authority about the use of sludge, and let the farmer make up his own mind, using his own information sources. The mechanism to use is the unique intercommunication web that provides the farmer with the information he needs to do the best thing possible with his land. Partners in the effort are private organizations such as the Farm Bureau Federations, State and Federal agricultural extension services, and the research programs of State and Federal agricultural agencies. These organizations do not produce all the information that a farmer needs, but they are his reliable counselors that assess the claims of equipment manufacturers, fertilizer producers, and seed suppliers, and give the farmer the good advice he needs.

The conventional intercommunication channel from sludge producer to receiver is not used. A measure of control by the city must be relinquished to the rural residents. The agricultural community decides what is safe, what sludge application rates are appropriate, and even what sludges should or should not be used on land. When this is done, the farm community reverses itself, and a difficult struggle for acceptance is turned into an enlightened program, where knowledgeable people who have the trust of the farmer make key decisions.

In Ohio, the nearly traditional confrontation between farm and city has been encountered and reversed. Cooperation between State, Federal, and farm organizations has produced a model program that may point the way nationally to the resource-conserving utilization of all the sludge that should be reused. With support of an EPA demonstration grant to the Ohio Farm Bureau Federation, Ohio is showing how city and country people can work together harmoniously to use municipal sludge on farms to benefit both the rural and urban communities. Involvement of concerned residents of both communities in planning and implementation of the sludge-use project has enabled them to avoid the distrust

and strife that has plagued so many prior efforts to recycle urban wastes on agricultural land.

Although sludge use on land is common in this country, there is still a general lack of understanding among participating farmers and municipalities of the management procedures necessary to assure the optimal benefits and minimal health and environmental risks. Residents of the communities involved in this project were invited to educational meetings where agricultural and medical scientists discussed the use of sludge as fertilizer – its benefits and risks. Thus, the negative attitudes associated with lack of information have been avoided.

Who is carrying out a project is often more important than what is done, or how, in determining its acceptability. This demonstration was initiated by the Ohio Farm Bureau Federation, an organization of farmers dedicated to the advancement of farmers. The Farm Bureau is one of the oldest and largest farmer organizations in America with County Farm Bureau Federations combining to form the Ohio Farm Bureau Federation which in turn combines with other state Farm Bureau Federations to comprise the American Farm Bureau Federation. The confidence that the farmers have in the sponsoring organization is important in gaining acceptance of, and participation in such projects.

The Ohio Farm Bureau Federation's interest in a project to learn how to use sludge beneficially developed out of its activities in defense of some of its members who were threatened with loss of their farms to a city for use as a municipal sludge farm. With the assistance of The Ohio State University, College of Agriculture, the Federation submitted an application for an EPA grant to support a large demonstration of safe beneficial use of sewage sludge on privately owned farm land. The grant application was submitted at a convenient time, because EPA was searching for a model demonstration of a successful way to plan, implement, and conduct a sludge use program on farm land. Such a demonstration would involve resolution of legal and institutional obstacles, following the best available site management, and educational programs to publicize the project.

A grant was extended to the Farm Bureau Development Corporation in 1977. The scope of the project was significantly expanded by addition of an epidemiological study to assess the effects upon the health of animals and humans from careful use of sludge on farms. The project is funded jointly by EPA's Health Effects and Municipal Environmental Research Laboratories in Cincinnati.

One of the important aspects of the project that distinguishes it from most previous efforts to apply urban wastes on rural land is the great number of participating agencies, organizations and individuals that have cooperated in the planning and implementation of it. They represent the rural communities, the urban communities, and the local, state, and federal government. The Ohio Farm Bureau Development Corporation accepted the EPA grant, contributed 25 percent of the funds, and provided overall supervision and direction. The Ohio State University and the Ohio Agricultural Research and Development Center serve as subcontractor and perform most of the scientific research work. The College of Agriculture participates through three departments and the Cooperative Extension Service. The Department of Agronomy tests soils and sludges and recommends sludge application rates and other soil and crop management practices to be followed. Soils and crops are periodically sampled and analyzed to determine changes caused by use of sludge. The Department of Agricultural Engineering advises in matters concerning sludge handling and application and studies the effect of sludge on soil density and compaction. The Department of Agricultural Economics assesses the economic impact of various sludge handling and application systems on the farm enterprise. The Extension Service is the leader in information dissemination and in obtaining farmer cooperators. They also set up field days and collect soil and plant samples.

The College of Medicine, The Ohio State University, participates in the epidemiological studies through two departments. The Department of Medical Microbiology analyzes sludge for pathogenic bacteria and viruses, and evaluates sludge-treated soil to determine the rate of survival of these pathogens. They also examine the cooperating farm families to determine any evidence of bacterial or viral infections from sludge application. The Department of Preventive Medicine cooperates in design of the epidemiological study and in analyzing the data.

The College of Veterinary Medicine cooperates in the study of the effect of sludge use on human health and monitors the effect of sludge on the health of domestic animals. They evaluate the effects of metals, *Salmonella,* and parasites. They also perform the Tuberculin sensitivity test on farm animals.

All of the participating departments of The Ohio State University (OSU) and the Farm Bureau have cooperated under the leadership of the Cooperative Extension Service in conducting meetings to inform both rural and urban residents of

the objectives and plans of the project and in obtaining cooperation of farmers. Volunteers to receive and use sludge and their neighbors have been fully informed of benefits and risks involved in sludge use on farms. Thus, enlightened decisions are made possible by publicity and educational programs. By involving affected residents in both the rural and urban communities, the volatile reaction that sometimes accompanies the initiation of waste disposal projects has been avoided.

Some of the other participants in the project include the Ohio Municipal League, State and County Health Departments and the municipal officials of the cities that furnish sludge for the project. Wastewater treatment officials transport and apply sludge on farms, sample sludge for analyses, and participate in educational phases of the program. The Ohio EPA is responsible for regulating sludge disposal within the state, so they not only approve sites but also participate in planning and implementation of the project.

The four communities that were originally selected for participation in the project were chosen because of geographical distribution and because of the soil and cropping patterns that were found there. In the meantime, one community, Montgomery County, withdrew because personnel changes in the Sanitary District resulted in loss of interest in the project. They were replaced by Columbus. Defiance elected not to participate in the health effects studies, but they have applied sludge on a few farms and the environmental effects are being measured. Zanesville had to withdraw because they could not produce sludge of desirable quality. The cadmium concentration was higher than desirable and efforts to control the influent to the treatment plant were not successful. Springfield replaced Zanesville and is in the process of conducting educational meetings, obtaining participating farmers, and planning the sludge application schedule. Medina County was the first community to get started in sludge application and with the epidemiological studies. They have nine farms receiving sludge and participating in the health studies. In addition, seven farms that receive no sludge are participating in the epidemiological studies. Columbus entered into the study late but have 21 farms that receive sludge and 20 farms that have not received sludge participating in the epidemiological studies.

The plan for sludge application and site management is a responsibility of the OSU Agronomy Department. Acid soils are limed as need is indicated by a soil test. Sludge is being applied to supply the phosphorus needs of the crop as indicated by the soil test. Therefore, the application rates, which range from 1 to 5 tons per acre of sludge solids, are lower than they would be if they were determined by the crop's nitrogen requirements. These low application rates assure that the risk of environmental or health problems will be very low. Supplementary nitrogen and potassium are usually needed.

Tours and field days are very important for publicizing the project. The Ohio State University established plots on the demonstration site of The Ohio State University's Farm Science Review, an annual three-day exposition of the latest methods and materials used in agriculture. About 100,000 people attended the exposition. Several thousand viewed the plots where sludge had been applied at several rates and heard the investigators discuss the benefits and risks of sludge use.

The epidemiological study is an important aspect of the study because it provides assurance to participants that no adverse effect on their health, if it does occur, will be untreated. These studies began in Medina County and in Zanesville and Columbus vicinities in 1978. A total of 1304 questionnaires were completed and checked. Each examination and interview was conducted with a physician and nurse. Blood and stool samples are collected and analyzed in addition to the physical examination to determine general health. To date, no differences in rate of illness or other indicators between sludge users and the non-users have been detected. Sixteen calves were tested prior to sludge application and at the time of slaughter with no adverse effects being detected. Sludge and fertilizer have been equally effective in enhancement of crop growth and yields. The value of the nutrients in one ton of sludge varies from about $7.00 to $46.00, depending upon the composition of the sludge.

Although results of the project are preliminary and no conclusions can be drawn concerning eventual environmental or health effects, it is apparent that publicity, educational programs and cooperative planning can do much to alleviate the suspicion and fear that often accompany the disposal of urban wastes in a rural community.

An average sludge applied to a crop that uses the nutrients efficiently, at a rate of 3 tons per acre, is worth $75.00 per acre.

Tertiary Wastewater Filtration

Filtration is considered to be the most important tertiary process in the implementation of the Federal Water Pollution Control Act Amendments of 1972 and 1977. Many existing secondary wastewater treatment plants cannot meet the

minimum monthly average effluent standard of 30 mg/l for suspended solids and biochemical oxygen demand (BOD) established by the Environmental Protection Agency in 1973. This is particularly true for small plants where removal efficiency is usually less than that achieved for large plants. The addition of tertiary filters will enable many plants to meet the standard and higher treatment levels for water quality limited streams. A survey conducted in 1974 identified only 77 operating U.S. tertiary filters treating secondary effluents with flows greater than 0.3 mgd (1,136 m^3/day). Based on tertiary filtration needs compiled in 1974, tertiary filters will be required at over 1500 plants to achieve water quality standards established by the 1972 Act. Approximately 94 percent of the plants will be smaller than 5 mgd (18,925 m^3/day) and 80 percent will be smaller than 1 mgd (3,785 m^3/day).

Research on tertiary wastewater filtration in the United States began in the mid-1960's. Since then numerous pilot-scale studies have been conducted to evaluate the effect of media size, media depth, and flow rate on process performance. It is generally recommended that pilot-scale studies be conducted at each site to develop design parameters for full-scale plants since filtration models cannot be used to reliably predict performance. The classical mechanisms for in-depth filtration, that were developed from studies of potable water filtration and from laboratory studies using suspensions with controlled properties do not adequately describe suspended solids removal for direct filtration of secondary effluents due to straining of large particles at or near the surface of the filter medium. In previous wastewater filtration studies, insufficient attention has been given to the effect of secondary effluent suspension properties on particle collection mode and clarification efficiency.

A study has recently been completed at Northwestern University with objectives to gain a clearer understanding of parameters affecting the clarification efficiency of full-scale granular media wastewater filters and to develop operational mathematical models to describe primarily this clarification efficiency. Operating and performance data were collected on tertiary filters at eight small treatment plants in the Chicago metropolitan area. The treatment plants had design flows between 0.8 and 2.5 mgd (3028 and 9462 m^3/day) and used 2-7 filters. Products from six filter manufacturers were represented. Filter design flows ranged 1.0-4.3 gpm/ft^2 (41-175 l/min-m^2). Five plants had filter configurations shown in Figure 12 with a backwash storage tank located above the sand and anthracite dual filter media.

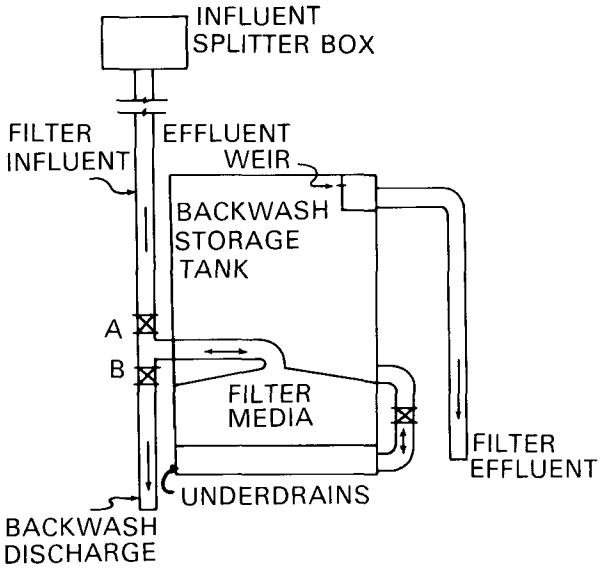

Figure 12. Filter design.

The other plants included either trimedia filters or single media sand filters of unique design. Typical filter installations are shown in Figures 13 and 14.

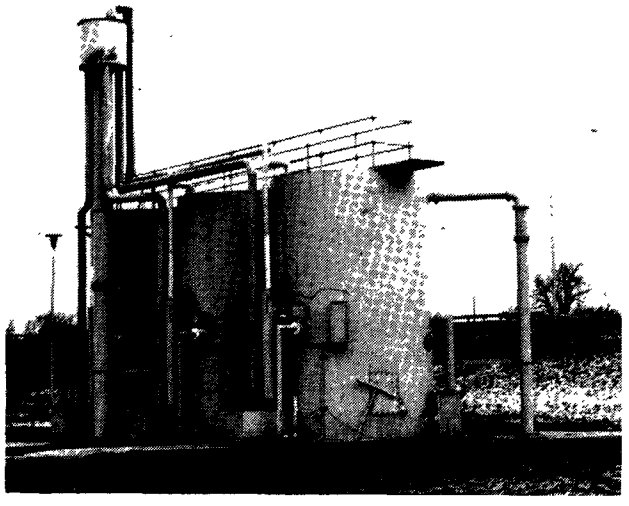

Figure 13. Picture of tertiary filter installation.

Filter clarification efficiency was characterized using conventional design and operating parameters, and the statistical properties of secondary effluent and filter effluent parameters were determined. Averaged secondary effluent suspended solids varied from 28 to 62 mg/l for the eight plants and average filter effluent suspended solids from 5 to 20 mg/l. The average removals of suspended solids varied from 47 to 83 percent for the eight plants. Average secondary effluent BOD

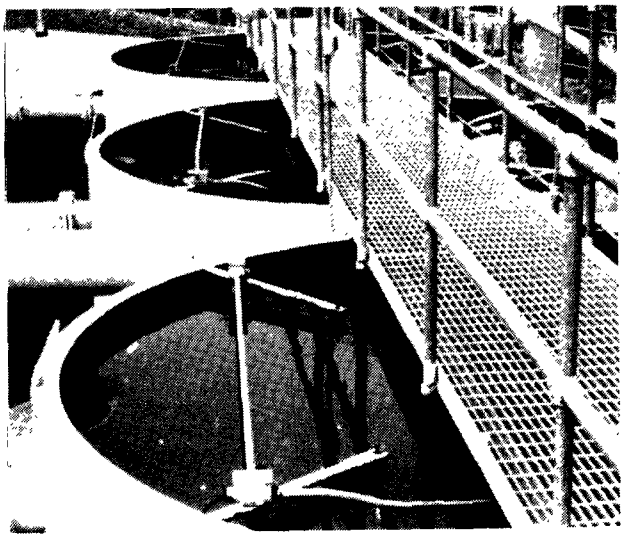

Figure 14. Picture of tertiary filter installation.

varied from 9 to 44 mg/l and average filter effluent BOD varied from 3 to 25 mg/l. The average removals of BOD varied from 18 to 87 percent for the eight plants depending largely on the soluble BOD content of the secondary effluent. Limited tests at two plants showed that a significant fraction of the soluble BOD was removed by the filters.

For plants where flow to individual filters was varied, average clarification efficiency decreased linearly with average flow rate. Correlation coefficients between filter solids removal efficiency and operating parameters such as flow, solids loading and run length were poor for data obtained over long time frames. Improved correlations were, however, obtained for data analyzed over shorter time periods which minimized the effect of seasonal and other variations in secondary plant effluent suspension characteristics. Differences in characteristics of secondary effluent suspended solids rather than media grain size and depth are most likely the major reason for variations in clarification efficiency between plants.

The following semiempirical model was developed for in-depth filtration: $C = 0.40\ C_o^{0.86} Q^{0.34}$

where: C = filter effluent suspended solids – mg/l

C_o = secondary effluent suspended solids – mg/l, and

Q = filtration rate – gpm/sf

In testing with independent data, the in-depth model was able to predict C within ± 25 to 85 percent of the data for three plants.

The most important single design consideration for small tertiary filtration plants that are not staffed 24 hours per day is the ability to handle secondary process upsets. This consideration appears to favor dual-media designs with relatively large media and high terminal headloss. Regular inspections should be made to detect problems in operation and preventive and corrective maintenance should be promptly scheduled. This applies particularly to accessories such as control valves which were observed to stick frequently in the open position.

In summary, tertiary filters provide a very effective means for upgrading secondary effluent to meet water quality standards if proper design criteria are followed.

TREATMENT PROCESS DEVELOPMENT BRANCH

The Treatment Process Development Branch is responsible for the development of technology and processes in the areas of biological treatment, physical-chemical treatment, and the ultimate disposal of solids.

Full-scale evaluations completed this year included the activated bio-filter system, the Max Plank Institute trophic system, and three types of fine bubble submerged air aeration systems. The first municipal Deep Shaft System in the United States was placed on stream at Ithaca, New York. A 16-month experimental program has been designed.

A study was completed on analyzing the operating and performance data from tertiary filters at eight small treatment plants. The data showed that tertiary filters provide a very effective means for upgrading secondary effluents if proper design criteria are followed.

Cost effectiveness is an important consideration of any sludge treatment process. Cost estimates are being prepared on three interesting processes: hot acid extraction to remove metals and improve dewaterability, vericomposting, and aerobic digestion that will pasteurize the sludge.

A sizable portion of the Branch research effort has been devoted to determining the fate and effects of nutrients and trace elements in sludge-treated soils. Copper, nickel and zinc have been identified as metals that are most likely to cause phytotoxicity. Cadmium is the element of most concern because of its adverse effect on human beings.

RELATED RESEARCH PUBLICATIONS

Bunch, R.L. PILOT PLANT DEVELOPMENT OF OZONE DISINFECTION. Presented at *Conference on Physical Methods for Water and Watewater Treatment,* Lublin, Poland, June 7-9, 1979 (Proceedings published by Pergamon Press).

Ultimate Disposal Section

The primary responsibility of the Ultimate Disposal program is to find environmentally acceptable and cost-effective approaches for treatment and disposal of municipal wastewater sludges. Frequently, toxic and pathogenic substances are either not present or can be neutralized so that constructive use can be made of the sludge. It is the program's responsibility to develop the potential for reuse to a maximum while at the same time safeguarding the environment from possible harm.

Sludge Processing and Treatment

Sludge processing and treatment include all of the steps from the first appearance of sludge until it enters the disposal step. A determined effort is underway to scrutinize quantitatively the cost-effectiveness of processes under development. A Boston-based engineering firm is completing cost estimates of three processes: hot acid treatment of sludge to remove metals and upgrade sludge dewaterability, vermicomposting – the use of earthworms to process sludge into a high grade potting soil, and aerobic digestion of sludge under conditions such that self-heating occurs and pasteurizes the sludge. If the processes prove competitive, the next step will be either large-scale pilot plant construction or demonstration.

The LA/OMA (Los Angeles, Orange County Metropolitan Area) project – an areawide study supported by EPA, is aimed at developing the best options for sludge processing and disposal in this geographical area. Experimental and engineering studies are completed and recommendations have been made. Public documentation of this project is now underway with MERL support.

Energy reduction in all aspects of wastewater treatment is of primary concern; however, if sludge is properly treated and utilized, it is possible not merely to reduce energy use but even to generate a major part of the energy needed in other parts of the plant. The Wilton, Maine, plant – an energy self-sufficient facility using solar energy and the methane generated in sludge digestion – was dedicated in the Fall of 1979. The plant was built with EPA funds and an evaluation is being financed by a joint EPA-Department of Energy grant. MERL will also be supporting along with DOE and the State of California a project, in which a modular turbine is bieng developed to generate heat and electricity from sludge gas. The development of a low-cost modular turbine is expected to make recovery of energy from methane cost-effective in smaller plants than is possible now.

The pathogen content of sludge is a major concern if sludges are to be reused for agricultural purposes or soil renovation. It is important to determine the effect of conventional treatment processes on pathogen densities, and if possible develop cost-competitive methods that pasteurize the sludge. Disinfection of sludge by thermoradiation is being studied at Sandia Laboratories in a project jointly funded with the Department of Energy. Previous excellent results showing inactivation of all pathogenic forms at bench scale in sludge by thermoradiation will soon be demonstrated at pilot scale. In a study at the University of Florida, inactivation of virus and bacteria in sludges during aerobic digestion is being investigated. Demonstration of a two-step thermophilic aerobic-anaerobic digestion process for sludge stabilization, developed by Union Carbide Corporation, has reached the operating stage. In this process, sludge is aerobically digested with oxygen for about one day, which causes it to self -heat to over 55°C. The sludge is then processed in a mesophilic digester for an eight-day stabilization period. The sludge is expected to be pathogen-free.

In-house evaluations of modern dewatering equipment are underway at the new Test and Evaluation Facility at Cincinnati's Mill Creek plant. An important study is underway to determine whether a high-metals fraction of sludge can be "scalped off" by passing liquid sludge through a solid-bowl "classifying" centrifuge. The small high-metals fraction could be separately disposed of, whereas the bulk of the sludge could now be constructively reused on the land.

Sludge Conversion

Sludge conversion is any process that changes the nature of the sludge so that it is no longer perceived as sludge. The static-pile forced- aeration process, developed by the U.S. Department of Agriculture with MERL and other EPA assistance, continues to provide answers to the sludge problems of many communities. Composting has provided a major relief valve for communities with no other acceptable sludge disposal options. Our research efforts on this process now are concentrated improvement of the process and of our understanding of its fundamental nature.

Composting sludge within vessels makes the process even more acceptable to communities than unconfined processes. MERL has funded studies of the economics of European within-vessel methods, as well as methods developed

by United States firms. MERL will also be sponsoring a test of composting in a barge-mounted plant.

Thermal conversion techniques, particularly those utilizing a low-grade fuel to supplement the thermal deficiency of dewatered sludge cake, are the object of high interest for sludge disposal. MERL is evaluating a coincineration plant (sludge and refuse-derived fuel – RDF) at Duluth, Minnesota. At this plant, solid waste is processed into metal and RDF fractions, the RDF is burned with sludge, and surplus steam is generated for plant use. About 100 acres of scarce landfill space will be saved annually by using this process.

Two innovative processes that form sludge into briquettes with another fuel are being investigated and show great promise. At the University of California (at Davis), sludge and RDF have been pelletized and burned in a down-flow gas producer. A grant application for a larger demonstration is in preparation. In New York City at Columbia University, the Sanoplex process is being evaluated with MERL support. In this process, a low value caking coal is pelletized with RDF, sludge, and a black liquor binder. The pellets are partially combusted with oxygen to produce a medium heating value fuel gas. Economic evaluations have been extremely encouraging. These novel processes may provide the solution to the sludge problem when logistics and/or high metals content of sludge preclude constructive reuse of sludge on land.

Beneficial Utilization and Disposal

Beneficial utilization includes any constructive use of sludge. The options for selection of systems for treatment, handling, and disposal of sewage sludge are numerous; however, land is the only acceptable ultimate receiver of sludge. Sludge may be utilized in or near the surface to enhance soil productivity or it maybe sequestered beneath the surface. The former offers the opportunity to consume some of the useful constituents of sludge while disposing of it economically in an energy-use efficiency manner. Sequestering sludge in landfills, basins, or trenches offers the possibility of economical disposal where sludge quality or site conditions make landspreading unfeasible. More information is needed for development of technology for utilizing or disposing of sludge under the multitude of sludge-soil-climate-land use conditions that may be encountered in planning and construction of public wastewater treatment facilities.

Plant nutrients, inorganic components, and organic components of sludge can be beneficial to soil and make it more productive, or they can be harmful to the environment or hazardous to public health, depending upon the amounts added to the soil and their environmental fate. The amount of each component that is acceptable is dependent upon site characteristics and management.

A sizable portion of MERL's research effort has been devoted to determining the fate and effects of the nutrients and trace elements in sludge-treated soils. Copper, nickel, and zinc have been identified as metals that are more likely to accumulate to phytotoxic levels in sludge-treated soils. Cadmium is the element of most concern because of its potential adverse effects on human health. It is assimilated by growing plants and is accumulated in the human liver and kidneys. Lead is of concern if sludge-contaminated forages are ingested by humans or animals. Nitrates can leach into ground water, and both nitrates and phosphates can be transported by surface runoff into streams and reservoirs. Progress has been made in identifying acceptable sludge application rates and appropriate site management techniques for application of specific sludges on specific soil-climate-crop combinations. A grant to Chicago is supporting a study of the accumulative effects of annual sludge applications over a long period of time. After 10 years, cadmium concentration in grain does not appear to be increasing. No phytotoxicity from metals has been encountered. Corn yields from sludge-treated soils are equivalent to, or superior to, conventionally fertilized plots. With MERL support, the Science and Education Administration of the U.S. Department of Agriculture at St. Paul, Minnesota, is developing site management technology to enable the beneficial use of sludge as a soil amendment. Diversion terraces, contour cultivation, and appropriate cropping systems are being used to minimize runoff and leaching of soluble and suspended sludge constituents. Animal feeding of sludge-produced corn silage is being used to determine the effect of the cadmium-enriched feed on animal health, carcass composition, and milk composition.

Toxic organic substances that may find their way into sludge are of increasing interest. The principal known organic constituents of sludge are polychlorinated biphenyls (PCBs) and pesticides, but concentrations of persistent pesticides in sludge are usually lower than in soils to which they are applied, so sludge application should be of concern only if sludges with unusually high concentrations of pesticides are used. PCBs are adsorbed on soils and have low solubility, plant uptake is negligible, but surface

contamination of crops could be significant. The lack of data on the environmental fate of the priority organic compounds has led to the development of a grant with North Carolina State University to determine their fate, and whether they are taken up by plants.

Pathogens in sludge and their possible transmission to humans when sludge is used on soil continue to be of concern. Technical support is being provided to EPA's Office of Solid Waste for the preparation of landfill criteria as required by the Resource Conservation and Recovery Act of 1976. One of the issues is the potential disease risk from landspreading of sludges. At the University of Illinois, studies are continuing to determine whether worm-free pigs housed in pens located on sludge-treated soils became infected with parasites. Evidence is accumulating that the pigs can be infected by parasites (e.g., *Ascaris suum*) by either direct feeding of sludge or through foraging on some sludge-treated soils. It appears that the degree of exposure, which governs the opportunity for ingestion and parasite density, must be very high to produce a significant degree of infection.

Laboratory studies are beginning at the University of Cincinnati to determine the rate of inactivation of helminth eggs under sludge lagoon environments. Eggs of parasitic species of nematodes and cestodes known to be resistant to conventional sludge stabilization will be seeded in sludges before and after mesophilic anaerobic and aerobic digestion.

Studies on the uses of sludge for non-food chain crops produced a final report on "Effects of Sludge Irrigation on Three Pacific Northwest Forest Soils," a grant project with Seattle, Washington. The results showed that liquid sludge (1 to 3 percent solids) applied at optimum rates of 20 to 30 metric-tons/hectar/year (Mt/ha/yr) (dry solid basis) was beneficial for growth of existing forest stands in a coniferous forest and will not cause environmental problems. Peer Consultants, Inc. is seeking the most feasible non-food chain crops for sludge use. The most promising non-food chain crops and crop categories for sewage sludge use application appear to be:

1. Monoculture timber tract operations
2. Forest nurseries
3. Horticulture specialties
4. "New" crops such as Jojoba, Guayule, and Eurphorbia.

Cotton is also being evaluated, though the use of cottonseed oil and meal is being eliminated because it is a food chain crop. A 3-year grant to the Ohio Agricultural Research and Development Center will "Demonstrate the Feasibility of Using Sludge to Produce a Valuable Non-Food Chain Crop." The purpose of the study is to elucidate the effects of digested sludge on:

(a) container-produced conifer and hardwood trees in the greenhouse
(b) conventional nursery production of forest tree seedlings
(c) mycorrhizal fungi (which are important in tree nourishment)
(d) plantation production of Christmas trees.

A four-year survey of the background concentrations of selected trace elements in the principal soils and crops of major food chain crop-producing areas of the United States is being conducted under a cooperative agreement with the U.S. Department of Agriculture and the Food and Drug Administration.

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Biological Treatment Section

New developments in wastewater control technology for municipal applications must be evaluated on a continuous basis. A large portion of the Section's activity is thus devoted to field scale studies of innovative unit processes that are monitored under carefully defined scopes of work. Results are published in EPA reports, technical journals, and seminars.

Technical assistance is provided to EPA regions, municipalities, and consultants on short term projects. Committee and workshop assignments are also considered an effective way to assist the technical community by transferring research information rapidly into practice.

Disinfection of Wastewater

The program on development of alternative disinfection technology has continued in the areas of ozonation, ultraviolet irradiation, and chlorine dioxide treatment.

Ozonation

A comparison of a bubble diffuser ozone contactor and a stirred turbine reactor on filtered and unfiltered municipal effluent revealed superior transfer efficiency and coliform reduction efficiency in the bubble diffuser. Factors affecting final coliform numbers in ozonated effluent were total chemical oxygen demand, nitrate, total suspended solids, and the absorbed ozone dose. A model was developed to predict final coliform density as a function of the absorbed ozone dose.

Ultraviolet Light

Demonstration of ultraviolet light (UV) as a viable, cost-effective alternative to chlorine was successful at Northwest Bergen County. A number of small treatment plants have already committed themselves to this technology as a result of the study. Data from the project provided sufficient information to formulate a design theory for UV equipment, and the theory will be tested in a second generation study planned in the upcoming year. A thin-film design will be compared with a thicker water wall design on a secondary standard municipal effluent.

Chlorine Dioxide

In a study conducted by Stanford University personnel, chlorine dioxide was found to be equally effective as chlorine on a mass dose basis, using a conventional secondary effluent. However, on a nitrified filtered secondary effluent, chlorine dioxide was clearly superior to chlorine, requiring only about 20 percent of dose to effect the same coliform reduction. Using the same nitrified effluent but without filtration, the two disinfectants were equally effective. Apparently, one or more critical components in the effluent were removed by the filter.

A commercial, field scale chlorine dioxide generator was evaluated for product yield. The generation technique was the acid activation of sodium chlorite. The chlorine dioxide yield was approximately 80 percent, compared with the 90 to 95 percent obtainable in the laboratory. The lower yield in the commercial unit could significantly affect costs, because of the relatively high cost of sodium chlorite. A complete cost evaluation is being conducted, based on all data collected in the laboratory and in the field.

Pre-Conference Workshop at Houston, Texas

The Water Pollution Control Federation Disinfection Committee sponsored a state-of-the-art workshop on wastewater disinfection alternatives. The workshop provided a forum for the exchange of practical information on chlorination/dechlorination, ozonation, chlorine dioxide treatment, ultraviolet irradiation, and bromochlorination. Case histories were also presented,

as well as discussions on the need for wastewater disinfection and methods for assessing the relative risks and benefits of alternative processes.

Of the 10 presentations, one was made by a MERL researcher and 4 were made by MERL grantees. The meeting was attended by over 110 persons. The papers will be published in a proceedings.

IJC Chlorine Objective Task Force

The first Chlorine Objective Task Force was formed in 1975 by the International Joint Commission to address the following issues: (1) the technical capabilities for monitoring the proposed maximum ambient concentration of total residual chlorine of 0.002 mg/l in the boundary waters of the Great Lakes; and (2) to investigate methods for achieving the proposed objective. In 1978, a second Chlorine Objective Task Force was constituted to assess the economic and social implications of achieving the chlorine objective and to evaluate alternative disinfectants for use in achieving the objective. A MERL staff member actively participated on the second Task Force in the past year. A final report is being drafted and should be available to the public early next year.

Analysis of Bio-available Phosphorus

Control technology for limiting phosphorus inputs into natural waters is becoming more refined. As these inputs diminish it would appear important to measure the fraction of total phosphorus that might readily stimulate the growth of algae.

Clarkson College, Potsdam, New York, is experimenting with a Dual Culture Diffusion Apparatus (DCDA) shown in Figure 15.

Figure 15. Dual culture diffusion apparatus.

The sample to be analyzed is placed in one half of the DCDA. The other half contains a defined algal culture. The two halves are separated by a membrane which allows only soluble constitutents to interchange between the two halves. The measured accumulation of phosphorus in the algal portion of the apparatus yields an estimate of the bio-available phosphorus liberated by the sample under the test conditions. Results are being correlated to chemical tests for rapid estimation of phosphorus bio-availability.

Samples for analysis were obtained from a field survey of four municipal treatment plants located in the Great Lakes drainage basin.

Oxygen Transfer Standard

A voluntary Subcommittee formed under the American Society of Civil Engineers' (ASCE) Technical Council on Codes and Standards and partially sponsored by EPA has been working since early 1978 to develop a tentative interim oxygen standard and/or procedural manual. The effort was initiated with a state-of-the-art workshop in April 1978 and will culminate in the spring of 1980 with the completion of an interim report. This report will cover the Subcommittee's recommendations on: (a) Modeling and Data Interpretation, (b) Clean Water and Unsteady State Tests, (c) Respiring System Field Tests, (d) Alpha, Beta, and Temperature Corrections, and (e) The Effect of Geometry and Mixing on Scale-up. If and when these recommendations are adopted as a final consensus oxygen transfer standard, uniform recognized procedures will be available to enable equitable comparative testing and data interpretation from one test site to another.

European Aeration Survey

An on-site survey of second generation fine bubble diffuser installations in the United Kingdom was conducted during September-November 1979. The survey was carried out for EPA by the U.S. Association of Metropolitan Sewerage Agencies (AMSA) in cooperation with the Water Research Centre of Stevenage, England. The objectives of this project were to review, evaluate, and document the operating and maintenance experiences of approximately ten treatment plants utilizing fine bubble ceramic dome diffuser systems arrayed in total floor coverage patterns. Emphasis was placed on collecting data related to headloss buildup and diffuser clogging rates, associated diffuser cleaning techniques, preferred diffuser and blower design configurations, operating power consumption, and process performance. These data will be compared to the minimal information available on similar sys-

tems in the United States and also with coarse bubble diffuser operational data and costs for publication in 1980.

Full-Scale Aeration Evaluation

Three types of fine bubble submerged air aeration systems will be evaluated over a 2-year period in full-scale aeration trains of the Los Angeles County Sanitation Districts' (LACSD) Whittier Narrows Plant. The three systems selected are ceramic dome diffusers, plastic tube diffusers, and jet aerators. The selection was based on the results of earlier clean water unsteady state oxygen transfer tests conducted by LACSD on various aeration systems including both fine and coarse bubble devices. The data to be generated in the second phase field study are divided into three categories: (a) long-term diffuser headloss and maintenance studies in mixed liquor, (b) oxygen transfer under respiring biological environmental conditions, and (c) process performance as a function of organic load. System design is underway with startup scheduled for the spring of 1980.

Deep Shaft Project Underway

The first municipal Deep Shaft pilot demonstration system in the United States started up in October 1979 at Ithaca, New York. The Deep Shaft process was originally conceived and developed in the United Kingdom and later refined in Canada where several systems are now operational. The unique features of Deep Shaft are the use of flotation to achieve final clarification and the injection of air to drive mixed liquor circuitously through a U-tube to create a vertical activated sludge reactor. In addition to savings in land and reactor volume, claimed advantages of the process include reduced power consumption, reduced excess sludge production, and the creation of a concentrated waste sludge that does not require separate thickening prior to handling and disposal. The Ithaca shaft is 18 in. (0.5 m) in diameter by 435 ft (133 m) deep and has a design capacity of 200,000 gpd (757 $m^3/day/m^2$) at a nominal detention time of 38 minutes. Operating and performance data will be collected over a planned 16-month experimental program which will terminate in March 1981.

ABF Project Nearing Completion

A 15-month assessment of Helena, Montana's existing activated bio-filter (ABF) system will be completed by the end of February 1980. This project represents the first full-scale comprehensive evaluation of a municipal ABF facility operating at or near the manufacturer's full recommended design organic and hydraulic loadings. These design loadings are 200 lb BOD_5/day/1000 ft^3 (3.2 kg/day/m^3) on the first-stage redwood bio-filter and 45 minutes of nominal detention time in the second-stage aeration tank. By removing various segments of the secondary treatment facility from service, an experimental program has been carried out which examined: (a) both the bio-filter and the aeration tank at approximately half design load – Phase I, (b) the bio-filter at approximately full design load and the aeration tank at approximately half design load – Phase II, and (c) both the bio-filter and the aeration tank at ap-

TABLE 8. OPERATIONAL & PERFORMANCE SUMMARY OF ABF PROJECTS*

Parameter	Phase I	Phase II	Phase III
Dates	12/1/78-2/22/79	2/23/79-7/12/79	8/13/79-9/13/79
Duration (weeks)	12	20	6 (partial)
Flow (mgd)**	3.67	3.75	3.48
Final Eff. BOD_5 (mg/l)	15	21	26
Plant BOD_5 Removal (%)	91	86	84
Final Eff. SS (mg/l)	10	24	27
Plant SS Removal (%)	92	86	85
Bio-filter Organic Loading (lb BOD_5/day/100 ft^3)***	91	184	177
Nominal Aeration Time (min)	110	104	56

*Project summary through September 1979
**1 mgd = 3785 m^3/day
***1 lb/day/1000 ft^3 = 0.016 kg/day/m^3

proximately full design load – Phase III. Phases I and II are over, and as expected, the ABF system performed satisfactorily. Effluent quality for Phase III is more than meeting a 30/30 BOD_5/suspended solids standard after the first 6 weeks, with the critical 1979-80 winter months still to go.

Trophic System Project Completed

An evaluation of the Max Planck Institute (MPI) system has been completed at the Moulton Niguel (California) Water District. The MPI system consists first of two filter trenches filled with three layers of gravel (15 cm of 5 cm gravel overlain by 30 cm of 2 cm gravel overlain by 7½ cm of pea gravel) topped with a 7½ cm layer of sand in which the reed *Phragmites* is planted and actively growing. Perforated plastic pipe at the bottom of the filter trenches transport first-stage effluent to a single second-stage polishing elimination trench filled with gravel and planted with bulrushes. Studies were conducted with both screened raw wastewater and extended aeration plant effluent used as system feed. Influent flow was alternated on a daily basis between the two first-stage filter trenches to allow for a period of drying and stabilization of the organic matter trapped on and in the filter.

Although substantial nitrification was observed, insufficient overall nutrient removal occurred to justify utilization of the MPI system in a tertiary treatment mode. As a secondary treatment option receiving raw wastewater feed, Moulton Niguel's system was able to consistently meet the Federal 30/30 BOD_5/suspended solids standard with hydraulic loadings of 15,000-25,000 gpd (57-95 m^3/day). Some form of effluent disinfection would be required where a bacteriological standard was imposed. Although additional research would be beneficial in the areas of plant harvesting and filtered sludge removal, the MPI system offers the small community a low-energy treatment alternative with minimal mechanical maintenance needs.

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Physical-Chemical Treatment Section

During the past two years, the emphasis of the Section has been shifted from research on physical-chemical treatment processes to investigations of toxic or hazardous compounds, organic and inorganic, in wastewaters. Thus research results will be presented both on physical-chemical studies which were completed during the year and preliminary results just now becoming available on toxics research.

Physical-Chemical Process Research

A report is available on the operation of a series of physical – chemical systems, during the period from June 1975 to January 1978, located at Rosemount, Minnesota. During the demonstration period, the facility treated an average flow of approximately 0.25 mgd (946 m^3/day) by a treatment system consisting of chemical clarification, filtration, carbon adsorption and ammonia removal by clinoptilolite. Both the activated carbon and the ammonia ion-exchange media were regenerated on-site. Performance data are summarized according to five process flow schemes. Cost data developed from this small demonstration were used to estimate the cost of operation and maintenance of a 10 mgd (38,000 m^3/day) facility. The study demonstrated that despite considerable fluctuations in raw wastewater influent, the treatment efficiency did not vary significantly in terms of percent removal which during the two-year period averaged 93 percent for BOD, 99 percent for suspended solids and 94 percent for phosphorus. Formation of sulfide was encountered when the carbon contactors were operated in a downflow mode, but the study showed that this problem could be controlled by addition of sodium nitrate and by daily backwashing of the columns. The capital and operating cost of a 10 mgd (38,000 m^3/day) facility similar to the demonstration system was estimated to range from $0.56 to $0.83 per 1000 gal (3.785 m^3).

The study showed that a physical-chemical system is fully capable of producing consistently not only a high quality effluent in terms of BOD and suspended solids but also an effluent low in both ammonia nitrogen and phosphorus. The cost of this system compares favorably with the cost of biological systems producing an effluent of equal quality.

In another report, the operation of a 5 mgd (19,000 m^3/day) physical-chemical tertiary plant at Piscataway, Maryland, is described. Effluent from an activated sludge plant was treated by lime, precipitation either single- or two-stage – followed by dual media filtration and activated carbon. Significantly, the single-stage lime treatment produced results similar to the two-stage system but at approximately one-half the dose of lime. Lime was recovered by calcination in a multiple-hearth furnace, while the combustion gases were used for recarbonation.

The carbon system consisted of three parallel trains of two columns, each column providing 18 minutes of empty bed contact at a hydraulic loading of 6.5 gpm/sq ft (265 l/min m^2). Carbon was regenerated in a multiple hearth furnace. Three

regenerations of the carbon were accomplished during the project period. Because of difficulties in obtaining accurate measurements of carbon, only estimates of carbon losses incurred during transfer and regeneration could be obtained, which were 8-10 percent per regeneration cycle.

The operation and evaluation of this full-scale tertiary system – biological treatment followed by a physical-chemical series of processes – demonstrated that a very high quality of effluent is produced which is suitable for a variety of reuse purposes.

Granular media filtration is considered to be one of the most important tertiary processes for plants to meet the requirements of minimum monthly average effluent quality of 30 mg/l for suspended solids and BOD, established by the Environmental Protection Agency in 1973. The filters are particularly useful for small plants, 5 mgd (19,000 m^3/day). A report has been prepared on a study of the clarification efficiency of eight full-scale tertiary granular media filters. The results of this study are described in more detail elsewhere in this progress report under the heading "Tertiary Wastewater Treatment."

Toxics Control

More recent activities of the Section have been concerned with toxics in publicly owned wastewater treatment plants. Studies initiated during the past one to one and one-half years are only now beginning to produce results for the several objectives of the program. The first objective is the development of a data base on the occurrence and concentration of priority pollutants entering the Nation's wastewater treatment plants. Three studies were funded for this objective, with only preliminary data available at this time.

A second objective in the research on toxics is the determination of the treatability/removability of priority pollutants (Figure 16). Pure compound research to determine treatability is being conducted on phenomena such as activated carbon adsorption, biodegradability, volatility and ozone oxidation. This research is being supplemented by pilot-scale studies to determine removability by treatment systems. Initial pilot plant studies will investigate removals obtained by conventional activated sludge systems. Mass balance calculations, obtained from analyses of influent, effluent, sludges and air emissions, will indicate the predominant mechanisms of removal; volatility, biodegradation or sorption on the sludge. It is likely that all these mechanisms of removal, plus others such as precipitation, hydrolysis, etc., will be involved.

A third major objective is evaluation of modifications to conventional processes for the enhanced removal of toxics. One of the more promising approaches is the addition of powdered carbon to a biological reactor. The study will include, besides carbon, other solid additives such as chars and powdered coal.

Figure 16. Modification of chemical extraction of priority pollutants.

A major benefit that will be derived from the above investigations, is the development of analytical procedures for trace organics and metals in such "difficult" media as raw wastewater and sludges. Without this analytical methodology, research on the priority pollutants would be severely hampered.

One of the major studies on development of data bases is a survey of 25 cities for all priority pollutants in a variety of treatment plants located throughout the country. This study is being coordinated with and will be complemented by a 40-city survey being conducted by the Office of Water and Waste Management in Washington. Thus, sampling a total of 65 cities located throughout the country and representing a wide variety of treatment processes and influent com-

position (industrial/municipal waste mixture) will provide an ample data base for the occurrence and removal of the priority pollutants in POTW's.

Some very early results show that some 61 priority pollutants have been found in wastewater influents; comprising 31 base/neutrals, 21 volatile and 9 phenolic compounds. Removals are highly variable, 16 to 99 percent, not unexpected considering the great diversity of chemical compounds on the list. Early evidence also shows substantial accumulation of compounds in the sludges, particularly the substituted benzenes such as methyl- ethyl- and chlorobenzenes. While the lower molecular weight phthalates were removed, probably by biological degradation, the higher molecular weight compounds, such as bis(2-ethylhexyl) and butylbenzylphthalates tended to accumulate in the sludge, presumably because of their lesser biodegradability and greater sorption on sludge.

Within the next year much will be learned about the presence and behavior of priority pollutants in municipal wastewaters as the results of these studies unfold.

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TECHNOLOGY DEVELOPMENT SUPPORT BRANCH

The Technology Development Support Branch provides technical and support services to the Division. It operates and maintains pilot plants and provides analytical services to all Division technology development operations. It is composed of the Pilot and Field Evaluation Section and the Waste Identification and Analysis Section.

Pilot and Field Evaluation Section

The Pilot and Field Evaluation Section is responsible for conducting most of the WRD pilot plant studies. These are conducted with U.S. EPA personnel at the Test and Evaluation Facility in Cincinnati, Ohio and under contract with the Los Angeles County Sanitation Districts, Los Angeles County, California. In addition, personnel of this Section manage the national program in Instrumentation and Automation for Wastewater Treatment Systems. Some of the instrumentation and automation work is conducted at the pilot plant facilities mentioned above, but most is implemented through contracts and grants.

During this year construction of the new Cincinnati Test and Evaluation Facility was completed. This facility provides over 30,000 square feet of experimental, pilot plant, laboratory and office space. It was designed to serve as a multipurpose facility for environmental technology research, and will be the main site of MERL pilot plant studies (Figure 17). The MERL projects selected for the Test and Evaluation Facility are:

1) A determination of the fate of the organic substances on the priority pollutant list once they gain entrance into the municipal wastewater collection system. The major objective is to determine the sinks

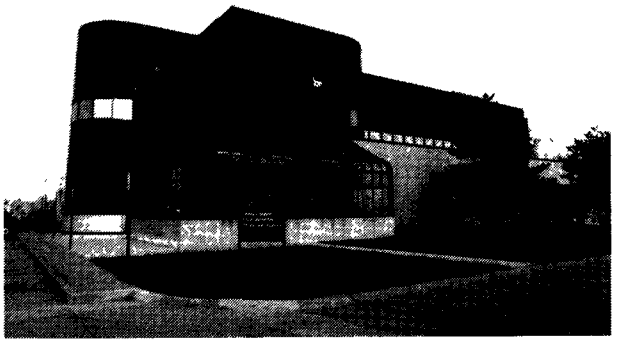

Figure 17. The U.S. Environmental Protection Agency Test and Evaluation Facility in Cincinnati, Ohio.

for those substances which are not biodegraded, and the degree of removal of priority pollutants which can be expected prior to the discharge of wastewater to the environment.

2) An evaluation of the effect of adding sanitary landfill leachate to municipal wastewater. The purpose of this study is to determine if it is feasible to treat leachate by putting it into the municipal collection system. A primary concern is the potential for activated sludge upsets caused by leachate.
3) A comparative evaluation of several types of Ozone Contactors. The major purpose of this is to develop mass transfer kinetic data on various types of ozone sewage contactors. These data can then be used by engineers and regulatory officials to reach cost effective decisions on the use of ozone for disinfection of sewage.
4) A comparative evaluation of sludge dewatering equipment. The purpose of this study is to develop information on the performance of pilot scale dewatering equipment such as vacuum filters, various types of centrifuges, and various types of belt pressure filters in parallel on the same types of sludges.

Provisions have been made in this facility for cooperative projects with the other Cincinnati EPA Laboratories, and to allow for quick response to special needs of the regions and operating programs. Development of one or more cooperative projects is anticipated in the next year.

Under the contract with the Los Angeles County Sanitation Districts three projects were completed in the past year. An evaluation of a rotary kiln for regeneration of granular activated carbon was conducted. It was found to achieve the same results as a multiple hearth furnace at about the same cost. The rotary kiln has a lower capital cost but higher operational expense. An evaluation of dechlorination with sulfur dioxide indicated that state-of-the-art control systems can function adequately to automate the system provided the chlorine residual probe is periodically exposed to some residual chlorine. If it is not, it loses its sensitivity to a chlorine residual. Shortly after dechlorination coliforms reappear in the effluent. It was found that this was *not* regrowth but rather an infestation from naturally occuring coliforms in the air and soil. The third study involved test tank evaluation of various generic types of aeration equipment. It was found that 2 types of fine bubble diffusers had markedly superior oxygen transfer capability. These will be tested in LACSD treatment plants to determine if clogging occurs and the actual power savings potential.

The Lebanon Pilot Plant was closed this year coincident with the Test and Evaluation Facility opening. Prior to the close some short studies on anaerobic digestion were completed. In one of these powdered activated carbon was added to anaerobic digestion systems. Contrary to claims reported by others it had no positive effect on process performance over the detention time range of 30 days to 5 days. A second study evaluated the kinetics of volatile acid production in anaerobic digestion. These data will allow construction of a new time dependent model of this process. The model will be used in computer simulation optimization studies.

Automation and Instrumentation Program

The basic purpose of this program is to develop and demonstrate automation and instrumentation which will improve performance and economics of wastewater treatment plants. The foundation of the program is fostering the use of reliable cost effective instruments. Because field surveys have often indicated customer dissatisfaction with the performance and reliability of many instruments, an instrument certification program has been initiated. One aspect of this certification program is development of protocols for instrument testing and certification. These are being developed for various types of flow measurement devices and selected chemical analysis instruments under an IAG with the National Bureau of Standards. The protocols will address: evaluation of manufacturers specifications for adequacy in the application of the instrument to the wastewater area, bench test pro-

cedures, maintenance procedures, and field evaluation procedures. The protocol for venturi type flow measurement devices will be published in the early part of 1980. These protocols will enable professionals in this field to make rational judgements on purchase specifications and acceptance tests for instrumentation.

A second objective of this program is to promote the establishment of a certification center or laboratory at which instrument testing can be conducted. The protocols developed under the NBS program described above would be utilized by this testing center. Such a center would preclude the need for individual organizations to test instruments and would thus serve as a center of information on environmental instrumentation. Public Technology Incorporated completed a preliminary feasibility study of such a center. They recommend that it be set up as a private nonprofit organization which tests instruments and makes its results available only to its members. Instrument manufacturers could have their instruments tested for a fee but could not be members. A "cooperative agreement" is now being considered for the next stage which will involve detailed planning of the organizational structure, staffing, physical facilities and cost evaluations.

Another major area of concern is the elucidation, implementation and demonstration of process control strategies. Under a grant with the Metropolitan Waste Control Commission of Minneapolis-St. Paul, automation of sludge conditioning, vacuum filtration and incineration is being tested. During this year all of the instrumentation and computer programming necessary to control the latter two devices was completed. In addition a correlation between sludge specific resistance and pH, ORP and shear stress was developed. These parameters can be monitored on-line. Thus as sludge characteristics change, the dose of chemical conditions can be automatically changed to maintain an acceptable rate of sludge filtration. During the coming year the overall automated sludge handling system will be tested in parallel with a manually operated system to ascertain cost effectiveness.

A third major area of effort is in the technology transfer area. During this year an automation and instrumentation Design Handbook for Activated Sludge Treatment Plants was completed. This document is intended to serve as a guideline for design engineers and regulatory officials who became involved in the design and/or review of automation and instrumentation of wastewater treatment systems. It includes a description of control strategies now being utilized in the field, and detailed instrumentation diagrams for implementing these. The strategies addressed are not only those for the activated sludge reactor and its sedimentation tank but for all of the liquid and sludge handling processes at a conventional treatment plant. Also included in this document are sections on control theory, generic types of instruments, cost analysis and computer systems. The Office of Water Programs has tentatively approved this document for use in review of designs for construction grant funding. During the next year a technology transfer seminar based on this document will be developed.

Waste Identification and Analysis Section

Analytical Support

Modern computerized equipment is used to provide accurate analyses of a wide variety of pollutants and to handle the increasingly large sample load. Analyses include heavy metals, algal nutrients, total and suspended solids and gross organics in wastewaters and sludges (Figure 18).

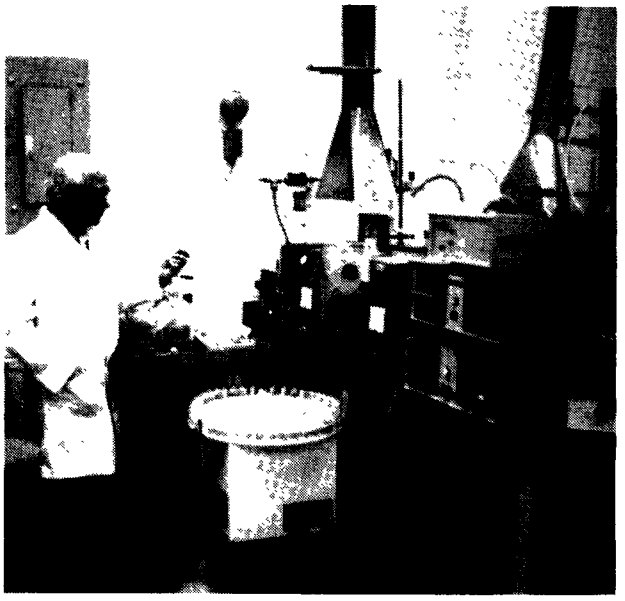

Figure 18. Heavy metals analysis using atomic adsorption.

The several analytical procedures have been developed to support the analytical needs of WRD. The most recent development was the adaptation of the COD test to an automated, computerized autoanalyzer, which provides a more rapid output of COD analyses and quality control data not readily available with manual procedure.

The protocol developed for the analysis of organics in sludges has been used to analyze a

number of sludges generated by the Physical-Chemical Treatment Section. These sludges were a result of a treatability/removability study which involved eight of the volatile and non-volatile priority pollutants.

The Computer Services and Systems Division, in conjunction with contractors, is preparing a sample file control system to be added to our computerized laboratory system. The sample file control will provide us with a more systematized, rapid and efficient way of keeping records of the workload and backlog, and of providing final reports for the requestors. The sample file control will also provide better quality control through the preparation of control charts and statistical data on recoveries, standard deviation, etc. MERL is serving as one of several model systems to demonstrate the utility of sample file control for the entire Agency.

Development of Procedures for Municipal Sludges

Several procedures for the determination of organics in municipal sludges continue to be evaluated. A "unified" procedure involving extraction and centrifugation followed by a chromatographic clean-up, and a modified Bellar technique for the volatiles was tested for the analysis of PCB's, pesticides and the volatile materials in sludges (Figures 19-21).

Figure 19. Continuous extraction of organic priority pollutants.

Figure 20. Priority pollutant extract clean-up using liquid chromatography.

Figure 21. Gas chromatograph/mass spectrometer analysis of organic priority pollutants.

The two alternatives, of base/neutral and acid extractions or acid/neutral and base extractions followed by gel permeation and silica gel chromatography clean-up procedures have been partially successful with sludges but are unsatisfactory for the analysis of all the priority pollutants, particularly some of the phenols. Additional steps such as "base" wash of the acid extract and steam distillation have been tried but are still not satisfactory for all of the phenols.

Landfill Leachate Analyses

Samples of leachates from a landfill in Cincinnati and the LiPari landfill in Glassboro, New Jersey, were analyzed using modification of the sludge analysis procedures on behalf of the Solid and Hazardous Waste Research Division. Results showed the presence of a number of priority pollutants, particularly various phenols and phthalates. One of the most significant contaminants found in the LiPari samples was bis(2-chloroethyl) ether. It is extremely carcinogenic and its concentration exceeded 500 g/l. The presence of this compound in the leachate was confirmed by the Laboratory in Region 2 and investigation showed it to be present in the surface waters in the surrounding area.

Analysis of the Cincinnati sample revealed fewer of the priority pollutants and in smaller concentrations.

Future Support

The Finnigan GC/MS System Model 4023 contains the latest Incos data system and will enhance our present capabilities considerably. The new capabilities will allow us to have three systems operating simultaneously, both analyzing and/or interpreting the data. This should increase our capacity to provide the Division and the T&E Facility with critical organic analytical services needed for toxic studies.

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SYSTEMS AND ENGINEERING EVALUATION BRANCH

The Systems and Engineering Evaluation Branch is composed of the Urban Systems Management Section, the Storm and Combined Sewer Section, and the Systems and Economic Analysis Section. Its programs include the study of methods for improving the design and operation of publicly owned treatment works and for developing approaches to controlling urban wet weather discharges. The Branch is also responsible for providing design methods for rural, institutional and individual home systems for conducting a program for water conservation and wastewater reuse.

Municipal Wastewater Reuse and Water Conservation

The objectives of the Reuse and Conservation Program are the: (1) implementation of research that proves the feasibility of the near term, less controversial, nonpotable use of wastewater to extend valuable water supplies by source substitution, and the longer term, or possible emergency use of wastewater for potable purposes; and (2) the development of data on the advantages and disadvantages of water conservation so that individuals and communities can make informed decisions on implementing programs for their own specific situations. The Wastewater Research Division (WRD) is supporting projects in both of these areas and is coordinating its activities with the EPA Health and Drinking Water Programs, and with other concerned Federal, State and municipal organizations engaged in similar research. A cooperative agreement with the American Water Works Research Foundation (AWWARF) provides for dissemination and exchange of information among participating reuse oriented organizations.

In order to assess the impact of unplanned potable reuse on water supplies, the Office of Drinking Water is using the results of a WRD project whose purpose was to determine the quantity of wastewater present in surface water supplies of U.S. cities of over 25,000 population. Twenty cities with a total population of over seven million were determined to have surface supplies containing from 2.3 percent to 16 percent wastewater during average flow conditions and from 8 percent to 350 percent during low flow conditions.

To assist implemention of reuse opportunities involving the use of reclaimed wastewater for direct recharge of groundwater reservoirs that have been depleted by years of over-pumping, Phase 1 of a project using injection of treated wastewater has been completed at Water Factory 21 in Orange County, California, and a new study involving several methods of recharge has been undertaken on Long Island, New York at facilities of the Nassau County Department of Public Works. Continuous operation and detailed monitoring programs at Water Factory 21 have demonstrated the reliability of advanced wastewater treatment to remove trace contaminants. Data necessary to evaluate the effectiveness of these treatment technologies to remove materials of public health concern is being collected to show that reclaimed wastewater is a viable and safe source of water for groundwater recharge.

Reuse of wastewater for potable purposes has received National attention as an alternative in selected areas for providing an additional source of water to meet expanding water demand. However, many health questions concerning the safety of these waters for use in domestic purposes need answers. As a result of Congressional action, Section 1444(a)(2) of P.L. 93-523, the Safe Drinking Water Act, authorized the establishment of a program to demonstrate the reuse of wastewater for drinking purposes. A $7 million project with the Denver Water Department was initiated as part of this program and will take advantage of most recent advances in treatment technology and includes the most complete health effects program ever considered in relation to reuse. This phase of the program is scheduled to be completed in 1988. In addition, a $4 million, five year program has been initiated and will complement the Denver project by taking advantage of existing municipal treatment facilities producing high quality water to provide more near-term information on the feasibility for potable reuse of systems less sophisticated (no reverse osmosis) than the system planned for Denver. The program will include a thorough evaluation of the treatment effectiveness and system dependability at several sites having: (1) different geographical characteristics; (2) different climatic conditions; (3) different institutional constraints; and, (4) different treatment processes. Health effects studies are anticipated and, because of the shorter time frame for projects in this program compared to the Denver project, they are expected to provide useful input to the design of the Denver analytical and health effects program.

If water conservation is to warrant national emphasis as cited in President Carter's water policy message of June 1978, measurements, in economic terms, are needed on its relative merits. Results of a project with the State of California Department of Water Resources designed to

evaluate the impacts of water conservation practices implemented during the 1976 to 1977 drought on wastewater collection and treatment facilities show no significant adverse effect on these facilities and indicate expected savings in capital costs at a 30 percent reduction in indoor water use. Also, data collected on treatment plant effluent quality indicated the impact of water conservation on wastewater reclamation was not significant.

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Urban Systems Management Section

Treatment Plant Operation and Design

The expansion in program activities during 1979 is evidenced by the change in program title from Operation and Maintenance (O&M) to Treatment Plant Operation and Design Program. Significant progress has been made in improving POTW performance and reliability, reducing construction and operating costs of municipal collection and treatment systems, encouraging energy conservation in plant designs and operation, and providing data and specific support to the Agency's operating programs and enforcement activities.

The Treatment Plant Operation and Design Program provides improved design information in the form of specific design guidelines based on comprehensive cost, engineering analysis, performance and operational studies of existing POTW's as well as emerging treatment processes and techniques. Design manuals and guidance information are developed and specific condensed guidance and checklists are provided to improve the state and federal review process with respect to design, plant start-up, operation, plant trouble-shooting and evaluation techniques. Specific studies identify and document improved process operation and improved unit process and system designs incorporating cost effective, reliable technology.

The detailed findings of the National O&M Cause and Effect Survey have provided the action impetus for decision makers who have made proper plant operation and design their priority concern. The 3½ year study that was conducted nationwide identified and ranked the specific factors causing poor plant performance and developed and implemented an approach, called a Composite Correction Program (CCP), to improve plant performance and move it toward compliance.

Because of the success achieved with the CCP this approach to improving compliance levels of municipal plants is being demonstrated by the State of Colorado on a statewide basis. The objectives of this areawide application of the CCP in the State's enforcement programs are to document the cost effectiveness and management feasibility of the CCP approach to improving performance on a statewide basis, increase levels of compliance, evaluate the integration of private sector technical expertise and state assistance in the implementation of a cost effective compliance/enforcement program, and provide guidance in the development of a state level compliance and enforcement strategy incorporating the CCP approach.

Recognizing that proper plant performance is the critical element in assuring POTW continuing compliance a methodology for conducting comprehensive plant performance evaluations has been developed. The protocol responds to the expressed requirements of the Office of Enforcement and Regional Offices in compliance enforcement activities and will assist the Regional Offices and States that may need to prescribe interim O&M requirements prior to and during major upgrading of existing facilities. The evaluation methodology is applicable to a wide range of plant sizes and types of attached growth and suspended growth biological systems. Specific detailed guidance is given for all phases of the plant evaluation from initial plant contact through presentation of findings and report preparation. The procedural recommendations have been developed and prepared as a user oriented analysis protocol and field manual which will be used by EPA, State or contract investigators who visit plants and submit reports. It

contains instructional descriptions and directions for use including all necessary graphs, figures, tables, forms, and checklists required.

Design of municipal wastewater treatment processes has been further emphasized during 1979. The major focus on design has been the development of the Design Information and Guidelines Series. This Series is a Wastewater Research Division effort, in conjunction with other Agency programs, to provide clear, concise, and up-to-date guidance for process design. The guidelines are intended to include the latest most widely accepted design practice and the most current research results from all old programs. The Treatment Plant Operation and Design Program has taken the lead role in planning and managing the guidelines development program and for developing the format and content of each guideline to be published.

Improving Plant Performance and Design

During 1979 many research projects have been initiated that are directly related to process design. A study of design deficiencies has defined 1,700 instances on which correction modules will be developed for both new designs and existing facilities. The impact of peak flows on process performance has been recognized and a project funded to determine the importance of peak flows for process design. The potential for performance problems in Rotating Biological Contactor (RBC) facilities which reach their design flows has been recognized. This has led to a research project to study RBC performance and design. Performance data and present design criteria at 26 operating RBC plants will be evaluated at design flow and changes in design procedures recommended if necessary. The continuing indictment of in-plant sidestream flows as major causes of poor plant performance has led to a study of the impact of these flows on mainstream process performance. This project includes the characterization of 23 separate sidestreams and the development of operational procedures and design guidance to minimize the impact of sidestreams.

Comprehensive dye tracer studies on eight common types of secondary clarifiers have revealed the complex phenomenon controlling clarifier performance. Although all of the phenomenon have not been quantified, it is obvious that factors in addition to surface area and weir length are important. Internal physical factors such as size, shape, inlet configuration and sludge removal mechanism have been found to impact clarifier performance. However, there are external factors, such as flow balancing between parallel units and the duration and frequency of peak flows, that may have a greater impact than the internal factors.

O&M costs represent a major commitment that municipalities must make in the future if they are to protect their investment in wastewater treatment facilties. Cost data have been collected in the past, but it has been too general in nature to be of any assistance in the management of plant operations. In cooperation with the Drinking Water Research Division a study has been funded to develop a cost analyses system where both water and wastewater utilities can track their O&M costs. This cost analysis system will be a useful management tool to determine, if possible, reduction in O&M costs are possible.

Reliability projects continue to make progress. A study of the impact of toxic organics on activated sludge process reliability is determining what concentration of toxic organics can be received by the process before overall performance is affected. Data on the reliability of mechanical components has been collected and analysis of this data is proceeding. From these results, reliability design guidelines will be developed which will incorporate reliability concepts into the design and operation of municipal facilities.

Improving Plant and Systems Management

The Wastewater Treatment Process Computerized Data Base, containing extensive data on over 300 facilities, is operational. Data from the 1978 Needs Survey is being incorporated so that information on national trends in wastewater treatment technology can be developed. Customized reporting and plotting programs are being developed by the WRD staff as information requests on the data base are received.

Research in instrumentation and automation has concentrated on development of new or verification of existing control strategies for the activated sludge process and selected sludge handling stabilization techniques. These areas are most important because of the large expenditures scheduled for these processes under the construction grant regulations. Emphasis has been placed on demonstration of the control strategy concept, and deliniation of improvements in process performance and/or process cost effectiveness. For the activated sludge process emphasis has been placed on strategies involving dissolved oxygen level control, and instantaneous food-to-microorganisms ratio control (F/M). The major recent effort was to produce a design handbook which could be used to aid engineers in designing the most cost effective systems. This recently published manual dis-

cusses the various activated sludge modifications, aeration methods, equipment and application techniques, compressors and blowers, D.O. control methods, and presents an economic analysis of manual versus automatic D.O. control. Under automatic D.O. control power savings of over 10 percent were achieved as well as improvements in BOD removals.

Studies of centralized managment of waste treatment plants are investigating potential O&M cost reduction and improved performance through changes in operational modes, resources allocation, administrative procedures, and institutional structures. Specific functions which may be impacted include the following: performance monitoring and control, preventive and emergency maintenance, laboratory analysis, training, personnel administration, accounting, purchasing, billing, spare parts control, regulatory reporting and liaison.

For each function, a variety of centralized approaches are possible. Studies are defining these alternatives and estimating the relative changes in costs and plant performance. Initial emphasis has been placed upon changes in operational control, including evaluation of remote telemetry, automated monitoring, microprocessors, and various circuit rider schemes.

Small Flows

Implementation of the Clean Water Act Amendments of 1977 (PL 95-217) has directed considerable attention to the continuing efforts of the Small flows Research Program.

The impact of the 1977 Clean Water Act on program activities has been: reassessing of research priorities and objectives to meet the immediate needs of engineers, planners, and regulatory authorities; providing technical assistance to a diverse array of people involved with small scale technologies for wastewater treatment and disposal; and instituting a series of seven Technology Transfer design seminars across the country on rural wastewater treatment alternatives.

The Small Flows Research Program has three main objectives. These include: (1) improved, cost-effective methods of planning, design, construction and management for small community wastewater systems; (2) evaluation of alternative technologies, with respect to performance, costs, applicability and limitations, and environmental impacts; and (3) development of new concepts for waste utilization, recycling, treatment and disposal which are commensurate with society's goals in the 21st Century.

In past years the majority of program resources has been devoted to the evaluation of alternative technology for small communities. Ongoing efforts in this area include studies of composting toilet and graywater system performance and public health risks through a grant to the California Water Resources Control Board. A continuing grant to the Oregon Department of Environmental Quality which is providing data on a variety of alternative on-site wastewater systems has produced several designs which are performing well in the field and has provided information on some less successful alternatives. A study which documents the costs, performance and success of several alternative blackwater systems installed in Appalachia six to eight years earlier has been completed. Of the seven alternatives installed, those systems employing conventional toilets and septic tanks followed by soil absorption or sand filters were found to have performed best, while recycling and incinerating toilets were generally unsuccessful due to high operation and maintenance requirements which often resulted in abandonment by the users.

Two studies of septic tank pumpings (septage) disposal at wastewater treatment plants were completed by the University of Lowell. The first documented the effects of receiving this waste in the plant mainstream on primary clarifiers and on biological processes without primary clarifiers. As a result, the recommended septage loading for extended aeration plants with sufficient aeration capacity is as follows:

% Design Wastewater Loading	Recommended Continuous (% Volume) Septage Load
25	3
50	2
75	1
100	0

Slug loads are permissable, but at one-half the rate shown above. The second study showed that septage could not be vacuum filtered, even with chemical conditioning. However, mixtures of 20 percent to 50 percent septage with thickened waste activated sludge, preconditioned with alum, iron or acid, were amendable to vaccuum filtration. The cost of handling septage directly in the sludge stream of a small wastewater treatment facility appears to be lower than the mainstream addition. Three other studies have been completed on septage management by composting, anaerobic digestion, and a variety of other systems based on a nationwide survey.

Other continuing studies include the demonstration of improved construction techniques for soil absorption systems at the University of

Wisconsin, a study of the cost competitiveness of innovative household evaporation systems, and a desktop study of the costs, performance and applicability of alternative on-site technologies.

State-of-the-art reports on pressure and vacuum sewers have been developed, and numerous demonstration projects have been completed that deal with these technologies. Recently, a project was completed that was designed to collect data on cost, performance, operation and maintenance requirements, and type of treatment provided for a number of pressure sewer installations in operation across the country. Another project has been completed which documents the performance of a small physical-chemical treatment plant with nitrification in packed towers.

In response to the needs of the EPA Construction Grants Program several studies have been undertaken to improve the grants process as it applies to small communities. A project has been completed which offers guidance to facility planners (Step 1) on how to develop the most cost-effective wastewater management for small (<3,500 population) communities. Another continuing project is developing a manual of on-site alternative systems for this application. A grant with Pennsylvania State University is attempting to quantify the value of water conservation systems in restoring to proper operation failing soil absorption systems. Desktop analyses indicate that this approach may be the most cost-effective retrofitting alternative for many cases.

The 1977 Clean Water Act stipulates that a "management district" or other public body must guarantee proper operation of individual systems for them to be grant eligible. In response, the Small Flows Research Program has an ongoing research contract which will include detailed case studies of existing on-site management practices and policies at the local and state levels. An analysis will be made of the appropriateness, effectiveness, and costs of alternative management approaches under different local situations. Recommendations will be outlined for selection and implementation of management structures and techniques.

For future years, it is anticipated that, while basic research will continue to be supported, more emphasis will be placed upon providing improved means of applying low-technology, decentralized alternatives which are viable, cost-effective approaches to ensuring environmentally sound waste management practices for rural and suburban communities.

Innovative and Alternative Technology

The Clean Water Act of 1977 clearly stated that innovative and alternative (I/A) technology was to be promulgated by the EPA through the Construction Grants Program. Several positive incentives, including increased grant assistance, are provided to municipalities which adopt solutions to their wastewater and other waste treatment needs that conserve or recover energy, reclaim or reuse water, recycle wastewater constituents, eliminate surface discharge, or lower total annual costs. The significance of I/A technology is reflected in the projection that one out of every four Fiscal Year 1981 grant dollars will involve such technology. Program Operations Memorandum (POM) 79-3 established four important program support activities within the Agency for I/A technology, of which one, the Technical Support Group (TSG), was located in MERL. The functions of the TSG are primarily to coordinate the I/A program as a central point of contact providing technical assistance to the regional offices and to ensure that technical information on I/A projects is properly disseminated nationwide through the Innovative and Alternative Technology Clearinghouse.

Approximately thirty proposed Innovative or Alternative Projects with accompanying facility plans have been reviewed by the TSG with recommendations submitted to the Regional Administrator through the Municipal Construction Division Director. The number of projects to be reviewed for potential I/A funding have steadily increased with time, and the TSG is now receiving two or three applications per week for review. It is expected that these activities will continue to increase with time.

In addition to formal application reviews, the TSG consults with the Regional I/A Coordinators and the regional ad hoc review groups on a frequent basis regarding details of technical analyses on I/A provisions and eligibility determinations.

A draft I/A Technology Manual was prepared and disseminated earlier in the year, and was revised based on comments submitted from all interested sources. A significant resource commitment was required to develop the draft manual. Not only the TSG staff, but other members of the Urban Systems Management Section, the Wastewater Research Division, and the R. S. Kerr Environmental Research Laboratory contributed significantly to this effort. The manual contains a users guide, I/A screening methodology, cost and energy effectiveness criteria and guidance procedures, as well as 123 two-page fact sheets containing costs, energy, performance, design and other pertinent data.

The purpose of the Innovative and Alternative

Technology Clearinghouse (IATC) is to insure that technical and other information regarding I/A projects is collected and analyzed with results appropriately disseminated. The I/A project information is collected from EPA Regional Office submittals of I/A technology and application clearinghouse records. The data sheets which are submitted are processed through a computerized system, and the summary report is distributed to the Regional Administrators through EPA Headquarters on a quarterly basis. The Regional Offices distribute copies to the appropriate State agencies and other interest groups.

Data which is collected and summarized includes project and set-aside fund status on a State and Regional basis, project classification according to qualifying criteria, and certain additional technical information when appropriate. The Clearinghouse Report also contains project descriptions and other relevant information extracted from the Clearinghouse forms describing pending and approved innovative and alternative technologies.

An I/A Technology public information brochure was developed and is being published. A Technology Transfer I/A Program was developed, and these two-day seminars were provided to each of ten EPA regions. In addition, ten two-day seminars/workshops were provided for federal and state facility plan reviewing officials at ten other locations around the country. Additional presentations have been made for several national and statewide organizations.

The future trends of the I/A technology program at MERL are to become more active in promoting I/A technology, to monitor and document the performance of the I/A systems constructed under the new Construction Grant regulations, to more actively disseminate I/A technology information, and to periodically review and transform to design guidelines the more successful technologies, starting with improved sludge handling and energy savings concepts.

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Storm and Combined Sewer Section

Control and/or treatment of storm sewer discharges and combined sewer overflows (CSO's) are major problems in the field of water quality management. Every time it rains, in the majority of the oldest and largest cities, tremendous volumes of mixed pollution laden urban runoff and raw sewage (CSO) spill into and contaminate receiving waters. Another problem area during wet weather exists due to man's land development activities which have initiated severe, highly undesirable, and damaging alterations in the natural sedimentation cycle, particularly in local areas, by drastically accelerating the erosion-sedimentation process. Over the past decade much research effort has been expended and a large amount of information has been generated, primarily through the Storm and Combined Sewer Section (SCSS).

Storm and Combined Sewer research and development effort has been directed to abatement of pollution loads from CSO. The technology that has been developed for CSO control in many cases has almost direct and complete application for the control of urban stormwater from separate storm drainage systems as well as aspects of sedimentation control.

There has been increased realization that, along with technology development, there is a need to better define the actual effects of wet-weather discharges on receiving waters. Results from work in this area are currently being evaluated. Also, because of the high capital cost of treatment methods, there is an increased effort being undertaken to consider other approaches that have much lower capital cost. These include management practices such as improved street sweeping and flushing of sewers during dry weather to reduce the amount of sediment that would otherwise be removed by the next storm.

Treatment and Control

Due to adverse and intense flow conditions and unpredictable shock loading effects, it has been difficult to adapt existing treatment methods to storm-generated overflows, especially the micro-organism-dependent biological processes. The new physical/chemical treatment techniques have shown more promise in overcoming these adversities. To reduce capital investments, projects have been directed towards high-rate operations approaching maximum loading boundaries by using the swirl, microstrainer, high rate filter, and dissolved air flotation processes. These processes, or combinations of these processes, can be adjunct to the existing sanitary plant or serve as remote satellite facilities at the outfall and the SCS Program recommends their acceptance in the 201 and Innovative/Alternative (I/A) Programs.

Major work in this area during 1979 include pilot demonstrations of the SALA-Magnetics high gradient magnetic separator which were conducted on combined sewer overflow and raw sewage in the Boston area. These tests built on the data from the first phase lab-scale project, with special emphasis on specific design and operational parameters, long-term durability and maintenance problems, and system adaptability to integrated wet and dry weather flow conditions. Results showed the effectiveness of magnetic filters for the dual treatment of CSO and raw sewage. At 90 gpm/ft^2, suspended solid (SS) removals approach 95 percent. A grant proposal from the Detroit Water and Sewer District for the full-scale demonstration of a 1 mgd high gradient magnetic separator is currently being prepared. The SCSS is planning to ride piggy-back on the project with anticipated funding from the Region V 108 Program.

A demonstration project in Boston will evaluate the swirl, helical bend and Teacup solids concentrators.

Source Control and Low Structural Cost Approaches

Nonstructural and low structurally intensive alternatives, termed best management practices (BMPs), offer considerable promise as the first line of action to control urban runoff pollution. By treating the problem at its source, or through appropriate legislation curtailing its opportunity to develop, multiple benefits can be derived. These include lower cost, earlier results, and an improved and cleaner neighborhood environment.

The greatest difficulty faced by BMPs is that the action-impact relationship is almost totally unquantified. It is clear that onsite storage, for example, can be closely related to reduced downstream conduit requirements but the net water quality benefits are far less defined. Similarly, cleaner streets and neighborhoods and enforced legislation will eradicate gross pollution sources but to what limit should they be applied and who will bear the cost? The final answers of cost effectiveness will not be found short of trial implementation. Key demonstration projects in this regard are ongoing this year. At Bellevue, Washington, and Orlando, Florida cost-effectiveness of various BMPs will be evaluated. Austin, Texas has been chosen to demonstrate various types of porous pavements to evaluate their effectiveness

in the control of both flooding and pollution from urban stormwater runoff.

Other significant BMP demonstration projects have been ongoing throughout the year and have yielded important results. A study at San Jose, California has developed sampling procedures to test street cleaning equipment performance in real-world conditions. The street cleaning equipment test showed that different test area conditions affected performance more than differences in equipment type.

In Rochester, New York, the SCS Program is providing technical advisors to Region II and to the Great Lakes Program on a combined sewer overflow project which will evaluate along with other minimal structural improvements an overall BMP program that includes sewer maintenance, catchbasin cleaning and street sweeping practices.

Another BMP project funded in the San Francisco area will investgate the treatment of stormwater runoff in a saltwater marsh. Evaluation will include water, sedment and biological conditions and the preparation of a manual on best vegetative control practices.

An investigation of periodic sewer flushing during dry weather for first flush relief has recently been completed in Boston, Massachusetts. A set of generalized procedures for estimating pollutant loadings associated with dry weather sewage solids deposition in combined sewer systems has been prepared to provide planners, engineers, and municipal managers with technical information so that they can make intelligent informed decisions on potential sewer flushing programs in combination with other combined sewer management controls.

Collection System Controls

Collection system control pertains to management alternatives for wastewater interception and transport. These include sewer separation; improved maintenance and design of catchbasins, sewers, regulators and tide gates; and remote flow monitoring and control. The emphasis, with the exception of sewer separation, is on optimum use of existing facilities and fully automated control. Because added use of the existing system is employed, the concepts generally involve cost-effective, low-structurally intensive control.

The Program state-of-the-art and manual of practice on infiltration/inflow (I/I) identified a significant problem which led to national emphasis on I/I control and fruitful countermeasure research. This year Program developments have included detection methodology and instrumentation; improved materials and improved installation, construction and rehabilitation techniques. Three new user's manuals including a product and equipment guide are available.

It is estimated that over 90,000 miles of new sewage collection pipe, at a cost of approximately $17 billion will be required nationally by 1990. Obviously, even a minor decrease in sewer construction related costs could result in a significant savings in the overall EPA construction grants program and other construction programs.

In San Antonio, Texas a project evaluated the strength increases, corrosion resistance and resulting infiltration prevention from sulfur impregnation of concrete pipe. Since pipe costs are significant, an increase in strength could lead to a decrease in pipe materials and construction costs. A final report is at press. Additionally, the benefits of impregnation as related to I/I reduction will be of major significance to the 201 programs (in lowering treatment and control costs).

The recent withdrawal of AM-9 grout by American Cyanamid has left the I/I rehabilitation program without a reliable product capable of being used with available equipment. Accordingly, there is an urgent need to assess the potential of products for use as sewer sealants. (Several products are currently available which have been identified as being of possible use.)

Last year the Office of Water Program Operations (OWPO) requested assistance from the SCS Program in identifying substitutes for AM-9. Accordingly, the Program entered a project to satisfy this objective. This project will also concentrate on field testing potential grouting materials along with possible equipment redevelopment work.

As a result of this project in conducting the current grouting assessment, the 3M Company has invested $500K on the development of a suitable replacement for AM-9 which can be utilized in existing equipment. This new material is an elastomeric hydrophilic polymer known as CR250. Preliminary field tests yielded excellent results. In-house toxicity tests indicated that CR250 is safe and exhibits no evidence of the neurotoxic characteristics of AM-9 (acrylamide grout).

Two new demonstration projects in cooperation with Regions III and V were started this year to determine the feasibility of relining deteriorated sewers with the new Insituform process. The process involves the use of a flexible polyester tubing inserted into a damaged sewer via an existing manhole. After hardening, a new pipe-within-a-pipe is formed. The basic advantages

are that it does not require expensive and disruptive excavation and it takes the form of a structurally sound pipe.

In the City of Hagerstown, Maryland an ORD funded evaluation will be made on 7,700 feet of Insituform lining funded by construction grants. A similar evaluation is being performed in Northbrook, Illinois.

Receiving Water Impacts

Data on the environmental impacts of urban runoff are being gathered as a first step in developing methodology to quantify pollutant stress and evaluate the impact in relation to receiving water standards and desired uses. Ongoing SCS Program projects as well as case studies of documented receiving water impacts are being reviewed and characterized in a project with the University of Florida. The project is expected to help identify the types of impacts requiring further verification and the research needed to quantify receiving water stresses.

A nationwide survey of dissolved oxygen meters indicated that large dissolved oxygen decreases in streams following storms over urban areas are not found in the majority of cases. The greatest effect is found in streams where the dissolved oxygen is already somewhat depressed from dry weather discharges. One river showing a measurable effect in dissolved oxygen from urban runoff is the Scioto below Columbus, Ohio. A more detailed dissolved oxygen study of a stretch of that river will be conducted in 1980. The study will provide data for verification of oxygen balance models.

A sediment transport model has been adapted to urban runoff particulates and has been checked approximately with solids data from the Cuyahoga River. Further verification of the model might be carried out on the Scioto River.

Systems and Economic Analysis Section

This group carries out a wide variety of mathematical and statistical analyses in support of other efforts within MERL.

Total phosphorus loading from municipal wastewater treatment plants to the Great Lakes was estimated together with the cost of alternative treatment strategies for the International Joint Commission (IJC). The IJC list of plants greater than 1.0 mgd numbered 325 plants for all the Great Lakes and 199 plants for Lakes Erie and Ontario. The plant size distribution was fit with a log-normal probability density function to estimate the number of plants in any size range below 1.0 mgd. The total number of plants was 974 for all the Great Lakes and 645 for Lakes Erie and Ontario. Total plant flow was 4258 mgd for all the great Lakes and 3085 mgd for Lakes Erie and Ontario. Treatment alternatives considered were (1) chemical addition in all plants greater than 1.0 mgd, (2) chemical addition in plants between 0.1 and 1.0 mgd, (3) doubling the settlers and increasing the chemical dose by 10 percent in all plants greater than 1.0 mgd, (4) dual media filtration in plants greater than 1.0 mgd, and (5) PHO-STRIP process in plants greater than 1.0 mgd. Assumed effluent quality was 1.0 mg/l P for chemical addition, 0.75 mg/l P for doubling the settlers, and 0.5 mg/l P for dual media filtration following chemical addition. The PHO-STRIP process was found to be competitive with chemical addition in the larger plant sizes when the influent phosphorus concentration was relatively great, but for the 5.8 mg/l P influent phosphorus assumed for present conditions the cost advantage never exceeded 20 percent. Thus, PHO-STRIP was not included in any of the treatment strategies studied. Chemical addition in plants greater than 1.0 mgd was found to be the most cost-effective alternative at a unit cost of about $0.90/lb P removed. Doubling the settlers in plants greater than 1.0 mgd and adding chemicals in plants between 0.1 and 1.0 mgd were about equivalent in cost at about $3.5/lb P removed. The most expensive alternative was dual media filtration at about $7.8/lb P removed. Applying combinations of treatment alternatives to plants grouped by size was also considered with a modest increase in cost-effectiveness shown.

The windrow composting process for wastewater treatment plant sludge has been simulated with a time-dependent mathematical model. The trapezoidal cross-sectional area was divided into rectangular and triangular areal increments (Figure 22) and the model computes the flux of air, oxygen, water vapor, and heat into each increment over each time interval. The pile is assumed to be aerated mechanically with the pressure source at the bottom center of the pile. Although this mode of aeration is not typical, it appears to have a number of advantages over conventional operation and is being pilot tested. Water vapor within the pile is assumed to be saturated at the local temperature. Water vapor and oxygen are transported by advection and diffusion and oxygen is used by the microbiological activity. The rate of microbiological activity is a function of the local temperature and the remaining concentration of biodegradable organic material. Heat transfer is by conduction and by movement of water vapor and air. Heat lost from the boundry with atmospheric air is by convection and by evaporation of surface moisture. Heat transfer to

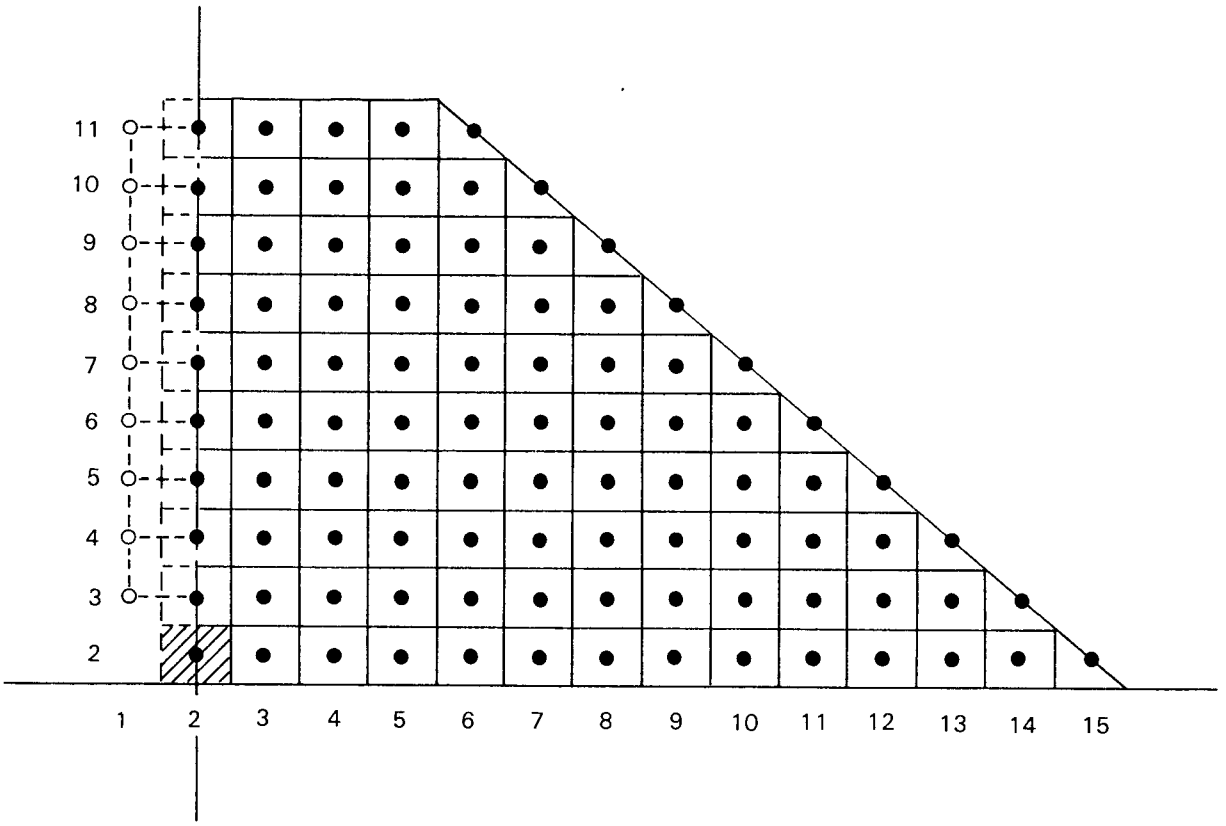

Figure 22. Discreditization scheme for numerical integration of windrow composting performance.

the soil is by conduction. Air flow streamlines are established first and used throughout the time-dependent integration. A time increment of 15 minutes has been found to be satisfactory. Running time on the PDP-11 computer is about one minute per day of real time. Initial runs show that the temperature history of the pile approximates that seen in experimental work with aerated composting windrows.

A study was undertaken to investigate the implications of designing municipal treatment systems on the basis of either cost- or energy-effectiveness. A computer model called EXEC/OP was used to select the least-cost and least-energy designs for a conventional treatment system from over 20 different unit processes that could be arranged into almost 14,000 different configurations (Figure 23). The differences in these designs for variations in design flow, effluent quality, and the price of energy was examined.

Results showed that the gap between least-cost and least-energy designs is reduced as attached growth biological processes are substituted for activated sludge treatment and anaerobic digestion with gas recovery is employed in sludge treatment. These changes can result in significant energy savings at rather modest increases in cost. However, the imputed energy cost associated with these changes (i.e., the price of energy which would make these changes cost-effective) can be much higher than the actual market price. For secondary treatment levels, increases in energy prices are much more influential in making digester gas recovery cost-effective than in making changes in the most cost-effective model of biological wastewater treatment. It was shown how EXEC/OP could be useful in generating several noninferior system designs that offer alternative cost-energy combinations.

A key feature of EPA's national program for controlling toxic materials discharged from POTW's is the establishment of categorical pretreatment standards for industries that utilize municipal treatment systems. Industrial pretreatment standards can be relaxed to the extent that reliable pollutant removal is provided by the POTW. A mathematical decision model for planning cost-effective integrated industrial-municipal pretreatment programs has been developed. The model seeks to determine the degree of industrial pretreatment and POTW treatment needed in a sewer district so that all POTW discharge requirements can be met at minimum cost. The basic premise which it explores is that

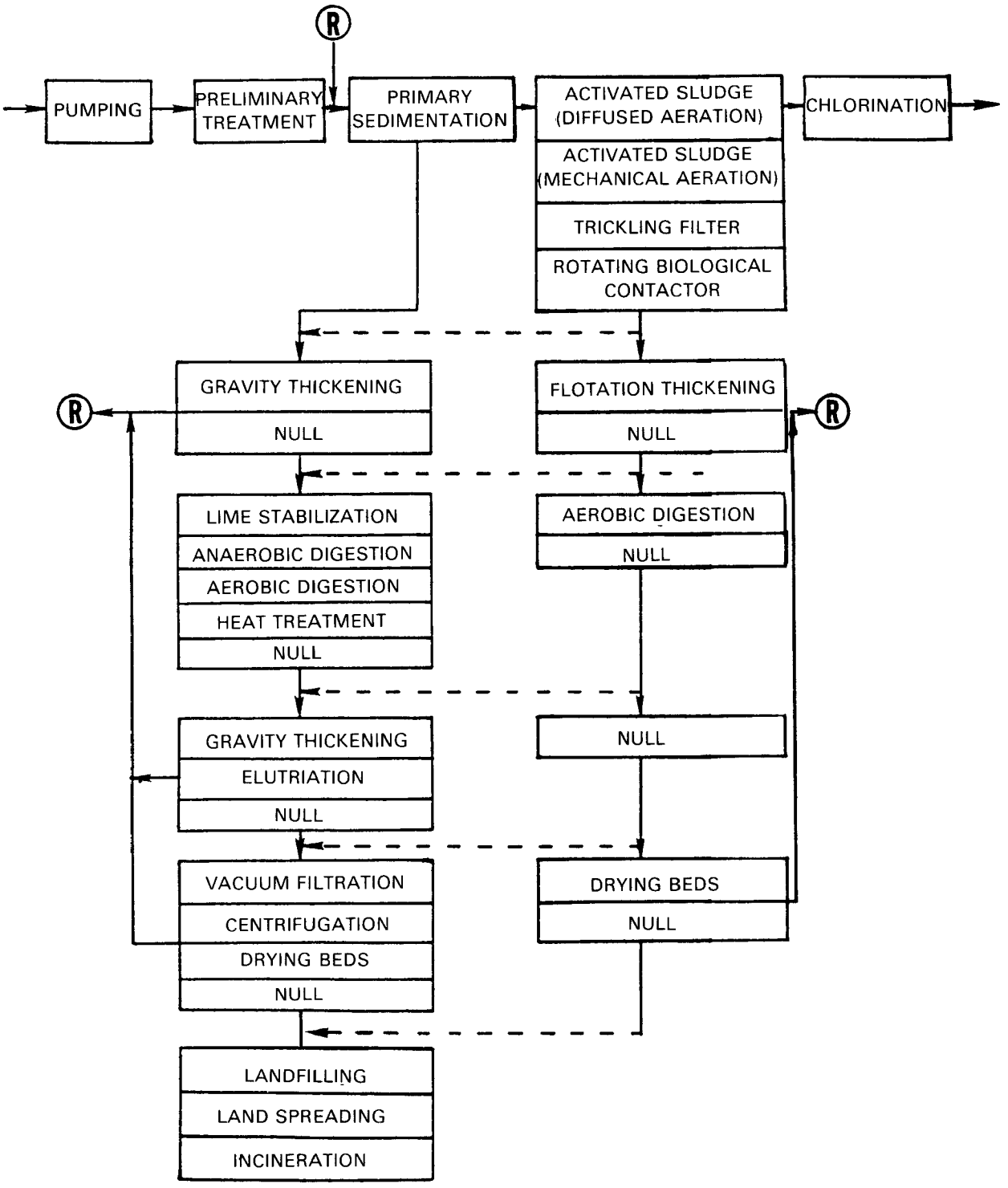

Figure 23. Multi-option flow diagram for conventional treatment system used in the cost- and energy-effectiveness study.

in some situations it may be more economical to have the POTW assume some of the burden in treating toxic pollutants rather than relying entirely on industrial pretreatment. The model is currently classified as a prototype because of several simplifying assumptions used in its de-

velopment. Work is proceeding on integrating our growing understanding of the occurrence and fate of these pollutants into the model's structure and in assessing its utility as a practical tool for effective toxics managment.

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DRINKING WATER RESEARCH DIVISION

The Drinking Water Research Division (DWRD) of MERL determines the occurrence of contaminants and conducts research and development to establish the water treatment and control technology, in accordance with the provisions of the Safe Drinking Water Act of 1974 (Public Law 93-523). The Division maintains liaison with the Office of Drinking Water in the Office of Water and Waste Management so that requirements of the Act can be met in a timely fashion.

The Division Director provides a focal point for the coordination of all water supply activities in ORD, including Municipal Environmental Research Laboratory, Cincinnati, Ohio; Health Effects Research Laboratory, Cincinnati, Ohio; Environmental Monitoring and Support Laboratory, Cincinnati, Ohio; the Environmental Research Laboratory, Athens, Georgia; and the Environmental Research Laboratory, Ada, Oklahoma. The Office of Drinking Water provides resources to these groups for technical assistance to the states, to water utilities, and to the general public.

Major issues that have spotlighted the research effort during the past year include the investigation of treatment practices to minimize the presence of organics in treated water, the examination of treatment technology and associated costs to reduce contaminant levels to those specified in the National Interim Primary Drinking Water Regulations (NIPDWR), the use of disinfectants other than chlorine and the determination of whether harmful by-products are formed, the removal of asbestos fibers from drinking water, the removal of *Giardia lamblia* from public water supplies not using filtration, the development of rapid methods for the detection of bacteria, the relationship of turbidity to disinfection efficiency, the role of viruses in disinfection, and the evaluation of point-of-use treatment devices.

PHYSICAL AND CHEMICAL CONTAMINANTS REMOVAL BRANCH

The objectives of the in-house and extramural research conducted by the Physical and Chemical Contaminants Removal Branch are to develop economic drinking water treatment unit processes to allow a water utility of any size to meet the Drinking Water Regulations, either those presently effective or those contemplated in the future, and to devise techniques to allow the distribution of water to the consumer without deterioration in quality. To accomplish this, the Branch is divided into five research areas: Inorganic Contaminants, Particulate Contaminants, Organic Contaminants, Economic Analysis, and Distribution System Quality.

Inorganic Contaminants

In-house studies and extramural research grant programs on the removal of trace metals and other inorganics listed in the National Interim Primary Drinking Water Regulations (NIPDWR) stressed the development of technology to remove the four significant ground water contaminants that impact small communities: arsenic, fluoride, nitrate, and selenium.

Activated alumina, which has been effectively used to remove fluoride from water, continued to be investigated for the removal of selenium and arsenic. This material was shown to remove selenium IV and VI and arsenic III and V from water under certain conditions. Studies also showed that slightly different regeneration processes for activated alumina may be required for the three contaminants of fluoride, selenium and arsenic. Ion exchange treatment was investigated for arsenic removal and results showed that strong base resins were effective for arsenic V, but not for arsenic III.

Field projects to complement in-house research continued to investigate the removal of all the inorganic contaminants listed in the NIPDWR from ground water by reverse osmosis; selenium from ground water by activated alumina; and nitrate from ground water by ion exchange and reverse osmosis (Figure 24). A new project was also funded to study the effectiveness of conventional package plant systems that have specific application for small communities. A mobile pilot plant housing activated alumina treatment, ion exchange, reverse osmosis, and electrodialysis was developed by the University of Houston. This mobile system will be operated

in small communities to provide practical information for the design and operation of treatment systems for small water supplies. Economic data will also be developed in all of the field projects.

Detailed information on completed jar test and pilot plant studies for trace metal removal by conventional treatment and lime softening is being published in a series of articles in the *Journal of the American Water Works Association.*

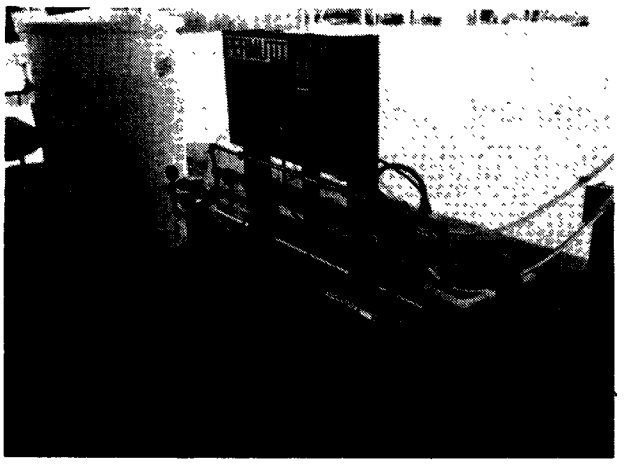

Figure 24. Reverse osmosis for the removal of inorganics from drinking water.

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Particulate Contaminants

Particulate removal studies continued for two types of contaminants – asbestos fibers and *Giardia* cysts. A comprehensive report on water filtration for asbestos fiber removal was prepared in order to explain results reported by other investigators, to provide information for designers of water filtration plants, and to give guidelines for the successful operation of filtration plants that are removing asbestos fibers from drinking water. This document reviews the literature of other investigators (mostly Canadian), summarizes filtration studies funded by U.S. EPA at Duluth and Seattle, and presents monitoring data gathered at water treatment plants in Philadelphia, Chicago, the San Francisco Bay area, and the Lake Superior North Shore.

Results of treatment for asbestos removal are now available for a number of widely separated geographic locations from coast to coast in the United States and Canada, for a wide range of source waters, from a pristine mountain lake to turbid rivers and estuarine waters, and for variations in flow from 10 gallons per minute or smaller to more than 200 million gallons per day and several modifications of granular media filtration.

Data from Seattle and Lake Superior show that chrysotile and amphibole fiber concentrations in drinking water can be substantially reduced by granular media filtration. Reductions of up to 99.99 percent were reported during storm conditions at Duluth, Minnesota. Effective granular media filtration required very diligent plant operation with careful control of pH, coagulant doses, and filtered water turbidity.

When a granular media filtration plant is properly operated, turbidity readings can be used as a guide to fiber removal efficiency even though turbidity cannot directly measure asbestos fibers in the concentrations found at water treatment plants. Filtered water turbidity should be 0.10 nephelometric turbidity units (ntu) or lower to maximize fiber removal. Turbidity increases of 0.1 or 0.2 ntu above this value generally were accompanied by large increases in asbestos fiber concentrations. The 1 ntu Maximum Contaminant Level (MCL) for turbidity is not a satisfactory quality goal if asbestos removal is needed.

Some of the results presented suggest that fiber removal is more easily accomplished when source waters have turbidities greater than 1 ntu, which is the raw water turbidity typical of Lake Superior and Seattle's Tolt Reservoir.

Diatomaceous earth filtration was found effective for asbestos fiber removal in bench-scale and pilot plant studies. A full scale diatomite filtration plant has not yet been evaluated for fiber removal efficiency. Research to date indicates that coating the diatomaceous earth filter aid with aluminum hydroxide substantially increases the removal of both amphibole and chrysotile fibers. Duluth results indicate that filtered water turbidity should be 0.10 ntu for most effective fiber removal.

Research on *Giardia* cyst removal by water filtration continued in the laboratory, with the use of *G. muris,* a mouse parasite, because the human parasite, *G. lamblia,* was not generally available in the Cincinnati area. *G. lamblia* and *G. muris* are similar in size, and both are electronegative (negative zeta potential), so results obtained with *G. muris* should be a good indicator of the behavior of *G. lamblia* under similar conditions.

Diatomaceous earth filtration studies showed that operating technique is important. Cyst removal with a clean filter operating at 1.0 gallons per minute per square foot (gpm/sf) ranged from 99.8 to 99.98 percent. At 1.5 gpm/sf removal ranged from 99.95 to 99.998 percent. Cyst removal at 1.0 gpm/sf by a filter that was not uniformly precoated dropped to 99.36 percent.

Granular media filtration tests utilizing dual media (coal and sand) show that for this kind of filtration proper operating technique is again essential. Bench scale tests with a 1.5 inch (4 cm) diameter f ilter indicated that changes that upset the equilibrium condition in the filter can result in the release of floc and cysts that had been stored in the media, or can result in the passage of cysts through the filter media. Abrupt increases in filtration rate, loss of chemical feed, and turbidity breakthrough at the end of a run all resulted in substantial increases in cyst concentration in filtered water. Small increases in turbidity (0.1 or 0.2 ntu) were associated with increases in cyst concentration of ten to one hundredfold.

When clear waters (1 – 5 ntu) are filtered, treated water turbidity must be well below the 1 ntu Maximum Contaminant Level for turbidity for the most effective cyst removal. Cyst removal generally exceeded 99.0 percent when effluent turbidity was in the range of 0.2 – 0.3 ntu.

Research on *G. lamblia* cyst removal by water filtration is under way in a pilot plant study at the University of Washington. The Drinking Water Research Division is completing construction of a trailer-mounted 20 gpm package plant for use by the University of Washington at various locations in the State of Washington. This work will be done during the 1980 calendar year.

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Distribution System and Water Quality

In-house studies utilizing sections of asbestos cement (A/C) pipe inserted in circulating systems with varying water quality conditions in the different systems have shown that (1) pH 8.2 and zinc concentrations $\leq$ 0.3 mg/l will protect A/C pipe from attack regardless of the zinc compound used to provide the zinc and that even waters with very low calcium concentrations do not attack the A/C pipe when these conditions exist; (2) calcium carbonate saturation of the water will prevent attack on A/C pipe; (3) sodium silicate added to the water can provide protection to A/C pipe; and (4) the same aggressive waters that do not attack the A/C pipe at pH 8.2 with zinc will attack A/C pipe when zinc is not present. A grant with the city of Greenwood, South Carolina showed that a concentration of 0.3 mg/l zinc provides much better protection of A/C pipe than do concentrations of $\leq$ 0.1 mg/l zinc.

Energy dispersive X-ray spectral elemental analyses using the electron microscope show that A/C pipe surfaces protected against attack by coatings, such as iron or zinc, have significant calcium peaks as well as iron and zinc peaks. A/C pipe surfaces showing attack have none or very low calcium peaks and insufficient iron or zinc peaks to indicate protection. The size of calcium peak for the protected pipe depends on the degree of coating. As the coating thickens the calcium peak size will decrease and a heavy coating of iron or zinc could very well eliminate the calcium peak for a protected pipe.

In-house studies on the corrosion of lead pipe are continuing by evaluating control techniques involving pH and alkalinity adjustments. Literature references to lead solubility diagrams had shown that the solubility of lead hydroxide decreased with increasing alkalinity and that minimum solubility occurred at pH 8.6. However,

laboratory corrosion rate meaurements using linear polarization techniques suggested that the protective coatings became more unstable as the alkalinity was increased while maintaining pH 8.5. Computer generated solubility diagrams showing the response of lead solubility to dissolved carbonate later showed that increased carbonate concentration would tend to dissolve lead hydroxide. Furthermore, these solubility diagrams showed that the minimum solubility of lead hydroxide would occur at pH 9.5 at an alkalinity of about 20 mg/l as calcium carbonate. Preliminary corrosion rate measurements appeared to confirm these predictions. Raman Spectroscopic techniques, which have been shown to be capable of analyzing surface films on lead pipes, will be used to corroborate these results.

In a grant with The Metropolitan Water District of Southern California, the EPA Mobile Water Quality Monitoring Labortory was used in a study to evaluate the effects of blending waters of different quality and to relate their composition to the corrosive effects of the water on the system. The mobile lab proved to be an effective tool for data collection at thirty Southern California locations in the Los Angeles area, especially after automation of the calcium deposition tester and modifications to the corrosion test equipment. Corrosion rates were correlated with the Langelier saturation index, the Ryzner index, the calcium concentration and conductivity. The calcium carbonate deposition test (CCDT) could readily detect changes in alkalinity or calcium hardness. The addition of corrosion inhibitors such as zinc orthophosphate could be detected by the CCDT. Although a number of effects of blending waters of various quality were observed during this study, none of the effects of blending imported surface waters with local groundwaters generated any serious problems in water in the distribution systems of the area. This work has now been completed and a final report has been received for publication.

The mobile laboratory was moved to the Lawrence Berkeley Laboratory where it is undergoing extensive updating and renovation under an interagency agreement with The Lawrence Berkeley Laboratory. A new computer and data acquisition system has been received so that all data can be handled at the mobile lab rather than through the outside terminal. After renovation, the mobile lab will be used in a study on corrosion control treatment for the water supply of Seattle, Washington.

Investigations are continuing at the University of Florida to evaluate water quality parameters for establishing a corrosion index that would be more useful in predicting corrosion rates in a metal pipe. Laboratory corrosion rate testing is being done on coupons in forty-eight sample containers under carefully controlled conditions. Data obtained for mild steel showed that corrosion rates in deaerated systems were low compared to those in aerated systems, and that there may be a relationship of corrosion rate to chlorine residual levels. Pipe loops studies using these metals are also in progress.

A laboratory corrosion study at John Hopkins University was completed to isolate the source of lead and other metals present in the drinking water in portions of Carroll County, Maryland. The lead in Carroll County's system is being picked up from the copper pipe distribution systems because lead is not detectable in the source water. The corrosion studies were conducted with copper pipe loops constructed with solders of various compositions to evaluate the effect of various water quality parameters and flow rates on corrosion rates. Test data showed highest lead levels when low pH (5.5), low alkalinity (10 mg/l) and low hardness (10 mg/l) simultaneously occurred. The effect of dissolved oxygen on corrosion rate was present at low pH and negligible at higher pH. Maximum lead levels were achieved within fifteen minutes.

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Organic Contaminants

The basic objective of our field investigations efforts is to evaluate and develop water treatment technology that minimizes the presence of potentially harmful organics in drinking water. The research projects involve organic substances associated with the disinfection of drinking water, such as trihalomethanes and precursors, and specific organic substances that occur in the source waters and are not substantially removed by commonly used water treatment methods. The projects also include evaluation of

the costs required for a given technology, whenever the scale of the project is large enough.

Surface Water Studies

Current investigations include studies of adsorbents, alternative disinfectants and modification of the points of application of disinfection to minimize organic contamination. Also, onsite granular activated carbon reactivation technology is under investigation.

Two extramural research projects on the combination of ozone and granular activated carbon (GAC) as a means of extending activated carbon bed life are expected to have the pilot plants in operation by December 1979. Shreveport, Louisiana will operate a 10 gpm pilot plant and Philadelphia, Pennsylvania will operate a 20 gpm pilot plant.

In-house studies are continuing on the combination of oxidants with granular activated carbon. A pilot scale in-house project is examining the effects of ozone followed by deep bed filtration (to maximize biodegradation of trace organics before adsorption). A parallel study is using hydrogen peroxide as the oxidant to see if the effects are similar to those obtained in earlier studies with ozone.

Granular activated carbon (GAC) studies involving both full-scale gravity contactors and pilot columns are progressing at a site along the lower Mississippi. Four, six-month phases of full-scale operation of gravity GAC beds using lower Mississippi river water have been completed (Figure 25). One bed was operated as a system. Preliminary results were reported in June 1979 at the AWWA in San Francisco, California and at the May 1979 EPA/NATO/CCMS sponsored Adsorption Techniques Conference held in Reston, Virginia. Preparation of the final project report has begun.

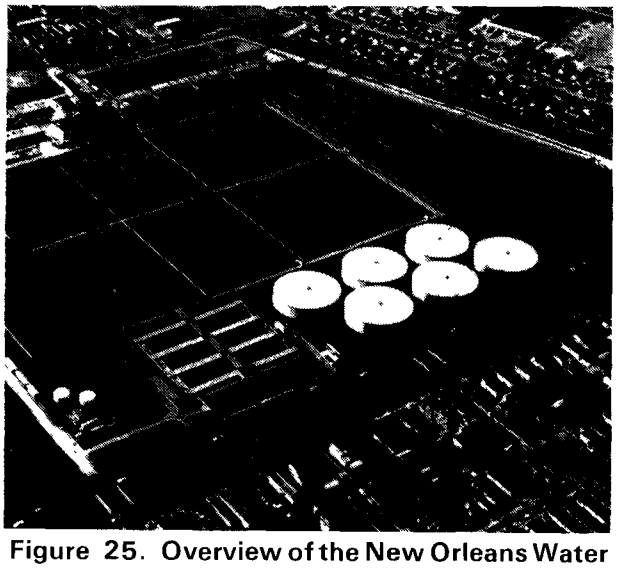

Figure 25. Overview of the New Orleans Water Treatment Plant.

At a site on the Ohio River, a recently instituted second phase of pilot column investigation using two types of carbon operated as post filter adsorbers along with columns operated as sand replacement systems in parallel with virgin and once reactivated carbon has been completed. Construction of the full scale water supply GAC post filtration pressure contactors is complete and one of the four 1 million gallon per day contactors was placed into operation in October. The remaining two will be put into operation at one month intervals. The on-site fluid bed carbon reactivation system is scheduled for shakedown tests and full operation by December 1979.

In 1979, full-scale operation of the on-site fluid bed carbon reactivation systems was begun at Manchester, New Hampshire. The system is reactivating carbon that has been used for surface water treatment.

Studies evaluating the potential of an electric furnace for reactivating granular carbon are nearing completion at the Little Falls, New Jersey site. Thus far, the infrared furnace looks very promising as an alternative to fossil fuel devices. Also encouraging are the indications that simple and inexpensive tests such as iodine numbers and apparent densities are reliable monitors of reactivation efficiencies. On a smaller scale, studies were initiated to compare three different type furnaces for reactivating granular carbon used in a sand replacement operation mode and a project was started to examine the potential for solvent regeneration by supercritical carbon dioxide.

A lower Ohio River study is using the full-scale plant as a control and a pilot plant at this location is being used for comparison of the effects of chlorine and chlorine dioxide disinfection both with and without GAC. Various modes of operation of the pilot plant have been evaluated in short term tests and a mode has been selected for long-term evaluation. Using pre and post chlorine dioxide disinfection, the performance of virgin activated carbon and subsequent off-site regenerated carbon will be evaluated (Figure 26).

Ground Water Studies

Groundwaters, particularly from deep well sources, have traditionally been considered less susceptible to organic pollution than surface waters. Improved analytical procedures, however, combined with more widespread monitoring are showing an alarming number of groundwaters

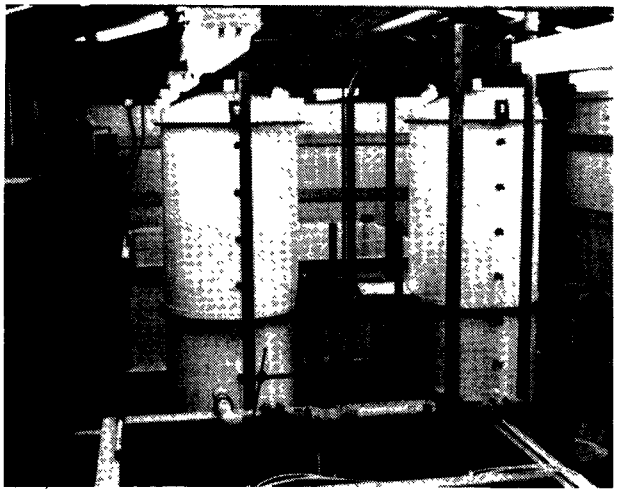

Figure 26. Carbon contactors at Evansville, Indiana.

contaminated with industrial solvents. In almost all cases, the water was being analyzed for other constituents (mainly trihalomethanes) when the solvents were discovered.

Currently (October 1979) dozens of wells serving several thousand people have been reported contaminated in New England, New Jersey, New York (particularly Long Island), Pennsylvania and Florida. California, Arizona, Michigan and Virginia also have reported isolated incidences of ground water pollution resulting from surface activities. More cases are expected as monitoring increases.

For the past two years the Drinking Water Research Division (MERL-Cincinnati) has conducted treatment experiments for removing these solvents from drinking water. Cooperative pilot scale studies with the U.S. Air Force and a utility in Connecticut and one in New Jersey have provided important information on the usefulness of treatment techniques such as aeration and adsorption (Figure 27).

In addition to our in-house activities, an extramural treatment project was started last fiscal year with a utility on Long Island and another indepth project is likely to be funded in New England at a utility that has no alternate source of water.

At the request of Region III, the DWRD participated in a workshop/seminar in Philadelphia, at which the state-of-the-art for treatment of organic contaminated groundwaters was the topic.

Pilot plant testing for the removal of organic contaminants from ground water began this year at Glen Cove, New York (Long Island), where several wells have been closed down. The processes of adsorption by a synthetic resin (XE-340®) and

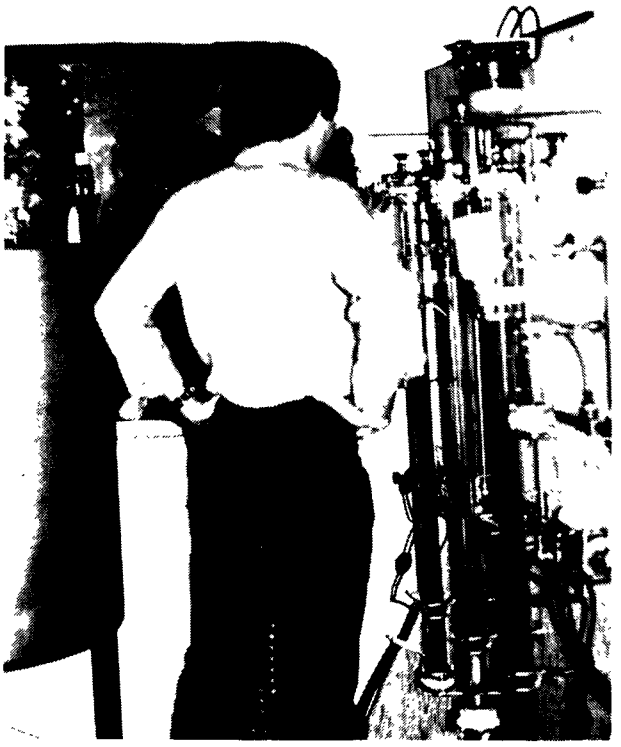

Figure 27. Pilot scale aeration and adsorption units to study groundwater decontamination.

aeration are being investigated as techniques for the effective removal of primarily trichloroethylene and tetrachloroethylene. In situ steam regeneration of the exhausted resin is taking place and represents the first such application for drinking water studies.

A third extramural research project on the combination of ozone and GAC (a 100 gpm pilot plant) will be in operation by December 1979 in Miami, Florida. Preliminary data from the Miami project were reported at the Reston meeting.

General Studies

Research is continuing to investigate the removal of specific organic compounds using GAC. Isotherm and kinetic data are also being generated to be used for evaluation of dynamic adsorption models developed under projects to be compiled in 1979.

Gas chromatographic methods using glass capillary column technology and both flame ionization and mass spectrometric detection have advanced to the point that they are being used to assess qualities of water samples from all stages of treatment including granular activated carbon effectiveness (Figure 28). This technology has

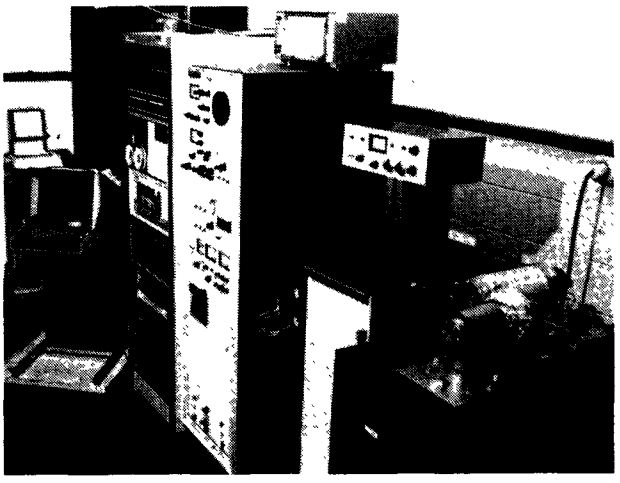

Figure 28. Gas chromatograph/mass spectrometer instrumentation for the confirmation of organics present in water.

now been applied at a number of full scale plants to gain qualitative impressions of unit process performance. A detailed broad spectrum quantitative analysis now seems to be a realistic goal.

Disinfection Byproducts

Organic byproducts of disinfection other than trihalomethanes have continued to be the subject of an intense research effort. Progress has been made on several fronts. Firstly, a three year study, originally designed to determine mechanisms of trihalomethane formation from aquatic humic material, has been successful in compiling more information on humic structures and chlorination byproducts than previously available in the literature, as well as in meeting the initial objectives.

Secondly, work on development of a routine method for measurement of organic substituted halogen has progressed to the point of acceptance of a standardized technique. Organohalides are adsorbed onto activated carbon, the carbon is combusted in a pyrolysis tube under a continuous gas flow, and the resulting chloride is determined by microcoulometric titration. The method and apparatus have been modified and simplified for routine laboratory use. The technique is being used to provide information on the degree of halogen substitution on high molecular weight compounds caused by various disinfectants including chlorine, chlorine dioxide, chloramines, and ozone. This work is being carried out on both laboratory model mixtures and various tap waters. In 1979 an expanded program to investigate the nature of these higher molecular weight disinfection byproducts will be initiated.

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Economic Analysis

Economic factors are to be considered in the implementation of the various provisions of the Safe Drinking Water Act. One of the major economic concerns facing EPA is small systems compliance. Economies of scale insure that small utilities have higher unit costs than do larger utilities. If these small water systems are forced to invest in additional expensive treatment processes, the cost burden may be more than many small communities can afford. Therefore, the Drinking Water Research Division is devoting a significant portion of its economic analysis effort to problems relating to small systems and the

management of technology in small utilities.

For example, the economic analysis unit has conducted a field survey of 10 small utilities in EPA Regions III, V, VI, VIII, IX and X. A report discussing the results of the data collected in Regions III, V and VI has been completed. Another phase of the small systems study deals with the use of package plants as a means of providing cost effective treatment for small water utilities. Package water treatment plants are prefabricated units constructed on site. A study has been completed and a report published detailing the results of a study of 36 small utilities utilizing package plant technology in Kentucky, Tennessee, and West Virginia.

Another important item in the study of water utility economics is that of standardized accounting systems. A cost analysis system that can be used by all utilities has been implemented in Kenton County Water District Number 1, in Kenton County, Kentucky. Included is a financial reporting system that will utilize data from the cost accounting system to generate standardized fiscal reports. A two volume report has been completed; one volume describes the philosophy and implementation procedures for the system and the second volume contains a series of detailed flowcharts that will allow the system to be implemented as a water utility management tool.

The Drinking Water Research Division has recently completed a detailed study of the cost of water supply unit treatment processes. This four volume report contains costs for 99 unit processes. It provides examples of how cost analysis can be conducted; shows typical flowcharts for several of the more common treatment processes; and contains the listing for computer programs that allows these cost data to be used in an efficient manner.

A study has been initiated to analyze the impacts and trade-offs associated with regional water supply systems. A computer model is being developed that allows users to make a realistic assessment of the cost of joining or not joining a regional water supply system.

A study has been undertaken to find an efficient computer-based system for analyzing research data generated from the Division's field and in-house studies. When fully implemented, the system will be interactive, allowing the project officers to manage and analyze their data efficiently and effectively.

Several studies have been conducted and papers and reports completed detailing the costs associated with the treatment of organics in drinking water. These studies are primarily oriented toward the use of granular activated carbon. Costs have also been developed for alternative disinfection systems such as ozonation, chlorination, and chlorine dioxide. A study was conducted in which a selected sample of utilities was studied in-depth to establish a cost record over a period of time and to examine the economic impact of Safe Drinking Water Act.

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MICROBIOLOGICAL TREATMENT BRANCH

The research strategy for the Microbiological Treatment Branch is designed not only to support the implementation of the National Interim Primary Drinking Water Regulations but to begin to lay a foundation of knowledge for anticipated revised regulations. Microbiological research to support these program needs include the broad areas of: 1) disinfection in alternative treatments; 2) water supply distribution quality; and 3) methods development.

Disinfection

Final reports on several primarily virus-oriented studies included studies on the range of resistance of enteroviruses to chlorine and studies of the effects of various kinds of turbidity on the resistance of viruses and bacteria to ozone and chlorine dioxide. A three year study of the effects of virus aggregation on the disinfection resistance of enterovirus, and a field study of the effects of water treatment processes on virus inactivation or removal are being completed.

Overall, the results of these studies indicate: 1) enteroviruses vary greatly in their resistance to chlorine; 2) the presence of inorganic ions can have pronounced effects on enterovirus inactivation rates and also on the aggregation characteristics of viruses; 3) while virus aggregation can cause differences in inactivation rates, extreme protection from disinfectants due to aggregation has not been observed; 4) turbidity can have major effects on enterovirus and coliform disinfection rates, the effects being largely dependent on the type of turbidity present rather than the amount.

Because of its increasing importance as a cause of waterborne giardiasis research on the protozoan etiologic agent, *Giardia lamblia,* and the effects of water treatment processes, particularly disinfection, on the cysts of the organism, was initiated in 1976. Success in development of a culture method for determination of *Giardia* cyst viability has made it possible to conduct the disinfection studies on this organism currently in program. In addition to studies of *G. lamblia,* the species pathogenic for humans, in-house disinfection research on *G. muris,* a related species infectious for mice is being con-

ducted. Reports on several aspects of this research are available and other reports are in press. The proceedings of a Symposium on Waterborne Transmission of Giardiasis, jointly sponsored by MERL and HERL also has been published and distributed. While we do not have precise information on the chlorine resistance of *G. lamblia* cysts, the information thus far developed indicates that the cysts can be inactivated by chlorine. This is contrary to the widespread impression that the cysts are virtually impossible to kill by disinfection. Our Branch participated in preparing a Report to Congress on the current status of information on viruses in water. The report, which will serve as a guide to Congress and the Agency in determining the future cause of virus research related to drinking water, has been published and distributed.

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Distribution System Studies

In addition to providing effective treatment, municipal potable water supplies must be continually alert for contamination problems in their distribution systems and the possible occurence of microbial degradation of water quality and pipe integrity. The persistence of organisms in pipe networks is influenced by a variety of physical and chemical conditions in the water, the type and age of pipe, and the availability of suitable sites for colonization. These sites are often created, in part, by corrosion, turbidity or inadequate treatment processes, including corrosion control.

Problems related to the use of corrosion control chemicals are currently being evaluated. Often the effectiveness of calcium carbonate or orthophosphate as corrosion inhibitors is impeded by flow characteristics, high pH or high sulfate concentrations in the water that prevent the formation of a uniform coating on pipe surfaces. Porous or irregular coatings of these so-called "corrosion inhibitors" can actually entrap and protect bacteria, promote tuberculation and finally enhance corrosion rates. Use of the correct chemical at the correct dosage in any given water supply, is essential for effective corrosion control.

Turbidity in finished water also contributes to sediment accumulations and in some cases, protects the microbial population from inactivation by residual disinfectants. Research programs investigating the effects of turbidity on bacterial survival have, in general, indicated that inorganic particles such as clay and flocculating agents may trap microorganisms, but provide little protective effect against disinfection. In contrast, cell debris, sewage solids, or other organic particulates, can provide microorganisms with protection from disinfection, an attachment site for population growth and a deposit of absorbed nutrients. A striking series of electron micrographs, obtained as part of our in-house effort in this area, very graphically demonstrates bacterial survival and protection in particulates. It appears that microorganisms are predominantly seen at the surface or near-surface areas, where nutrients and oxygen are constantly present.

Bacterial survival and regrowth in distribution systems is an extremely complex phenomenon that is dependent on many interacting conditions. Most of the above mentioned studies have been characterizing bacterial populations that are existing and multiplying in finished water distriBution systems. How these various bacterial populations affect one another is not yet clear, but grouping those identifiable isolates to genera or species, does provide
useful information about the occurrence of bacteria that may have pathogenic significance or that may interfere with coliform persistence or isolation. One current project is studying pathogen survival under varying conditions in an unused section of a full scale distribution system within a military base.

The effects of handling and storage on bacterial densities in potable water samples is being investigated. Often, problems in shipment or transport of samples to an examining laboratory result in delays exceeding the 30 hour recommended time prior to analysis. Changes in coliform and standard plate count populations may occur during this time and would directly impact on compliance with the Drinking Water Standard. Additionally, an attempt to consider all of the above processes and interactions and how they

should impact on sampling frequency in compliance with the National Interim Primary Drinking Water Regulations, is continuing.

In short, microbial quality degradation of drinking water transmitted through distribution systems may be minimized with an effective disinfectant residual. However, this entire effort is superfluous without a good understanding of treatment dosages and a conscientious system maintenance program to present the accumulation of sediment and corrosion products which provide the nutrient substrate and protection necessary for microbial survival.

RELATED RESEARCH PUBLICATIONS

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Methods Development

The agar pour plate procedure for enumeration of the aerobic heterotrophic bacterial count of water (standard plate count) is used to monitor changes in the bacterial concentration of finished water throughout a distribution system. However, the pour plate procedure is limited by the volume of sample that can be examined thus creating a need for a procedure that would allow examination of sample volumes larger than one milliliter. Medium-standard plate count (M-SPC) medium used with the membrane filter technique was developed to permit analysis of sample volumes ranging from decimal dilutions to more than one liter when necessary or desired. Though not yet acceptable as a standard method, the m-SPC procedure generally yields bacterial count results equal to or greater than the standard plate count procedure. A total of 1,970 drinking water samples from 50 different sampling sites were examined by both the m-SPC and the standard plate count procedure in order to establish comparability of the m-SPC medium with the accepted standard method. Commercial preparation of the m-SPC medium is available on special request and results in a significant savings in time and effort over preparing the medium from individual ingredients. By permitting bacterial plate count analysis of samples larger than the one milliliter maximum volume used in the standard pour plate procedure, the number of statistically acceptable sample results should be increased significantly for most users.

Development has been completed on a rapid 7-hour test medium (m-7HrFC) for fecal coliform bacteria. This membrane filter procedure uses a lightly buffered lactose and mannitol based medium and incubation at 41.5°C for detection of fecal coliform bacteria in 7-hour to 7.25-hour m-7HrFC medium can be utilized in an emergency situation to detect gross contamination of potable water due to events such as line breaks or cross-connections.

The 7-hour fecal coliform test can also be used to monitor bathing beach waters. Results from the 7-hour fecal coliform test can be used to judge the necessity for opening or closing bathing beaches to public use. The procedure may also be useful for stream survey work.

RELATED RESEARCH PUBLICATIONS

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5. Allen, M.J. MICROBIOLOGY OF GROUNDWATER. *Journal Water Pollution Control Federation,* 51(6):1743-1746, 1979.
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INTERNATIONAL ACTIVITIES

During 1979 the Municipal Environmental Research Laboratory (MERL)-Cincinnati received 59 foreign visitors representing national and local governments, industry, academic and other institutions from 15 countries. The countries represented by these visitors and the number from each during this period were: Japan, 15; People's Republic of China, 9; Canada, 7; Sweden, 7; England, 4; Poland, 3; South Africa, 2; Netherlands, 2; Mexico, 2; Germany, 2; Australia, 2; and one each from Italy, Switzerland, and Pakistan.

These visitors were interested in all phases of work in MERL. Quite often other laboratories within the Environmental Research Center were also visited.

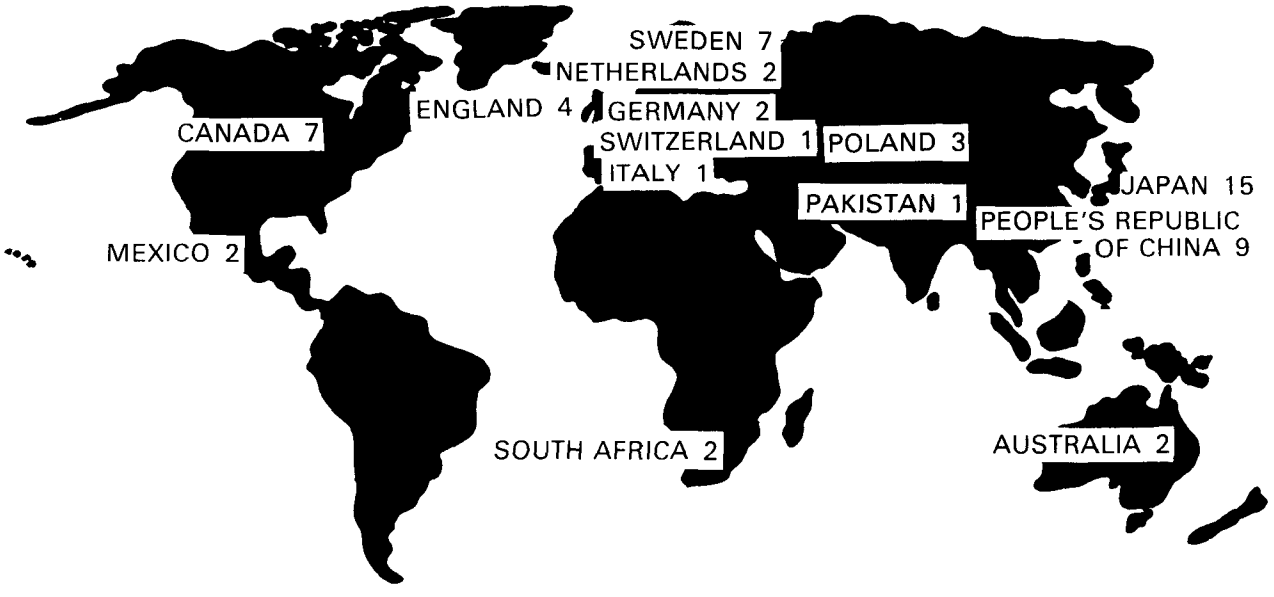
Committee on the Challenges to Modern Society (CCMS)

This NATO-sponsored committee attempts to bring together several countries in various peaceful endeavors. The Municipal Environmental Research Laboratory has been involved in projects on wastewater treatment and drinking water supply research. Dr. Robert L. Bunch, WRD, is a member of the Advanced Wastewater Treatment Group and U.S. Representative.

ORD's active participation in CCMS began in January 1973 and is to continue with yearly workshops to provide various technical discussions of wastewater technology and serve to acquaint all participants with the research going on in member countries.

Two projects were conducted, one on advanced treatment of wastewater by physical-chemical processes and one on the use of pure oxygen in activated sludge pilot plant at Wuppertal, Germany.

The last meeting of the delegates was in London on June 14, 1979. The final report on the Advanced Wastewater Treatment studies done at Coleshill, England, has been completed and published as NATO/CCMS Report No. 90.



PUBLIC LAW (PL) 480 Projects

Under PL 480, the U.S. is financing projects in foreign countries designed to advance scientific and technical research that is of mutual benefit to both countries. Project Officers from MERL supervise the following projects:

TITLE: Water Reclamation and Useful Utilization of Sewage Solid Waste
LOCATION: University of Karachi, Karachi, Pakistan
GRANT PERIOD: October 1, 1976 to December 21, 1980
PRINCIPAL INVESTIGATOR: Dr. M. Zain-ul-Abedin
PROJECT OFFICER: Robert L. Bunch, MERL-Cincinnati, WRD, TPDB (Phone: 684-7655).

TITLE: Investigations of Biodegradability and Toxicity of Organic Compounds
LOCATION: Institute of Meterology and Water Economy, Warsaw, Poland
GRANT PERIOD: March 1, 1975 to February 28, 1978, extended to February 28, 1979
PRINCIPAL INVESTIGATOR: Dr. Eng. Jan Dojlido
PROJECT OFFICER: Robert L. Bunch, MERL-Cincinnati, WRD, TPDB (Phone: 684-7655).

ENGINEERS EXCHANGE PROGRAM

Two Japanese engineers were sponsored under the auspices of the United States/Japan Environmental Agreement (Sewage Treatment Technology Project) to work at the Municipal Environmental Research Laboratory in Cincinnati, Ohio.

Dr. Tadahiro Mori, Japan Sewage Works Agency, Today City will work in the Ultimate Disposal Section, Wastewater Research Division from September 1, 1979 through February 28, 1980.

Mr. Shunsoki, Ministry of Construction Tokyo will work at the Test and Evaluation Facility, Wastewater Research Division from September 1, 1979 through August 31, 1980.

FOREIGN TRAVEL AND MEETINGS ATTENDED

Dr. Robert L. Bunch

Monitored research project PL 480, "Investigations of Biodegradability and Toxicity of Organic Compounds," at Warsaw, Poland in May 1979. The project is now completed and the final report published in March 1980.

In May 1979 presented a paper, "Pilot Plant Development of Ozone Disinfection," at Marie Curie-Sklodowska University in Lublin, Poland.

Participated in the 4th International Liquid Chromatography Symposium in Strasbourg, France, on October 23-26, 1979.

In October 1979 trips were made to Karachi and Islamabad, Pakistan, to monitor research project PL 480, "Waste Reclamation and Useful Utilization of Sewage Solids Waste," at Univesity of Karachi. Lectures were given on "Wastewater Treatment Processes" at University of Karachi and on "Advances in Wastewater Treatment" at Quaid-e-Azam University at Islamabad.

Dr. James A. Ryan

Visited the University of Guelph and Canada Centre for Inland Waters to discuss land application of sludges on October 24-26, 1979 in Burlington and Guelph, Ontario, Canada.

Dolloff F. Bishop

On November 6-8, 1979 in Toronto, Ontario, Canada attended the 33rd meeting of the Science Advisory Board of the International Joint Commission (IJC).

Edwin E. Geldreich, Jr.

Attented a World Health Organization Conference to develop "WHO Guidelines for Drinking Water Quality," and served on a Microbiological Contaminants Subcommittee on December 17-21, 1979 in Medmenham, England.

John J. Convery

Attended and participated in the International Joint Commission's (IJC) Great Lakes Research

Advisory Board 29th meeting on February 5-7, 1979 in Windsor, Ontario, Canada.

On May 8-10, 1979 attended and participated in the Science Advisory Board meeting in Windsor, Ontario, Canada.

Attended and participated in a meeting of IJC Phosphorus Management Strategies Task Force on December 5-7, 1979.

Richard I. Field

Participate and present paper entitled "Urban Stormwater Pollution Control in the United States" at the Second (1979) Short Course on Urban Water Resources Workshop sponsored by the University of Toronto. Also reviewed on-going project at LaSalle Hydraulic Laboratory in Montreal. This trip occurred on March 12-16, 1979 to Montreal and Toronto, Canada.

Douglas C. Ammon

Represented Storm & Combined Sewer Section at the EPA Storm Water Management Model (SWWM) meeting sponsored by the Office of Air, Land and Water and Canadian Ministry of the Environment on May 23-29, 1979 in Montreal, Canada.

James F. Kreissl

On September 15 thru October 1, 1979 in Oslo and Aas, Norway; and Malmo and Stockholm, Sweden exchanged information on research activities on alternative systems for small communities and individual homes with three European countries most active in this area.

Albert D. Venosa

Attended the International Joint Commission (IJC) Meeting of Chlorine Objective Task Force on March 14-15, 1979 and October 24-25, 1979 in Windsor, Ontario, Canada.

Michael Roulier

On June 3-9, 1979 participated as a member of the U.S. Delegation to the NATO/CCMS Pilot Study Meeting on "Disposal of Hazardous Wastes (Phase 2)." This participation related primarily to landfill research activities and required several presentations of papers discussing the current SHWRD/MERL research activities in this overall area. The meeting was held in Vancouver, British Columbia, Canada.

Richard Carnes

Participated in a roundtable discussion on incinerator technology for hazardous wastes on December 11-13, 1979 in Ottawa, Canada. This was part of a continuing coordinated research between the SWMB, Environmental Canada and the Disposal Branch, SHWRD/MERL.

Dirk Brunner

From September 17 thru October 7, 1979 traveler visited London, England; Paris, France; and Zell, Dannenberg, and Berlin, Germany. The purposes for the trip were to participate (by invitation) in an International Roundtable Discussion on Landfilling of Municipal Waste, specifically baled refuse and gas production; to attend an Energy and Materials Recovery International Conference; to observe a proposed hazardous waste disposal site near Dannenberg; and to observe solid waste management practices in Berlin where land use is intense.

Norbert Schomaker .

In Munich, Germany on September 24 thru October 13, 1978 participated as a member of the U.S. Delegation at the NATO/CCMS Pilot Study Meeting "Disposal of Hazardous Wastes (Phase 2)" and presented a paper which described the USEPA landfill research programs with specific emphasis on the chemical fixation activities.

On June 3-9, 1979 participated as a member of the U.S. Delegation to the NATO/CCMS Pilot Study Meeting on "Disposal of Hazardous Wastes (Phase 2)." This participation related primarily to landfill research activities and required several presentations of papers discussing the current SHWRD/MERL research activities in this overall area. The meeting was held in Vancouver, British Columbia, Canada.

Again on October 13-21, 1979 traveler attended an experts meeting of the NATO/CCMS Pilot Study on

Hazardous Waste Disposal (Phase 2). A paper was presented describing the U.S. EPA landfill research programs with specific emphasis on planned revisions to the current program regulations relating to hazardous waste disposal as it relates to the Resource Conservation Recovery Act. This meeting was held in Paris, France.

Carlton Wiles

Represented EPA at Norchem Laboratories in Oslo, Norway in discussions about hazardous waste encapsulation. Inspected hazardous waste emplacement into salt mines, observed technical operations, and obtained data on precautions used, waste handling procedures, and waste containerization methods.

Haynes Goddard

Attended a meeting of the Organization for Economic Cooperation and Development (OECD) and met with experts on waste policy research for planning research programs for the next several years in Paris, France, on October 3-6, 1978.

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Contact - Diana Irwin (513-685-7957)

16. ABSTRACT

The Municipal Environmental Research Laboratory is the EPA research organization responsible for the development of technology, systems, and processes to control or remove environmental pollutants that trouble our communities and municipalities. The MERL Report of Progress will provide you with updated information about the programs of the Laboratory in 1979.

The report will discuss the development and demonstration of cost-effective pollution control methods in the areas of municipal wastewater, solid and hazardous wastes, public drinking water supplies, and urban systems management.

Although some of its content is technical, the report is written to be informative for the broader audiences in business and industry, education, and government, and others who are interested in the environment and related fields.

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Water Reclamation	Water Treatment	Drinking Water Research	13B
Wastes	Waste Disposal	Wastewater Research	

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