PROCEEDINGS OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY MUNICIPAL WASTEWATER TREATMENT TECHNOLOGY FORUM 1990

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NOTICE

PREFACE

The 1990 Municipal Wastewater Technology Forum, sponsored by EPA's Office of Municipal Pollution Control (OMPC), provided the opportunity for wastewater treatment professionals from the Federal and State governments as well as Canada to discuss foremost wastewater treatment technology development and transfer issues. Presentations were made on sludge management, secondary treatment technologies, operations and maintenance (O&M) issues for publicly owned treatment works (POTWs), constructed wetlands, disinfection, toxicity management, and small community wastewater technologies. Three well-attended field trips allowed participants to visit treatment plants that employ some of the discussed technologies.

The Forum represents a part of OMPC's National Technology Support Program. One of the main elements of this program is the Wastewater Technology Transfer Network (WTTN), which supports and enhances the network of Regional and State wastewater technology transfer coordinators. This yearly meeting provides these coordinators with the opportunity to exchange information and learn from each other about promising and problem technologies.

The impending new sludge regulations and the close-out of the construction grants program are just two of the changes taking place at the Federal level. These changes present new challenges to all those involved in wastewater technology development and transfer. The widespread geographical representation (9 Regions and 35 States) at this year's meeting has been very helpful to OMPC in its efforts to establish the WTTN and provide useful assistance to States and municipalities.

In addition to providing summaries of the speakers' presentations, this document contains several appendices that can be useful to those involved in the WTTN:

- Appendix A includes the Forum Agenda and a list of the speakers' addresses that can be used to obtain more information about the presentations.
- Appendix B is a list of national contacts for wastewater technology, sludge technology, and O&M operator training.

- Appendix C is a list of addresses for Regional and State wastewater technology, sludge, and O&M coordinators.
- Appendix D lists EPA's Regional wastewater treatment outreach coordinators.
- Appendix E is a summary of the innovative and alternative (I/A) technology projects by State.
- Appendix F lists the current status of EPA's modification/replacement (M/R) grant candidates by State.
- Appendix G is a list of wastewater technology publications.

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INTRODUCTION

KEYNOTE ADDRESS

Jack Lehman, Deputy Director, EPA Office of Municipal Pollution Control
Washington, D.C.

On behalf of Mike Quigley, Director of OMPC, and myself, welcome to the Municipal Technology Forum, one of the more important activities OMPC conducts. Three main topics may be of interest to the participants of this event, including current events, in Washington and the rest of the world; the main themes of current EPA policy that affect the field of municipal pollution control; and the municipal wastewater treatment programs conducted at OMPC.

<u>Current events</u>. In terms of current events, the 20th anniversary of Earth Day will take place on April 22. Because the original Earth Day led directly to the formation of EPA in December 1970, EPA also will celebrate it's 20th anniversary this year. As indicated by public opinion, there is a lot of support for EPA activities as well as for Earth Day. Hopefully, this enthusiasm will stimulate a renewal of the environmental ethic that we have in the United States. For the celebration, EPA and other environmental groups will sponsor an open house on the Ellipse behind the White House in Washington, D.C. Earth Day should be meaningful and fun for us all, especially those of us in the environmental business.

Another current event is the President's recommendation to elevate the Environmental Protection Agency to a department level (making the Administrator of EPA a Cabinet Secretary). Both Houses of Congress have similar bills pending to make this change. There is a lot of momentum behind this initiative, so this change will likely take place some time this year.

In Eastern Europe, there is a breathtaking pace of change taking place. Even though these changes are occurring far away, they affect the way the United States approaches environmental protection worldwide.

EPA's current themes. One of the main themes of EPA policy that affects the field of municipal pollution control is *risk reduction*. For example, the radon indoor air pollution issue has been getting EPA's management attention. Lifetime risks of cancer for maximum exposed individuals were being calculated in the range of 10^{-2} to 10^{-3}. EPA's target for risk reduction typically has been 10^{-4} to 10^{-6}, one in a million, not one in a hundred. EPA focused primarily on human health effects, but the Agency is now beginning to understand that there are risks associated with ecological damage, as well.

One of Administrator Riley's main themes is *good science*. In some ways, everyone wants to find the technology that will make some quantum leap forward in terms of pollution control or risk reduction. "Silver bullets" are rare, but that doesn't mean that researchers shouldn't try to find them. Additionally, wastewater professionals should keep improving the present level of technology to make it as efficient and as low cost as possible.

Another current EPA theme is *pollution prevention*, defined by EPA as reducing or eliminating pollution at its source before it is emitted, as opposed to controlling pollution after it is produced. A growing number of EPA staff also include resource conservation, recycling, reuse, and some aspects of sludge and wastewater reuse in the definition.

A fourth theme EPA is committed to is *Total Quality Management* (TQM), which is a concept that emphasizes the quality of the product or service being offered and focuses on "value-added" activities, team building, responsibility, and decision making. If done right, TQM can be re-energizing and provide a new perspective on the work at hand.

Municipal Wastewater Treatment Technology Program. The focus of the Municipal Wastewater Technology Program is to ensure that wastewater treatment facilities are in compliance with the Clean Water Act. The two basic activities conducted by OMPC are providing incentives to municipal facilities for compliance [such as construction grants or State Revolving Fund (SRF) loans], and providing information on new technologies (technology transfer), which can help municipal decision-makers achieve and maintain compliance. To achieve these goals, OMPC seeks technological innovations through research and development to provide better, more cost-effective wastewater treatment. The Office provides technical assistance to help solve problems, and operations and maintenance (O&M) assistance and education training for operators and municipal decision-makers.

<u>**Technology support program**</u>. The technology support program promotes the acceptance of effective treatment technologies presently in operation. The program involves managing, supporting, and enhancing existing technology transfer networks and providing targeted direct technical assistance in areas of national significance. The sources of information include OMPC and ORD, which continue to produce technical studies that are shared with the Regional offices, States, and municipalities. The Regions and States themselves generate technical studies that are used by others and supported by OMPC, such as the revision of the Water Pollution Control Federation (WPCF) Manuals of Practice.

OMPC also is setting up a Wastewater Technology Transfer Network, which is broader in scope than the network it replaces, the Innovative/Alternative (I/A) Coordinators Network. Network coordinators will monitor new technologies, identify new and emerging problems in specific technologies, and respond to inquiries about these technologies. Other anticipated activities include peer matching for problem solving; distributing technical information; and cooperating with other networks already providing assistance to municipalities, such as the U.S. Department of Agriculture Extension Service, the National Small Flows Clearinghouse, and the Farmers Home Administration.

Another aspect of this technology support program is to provide Targeted Direct Technical Assistance to Regions and States, through telephone consultations, written information, or referrals to qualified experts. As resources permit, in some instances, OMPC will conduct site visits, based on whether the site is dealing with a priority issue, such as toxics or the new sludge requirements. The problem also must be national in scope, not yet solved satisfactorily, and have a significant environmental dimension.

Existing support programs. EPA provides strong technical support through many other programs, including SCORE, the Small Community Outreach and Education Program; the MWPP, the Municipal Water Pollution Prevention Program; and the O&M Program.

SCORE was initiated about 4 years ago to address the municipal wastewater treatment needs of communities of less than 10,000 people. The program awards Incentive Grants by the Regions to establish State outreach programs, and includes financial management planning grants, public education, and operation and maintenance activities. SCORE also promotes Federal outreach coordination and Regional outreach activities by promoting innovative approaches and helping communities set priorities.

SCORE works in cooperation with other existing networks (such as those mentioned above) and EPA's Office of Drinking Water, because often in small communities, the wastewater and drinking water facilities are operated by the same local office. SCORE also deals with the International City Managers Association, the National Association of Towns and Townships, and so forth. SCORE administers the Small Flows Clearinghouse and computer bulletin board at the University of West Virginia (see p. 133); is developing a national policy on municipal water use efficiency; and produces brochures on financial management and planning.

The Municipal Water Pollution Prevention Program encourages "preventive medicine" through self-auditing by POTWs once per year, which has proven to be successful in terms of compliance rates. The program also can improve planning for capacity increases and financial needs. The MWPP involves a substantial amount of technical assistance because some of the solutions require innovative technologies.

The O&M program (see p. 64) includes running an onsite assistance program, as mandated by Section 104 (g) of the CWA; operating 39 Environmental Training Centers, as per Section 109 (b); and sponsoring annual operator training conferences and a very successful awards program, presented in conjunction with the Water Pollution Control Federation (WPCF). O&M program personnel also visit small treatment plants that are having trouble to study the performance-limiting factors and provide feedback to system designers. The program publishes a quarterly newsletter called *On-site/Oversight.*

Summary. OMPC's mission in the National Technical Support Program and the other programs discussed above is to distribute technical information, promote networking among members and other groups, and provide technical assistance to POTWs. These activities all confirm OMPC's commitment to continue Technology Assessment and Technology Transfer initiatives.

The agenda for this conference is ambitious and exciting and will give the participants a thorough update on EPA programs that cover international activities, O&M issues, combined sewer overflows (CSO), and several small community programs. Speakers will present information on the cutting edge of municipal wastewater treatment technology in the areas of sludge management, secondary treatment, constructed wetlands, disinfection, toxicity, and small community sewage systems. The conference also includes field trips to a phosphorus removal facility, an in-vessel composing plant, a vacuum sewer system, and two constructed wetlands, and several interagency workgroups on small wastewater systems.

This conference is a major commitment of time for all participants. OMPC aims to make this an energetic event, provide some "quality value-added time," and make sure all participants take home new knowlege to apply towards solving the major issues facing the field of municipal wastewater treatment. This conference also intends to help participants realize how their work coordinates with EPA policies and the worldwide situation. Only with proper wastewater treatment technology can the entire municipal pollution control program succeed.

STATE OF FLORIDA WELCOME

Robert E. Heilman, Chief
Bureau of Water Facilities Planning and Regulation
Florida Department of Environmental Regulation

Good morning. On behalf of the Department of Environmental Regulation (DER), I'd like to welcome you to the great State of Florida and to the beautiful City of Orlando.

I'd like to briefly share some interesting statistics with you to give you an appreciation of the environmental situation we have here in Florida. Florida's population is growing at the rate of 6,000 persons each week. Almost 80 percent of the 12 million people in Florida live near the coast. The rest of the population either lives on or near inland surface waters.

Near the coast, ground-water supplies are limited, shallow, and vulnerable to salt water intrusion. Furthermore, Florida does not have large, rapidly flowing streams that can assimilate large volumes of wastewater discharge. Florida's numerous streams tend to be small, flow slowly, are warm year round, and flow into lakes or coastal waters that are prone to excessive growth of algae and nuisance aquatic weeds.

In a State that depends upon high quality surface water for an important tourist industry, as a drawing card for growth and development, and as a basis for a high quality life, protection of our water resources is a formidable task.

In a recent statewide public opinion survey, conducted by the Florida State University Survey Research Laboratory for the Department of Environmental Regulation, water pollution was identified as the chief environmental concern. The survey also indicated that our State government is doing as well as, or better than, other States in environmental protection.

So, now that we've gotten these high marks from the regulated public, what have we done to protect Florida's fragile environment? To that end, Florida has been on the cutting edge of environmental protection in a number of ways. First, more and more surface water discharges are required to meet advanced wastewater treatment requirements. We are moving farther and farther away from secondary treatment being a minimum requirement. In Florida, advanced waste treatment is now becoming the "norm" in most of our permits.

Secondly, due to the ever increasing demand on our potable water resources from the growing population and the limited assimilative capacity of receiving waters, there is an increased emphasis on reusing our treated wastewater for a multitude of purposes. We now look at our wastewater treatment facilities as "water factories." Rather than treatment and discharge, the reclaimed water from these facilities is used for landscape irrigation, agricultural irrigation, ground-water recharge, industrial use, fire protection, toilet flushing, aesthetic fountains and ponds, construction dust control, and wetland restoration. This not only reduces the potable demand, but reduces the load on the receiving streams. In Florida we have some nationally acclaimed reuse projects such as:

- St. Petersburg Dual Distribution System, where over 6,000 residential laws receive reclaimed water for irrigation.
- Conserv II, which is an award-winning project using reclaimed water from Orange County and Orlando for irrigating 7,000 acres of citrus groves and 10 acres of ferns.
- Tallahassee Spray Irrigation System, where the city of Tallahassee irrigates approximately 2,000 acres of corn, soybean, and other fodder crops with reclaimed water.
- Orlando Wetlands, which uses reclaimed water to feed a 1,000 acre wetland system used for hiking, jogging, and nature observation.
- Other reuse systems are located in Cocoa Beach, Naples, Altamonte Springs, and Palm Beach County.

By 1991, mandatory reuse programs will be required in critical water supply problem areas throughout the State.

Another area where Florida is encouraging beneficial reuse is in the area of land application of sewage sludge, or as we now call it here, "domestic wastewater residuals." We have just completed a year's work in developing a new domestic wastewater residuals rule to control the disposal practices and document the quality and quantity of these residuals that are land applied. There are approximately 220,000 dry tons of residuals generated in the State of Florida annually. Approximately 70 percent of these residuals are land applied. The previous rule did not provide any accountability for the residuals produced by the wastewater treatment facilities. For the most part, once the disposer picked up these residuals from the treatment facility, no one but the disposer knew where they were going. Our new rule corrects this deficiency without discouraging the current disposal practices. We have developed a rule that requires the generator to be liable for the disposal of the residuals unless he has transferred that liability through a legally binding agreement. The rule also requires agricultural use plans or dedicated site plans for the application sites. We feel this new rule will produce the level of accountability that we must have to protect the public.

The last area I'd like to discuss is toxicity and how Florida is dealing with it. The State of Florida is not an NPDES-delegated State. Therefore, EPA issues federal permits for surface water discharges and we issue our own State permits. As we are all discovering, we can no longer just look at conventional pollutants for discharge permits, but we must also consider the nonconventional constituents. We are finding more and more facilities are adversely impacting the receiving streams they discharge to through heavy metal toxicity, ammonia toxicity, and even chlorine toxicity. Our existing rules regarding toxicity differ somewhat from EPA's. In our rules, we do not recognize the zone of initial dilution. While many EPA permits require 48-hour acute toxicity tests and the DER often uses 48-hour tests for screening purposes, our permits require that 96-hour tests be conducted to show compliance with DER acute toxicity regulations. A final area where we differ with EPA is in the species selected for testing toxicity. Some of the State's requirements are more restrictive than EPA's, but we feel they are necessary to protect our surface waters. During the next 5 years, we anticipate that toxicity testing and biomonitoring requirements will be incorporated into the permits of all major domestic and industrial facilities discharging to surface waters.

In closing, the State of Florida needs and appreciates these kinds of technology forums. It is essential that research efforts in the wastewater treatment field continue in order for us and other States to meet future water quality goals. The future demands for environmental protection that will be made of State agencies can only be met if technological advances in wastewater treatment are continued. Without technological solutions to environmental problems, rules and regulations are meaningless.

As we approach the 20th anniversary of Earth Day on April 22 and also the 20th anniversary of the Clean Air Act in October 1992, I believe a new era of environmental awareness is taking place. The public's awareness of environmental problems is at the highest level ever. For the Department of Environmental Regulation, every day is "Earth Day." We have come a long way in 20 years, but still have a long way to go. To get there, we need people like you. Thanks for being here and I hope you all enjoy your stay in our great State.

SLUDGE MANAGEMENT TECHNOLOGIES

TRENDS IN MUNICIPAL SLUDGE MANAGEMENT PRACTICES

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<u>Introduction</u>. It is encouraging that this technical program for 1990 is initiated with an overview of the directions being taken in municipal sludge management practices. The proportionate amounts of time, dollar, and other resources devoted to sludge management continues to increase in municipal treatment plant budgets each year, driven by each new environmental initiative from the Congress. Within the next few years, we will see the implementation of the ocean sludge dumping ban in the New York-New Jersey Metropolitan Area, full secondary treatment in Southern California and in the Metropolitan Boston area, and air toxics emissions controls on wastewater treatment plants in many urban centers of the nation. At the same time, we will see the implementation of the Part 503 sludge management regulations in a form not likely to be much different from what was promulgated in February 1989 and the continued emphasis on the reduction of effluent toxicity.

The sludge quality and production at a POTW is typically impacted adversely by any environmental initiative. The continuing flow of environmental initiatives expected in the 1990s will therefore keep the pressure on municipal sludge managers, and sludge management costs will continue to rise accordingly. That cost will become an increasing fraction of the wastewater treatment budget and ultimately motivate the larger cities toward mega-solutions. Typical mega-solutions will include long distance rail haul to remote landfills or land reclamation sites, and electrical power production facilities using local sludge production as a small component of the fuel supply for regional electrical and steam power production centers. How far ahead are these developments? My conjecture is: "within the decade." To see how I arrive at this conclusion, let me share with you a brief look at where sludge management is today and where it is going.

Where are we starting the nineties? As this decade begins, we continue to see municipal wastewater treatment plant projects take 7 to 10 years to implement from start to finish. Secondary treatment is in place around the nation, but we now appear to be headed to minimal levels well beyond this in environmentally sensitive areas. With reference to sludge processing, anaerobic digestion has become a mainstay in most of the major plants in the nation, but as higher treatment levels become more common, the continuation of this practice will be questioned as nutrient removal is implemented, making the treatment of supernatant more costly. Lastly, as was noted above, the decade is starting with numerous regulations in the development process, and it should be obvious to all that there will be significant changes in accepted treatment practices ahead.

Example impacts of the new regulations. To build on this theme, let us for a moment consider some of the impacts of the new regulations. The pathogen reduction requirements of the new Part 503 regulations will require the installation of new or alternative terminal sludge processes at many plants. The health risk basis of these same regulations will require extensive upgrades of the APC (air pollution control) systems at most of the multiple hearth furnace installations in the nation. The BACT (best available control technology) air quality mandates of many States will add stringent APC requirements for sludge dewatering, composting, and lime stabilization processes. Toxicity reduction rules will result in the concentration of these materials with new sidestream treatment processes being needed to minimize adverse quality impacts on sludge quality.

At the same time, the implementation of the CSO and stormwater rules this year will result in more in-line flow controls, and more flow into the main plant. These weaker flows will have more inerts and street washoff and result in sludges with more metals and TPH (total petroleum hydrocarbons). Meanwhile, new regulations in several States require that sludges contain as much as 50 percent dry solids for landfill disposal.

It is in this same milieu that the cessation of ocean dumping of sludge is taking place. This action alone will place some 200,000 dry tons annually of dewatered sludge from the New York-New Jersey metropolitan area "on the street" in the early 1990s. The ancillary effects of this mandate have been seen already in the lack of excess centrifuge manufacturing capacity for the next 2 or 3 years, as the vendors rush to fill orders for the ocean dumpers. Other effects have included the issuance of an Executive Order by the Governor of Pennsylvania limiting the influx of sludge and refuse to the State, and the rapid escalation in the cost of landfill disposal for local jurisdictions in Pennsylvania, Ohio, and elsewhere.

Other trends are also taking place at the start of the 1990s. One of the most important is the recognition, sometimes grudgingly, of the larger POTWs, that diversification of sludge is essential to avoid the "Philadelphia syndrome" of not being able to move its compost production. The Philadelphia situation is one of regional saturation of the markets, a phenomenon ill-understood by the various participants in the sludge management industry. Offsetting this is the development of new and innovative outlets for sludge products, including the use of dried sludge pellets as chemical fertilizer bulking agents, and chemically stabilized sludges as a substitute daily cover and base to final cover for landfills.

A look into the 1990s. A road map into the 1990s would show sludge going to incineration, compost, substitute soils, and landfills at the start of the nineties, and, I conjecture, to gasification by the end of the nineties. Let's start with dewatering to begin our look at the trends. Dewatering to the 25 to 30 percent dry solids range will become commonplace as agencies shift to better equipment that has been purchased after pilot testing and with specifications tailored to the specific sludges at a plant. A movement towards high solids centrifuges will also continue in situations where compact space is available and where BACT requirements must be met.

In reference to substitute soils, there is a growing list of end uses with each new installation. The breakthroughs with the chemical stabilization and fixation processes used to produce substitute soils have been in the areas of pathogen destruction (requires enough ammonia in the sludge), bearing capacity of the cured product, and the dilution of lesser quality sludges with the "ingredients" added. One process flow diagram can serve many different variations of the process (and there are many) with common equipment and curing facilities.

Thus an installation that can produce a substitute soil has considerable flexibility, including as a backup process.

The trend with composting has been toward continued process improvements to negate early adverse experiences, which are replete in the literature. Also evident now are alternate uses for compost, the development of "designer" products, and the introduction of more sophisticated marketing techniques. On the negative side has been the regional saturation of markets that seems to have occurred in connection with Philadelphia's products, and the 10 to 30 percent cost uplift that the installation of BACT air pollution control equipment can have on the total project cost.

Incineration will continue to be a mainstay process for larger POTWs in the 1990s, but with some important new developments. Improved energy recovery will be realized through integrated steam and electricity production, and the use of steam for the drying of sludge prior to incineration as well as for digester and space heating. APC efficiencies will be improved through the incorporation of devices like the wet electrostatic precipitator and the regenerative afterburner. Also plume suppression and less-than-GEP stack heights will become more common as POTWs seek a "lower" and less visible profile. Lastly, ash management will become more of a reality, with recovery and reuse a slow-to-develop but vital prospect.

As far as technology, I look to the integrated technologies that will use sludge and coal as fuel to produce steam and electrical energy as the next major development to be implemented by the end of the decade. Examples of such technologies are the variations of the slagging gasification systems that Texaco and British Gas have developed. These processes use sludge as a small (say 10 percent) fuel component with coal or oil as the mainstay. The feed mixture is gasified in an environment that slags the ash while yielding a low BTU gas. The gas is then used in a combined turbine to produce electricity, and waste heat is recovered as steam. This technology is most suited to metropolitan areas where the electrical power utilities already have the large sites, coal handling equipment, and power transforming, switching and distribution equipment that are needed.

The next 5 years. To conclude, a comment about the next 5 years is appropriate. I look to sludge haul and disposal costs of $150 per wet ton from the New York-New Jersey metropolitan area, with hauls being up to 200 miles by truck and 1,000 miles by rail. Around the nation, there will be huge investments in new incinerators and in upgrades of existing units. Ash recovery and reuse will become a fledgling industry, and the diversification of sludge management programs will become commonplace. There will be substantial outlays for APC equipment to control emissions of odors, criteria pollutants, and toxic pollutants, as sludge managers anticipate and respond to the demands of the public. In summary, the agenda is full and the expenditures required are great as we approach this new decade. Thank you for this opportunity to offer my views.

For more information about these trends, contact Tim Shea (see Appendix A). See Appendix E for a summary of EPA's innovative/alternative (I/A) technology projects.

ORGANIC CONTAMINANTS AND LAND APPLICATION OF MUNICIPAL SLUDGE IN CANADA

**Melvin Webber, Wastewater Technology Centre, Environment Canada
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Applying municipal sludge on agricultural land is a cost-effective method of sludge use that recycles essential nutrients into the soil. It is practiced widely in Europe and the United States and accounts for one-third of Canadian sludge production. Organic contaminants (OCs) can enter sewerage systems through industrial and domestic effluents and remain in municipal sludge. OCs in sludges that are applied to agricultural land have the potential to enter the food chain and affect human and animal health. Sludge managers must, therefore, understand the persistence of OCs, their fate in soils, and how to apply sludges that contain OCs on agricultural lands.

Studies of volatile organics in soils. The Wastewater Technology Centre (WTC) of Environment Canada conducted several laboratory studies to determine the persistence of volatile organic contaminants (VOC) in soils containing varying amounts of organic matter and clay. The first was a soil incubation study that measured the persistence of 1,1-dichloroethane (DCE), trichloroethylene (TCE), toluene (TOL), and ethylbenzene (ETB) in sludge-treated soils. The sludge was 3 percent dry weight (dw) in the soil. The concentration of each VOC was 50 mg/kg, except TCE, which was 2.5 mg/kg. The tests were conducted at 22°C (room temperature) and then heated to 95°C to determine total residual VOC levels in the soil. The test systems were aerated at varying intervals. Gas chromatography and flame ionization detectors were used to analyze samples.

The results of the studies are presented in Figure 1. Hatched sections of the bars represent VOC volatilized at 22°C, and the open sections represent residual VOC in the soil (i.e., the amounts volatilized at 95°C). At 22°C, the VOC recoveries increased continuously from about 15 minutes to 2 days. There was almost no residual DCE and TCE in the soil (95°C test) within 24 to 48 hours and almost no residual TOL and ETB in the soils within 144

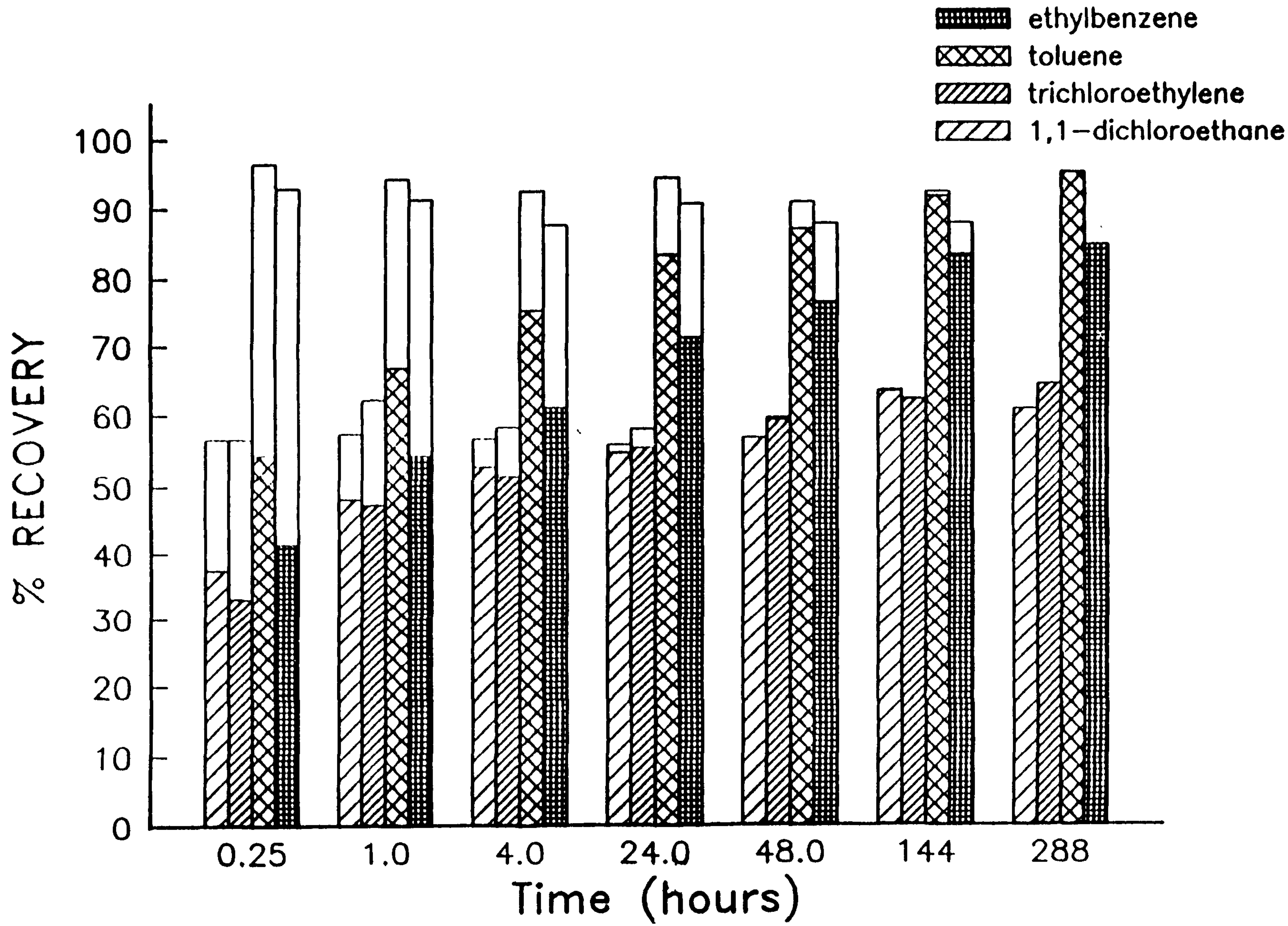

Figure 1. **Total and 22°C (Hatch-Marked) Recoveries of Four Volatile Organic Contaminants from a Sludge-Treated Loamy Sand Soil**

to 288 hours. The authors have no satisfactory explanation for the low recoveries of chlorinated compounds (DCE and TCE), as indicated on Figure 1.

A second study considered a larger number of compounds and soil types. Figures 2 and 3 show the results of these tests for periods of 24 hours and 12 days. Patterns are similar for the 24-hour and 12-day study periods. On average, the total amounts recovered after 24 hours are closer to 100 percent than the total recoveries for the 12-day period. It appears that with time, there is some degradation and/or irreversible sorption of compounds in the soils. These effects are largest for muck soil with the highest organic matter.

Plant uptake studies. In another study, microcosms in which ryegrass was grown in sludge-treated soils were used to study plant uptake of OCs. Figure 4 is a schematic of the experimental system. ^{14}Carbon was used to label and then measure OCs in the system. Air was drawn through the system continuously, to be able to recover ^{14}C as either carbon dioxide or as a volatile organic. Researchers also determined ^{14}C levels in the plants after they were harvested.

Some preliminary results of these studies are shown on Table 1. ^{14}C recoveries in ryegrass were small and indicated no appreciable uptake of the OCs. Recoveries of $^{14}CO_2$ indicate considerable degradation of pentachlorophenol, and recoveries of ^{14}C-labeled volatile organics indicate complete volatilization of 1,2,4-trichlorobenzene. Another study conducted over a 19-week period showed a similar recovery pattern for anthracene.

Bioconcentration factors. The bioconcentration factor (BCF) is the concentration of ^{14}C in the plant material compared to the initial concentration of ^{14}C added to the soil. A BCF of 1, indicates that ^{14}C is not accumulating or being excluded from the plants. If the BCF is greater than 1, there is some accumulation; if it is much less than 1, the material is not entering the plants through the roots. In a study with ^{14}C-labeled anthracene, the BCFs for ryegrass were extremely low, suggesting that anthracene was not taken up by ryegrass.

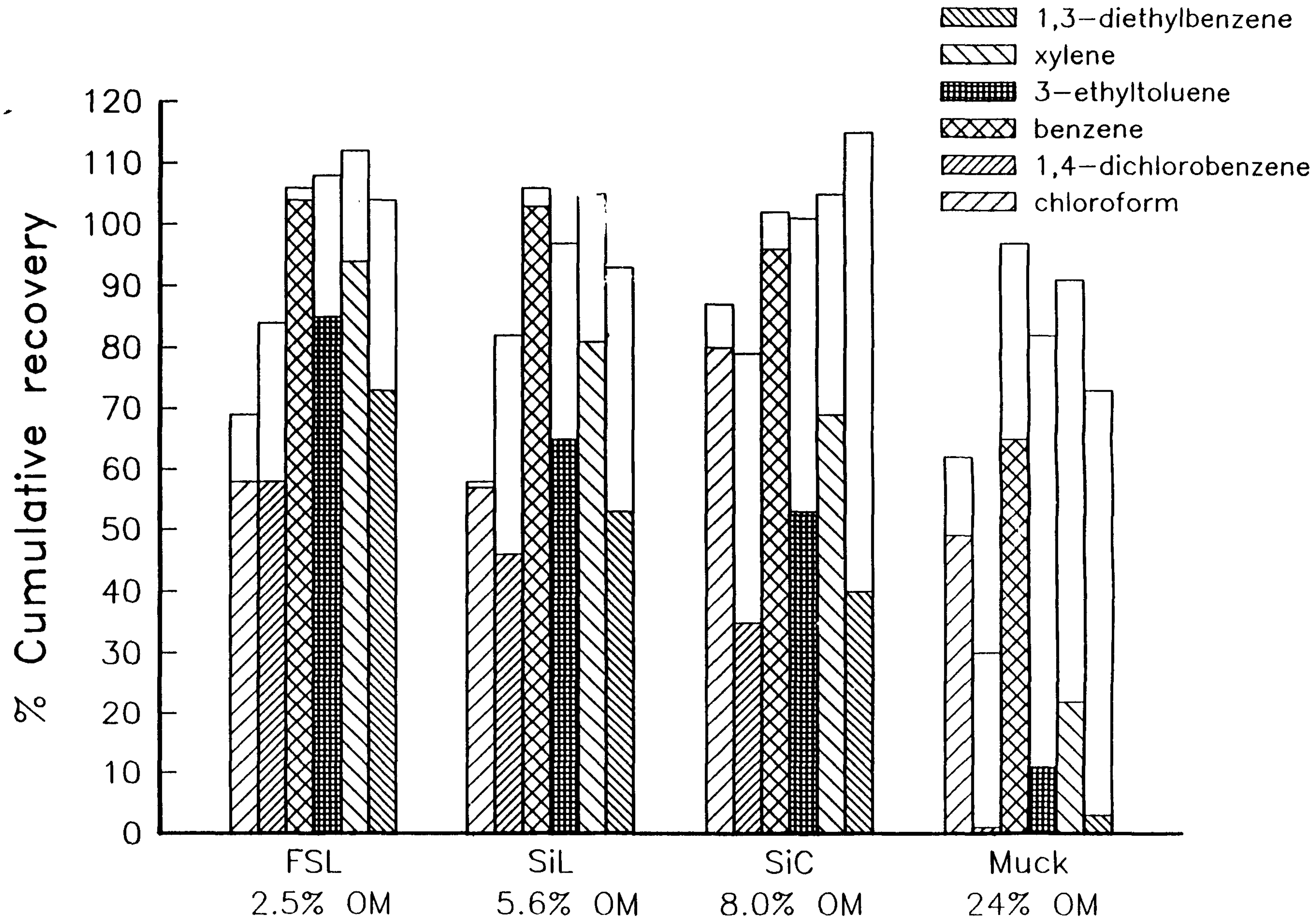

Figure 2. **Total and 22°C (Hatch-Marked) Recoveries of Six Volatile Organic Contaminants During a 24-Hour Period**

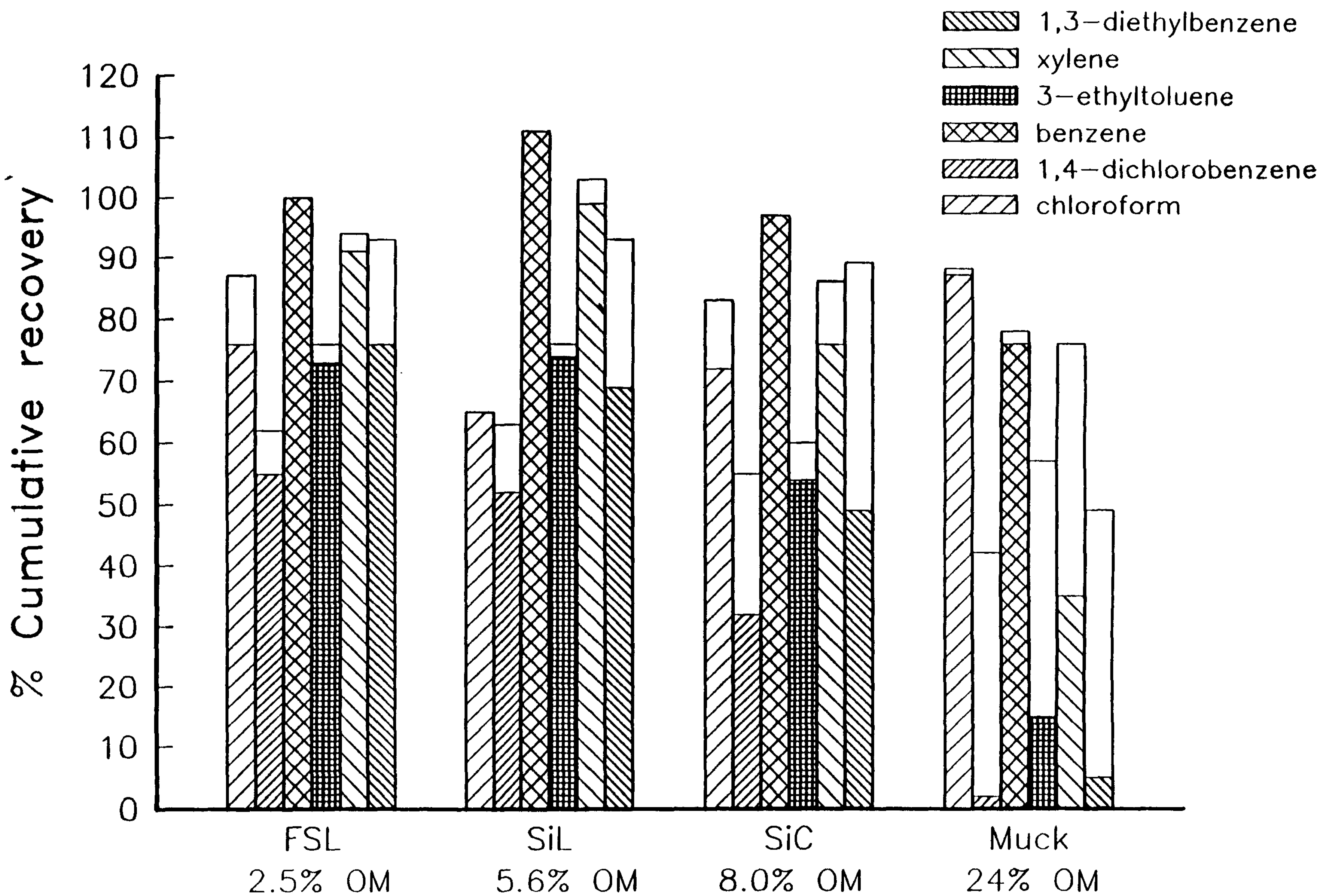

Figure 3. **Total and 22°C (Hatch-Marked) Recoveries of Six Volatile Organic Contaminants During a 12-Day Period**

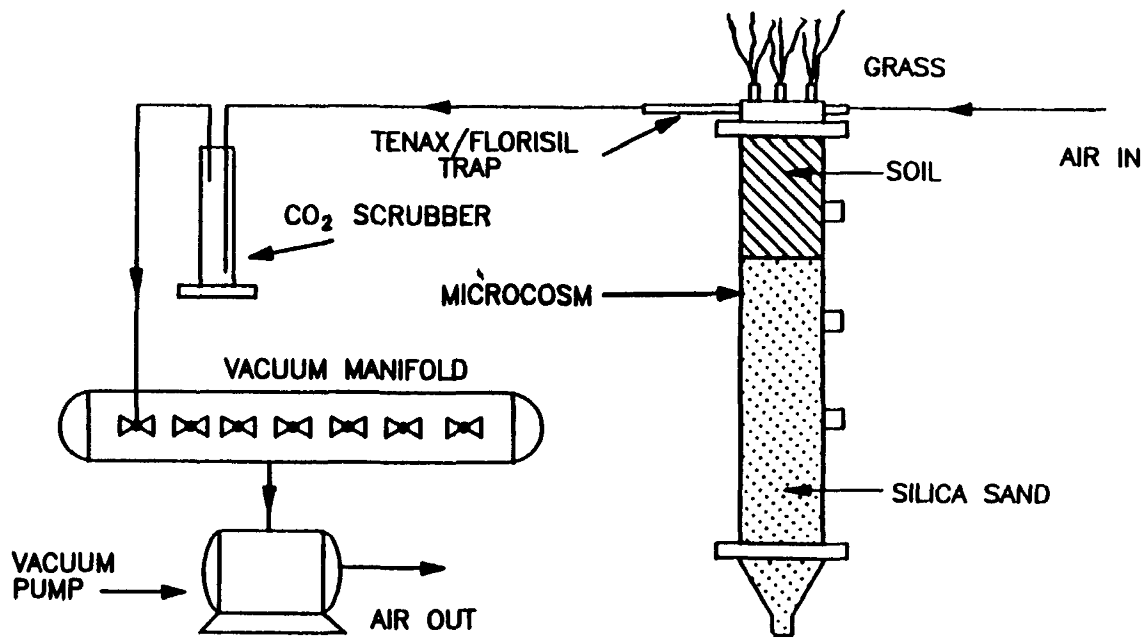

Figure 4. **Schematic of the Microcosm System Used to Study Plant Uptake of Organic Contaminants**

TABLE 1

PERCENT RECOVERIES OF ^{14}C IN PLANT UPTAKE STUDIES

COMPOUND	CO_2	Volatile Organic	Rye-Grass	Total
1,2,4-Trichlorobenzene	3.7	144[a]	0.13	147
Anthracene	8.2	0.01	0.05	8.3
Benzo(a)pyrene	1.0	0.02	0.08	1.1
2,2',5,5'-Tetrachlorobiphenyl	1.2	0.02	0.14	1.4
Pentachlorophenol	67	0.08	0.14	67

[a]A high percentage was recovered for an unknown reason.

Summary. This information indicates that VOCs escape relatively rapidly from mineral soils and less so from soils with high concentrations of organic matter. It does not appear that VOCs would cause a significant problem for agriculture. Additional information is needed however, on persistence and plant uptake for other organic contaminants that may occur in sludge.

The WTC plans to expand plant uptake and persistence studies in soils of representative organic contaminants; study the fate of detergent builders, which according to European information, can be present in sludge at concentrations greater than 1 percent by dry weight; and conduct a survey of organic contaminants in Canadian sludges.

For more information, contact Melvin Webber (see Appendix A).

ALKALINE PASTEURIZATION OF MUNICIPAL SLUDGES FOR BENEFICIAL UTILIZATION

David S. Sloan, N-Viro Energy Systems
Coral Spring, Florida

The N-Viro "AASSAD" process is an advanced alkaline sludge stabilization process with subsequent accelerated drying. The process stabilizes and pasteurizes wastewater sludges with the use of alkaline materials and is EPA certified as a Process to Further Reduce Pathogens (PFRP).

The objective of N-Viro Energy Systems (NES) is to create a product that requires little control and that can be placed back in the community for beneficial use. Through its Agency network, the company has projects on-line in Portland, Maine; Boston, Massachusetts; Syracuse, New York; Bristol, Connecticut; Wilmington, Delaware; Toledo, Ohio; Lexington, Kentucky; Des Moines, Iowa; Jupiter, Florida; and other locations. The product has been used as an organic soil amendment, a liming material, as landfill cover, and other applications. N-Viro soil has demonstrated community acceptability, numerous product markets, and low capital and life-cycle costs. It also is a simple reliable operation that uses standard equipment.

The alkaline admixture (AA), often a by-product kiln dust, has a pH that varies from 8 (if the dust is nonreactive and hasn't been calcified in the kiln) to slightly over 12, depending on the amount of carbonate that has been driven off and calcium oxide that has been created. The kiln dust contains a variety of oxides, primarily calcium in the form of calcium oxide (see Table 2). It contains almost 6 percent potassium, which is what is missing from most sludge fertilizers. With the high amount of acid rain that falls in Florida (in this State, the average rainfall pH is 4.5), the calcium and potassium in the N-Viro soil both help increase the natural soil pH and provide optimum release of plant nutrients. Kiln dust alone is very valuable, especially to agriculture, but because it is so dusty, it is difficult for farmers to incorporate into

TABLE 2

OXIDE ANALYSIS OF CEMENT KILN DUST
(% by weight)

SiO_2	13.80
Al_2O	3.80
Fe_2O_3	4.50
CaO	43.90[a]
MgO	0.59
SO	7.80-10.33
PO	0.12
K_2O_5	5.80
NaO	0.87
Ti^2O_2	0.15
Mn_2O	0.27

[a]Total calcium-free lime = 6.9 percent.

the soil. When the N-Viro process wets the dust with sewage sludge, it becomes a controllable substance enhanced by the nitrogen, phosphorous, and organics found in sludge.

N-Viro process alternatives. There are two N-Viro processes. The first process involves raising the pH of the mixture to 12 for at least 7 days, drying it until the solids exceed 60 percent while the pH remains above 12, and holding the mixture on site for the balance of the 30 days. Many facilities choose not to hold sludges on site, even though the odor of the treated end material is minimal.

The second process combines pH, heat, and drying, to speed up the process. In the second process, the pH is held at 12 for at least 72 hours and until a minimum of 50 percent solids is obtained. Calcium oxide contained in the AA raises the temperature of the sludge to 52°C and holds it there for at least 12 hours. This alternative has the three disinfectant killing mechanisms--high pH, high temperature, and drying. (A forth mechanism is the liberation of the ammonias, as the pH is raised to 12.)

N-Viro PFRP process steps. The N-Viro process steps are shown in Figure 5. The AA is delivered to the treatment plant facilities in 24-ton pneumatic conveying vehicles, much the same as those used to deliver hydrate lime and quick lime. Facilities usually have a standard lime silo.

In the N-Viro process train, the sludge cake is loaded into a hopper by a conveyor or a front end loader. The AA (cement and/or lime kiln dust and/or lime) are added from the silo. The sludge and AA are mixed in a pug mill mixer and then held in a heat pulse container for 12 hours to bring the temperature to 52°C. At the end of the heat pulse phase (12 hours), the mixture is laid out in windrows and air dried. The end product is then stored until use.

Dewatering. The dewatering phase is upstream from the N-Viro process and controls how efficient the process will be. The typical sludge feed has a solids content of from .5 to 5 percent. The discharge solids content ranges from 12 to 30 percent, with the optimum content being at least 18 percents solids. The two main process considerations for dewatering are that

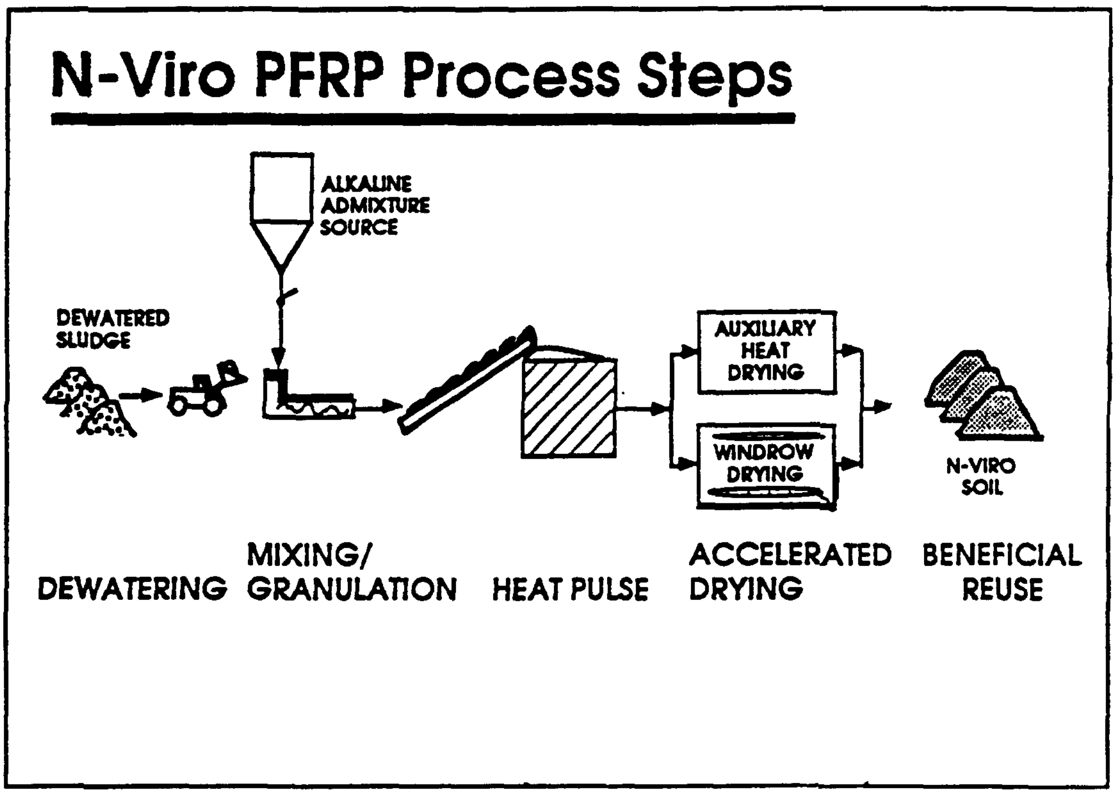

Figure 5. N-Viro PFRP Process Steps

the higher the percentage of cake solids, the lower the AA dose will be. Also, the polymer must be alkaline compatible.

Mixing/granulation. The N-Viro process begins with the mixing granulation phase. The objective is to obtain a complete and uniform mix with a granular discharge. Typical parameters are an AA dose range of from 25 to 50 percent of the wet weight and a solids content of the discharge from the mixer of 40 percent or more. For 1000 pounds of sludge cake, 250 to 500 pounds of AA will be added to the mixture to provide a satisfactory mix and begin the drying action. Process considerations are a uniform pH and temperature attained by complete mixing and a good granulation for enhanced drying.

Heat pulse phase. The heat pulse phase reduces pathogens to pasteurization levels. The temperature must be held at 52°C for 12 hours. The optimal temperature range is from 52 to 65°C. A temperature of over 65°C will begin to create a sterile end product, not a soil, that is open for reinfestation and will not have nearly as good odor control. Process considerations for the heat pulse phase are that the alkaline materials are proportioned to provide optimum heating, storage is designed to minimize heat loss, and odor/ammonia must be controlled.

Accelerated drying. Facilities use accelerated drying to complete the pasteurization process and reduce the volume and the weight of the material. The windrow facility and equipment should be well thought out, and dust emissions and odors must be controlled.

Presently, the most difficult aspects of the process are the drying and windrowing operations. The company is presently investigating different methods of drying, including rotary kilns, heated surface paddle dryers, and other methods of drying. NES recommends windrowing undercover for up to 5 days, so that the process does not require an extensive windrow area.

End product. Typically, after one day of windrowing, the end material contains 50 percent solids, meeting EPA requirements. This product can be used as landfill cover. If the material is going to be recycled as a soil amendment or liming "product", the final mixture must be in a form familiar to the user and have a uniform particle size. Therefore, the mixture is windrowed until it contains at least 65 percent solids and produces a granular, more uniform-sized end material.

The end product looks much like a sandy, loamy soil. N-Viro soils can be stored to meet distribution schedules, typically for 30 to 90 days. The product stores well without a cover and stacking conveyors can be used to reduce space requirements. The odor is one that does not attract flies. The pH can be lowered and nutrients added to enhance the product.

Product uses. N-Viro soil is used as a soil amendment product, sold retail. It is also directly land applied, used on land reclamation sites, and used as landfill cover material. A nonagricultural application is its use for turf. It is also used as a topsoil and fertilizer filler. Many field tests have shown that N-Viro has enhanced the growth of a variety of plant species.

The total beneficial reuse value of N-Viro soil is shown in Table 3. The total reuse benefit is about $33/ton. The product is not selling for this amount, but the company is satisfied if the soil sells for $5/ton (as it is in Florida) and the customers are convinced they are getting $33/ton worth of benefit.

For more information, contact David Sloan (see Appendix A).

TABLE 3

N-VIRO SOIL (PFRP) BENEFICIAL REUSE VALUE PER TON
(Assume 50% Sludge Solids; 50% Alkaline Admixture)

Nitrogen at 1.5%	$4.50
Phosphorous at 1.5%	$6.00
Potassium at 1.5%	$3.60
Organics at 25%	$10.00
Calcium Carbonate at 30%	$6.00
Trace Minerals (S, Mg, etc.)	$ 3.00
TOTAL REUSE BENEFIT	$33.10

ODOR CONTROL FOR COMPOSTING

Terry Crabtree, Smith Environmental Engineering
Broomall, Pennsylvania

Odor is the number-one problem facing the composting industry today, and facilities are being shut down due to odor complaints from neighborhoods surrounding offensive operations. Because the components of composting odor problems are similar to many industrial applications, composting system designs can borrow a solution to this problem from other industries that have long dealt with volatile organic compounds (VOC). One such technological solution uses thermal afterburners, which can convert organics to water and CO_2, and which represents the Best Available Control Technology (BACT) for odor control.

Figure 6 is a schematic of an early afterburner system. In the original system, 12,000 scfm of air at 200°F was created by the industrial process. The air entered the burner, which raised the temperature of the air to over 1,100°F. The solvent from the organics then raised the temperature further to about 1,400°F. The air was then released into the atmosphere.

One objection to this type of thermal odor control is high operating cost. Raising the temperature of process exhaust air from typically 100°F to 1,200°F requires significant amounts of fuel. Despite this high operation cost, however, plants in the pulp and paper industry and some other unique industries (such as those making fishmeal) have been using afterburners for 20 years, as this is the only method that removes exhaust odors.

Historical use of afterburners. Figure 7 shows schematics of three basic technologies applied from the 1960s through the 1980s. The use of afterburners began in the 1960s, when major odor and VOC offenders used the technology to comply with air quality regulations. The high VOC content generated by the industrial processed provided significant fuel (BTU) contribution to the afterburner process.

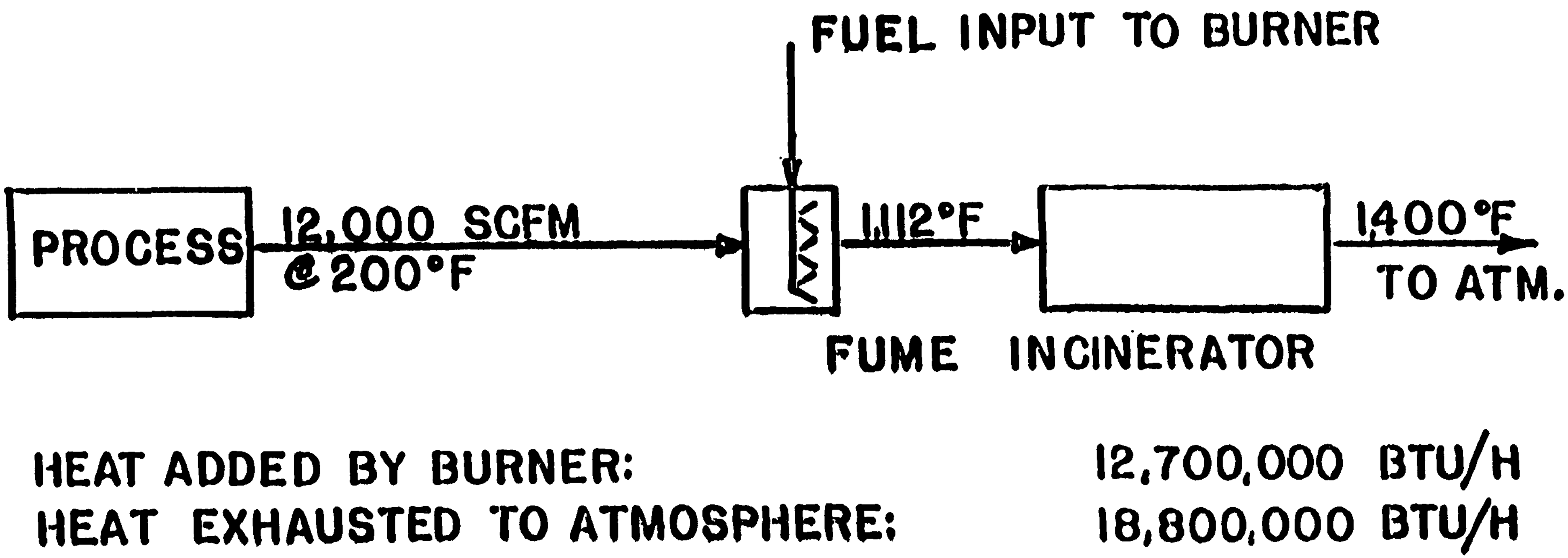

Figure 6. Schematic of an Early Afterburner System

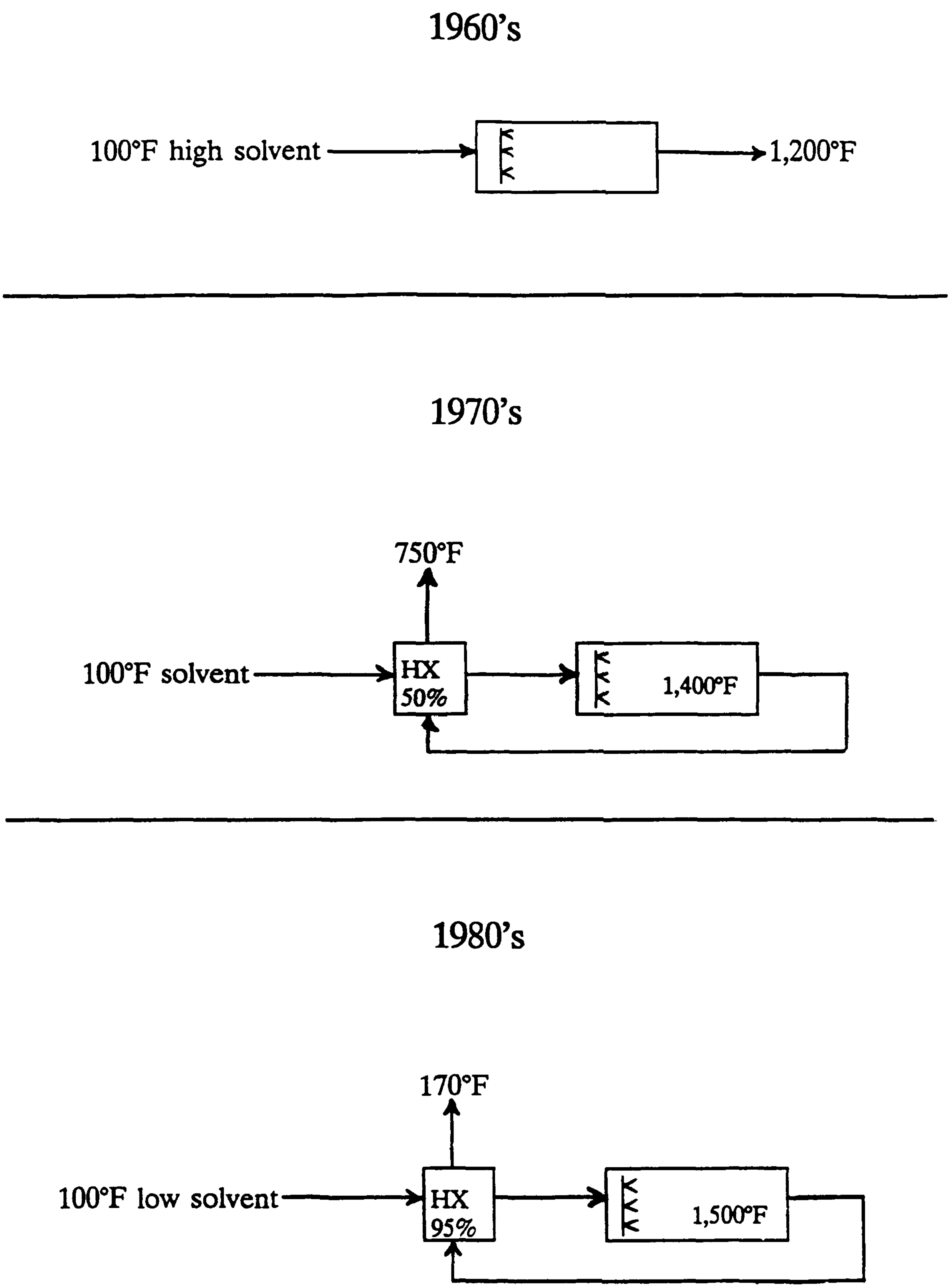

Figure 7. **Schematics of Three Basic Afterburner Technologies (1960s to 1980s)**

The regulations promulgated in the 1970s restricted emission levels further, requiring 90 percent destruction of VOCs. Additionally, fuel costs became higher, so it was not cost effective for industries to discharge 1,200°F air. Industries then began to apply heat recovery methods to remove the odor-causing organics and more economically met air quality requirements.

In the 1980s, only very low levels of VOCs from process exhausts could legally be emitted and the issue of odor control became more of a process exhaust concern. For one polystyrene manufacturing plant, the level of solvent that can be released is only 200 ppm, which is very low. At peak value, 95 percent of VOCs must be controlled. The process involves incinerating at 1,000°F, recovering 95 percent of the heat, and emitting 170°F air. Some facilities are even using the 170°F air to perform drying operations.

New technologies. Some new technologies are regenerative thermal oxidation systems, recuperative type oxidizers, and thermal oxidizers. Figure 8 is a diagram of the Smith Regenerative Thermal Oxidation System. In this system, a regenerative heat exchange cycle is used to alternately heat and cool relatively shallow beds of special ceramic media.

The process begins when VOC-containing process exhausts enter the system and pass vertically through a heated ceramic bed (the heat exchanger) which preheats the exhausts to almost final oxidation temperature. These preheated exhausts then enter a combustion chamber where they are further heated and retained at final oxidation temperature to achieve high destruction efficiency. The hot clean gases exiting this chamber pass through a second ceramic bed cooled in an earlier cycle. This bed absorbs most of the heat from the gases, cooling them before discharge to the atmosphere. A third ceramic bed/heat exchanger vessel is simultaneously being purged of any exhaust still contaminated with inlet VOC emissions to insure high overall VOC destruction efficiencies for the system. The cycle is repeated, alternating between the three ceramic beds for heating, cooling, and purging operations. The quantity and configuration of the bed media are varied to provide for thermal efficiencies of up to 95 percent. Additional heat exchanger vessels can be used to handle very high exhaust flow rates.

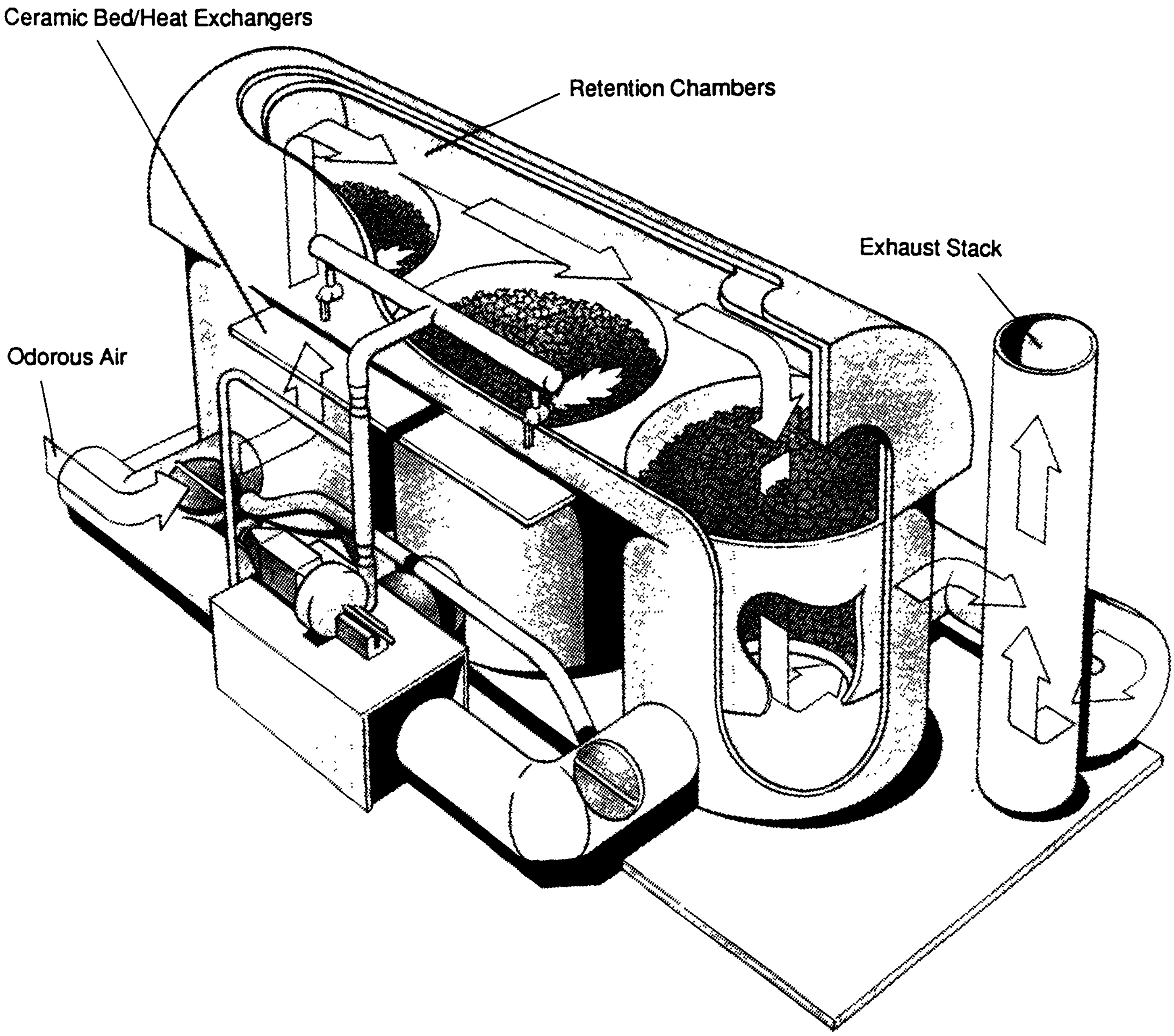

Figure 8. Smith Regenerative Thermal Oxidation System

Benefits for wastewater treatment. One of the benefits of the new technologies is that all the VOCs are removed, as opposed to just being moved to another media, like that which occurs with air scrubbers. The equipment also is very fuel and cost efficient and requires little attention during operation because it is run by programmable controllers.

Table 4 lists average operating costs for the Regenerative Thermal Oxidative System, where the heat recovery value is 95 percent and the amount of fuel consumed is about 1.3 million BTUs per hour. The blowers consume about 120 hp. Operating costs for natural gas systems would be about $5.00/million BTUs per hour, depending on regional location. Typical electrical costs are $.06/KWh. Operating the Smith Regenerative Oxidizer 365 days a year, 24 hours a day, will cost about $131,150.

A thermal oxidizer will treat any type of organic material at any level of concentration. At a sewage composting plant, the level of pinines and turpines (odor-causing byproducts of wood) vary with the type of wood chips selected. This offers potential cost savings by allowing selection from a wider variety of woods.

Concerns. Capture of the organics is one critical concern. To remove odors, they must be captured and sent through the oxidizer. Another concern is that there may be instances when the air stream from a wastewater treatment plant will require conditioning prior to or after the thermal odor treatment process. For example, if halogenated solvents are present in the process exhaust, a caustic scrubber may be required after the thermal oxidizer. In another example, high levels of ammonia in the process would require a water scrubber prior to the oxidizer.

Initial equipment costs are high and costs will escalate significantly with the air flow levels. Equipment for a system that exhausts 50,000 to 60,000 scfm could cost $1 million.

For more information about these systems, contact Terry Crabtree (see Appendix A).

TABLE 4

AVERAGE OPERATION COSTS FOR THE REGENERATIVE THERMAL OXIDATION SYSTEM

Process Flow	20,000 scfm
Process Temperature	100°F
Operation Temperature	1,500°F
Retention Time	1.0 second
Normal Heat Recovery	95%
Burner Contribution	1.92 MM BTU/Hour
Electrical Load (Total)	120 BHP
Typical Natural Gas Cost	$5.00/MM BTU/Hour
Typical Electricity Cost	$0.06/KW-Hour
Annual Operating Cost (365 days/year; 24 hours/day)	$131,150

SECONDARY TREATMENT TECHNOLOGIES

AUTOHEATED THERMOPHILIC AEROBIC DIGESTION

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Morgantown, Pennsylvania

Historically, POTWs have treated sludges using digestion or composting processes that stabilize the sludge under controlled conditions. Conventional stabilization processes can be aerobic or anaerobic and destroy about 40 percent of the organic solids with a significant decrease in the number of attendant pathogens. Conventional systems typically accomplish this level of treatment within 20 to 60 days, depending on the specific method of treatment used.

Liquid composting. Autoheated thermophilic aerobic digestion (ATAD) is a sludge digestion process that operates under thermophilic temperature conditions without introducing supplemental heat. The system relies on the heat released during the digestion process itself to attain and sustain the desired operating temperatures. Perhaps because of its thermophilic operating temperature and self sustaining nature, the process was referred to as "liquid composting" during the early stages of its development.

The ATAD process was the subject of intensive research in the sixties and seventies in both the United States and Europe. The technology has been widely implemented in Europe, primarily in the Federal Republic of Germany (FRG), where approximately 43 full-scale facilities are in operation. Three installations are known to exist in Canada, two of which are similar to the FRG version and one of which is a unique system. In the United States (Connecticut), one full-scale application is being planned.

Technology assessment. In 1989, the U.S. EPA Risk Reduction Engineering Laboratory (RREL) initiated a technology assessment of the alternative ATAD systems implemented in the FRG. The assessment included visiting a number of facilities to evaluate operator satisfaction and overall system performance, and interviewing design engineers, system manufacturers, and the research community.

The assessment showed that the most widely used ATAD configuration uses covered insulated reactors that are normally installed above ground (see Figure 9) and an efficient atmospheric air aeration system that is considered to be essential for attaining the desired operating conditions. Typically, facilities use two-stage systems to insure that pathogen reduction meets regulatory requirements. Reactor temperatures in the second stage are normally in the range of 50°C to 60°C, and the total hydraulic detention time at design loadings is about 6 days. Volatile suspended solids reductions ranged from 30 to 50 percent in the facilities evaluated.

The application capacities of the FRG installations range from 3,500 to 80,000 population equivalents (PE), with more than 70 percent smaller than 15,000 PE. Most facilities are located in central and southern Germany, in agricultural areas that closely link the technology with the agricultural use of sludge. A number of studies determined that the system produces an "hygienically safe" sludge, a criteria category that is required in the FRG for using sewage sludge on agriculture (see Table 5).

For the 22 facilities studied, installation cost data indicated that the process was generally more cost effective than operating conventional alternatives, even without considering enhanced pathogen reduction. Operating personnel reported minimal maintenance requirements and noted the simplicity in process operation.

Odors were a particular focus during the site visits due to the increased public sensitivity related to locating wastewater and sludge treatment systems in nonrural areas. Typical soil and humus-like odors were noted in most facilities that were not equipped with odor control systems. One facility was noted as odorous during a 30 percent overload condition brought about when grapes were being processed at a local winery. A present odor control practice for nonrural applications is to use a compact upflow scrubber (see Figure 10).

EPA prepared a detailed technical report that summarizes the pathogen reduction studies, operating experiences, design criteria, and costs associated with Autoheated Thermophilic Aerobic Digestion. Copies of the report can be obtained by contacting Kevin Deeny (see Appendix A).

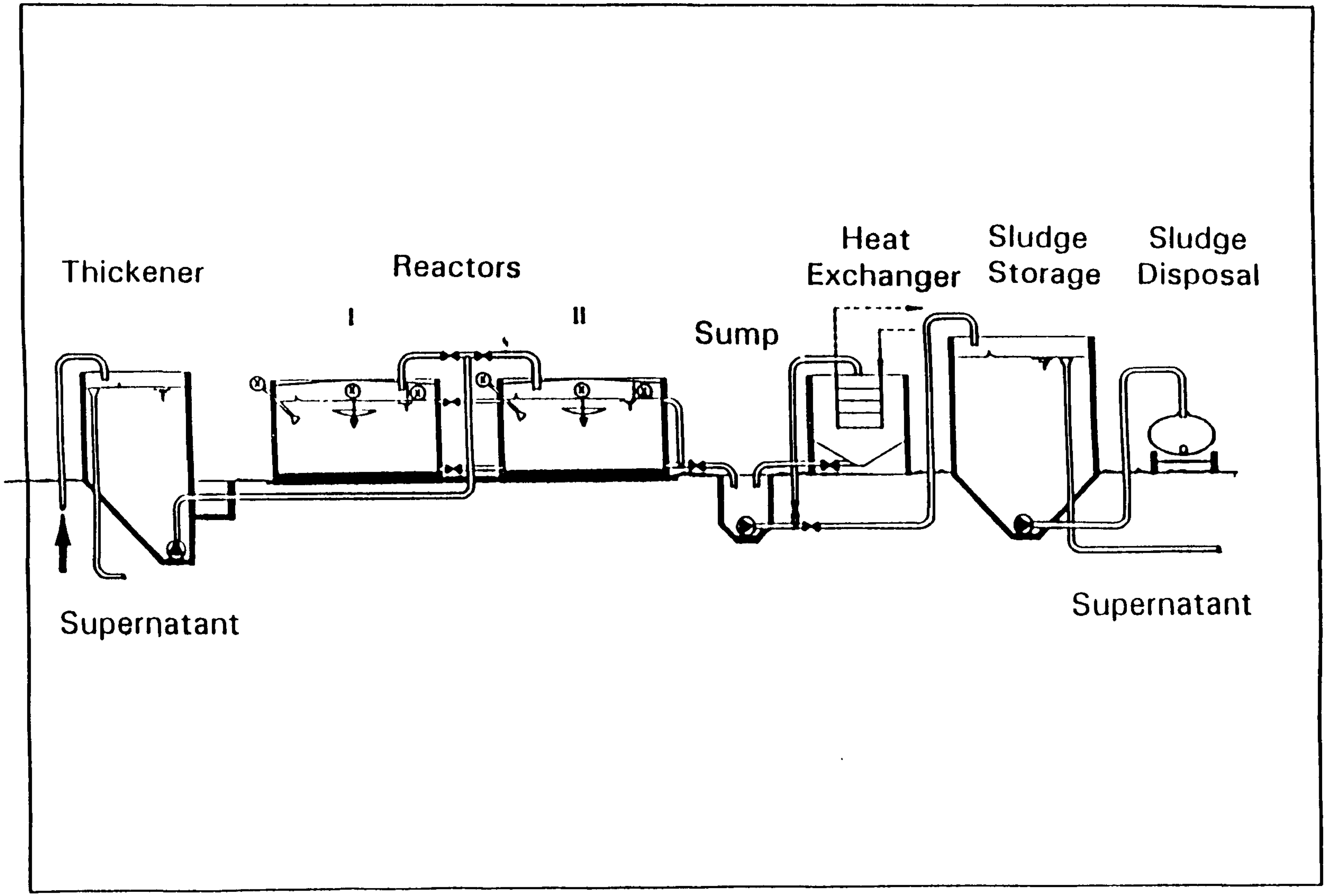

Figure 9. Flow Diagram of a Two-Stage ATAD Facility with Heat Recovery

TABLE 5

PROPOSED CRITERIA AND CONDITIONS FOR HYGIENICALLY SAFE SLUDGE IN THE FEDERAL REPUBLIC OF GERMANY

- The sludge treatment technology must be proven to:
  - reduce the number of indigenous or intentionally seeded *Salmonella* by at least 10^4
  - render indigenous or seeded eggs of *Ascaris* noninfectious.
- Sludge sampled directly after treatment must contain:
  - no salmonella
  - less than 100 enterobacteriaceae/gm
- The sludge treatment technology must be operated within guidelines developed specifically for the technology. For ATAD these include:
  - minimum 2-stage configuration
  - undisturbed (i.e., no feeding) reaction time as below:

    Time $\geq$ 23 hours, Temp. > 50°C
    Time $\geq$ 10 hours, Temp. > 55°C
    Time $\geq$ 4 hours, Temp. > 60°C
  - total detention time > 5 days
  - pH $\geq$ 8

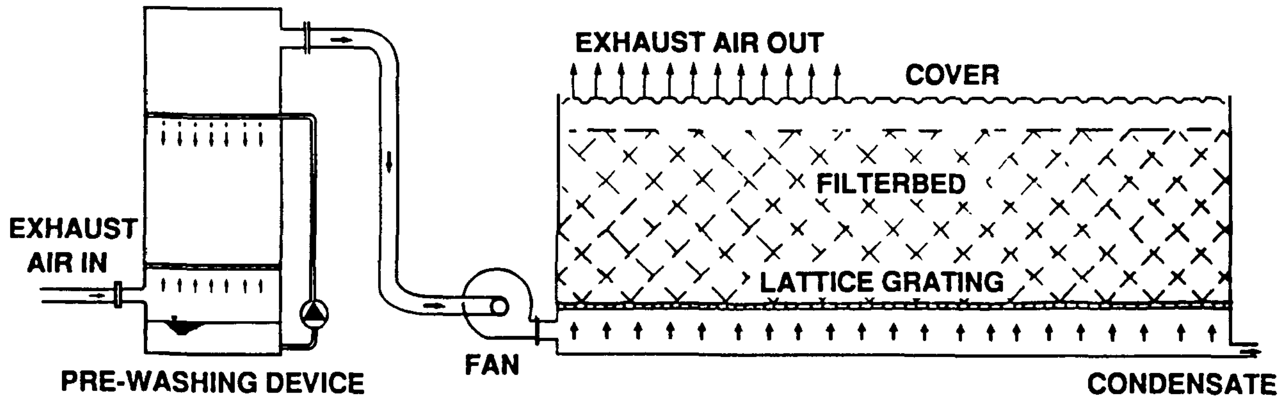

Figure 10. Schematic of a Compact Upflow Scrubber (Fuchs Biofilter)

CAPTOR STUDY OF MOUNDSVILLE/GLENDALE MUNICIPAL WASTEWATER TREATMENT WORKS

Elbert Morton, West Virginia Department of Natural Resources
Charleston, West Virginia

The "Captor" process is a high biomass biological treatment process for municipal wastewater, originally developed and widely used in England. In effect, this process transforms a suspended growth system into an attached growth system through the use of large quantities of polyester foam pads in the aeration tanks. The pads, 1 inch by 1 inch by 1/2 inch in size, encourage the growth and adherence of the biomass onto the surface and reticulated infrastructure of the foam pads. In the Captor basins, primary effluent comes in contact with the fixed film of biological organisms growing on the pads, which provides organic material food for the organisms. Based on general food to biomass loading considerations, the volume requirements of the aeration basin decreases in proportion to an increase in biomass concentration. In the Captor basins, both biological oxygen demand (BOD_5 or BOD) and part of the secondary treatment process oxygen demand are reduced.

The pads can be adequately mixed with a fine bubble diffuser at 1,100 pads/cu.ft. The higher oxygen transfer capacity of the fine bubble aeration technology applied to the Captor process maximizes the potential to substantially increase the biomass concentration. The high density of pads also allows the system to obtain higher biomass concentrations than those typically encountered in municipal activated sludge processes.

Another aspect of the Captor process is a unique wasting technique that removes excess sludge by extracting a certain percentage of the pads from the reactor and passing them through rollers that squeeze out the waste sludge. Compared to conventional biological processes, substantially higher dry solids concentrations can be obtained with the wasting process, thereby eliminating the need for separate sludge thickening.

Project history. From 1984 to 1989, the West Virginia Department of Natural Resources (DNR) studied the Captor process at a 2.35 MGD regional wastewater treatment plant servicing the cities of Moundsville and Glen Dale, West Virginia, and the surrounding areas. The U.S. EPA awarded the project with a Step II/III grant requiring DNR to conduct a field test before EPA would issue final approval to begin the design.

The project team tested a Captor pilot unit to determine if the Captor process could meet secondary treatment standards and decrease the required aeration zones. The pilot unit consisted of a 10 ft. high by 10 ft. wide by 45 ft. long steel tank that included four separate aeration zones equipped with fine bubble diffusers, an effluent channel, a clarifier with a hopper bottom, an air lift sludge return, and a scum skimmer. The first aeration zone was equipped with a pad cleaner and an effluent screen. The pilot plant operated with the Captor and activated sludge basins in series, and the effluent from the activated sludge compartment directed to the clarifier. When the process stabilized, flow rates, detention times, pad cleaning, and other test parameters were varied to determine their effect on plant performance.

Design. Consistent with the findings from the pilot study, the final plant design consists of a Captor aeration area, followed by activated sludge and secondary clarifiers. Hydraulic detention time for the Captor area is 1 hour at the average design flow of 2.35 MGD and 2 hours in the activated sludge area. The system consists of a mechanically cleaned bar screen, an aerated grit chamber, 2 primary clarifiers, the Captor aeration basin, an activated sludge area, 2 secondary clarifiers, and an open channel ultraviolet (UV) disinfection unit. The sludge is treated by single primary and secondary anaerobic digesters and two belt filter presses. This system has two parallel aeration units, and the Captor pad basins make up the first stage of the 2-stage secondary treatment process.

Plant start-up. The system began operating in June 1989. During its initial phases, several problems occurred with the influent and effluent screens and the approach to sludge management. About 2 weeks after start-up, the stainless steel screen separating the Captor process from the activated sludge unit became clogged and bent, allowing about 4 million pads to escape into one of the secondary clarifiers. The clogging was attributed to biological growth binding to the screen, which occurred during a peak hydraulic loading after a storm. The clarifier was shut down, and the pads were removed using a sewer/vacuum truck. A few days later, the additional flow added to the one operating unit caused the effluent to build-up enough to bend the screen in this unit, too, although the effluent did not flow over the screen in significant quantities as a result. The screens from both units subsequently were redesigned by the manufacturer, Ashbrook Simon-Hartley, and were put back into service by September, 1989. The new screens have additional structural bracing against the concrete tankage.

In mid-September, 1989, the influent Captor screens in one of the units failed, apparently due to backflow from the effluent screen, the build up of biological mass on the screens, and inadequate bracing. In October, the influent screens from both units were removed and not replaced. To limit the amount of biomass on the effluent screens, the State, engineer, and manufacturer agreed to increase the mixing and aeration in the system to help the pads act as a scouring agent against the effluent screens. The group also decided that the effluent screens needed to be mechanically cleaned to remove the biomass build-up, so air knife scouring devices were added to both units.

After the major repairs were completed in October, the air knives were properly aligned, the aeration diffusers were repaired, and additional sections of screening were added to the top of the effluent screen to prevent overflow of the pads. The biological system stabilized by November, and the UV system was placed into operation December 1. (Prior to this time, the effluent was chlorinated using the effluent line as the contact chamber.)

The complete sludge handling equipment was not fully operational until November 1989. The facility experienced problems with the start up of the belt filter presses, preventing sludge stabilization within a reasonable start-up time. This problem was attributed to operator inexperience. The operator was also carrying a significant sludge blanket into the primary clarifier, contributing to the delay in the acceptable operation of the Captor process.

Operation. Table 6 shows BOD_5, total suspended solids (TSS), total keldjian nitrogen (TKN), and fecal coliform count for the plant from December 1989 through February 1990. Based

TABLE 6

PLANT EFFLUENT RESULTS FOR THE MOUNDSVILLE/GLENDALE MUNICIPAL WASTEWATER TREATMENT PLANT (November 1989 to February 1990)

MONTH		SUSPENDED SOLIDS	BOD_5	TKN Mg/L	FECAL
	Avg.	22	31	19	5
Nov.	Max.	27	32	18	20
	Min.	18	28	19	
	Avg.	24	27	16	16
Dec.	Max.	29	30	17	10
	Min.	19	21	14	165
	Avg.	21	41	16.8	108
Jan.	Max.	27	65	15	319
	Min.	17	20	19	11
	Avg.	14	30		81
Feb.	Max.	20	26		256
	Min.	7	34		28

solely on the operation data, the system shows the potential to meet secondary wastewater treatment requirements.

One factor affecting these results is that solids accumulated in the system because the sludge handling system was not stabilized. Since January 1990, excess amounts of solids have been removed from the plant via the belt filter presses and disposed of in a landfill. The average suspended solids and BOD_5 loading rate to the primary clarifiers is shown in Table 7. Excess solids still must be removed from the system due to the amount of loading from the digester.

Another operational problem is due to the biological makeup of the system. Because the mixed liquid suspended solid (MLSS) of the activated sludge zone has varied from 2,000 to 5,000 mg/l, system operators have found it difficult to obtain and maintain a steady biological growth or establish a standard return activated sludge or a waste sludge. The operator has found that the most effective operation rate for the plant is between 3,000 and 3,500 mg/L.

A third operational problem was the excessive growth of *carchesium* protozoan in December 1989, which appeared as a gray slime on the exterior of the sponges. To eliminate the overgrowth of this organism, the dissolved oxygen has been lowered enough to cause them to die off, and aeration and mixing was enhanced to scour the organism off the pads. These methods appear to be working, but it is still not known which method contributes more to the die off.

The Captor sludge vortex pumps also have been problematic. The pads become squeezed between the impeller and the wall of the pumps, binding the impeller and preventing the pads from being cleaned. To solve this problem, the system engineer is considering either changing the pump or the present operational mode to provide a backflush of the pump or an alternate method of removing the pads.

<u>Conclusions</u>. At this time, the success or failure of the Captor system cannot be judged. Based on the monitoring results, the system should be able to function as a secondary process if

TABLE 7

AVERAGE SUSPENDED SOLIDS LOADING RATES TO THE PRIMARY CLARIFIER OF THE MOUNDSVILLE/GLENDALE WASTEWATER TREATMENT PLANT (November 1989 to February 1990)

	SS Mg/L	BOD_5 Mg/L
November 1989	477	355
December 1989	476	341
January 1990	544	419
February 1990	400	345

system designers can address the problems encountered. A detailed analysis of the site specifications criteria must be considered.

Based on the limited data available, the Captor process may not be cost effective for a new secondary plant, but it may be suitable for upgrading an existing plant where space for expansion is limited. Detailed operation and maintenance costs have not yet been examined.

To obtain a more complete description of the system and project, contact Elbert Morton (see Appendix A).

PHYSICAL-CHEMICAL PROCESS PROVIDES COST-EFFECTIVE SECONDARY WASTEWATER TREATMENT

Robert D. Sparling, City of Tacoma Sewer Authority
Tacoma, Washington

In September 1986, the City of Tacoma, Washington, began an extensive investigation on the benefits of using a physical-chemical process to achieve secondary treatment at its North End Wastewater Treatment Plant. This investigation was prompted by the results of previous engineering studies that indicated that the existing plant would need to be demolished and a new plant would need to be rebuilt to achieve secondary treatment with a conventional biological process. Before choosing this extreme option, the city wanted to investigate alternative secondary treatment processes that would require less construction.

Pilot test. The city and the State of Washington Department of Ecology conducted full-scale pilot tests at the North End Plant from January 1987 to July 1989 to collect comprehensive operational data on a physical-chemical process under actual conditions. Prior to this time, the plant had been only a primary treatment facility. Wastewater flows at the plant averaged 4.5 MGD, providing wastewater treatment for an estimated sewer population of 43,750. A schematic flow diagram of the pilot plant is shown in Figure 11. Table 8 is a summary of existing plant waste loads.

For the pilot tests, temporary chemical storage containers, piping, and chemical feed equipment were installed at the plant. Alum and various polymers were then added to the existing primary treatment processes at locations as shown in Figure 11. The plant was operated without making any other modifications to the physical structures. Throughout the test period, daily component samples were analyzed for BOD, soluble BOD (SBOD), and suspended solids (SS). The average 30-day concentration and removal efficiencies are shown in Table 9.

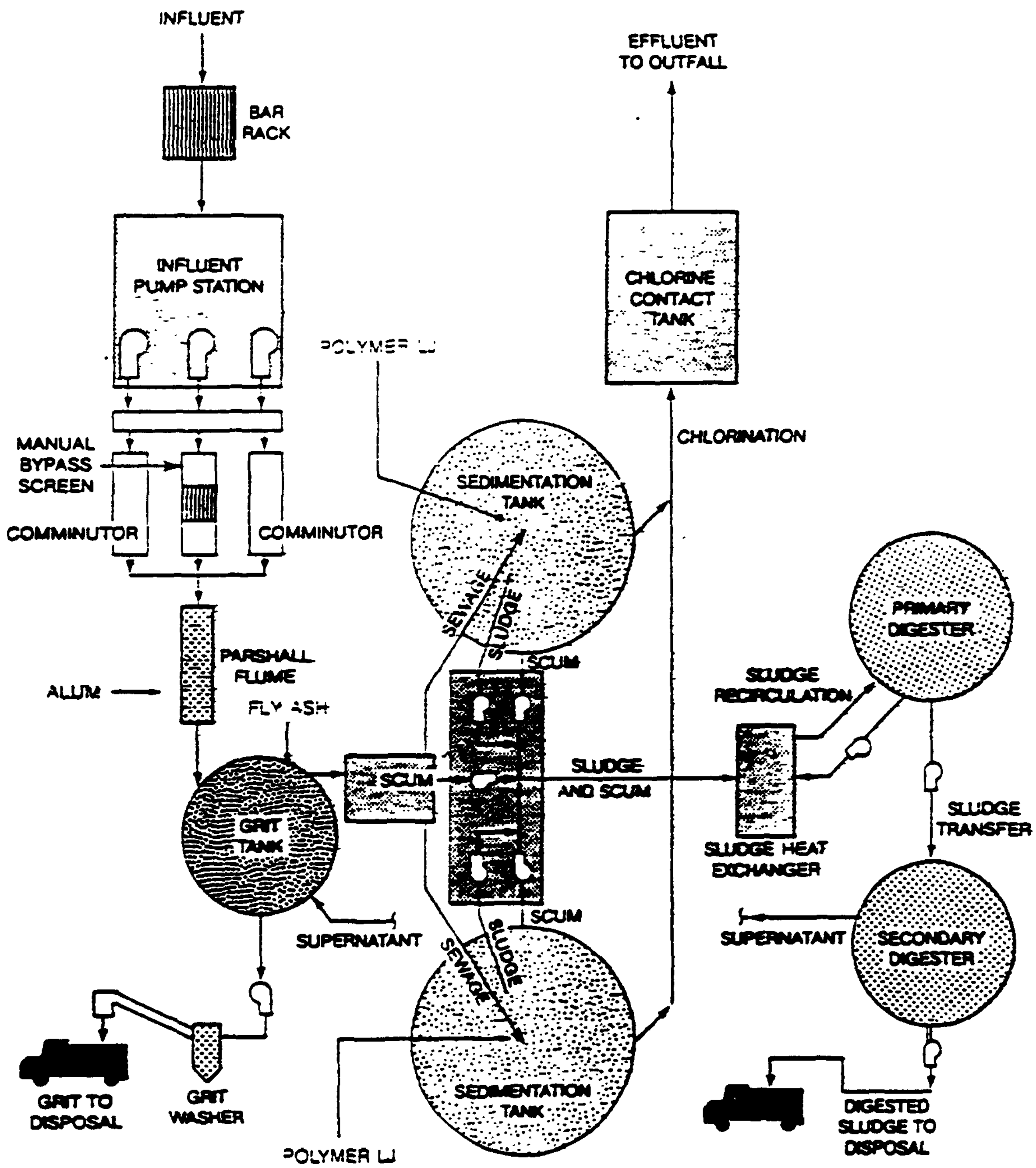

Figure 11. Flow Diagram of the Tacoma, Washington, Pilot WWTP with Physical-Chemical Treatment

TABLE 8

SUMMARY OF EXISTING PLANT WASTE LOADS AND STATISTICAL ANALYSIS

	Calculated Concentration (mg/L)	Observed Plant Flow (MGD)	Observed Loading (#/day[1])
BOD			
Annual Average (AA)	163	4.5	6,100
Average Dry Weather (ADW)	161	4.2	5,540
Average Wet Weather (AWW)	166	4.9	6,780
Maximum 30-day	185	5.1	7,850
Maximum 7-day	152	9.2	11,700
SBOD[2]			
Annual Average	47	4.5	1,770
Average Dry Weather	46	4.2	1,610
Average Wet Weather	49	4.9	2,000
Maximum 30-day	54	5.8	2,600
Maximum 7-day	81	4.5	3,070
Suspended Solids			
Annual Average	166	4.5	6,230
Average Dry Weather	167	4.2	5,850
Average Wet Weather	165	4.9	6,730
Maximum 30-day	234	4.9	9,550
Maximum 7-day	259	7.2	15,540

[1]Observed loadings of plant influent.

[2]Defined as passing 0.54 micron filter.

TABLE 9

PILOT TEST EFFLUENT BOD, SBOD[1], AND EFFLUENT SS

	Effluent BOD		Effluent SBOD[1]		Effluent SS	
	mg/L	Percent Removal	mg/L	Percent Removal	mg/L	Percent Removal
Annual Average	28	82	22	53	12	93
Dry Weather	27	83	10	59	11	94
Wet Weather	29	82	24	51	13	92
Maximum Month	30	80	27	50	16	89

[1] Defined as passing a 0.54 micron filter

The toxicity of the physical-chemical process effluent was also compared to that of a conventional biological secondary process. Both trout and *Daphnia* bioassays were performed using effluents from both the North End Plant and a nearby secondary plant that uses a biological treatment process. These tests indicated that there was no significant difference in trout or *Daphnia* mortality between the two plants.

The results of the pilot test demonstrated that a physical-chemical process could sufficiently remove organic material and suspended solids equivalent to secondary treatment. In terms of efficiency, the physical-chemical process reduces suspended solids well below the regulatory limit of 30 mg/L or 85 percent removal. On an annual average, the process removed 92 percent of the suspended solids, which is about one-half of the total secondary discharge allowed. The reduced solids discharge is significant in terms of total potential for solids deposition and toxicant removal. This conclusion was reached without the full benefit of accurate chemical dosages and optimum coagulation and flocculation because these data were not possible to collect using the temporary equipment installed for the test period.

The physical-chemical process removed an average of 73 percent of priority pollutant metals compared to 55 percent for the activated sludge process. The total mass emission of toxicants by a physical-chemical process would be approximately 50 percent of that expected from secondary permit limits.

New plant construction. Based on the data, in 1989 the City of Tacoma began building a permanent physical-chemical treatment plant at the North End site that includes a new chemical feed building. Only relatively minor modifications were necessary. The new facility allows for maintaining accurate chemical dosages during the process regardless of wastewater flow.

Since completion of the new chemical feed building, Tacoma's North End Plant has achieved secondary treatment using a physical-chemical process. The city has demonstrated that they saved significant capital, operation, and maintenance costs by using this process compared to conventional biological secondary processes.

To obtain a complete report with extensive application and operational data on using a physical-chemical process, contact Robert Sparling (see Appendix A).

BIOLAC TECHNOLOGY EVALUATION

Karl Scheible, HydroQual
Mahwah, New Jersey

Biological Aeration Chains (Biolac) constitute an extended aeration system first used in Europe. The technology was introduced into the United States in 1986, and since that time, a significant number of Biolac plants have been installed in this country. The U.S. EPA Office of Municipal Pollution Control (OMPC) sponsored a study to assess this technology and problems that may have been encountered at several Biolac facilities.

The Biolac system is an innovative technology for extended aeration. It uses high efficiency fine bubble aeration and accomplishes mixing with relatively low horsepower (HP) requirements. Most Biolac systems use integral clarifiers and are generally designed for low loadings. As a result, the systems have high process stability and BOD, TSS, and NH_3-N removals. In general, Biolac systems have lower capital costs and potentially lower O&M costs compared to conventional extended aeration systems.

For the EPA study, OMPC surveyed and evaluated Biolac system configurations, plant operations, operating levels compared to design capacities, problems encountered, and how the problems were resolved. The study team collected data on system performance (relative to design specifications) and capital costs. OMPC contacted facilities by telephone or through direct visits.

System description. Survey results indicate that as of September 1989, 59 Biolac plants are located in 20 States, and 12 more are being planned. Forty of the operating facilities are municipal installations, with design flows ranging from less than 0.1 MGD to 54 MGD. Twenty-five of the municipal plants use clarification and solids recycle (designated as the Biolac-R), while the rest use flow-through lagoons with no solids return (Biolac-L).

The basic Biolac configuration consists of a basin or lagoon equipped with floating aeration chains (see Figure 12). The chains are made of Wyss fine-bubble diffusers attached to flexible headers. The diffusers are weighted and hang from a float assembly. Several of these diffuser/float assemblies are connected and form a chain across the basin, which is anchored to the basin sidewall. These floating aeration chains oscillate across the basin surface, propelled by the rising bubbles from the diffusers; this moves the diffuser assembly through the liquid, thereby mixing and aerating the wastewater simultaneously. When a chain moves to full tension in one direction, the diffuser assemblies swing slightly and cause the chain to move in the opposite direction, repeating the oscillation cycle. Some aeration chain systems had been retrofitted onto existing basins, replacing conventional mechanical or diffused air systems.

The typical Biolac-R system (see Figure 13) uses extended aeration/activated sludge equipment with integral clarifiers, although retrofits have used existing external clarifiers. The systems have waste sludge holding basins and often a polishing basin that can be divided by a floating curtain wall, with the first section aerated and the second section used for additional settling. The polishing basin is optional but generally recommended for new facilities to assure effluent quality. The integral clarifier (see Figure 14) has two concrete walls extending from the basin and a floating partition wall that separates the clarification zone from the aeration zone. A rake moves back and forth across the clarifier to concentrate the sludge, which is then removed with an airlift pump. Overflow weirs are generally designed at an average loading of 10,000 gpd/ft.

The Biolac-R systems are often conservatively designed for a hydraulic residence time (HRT) of 2 to 4 days and a solids residence time (SRT) of 30 to 70 days. BOD loadings range from 0.03 to 0.1 pounds per pound of mixed liquor suspended solids (MLSS) per day (lbs BOD/lbs-d). The design loading rate for the aeration basin is typically 975 lbs BOD/MG-d. The diffusers are installed at an average rate of 385/MG. This is equivalent to an air flow of 1,350 scfm/MG, at the typical air flow of approximately 3.5 scfm per diffuser. From a survey of 25 operating Biolac-R plants, the average operating HP is 45 HP/MG, with the plants typically operating at 40 to 60 percent capacity. Most plants are equipped with 3 blowers -- one is used

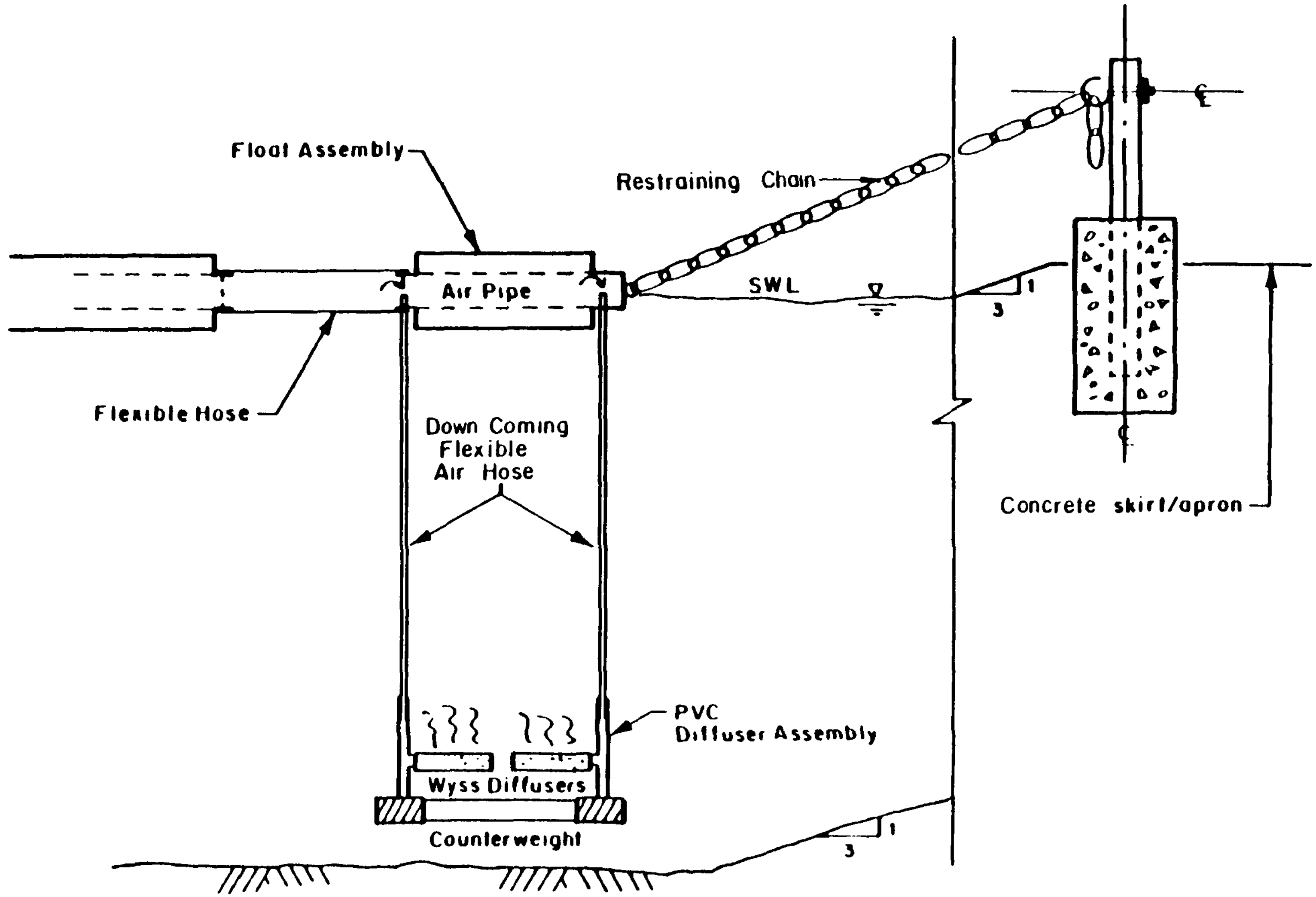

Figure 12. Biolac Aeration Chain Detail

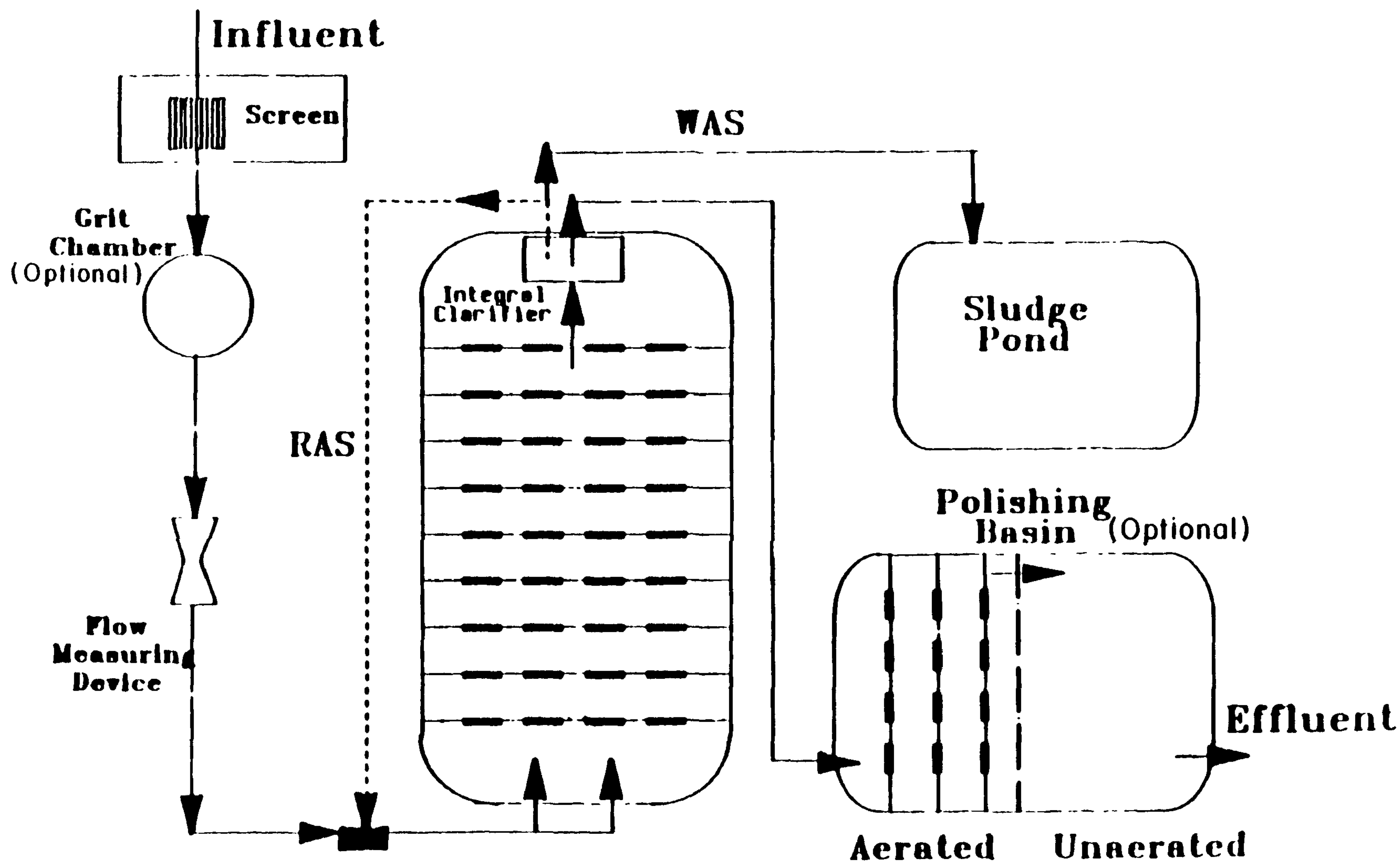

Figure 13. Flow Diagram of a Typical Biolac-R System

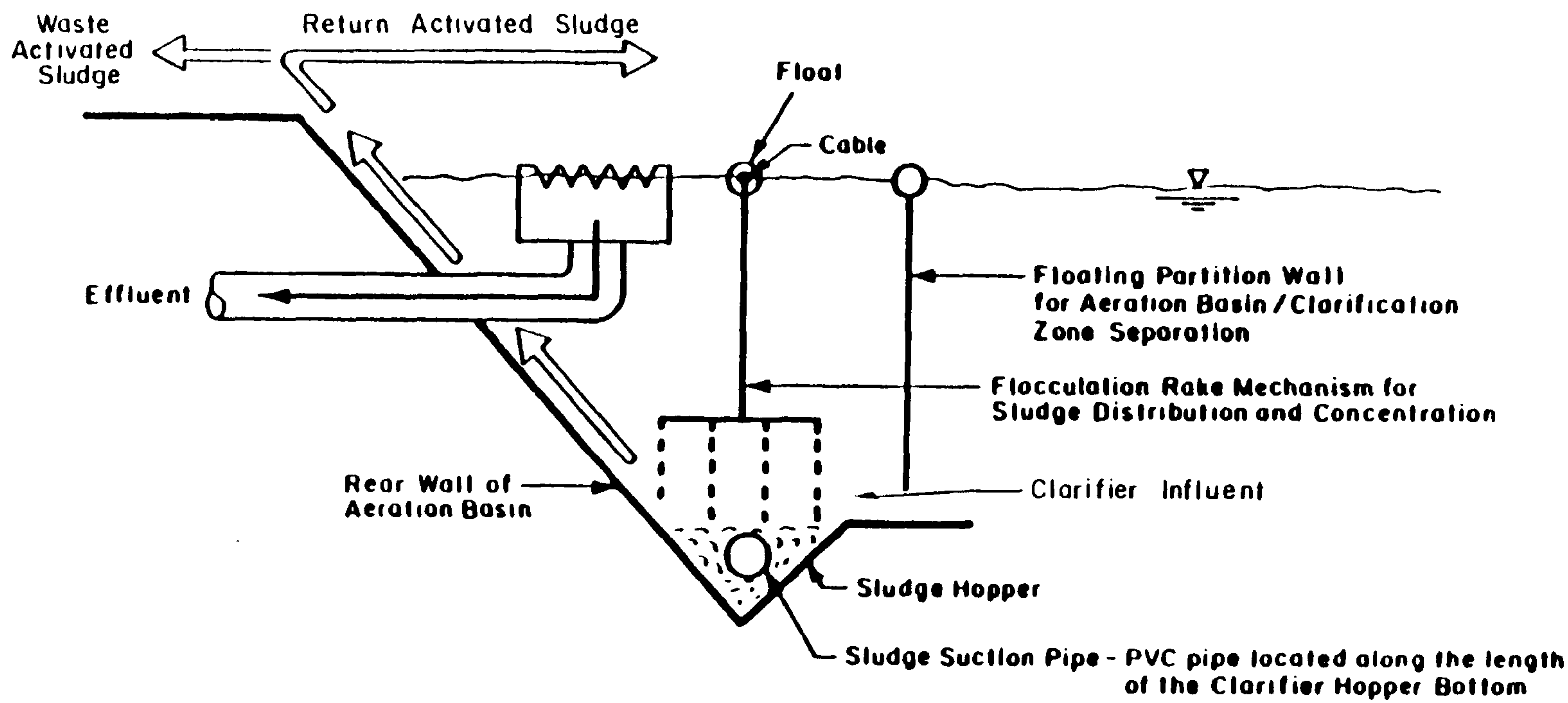

Figure 14. Schematic of Integral Biolac-R System Clarifier

full-time, a second is used intermittently on demand, and a third is on standby. The power usage is about half that required for conventional systems.

The Biolac-L configuration is an aerated flow-through lagoon that eliminates the use of solids recycle. The Biolac-L systems are generally designed for HRTs of 6 to 15 days, which are higher than the HRTs of conventional aerated lagoon systems. Polishing basins are used primarily for solids settling; these have an HRT of 2 to 4 days, with long-term storage capacity for sludge.

A modified Biolac-R system, known as the Wave Oxidation System, is relatively new and is operating at one plant in Arkansas to remove nitrogen, as well as BOD and TSS. The modified system controls and throttles air flow to each chain in progressively alternating groups of chains, which creates several oxic and anoxic zones. To maintain mixing, after about 15 minutes, the air flow is redistributed and the low air chains receive high air flow and vice versa. This process forms a dynamic moving "wave" of alternating oxic and anoxic zones.

Table 10 is a summary of performance data from several plants, most of which are new and operating with BOD removal ranging from 95 to 98 percent and TSS removal ranging from 85 to 95 percent. Effluent ammonia concentrations are typically less than 7 mg/L. Excellent removals were accomplished overall by each of the plants for which performance data were available.

Problems encountered. Many of the problems reported by the surveyed facilities related to the construction materials used. Various hardware elements corroded and restraining cables showed excessive wear. The facilities now use stainless steel hardware and 3/16 inch chrome-plated steel chain cables.

Some of the older Biolac plants experienced problems with the diffusers, which loosened and filled with sludge, probably due to poor installation and loosening of the attachment clips. Improper maintenance of diffuser "flexing" also caused the diffuser to clog. This problem can

TABLE 10

SUMMARY PERFORMANCE OF BIOLAC PLANTS

Plant	% of Design Flow	Start Up	% BOD Removal	% TSS Removal	Effluent NH_3-N mg/L
Morgantown, KY	58	1989	92.3	85.7	0.1
Greenville, KY	53	1988	96.5	94.7	0.5
New Brockton, AL	25	1989	95.5	94.4	1.9
Edmonton, KY	39	1989	91.1	89.5	3.2
Fincastle, VA	67	1988	91.2	89.7	-
Lowell, OH	203	1989	91.8	86.3	6.7
Hanceville, AL	88	1989	92.0	92.0	0.8
Livingston Manor	63	1986	97.9	95.3	1.9

Effluent	BOD mg/L	5.1 to 20.8[a]
	TSS mg/L	6.7 to 34.8[a]
	NH_3-N mg/L	0.1 to 30.9[a]

[a] Five plants with no influent data included

be resolved through weekly air flow cycling to each chain to effectively exercise the diffuser membrane.

Some facilities experienced a problem with inadequate mixing and air distribution, primarily in corner areas, which they resolved by using corner diffusers and cycling the blowers to increase mixing periodically. The integral clarifier rake switch targets needed to be fine-tuned, based on problems encountered at the earlier plants. Another problem has been clogging of the sludge withdrawal line, which may have been due to either insufficient pipe size or the lack of preliminary screening. Smaller-sized debris (particularly after comminution) tended to aggregate in the aeration basin and cause clogging in the air lift line.

System costs. The average capital cost for 10 Biolac-R plants installed from 1986 to 1989 was $1,260,00 per MGD of design flow. These plants are greater than 0.5 MGD in capacity and treat typical municipal wastewater.

Summary. The Biolac process is a viable, cost-effective system. The existing municipal Biolac-R systems, operating at about 40 to 60 percent of design flow and loads, are producing effluents with qualities that are consistent with other extended aeration technologies. Plants are attaining greater than 90 percent BOD and TSS removals on a consistent basis. Problems with the equipment related to the materials used for construction, corrosion failure, excess wear, diffuser clogging and failure, and sludge pump clogging. These problems appear to have been adequately resolved at the plants that reported problems, and have been accounted for in the newer plant designs.

The Biolac systems appear to have lower operating costs and less labor requirements, based on reported average operating horsepowers of only 40 to 50 HP/MG, as compared to fixed systems that require up to 100 HP/MG.

For more information about EPA's evaluation of Biolac systems, contact Karl Scheible (see Appendix A).

O&M ISSUES FOR POTWS

Hitesh Nigam, EPA Office of Municipal Pollution Control
Washington, D.C.

The National Operations and Maintenance (O&M) Program is a team effort of Federal, State, and local governments, national organizations, and the general public that provides a support system for municipal wastewater system operations. The program has assisted many local governments in their efforts to efficiently operate their wastewater facilities to meet permit requirements. These programs must be strengthened, however, to respond to current needs and new challenges facing the wastewater treatment industry.

The main challenges facing the O&M program are a shortage of trained operators in several areas of the country; control of toxics in wastewater; operation of unconventional technologies such as natural treatment systems (constructed wetlands, and land treatment projects); and the competing demand for support for wastewater treatment by other environmental concerns and public programs.

Goals of the O&M program. The broad goals of the O&M program are to attain and maintain environmental and safety standards; prevent pollution; protect the wastewater infrastructure (EPA has spent over $50 billion over the last 15 to 20 years to build systems); promote cost-effective operations; assure an adequate supply of trained personnel; and increase public support for wastewater treatment.

New program strategy and initiatives. To address the goals and objectives of the O&M program, the representatives of OMPC, EPA Regional offices, State regulatory agencies, and State environmental training centers met in Washington D.C. early in 1989 to draft a national program strategy. The purpose of this strategy is to provide a 3-year framework within which the EPA and the State O&M support groups can strengthen their activities, coordinate with other programs, and grow to meet new opportunities and new challenges. After 2 days of intense discussion, the group recommended that the program implement several initiatives within the next 3 years, including wastewater management training, public awareness, program management, onsite technical assistance, and State training centers

Management training. The wastewater management training initiative will support and develop training and certification programs for the effective management of wastewater facilities. It also will help establish and maintain an adequate supply of qualified wastewater personnel. These goals can be achieved by supporting the development of training curriculum for the operation and maintenance of conventional technologies and developing a network of expertise through training center programs. The O&M program will soon begin to train wastewater operators and provide technical assistance for overland flow projects.

These goals also can be achieved by implementing *Youth and the Environment* programs to introduce urban youths to the wastewater treatment field through summer employment at treatment plants, and developing a partnership with the Department of Labor to incorporate wastewater training into the Job Corps program. OMPC plans to implement *Youth and the Environment* programs in the summer of 1990 in Boston, Atlanta, Washington D.C., Denver, and Kansas City.

OMPC will continue to hold annual or semi-annual National/Regional meetings with the States.

Public awareness. The initiative on public awareness will inform local government officials and the general public of wastewater facility O&M issues. It also will inform communities of the services available through the program and help raise the public image of wastewater management personnel. One step recommended to achieve these goals is to prepare a pamphlet targeted to local officials that discusses the importance of operations maintenance and describes the services available under the program. Another step is to produce public service announcements for radio and television that urge support for wastewater treatment. Earth Day and Arbor Day are excellent opportunities for OMPC to promote the O&M program. A third step is to solicit support through Indian health service and the O&M awards program for the Indian tribes.

One additional promotion of the O&M program is the idea of collecting household hazardous waste at wastewater treatment plants. This activity can provide a useful service to the community, and make people more aware of where their wastewater treatment plant is.

Program management. The program management initiative will enlist support for strategy implementation; improve O&M program communication and coordination, internally and with others; and assure the availability of adequate personnel, financial, and material resources for program maintenance and growth. The actions necessary to meet these objectives will be to coordinate representatives from Federal agencies and appropriate national organizations, and form environmental training centers to coordinate O&M activities among programs.

The program plans to expand the *Onsite/Oversight* newsletter by broadening the mailing list, encouraging the contribution of articles, and publishing it quarterly. The office also will support the electronic bulletin board that links EPA State agencies and State training entities, and meet with representatives of State and other Federal agencies to develop plans to better coordinate technical assistance activities. The electronic bulletin board has already proven to be beneficial to the O&M program.

Onsite technical assistance. The objective of the onsite technical assistance initiative is to continue to expand the onsite technical assistance program, including the 104(g) program that assists small communities and Indian tribes in operating their wastewater facilities and achieving and maintaining permit compliance. The 104(g) program, which has contributed about $1.8 million annually, has been extremely helpful. This effort may be difficult due to declining grant funds.

To increase publicity and the base of support for onsite technical assistance and foster coordination of technical assistance programs at Federal and State levels, the O&M program plans to investigate other potential sources of funding, including other municipalities, States, and Federal agencies.

The program also plans to promote onsite assistance as a tool to maintain compliance and prevent pollution and expand technical assistance services to include financial management, plant startup, and maintenance management. If possible, the program will expand technical assistance services to include Indian tribes and other Federal facilities. The Department of Energy already has shown an interest in obtaining technical assistance.

The onsite technical assistance program will be publicized through the O&M awards program. A new awards category is "The Most Improved Treatment Plant," which will recognize an outstanding trainer and facility that has received onsite assistance. The awards are acknowledged at the WPCF conference each year.

State training centers. To expand State training centers, the O&M program will complete, update, and expand the environmental center directory to include every State and special areas of wastewater expertise. There are 39 State training centers at this time. The electronic bulletin board system will be used to facilitate communication and networking among the training centers.

This initiative will also promote, where appropriate, multi-disciplinary environmental training at the State centers and the participation in special sessions at the Rural Water 2000 Conference to publicize State training centers and form linkages with the Rural Community Assistance Program (RCAP) and other programs.

OMPC sent the draft O&M strategy to EPA Regional offices, State regulatory agencies, and State environmental training centers for comment. The strategy will be finalized in mid-1990. For more information, contact Hitesh Nigam (see Appendix A). See Appendix B for a list of National O&M contacts, and Appendix C for a list of Regional and State O&M Coordinators.

DENITRIFICATION USING SUBMERGED ROTATING BIOLOGICAL CONTACTORS A CASE STUDY

Phillip K. Feeney and Charles E. Hucks, Post, Buckley, Schuh, & Jernigan, Inc.
Orlando, Florida

In February 1982, the City of Orlando, Florida dedicated the Iron Bridge Road Regional Water Pollution Control Facility, a 24-MGD advanced wastewater treatment plant. The facility was designed to produce an effluent quality of 5 mg/L BOD, 5 mg/L TSS, 3 mg/L TN, and 1 mg/L TP (5/5/3/1) using rotating biological contactors (RBC), alum precipitation, and tertiary filtration. Figure 15 is a flow diagram of the facility as designed. In this system, the denitrification process follows the secondary clarifiers (where alum is added for phosphorus removal) and precedes the Automatic Backwash (ABW) Filters(TM).

At the time the facility was dedicated, it was the largest in the country using RBC technology, with 171 shafts for carbonaceous removal and nitrification and an additional 42 shafts for denitrification. Each shaft is about 15 ft in diameter. The carbonaceous/nitrification shafts are 25 ft long and contain from 100,000 to 150,000 ft^2 of effective surface area. The denitrification shafts (SRBC), which operate completely submerged, are 35 ft long and contain about 100,000 ft^2 of surface area.

During the first year of operation, when the denitrification units were operated, there was a rapid loss in denitrification and a rapid clogging of the tertiary filters, resulting in a steady increase in backwashing times. In February 1983, the denitrification unit was shut down until pilot studies could be performed. The city hired the consulting engineering company of Post, Buckley, Schuh, and Jernigan, Inc. to assist in optimizing the plant's performance.

Although the plant experienced several problems with additional unit processes in both the liquid and solids processing trains, this paper summarizes the problems the plant experienced with the denitrification unit process.

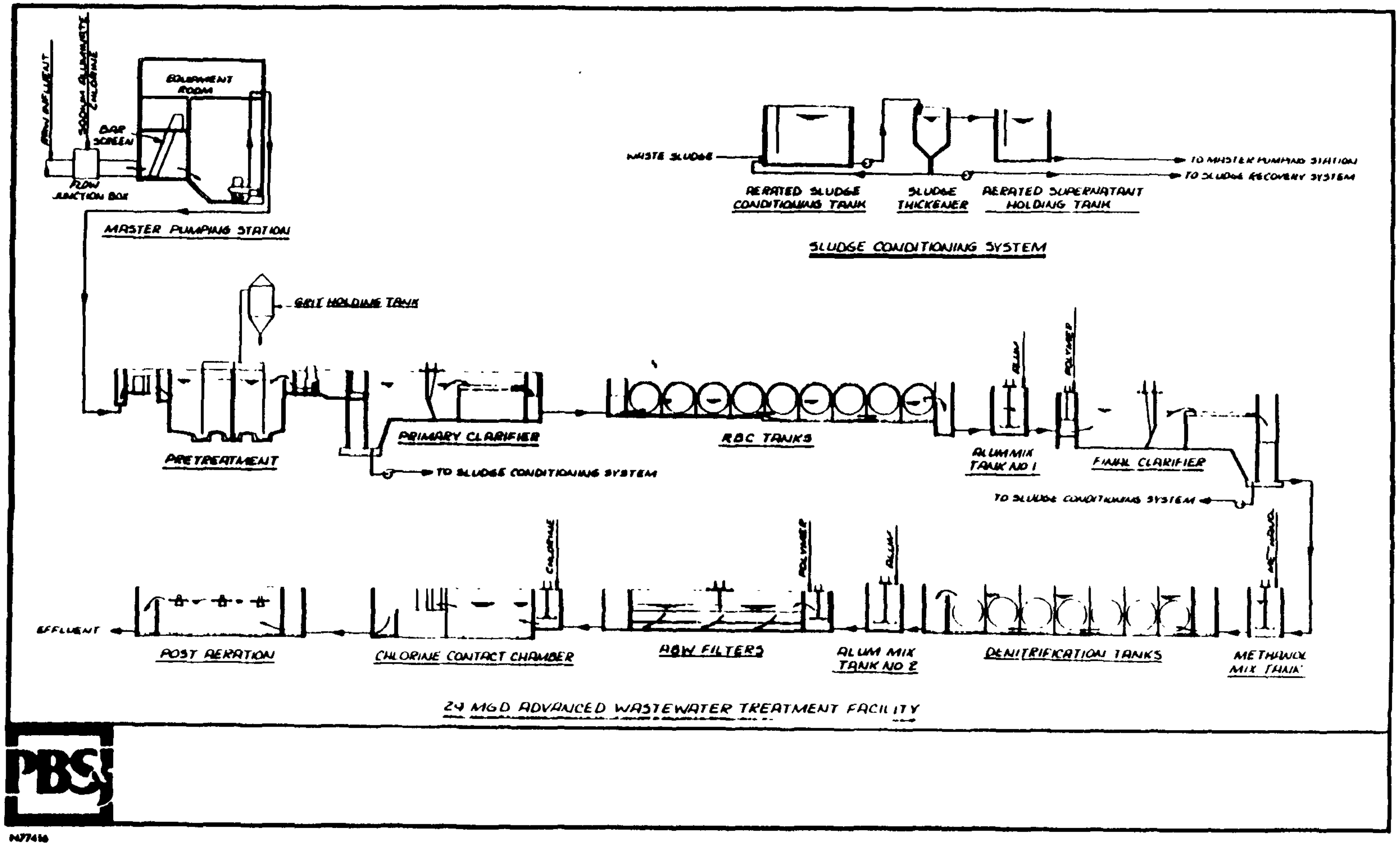

Figure 15. Original Iron Bridge Wastewater Treatment Plant Process Flow Diagram

Early pilot tests. In March 1983, the RBC manufacturer, Envirex, Inc., began a series of onsite pilot tests to identify why the attempts to achieve satisfactory denitrification failed. Envirex ran two treatment units, one to receive effluent directly from the carbonaceous/nitrification RBCs, and the second to receive clarifier effluent. A methanol carbon source was added to both units. Within 2 to 4 weeks, denitrification was established in the first unit, while the other produced only minimal results. Envirex concluded that the denitrification was inhibited by a lack of phosphorus. When phosphorus was added to the second unit, satisfactory denitrification was accomplished. This study was able to establish that the rate of denitrification, sludge production, and the required methanol dosage were dependent on phosphorus addition.

Initial plant modifications. In December 1983, after the city added a phosphoric acid feed system and increased the shaft speed in all the basins from 1.6 rpm to 5 rpm to improve mixing, the denitrification process was restarted. Several weeks later, total nitrogen was reduced to 6.0 mg/L, although system operators experienced problems with the final filters (backwashing times approached 24 hours/day and some filter bypassing was required). The filters were dismantled and cleaned, the underdrain system reinstalled, and new filter media added, and the denitrification process was restarted in June 1984. One month later, the plant met its effluent requirements of 5/5/3/1, but this only occurred one time, again due to final filter malfunctions. The plant discontinued using the denitrification process in September 1984.

Environmental Elements Corp., the filter manufacturer, determined that the nitrogen gas was affecting filter operation and that stripping the fine gas bubbles from the waste stream would improve filter operation. To overcome the problems associated with the nitrogen gas and/or denite solids, the seventh SRBC shaft was removed and converted into an aeration bay with the installation of an air diffusion system. This modification allowed the "degasified" SRBC effluent to be fed directly to the final filters. A second more comprehensive process flow modification, called the "Denite Pumpback" system, was also developed through pilot tests, whereby, in addition to the degas aeration bay, the SRBC was hydraulically placed between the RBCs and the clarifiers (see Figure 16). This arrangement allows for the removal of minute nitrogen gas bubbles, preventing discharge to the final filters; clarification of the denite solids

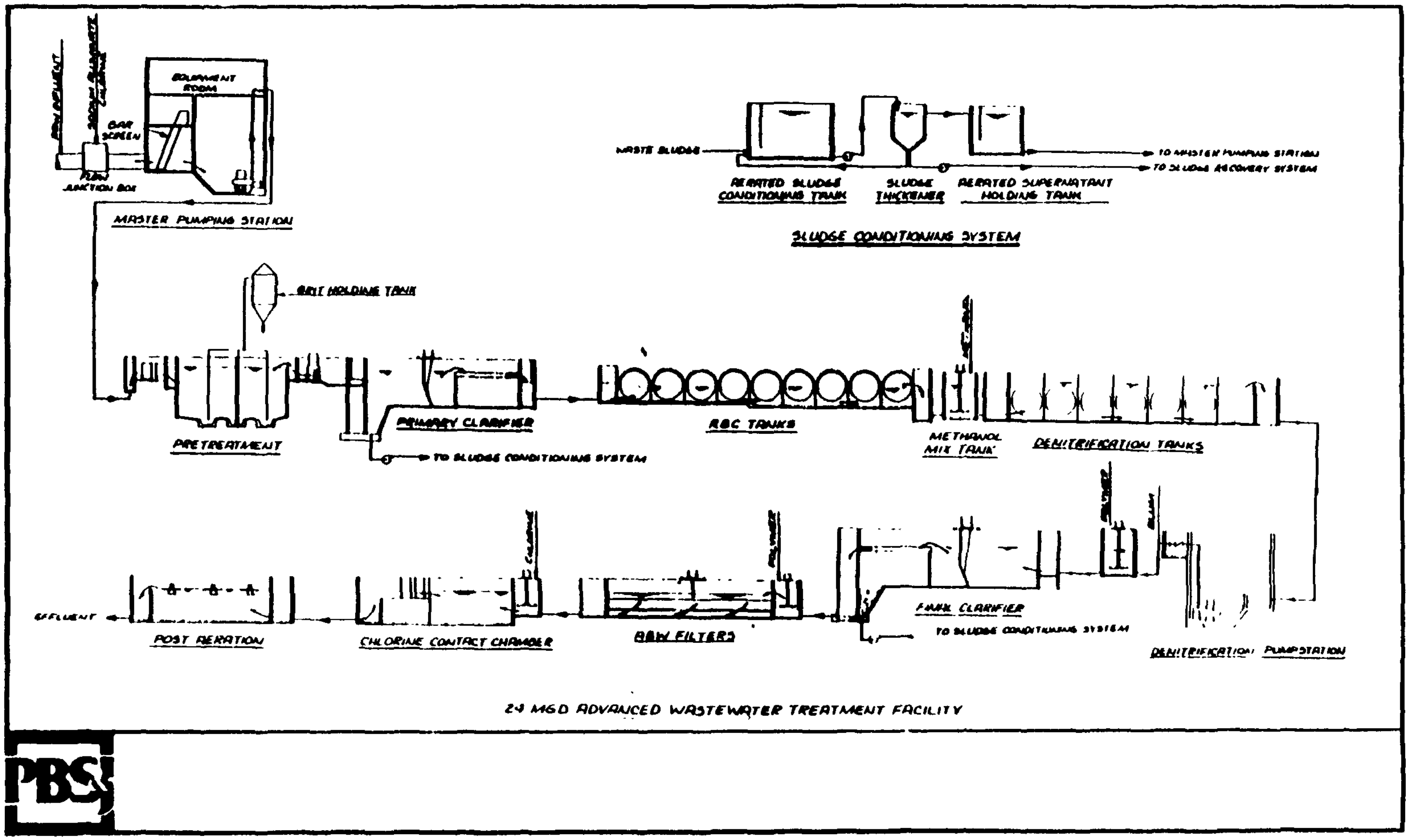

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Figure 16. Iron Bridge Denite Pumpback Process Flow Diagram

before discharge to the final filters; and elimination of the need to add supplemental phosphorus.

Denite pumpback pilot test. The denite pumpback pilot tests were conducted as a result of a U.S. EPA Consent Decree requiring Orlando to conduct a 4-MGD pilot test program, determine if reconfiguration of the plant flow would allow the existing facilities to achieve permit limits, and construct the modifications indicated as necessary by the testing program. Specific objectives included determining the required methanol addition and nitrate removal that might be expected from the denite process; allowing long-term operations of the denite process under controlled conditions for full development of process biology; examining clarifier performance and chemical requirements for phosphorus removal and solids settling; evaluating filter performance when operated in conjunction with the denite process; and evaluating overall system performance, flexibility, and reliability.

Testing the denite pumpback configuration consisted of pumping RBC effluent directly to one of the denite RBC trains, pumping the denite effluent back to one of the secondary clarifiers, and then pumping the clarifier effluent to one of the plant filters. The system was operated with full-scale equipment for about 6 months beginning in January 1985. The tests indicated that the system would work at optimum performance if more methanol was added than the amount stoichiometrically required (1-1/2 to 2-1/2 the theoretical range).

Pilot test operators slowly increased the methanol feed rate until the beginning of February 1985, when the feed rate was set at 57 mg/L. Because BOD limits were being met for the plant effluent, the methanol feed rate remained at this level to observe the performance of the denite system. The plant achieved complete denitrification in mid-February 1985, at which time operators initiated 24-hr composite sampling.

Denitrification biology versus process efficiency. Operation and the efficiency of the submerged RBC denite process was complicated by the growth of nondenitrifying filamentous organisms in the denite tank and on the denite media. These organisms, the growth of which can be stimulated by short chain organic compounds such as methanol, are successful competitors for organic substrates in low dissolved oxygen environments. Excessive growths in the Iron Bridge nitrifying RBC system are routinely handled by using air to purge the shafts. Air headers were placed under each shaft and connected to a central air distribution system. The solids are captured in the plant clarifiers and air flow is returned to normal levels. Shifting the methanol feed point shifts the position of both effective denitrification and filament growth in the train.

Pilot test results and conclusions. Effective operation of the system for evaluation purposes was not considered to have begun until early April 1985. Operating averages for the system are summarized in Table 11.

The RBC process functioned efficiently, producing average effluent NH_3-N levels ranging from 1.0 to 2.0 mg/L. By eliminating the need to add phosphorus and allowing high methanol feed rates without increasing BOD, the system continued to reduce ammonia and produce sufficiently low levels of effluent NO_x-N to achieve permit limits for total nitrogen (TN). The filter was biologically active, removing nitrates, TKN, BOD, and TSS. Data for August 1985, which include results for increased flow, also indicated an improvement in the removal of NO_x-N and a reduction in ammonia. Operating with a repaired filter in May, the pumpback treatment configuration allowed the 4-MGD process to achieve simultaneous compliance with discharge limits for effluent BOD, TSS, TN, and total phosphorus (TP).

The results indicate that the pumpback treatment configuration was a viable alternative to the original plant flow scheme. The system allowed the denite process to be operated without fouling the ABW filters, which remained in continuous service without bypassing or cleaning for over 3 months and met TSS permit limits for 5-1/2 months. The study also confirmed the results of other testing in determining that the Iron Bridge WPCF must function as a unified system with each process performing effectively to achieve permit compliance.

Full-scale operation. Based on the pilot test results and pursuant to the Consent Decree, full-scale modifications were designed, constructed, and placed into operation in late November 1986. Within 10 days of methanol addition, sufficient denitrification was established to achieve

TABLE 11

IRON BRIDGE WWTP DENITE PUMPBACK PILOT STUDY MONTHLY AVERAGES AND RANGES

PARAMETER	FEBRUARY RBC EFFLUENT	FEBRUARY DENITE EFFLUENT	FEBRUARY CLARIFIER EFFLUENT	FEBRUARY FILTER EFFLUENT	MARCH RBC EFFLUENT	MARCH DENITE EFFLUENT	MARCH CLARIFIER EFFLUENT	MARCH FILTER EFFLUENT	APRIL RBC EFFLUENT	APRIL DENITE EFFLUENT	APRIL CLARIFIER EFFLUENT	APRIL FILTER EFFLUENT	MAY RBC EFFLUENT	MAY DENITE EFFLUENT	MAY CLARIFIER EFFLUENT	MAY FILTER EFFLUENT
FLOW, MGD																
AVERAGE	3.7	3.7	3.7	3.7	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	4.0	4.0	4.0	4.0
RANGE	3.5-4.1	3.5-4.1	3.5-4.1	3.5-4.1	2.5-4.7	2.5-4.7	2.5-4.7	2.5-4.7	2.6-5.4	2.6-5.4	2.6-5.4	2.6-5.4	4.0-4.2	4.0-4.2	4.0-4.2	4.0-4.2
BOD, mg/l																
AVERAGE	51	144	12	9	70	66	14	9	71	72	11	6	---	---	9	4
RANGE	38-68	13-820	4-28	3-16	28-190	28-120	1-42	2-25	32-104	42-126	6-27	1-13	---	---	2-10	1-8
TSS, mg/l																
AVERAGE	87	298	21	11	136	129	26	9	120	113	20	4	169	98	27	5
RANGE	40-144	18-2041	7-46	3-36	65-361	64-255	6-52	2-22	21-257	75-191	10-39	2-9	78-290	50-202	13-60	2-10
TN, mg/l																
AVERAGE	19.3	15.6	11.5	11.0	23.5	13.9	6.5	6.3	21.5	11.1	4.1	3.0	---	---	4.5	3.4
RANGE	10.8-22.4	10.4-17.0	9.4-13.2	8.5-13.9	10.1-35.4	3.6-26.5	2.8-12.3	3.0-14.0	14.4-31.8	6.4-15.4	1.0-6.7	0.9-4.3	---	---	2.6-8.5	1.0-4.5
TP, mg/l																
AVERAGE	6.4	7.7	0.5	0.3	5.0	4.8	0.9	0.8	5.4	5.2	1.9	1.6	4.7	4.5	0.6	0.6
RANGE	5.5-8.5	5.0-10.8	0.4-0.7	0.2-0.5	1.6-10.0	1.9-8.1	0.0-3.2	0.0-3.1	4.0-6.4	4.1-6.5	0.2-5.5	0.2-5.3	---	---	0.2-2.1	0.3-1.5
NH3-N, mg/l																
AVERAGE	5.2	5.2	4.7	4.6	6.4	3.8	3.9	4.4	1.6	0.9	0.7	0.9	2.1	1.1	0.6	1.0
RANGE	3.8-6.5	3.7-8.2	3.7-5.7	3.5-5.6	1.4-14.6	0.6-10.1	0.1-8.9	0.1-11.3	0.2-2.4	0.5-1.5	0.1-1.5	0.2-2.1	1.2-4.0	0.3-3.3	0.1-1.9	0.2-2.2
NO3-N, mg/l																
AVERAGE	9.2	5.4	5.4	5.8	6.9	0.7	0.6	0.0	10.2	0.9	0.7	0.5	0.0	0.7	1.0	0.9
RANGE	8.3-9.9	1.2-7.0	2.7-6.9	2.4-8.7	1.0-14.7	0.1-3.9	0.1-1.0	0.0-0.9	7.6-12.3	0.2-1.6	0.1-1.2	0.0-1.2	0.0-10.3	0.0-1.5	0.0-2.7	0.1-1.7
NO2-N, mg/l																
AVERAGE	0.9	0.4	0.5	0.2	1.1	0.3	0.3	0.1	0.7	0.7	0.6	0.4	0.9	0.5	0.7	0.3
RANGE	0.4-1.6	0.2-0.6	0.4-0.6	0.2-0.2	0.2-3.2	0.0-1.0	0.0-1.2	0.0-0.9	0.2-1.3	0.4-0.9	0.3-1.0	0.1-1.1	0.5-1.3	0.1-0.8	0.3-1.3	0.1-0.9
METHANOL FEED mg/l																
AVERAGE	61.9	---	---	---	42.5	---	---	---	44.0	---	---	---	42.0	---	---	---
RANGE	55.6-65.1	---	---	---	0.0-65.5	---	---	---	20.1-64.0	---	---	---	40.2-57.2	---	---	---

TABLE 11 (cont.)

PARAMETER	JUNE NBC EFFLUENT	JUNE DENITE EFFLUENT	JUNE CLARIFIER EFFLUENT	JUNE FILTER EFFLUENT	JULY NBC EFFLUENT	JULY DENITE EFFLUENT	JULY CLARIFIER EFFLUENT	JULY FILTER EFFLUENT	AUGUST NBC EFFLUENT	AUGUST DENITE EFFLUENT	AUGUST CLARIFIER EFFLUENT	AUGUST FILTER EFFLUENT	SEPTEMBER NBC EFFLUENT	SEPTEMBER DENITE EFFLUENT	SEPTEMBER CLARIFIER EFFLUENT	SEPTEMBER FILTER EFFLUENT
FLOW, MGD																
AVERAGE	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.1	4.1	4.1	4.4	4.4	4.4	4.4
RANGE	3.0-4.0	3.0-4.0	3.0-4.0	3.0-4.0	4.0-4.0	4.0-4.0	4.0-4.0	4.0-4.0	4.0-4.5	4.0-4.5	4.0-4.5	4.0-4.5	4.0-6.0	4.0-6.0	4.0-6.0	4.0-6.0
BOD, mg/l																
AVERAGE	—	—	10	8	—	—	7	3	—	—	9	4	—	—	15	4.5
RANGE	—	—	1-27	2-10	—	—	1-19	1-12	—	—	5-17	1-8	—	—	—	—
TSS, mg/l																
AVERAGE	129	76	25	4	118	75	21	2	135	86	25	3	150	78	20	3
RANGE	38-402	20-125	9-123	1-10	36-217	0-179	3-75	1-4	17-282	16-291	9-102	1-9	101-256	55-134	14-35	2-4
TN, mg/l																
AVERAGE	—	—	4.4	3.2	—	—	4.5	2.1	—	—	4.4	2.9	—	—	4.4	2.8
RANGE	—	—	2.3-7.9	2.0-5.5	—	—	2.1-10.1	1.0-3.0	—	—	2.7-6.5	1.4-5.5	—	—	2.9-6.4	2.0-3.9
TP, mg/l																
AVERAGE	—	—	0.8	0.4	—	—	1.2	0.3	—	—	1.1	0.4	—	—	1.2	0.6
RANGE	—	—	0.1-3.4	0.1-0.6	—	—	0.3-1.8	0.1-0.6	—	—	0.6-2.5	0.2-0.6	—	—	0.9-1.7	0.2-1.1
NH3-N, mg/l																
AVERAGE	1.8	1.2	0.6	1.1	1.4	0.6	0.5	0.5	2.3	1.5	1.0	1.1	2.0	1.1	1.0	1.2
RANGE	0.7-4.6	0.2-2.3	0.1-1.9	0.2-3.4	0.4-2.6	0.1-1.9	0.1-1.2	0.1-1.5	1.4-5.0	0.2-5.6	0.3-2.0	0.3-2.4	0.9-3.0	0.1-2.1	0.2-1.9	0.6-2.4
NO3-N, mg/l																
AVERAGE	9.0	1.3	1.2	0.6	9.3	0.7	0.9	0.4	8.2	0.5	0.8	0.4	7.4	0.7	0.8	0.3
RANGE	7.0-10.8	0.6-4.8	0.2-3.7	0.2-1.4	7.3-10.9	0.4-1.4	0.3-1.7	0.1-1.6	5.0-10.0	0.3-0.9	0.1-2.0	0.1-0.8	5.5-8.9	0.4-1.1	0.2-1.3	0.2-0.7
NO2-N, mg/l																
AVERAGE	0.5	0.5	0.4	0.3	0.6	0.4	0.4	0.1	0.7	0.3	0.4	0.2	0.8	0.3	0.5	0.1
RANGE	0.0-0.8	0.1-1.2	0.1-1.3	0.1-1.4	0.4-0.7	0.1-0.9	0.2-0.7	0.1-0.5	0.5-1.0	0.1-0.6	0.1-0.9	0.1-0.6	0.6-1.0	0.1-0.6	0.1-1.0	0.1-0.2
METHANOL FEED mg/l																
AVERAGE	57.8	—	—	—	57.2	—	—	—	56.1	—	—	—	52.2	—	—	—
RANGE	57.2-76.0	—	—	—	—	—	—	—	50.6-57.6	—	—	—	45.6-57.0	—	—	—

the desired effluent total nitrogen limit of 3 mg/L. Effluent BOD was also brought under control, and by mid-December, the plant was meeting its four primary effluent parameters.

Table 12 is a summary of operating performance of the facility for January to July 1987. Discounting the impacts of a toxic industrial discharge in February and a record flow in March, the plant achieved its effluent requirements. Breakpoint chlorination was used to help trim effluent ammonia and has contributed greatly to the consistent quality of the effluent.

To obtain more details on the pilot test, operational data, problems encountered, and costs of this project, contact Phillip Feeney (see Appendix A).

TABLE 12

IRON BRIDGE WPCF 1987 OPERATING RESULTS

	Flow (MGD)	BOD (mg/L)	TSS (mg/L)	NH3-N (mg/L)	TKN (mg/L)	TN (mg/L)	TP (mg/L)
January	21.6	3.6	2.6	0.5	1.1	2.8	0.2
February	22.9	6.6	5.4	0.5	1.1	2.7	0.4
March	23.9	4.7	3.3	0.6	1.2	2.8	0.2
April	28.6	5.1	3.2	2.1	2.6	4.3	0.2
May	24.0	3.8	4.0	0.8	1.2	1.9	0.2
June	22.6	3.6	2.7	0.7	1.2	1.8	0.3
July	21.1	3.0	2.0	0.5	1.1	2.0	0.2
Average	23.5	4.3	3.3	0.8	1.4	2.6	0.2
Limit	24	5	5		2.5	3	1

OVERVIEW OF THE NATIONAL CSO STRATEGY

Harry Thron, EPA Office of Water Enforcement and Permits
Washington, D.C.

Combined sewer overflows (CSO) are flows that do not reach POTWs for treatment. Under conditions of heavy rainfall, CSOs discharge sewerage, industrial waste (in industrial areas), and rainwater directly into surface waters without any treatment. CSOs may create serious violations of water quality standards, can close beaches and shellfish beds, and create navigational hazards.

There are approximately 20,000 combined sewer overflows in the country, originating from about 1,150 systems. The total number of NPDES permits in existence now for major and minor industrial and municipal dischargers is 62,000. Thus, CSOs potentially represent one-third of the permitting workload in the NPDES program.

Due to other priorities, such as dealing with industrial dischargers and POTWs in attaining secondary treatment levels, EPA's Office of Water Enforcement and Permits (OWEP) has recently begun to address the problem of combined sewer overflows. Based on the level of technology that will be needed to deal with CSOs, the Agency, Regions, States, and consultants will need a significant amount of resources to deal with this problem. Even though finances are limited and diminishing, compliance with CSO permits will be required. Unpermitted CSOs are illegal discharges and must be permitted expeditiously or eliminated.

National CSO strategy and permits. OWEP has initiated a national CSO permitting strategy as part of the NPDES permit program, to minimize the impacts of CSOs on water quality and human health. The strategy insures that CSOs occur only as a result of wet weather (dry weather overflows are prohibited). The purpose of the strategy is to bring all CSOs into compliance with the applicable State water quality standards and technology-based requirements of the Clean Water Act, including best practicable, control, and available technologies (BPT, BCT, and BAT). CSOs are not subject to secondary treatment.

CSO permits apply to either the collection system (the POTW permit), or individual CSO dischargers (individual permits). Since EPA has not developed any effluent guidelines for CSOs, best professional judgement (BPJ) should be used to establish permit limits. This means that the CSO permits will be complex, difficult, costly, and controversial.

State CSO strategies. By January 15, 1990, States needed to develop and submit to EPA CSO strategies. For this process, the States were supposed to identify their CSOs, determine the permit status of each one, and set up programs to establish priorities for CSOs that are inadequately permitted (most CSOs are unpermitted or inadequately permitted). Most States have complied and have submitted CSO strategies. However, some strategies were deficient and some States do not know where their CSOs are. March 15 was the deadline for approving the State strategies. Without the basic inventory of CSOs, it is impossible to proceed with a meaningful program to permit CSOs.

State CSO strategies must include an adequate O&M program, a plan for maximizing the collection system for storage, a schedule for activities such as periodic sewer flushing, a prohibition of dry weather overflows, and the like. The strategies should also include provisions for upgrading pretreatment programs. Control measures include sewer rehabilitation, best management practices (BMPs) (qualitative O&M-type controls), construction, and sewer separation in areas of urban development or redevelopment.

EPA is presently writing a guidance manual that will help States understand CSO permit requirements. The document relies heavily on the WPCF manual of practice issued in October 1989.

CSO Costs. CSO controls are costly and funding is limited. There are a few mechanisms available, however, to fund CSO improvements, including the 20 percent governor's discretionary set-aside and the State Revolving Fund (SRF). In many cities, stormwater management utilities have been developed to address stormwater problems, including CSOs.

To date, 21 judicial actions have been taken against CSOs, a figure that will likely increase in the 1990s due to the implementation of EPA's CSO strategy. Developing a viable, flexible program to solve the problem requires the collaboration of OWEP, OMPC, R&D, Regions, States, and those in private industry, academia, and professional organizations. If EPA effectively implements the CSO strategy, after 20 years of benign neglect, CSO discharges can be controlled and water quality benefits should be realized.

For more information on the National CSO Strategy, contact James Taft, U.S. EPA, OWEP, (202) 475-9536.

COMBINED SEWER OVERFLOW (CSO) MANAGEMENT IN EPA REGION I

Richard Kotelly, U.S. EPA, Region I
Boston, Massachusetts

The first serious attempt the U.S. Congress undertook to clean up our nation's waters occurred with the enactment of the Clean Water Act Amendments in 1972. Since that time, the Federal government has appropriated and expended billions of dollars for the construction of publicly-owned treatment plants to treat sanitary and industrial wastes. Direct industrial dischargers have also spent significant amounts of monies to comply with the effluent guidelines enacted by the 1972 Act.

Noticeable improvements in the quality of our rivers and streams have taken place. Fish kills caused by the discharges of inadequately treated sewage in urban and industrialized areas are less frequent. Yet, despite some obvious gains in the abatement of water pollution, other visible problems have surfaced to challenge the environmental regulators. In many parts of the country, the desired or mandated improvements in water quality have not been attained. National attention is currently focusing on storm-related pollution in the form of storm sewer discharges and especially combined sewer overflows (CSOs).

<u>**Combined sewer overflows**</u>. Combined sewer overflows are one of the oldest sources of water pollution that affects the intended use of our waters. Combined sewers are collection systems that convey both sanitary sewage and stormwater, typically found in older cities, especially in the northeast, the upper midwest, and in the Northern Pacific States. Typically, WWTP systems collect and carry dry weather flows, primarily sanitary and industrial waste, to the treatment plant. During storms, however, the combined flows may exceed the sewer and/or the treatment plant capacity. When this occurs, the systems discharge excess flows directly to surface waters at one or more overflow points in the system. Figure 17 shows a combined sewer system.

Overflows can contribute a significant amount of organic material, nutrients, microorganisms, oil and grease, metals and other toxic substances into the receiving water. Depending on the nature of the receiving waters, overflows can have a variety of effects, from

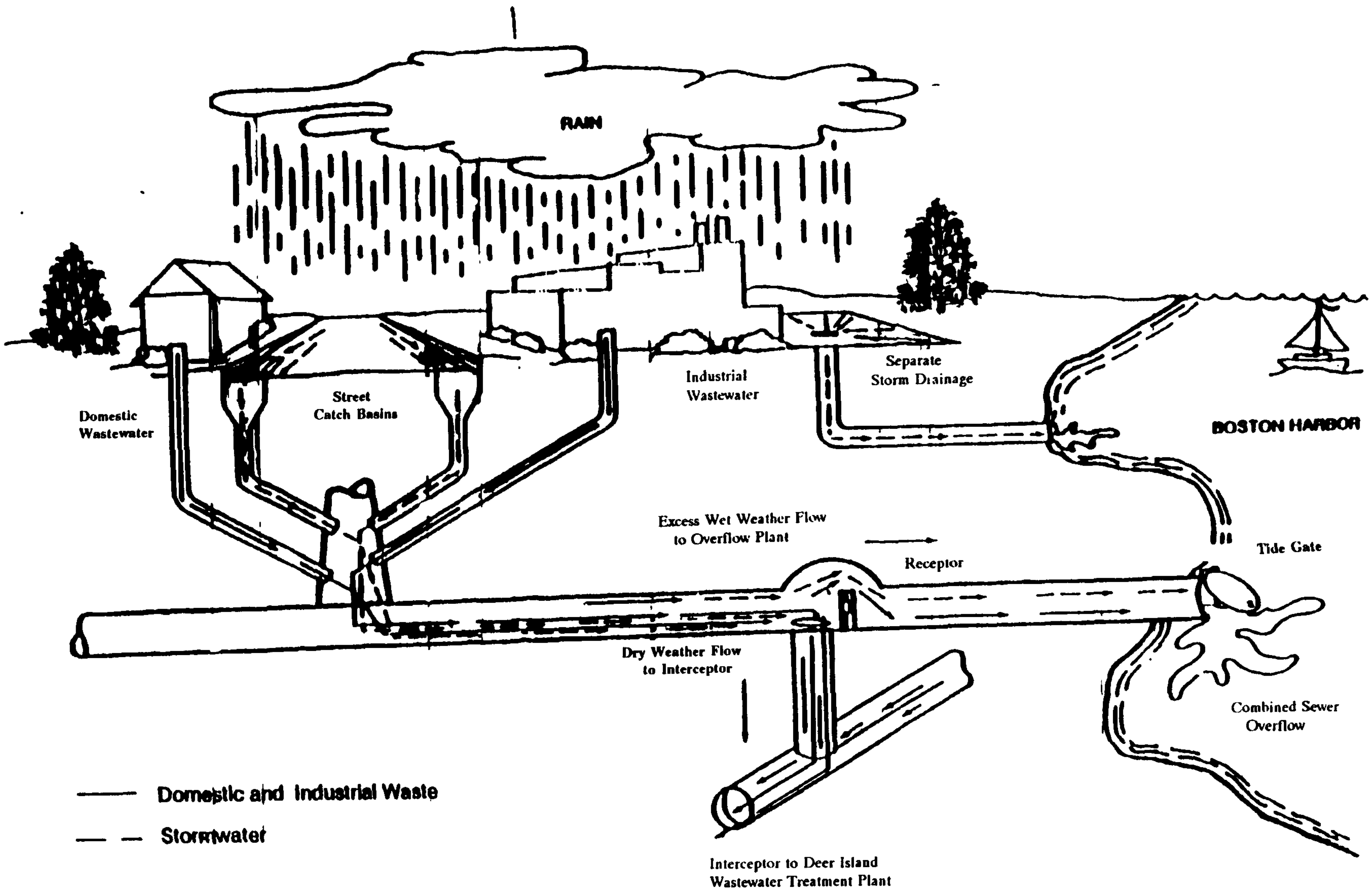

Figure 17. Ilustration of a Combined Sewer System

serious to very minor. The strategy to control these overflows and the cost of complying with such controls represent a major challenge to the regulatory agencies and to the affected communities, respectively.

Region I approach. Region I (the New England States) began to deal in earnest with the combined sewer overflow issue in the early to mid-1980s. A number of major permittees in the Region, such as Boston, Lynn, and New Bedford, Massachusetts; Providence, Rhode Island; and Portland, Maine, all had NPDES permits that needed to be reissued. In addition, there were 150 other communities in New England that were identified with CSO systems. When the permits were reissued, EPA made clear that all CSOs are point discharges subject to the requirements of the CWA. This means that each discharger must meet technology-based requirements and water quality standards.

The difficulty in dealing with CSO regulations is not in knowing what the requirements are, but how they should be interpreted by the consultants hired by the communities to design treatment systems. It became clear to us in the Region that we had no clear guidance to offer communities on how to deal with CSOs. Because there was only a limited amount of money available for the correction of CSO problems, a national policy had not yet been formulated. The closing of beaches along the East Coast due to the discharge of medical debris might have been the drastic signal that finally galvanized the public to demand that the government (EPA) "do something" and create a sorely needed national policy on CSOs.

Because EPA headquarters had no policy, the Region formed a task group made up of permit writers, water quality standards experts, lawyers from our Regional Counsel's Office, and others to develop a Regional policy. After countless internal meetings and meetings with the six New England States, the Region finalized its policy in October 1987. Nothing in Region I's policy was contradicted by the National Policy which was issued 2 years later. Some highlights of Region I's CSO policy are as follows.

- All dry weather overflows must be eliminated. CSOs are point sources subject to both the technology-based and water quality-based requirements of the CWA.

- Every effort must be made to eliminate CSO discharges from critical use areas such as drinking water sources, beaches, and shellfishing areas.
- It must be recognized that it may not always be possible to achieve total compliance with water quality standards.

Region I asked each discharger to prepare a facilities plan that assessed a range of alternatives that would result in complete elimination of discharges or compliance with water quality standards. This requirement elicited the most heated discussions with the States and permittees. In effect, what the policy says is that a CSO community must examine all alternatives, from hydraulic elimination of all overflows, to satellite treatment, to the so-called "no action" alternative. They should develop a matrix arraying the economic, environmental, technical, and institutional costs and benefits of each alternative. Region I suggests developing alternatives with flexibility, so that a creative mix of options can be used to reach maximum protection in the critical resource areas. The preferred alternative will be selected through agency review coupled with public participation.

If a proponent projects that a water quality criterion or water use will be impaired even after all proposed controls are implemented, the proponent must show that attaining the designated use is not possible because controlling the discharge would result in "substantial and widespread economic and social impact." (It would be too costly to fix.) In the simplest terms, a community has two choices. It can select an alternative that fully complies with its State's current water quality standards, or it can request that the State adjust the standards downward.

These water quality standards redesignations will be granted only on a case-by-case, water-segment-specific basis after the facts have been established and with the full spectrum of public participation. It is important to emphasize that it is not the Region's intention to encourage the States to change existing water quality standards classification to allow the continued operation of CSOs. To the contrary, the Region supports the current water quality standards and there is a difficult burden to be met if a revision to standards is to be sought. However, since it may not always be practicable to construct CSO facilities to meet current water quality standards due to the high costs, the Region's policy suggests an approach for addressing CSO discharges that is consistent with the law, regulations, and sound engineering economics.

<u>**National CSO policy**</u>. When the National Strategy was adopted in 1988, it did not negate any aspect of Region I's policy. However, one provision that the Region may ask headquarters to reevaluate is the provision that all flows reaching the POTW must meet secondary treatment regulations. Region I has several situations where a POTW has more hydraulic capacity in their primary systems than the secondary ones. Before the National Policy was adopted, mostly all of the wet weather reaching the POTW received primary treatment as a minimum and secondary treatment for the flow that could be handled by the secondary unit processes. The combined flows, however, would not meet the NPDES maximum weekly effluent limitations.

Because of the National Policy, the POTWs have no option now but to reduce wet weather flows or else violate their permits. Region I is encouraging POTWs to treat the overflows where they occur, but this action may take years to come about.

<u>**Massachusetts Water Resources Authority's approach**</u>. Region I recently received the Massachusetts Water Resources Authority (MWRA) Facility Plan for the cleanup of Boston Harbor. It is an example of how complex and costly CSO treatment can be.

Boston Harbor encompasses 50 square miles with many swimming beaches and salt water marshes and 1,200 acres of shellfish beds. It also serves commercial interests with oil tanker and cargo transport. The area is presently treated with two primary WWTPs, which have gone into disrepair. They will be replaced with one treatment plant (on Deer Island), which will be one of the largest WWTP in the United States, with a capacity to treat 1.2 BGD. It will use "stacked clarifier" technology, widely used in Japan, but not yet in this country.

The population affected by the CSOs is 300,000 (total population served in Boston Harbor is 2.5 million). The CSO area consists of 12,500 acres with 400 miles of combined sewers. About 5,000 industries are connected to the system. There are 87 points of overflow in the service area and 10 billion gallons per year that flow directly into the Harbor. Beaches are closed one-third of the time. Shellfish beds are closed one-half of the time, and for those that are opened, shellfish that are commercially harvested must be depurated at a State-approved facility.

The MWRA has recently updated their CSO plan. In the plan, about 5 billion gallons of CSO wastewater will be sent directly to the Deer Island WWTP. Of the remaining 5 billion gallons per year that will need treatment, about 95 percent will be first captured and stored, and then pumped to Deer Island. Figures 18 and 19 are diagrams of typical near surface storage and storage tunnel systems. The system will capture 5 million gallons per year and is estimated to remove 85 to 95 percent BOD, TSS, and fecal coliforms. The system will contain a 300-foot deep shaft and 16 miles of 25-foot diameter tunnels below the Harbor. One of the existing primary WWTPs will be replaced with a pumping station and a 12-foot diameter tunnel, with outfall flowing through a 24-foot diameter tunnel. After treatment at Deer Island, secondary effluent will be pumped and discharged 9.5 miles out into Massachusetts Bay. The system will cost about $1.2 billion with limited Federal assistance.

For more information about the CSO policy, contact Richard Kotelly (see Appendix A). To obtain a copy of MWRA's plan, contact MWRA, 100 First Ave., Boston, MA 02109.

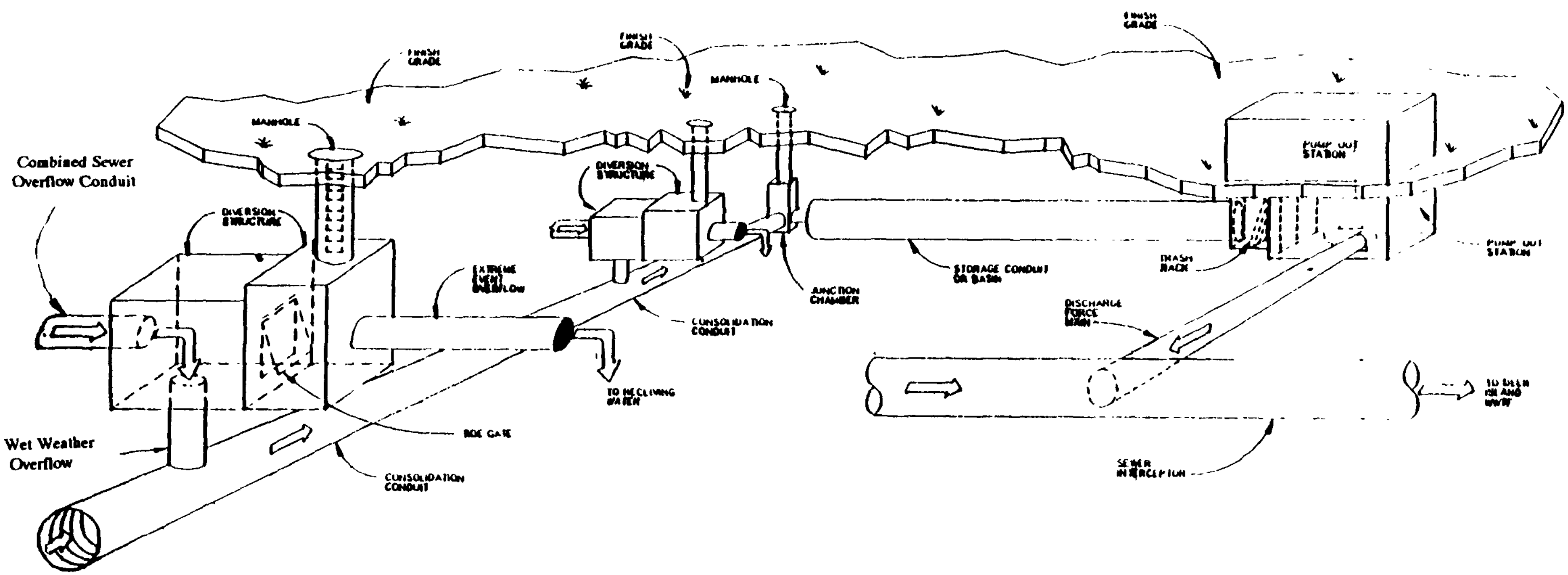

Figure 18. Typical CSO Near-Surface Storage System

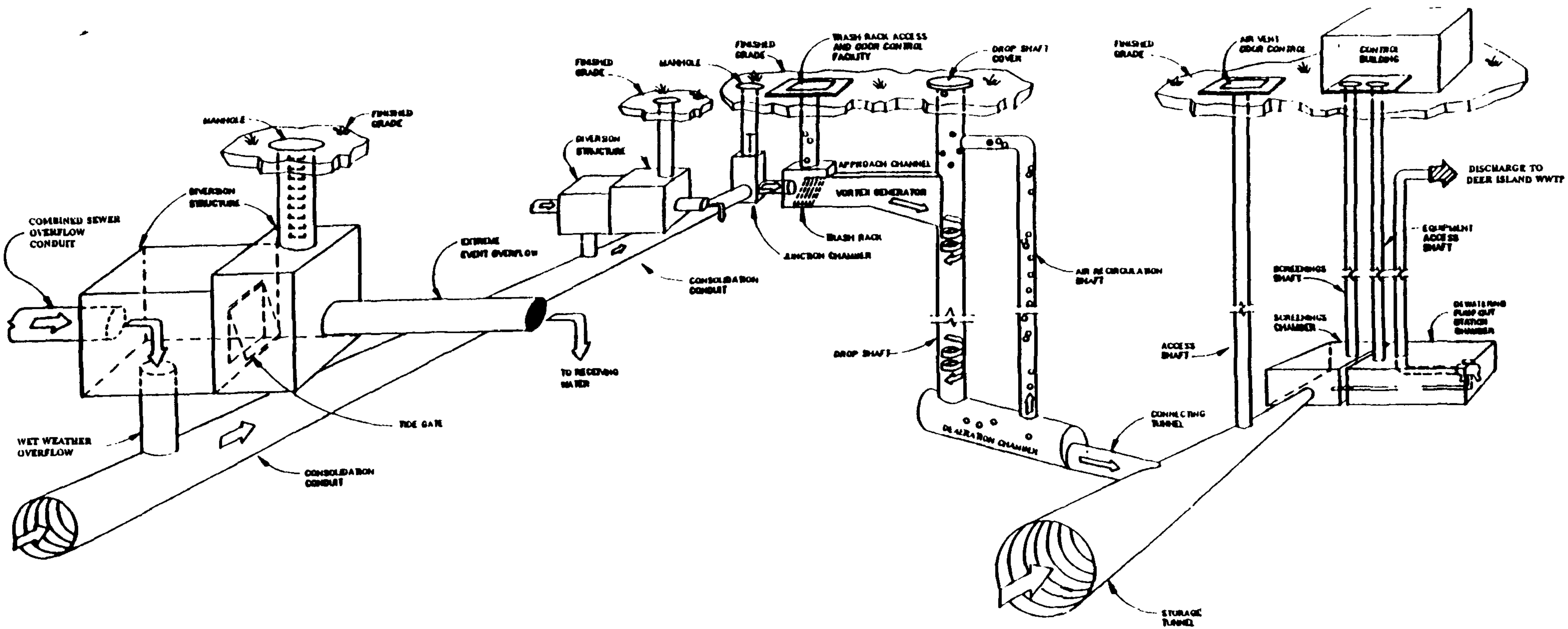

Figure 19. Typical CSO Storage Tunnel System

COMBINED SEWER OVERFLOW PLAN FOR EAST LANSING, MICHIGAN

Charles Pycha, EPA Region V, Water Management Division
Chicago, Illinois

Many communities find it difficult to control combined sewer overflows (CSOs) because of the large costs associated with separating stormwater from municipal sewer systems or providing conveyance, storage, and treatment for CSOs. EPA Region V contains over 500 communities with combined sewers. To help them deal with typical CSO problems, in 1986, the Region developed an official CSO policy and published a *Technical Guidance Document for the Development of a Combined Sewer Operational Plan* (CSOP). The primary objectives of a CSOP are to determine the status of an existing CSO collection and treatment facility and identify alternate ways to operate the facility to reduce the volume and occurrence of CSOs with minimal costs.

Preparing a CSOP has two phases. In Phase 1, municipalities examine their existing combined sewer system and determine potential capabilities to improve system operations, such as providing additional treatment or constructing new facilities. Phase 2 involves implementing the recommendations generated during Phase 1. A CSOP should either precede or be a component of a wastewater facilities plan.

Region V requires all communities in its jurisdiction to prepare a CSOP. In the plans that have thus far been submitted to EPA, many municipalities concluded that they do not need to make major changes to their CSO systems or that they can not afford to implement the necessary changes identified.

To provide a model for other municipalities on how to prepare a CSOP, EPA and the City of East Lansing, Michigan, worked together to prepare the city's CSOP. The plan is described in the document, *Combined Sewer Operational Plan for East Lansing, Michigan*. The plan consists of five major elements, including an inventory of the physical characteristics, limitations, and hydraulics of the combined sewers, interceptors, overflow structures, and treatment facilities; an examination of the permits, ordinances, and other administrative controls implemented by system users; a review of maintenance practices; the development of a control strategy; and a schedule for implementing the recommended actions. The hydraulics analysis, rainfall analysis, modeling of system flow, and consideration of industrial inputs were four specific areas of focus of the East Lansing CSOP.

In evaluating system hydraulics, storage capacities present in the different areas of the city were identified and used to estimate total flow requirements for the system. The more overflow that can be stored in any one area may mean that much less overflow will need to be controlled in another area either through end-of-pipe treatment or treatment at the POTWs, or that fewer supplemental storage basins will need to be built.

The rainfall analysis determined that with a minimal increase in capital or O&M costs, the city could partially or completely control 65 to 70 percent of the overflow caused by storms of up to about .5 inches of rainfall, an event that is exceeded only 12 times per year. In addition to determining the amount of control that is needed to control average yearly rainfall, the rainfall analysis also helped the city determine the degree of treatment that will be needed to control peak rainfalls that are predicted to occur every 5 to 10 years.

Using computer models and accurate historical records, EPA and the city generated flow diagrams of the existing CSO and treatment plant systems and collection capacities. They also created diagrams of the major interceptors used that included the sizes of the sewer and pipe interfaces. The diagrams were used to identify areas where there may be flow restrictions or capacity problems.

Because industries contribute to the volume of CSO in East Lansing, the project team evaluated industrial CSO storage capacity and the options for flow attenuation, the possibility of eliminating the discharge of cooling water or nonprocess waters into combined sewers, and interceptor and bypass capacities.

The CSOP identified several actions that East Lansing could take to better use existing facilities to reduce CSOs, including:

- Administratively changing how the city deals with the users served by contract.
- Alternating the use of CSO storage with the storage available at the treatment plant to increase the amount of wet weather flow treated.
- Diverting some CSO to an alternate interceptor, increasing the wet weather flow that can be conveyed to receive treatment.
- Providing dedicated control structures to allow for for in-line storage in major combined sewer collectors that could store CSO during rainfall events.
- Providing off-line storage in drainage basins where in-line storage does not exist.

Implementation of the plan is expected to take about 5 years. EPA and East Lansing estimate that over two-thirds of the CSOs from the city's system can be reduced or eliminated by the plan. Because much information is readily available today on CSO controls, EPA expects that the CSOP will be less expensive to implement than it would have been 5 to 10 years ago.

The operational plan for East Lansing is particularly useful as an example because of the extent of variations encountered in this combined sewer system. For copies of the CSO documents or additional information on CSOPs, contact Charles Pycha (see Appendix A).

CONSTRUCTED WETLANDS FOR WASTEWATER MANAGEMENT

OVERVIEW OF WETLANDS TREATMENT IN THE UNITED STATES

Robert Kadlec, University of Michigan
Ann Arbor, Michigan

About 450 types of wetlands systems exist for treating a variety of wastes, including municipal wastes, mine water waste, stormwater, and various industrial wastewaters. Wetlands treatment can take place in natural or constructed wetlands sites. Principal categories of constructed wetlands systems include densely vegetated overland flows, underground systems, pond and island systems, and channels with floating plants. The forested wetland is a natural treatment system.

The largest existing wetlands treatment system is Iron Bridge (see p. 109), which currently treats about 13 MGD. Columbia, Missouri, is designing a system to treat 19-1/2 MGD. Most wetlands systems could serve populations of up to 10,000. Single family systems are being promoted in Louisiana.

Natural wetlands. One way in which natural wetlands differ from constructed wetlands is that the original plant species found in natural wetlands are almost always replaced or modified when extra water or nutrients are added to the system. The natural species sometimes do well in spite of this replacement. For example, in Drummond, Wisconsin (population 700 to 800), instead of discharging lagoon water into a Class A trout stream, the town pumps the water into a spruce sphagnum bog. The water progresses through the upper layer of the peat, then to a small stream, and finally to the trout stream. In this system, some original sedge was taken over by jewel weed and impatiens, and the cattails replaced some spruce and other species. New growth for larch, however, was greater in the wetlands than other natural areas.

Densely vegetated overland flow. Densely vegetated overland flow channels are much like trickling filters. The main purpose of the vegetation in this system is to create sites for the bacteria to live. These systems provide effective treatment, although the plants in the system do not provide good habitat for other animal species.

One example of an overland flow system is in Incline Village near Lake Tahoe, Nevada, where wastewater is first treated by a conventional aeration/clarification treatment plant and is then piped 20 miles to a wetlands complex that previously was a desert ecosystem. The system is operated only during the winter months because during the summer, evaporative processes and irrigation of ranch land dry up the system. The level of nitrate in the effluent that enters the wetland is about 40 mg/L, while at the far cells in the system, the level is only 1 to 2 mg/L.

Another overland flow system is in Gustine, California. In addition to treating municipal wastewater, the WWTP must also process significant quantities of waste from a dairy plant. After treatment in lagoons, the water is distributed to a set of parallel constructed wetland cells and then to collection devices. After treatment in the wetlands, the water is chlorinated and discharged into the receiving stream.

The town of Listowel, Ontario, and the Ontario Ministry of the Environment in Canada conducted a 4-year landmark project that investigated five parallel wetland systems and ran extensive monitoring program. In essence, they created the first data base on constructed wetlands. The facility was fully operational within 4 weeks, because they did an intensive planting with the help of local school children. In one experiment, cattails were clipped to try to remove nutrients by harvesting. About 10 percent of the phosphorus was removed by this method, but due to problems with the harvesting equipment, this method was abandoned.

The Des Plains River is a typical muddy midwestern river located in northern Illinois. During the summer, suspended solids rise to a level of about 150 mg/L and there is a substantial nitrogen and phosphorous load from surrounding agricultural areas. In this system, land that was previously a natural wetland area, an agricultural and Christmas tree farm, and then a gravel pit was converted to a series of constructed wetlands. The water is pumped from the river into 4 cells of the complex and then back into the river. The water quality improved to a suspended solids level of about 10 mg/L.

Underground systems. Another type of system is called underground, gravel bed, or rock bed wetlands, or rock reed filters. The distinguishing feature of this system is that the water is maintained underground. The wetland plants that grow in the substrate pump oxygen into the water below ground, thus treating the wastewater. Typical vegetation for this system is reeds.

A lagoon system in Benton, Kentucky (population about 4,500), was modified by the TVA to provide a gravel bed system. Perforation in the piping system allows the lagoon water to seep through the rocks and then down to the wetlands cell. During the winter, the vegetation usually dies and stops nutrient uptake, but because microorganisms provide much of the treatment, system efficiency can slow down but does not stop completely.

Also, Weyerhauser Paper Company ran a gravel bed test facility in Columbus, Mississippi. The wastewater treatment system discharges secondary water into the wetlands system; the treated water is then cascaded for oxygenation and discharged to surface waters. One of the problems with this type of system is that the water does not always enter the wetlands beneath the gravel, although it will eventually flow down into it. System designers tried a variety of planting schemes to correct the problem, but additional research on the hydraulics of these systems is needed. Overall, the system provides effective treatment (60/60 BOD/TSS entering the system; 10/10 leaving the system).

Pond and island systems. A third wetlands treatment type is the pond and island system. These wetlands are not always designed solely for water treatment because the partially treated water from these systems is used to maximize wildlife benefits. These wetlands contain some open water and some vegetation to the extent that the "edge effect" is maximized for birds and other animals.

A typical pond and island arrangement in southern Mississippi, provides habitat for endangered species. Another pond and island treatment system in Northern California is a marsh and wildlife sanctuary that treats secondary water. Several hundred thousand visitors per year visit the facility to hike, walk their dogs, and jog. The layout of the system contains twists and curves, as opposed to the typical rectangular cells. A similar type of facility in Lakeland, Florida, is about 1,150 acres with no public access allowed.

The AMOCO refinery in Mandan, North Dakota, built a pond and island wetland complex for treating refinery wastewater instead of dumping it straight into the nearby river. Conjecture was that if the system didn't improve water quality, it would at least provide habitat for water fowl. The refinery also placed trout in the last pond of the system and won an award from the National Wildlife Federation for this project.

Channels with floating plants. Channels with floating, emergent plants are a fourth category of constructed wetlands. Water hyacinths and duck weeds are two common plants used in this treatment system. An example of this type of system is the lemma lagoon.

Stormwater wetlands treatment. Many stormwater wetlands treatment systems, both constructed and natural, are located along the eastern seaboard. In an Andover, Massachusetts, system, runoff from a 7,000-car parking lot that surrounds a 7-acre computer manufacturing facility is channelled into a wetlands complex that blends with the natural landscape. Another system adapted a natural red maple swamp for stormwater treatment. The Orlando Urban Wetland Project, located on property that used to be a dump, is now a park, planted and constructed for stormwater detention and treatment.

Infiltration. A few systems infiltrate into the ground water, but most systems do not. Where natural soils do not provide a seal, liners such as those made of compacted clay (bentonite) are used. In most natural systems, the wetlands formed because there is a natural seal.

Seasonal operations. Although some systems in northern climates slow down or stop operating during the winter months, some processes continue. This can occur because microbial action continues and filtration, removal of suspended solids, and denitrification can proceed. Also, in an average winter, a northern wetland may not freeze at all. The vegetation holds up the ice, which in turn supports a blanket of snow that insulates the system from the extreme weather.

For more information on wetlands treatment, contact Bob Kadlec (see Appendix A). (Also see Appendix E for a list of EPA Alternative Technology projects and Appendix F for the current status of Modification/Replacement (M/R) Grant candidates by state.)

DESIGN OF CONSTRUCTED WETLANDS/ STATUS OF CONSTRUCTED WETLANDS IN MISSOURI

Robert Kadlec, University of Michigan, Ann Arbor, Michigan
Randy Clarkson, State of Missouri, Jefferson City, Missouri

ROBERT KADLEC - Design of Constructed Wetlands

Based on 10 years of experience, environmental engineers have defined several parameters and fundamental ecological processes that must be considered when designing constructed wetlands. The main objective of these factors is to create resilient systems that can tolerate wide natural and manmade upsets and still meet water quality limitations.

Design considerations. One basic consideration in designing constructed wetlands systems is to plan ample time for meeting the treatment objectives. Some early constructed wetlands treated water with extremely high hydraulic loading rates, which did not work efficiently. These systems gained a poor reputation as a result. Other major considerations are to accurately calculate the required water depth and flow regime of the system to properly foster the growth of the selected plant species and protect ground water.

Wetlands systems must also be easy to operate and maintain. Gates, which often require a lot of maintenance, should be carefully designed so that they function well. Operators should be able to recognize potential problems in advance and be ready to handle unforeseen circumstances such as dike failures and the plugging of structures with detritus.

Natural factors. Another major design consideration is that constructed wetlands are subject to strong environmental forces beyond human control. System operators must be able to manage the flow of water under all probable and extreme hydrological and climatological scenarios. For example, the rainfall and evaporative conditions in Michigan for the last few years have varied dramatically. It rained 12 inches in September 1986, while it did not rain at all during the summer of 1988. In 1986, there was 30 percent added flow, while in 1988 there was a -80 percent flow (80 percent of the water evaporated). For this reason, constructed wetlands might never operate at steady state conditions, and they may be difficult to evaluate from a regulatory standpoint.

Another ecological factor to consider is that plant growth in constructed wetlands can be faster than in a natural setting because seedlings can take up considerable amounts of nitrogen, phosphorous, and other constituents. The biological processes of system operations also can be affected by the accumulation of detritus. Data collected from newly built systems may therefore represent the building up of vegetative crops, whereas data for older systems may represent the decomposition of dead plant matter as well as the wastewater.

Calculating design parameters. System designers have been successful using dyes to study fundamental wetlands processes, such as surface flow and transition flow regimes. The standard hydrological "Manning's equation" that describes water flow through vegetated channels does not seem to apply to constructed wetlands, however, where there are dramatic changes in water depths, although other empirical hydrological formulas have been found to be useful. Design equations available for estimating water quality considerations (i.e., BOD) are included in an EPA design manual and other references (see below).

Other standard water quality parameters that must be calculated for designing constructed wetlands are temperature coefficients, where the decay constant decreases as the temperature decreases. For estimating contact time, system designers must consider blockage of flow due to clumps of vegetation and channelization factors.

Instead of presuming first-order kinetics, system designers can use a mechanistic approach to describe predicted performance of a wetlands system. For doing so, design factors such as the hydraulic loading rate and influent concentration would be entered into a computer program to generate reasonable performance of a system. A third approach is to evaluate data using graphical means, such as plotting average annual BOD for an existing system.

Case study. Columbia, Missouri, intends to upgrade its wastewater treatment by building a wetlands system that treated wastewater before discharging it into the Missouri River. The important considerations in designing this system were space limitations, land acquisition and ownership, preservation of a wildlife area, and flood protection. The project will cost about $17 million, which included several million dollars for treatment plant upgrades; $4-1/2 million for earth moving activities (which often can be the most expensive part of a project); $1 million for a pumping station; and $4 million for the connecting plumbing.

Reference sources. Even though constructed wetlands is an innovative technology, numerous sources of information are available on designing these systems. EPA headquarters and Regions IV and V, and the Tennessee Valley Authority (TVA) wrote several manuals and proceedings documents. These sources contain thousands of references on wetlands and wastewater, ecological effects, and over 50 specific systems. Some of the sources are difficult to obtain, however; about 80 percent of the material is not available through standard "searchable" literature.

Contact Bob Kadlec (see Appendix A) for more information about the design of constructed wetlands and the sources of additional information.

HOWARD MARKUS and RANDY CLARKSON - Status of Constructed Wetlands in Missouri

The use of constructed wetlands for water quality improvements is growing rapidly in the United States. They are low cost, low maintenance systems that are the appropriate choice of water treatment in many settings. The Missouri Department of Natural Resources (MDNR) has limited experience with constructed wetlands. There are two facilities in operation in the State at the present time and several more are planned. For these efforts, the MDNR also evaluated three other facilities in a neighboring State.

Wetlands process. Wetlands remove pollutants through a complex series of physical, chemical, and biological processes, especially adsorption, precipitation, sedimentation, and bacterial transformations. In wetlands, oxygen is transferred down to the roots and rhizomes in the rhizosphere, which is the major zone of activity for the aerobic bacteria. The oxygen that leaks out of the plants is used by the bacteria during respiration. Important reactions are nitrification, the oxidation of complex organics to CO_2, and the transformation of reduced iron to oxidized iron.

The two most common types of constructed wetlands are subsurface flow systems and open water systems (see p. 93). As a very general rule, after primary treatment, subsurface systems require a surface area of 20 acres for each MGD of effluent. Surface water systems require a slightly larger capacity, although each system must be designed individually.

<u>**Case studies**</u>. In Shelbyville, Missouri, the treatment system consists of primary and secondary lagoon cells, followed by a 4-cell open water and submerged bed constructed wetlands system. The wetlands area is about 0.4 acres and consists of duckweed, pennywort, cattail, and reed canary grass. The system operates at approximately 90 percent of design capacity. About one year after the system was started, operators dredged the sludge and drained the initial treatment cells. This wetland has not operated consistently well. MDNR identified unusual loading to the system, slow plant growth, or extreme cold weather in winter as potential causes of this problem.

Bethel, Missouri, is presently a small unsewered community. The proposed system for this town is a 0.75-acre primary lagoon cell, followed by a 0.83-acre open water marsh wetlands cell. The design P.E. is 150. Despite budgetary constraints, planners are optimistic that the system will provide the needed effluent quality. One concern is the potential for mosquitos to breed, as the site is adjacent to homes.

Philadelphia, Missouri, another small unsewered town, is building a 1.34-acre primary lagoon cell followed by a 0.63-acre 3-cell open water wetlands system. The design P.E. is 270.

Sturgeon, Missouri, is a low income farming community. It currently has three overloaded 1-cell lagoons. The proposed system contains a 2-cell lagoon (6.36 acres and 1.91 acres), a 3.2-acre overland flow system, and a 0.88-acre 4-cell constructed wetlands (2 open water cells and 2 submerged flow cells). The pipe valving of this system will allow for maximum flexibility. For example, over 60 flow combinations will be available throughout the system. The design P.E. is 1,272.

The Sturgeon project is funded by the town and through grants. Officials are trying to obtain additional funding for the University of Missouri to conduct research, collect significant amounts of data, and demonstrate system performance.

Columbia, Missouri, currently operates a mechanical plant that discharges to Perche Creek. The proposed system consists of a hydraulic expansion of the mechanical plant and the addition of 4 open water constructed wetland plots totalling 135 acres. The design P.E. is 137,000.

One major consideration in building this facility is the flooding conditions of Perche Creek and potential damage that can occur to the constructed wetlands due to high currents of natural floods.

For more information about constructed wetlands in Missouri, contact Howard Markus or Randy Clarkson (see Appendix A).

OPERATIONAL PERFORMANCE OF REEDY CREEK WETLANDS TREATMENT SYSTEM AND OTHER SOUTHERN WETLANDS

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In the southern coastal plain states, wetlands make up a significant percentage of the landscape. Florida has 11 million acres of natural wetlands, which cover nearly 30 percent of the State. These natural wetlands, as well as constructed wetlands, play an important role in the environmentally safe management and treatment of domestic wastewaters.

Overview of Florida wetlands treatment systems. Much of the original research on the water quality treatment potential of wetlands is taking place in Florida. The State currently has 12 permitted active wetlands treatment systems including 2 constructed wetlands, 9 natural wetlands, and 1 hybrid system.

The central Florida area contains examples of both constructed and natural wetlands treatment systems. This presentation will contrast five different operational systems and focus on the performance of the Reedy Creek system, which has the longest monitoring record of the wetland systems in Florida. The main goal of this comparison is to demonstrate which treatment processes are effective and which approaches may not be appropriate for wetlands treatment. Table 13 is a summary of these five central Florida Wetlands Treatment Systems.

Poinciana Boot Wetland. The Poinciana Boot system was built in 1985 as a cypress dome treatment system. It has the lowest flow of any of the central Florida wetlands, currently permitted for 0.35 MGD with a proposed expansion to 0.85 MGD. After 5 years of operation, the Boot system continues to consistently remove total nitrogen and total phosphorus. These removals are partially the result of a long hydraulic residence time.

Orange County Eastern Service Area. The Orange County Eastern Service Area is a hybrid system that combines overland flow, constructed wetlands, and natural wetlands components.

TABLE 13

CENTRAL FLORIDA WETLANDS
TREATMENT SYSTEMS SUMMARY

System Name	Area (AC.)	Start Date	Average Flow (MGD)	Average Concentration (mg/L)						Permit Limits (mg/L)	
				BOD_5		TN		TP		TN	TP
				In	Out	In	Out	In	Out		
Boot Wetland	115	1985	0.32	3.5	3.8	7.1	2.6	3.7	1.1	—	—
Eastern Service Area	220	1988	0.70	1.5	1.3	3.4	1.7	0.5	0.05	2.2	0.2
Lakeland	1,230	1987	8.0	3.0	2.5	7.0	2.0	9.3	4.3	4.0	—
Iron Bridge	1,220	1987	12.0	6.0	2.6	4.8	0.9	0.6	0.08	2.3	0.2
Reedy Creek WTS1	85	1978	3.1	5.8	1.8	8.0	1.8	1.4	1.7	2.0	0.50
Reedy Creek WTS2	88	1988	3.1	2.5	6.1	6.0	5.3	0.5	0.5	2.0	0.50

Flow into this system has been relatively low during its first 2 years of operation (1988 through 1989), and nutrient removals have been excellent. Suspended solids increase significantly in the system.

Lakeland Constructed Wetlands. The Lakeland system was built in an abandoned phosphate mining area and has been operating since 1987. An excellent network of monitoring stations and a high level of interest by the operations personnel have resulted in the collection of some useful information in a relatively short time for evaluating system performance. Phosphorus levels are high in this system due to high influent concentrations and existing sediment phosphorus load. Nitrogen removal has been excellent and clearly illustrates the dependence of nitrogen removal efficiency on influent nitrogen concentrations. Nitrogen removal efficiency is typically over 70 percent at inflow nitrogen concentrations above 8 mg/L, and declines to zero at a nitrogen inflow concentration of about 2 mg/L.

Iron Bridge Constructed Wetlands. As with the Lakeland Wetlands, the Iron Bridge Constructed Wetlands Treatment System (see p. 109) provides a high level of habitat value in addition to its value for final effluent polishing. This habitat value results from a diversity of wetland and open-water aquatic areas as well as the nutritive value of the highly treated influent wastewater. Treatment performance at the Iron Bridge system to date also has been excellent; however, the very low effluent goal for phosphorus may present problems in the future.

Reedy Creek Wetlands. At Reedy Creek, one treatment area (WTS1) has been in operation since 1978 at higher hydraulic loading rates (HLR) than any other permitted system in the country. Monthly average flows have varied from about 1.5 to 6.0 MGD for a HLR range of 4 to 18 inches per week. A very healthy wetland ecosystem coexists with this HLR.

Influent water quality at Reedy Creek has varied significantly during the system's 13-year operational history, although wetland outflow quality has been very stable. This system has consistently reduced BOD_5 and TN to less than 2.0 mg/L. Phosphorus removal does not occur in this forested cypress wetland, apparently due to very low hydraulic residence times and phosphorus-saturated sediments. Table 14 is a performance summary of Reedy Creek's WTS1 from 1988 to 1989.

A second wetland (WTS2) was modeled after the success of WTS1. This system was brought online in June 1988. Increases of BOD_5, TN, and TP occurred as water moved through WTS2. This resulted from solubilization of minerals left from peat oxidation in this system after it was drained in 1969. While these outflow concentrations were declining over time, this flushing effect was too gradual to allow continued operation without some other treatment of these constituents prior to final discharge to Reedy Creek. WTS2 was abandoned in September 1989. A performance summary of WTS2 is shown in Table 15.

Summary. Florida continues to be a major proving ground for the use of natural and constructed wetlands for water quality management. Florida's innovative Wastewater to Wetlands Rule provides biological criteria for assessing the success of these projects and may serve as an example for other areas. Biological criteria such as allowable changes in plant importance values, macroinvertebrate diversity, fish populations, and populations of threatened or endangered species provide a more meaningful indication of environmental protection in wetlands than traditional water quality criteria such as dissolved oxygen. Also, Florida's Wetlands Rule recognizes the important treatment role of wetlands receiving wastewaters and permits this treatment to occur in State waters as long as the biological criteria are met. Reviewers of permit applications for new wetland discharges should be cognizant of the natural factors at work in these systems and of realistic performance expectations. Research in Florida's wetlands has contributed greatly to our understanding of these factors and how they contribute to final effluent water quality. Wetlands treatment system permit language should be flexible to allow for successful operation of these large, natural systems.

For more detailed information about the performance of each wetland system, contact Robert Knight (see Appendix A).

TABLE 14

REEDY CREEK NATURAL WETLANDS TREATMENT
SYSTEM NO. 1
PERFORMANCE SUMMARY[a]

	BOD$_5$			TN			TP		
Year	In	Out	RR	In	Out	RR	In	Out	RR
1978	7.3	1.4	1.1	8.9	0.8	1.4	1.4	1.9	-0.01
1979	10.4	1.5	1.6	10.3	1.6	1.5	2.5	3.0	-0.53
1980	10.8	1.5	2.2	9.8	1.0	2.1	2.7	3.2	-0.53
1981	4.2	1.7	0.9	8.5	0.8	2.1	2.4	3.0	0.16
1982	7.3	1.3	1.2	8.8	1.2	1.9	2.4	3.5	-0.32
1983	10.0	1.3	3.4	6.2	1.1	2.0	0.7	1.3	-0.47
1984	3.1	2.0	0.4	5.0	1.1	1.6	0.6	0.7	-0.07
1985	2.5	1.8	0.3	5.4	1.2	1.7	0.5	0.7	-0.06
1986	3.5	2.0	0.7	7.3	2.1	2.6	0.6	0.7	-0.05
1987	5.6	3.7	0.8	12.8	7.2	2.3	1.4	1.5	-0.04
1988	3.0	1.4	0.4	6.2	1.6	1.2	0.6	1.0	-0.01
1989	2.0	2.5	-0.2	7.1	2.1	2.2	0.4	0.4	0.00

[a] In = Inflow Concentration (mg/L)
Out = Outflow Concentration (mg/L)
RR = Mass Removal Rate (kg/ha/d)
Area = 35 ha (85 ac)

TABLE 15

REEDY CREEK NATURAL WETLANDS TREATMENT SYSTEM NO. 2[a] PERFORMANCE SUMMARY

	Concentration (mg/L)							
	BOD_5		NO_3-N		TN		TP	
Period	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Jun-Dec 1988	2.6	6.8	3.0	0.04	5.2	5.7	0.46	0.77
Jan-Sep 1989	2.4	5.5	3.0	0.05	6.9	4.8	0.44	0.49

[a] Area = 88 Acres

CONSTRUCTED WETLANDS AT IRON BRIDGE TREATMENT PLANT: ORLANDO EASTERLY WETLANDS RECLAMATION PROJECT

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In 1987, the City of Orlando, Florida, constructed a 1,220-acre wetland to remove additional nutrients from treated municipal wastewater from the Iron Bridge Regional Water Pollution Control Facility (WPCF) prior to being discharged to the St. John's River. The city deemed the additional level of advanced treatment necessary because of the sensitivity of the rivers and lakes in Florida to even small increases in nutrient concentrations. The system has a 20 MGD design capacity.

The wetland was constructed on low-lying land that previously had been heavily ditched and drained to provide cattle pasture. To maximize operational control, over 15 miles of earthen berms were constructed on the site in a segmented design. Water passes between the cells through pipes located in the berms. Control structures, made up of box culverts and flashboards, are on the upstream end of each pipe. System designers took advantage of the natural grading at the site, which is approximately 0.2 percent from the influent to the effluent discharge structure.

To enhance the use of the area by wildlife, the Orlando wetland is a surface flow system with four ecological communities -- a wet prairie, a shallow mixed marsh, a hardwood swamp, and a lake. Depths range from 1 foot in the hardwood swamp, to 1.5 feet in the shallow mixed marsh, 3 feet in the wet prairie, and 30 feet in the lake. The substrate consists of mineral soil with 2 to 15 percent organic matter, primarily from the former cattle ranching activities. The wet prairie is planted with *Typha spp*. and *Scirpus spp*., the mixed marsh with about 30 indigenous herbaceous species, and the hardwood swamp with nearly 160,000 seedlings of a variety of tree species, primarily *Taxodium distichum.*

The wetland began receiving flow from the Iron Bridge WPCF in July 1987. Initial flow was 8 MGD, which was increased to 13 MGD in August 1988. System operators anticipate that flows will increase to the full 20 MGD capacity by 1991. At the design flow, the detention time through the wetland is estimated to be about 30 days. Water leaving the constructed wetland flows across an adjacent natural marsh to the St. John's River.

Monitoring results and discussion. System operators monitor the water quality of the wetland using a series of sampling stations located throughout the system, from the influent to the discharge structures. Data are obtained monthly from three consecutive daily grab samples taken from each monitoring station, except the influent and effluent stations, which are sampled daily. Annual average total nitrogen and total phosphorus concentrations for 1988 and 1989 are summarized in Table 16. Maximum effluent concentrations permitted by State and Federal regulatory agencies are 2.31 mg/L for total nitrogen and 0.20 mg/L for total phosphorus.

Both required effluent limits were achieved in 1988 and 1989 in the first portion of the wet prairie, which represents 11 percent (130 acres) of the system. Over 78 percent of the nitrogen removal occurred in this section of the system, whereas no other cell indicated significant decreases in nitrogen concentration. The influent nitrogen concentration increased by 32 percent in 1989, yet the system removed similar amounts of nitrogen during both years, 80 percent in 1988 and 83 percent in 1989.

In 1988 and 1989, over 98 percent of the phosphorus removal occurred in the first 11 percent of the system, which is a more significant percentage compared to the nitrogen data. Phosphorus removal was less significant in the remaining cells, and some cells indicated an increase in phosphorus concentration. The overall percent removal of phosphorus through the wetland system was 83 percent in 1988 and 89 percent in 1989.

Operation and design considerations. The ability of the Orlando wetland system to provide greater than anticipated levels of treatment may be due to the operational ability to control and manage system flows. System operators have been able to prevent adverse effects due to extreme flushing events and short-term winter conditions by storing water in the various wetland cells and gradually drawing the water down. The system was designed with 3 feet of freeboard

TABLE 16

WETLANDS NUTRIENT CONCENTRATIONS AT IRON BRIDGE WWTP, 1988 AND 1989

Monitoring Station	Nitrogen[1]		Phosphorus[1]		Percent Area Up-stream[2]	Detention Time[3]	
	1988	1989	1988	1989		1988	1989
Wet Prairie (WP)1 (influent)	4.18	5.52	0.572	0.72	0	0	0
WP3	1.53	1.92	0.103	0.08	11	6	5
WP4,5	1.51	1.74	0.102	0.15	16	9	7
WP6	1.27	1.59	0.106	0.07	32	18	14
Mixed Marsh (MM)8	0.96	1.22	0.091	0.05	67	31	24
Hardwood Swamp (HS)10 (effluent)	0.84	0.92	0.095	0.076	100	57	45

[1]Figures are mg/L.

[2]Percent upstream area equals percent of the wetland area upstream of the sample station.

[3]Detention time in days approximated based on volume.

above the normal high water line, allowing an additional 58 days of storage capacity at design flows.

Another beneficial operational feature is the ability to isolate individual cells from receiving flows. This control mechanism allows for draining individual cells and oxidizing and compacting the sediments. System operators can then reflood a cell and allow it to stabilize before it is brought back on-line.

Conclusions and recommendations. The 2 years of operating data from the Orlando wetland provides evidence that it is possible to achieve nutrient concentrations lower than those normally attained by conventional advanced waste treatment processes. The system was well within compliance of permitted effluent limits, although the limits are among the most stringent imposed in Florida. Design features that allow for controlling water depths and isolating portions of the system are important factors in providing consistent and reliable nutrient removal. Orlando system designers recommend that other systems build in this operational flexibility.

From the data presented, it appears that the system was underloaded. Since only 11 percent of the wetland is providing treatment at a level greater than anticipated, system managers expect that the system will continue to meet permitted effluent limits as the flows approach design conditions.

For more information on the Iron Bridge constructed wetlands, contact J.A. Jackson (see Appendix A).

COMPLIANCE WITH PERMITS FOR NATURAL SYSTEMS

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Treating wastewater though natural systems is an innovative technology that has proven to be a viable wastewater treatment alternative for many small and large municipalities. Because natural systems are much less predictable than standard wastewater treatment technologies, municipalities have raised several unique issues concerning how EPA is developing NPDES permits for these systems. EPA enforcement personnel are presently investigating how to deal with these issues so that this promising technology can be encouraged at the same time the waters are protected.

EPA Region IV is an 8-state primarily agricultural area with an agrarian-based economy. The Region contains numerous constructed wetlands and overland flow systems that treat a variety of wastes including wastes generated from milk, beef, and pork production; livestock excrement; and municipal waste. Although constructed wetlands show much potential for treating a greater amount of these wastes, the Region has faced some difficulties in issuing permits for these systems.

Permitting problems. One of the major difficulties in permitting natural systems is determining an adequate length of time for a start-up period and the date when compliance should begin. Natural systems do not operate like activated sludge plants or oxidation ditches that are functional as soon as they are put into operation. Constructed wetlands might take two or three growing seasons to reach steady-state conditions and provide efficient treatment, and an exact length of time is difficult to predict. Also, unforeseen circumstances can arise in natural systems, such as the presence of soils with high organic content that can affect initial performance when subject to innundation.

As the permitting process is currently structured, permittees must submit Discharge Monitoring Reports (DMR) every month that state if the system is in compliance. Permittees must meet specific effluent and flow limits and monitor the system at predetermined intervals. The permits often provide no flexibility in dealing with widely varying growing seasons, weather conditions, plant growth rate, and other ecological and meteorological factors, but when compliance limits are included in a permit, they are very difficult to change administratively.

A Walt Disney World constructed wetlands, Reedy Creek (see p. 103), is one example of a system that must pay a fine of nearly $400,000 because of permit noncompliance. Instead of being allowed to continue to work with the wetlands, Disney World must construct a land treatment system to replace the wetland that is in noncompliance.

Recommendations. It is important for permit writers to be aware that natural systems are not as predictable as other wastewater treatment technologies. EPA must work with the States, municipalities, industries, engineers, and biologists to develop a sensible compliance approach for natural wastewater treatment systems that considers the viability of each natural system to meet its intended application.

If EPA permit writers can tolerate multi-year start-up periods, constructed wetlands can be a viable option for many municipalities. If not, then another means of wastewater treatment should be seriously considered. The permit writer also may request that a system conduct more intensive planting so that the system is closer to being fully operational when it starts up. This is a more costly option then allowing the plants to grow naturally to fill out the natural system, but may be an appropriate compromise. The facility and the enforcement agency also may need to develop a reasonable compliance schedule.

Permit writers must ask what level of water quality can be achieved by a stringent versus a more lenient approach. As natural systems attain steady-state conditions, they may result in short-term adverse impacts on water quality, but the long-term benefits may be greater overall. If EPA wants to continue to encourage the application of natural treatment systems, it must be flexible in its approach to permitting these systems.

For more information on permitting Natural Systems, contact Robert Freeman (See Appendix A).

INVENTORY OF CONSTRUCTED WETLANDS SYSTEMS IN THE UNITED STATES AND WPCF MANUAL OF PRACTICE ON NATURAL SYSTEMS

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EPA's Risk Reduction Engineering Laboratory (RREL) is compiling an inventory of wetlands systems in the United States that are being used to treat municipal wastewater. The inventory contains information on system location and design parameters. This information will be used to compare and assess the different systems in operation, focusing on the common factors found throughout. The universe for this inventory is relatively small and only includes constructed wetlands with emergent vegetation for treating wastewater.

About 300 questionnaires were sent to EPA Regional offices and State agencies. Data for over 102 systems have been returned and logged into a computer data base that will be used to summarize and analyze the data.

System types in operation. Of the systems for which data has been collected, two basic types are presently in operation in about equal frequency--*free-water surface* and *subsurface flow systems*. Although at least one wetlands system is located in each EPA Region, over 50 percent of the systems are found in EPA Regions IV and VI. This may be due in part to the active encouragement of the Regional office staffs. (See Appendix E for a list of EPA's Alternative Technology projects.)

In *free-water surface wetlands systems*, the water surface is exposed to emergent vegetation. The system contains some type of substrate to support that vegetation and a liner to protect the ground water. From an engineering perspective, the plants in this system are an attached root substrate. The microbial life that provides the majority of the treatment attaches to the plant surfaces, the detritus, and other materials in the water column.

The plants in a free-water surface system transmit oxygen to their root zone for survival. The primary oxygen used to treat the wastewater, however, is based on surface reaeration. If the plant canopy of a free-water system becomes too dense, the system may experience a very low dissolved oxygen level at certain times of the year.

Subsurface flow wetlands are also called gravel bed wetlands, rock reed wetlands, and other names. These systems have permeable media of up to 2 to 3 ft deep that support the same emergent aquatic vegetation as the free water systems. These systems also contain a liner, and a way to maintain the water level at a predetermined depth below the media surface. Typical media are natural gravel or rock, but plastic media is also used. In subsurface flow wetlands, significant treatment is provided by the plants, which pump oxygen into the effluent being treated. If there is enough oxygen, the system will support nitrification and denitrification as well.

Hydraulic loading rates. Preliminary findings show that most hydraulic loading rates are expressed in terms of gallons per acre per day, or number of acres per MGD of system capacity. Other important parameters, particularly for subsurface flow systems are surface area loading and cross-sectional loading rates. In subsurface flow systems, accurately calculating these parameters will help optimize the use of the gravel or rock surface.

Of the data thus far tabulated for the inventory, the mean value for the hydraulic loading rate for free-water systems is about 8 acres per MGD. The loading rate for a system designed for Columbia, Missouri, is about 5 to 6 acres per MGD. Earlier free-water surface systems are larger by design then newer systems. As system designers began to recognize the capabilities and limitations of these systems in terms of BOD and suspended solids removal, they designed systems with less acreage.

The average capacity of subsurface or gravel bed systems is about 6 acres per MGD. These systems can theoretically be smaller by design than free-water systems because the gravel provides additional surface area for bacterial growth and wastewater treatment, similar to the treatment provided by trickling filters or rotating biological contactors (RBC). As a result, reaction rates should be higher and performance should be better than with free-water systems in equal periods of time.

<u>**Comparison of subsurface designs**</u>. There are two main approaches to designing subsurface flow systems in terms of system configuration, preferred media, and optimal flow rates. One design is configured in long narrow trenches layered with about 18 inches of 2- to 4-inch rock, 6 inches of pea gravel, and some kind of emergent plant at the interface of the pea gravel and coarse rock. Detention time for this type of system is designed to be about 1/2 to 2 days. Because these systems are not designed to oxidize ammonia, and are only concerned with meeting BOD and suspended solid limits, the penetration of the root system into the full bed is not extremely important; BOD and suspended solids can be removed in an anaerobic reaction.

The second type of subsurface flow system is designed to oxidize ammonia. This type of system is configured with a wider entry zone bed and a smaller diameter stone, and the plants are expected to eventually penetrate the full depth of the bed. The detention time is designed to be 5 to 7 days. Several reports from operators of systems that have been on-line for several years have indicated, however, that the roots of the plants have not yet penetrated below the pea gravel coarse rock interface, but are spreading out at the interface instead. Because the plants in these systems are the only source of oxygen, it seems that for these systems to successfully nitrify, designers must either determine a way for the roots to penetrate or economically provide an additional source of oxygen. If either of these measures is taken, nitrogen should by effectively removed.

<u>**Comparison to lagoon system hydraulics**</u>. Both types of subsurface systems are experiencing clogging and accumulation of detritus, perhaps due to hydraulic loading rates that are too high (800 to 3,000 gallons per sq. ft per day) and bed configurations that are too long and narrow. This conclusion can be made by comparing these systems to rock filters in wastewater treatment lagoon systems built in the 1970s that are still operating today without clogging. These systems were designed to strip algae from the lagoons to improve BOD using rock filters. They contain very course rock (3- to 4-inch diameter) across the entire width of the lagoon cell. The effluent of these systems must pass through the rock bed and then the collection pipe before

being discharged, which is a relatively small cross-section. Overall, the lagoons have a long wide entry zone and a relatively short distance where the treatment take place. Hydraulic loading rates are from 2 to 6 gallons per day per cu. ft. of rock, or 100 gallons per sq. ft. per day.

Rectangular or square beds may now be preferred over the long narrow cross-sections of subsurface wetlands systems. As long as there is adequate entry and withdrawal distribution piping, like that of lagoon systems, plug flow should not be a major concern and detention times should be less than 2 days to meet BOD limits.

Other observations. In terms of removing algae, gravel bed systems seem to work more effectively and consistently than free-water surface wetlands. Gravel systems also seem to work better for smaller systems and can be located nearby to developments, schools, public places, and the like because treatment occurs below the water surface and odors and mosquitoes do not cause any major problems.

Water Pollution Control Federation (WPCF) Manual. Encouraged by EPA's Innovative/ Alternative program, the WPCF wrote a Manual of Practice (WPCFMOP) on Natural Systems. The document took 2 years to complete and includes the input of many experts in this field, including people from EPA Headquarters and the Regions and States. The manual contains information on aquaculture, land treatment, lagoons, wetlands systems, large-scale onsite systems, and other technologies. To obtain a copy of this manual, contact the WPCF.

For information about the wetlands inventory, contact Woody Reed (see Appendix A).

DISINFECTION

ULTRAVIOLET DISINFECTION STUDIES AT REHOBOTH BEACH, DELAWARE

Karl Scheible, HydroQual, Inc.
Mahway, New Jersey

In July through August 1989, a large-scale field study was conducted at the Rehoboth Beach Water Pollution Control Plant in Rehoboth Beach, Delaware, to investigate the ultraviolet (UV) light disinfection process. The U.S. EPA (OMPC and RREL) and the City of Rehoboth Beach sponsored the project. The study had several objectives. First, EPA wanted to develop UV design information for *Enterococcus* and *E. coli.*, which may be used to establish permit requirements in lieu of fecal or total coliform. Second, the study would demonstrate the UV process design protocol described by the EPA design manual, *Municipal Wastewater Disinfection*. Third, the project would assess the capacity and sizing of the existing UV system at Rehoboth Beach using the design model approach, and determine the corrective action needed to bring the system into full compliance. The experimental design, data collection program, and analysis of data were based on the format and protocols presented in the design manual.

Facilities. The treatment plant operations (Figure 20) include screening, oxidation ditches, secondary clarification, microsceening, UV disinfection, post aeration, and final discharge into the Lewes Canal. The system is designed for BOD and nitrogen removal. It is constructed as two parallel trains, both of which are utilized during the summer beach season, while only one is needed during the "off-season." Sludge is aerobically digested and land applied.

The average design flow of the plant is 3.4 MGD. The design maximum daily flow is 5.1 MGD. The average BOD and TSS limits are 19 and 15 mg/L, respectively. Nitrogen removal is required from April through September, with an average limit of 3 mg/L. Disinfection limits are an average fecal coliform (col) density of 200 col/100 mL, and a total coliform density not to exceed 1000 col/100 mL. The total coliform requirement is the limiting factor when considering the capacity of the UV process.

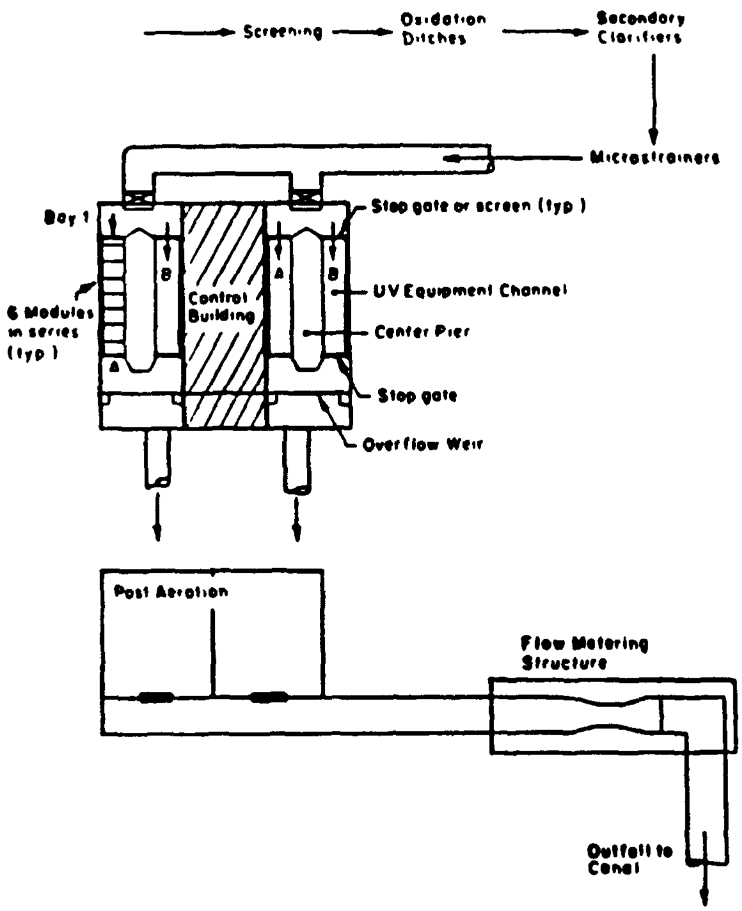

Figure 20. **Schematic of the Rehoboth Beach, Delaware, Wastewater Treatment Plant Operations**

The UV system is comprised of two bays, each capable of receiving the peak total plant flow and each with two channels fitted with UV equipment. Each channel has six modules placed in series and divided into three banks (two modules per bank). Each module contains 28 lamps sheathed in quartz sleeves, yielding a total of 168 lamps per channel and 336 lamps per bay. The lamps are placed vertically into the channel, with the flow direction perpendicular to the lamp axis. The lamps have an effective arc length of 0.75 m. The liquid level is set by a fixed downstream weir in each bay.

New UV equipment was installed in the second bay to accommodate the experimental studies (see Figure 21). Four new vertical lamp modules were installed in the first channel, differing from the existing vertical lamp modules by their lamp arrangement and by their head loss. Each module contained 28 lamps and had the same UV density as the existing modules. The four modules were operated as two banks in series. Horizontal lamps were installed in the second channel, arranged as two banks in series. There were seven modules per bank, each with four lamps. The direction of flow in this system was parallel to the axis of the lamps.

Process design. The study focused on generating data to calibrate the UV disinfection design model (primarily set by the inactivation rate and the water quality characteristics of the plant effluent), and verifying the calibration by comparing its predicted performance to that actually observed over a range of operating conditions. The UV process design model estimates the effluent density as a function of the wastewater quality (particulate density, suspended solids, UV transmittance, and initial density), reactor intensity, pathlength through the reactor, and the hydraulic dispersion within the reactor.

The experimental protocol addressed specific data needs for the process design, including direct testing for system hydraulic characteristics (dispersion), particulate bacterial density as a function of suspended solids, and the inactivation rate as a function of the average reactor UV intensity. Reactor intensities were estimated by the point source summation method as a function of the wastewater UV transmittance (at 253.7 nm). The study team used wastewater data to estimate the design conditions for sizing and the calibrated design model to estimate the lamp requirements for the plant at these design conditions. Performance data

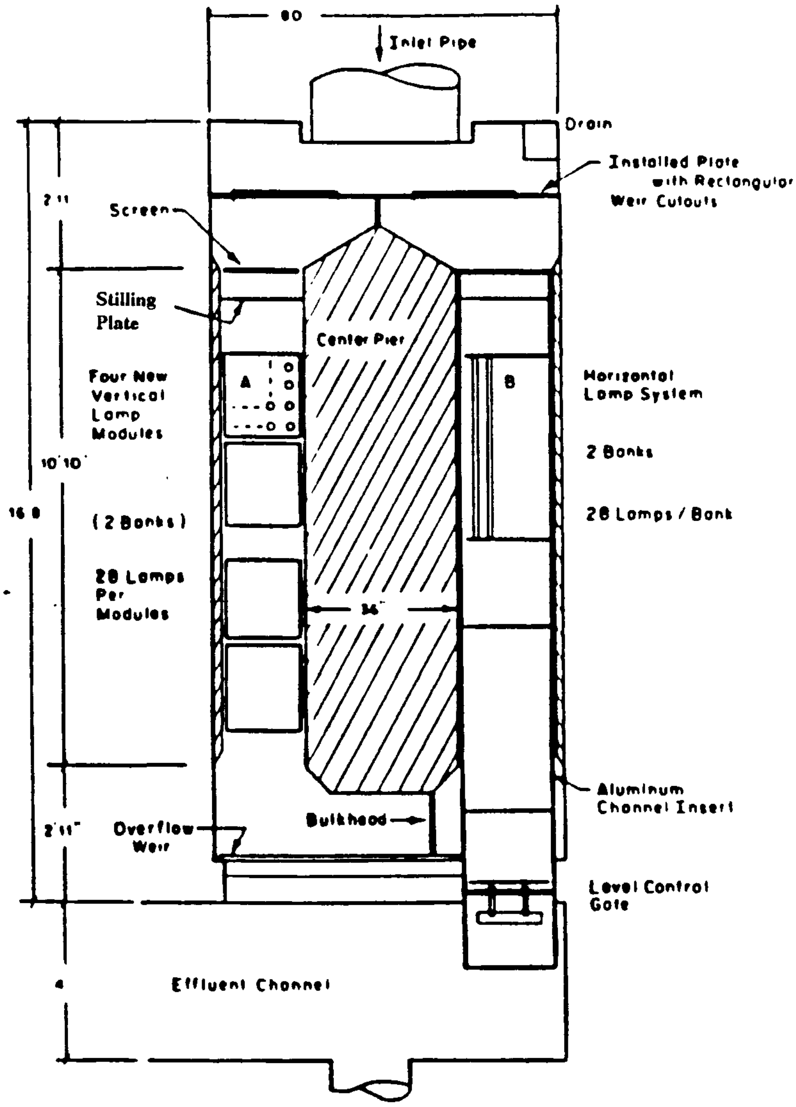

Figure 21. **Schematic of the Rehoboth Beach, Delaware, WWTP with Ultraviolet Disinfection Equipment**

were collected over a range of operating conditions. The variables that could be controlled were the flow rate and the number of banks in operation during a specific sampling. Each sampling consisted of an influent and effluent sample, both of which were analyzed for total and fecal coliforms, *Enterococcus* and *E. coli*. The influents were also analyzed for total suspended solids and UV transmittance at 253.7 nm.

Wastewater characteristics. Overall, the quality of the Rehoboth Beach effluent was very high during the term of the study. Table 17 summarizes average conditions for the plant. The flow to the plant averaged 1.7 MGD, approximately one-half the design average flow. Because the plant was operating at significantly less than capacity, the effluent may have been a higher quality than what might have been produced if the plant approached design capacity. Therefore, it may not be appropriate to test a UV system simply at its hydraulic design loadings because possible undersizing problems may be masked by the wastewater quality. This points to the utility of the analysis approach that calibrates the process equation, and then projects the alternate water quality conditions that are reflective of design loadings.

Table 18 is a summary of the bacterial characteristics and degree of photorepair observed at Rehoboth Beach. Particulate bacterial densities (not shown) estimated for Rehoboth Beach were approximately one-third the levels previously shown for other plants and reported in the Design Manual. Inactivation rates for total and fecal coliforms, *Enterococcus* and *E. coli*, all were high relative to those estimated in a similar fashion at other plants. These are summarized on Table 19. The rates for *Enterococcus* and *E. coli* both were somewhat lower than observed for fecal coliforms. Table 20 summarizes the fecal coliform inactivation rates of Rehoboth Beach and 6 other facilities. As shown, sensitivity to UV exposure is higher at Rehoboth Beach. This, in turn, would result in a lower lamp requirement for equivalent disinfection performance.

Process model calibration. After the study team defined the coefficients and system characteristics, they calibrated the process model to the site application, and used the model to develop design curves. To test the calibration, the team compared final effluent densities predicted by the process equation to the effluent densities measured under specific operating

TABLE 17

WASTEWATER CHARACTERISTICS AT REHOBOTH BEACH WWTP

July and August, 1989
(Beach Season)

	Average	**95%**
Flow (MGD)	1.74	2.56
Effluent		
BOD_5 (mg/L)	5.2	21.6
TSS (mg/L)	6.1	10.2
% T (T)	69.8	74.1 (10% = 68%)
% T (F)	71.7	77.7 (10% = 68%)
Total Coliform (100 mL^{-1})	182,400	700,000
Fecal Coliform (100 mL^{-1})	28,200	200,000
Enterococcus (100 mL^{-1})	1,140	13,700
E. coli (100 mL^{-1})	3,600	73,200

TABLE 18

BACTERIAL CHARACTERISTICS AND DEGREE OF PHOTOREPAIR AT REHOBOTH BEACH

July and August, 1989

	Influent (Mean Ratio to FC)	**Effluent** (Mean Ratio to FC)	**Photoreactivation** (Mean Log Increase)
Fecal Coliforms	1.0	1.0	1.56
Total Coliforms	6.5	5.4	1.96
Enterococcus	0.04	1.3	0
E. coli	0.13	0.7	0.84

TABLE 19

BACTERIAL INACTIVATION RATES ESTIMATED FOR REHOBOTH BEACH

	Coefficients[a]		K at I_{avg}[b]	
	a(x10^{-5})	**b**	**3,000**	**6,000**
Total Coliforms	0.0037	2.19	1.52	6.95
Fecal Coliforms	0.0075	2.09	1.39	5.91
Enterococcus	0.058	1.82	1.23	4.36
E. Coli	0.043	1.86	1.26	4.58

[a]$K = aI_{avg}^{b}$
[b]Inactivation Rate, K(second^{-1}) at Avg. Adj. Intensity, I_{avg} (uW/cm^2).

TABLE 20

COMPARISON OF REHOBOTH BEACH WWTP FECAL COLIFORM INACTIVATION RATES WITH OTHER PLANTS

	Fecal Coliform			
	Coefficients[a]		K at I_{avg}[b]	
	a(x10^{-5})	b	3000	6000
Rehoboth Beach, DE	0.0075	2.09	1.39	5.91
Bristol, CN	2.44	1.18	0.31	0.70
Newburgh, NY	1.08	1.29	0.33	0.81
New Windsor, NY	0.00061	2.2	0.27	1.23
Suffern, NY	0.004	1.92	0.19	0.72
Monticello, NY	0.69	1.4	0.51	1.34
Port Richmond, NY	1.45	1.3	0.48	1.18

[a] $K = aI_{avg}^{b}$
[b] Inactivation Rate, K($second^{-1}$) at Avg. Adj. Intensity, I_{avg} (uW/cm^2).

conditions. The process model was shown to respond correctly to site conditions and was then used to predict system performance at varying design conditions.

Summary. The following general observations were made, based on the results of the Rehoboth Beach analysis.

- Conventional UV systems effectively inactivate *Enterococcus* and *E. coli*; their rates of inactivation were lower than observed for either total or fecal coliform.

- System sizing on the basis of fecal coliform inactivation will be sufficient for subsequent consideration for *E. coli* or *Enterococcus*.

- Collection of relevant data at existing plants would benefit the assessment of any changes in criteria. Data should include initial and final densities of the target bacteria over an extended period of time.

- When a new UV disinfection facility is being considered, piloting would be useful for developing rate and performance data necessary for design sizing. If piloting is not possible, it would be appropriate to use conservative estimates of the rate coefficients and anticipated wastewater characteristics.

- The process model approach is an effective way to size UV systems and evaluate alternate configurations at projected design wastewater conditions.

For more details about this project, including the equations used, data collected, data analysis, and a design example, contact Karl Scheible (see Appendix A).

EPA REGION V SPECIAL EVALUATION PROJECT OF CHLORINATION-DECHLORINATION

Charles Pycha, EPA Region V, Water Management Division
Chicago, Illinois

For several decades, municipal wastewater treatment plants (WWTP) have preferred using chlorination to disinfect water and wastewater because this methodology is easy to use, efficient, and less expensive than other technologies. Despite these advantages, disinfecting water and wastewater through chlorination can result in several adverse environmental impacts because toxic levels of total residual chlorine can be discharged into the receiving waters and toxic halogenated organic compounds can be formed. Dechlorination is one of the alternatives used to reduce the impacts and concerns associated with chlorine residuals.

Many wastewater treatment plant operators have expressed concerns about chlorination. Other municipalities operate rudimentary systems or systems that do not operate properly. To address these concerns, EPA is in the process of issuing a new policy on chlorination that emphasizes the concern for aquatic toxicity due to the discharge of excessive levels of chlorine into receiving waters. To provide additional guidance to utility operators and managers and State personal, in March 1990, EPA Region V published a special evaluation report on chlorination-dechlorination of municipal wastewater. The report examines various methods that minimize the use of chlorine for disinfection, as well as the control systems available for chlorination-dechlorination. Data for the report was assembled from the *EPA Design Manual on Municipal Wastewater Disinfection*, a draft *Municipal Wastewater Disinfection Policy Development Document*, various Water Pollution Control Federation (WPCF) Journal articles, reports on improving chlorine disinfection efficiency and chlorine mitigation studies from the Vermont Agency of Natural Resources and the Connecticut Department of Environmental Protection, and information collected from Region V States.

Conclusions. The report includes several conclusions about chlorination-dechlorination. First, the most practical and cost-effective solution for facilities that currently disinfect wastewater with chlorine appears to be optimizing the existing chlorination system, which will minimize the amount of chlorine residual that reaches the waterways and aquatic life. Although optimization procedures will vary from system to system, the principles are applicable to all WWTPs.

Another conclusion of the report is that the degree and efficiency of treatment that precedes the chlorine disinfection process has a direct impact on the effectiveness of the process. Effluent from a tertiary WWTP requires less chlorine than effluent from a secondary WWTP. The same holds true for a well-operated secondary treatment plant, compared to a similar facility operating with less efficiency. An exception to this occurs when low levels of ammonia-nitrogen are present, forming monochloramine, which is a more potent disinfectant than free chlorine. The interaction of the free chlorine and nitrified effluents is not totally understood at this time.

A third conclusion of the report is that a well-designed chlorine disinfection process includes rapid and thorough initial mixing to enable the more lethal free chlorine to work as a disinfectant. A contact time of at least 30 minutes at peak flow in a plug flow contact chamber that has a length to width (L/W) ratio of 70 to 1 maximizes the use of the applied chlorine dose. Data collected over the course of a disinfection season will enable a WWTP operator to correlate flows and residual amounts to required coliform limits and to add only the necessary amount of chlorine to the system.

The fourth conclusion is that applying automatic chlorine residual control increases the opportunities for minimizing the use of chlorine. Automatic controls include simple flow proportional controls, feedback residual controls, and compound loop controls.

The final conclusion is that plants must dechlorinate if they discharge chlorinated wastewater into sensitive streams that require very low or zero chlorine residual permit limits to be met. Sulfur dioxide is the commonly chosen agent to eliminate chlorine residuals. Turbulent mixing at the point of sulfur dioxide application and a contact time of at least 60 seconds is usually adequate for residual control. Since no control system specific to sulfur dioxide exists, the feed rate is controlled by measuring the chlorine residual. Two chlorine residual analyzers are often used, one to control the chlorine dosage and one to regulate the sulfur dioxide dose rate. Continuous feedback control of chlorine residuals and on-line monitoring to levels as low as 0.001 mg/L is now possible.

Recommendations. The report made several specific recommendations to wastewater treatment facilities that chlorinate to minimize the impacts of chlorination on receiving waters and aquatic life:

- Ensure that the processes preceding chlorination are optimized to reduce the organic and pathogenic load to the chlorination process.

- Optimize the chlorination process by ensuring that rapid chlorination/wastewater mixing takes place prior to when the wastewater is in the chlorine contact tank. Make sure the chlorine contact tank has no short-circuiting or turbulence and that the tank resembles a plug flow reactor.

- Practice some form of chlorine feed rate control to prevent over- and under-dosing. A properly sized feed rate control is necessary, and automatic flow proportional control is recommended, as a minimum, to vary the chlorine dose in relation to the wastewater flow rate. Also recommended is the use of feedback residual and compound loop controls, which vary chlorine dose based on wastewater flow rate and effluent chlorine residual, if economically feasible. Chlorine feed rate controls and residual analyzers range in price from $1,000 to $2,000, a cost that EPA feels is necessary and will save money in the long run.

- Dechlorination facilities should follow the same recommendations for feed rate control as chlorination systems.

The cost of implementing these recommendations and new controls, especially for plants that must dechlorinate, can be offset in many cases by a short payback period.

Contact Charles Pycha (see Appendix A) to obtain a copy of this report.

SMALL FLOWS CLEARINGHOUSE

NATIONAL SMALL FLOWS CLEARINGHOUSE COMPUTER BULLETIN BOARD

Anish Jantrania, University of West Virginia
Morgantown, West Virginia

The National Small Flows Clearinghouse operates the Wastewater Treatment Information Exchange (WTIE), a computer bulletin board system (BBS) that provides the facility to exchange information on current research, news, available publications, and issues that affect small community wastewater systems. The service is available free-of-charge nationwide, 24 hours per day. Some functions of the system include sending and receiving electronic mail; advertising conferences; posting calendars of events and bulletins on environmental news; accessing files on newsletter stories and research papers (without mailing diskettes); and conducting surveys.

To access WTIE, the user needs a personal computer, a modem, and communications software. The communications package must emulate an ASCII terminal with the following setup:

- Baud Rate: 1200 or 2400
- Data Bits: 8
- Parity: None
- Stop Bits: 1
- BBS Number: 1-(800)-544-1936

The logon procedure for WTIE is listed on Figure 22.

If you have questions about accessing the bulletin board, call the Clearinghouse voice number at (800) 624-8301. Also refer to Appendix B for how to contact the National Small Flows Clearinghouse Manager.

ATDT 1-800-544-1936
CONNECT 1200

```
=====================================================================
=====================================================================

W                     W   TTTTTTTTTTTTT     IIIII        EEEEEEEEE
 W          W        W          T             I          E
  W        W W      W           T             I          E
   W      W   W    W            T             I          EEEEE
    W    W     W  W             T             I          E
     W  W       W W             T             I          E
      W          W              T           IIIII        EEEEEEEEE

=====================================================================
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W E L C O M E

to the

Wastwater Treatment and Information Exchange Bulletin Board System

Press Any Key to continue

What is your FIRST name? *joe*
What is your LAST name? *blow*

Checking Users...
User not found
Are you '**JOE BLOW**' ([Y],N)? *Y*
What is your CITY and STATE? *Orlando, FL*

Welcome message

JOE BLOW from **Orlando, FL**
C)hange FIRST name/LAST name/CITY and STATE, D)isconnect, [R]egister? *r*
Enter PASSWORD you'll use to logon again (dots echo)? *password*
Re-Enter PASSWORD for Verification (dots echo)? *password*
Please REMEMBER your password

CAN YOUR TERMINAL DISPLAY LOWER CASE ([Y]/N)? *y*
UPPER CASE and lower

GRAPHICS for text files and menus
Change from N to N)one, A)scii-IBM, C)olor-IBM, H)elp ([ENTER] quits)? *n*
Text GRAPHICS: None

Figure 22. Log On Procedures for the Wastewater Treatment Information Exchange (WTIE)

```
Do you want COLORIZED prompts ([Y],N)? _n_
Default Protocol
A)scii,X)modem,C)rcXmodem,Y)modem,N)one? _n_
Protocol: None
TurboKey: act on 1 char command without waiting for [ENTER]
Want TurboKeys (Y/[N])? _n_
TurboKey Off

           -------- Small Flows Clearinghouse --------
            -------- New User Questionnaire --------

Please enter your phone number
 999-99-9999

Enter first affiliation (or private citizen if not a member of
                     any organization)
 environmental consulting firm

Please enter your address below...

 999 East Washington Street
 Orlando, FL 99999

Logging JOE BLOW
RBBS-PC CPC17.3 NODE 2, OPERATING AT 1200 BAUD,N,8,1

              ---------- Bulletin Menu ----------

 1 - 01/02/90  Calendar of Events (February through December 1990)
 7 - 01/24/90  WVU's demo project helps southern communities
 8 - 01/26/90  MCLs for 38 organic and inorganic chemicals

Caller # 1224  # active msgs: 99  Next msg # 383

 40 min left
                              M A I N   M E N U
                              -----------------

 PERSONAL MAIL    SYSTEM COMMANDS       UTILITIES          ELSEWHERE
 ---------------------------------------------------------------------
E)nter a Message | B)ulletins          | H)elp              | F)iles Menu
K)ill a Message  | C)omment            | J)oin Conference   | U)tilities Menu
R)ead Messages   | I)initial Welcome   | X)Expert/Novice    | G)oodbye
S)can Messages   | P)ersonal Mail      |    toggle          |
T)opic of Msgs   |                     |                    |
---------------------------------------------------------------------

MAIN command <?,B,H,I,J,Q,R,S,T,U,X>?
```

Figure 22. (Continued)

TOXICITY MANAGEMENT AT POTWS

TECHNOLOGIES FOR TOXICITY REMOVAL AT POTWS

Perry W. Lankford, Eckenfelder Incorporated
Nashville, Tennessee

In general, there are three types of procedures for reducing toxicity from wastewater treatment systems, regardless of the nature of the influent feed. The alternative approaches are the *causative agent approach*, the *source treatment approach*, and the *treatment approach*.

The causative agent approach identifies and eliminates one (or more) chemical, which is either the sole or predominant cause of the toxicity. This approach relies on conducting a toxicity identification evaluation (TIE) to produce sound data on the chemical "culprits." If the culprits identified by the TIE are not present in a form that can be eliminated, they must be addressed through another approach.

The source treatment approach is where one or more source streams (as opposed to a few compounds) is found to cause most of the problem. Although precise causative agents may not be known, plant investigators can identify the segment of the collection system, plant, or plants that may be causing the problem, and then treat the source. This approach appears to be practical with at least a reasonable success rate. Experience suggests, however, that when dealing with complex systems, large POTWs, industrial inputs, and sensitive aquatic organisms, multiple sources, rather than a single chemical or source, are responsible for the toxicity.

The treatment approach identifies weak areas in the treatment system and implements improvements to the system to resolve the toxicity problems. In the majority of cases studied, the treatment approach has been shown to be most effective.

Causative agent approach. An essential part of the causative agent approach is a fractionation procedure, which involves making a series of decisions (see Figure 23) on what laboratory tests to conduct, based on the extent of the toxicity and the results of tests conducted early in the procedure. The goal of fractionation is to chemically eliminate a fraction of the contaminants and thereby determine the amount of toxicity that is removed. This approach can identify the

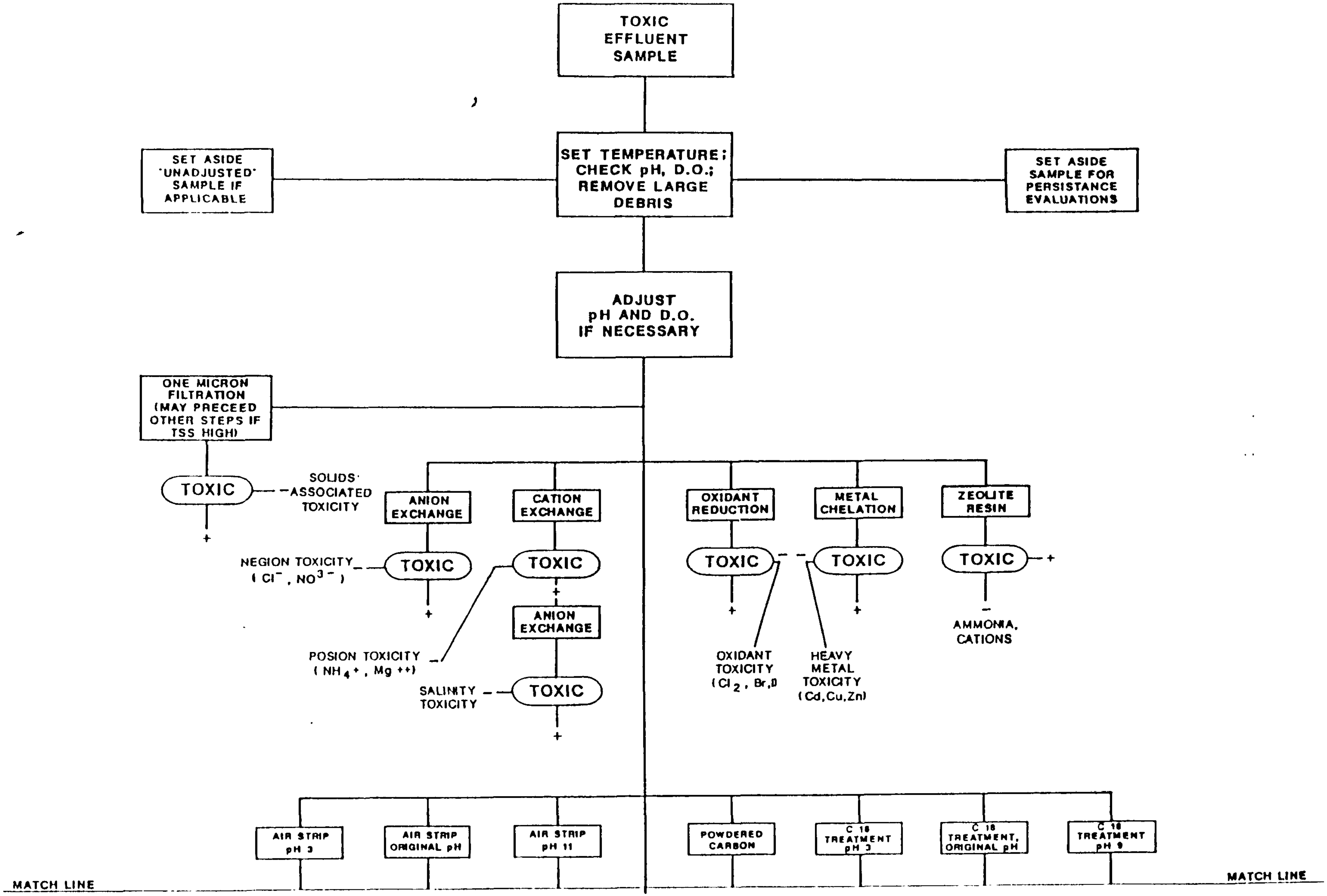

Figure 23. Causative Agent Approach Flow Diagram

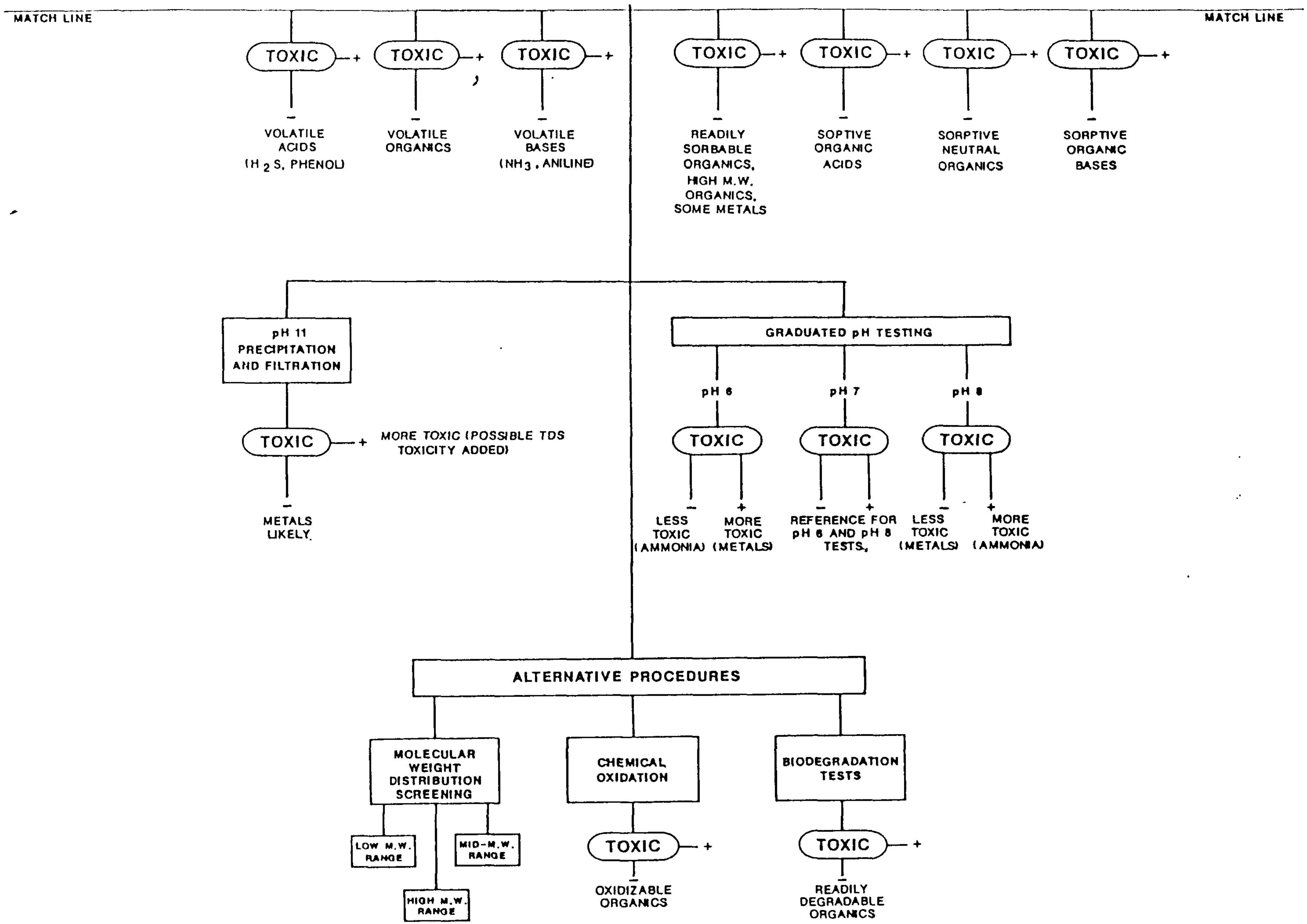

Figure 23. Causative Agent Approach Flow Diagram (continued)

specific component that is toxic or a method to reduce the toxicity. However, the majority of cases where the results of fractionation procedure tests lead to identifying a single contaminant are in POTWs that have effluents with low to moderate toxicity. More often than not, the results are ambiguous and identify several series of test procedures that can be conducted to reduce the toxicity to simpler levels.

<u>**Source treatment approach**</u>. The source treatment approach identifies a greater number of possible causes and solutions due to the broader nature of the approach (i.e., it deals with source streams and not single chemicals). This approach is more cumbersome, however, because the focus is not on the source of the toxicity *per se* before it reaches the treatment system, but the toxicity that passes through the treatment system. For this approach, investigators must follow a specific technique or series of analyses (see Figure 24) to identify the toxic source or sources. To further screen out potential causative agents, provide definitive answers, and identify treated samples that need further evaluation, biodegradability analyses have been used. These analyses include BOD/chemical oxygen demand (COD) tests, glucose inhibition tests, continuously fed batch reactor tests, biotreatability tests, and others.

Experience with character, toxicity, and screening tests has shown that successful source treatment technologies can be applied to remove heavy metals, volatiles, organic chemicals, and ammonia, as shown in Figure 25. Removal of heavy metals is well-established using metals precipitation. Volatiles are rarely found to be a problem in POTWs because they are not very toxic to aquatic organisms and are removed through standard procedures. Organics are, therefore, the target of most toxicty reduction evaluation projects.

<u>**Organics removal technologies**</u>. One promising new technology to remove organics is peroxide oxidation of source streams using ultraviolet (UV) disinfection light catalyses. Chemicals such as tri- and tetrachloroethylene, 2-butanol chloroform, methyl ketones, carbon tetrachloride, and tetrachloroethane have been effectively removed using this technique.

Researchers have also demonstrated ozonation to be an effective pretreatment for removing many of the same organic chemicals, whereas anaerobic treatment can completely

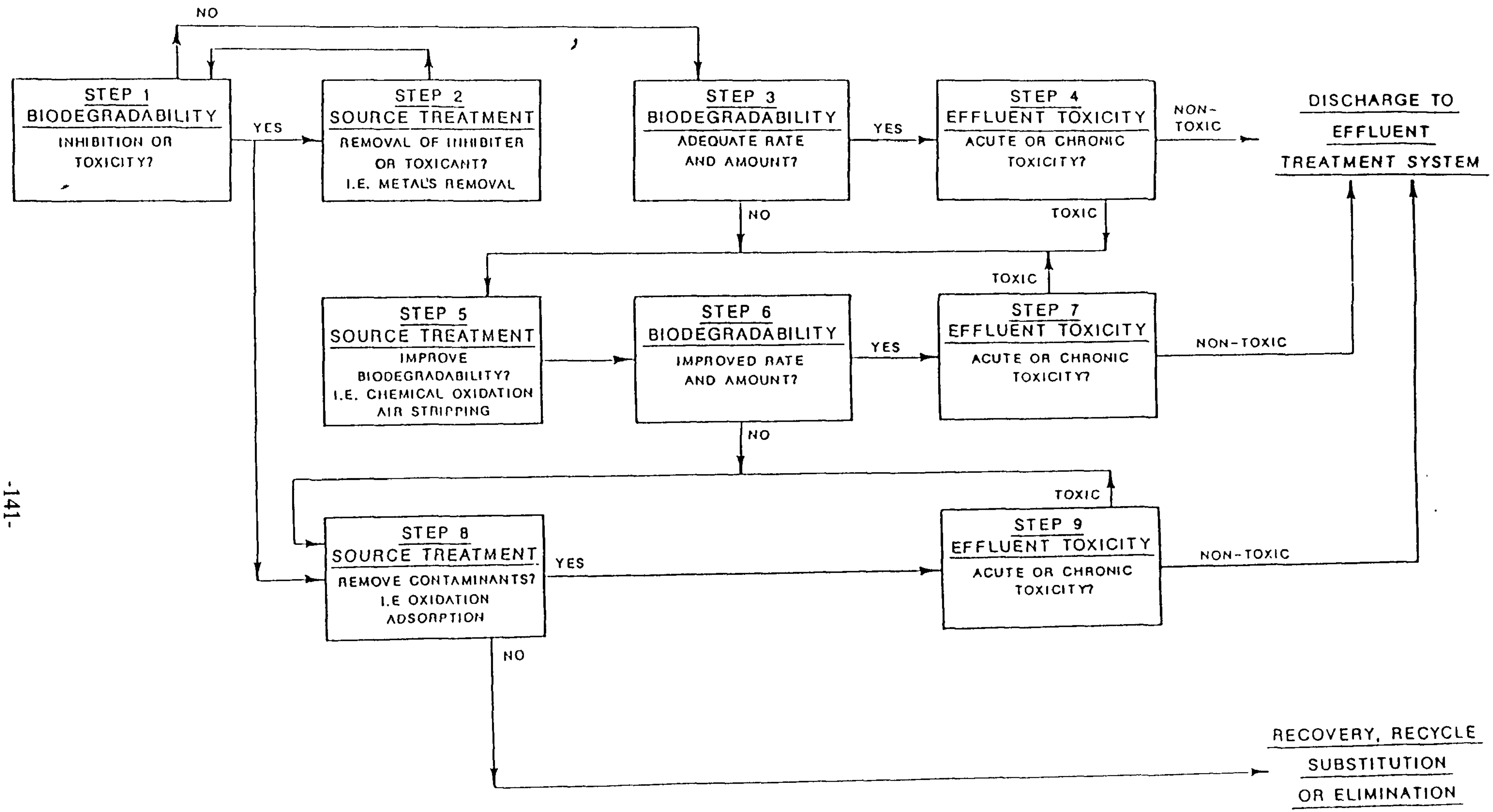

Figure 24. **Source Testing and Treatment Flow Diagram**

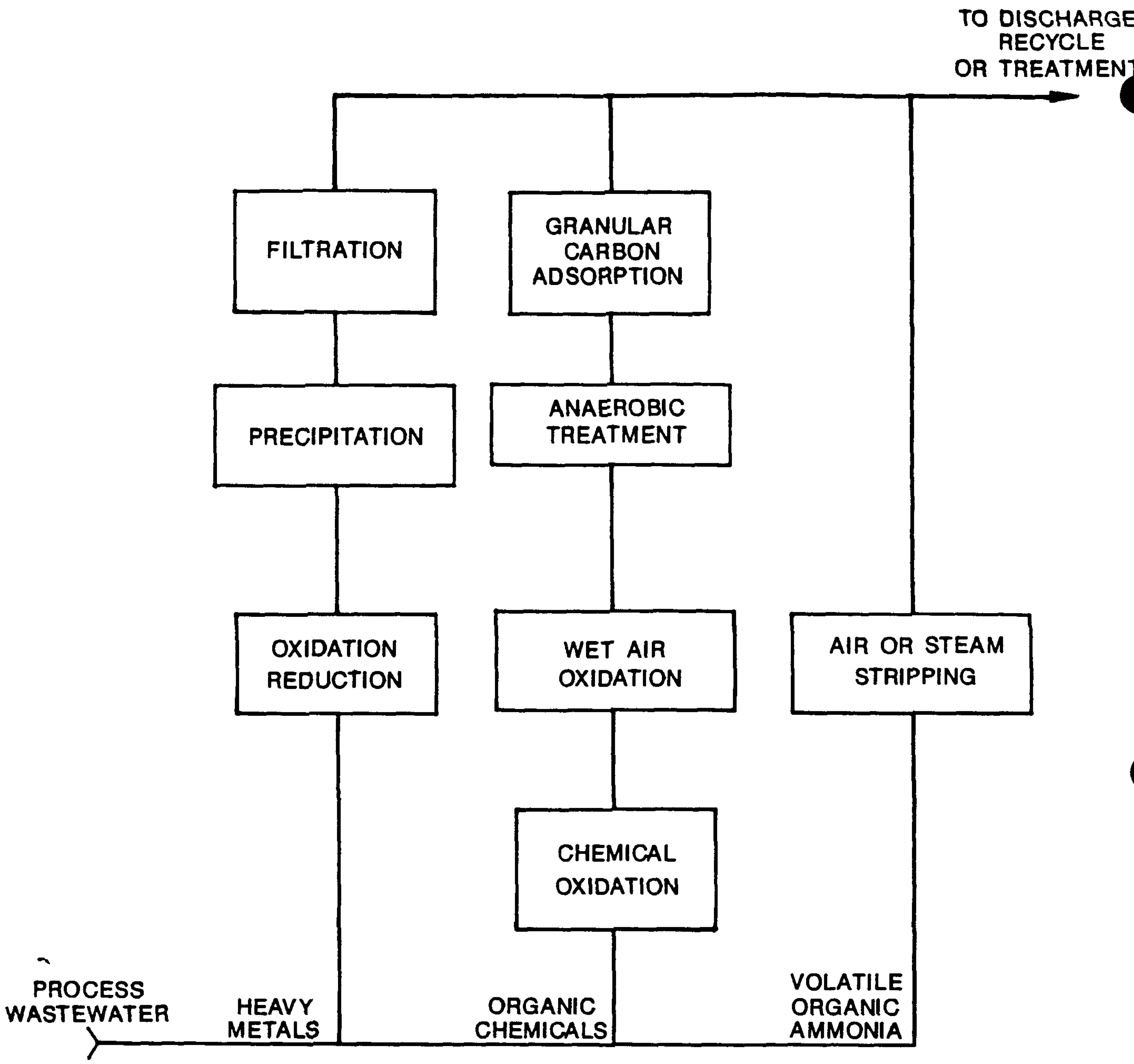

Figure 25. Source Treatment Technologies for Toxicity Reduction

degrade or chemically alter the chemicals. In complex systems, aerobic biological treatment is the most often used end-of-pipe toxicity reduction treatment, which can be accomplished by optimizing or upgrading the existing system.

Powdered Activated Carbon Treatment (PACT™) is another end-of-pipe treatment used more frequently today to enhance the performance of activated sludge systems and remove organics. As shown in Figure 26, an increase in PAC results in a logarithmic decay of most of the residual contaminants, including total organic carbon (TOC), metals, color, and toxic units. Different carbon supplies have shown different results, some being up to 10 times more effective than others. The significance of these differences is that carbons that can function effectively at low dosages can be more readily used in systems where the WWTP is physically limited.

Researchers have found solids retention time (SRT) or sludge age to be a principle design criteria for biologically removing specific organics as opposed to organics in mass (like TOC). In some instances, an adjustment of SRT alone can solve toxicity reduction issues. Figure 27 shows the effect of SRT on reducing the toxicity of nonyl phenolics at one WWTP. What occured at this site was that initially there was improved biodegradation, but toxicity worsened as more BOD and TOC were removed. The investigators determined that as the long chain nonyl phenolic surfactants biodegraded, which readily occurs, more toxic short chain surfactants were created. The plant was, therefore, producing a more toxic effluent through the implementation of so-called improvements. Extending the SRT from the initial 4.5 days to about 20 days eventually improved the removal of the nonyl phenolics and the toxicity problem. This is an economically favorable solution.

When using granular activated carbon columns to remove TOC and other organics, columns can reach exhaustion sooner if toxicity were the breakthrough parameter. Either biological regeneration and/or substitution adsorption is the probable cause of this phenomenon. Substitution adsorption is a speculative theory that assumes that higher molecular weight long chain organics are more toxic and adsorptive, and shorter-chain materials that had previously been adsorbed can be displaced by the longer chain materials. In one investigation, the

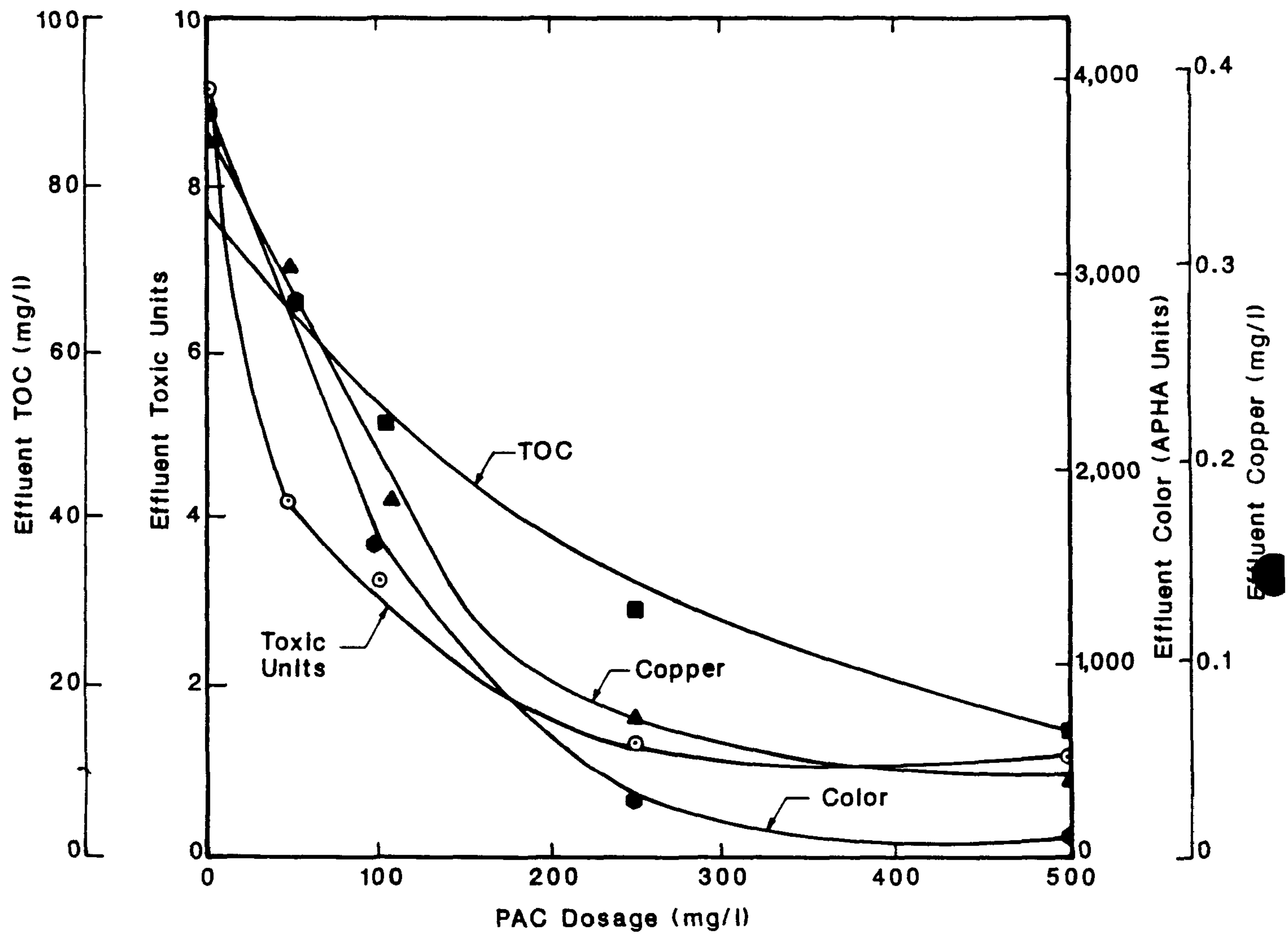

Figure 26. Contaminant Removal Trends in PACT™ Systems

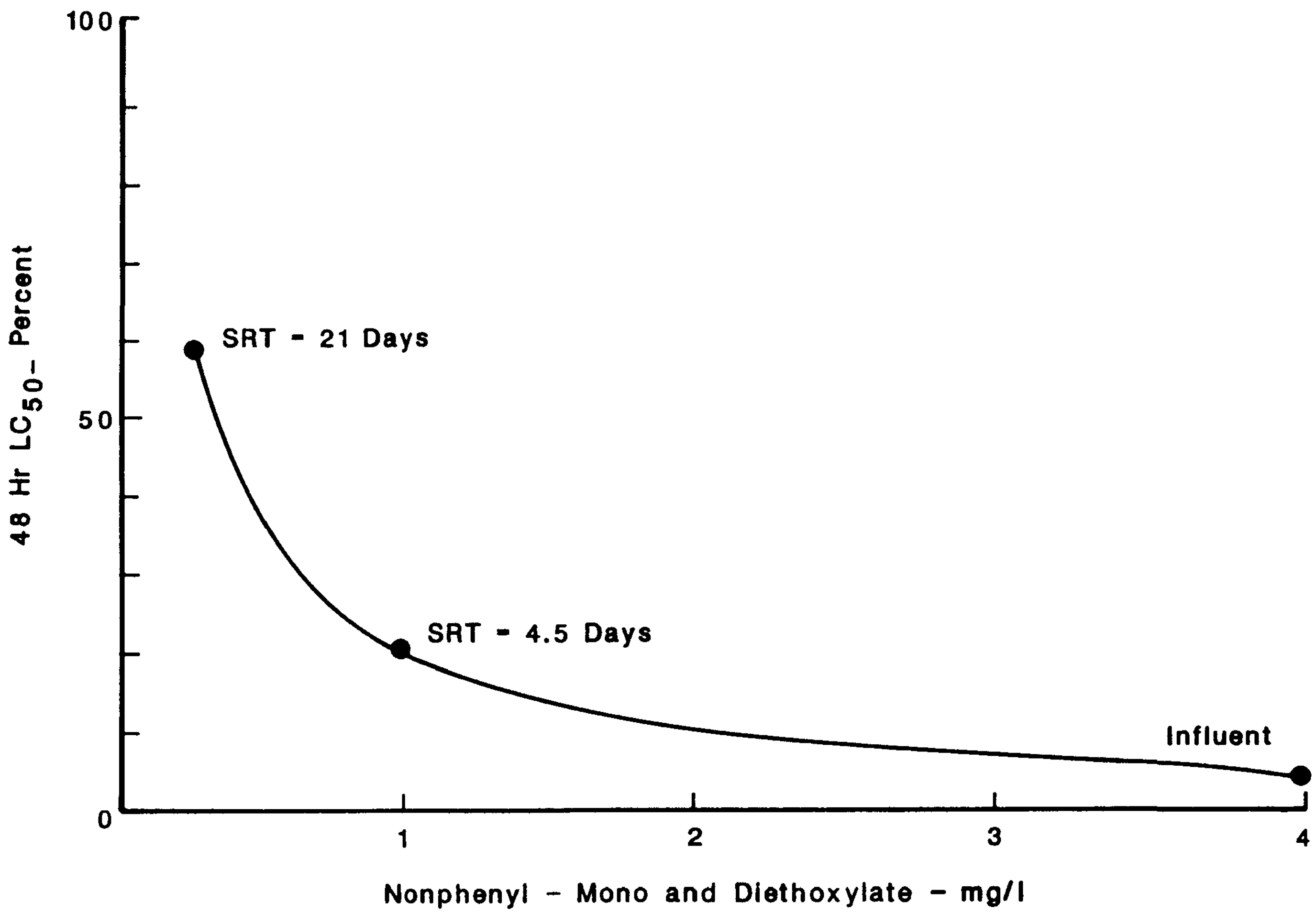

Figure 27. Effect of Solids Retention Time (SRT) on Toxicity Reduction for Nonyl Phenolics

breakthrough for toxic units did not occur until day 60 on the test columns, whereas the breakthrough for TOC occurred by day 10.

Ammonia removal. The toxic form of ammonia is free ammonia, not total ammonia. The amount of the total ammonia in the free form varies according to the pH and to a lesser extent, temperature. At a pH of less than 7, ammonia levels below 100 mg/L would not be a toxicity issue; this is the case in most POTWs. An ammonia level above 100 mg/L would be a compliance problem for other reasons. At elevated pH levels (above 7.5), ammonia levels as low as 20 mg/L can result in effluent toxicity. Nitrification is one of many established control technologies available to deal with this problem.

For more information on toxicity reduction at POTWs, contact Perry Lankford (see Appendix A).

DEVELOPMENT OF COMPUTER-BASED MODEL AND DATA BASE FOR PREDICTING THE FATE OF HAZARDOUS WASTE AT POTWS

John Bell, Enviromega Ltd.
Campbellville, Ontario, Canada

Environment Canada's Wastewater Technology Centre (WTC) is sponsoring a project to develop a computer-based model and data base for predicting the fate of hazardous compounds in wastewater treatment plants. A preliminary model is near completion and the data base will soon be used to calibrate the model. The model is designed for microcomputer application (IBM PC) and is user-friendly through the use of menus. It has the capability to simulate both steady-state and dynamic systems and conduct sensitivity analyses. The model is designed to be used by regulatory agencies as well as designers and operators of wastewater treatment plants.

The dynamic model allows the user to enter various kinds of input concentrations of a compound or data on a spike or step input, and features built-in diurnal flow variations. The built-in sensitivity analysis allows the user to vary one parameter, such as a compound's biodegradation rate constant or Henry's Law Coefficient or a plant's recycle or flow rate, to determine how plant performance might change as a function of the particular parameter. The model also has one internal chemical data base, which a user can access but not change, and a data base the user can change by inputting new data.

<u>**Unit processes and removal mechanisms**</u>. The model can simulate four unit processes, including grit removal in aerated or nonaerated grit chambers; primary settling; aeration tanks, which can be modeled as a series of 1 to 10 complete mix tanks; and secondary settling. The four removal mechanisms modeled are volatilization (i.e., evaporation from the surface of clarifiers), stripping (that occurs in aerated process vessels), sorption, and biodegradation.

The model takes into account the volatilization that takes place at air/water interfaces and the prevailing conditions at these interfaces. Surface volatilization, from the surface of tanks, is a function of the contaminant properties (i.e., Henry's Law Coefficient and diffusion coefficients), wind speed, and the tank surface area. Volatilization at clarifier weirs is a function of the contaminant properties as well as the weir loading and dimensions.

The model allows input of subsurface or diffused aeration and surface aeration to account for the two ways contaminants can be stripped in aerated process vessels. For diffused aeration, the amount of stripping that takes place is a function of the contaminant properties, oxygen transfer efficiency, and the airflow rate. For surface aeration, the stripping is a function of the contaminant properties and the oxygen transfer rate. In the model, the oxygen transfer rate is estimated from various input parameters, such as the aerator horsepower and the standard oxygen transfer rates.

The model makes several assumptions about the sorption of contaminants onto primary and activated sludge. The first assumption is that the sorption process is reversible; both sorption and desorption can occur. Second, sorption and desorption are rapid processes compared to the other processes taking place in the treatment plant. At every point in space and time within the plant, equilibrium is established instantaneously. Third, the model assumes a linear partition equation (i.e., absorption equilibrium can be characterized by a linear partitioning equation that generally holds true at the low concentrations characteristic in municipal treatment plants). The forth assumption is that the partition coefficient for primary and activated sludge is the same when no experimental evidence to the contrary exists. When no experimental partition coefficients exist, they can be obtained from the octanol/water partition coefficient, available for many compounds of interest.

The model makes several assumptions for the biodegradation removal mechanism. The model assumes a pseudo first-order kinetics for biodegradation, based on the low concentrations of these contaminants normally found in municipal treatment plants. Also, the biomass concentration in the system is assumed to be constant for both the dynamic and steady-state model. (This condition would normally be present in the steady-state model.) The model also assumes that the biodegradation rate coefficients are obtained from experiments because to date, there is no reasonable way to obtain this information from theory.

Pilot and bench scale tests. Model developers are conducting pilot plant and bench scale tests to develop a data base of treatability parameters to be used to calibrate the model. Parameters include biodegradation rate constants, sorption partition coefficients, and gas/liquid partition coefficients (Henry's Law Coefficients).

One pilot test is taking place in Burlington, Ontario. The aeration tank for this test is roughly 10 ft. high to simulate the depth of a full-scale plant. The pilot plant receives about 5 gallons per minute of influent (degritted raw sewage) from the local sewage treatment plant. Another pilot study was conducted near Toronto. This plant received a larger input of industrial waste and has higher concentrations of some of the compounds of interest.

Figure 28 is a graph of a dynamic experiment that estimated the biodegradation rate constant and the sorption partition coefficient of an unacclimated system. In this case, 2-4-6-trichlorophenol was spiked into the system at time zero and at 24 hours. Researchers cut off the spike at 48 hours, after which time they observed the decay of the concentration in the plant effluent. They used the data collected in conjunction with the model's nonlinear regression routine to fit the treatability parameters to the data. As shown on Figure 28, the model fit the observed data to the predicted data fairly well.

Similar tests were conducted with pentachlorophenol and for metals. Although in the test for nickel, the model estimates for sorption closely fit the test data, results for cadmium and other metals did not (see Figure 29). This might be because most of the metals are removed by precipitation, and the model assumes they are removed through sorption onto the solids. WTC is refining the model to handle more complex systems.

Figure 30 shows the experimental versus the observed results for steady-state pilot plant tests on p-xylene stripping. These experiments were carried out under increasing air flow rates, from Experiment #1 to #6. As shown on Figure 30, xylene is primarily removed by biodegradation, but greater stripping occurs as air flow rate increases. The model predictions were fairly close to the actual data.

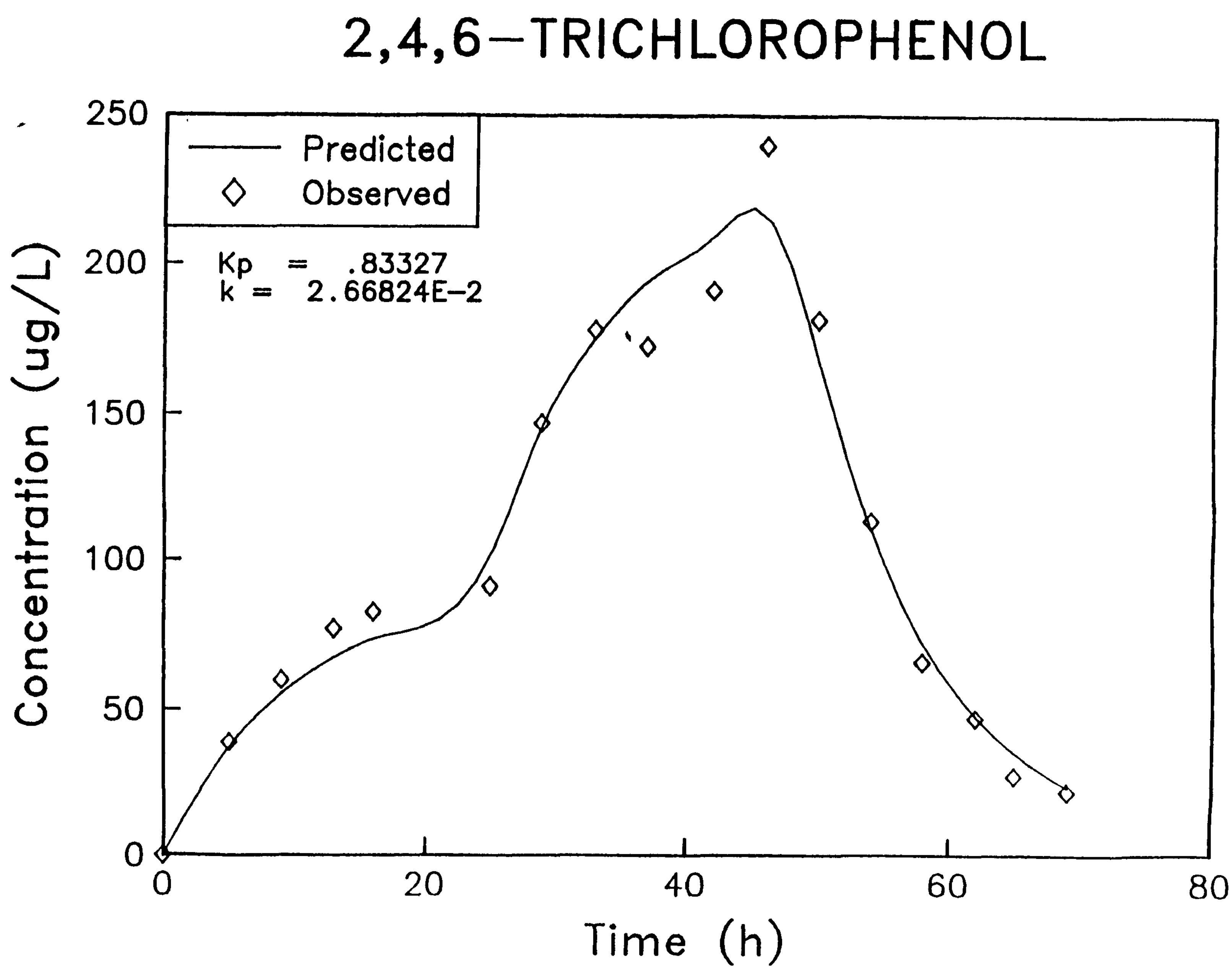

Figure 28. Predicted Versus Observed Effluent Concentration for 2,4,6-Trichlorophenol

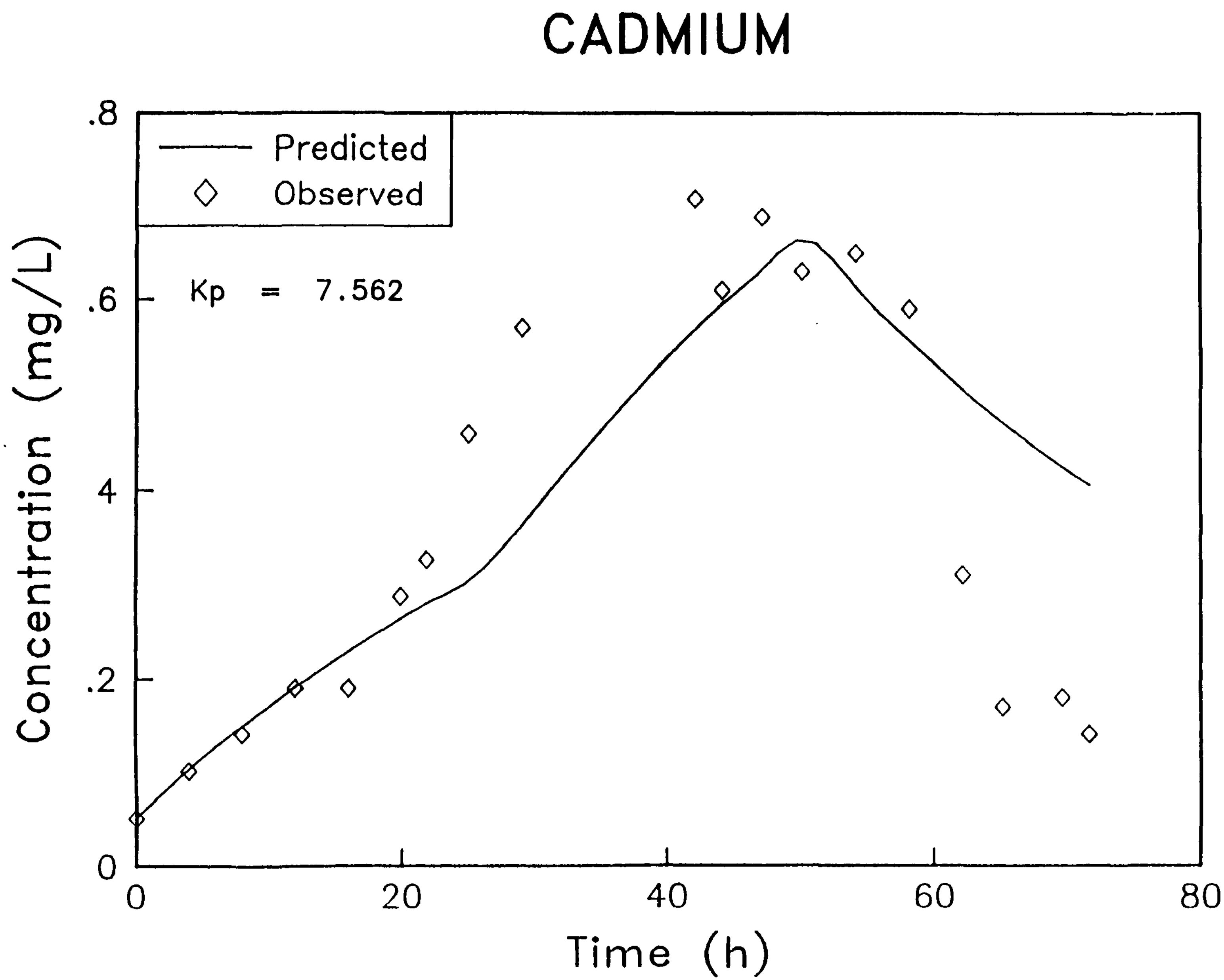

Figure 29. Predicted Versus Observed Effluent Concentration for Cadmium

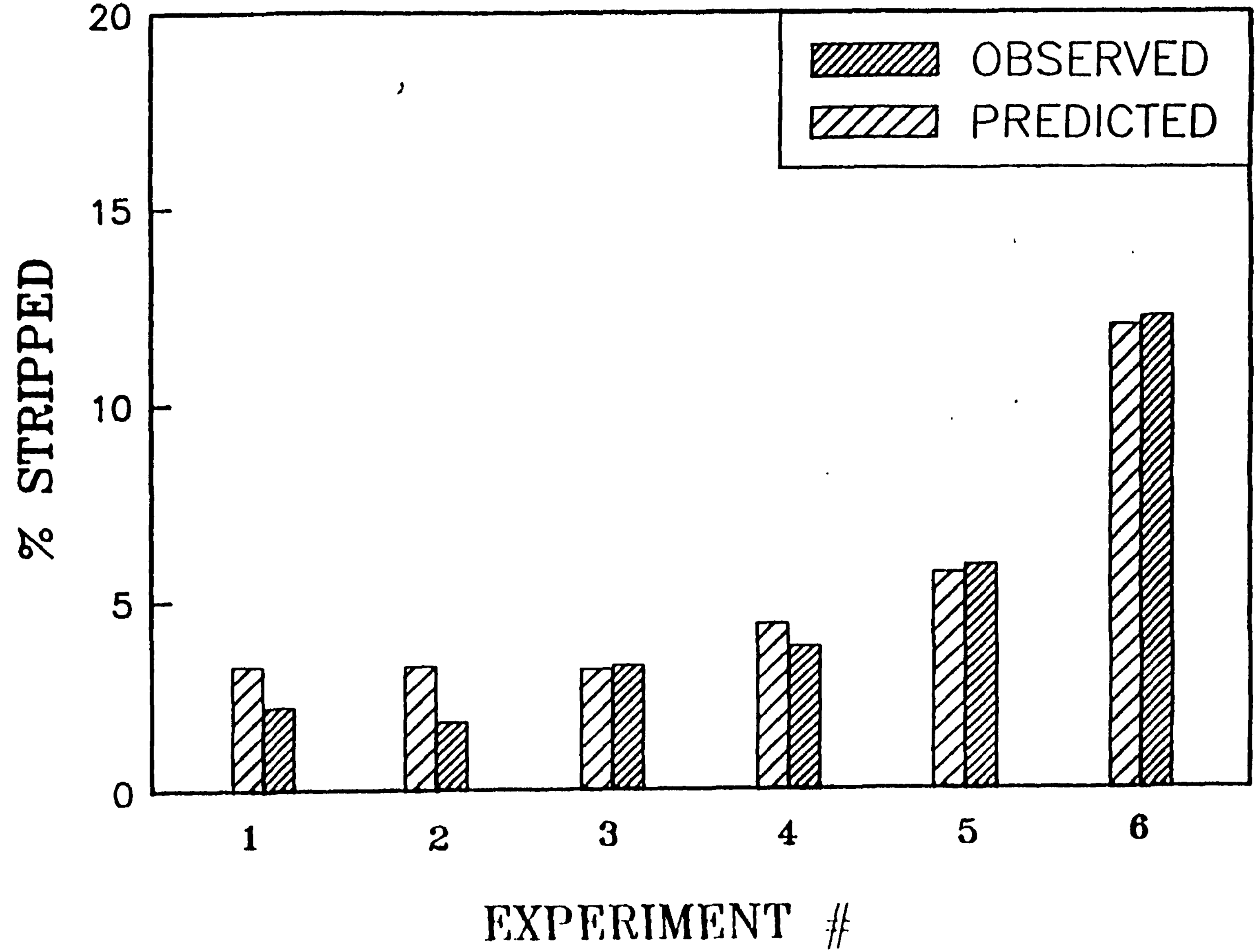

Figure 30. **Predicted Versus Observed Stripping Removal Rates for P-Xylene**

Preliminary full-scale tests of the model were carried out using data from three petroleum refinery wastewater treatment plants (WWTP) and a POTW. Table 21 shows results of the model tests that compared predicted and observed removal rates of several highly degradable nonchlorinated aromatic compounds. As shown in Table 21, the model predicted almost 100 percent removal, which matched actual test results. Other tests indicated that the bench-scale and pilot plant data can provide adequate estimates of treatability parameters for use in calibrating the model.

Steady-state tests were conducted at a WWTP near Toronto that has a fairly heavy industrial waste load and receives many types of volatile organic compounds. Table 22 shows the predicted versus observed results for stripping and biodegradation. The model predicts the results of all compounds fairly well, except tetrachloroethylene, which shows somewhat reversed results. Model developers are reevaluating the model's parameter estimations for biodegradation and stripping and running additional tests on this compound. Dynamic tests were also conducted at a WWTP, the results of which showed the close prediction by the model.

In the future, the model will be refined to include sludge processing operations in addition to the conventional activated sludge process, such as digestion, dewatering, incineration, and final disposal. The WTC aims to make the model more flexible for handling different plant designs and refine the biodegradation model to include different concentration ranges and acclimation conditions. The data base also will be expanded to cover all the priority pollutants. The WTC also would like to conduct comprehensive tests to field-verify the model, investigate simpler parameter estimation techniques, and investigate the use of structure activity relationships for developing biodegradation rate data.

For more information, contact John Bell (see Appendix A).

TABLE 21

MODEL TEST: COMPARING PREDICTED AND OBSERVED REMOVAL FROM THREE OIL REFINERY WASTEWATER TREATMENT PLANTS

Compound	Observed Removal (%)	Predicted Removal (%)
	Esso Refinery	
Benzene	> 99	99.7
Toluene	> 98	99.7
Xylenes	> 99	99.5
Ethylbenzene	> 98	99.7
	Petro Canada Refinery	
Benzene	> 99.9	99.9
Toluene	> 99.9	99.9
Xylenes	> 99.9	99.9
Ethylbenzene	> 99.2	99.9
	Montreal East Refinery	
Benzene	99.6	99.4
Toluene	99.4	99.4
Xylenes	98.4	99.2

TABLE 22

MODEL TEST: PREDICTED AND OBSERVED REMOVAL FROM THE HIGHLAND CREEK WPCP

Compound	% Stripped		% Biodegradation	
	Predicted	Observed	Predicted	Observed
Dichloromethane	3.5	2.6	81.2	92.4
Chloroform	3.6	7.4	69.2	73.6
1,1,1-Trichloroethylene	5.3	10.5	88.8	79.7
Trichloroethylene	7.6	10.7	83.4	82.7
Toluene	0.4	1.2	99.1	98.6
Tetrachloroethylene	8.9	58.7	81.1	15.8
p-Xylene	0.9	1.3	98.6	98.1
1,4-Dichlorobenzene	17.0	19.1	34.6	54.7

PLANT PERFORMANCE EVALUATION
CROSS CREEK WASTEWATER TREATMENT PLANT
FAYETTEVILLE, NORTH CAROLINA

Bill Cosgrove, U.S. EPA, Region IV
Athens, Georgia

The Cross Creek Wastewater Treatment Plant (WWTP) is a 16 MGD (by design) pure oxygen activated sludge plant operated by the Fayetteville Public Works Commission (PWC). During November 1989, the U.S. EPA, Region IV, Environmental Services Division (ESD) conducted a Plant Performance Evaluation (PPE) at the facility. Engineering Science, Inc. (ES) of Fairfax, Virginia, requested the PPE to support a Toxicity Reduction Evaluation (TRE) the company was conducting at the plant for EPA's Risk Reduction Engineering Laboratory (RREL).

The objectives of the ES project were to evaluate selected TRE approaches and refine the existing EPA protocol for planning and implementing TREs at municipal WWTPs. A major objective of the EPA study was to demonstrate the PPE as a method within the TRE process for identifying and correcting operational problems that may be influencing system performance and effluent toxicity.

Toxicity reduction evaluations. The EPA protocol for municipal WWTPs is contained in the 1988 EPA publication, *Toxicity Reduction Evaluation Protocol for Municipal Wastewater Treatment Plants* (EPA 600/2-88/062). The objectives of a TRE are to evaluate the operation and performance of a WWTP to identify and correct treatment deficiencies causing effluent toxicity; identify the toxic compounds causing the toxicity; trace the toxicants to their source; and evaluate and implement methods to control the toxicity.

Plant performance evaluations. A PPE is typically conducted as a first step in a TRE. The objectives of the PPE conducted at Cross Creek were to collect design and operations information to establish a data base for the PPE; review performance of the WWTP in reducing conventional (BOD_5, TSS, NH_3, etc.) and nonconventional (organic compounds/metals) pollutants; evaluate hydraulic and organic loadings compared to design criteria; evaluate characteristics of the sludge in the A/S system; review the operational strategies for solids inventory, dissolved oxygen (DO), and return sludge control; and review the pretreatment program and screening of septage/waste haulers.

Treatment facility process. The Cross Creek WWTP consisted of preliminary treatment, pure oxygen-activated sludge, secondary clarification, and chlorination prior to discharging into the Cape Fear River (see Figure 31). The plant was being modified to include an extended aeration process (scheduled to be completed in 1991).

Waste activated sludge (WAS) was pumped to a gravity belt thickener, stabilized in two aerobic digesters, and land applied. No supernant was being returned to the treatment process from the aerobic digesters during the PPE; however, filtrate from the belt thickener was being returned to the secondary clarifiers. About 25 percent of the total flow to the WWTP was from industrial sources and included organic chemicals, meat rendering, metal finishing, animal feeds, yarn dyeing, tire/rubber products, tank truck cleaning, electrical components, and fabric bleaching/dyeing.

Process control testing and operational strategy. Process controls testing completed by the operations staff included aeration basin DO; sludge settleability; MLSS/MLVSS; clarifier sludge blanket depth; and waste thickened and digester sludge concentrations and settleability. Operational parameters calculated included the sludge age based on mean cell residence time (MCRT), food to microorganism ratio (F:M), and aerobic digester detention time.

The operational strategy included a target MCRT of 2.0 days for solids inventory control; using an anoxic first stage in each pure oxygen train for *nocardia* control; maintaining DO levels at the pure oxygen basin outlet of 6.0 mg/L with a 4.0 mg/L as a minimum; maintaining a 3-ft sludge blanket depth in all 5 clarifiers; controlling the WAS flow rate based on a series of settleability tests; and manually adjusting the chlorination rate to attain a residual of 2 mg/L at the application point.

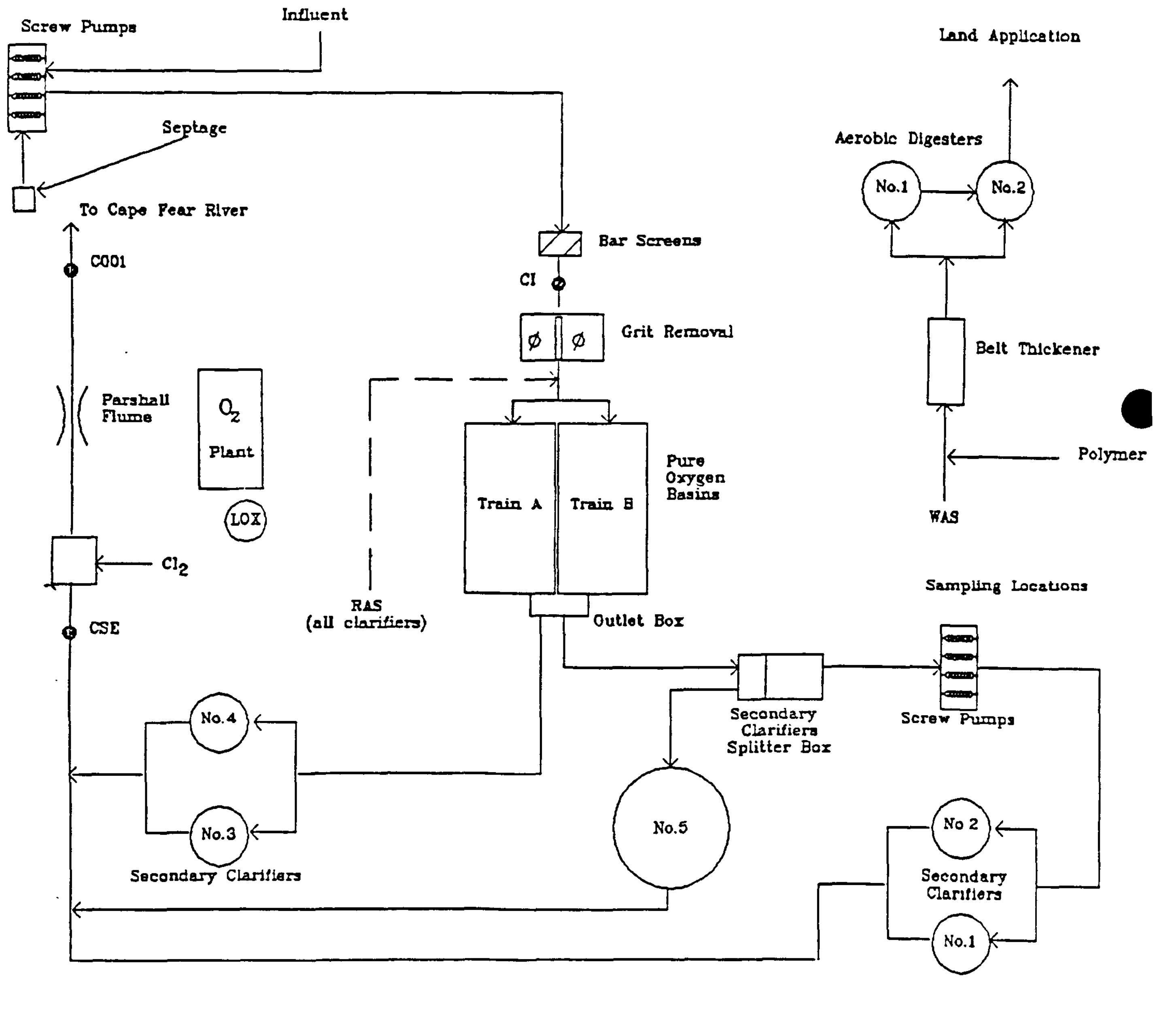

Figure 31. Cross Creek, North Carolina, WWTP Flow Diagram

Results. The average effluent BOD_5 and TSS concentrations for October 1988 to November 1989 were 10 and 18 mg/L. The influent BOD_5 and TSS concentrations averaged 150 and 188 mg/L, well below the design value of 250 mg/L. The plant had received high-strength industrial slugs during the period. Influent pH values were extreme in April and June, 1989, at 9.0 and 4.9 S.U., respectively. Sampling did not indicate the regular presence of organic compounds in the raw wastewater or final effluent.

Conventional parameters for the plant's performance for the EPA study, November 14 to 16, 1989, are listed in Table 23. The average effluent BOD_5 and TSS concentrations were within permit limits, and the average influent TSS concentration (58 mg/L) was low for an industrial/domestic wastewater.

A continuous-reading pH meter installed for the EPA study showed several periods of abrupt pH change on November 15, 1989 (0.5 to 1.5 S.U during the morning and 7.0 to 9.2 S.U in the evening). Severe pH excursions demonstrate the influence that industrial users can have on raw wastewater characteristics of a WWTP and that slug loadings can influence plant performance in terms of both pollutant removals and effluent toxicity. The Cross Creek staff would normally not have discovered this slug loading, and would not have been able to comply with EPA regulations requiring POTWs to assess the potential for interference and pass-through, notify EPA and State authorities, and take appropriate measures to minimize the impacts to the treatment works and the environment. The slug did not apparently upset the A/S system.

Table 24 lists the extractable and purgeable organic compounds, PCBs, pesticides, and metals that were detected during the EPA study from samples collected at stations CI, CSE, and C001 (see Figure 31). Twenty-one organic compounds and copper and zinc (of 31 metals analyzed) were detected in the raw wastewater, all at levels well below those reported to have an inhibitory effect on the A/S process. The final effluent had 9 of the original 21 organic compounds above detection limits. The study detected seven different pesticides from samples obtained from the first-stage aerobic digester, but no extractable or purgeable organic compounds.

TABLE 23

CONVENTIONAL PARAMETER RESULTS[1]
INFLUENT, SECONDARY EFFLUENT, AND FINAL EFFLUENT

Parameter	Units	Influent (CI) 11/14-16/89	Secondary Effluent (CSE) 11/14-16/89	Effluent (C001) 11/14-16/89
Flow	MGD			15.1
pH	SU	6.5-10.2	NA	7.2
BOD_5	mg/L	170	17	17
$SBOD_5$	mg/L	85	6	10
TSS	mg/L	58	14	14
COD	mg/L	465	90	90
TKN	mg/L	23	14	12
NH_3	mg/L	14	11	11
NO_2-NO_3	mg/L	ND	ND	ND
T-P	mg/L	5.6	3.4	3.0
Alkalinity	mg/L	170	135	115
Oil/Grease	mg/L	80	7[2]	ND[2]
Cyanide	mg/L	ND	ND	ND
Sulfide	mg/L	2.6	ND	ND
Phenols	mg/L	0.21	0.027[3]	ND

1 - Average of two composites (11/14-15 and 11/15-16) or grab samples, or in the case of station C001, a composite for 11/14-15 and a grab on 11/16.
2 - One sample collected.
3 - One sample below detection limits.
NA - Not analyzed.
ND - Analyzed for but not detected.

TABLE 24

ORGANIC COMPOUNDS AND METALS RESULTS
INFLUENT, SECONDARY EFFLUENT, AND FINAL EFFLUENT

Parameter[1]	Influent (CI) 11/14-16/89	Secondary Effluent (CSE) 11/14-16/89	Final Effluent (C001) 11/14-16/89
Copper	35	ND	ND
Zinc	170	33	31
Purgeable Organic Compounds			
Acetone	230	ND	ND
Methylene Chloride	ND	ND	ND
Cis-1,2-dichloroethene	2.9[2]	0.73[2,3]	0.67[2,3]
Methyl Ethyl Ketone	25[2,3]	ND	ND
Chloroform	13[2,4]	5.5[2,4]	5.6
1,1,1-trichloroethane	31	10[2,4]	4.8[2,3]
Benzene	2.7[2,3]	ND	ND
Trichloroethene	1.2[2,3]	0.7[2,3]	ND
Toluene	18[2]	0.83[2,3]	0.6[2,3]
Tetrachloroethene	23	8.7	8.7
Ethyl Benzene	3.7[2]	ND	ND
(M &/or P) Xylene	19	ND	ND
O-xylene	12[2,3]	0.91[2,3]	ND
Styrene	99[2]	ND	ND
O-chlorotoluene	55	9[2,4]	8.6[2,4]
P-chlorotoluene	4.1[2]	ND	ND
Extractable Organic Compounds			
1,2,4-trichlorobenzene	31[2]	5.4[2]	11[2,4]
Naphthalene	14[2]	ND	ND
Bis (2 Ethyl/Hexel) Phthalate	ND	18	ND
Phenol	10[2,3]	ND	ND
(3 &/or 4) Methyl Phenol	16[2]	ND	ND
PCBs/Pesticides			
Aldrin	0.27	ND	ND
Diazinon	0.88[3]	0.52[2,4]	0.65
Gamma-BHC (Lindane)	ND	0.046[2]	0.06[2]

[1] - All units in ug/L.
[2] - Estimated concentration.
[3] - Detected in one sample and below detection limits in the second sample.
[4] - One of the two results is an estimated value.
ND - Analyzed for but not detected.

Although the concentration of organic compounds and metals observed during the EPA study did not indicate significant pollutant pass-through or toxicity to the A/S process, the presence of numerous priority pollutants and the occurrence of a slug loading on November 15, indicated a potential for A/S system upsets.

Acute toxicity tests showed that no significant mortality occurred in the fathead minnows (*Pimephales promelas*) in either the secondary or final effluent. Significant mortality did occur in the daphnids (*Ceriodaphnia dubia*) in all samples. Chlorine did not appear to play a role in the cause of toxicity, as demonstrated by identical LC50s in the secondary and final effluent samples. The pesticide, diazinon, was apparently related to the toxicity results at the final effluent.

The EPA conducted unit process evaluations on the grit chambers, pure oxygen basins and secondary clarifiers. Table 25 lists the operating parameters of the pure oxygen system, based on data collected during the EPA study and average data for October 1988 to September 1989. The system was not hydraulically or organically overloaded during the study.

Recommendations. Several recommendations were made to the Cross Creek WWTP, reflecting the conditions observed at the time of the EPA study:

- The PWC must eliminate the receipt of slug loadings that can potentially upset the A/S system, influence performance, and result in effluent toxicity. The PWC should increase alarm system monitoring of influents and the frequency of priority pollutant monitoring in raw wastewater.
- The source of the pesticides detected in the raw influent and aerobic digester should be identified, and the influence on pesticides on POTW performance and effluent toxicity should be evaluated.
- The DO levels in the pure oxygen system should be increased to the minimum target concentration of 6.0 mg/L and the actual detention time in the pure oxygen basins should be determined by dye dispersion testing.
- The WWTP staff should monitor the delivery of septage to the plant.

TABLE 25

PURE OXYGEN SYSTEM OPERATING PARAMETERS
EPA STUDY AND 10/88 to 8/89

Parameter	Units	EPA Study	10/88 to 9/89	Design (22)
MLSS	mg/L	3,600	4,030	6-8,000
MLVSS	mg/L	2,950	3,220	
Detention Time [1]	hr	2.4	2.6	1-3
[2]	hr	1.7	1.8	
Organic Loading	lb BOD_5/1000 cu ft/d	107	85	100-200
F:M[3]	d^{-1}	0.58	0.4	0.25-1.0
MCRT	d	NC	2.9[4]	8-20
Surface Overflow Rate	gal/sq ft/day	460	416	400-800
Solids Loading	lb/sq ft/day	21	21	20-30

1 - Not including return activated sludge (RAS) flow.
2 - Including RAS flow (assume RAS 50 percent of plant flow).
3 - Based on basin outlet MLVSS.
4 - Based on average for seven months.
NC - Not calculated.

- The Chief Operator should be provided with software that can quickly prepare trend charts and basic statistical comparisons.

- The oxygen uptake rate should be measured on a regular basis to establish a baseline record of sludge activity.

For a more detailed report on the Cross Creek WWTP project, contact Bill Cosgrove (see Appendix A).

WASTEWATER TECHNOLOGIES FOR SMALL COMMUNITIES

EPA'S SMALL COMMUNITY STRATEGY

Ann Cole, U.S. EPA Regional Operations, State and Local Relations
Washington, D.C.

In the United States, there are 40,000 units of government below the State level. The average local government serves between 1,000 to 2,000 people, for which it receives only about $200,000 per year from all funding sources--Federal, State, and local. With these limited resources, the town or municipality must fund its entire budget, including road and bridge repairs, police and fire protection, libraries, landfills, sewerage, salaries, rents, mortgages, insurance, contributions to trust funds, and compliance with local, State, and Federal regulations. To address questions concerning the extent to which small communities can comply with environmental regulations and to ensure that small municipalities build environmentally healthy communities without being overly burdened, EPA established the Small Community Coordinator (SCC) program.

The role of the SCC is two-pronged; one aspect deals with rule-making and the other is outreach. To accomplish rule-making that will be tolerable by local communities, the SCC program aims to improve the implementation of the Regulatory Flexibility Act of 1980 in cooperation with the Office of Standards and Regulations. This act requires Federal agencies to estimate the economic impacts of implementing a particular regulation on small communities compared to the level of resources available for compliance, and suggest less expensive or nontechnical compliance alternatives for the communities. To help conduct economic analyses of small community regulations, the SCC program will develop a cross-media data base.

To ensure that a geographic perspective is represented in Agency policies, the SCC promotes Regional office involvement in small community issues. To attain this goal, EPA has assigned a representative from each program office and Region to work with the SCC to represent the small community contacts nationwide and programwide. The SCC program plans to identify gaps and overlaps among all the Agency's small community programs and coordinate efforts to close the gaps.

To accomplish greater outreach, the SCC program is coordinating cross-media information exchange activities, because in a small community, the air, drinking water, and wastewater coordinator might be the same person working with one limited budget to comply with all environmental regulations. Helping EPA's cooperative management, technology transfer, innovative financing, and technical assistance programs focus on and consider small community issues and concerns is another goal of the SCC program.

The SCC cooperates with key external organizations to develop greater understanding of small community environmental problems and the need for the SCC program, coordinate the Agency's perspective on the localities, and establish a working relationship that will maximize environmental results. These organizations include the National Advisory Council on Environmental Policy and Technology (NACEPT) and the Environmental Financial Advisory Board (EFAB).

Specific to wastewater treatment, one way the SCC will work with OMPC's SCORE program (see p. 167) will be to discuss ways in which small communities can address the new more stringent sludge regulations. It is likely that many small community local officials will need assistance in figuring out viable alternatives for sludge disposal, if landfills are full or regionalizing, land application is no longer allowed, or incineration causes unacceptable levels of air pollution.

EPA's mission to protect human health and the environment applies to all of the nation's citizens. Although small communities present a unique implementation arm of the law, citizens of these jurisdictions must also have equal access to environmental protection.

For more information on EPA's Small Community Strategy, contact Ann Cole (see Appendix A). Also see Appendix D for a list of EPA's Regional wastewater treatment outreach coordinators.

APPROPRIATE TECHNOLOGIES FOR SMALL COMMUNITIES

Randy Revetta, U.S. EPA., OMPC
Washington, D.C.

OMPC's Small Community Outreach and Education Program (SCORE) provides technical and financial management information about wastewater treatment to nontechnical decision-makers, such as small community local officials. In addition to distributing publications and participating in conferences/workshops, SCORE works closely with other Federal agencies and National Associations to leverage support to address the needs of small communities. SCORE sponsors a limited number of national demonstration projects and supports the establishment of State-level outreach programs by providing incentive grants through the Regions to State programs and State-level assistance providers. In the past 3 years, SCORE has distributed over about $450,000 in funding to States and other outreach providers.

As Federal funds decrease over the next few years, small communities will be forced to finance entire costs of building conveyance and treatment facilities and thus will have to adopt more affordable and appropriate technologies. They also will continue to look to EPA for help in evaluating new and promising cost-effective technologies. To support this level of assistance, a Small Communities Outreach and Technology (SCOT) initiative is being developed within the SCORE program. Specifically, the SCOT initiative plans to integrate technology transfer efforts with training assistance on wastewater and drinking water management and, possibly, solid waste management.

At present, EPA's R&D laboratories in Cincinnati disseminate technology transfer information to technical audiences, primarily through their Center for Environmental Research Information (CERI). The SCOT initiative plans to broaden the delivery mechanism and disseminate the information to a larger, less technical audience. Of course, this approach assumes that the technical information will be revised and repackaged for a less technical audience.

The SCOT initiative will first focus on developing training materials based on information on Innovative/Alternative (I/A) collection and treatment technologies that have already proven to be reliable and appropriate for small community applications. The materials should be based on performance data and design information already produced and distributed as O&M and design manuals. The initiative also plans to develop training materials on sludge disposal regulations, particularly O&M and septage disposal issues. These materials can be used by State training centers and other national organizations or Federal agencies with grass roots networks already in place to disseminate this information. A third area of focus for the SCOT initiative is helping small communities deal with the potential impacts that regulations can have on small communities.

Another proposed task for the SCOT initiative is to help small communities upgrade existing treatment facilities by developing training materials on how small communities can conduct environmental audits to evaluate and identify more effective and efficient ways of meeting their wastewater requirements. This task can be accomplished by evaluating the most common wastewater technologies presently employed by small communities and identifying low-cost technological and operational modifications to these technologies.

For more information about the SCOT initiative or SCORE program, contact Randy Revetta (see Appendix A). See Appendix E for a list of EPA Regional wastewater treatment outreach coordinators.

NEW DEVELOPMENTS FOR SMALL COMMUNITY SEWER SYSTEMS

Dick Otis, Owen Ayres and Associates, Madison, Wisconsin
Rich Naret, Cerrone & Associates, Inc., Wheeling, West Virginia
W.C. (Bill) Bowne, Bowne Associates, Eugene, Oregon

DICK OTIS - Small Diameter Gravity Sewers

Small diameter gravity sewers are a nonwater carriage system of wastewater collection. They were first introduced in Australia as low-cost alternatives to failing septic tank systems, the principle being to collect the drainage from the existing septic tanks for common treatment. In the late 1970s, the technology was introduced in the United States, and today hundreds of these systems have been installed across the country. Except for minor startup problems, the systems have been operating well. Because of the success with initial applications, these systems will likely see a greater number of applications in the near future.

Small diameter gravity sewers are typically used in low density developments where the number of connections ranges from 200 to 500. In these systems, a septic tank located before each connection removes suspended solids, trash, and grit that can cause obstructions. Small diameter pipes, which are typically 4-inches in diameter, are used to collect the septic tank effluent from the home, while the solids remain on site in the septic tanks. Periodically, the solids are removed from the tanks.

Presently, the standard practice for designing small gravity sewers is evolving as engineers learn potential applications and limitations of the technology. They have found that initial design guidelines for the Australian systems have been very conservative. For example, they have found that pipe-sizes smaller than 4 inches can be used successfully and that variable gradients rather than uniform gradients are possible. Also, achieving minimum velocities of 1.5 feet per second (fps) during peak flow conditions is not necessary.

Concerns. The acceptance of these systems was tentative at first, because the small diameters of the pipe led to concerns about hydraulic capacity and the ability of the system to handle peak and wet weather flows without creating backlogs or overflows. Another technical concern was whether the small diameter lines would be subject to obstruction. To date, however, no obstructions have occurred in any system. Whatever biomass has accumulated on the pipes has turned anaerobic, sloughed off very easily, and has been carried on the floor of the pipes without any problems.

Manhole covers have been sources of grit, detritus, trash, and other materials the sewers are not designed to carry. To deal with this problem, cleanouts have replaced manholes with spacings up to 1,000 feet apart. In 8 years of operation of these systems, none of the systems has been cleaned or had problems with obstructions. Australian systems have been operating for over 20 years without cleaning, but most of these systems have a uniform gradient with a minimum flow velocity.

Designers of gravity sewers are finding that the systems need greater ventilation to provide a free-flowing condition within the sewers. Odors can be a problem with increased ventilation, however. To deal with odors, vacuum/air release valves are being installed on cleanouts. These may be vented directly into the soil.

Odors can also be a problem at lift stations and anywhere there is turbulence in the system. To prevent most odors from escaping, drop inlets have been installed at lift stations below the low water mark. Elevated vents have also worked. Capping the top of the septic tank inlet can eliminate the odors coming back from the sewers themselves into home stack vents.

To deal with surge and peak flows, system engineers are trying to stabilize and maintain a fairly uniform flow from each home. In many systems, the septic tank does a fairly good job in attenuating flows, which rarely exceed .5 gallon per minute coming from the septic tank. If flows are greater, they are usually for less than 15 minutes.

Surge storage devices have helped regulate flows where septic tanks do not, but these tanks can create significant head loss of a few feet throughout the system, which would require the system to increase depth of excavation and associated installation costs. Insert screens installed within the septic tank work well to reduce any head loss, and less leakage occurs when the tanks are made of plastic or fiberglass. Check valves installed in some systems have prevented the septic tanks from backing up into the home. To avoid corrosion, designers use dry pit construction for lift stations.

System maintenance. Maintenance of gravity sewers is minimal. The most routine maintenance is pumping the septic tanks, for which designers initially recommended a schedule of once every 3 years. Because system operators have found that this schedule is far in excess of what is needed, new estimates recommend pumping the tanks once every 7 to 10 years. Some commercial connections will require pumping every 6 months to 1 year. Unskilled labor can perform the maintenance work involved.

Costs. Costs of the systems vary widely from about $1,500 for equipment and installation per home to $10,000 per home, depending on site specifics and client interests. Costs for installation, equipment, service connectors, the main collector, and so forth range from $15 to $80 per foot. These costs will probably decrease when the pipes are installed through trenching rather than excavation, which is presently the most costly aspect of the system.

For more information on gravity sewers, contact Dick Otis (see Appendix A). Also see Appendix E for a list of EPA's Innovative small diameter gravity sewer projects.

RICH NARET - Vacuum Sewer Technology

The areas best suited for vacuum sewer technology include sites with unstable soils, flat lands, high water tables, rocky conditions, and generally low population densities. The advantages of using vacuum sewers is that they use small pipe sizes, usually 3 to 8 inches, that can be installed in very shallow depths. Unlike gravity sewers that have manholes at two fixed points at a constant grade, vacuum sewer construction can go over, under, or around any unforeseen obstacles, and contractors can easily make field changes as necessary. These advantages result in lower construction costs. Operationally, the introduction of air into the vacuum sewers and the short detention time the sewage spends in the sump results in very few odors. There are very few corrosion problems, as well.

The size of most vacuum systems is about 200 to 400 customers, with one vacuum station, but systems range from less than 50 customers to 2,000 customers per station. Experience has indicated that vacuum systems need 75 to 100 customers to make the technology cost effective. Presently, about 40 to 50 systems are operating in the United States in about 12 States. There are a few additional private installations and some small commercial and industrial applications.

In the 1960s, four manufacturers were involved in introducing vacuum technology into this country: Electrolux, Vacutec, Envirovac, and Airvac. The Airvac design predominates the market today; about 90 percent of the systems use this equipment, and the few systems that are not Airvac systems are being retrofit with Airvac valves.

As is normal for innovative technologies, the vacuum industry went through a series of growing pains. Early problems were based on systems that had been installed without sufficiently field testing the components. Operation and maintenance guidelines also were not yet available. Additional problems occurred because designers and operators lacked a clear understanding of the two-phased flow concept that forms the basis for this technology. Fortunately, many of the early problems encountered have improved, although the literature is not yet up to date with reporting the technological advances.

Cerrone & Associates has engineered six systems (with a total of nine vacuum stations and 2,000 valves) in the United States, including design, planning, construction inspection, and troubleshooting. The firm also is presently involved in the construction of another system, and two or three more are scheduled to be built within the next 2 years. In addition, the company has visited six other systems throughout the country to survey operating experiences. It investigated systems that would provide a good cross-section of the technology, based on topography, geographic location, size, and varying design concepts. The company also surveyed an early system to find out if any improvements have been made.

Although most of the systems surveyed experienced problems, most of the problems occurred during the startup phase and were very short-lived. The problems occurred in six general categories, including component defects (i.e., some of the small components of the valves, small tubing, and controller parts were defective); design shortcomings (such as improper selection of pump sizes and poor selection of discharge pumps); operator error; construction mistakes (i.e., broken fitting, poor compaction); equipment malfunction; and extraneous water from the home user.

The first four categories account for 80 percent of the problems that occurred. These problems can be avoided through improved design, tougher inspections, and hiring of more skilled labor. Equipment malfunctions accounted for 5 percent of the problems that occurred. This type of problem seems to be unavoidable because any mechanical equipment can unexpectedly break down. The most devastating problem that has occurred to vacuum sewer systems, accounting for 15 percent of the problems, related to extraneous water introduced into the system by homeowners.

Despite these problems, the systems surveyed have all been providing reliable efficient service due to significant improvements to key components. These improvements have reduced the problems that plagued the early systems by 50 to 70 percent. As evidence of these improvements, in a 1977 EPA technology transfer manual, the failure rate of vacuum systems and the average time between service calls was 4 years, whereas in the systems surveyed in 1984, the average time between service calls was about 10 years. If designers, contractors, and operators continue to learn about proper techniques, they can further reduce problems with vacuum sewers.

The vacuum system industry has come a long way in the last 20 years. The early reports of problems were not unfounded, but standardizing the industry, improving components and designs, and more thoroughly understanding the technology, itself, has led designers to make significant system improvements and create fewer problems. Vacuum sewers will most likely provide a cost-effective reliable service to many small communities in the future.

For more information on vacuum sewer technology, contact Rich Naret (see Appendix A). Also see Appendix E for a list of EPA's Alternative vacuum sewer technology projects.

<u>**BILL BOWNE - Pressure Sewers**</u>

For an EPA project, Bowne surveyed several pressure sewer systems around the United States with various equipment configurations.

A system in Pierce County, Washington, uses grinder pumps with built-in overflow mechanisms used when the reserve space is filled. Most of the equipment is buried near to the household. Any overflow that does occur drains into the existing tank and drain field. Each pump is connected with a telemetry system so that high water alarm conditions are reported directly to a computer located in the field office.

A system in Lake LBJ, Texas, uses 1,000 pumps with the grinder pump basin located very close to the home. This means that the system has a short building sewer, a short electrical service, and a nearby control panel, which eliminated the need for the electrical junction box. The pump has a long cable that runs the wiring directly from the pump to the panel. The extra amount of pump cable inside the grinder pump vault allows system operators to lift out the pump easily without loosening any connections. Other systems in Texas use from 1,000 to 1,800 grinder pumps.

One major concern with the type of pressure sewer system used in Texas is the potential for operators to receive electrical shocks. For example, to deal with a service call, the operator must locate and dig up buried equipment. Because the systems use such small vaults (about 2 feet in diameter and 4 to 5 feet deep), by the time the field personnel arrive, the basin is full and overflowing. If maintenance personnel need to do electrical splicing, they are in danger of getting shocked.

A system in Oregon is a septic tank effluent pump-type pressure system. The septic tank and the pump vault extend down in the tank. The sludge settles to the bottom of the septic tank, and the system pumps only septic tank effluent, not sludge or scum. The liquid level is held lower than in typical septic tanks so that a reserve space is available for dealing with high waters. When an alarm sounds, the system has available storage of about 150 to 250 gallons.

A system in Palm Coast, Florida, is installed in the front yard very near to the property line. If an adjacent home were to be built, the next tank would be installed adjacent to the first one, so two 10-foot easements would combine to provide a 20-foot width for construction and maintenance access.

One system in Missouri has been operating for about 15 years. It is a dry pit installation with a 2-foot diameter pump vault that houses the pump and motor. The septic tank effluent together with the sludge is pumped. This pump is self priming.

For more information on pressure sewer technology, contact Bill Bowne (see Appendix A). See Appendix E for a list of EPA's Alternative pressure sewer technology projects.

COMMUNITY MOUND SYSTEMS

Dick Otis, Owen Ayres and Associates
Madison, Wisconsin

Community mounds are a type of subsurface infiltration system for treating wastewater. They are built above the natural ground surface in a bed of engineered sand fill material, with the primary infiltrative surface constructed within the bed. A typical configuration contains a pressurized wastewater distribution network within a gravel bed. The entire system is capped with locally available fine-textured soil.

The largest community mound system in the United States has a capacity to treat about 20,000 gallons of wastewater per day (gpd), but the technology can be used to treat more than 30,000 gpd where costs become a limiting factor. The systems can have high capital costs, but low operating costs, making them an attractive option for small communities. Unskilled labor can operate these systems.

Community mound systems have faced many problems, and in 1986, EPA issued a technical advisory to stop issuing construction grants for these systems. In 1984, Owen Ayres and Associates conducted a survey of these systems and concluded that system designers and evaluators had an incomplete understanding of how community mound systems function. If properly sited, designed, constructed, and operated, community mound systems can provide an excellent form of wastewater disposal.

One issue that remains a concern for managers and operators of small community mound systems is ground-water protection. Nitrates from wastewater can leach from these systems in levels that exceed drinking water standards. Strict standards protecting ground water may continue to restrict the implementation of community mounds.

Siting, design, and construction. Designers of community mound systems must investigate site topography, land use, geology, hydrogeology and soil texture, structure, and bulk density. They must determine the most effective way for the water to penetrate the soil, the most likely flow pattern, and whether or not the system can achieve the desired level of treatment.

Siting remains the most significant cause of failures of this technology. Unlike conventional wastewater treatment systems that can be built independent of the site characteristics, community mounds must be built on well-drained sites with suitable soils for wastewater percolation.

Community mound systems have two infiltrative surfaces. The primary infiltrative surface is at the base of a gravel bed, where the raw wastewater actually infiltrates into the sand fill material. The secondary infiltrative surface is the natural soil, which the wastewater must infiltrate without creating a saturated condition that extends up into the sand fill. If the sand fill becomes saturated, the "toe" of the mound most likely will leak. For optimal treatment, most systems require at least 1 foot of sand fill and 1 foot of unsaturated natural soil at all times below the primary infiltrative surface.

Systems designers typically either overestimate or underestimate ground-water mounding conditions during mound operation. A number of analytical models can be used to estimate the rise in the water table and investigate mound designs that will prevent encroachment of the water table into the soil treatment zone. Although actual field experience does not correlate well with the results of the models, the models help system engineers investigate a site and evaluate a design more thoroughly.

Site evaluators can use soil borings to provide information on potential vertical water movement, but borings do not always provide a clear picture of soil stratification. Small stratifications within a boring can be missed. Backhoe pits that expose an undisturbed soil profile are necessary to properly evaluate the soils for wastewater disposal.

To minimize the amount of land required for areas with slowly permeable soils, the permeable topsoil must be left in place so that the topsoil can accept wastewater and move it laterally as it slowly works into the subsoil. Mounds are also effective where a shallow water table exists due to slowly permeable subsoils or in areas with a shallow creviced or porous bedrock. If the bedrock is not creviced or porous (such as in a granite impervious bedrock), mounds will not function well because water will have no place to go.

Applying proper plowing methods during site preparation breaks up the organic layer and creates a rough fill/natural soil interface. Contractors most often use chisel plows, plowing along the site contours. Fill is placed over the plowed area with the tracked equipment, keeping at least 8 to 12 feet of fill underneath the tracks of the equipment to prevent compacting of the plowed soil surface.

Site criteria. Because recent experience has shown that mound systems are effective in treating wastewater, some designers have begun to relax many site criteria. For example, when mounds were first introduced, the minimum depth of the saturated zone from the original soil surface was 24 inches. Research has shown that this can be reduced to 10 inches. Systems are performing well at this depth. For vertical conductivity, earlier mounds were restricted to sites where percolation rates were 120 minutes per inch. Today, the acceptable rate has increased to 300 (and in some cases 600) minutes per inch. Initial slope restrictions were 12 percent, but now the criteria allows for steeper slopes. Systems now use retaining walls to support the downslope of the mounds with steeper slopes.

Fill materials. Fill materials vary widely, and system designers must select them carefully. The sand fill should have an effective size close to 0.3 mm and have a uniformity coefficient of less than 7. Many systems use concrete sand. The ASTM Standard C-33 for fine aggregate is an acceptable fill specification. If finer fill material is used, the design loading rates must be reduced.

The design loading rate for earlier systems was 1.2 gallons per day per square foot for the primary infiltrative surface area, but design criteria have changed somewhat in recent years. For larger systems, the design flows are much closer to the actual flows, and it has been necessary to reduce the design loading rates to more closely match actual operating infiltration rates.

The type of fill material used determines the most effective size for the gravel bed area. Long and narrow infiltration beds are necessary to avoid organic clogging of the primary infiltrative surface. It is difficult to diffuse oxygen underneath and through the center of a square bed, and long and narrow beds help keep the underlying sand fill aerobic. Bed widths are often 10 feet wide in smaller systems and up to 20 feet wide in larger systems.

Due to settling, the sand fill should not be deeper than about 3 feet under the gravel bed on a sloping site. A 2 percent settling rate can tilt the bottom surface, overload the downslope side, and create a breakout at that point. Beds within the mound can be tiered on steeply sloping sites.

<u>**Wastewater distribution**</u>. Community mound systems must be able to distribute wastewater within the mound as uniformly as possible. A pressurized network of pipes accomplishes this task more effectively than a large diameter pipe. Multiple cells provide standby capacity to allow for proper system management. Multiples of four cells are preferred, with each cell designed to accommodate 50 percent of the flow, thus providing 100 percent standby capacity. At a minimum, the cells should be rotated on an annual basis.

To obtain additional information on community mounds, contact Dick Otis (see Appendix A).

SEQUENCING BATCH REACTORS

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Cincinnati, Ohio

Sequencing batch reactors (SBRs) are variable volume wastewater treatment systems in which the aeration, settle, and decant phases for each treatment cycle take place in a single reactor. Consequently, SBR systems contain no dedicated secondary clarifiers or associated return sludge facilities.

In 1989, EPA sponsored a study to investigate this technology. The study team visited 1 industrial and 20 municipal SBR facilities that had been operating at least 1 year and telephoned 20 to 30 additional facilities for supplemental information. EPA is presently analyzing the final data, so this discussion focuses on the different design approaches and equipment that are being used.

Background. Many full-scale fill and draw systems were operated between 1914 and 1920, but most were converted to continuous flow operations. The next attempt to use fill and draw technology for municipal systems was the Pasveer ditch introduced in Denmark in 1962. This approach used a modified oxidation ditch system with continuous inflow and intermittent settle and discharge phases obtained by periodically turning off the aerator. In 1976, one facility in Australia demonstrated a rectangular continuously fed intermittent discharge system, and since that time, cyclic systems ranging in capacity from 18,000 gpd to 2 MGD have been used in that country. The first modern SBR facility operated in the United States for municipal wastewater treatment was a retrofit plant in Culver, Indiana, which went on-line in May 1980.

EPA last evaluated SBR technology in 1984. At that time, only four facilities were known to be operating in this country and the Culver plant was the only facility that could supply a significant body of operating data. Since then, over 150 SBR plants have been designed or been in operation in the United States. About 80 percent of the plants have flows of 1 MGD or less; 70 percent of these have flows of 0.5 MGD or less. Cleveland, Tennessee, has the largest plant in this country, with a design capacity of 9.2 MGD.

SBR technology evolved rapidly in the United States during the 1980s. Today, there are five major vendors of SBR equipment: Austgen Biojet (ABJ), Aqua Aerobics, Fluidyne, JetTech, and Transenviro. These manufacturers provide considerable variation in tank configurations, system hydraulics, aeration, mixing techniques, effluent discharge equipment, and sludge wasting methods. Numerous variations of SBR technology are currently in use. Most systems use a number of different operating sequences to accommodate a range of influent flow rates and automatically vary operations in response to changes in influent flow rate or allow operator-initiated changes in either total cycle or phase times.

Continuous feed and intermittent discharge systems. One type of SBR system is the continuous feed and intermittent discharge system (CFID). In this approach, the reactor receives influent wastewater during all phases of the treatment cycle. When a system has more than one reactor, which is common in municipal systems, the reactors work in parallel and receive equal amounts of influent. Figure 32 illustrates a typical ABJ CFID system for a two-reactor SBR plant. In this system, one SBR aerates, while the other settles and decants, so the system needs only one blower to aerate both reactors. For a four-reactor system, the individual reactor cycles usually are operated in such a way that the treatment plant discharge is continuous.

The dry weather flow cycles for most of the CFID systems evaluated by EPA were most often set at either 3 or 4 hours. Typically, 50 percent of each cycle is devoted to aeration, 25 percent to settle, and 25 percent to decant. Facilities often use 2-hour cycle times to accommodate stormwater flows.

In CFID systems, the settling and decant phases begin according to a preset cycle times. Because inflow rates can vary during aeration and settling, the top water level, which occurs at the start of the decant cycle, can also vary. The volume decanted during each cycle includes both the reactor volume between the top and bottom water levels for that cycle and whatever

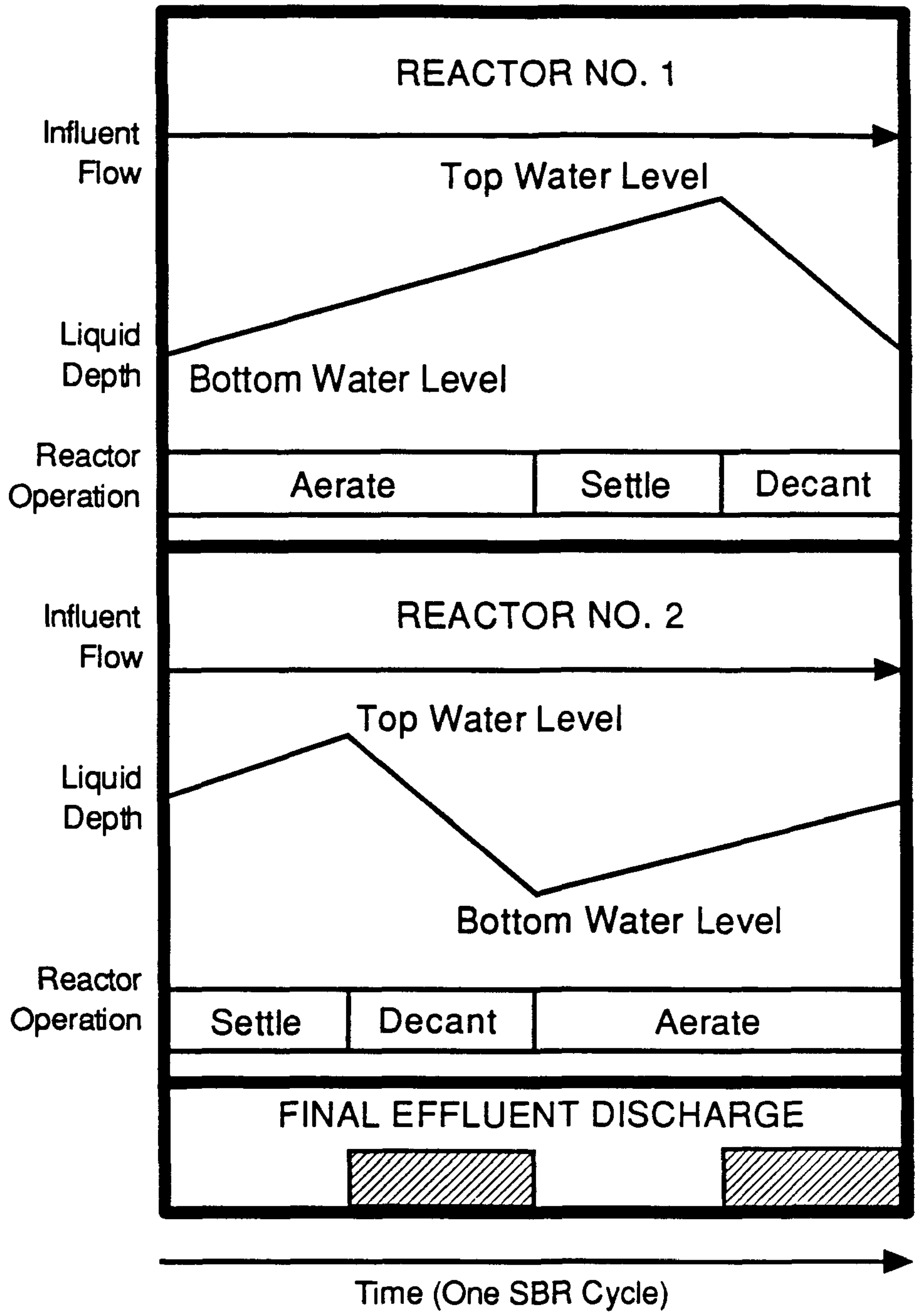

Figure 32. Typical Operation for a 2-Reactor CFID System

inflow volume occurred during the decant phase itself. For the system depicted in Figure 32, the actual discharge flow rate of the effluent for one cycle is twice the plant influent flow rate during the same cycle because the two SBR reactors discharge only 50 percent of the time.

Because inflow is continuous in a CFID system, a key design consideration is to minimize short circuiting between influent and effluent. Therefore, influent and effluent discharge operations are often located at opposite ends of rectangular reactors, with length to width ratios of about 2:1 to 3:1. A standard feature of the ABJ CFID systems is a prereact chamber separated from the main react chamber by a baffle wall.

Intermittent flow and intermittent discharge systems. In the United States, the intermittent influent flow and intermittent discharge (IFID) systems are sometimes referred to as the conventional or "true" SBR systems. A common characteristic of all IFID systems is that the influent flow to the reactor is discontinued for some portion of each cycle.

Figure 33 depicts a typical IFID system for a plant containing two SBRs. Each reactor in this system operates with five discrete phases during a cycle, including fill, react (continuous aeration), settle, decant, and idle. When influent wastewater is first added to the reactor during the fill phase, any combination of aeration, mixing, and quiescent filling may occur. A mixing phase independent of aeration is accomplished by using a jet aeration system (a JetTech approach) or separate mixers (an Aqua Aerobics approach). Some variations of this system distribute the influent over a portion of the reactor floor so that the influent will contact the settled solids during unaerated and unmixed fill. The end of the fill cycle is controlled by either a preset length of time or volume. To accommodate a range of influent flow rates and automatically vary the time allocated to aerate, mix, and fill, many IFID systems use a programmable logic controller (PLC). The PLC uses data on plant influent flow or the rise rate in the reactor determined by a series of floats.

At the end of the fill phase in this system, the influent flow to the first reactor stops, and the plant influent flow diverts to the second reactor. In IFID systems with a dedicated react phase, continuous aeration occurs for about 1 to 3 hours, after which the mixed liquor settles

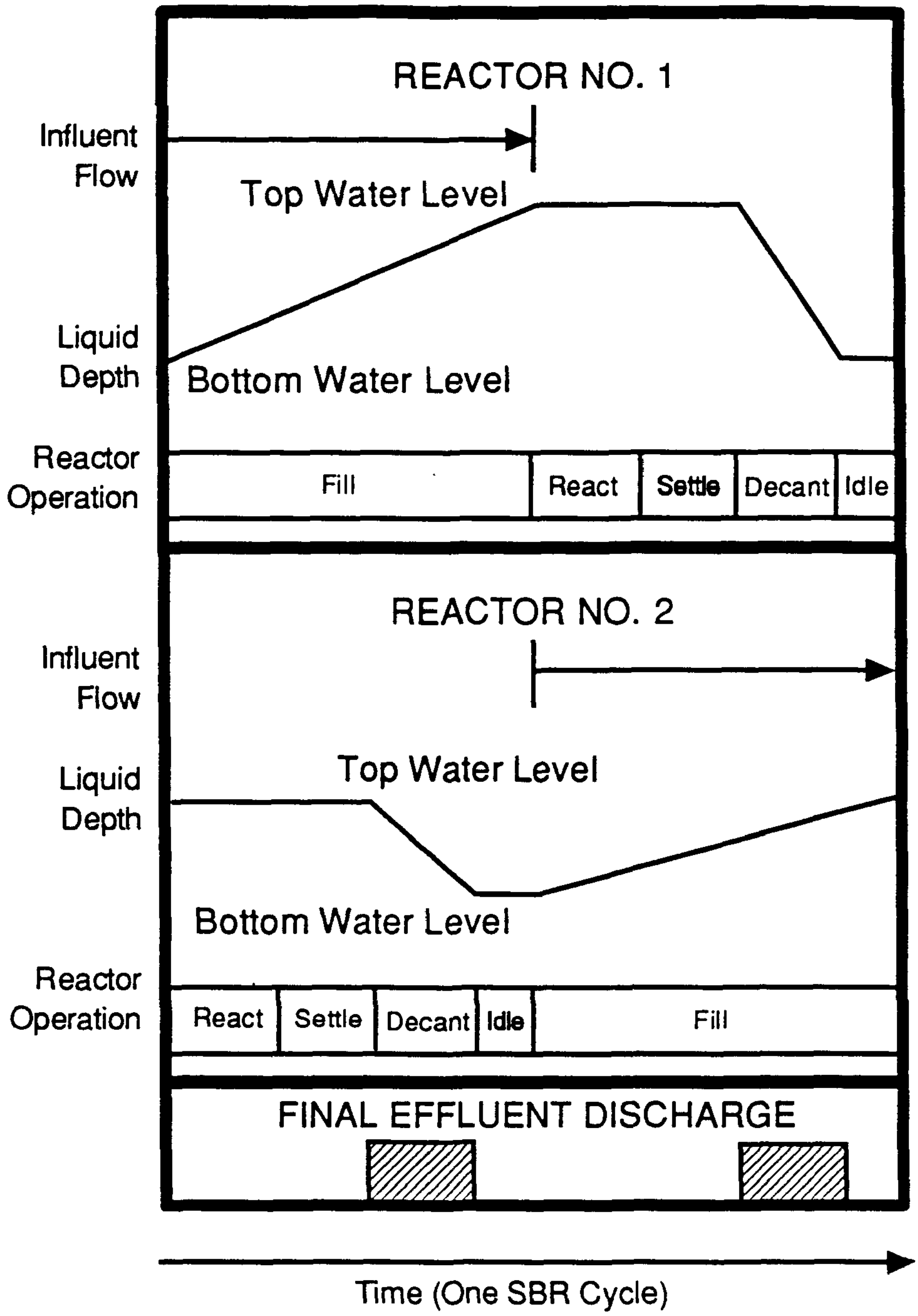

Figure 33. **Typical Operation for a 2-Reactor IFID System with Fill, React, Settle, Decant, and Idle Phases**

under quiescent conditions for 30 to 60 minutes. Clarified effluent then decants from the tank at a controlled rate (fixed or variable), to limit the disturbance of the settled mixed liquor, and continues until the bottom water level is reached. The idle period occurs after the decant phase is completed and before the influent flow is again redirected to a given reactor. The idle phase is often minimal during periods of high flow.

For the system depicted in Figure 33, the actual discharge flow rate can be several times higher than the influent flow rate. For example, if the two-reactor system typically has cycle times of 3, 1, 0.75, 0.75, and 0.5 hours for the fill, react, settle, decant, and idle phases, respectively, the actual discharge flow rate is four times the average influent flow rate. Plant designers must carefully plan discharge flow rates to determine the capacity of downstream hydraulics and the disinfection or filtration systems.

A typical Fluidyne IFID system does not have a dedicated react phase, and the amount of time allocated to aeration, mixing, or quiescent filling during the fill phase varies. Once the reactor fills to the top water level (based upon either a predetermined time or liquid level), the flow is immediately diverted to the second reactor, aeration ceases, and settling begins.

A Transenviro IFID approach typically treats domestic wastewater with a 4-hour cycle (2 hours of aeration and 2 hours of non-aeration), and stormwater flows with a 2-hour cycle. Influent enters the reactor at all times except for the decant phase, so that normal system operations consist of the following phases: fill - aerate; fill - settle; no fill - decant; fill - idle. These systems are also configured with an initial captive selector compartment that operates at a constant or variable volume and serves as a flow splitter in multiple basin systems. The system directs biomass from the main aeration zone to the selector.

Table 26 shows a typical operating strategy for a two-reactor JetTech IFID system designed for a flow of 1 MGD. In this system, the influent flow rate determines the cycle protocol. As the influent flow rate changes, both the total cycle time and the time allocated to specific cycle operations change. During the decant phase, influent does not enter the reactor

TABLE 26

TYPICAL JETTECH OPERATING STRATEGY

	Flow, MGD		
Phase	**0.5**	**1.0**	**3.0**
Filled Decant (hrs)	0	0	0.81
Anoxic Fill (hrs)	3.0	2.44	0.27
Aerated Fill (hrs)	1.0	0.81	0.81
React (hrs)	1.0	1.63	1.08
Settle (hrs)	0.75	0.75	0.75
Non-Fill Decant (hrs)	0.31	0.50	0.06
Idle (hrs)	1.94	0.38	0
Total Cycle (hrs)	8.0	6.52	3.79
% Cycle with Influent	50	50	50

at design flow rates or below. At three times the design flow, the system introduces influent into the bottom of the reactor for the majority of the decant cycle (0.81 hours).

SBR systems can also be designed for nitrification/denitrification and enhanced biological phosphorus removal and be configured to switch from IFID operation to CFID operation when necessary to accommodate stormwater flows or to allow a basin to be removed from service.

Decanters. Although early decanters faced significant problems, SBR equipment manufacturers have made significant improvements in their respective decanting systems. Today, the Aqua Aerobics system is a large floating plug valve, where the seat for the valve located in the bottom section of the decanter is driven down during the decant phase. This system allows wastewater to enter from below the wastewater surface and flow up over an internal discharge weir. ABJ and Transenviro systems use mechanically driven decanters that are raised and lowered as required; scum baffles prevent surface scum from mixing with the discharge. The Fluidyne decanter is mounted on the reactor wall, and a solenoid-operated air valve starts the decant phase. Throughout the Fluidyne decant phase, wastewater enters the decanter at the bottom water level. The JetTech decanter is basically a draw tube that attaches to a set of floats so that it remains below the liquid surface.

Influent Distribution. Some influent systems are simple configurations with just a pipe through the reactor wall with a small structure to deflect the influent flow downward into the main SBR reactor. Other systems use prereact tanks or captive selectors to achieve a higher food-to-mass (F:M) ratio at the head of the reactor. Still other systems, such as the JetTech system, have combined the influent distribution and sludge withdrawal piping so that influent can be distributed up through the sludge blanket during anoxic fill.

Aeration. Fine bubble, coarse bubble, jet aeration, and mechanical aeration systems are all being used in SBR facilities. Some systems, such as Aqua Aerobics, use a mixer to provide independent aeration and mixing if desired. Jet aeration systems also allow for this capability.

System Performance. The EPA study found that a number of SBR facilities experienced some mechanical problems with the jet aeration equipment, diffusers, solenoid valves, and several decanters, but no system had any major process failures. Operator satisfaction was extremely high, as well. Preliminary analysis of effluent data indicates that SBR facilities often achieve high quality effluent. EPA must analyze the data further to fully correlate effluent characteristics with process characteristics. This analysis is now underway.

For more information on SBR technology, contact Jim Heidman (see Appendix A).

APPLICATIONS OF LAGOONS AND OVERLAND FLOW TREATMENT TO SMALL COMMUNITIES: EMMITSBURG, MARYLAND - A CASE HISTORY

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To upgrade its wastewater treatment plant facility, the town of Emmitsburg, Maryland, has combined the use of lagoon stabilization ponds, overland flow (OF), and the reuse of treated effluent for crop irrigation. After only 1 year of operation, the system has shown encouraging and satisfactory results. A schematic diagram of the Emmitsburg system is shown in Figure 34.

Lagoons have been used in the United States since 1901, and over 7,000 ponds exist in this country today to treat wastewater. Overland flow is a relatively new technology that involves applying wastewater to the upper reaches of grass-covered slopes, which then flows over the vegetated surface into runoff collection ditches. The OF process is best suited to sites having relatively impermeable soils, although it has been used successfully on moderately permeable soils with relatively low physical, chemical, and biological means, and where wastewater flows in a thin film down the length of the slope. Figure 35 is a schematic view of the Emmitsburg OF treatment system, which indicates that there is relatively little percolation due to the presence of impermeable clay soil. Effluent that runs off from the OF system is stored in a large holding pond (irrigation system reservoir) until it is applied to crops.

Emmitsburg decided to use the OF effluent to irrigate crops during the summer because it seemed easier and more cost efficient to meet the acceptable limits for irrigation rather than the stringent effluent limits for stream discharge. The crop irrigation system is composed of center pivot irrigators in separate fields and covers a total of 210 acres. Although the summer of 1989 was relatively wet, 13 million gallons of treated wastewater were used for irrigation purposes, over 9 million gallons during the month of August alone. Application rates ranged from 3/16 to 1/2 inch per week.

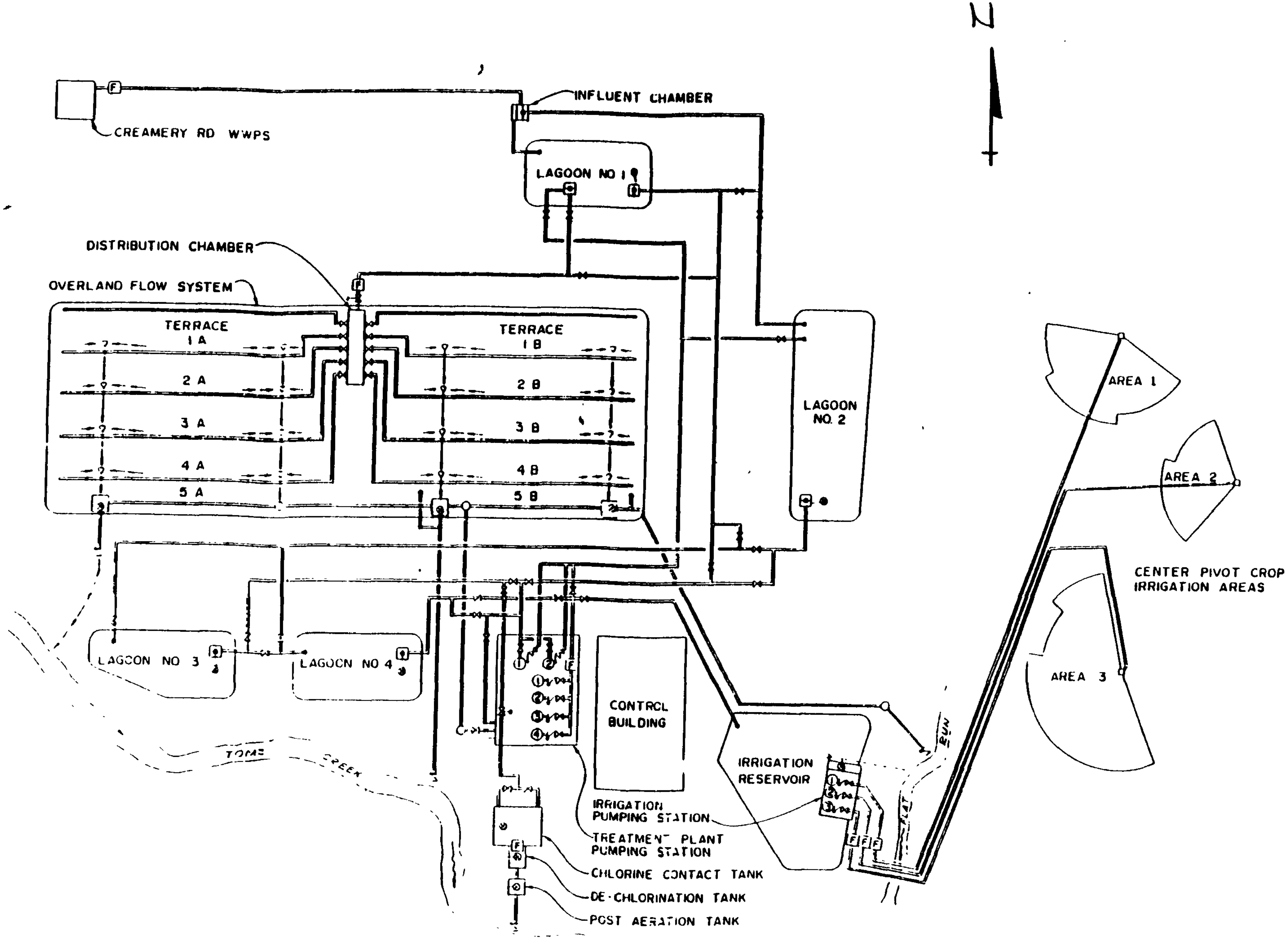

Figure 34. Schematic of the Emmitsburg, Maryland, Wastewater Treatment Plant Facility

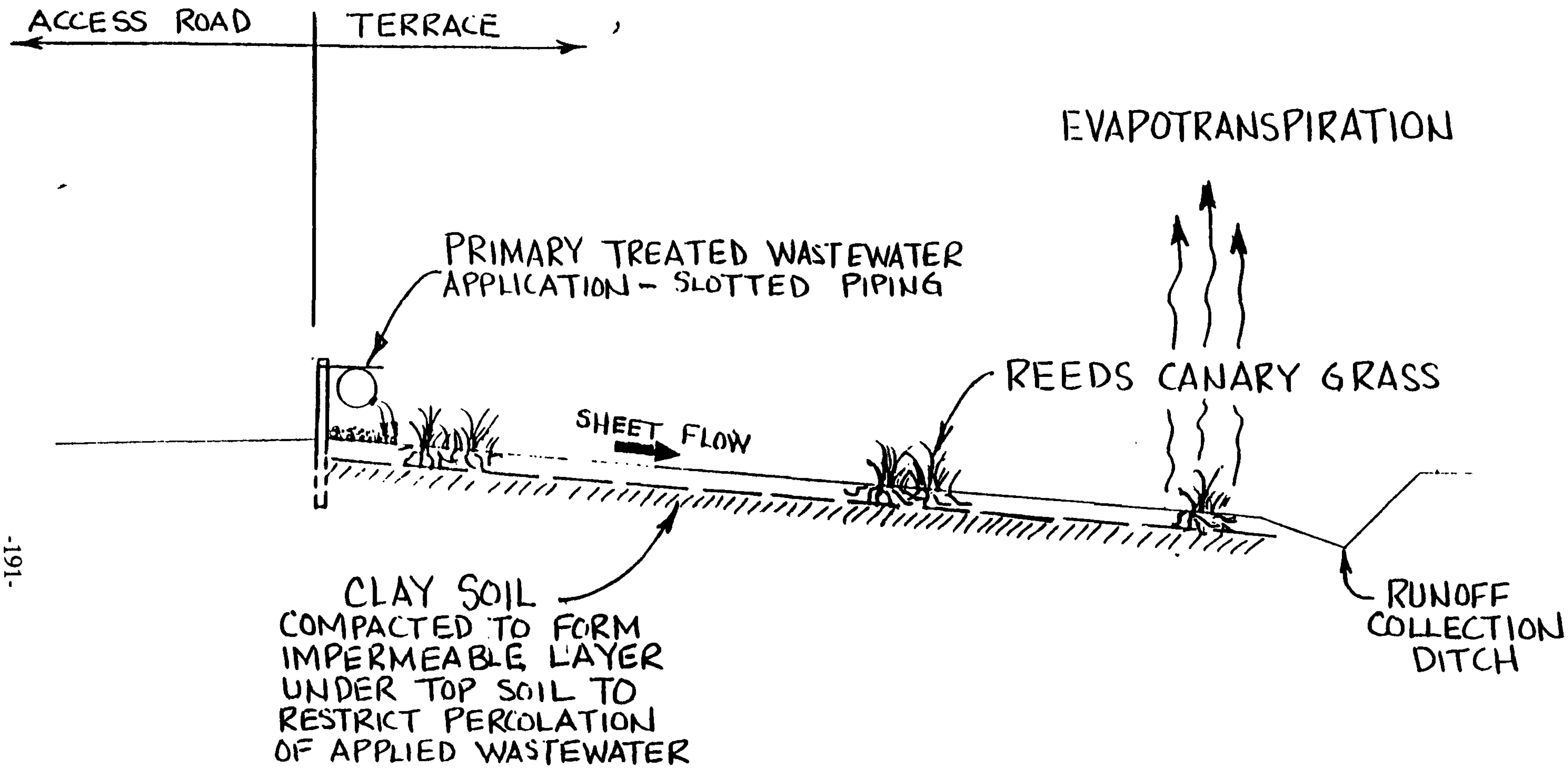

Figure 35. **Schematic of the Emmitsburg, Maryland, Overland Flow System**

System performance. The facility has seasonal effluent limitations for surface water discharge. Winter parameters, from October 1 through April 30, and summer parameters, from May 1 to September 30, are shown in Table 27. Ground-water discharge parameters from May through September also are shown in Table 27.

From October 1988 through April 1989, when the facility used the series lagoon system, the effluent BOD averaged 19 mg/L per month. From May through September, 1989, when the overland flow system was used, the average BOD was 7 mg/L and TSS was 15 mg/L. Prior to being pumped to the spray field, the BOD in the storage reservoir averaged 4 mg/L, TSS measured 5 mg/L, and the average TKN for the summer period was 2 mg/L. The water in the irrigation storage reservoir thus proved to be a higher quality than the water in the lagoon system. The crop irrigation system performed as expected during its first summer of operation.

Unfortunately, the results from the overland flow area could not be correlated with application rates because the Emmitsburg facility lost the use of a magmeter, which measured the flow of wastewater to the overland flow area.

Problems encountered. The Emmitsburg facility encountered several problems during the first year of system operations. An extremely wet spring and early summer in 1989 greatly affected the OF and crop irrigation systems. Consequently, attempts were made to store the wastewater in the lagoons, which had been drawn down to relatively low levels by May 1 to accommodate moderate wet weather conditions. (The system was designed for the wettest year in 10.) As the wet weather continued, the storage space was depleted, requiring the lagoons to discharge effluent to the stream. The facility could not meet the stringent 3 mg/L BOD level required during spring and summer with only lagoon treatment.

During extremely wet summer conditions, increased storage of wastewater may not be possible or cost effective. Discharging from the irrigation storage reservoir, however, would more closely satisfy the town's surface water discharge limits. This option can be economically accomplished by using one of the irrigation system pumps and modifying some existing piping,

TABLE 27

WINTER, SUMMER, AND GROUND-WATER PARAMETERS FOR THE EMMITSBURG, MARYLAND, WASTEWATER TREATMENT FACILITY (MONTHLY AVERAGES, 1989)

Parameter	Winter (10/1-4/30)	Summer (5/1-9/30)	Ground-Water (5/1-9/30)
BOD, mg/L	30	3	30
TSS, mg/L	30	30	30
TKN	NA	30	NA
Total N, mg/L	NA	NA	10
DO, mg/L	5.0(minimum)	7.0(minimum)	NA
PH	6.5-8.5	6.5-8.5	6.0-8.5
Fecal Coliform, mpn/100 ml	20	200	200

to enable the irrigation reservoir effluent to be processed in the same manner as the lagoon effluent.

Consideration also should be given to relaxing permit requirements and basing them on increased stream flow during a rain event or extended wet weather. Installing a gauging station to measure stream flow may prove cost effective compared to providing increased storage capacity. Emmitsburg is presently requesting that EPA incorporate this condition in the town's NPDES permit, which is up for renewal.

A problem experienced in the overland flow system was that some applied wastewater flowed *away* from the terrace and across an adjacent access roadway. This was due to the relatively flat cross slope of the terrace at the application point and the lack of positive drainage of the "splash block" (made of crushed stone) toward the terrace. System managers have not yet resolved this problem; however, they are planning to install treated timbers on the upper side of the crushed stone to divert wastewater back toward the terrace.

Costs. Actual project costs for the Emmitsburg system are shown on Table 28. Although capital costs are comparable to conventional treatment facilities, Emmitsburg anticipates that operation and maintenance costs will be lower because maintenance of the Emmitsburg system is not labor intensive. Presently, two full-time employees (a certified operator and a trainee) operate and maintain the system, and system managers anticipate that additional full-time assistance will not be required.

O&M costs for FY90 are expected to be about $114,000. An additional $106,000 is needed to amortize debt service, for a total budget of $220,000. Sewer user fees average $150 per year for residences (738 connections), which is favorable to the users. The remainder of the income is paid by major system users (institutions, schools, etc.) and new users, for connection fees.

Conclusions. Treatment results from the Emmitsburg system have consistently met the NPDES permit requirements. The overland flow treatment area has performed as expected in reducing

TABLE 28

ACTUAL COST PROJECTIONS FOR THE EMMITSBURG, MARYLAND, LAGOON, OVERLAND FLOW, AND WATER REUSE SYSTEMS

Design Engineering	$ 350,000
Construction	6,250,000
Equipment	310,000
Land	194,000
Construction/Startup Engineering	660,000
Misc. (Admin., Legal, etc.)	50,000
Total	$ 8,264,000[a]

[a] The local share after EPA and Maryland State grant reimbursements is approximately $1,000,000.

nitrogen to acceptable levels and has surpassed the expectations of facility managers for BOD removal.

The crop irrigation system has proven to be a reasonable alternative for disposing of treated effluent during the summer months when stream discharge requirements are extremely stringent. The crop production benefit of the crop irrigation system can be easily demonstrated as well. By irrigating crops with treated wastewater effluent, Mason Dixon Farms has doubled and tripled their expected yields during several growing seasons. During the dry summer of 1988, while other farms in the area reaped 3 to 5 tons per acre of barley and corn silage, Mason Dixon Farms harvested 16 tons and 31 tons, respectively.

Due to battles over water rights, recent dry growing seasons, and the pressure on agriculture to produce more crops, or at least as many, from an ever-decreasing amount of farmland, reusing treated effluent for crop irrigation is a viable way to use treated wastewater. The irrigation system can also remove some of the weather uncertainties and provide the farmer with some assurance that crops will be produced even in a dry year. This benefit, in itself, could prevent a farm from disappearing (to development) due to bankruptcy and help maintain a balance of open space in the environment.

Small communities, when planning expansion or upgrading of their wastewater treatment facilities, should not hesitate to consider land treatment and disposal. Based on the availability and cost of land for the system, capital costs for construction should be comparable to conventional systems.

For more information about this system, contact Duke Martin (see Appendix A).

REVIEW OF LAGOON UPGRADES IN MISSOURI

Howard D. Markus and Terris L. Cates
Missouri Department of Natural Resources
Jefferson City, Missouri

Several methods used to upgrade lagoon wastewater treatment systems treat the lagoon effluent rather than increase the treatment capability of the lagoon itself. These methods include submerged rock filters, intermittent sand filters, slow sand filters, microscreens, and land application.

In Missouri, 347 municipal lagoon facilities have obtained permits and have been upgraded or will be upgraded to meet NPDES discharge limits. For existing lagoons, Missouri has applied the NPDES provision to revise the lagoon limits up to a maximum of 45 mg/L BOD_5 and 80 mg/L nonfilterable residue (NFR) when allowed by water quality standards. For those facilities that can achieve higher levels of treatment, however, more stringent permit limits have been required (e.g., 30 mg/L BOD_5 and 60 mg/L NFR).

This study surveyed a number of unique lagoon upgrades that applied the treatment capability of the existing facilities, required low capital construction costs, and provided low annual operating costs. The study team analyzed the Discharge Monitoring Reports submitted to the Missouri Department of Natural Resources (MO-DNR) by the municipalities to compare the 5-day BOD_5 and NFR data before and after the lagoon upgrades were completed. The lagoon facility parameters and study results are shown in Table 29.

Conclusion. The findings of this work indicate the following conclusions:

- It is possible to upgrade lagoon systems by methods that do not conform to normal design standards. These upgrades are unique to each facility and require careful and conservative planning by the designer.

- The designer should consider the operating volume that the sludge displaces in the existing lagoon cells, as well as the nutrient load the sludge may add to the cells.

TABLE 29

LAGOON SYSTEM UPGRADES IN MISSOURI

City/ County	Date Original System Built	Type of Facility	Operating Depth (ft)	Estimated Population Served	Average Daily Flow	BOD_5 Loading (lb/day)	Lb BOD_5/ Acre	Date of Upgrade	Type of Upgrade	Added Aeration Capacity (lb O_2/lb BOD_5 Removed)	BOD_5 Permit Limit (mg/L)	NFR Permit Limit (mg/L)	Results
Albany/ Gentry	1963	2-cell waste stabilization lagoon; 9.1-acre 1° cell; 2.7-acre 2° cell	3	2,200 (June 1983-May 1985)	220,000 gpd	374	41 in 1° cell	May 1985	46-acre aeration basin, 10 ft operating depth; 3.5-hp surface aerators; 6.8 day DTIME; no sludge removed	4	30	60	Notable improvement in BOD_5
Canton/ Lewis	1969	11.9-acre 1° cell; 2.3 ft. and 4.3 ft drawoffs	4	NA	NA	NA	NA	June 1985	Multiple drawoffs at 1.4-ft, 3-ft, and 5-ft levels	NA	45	80	No significant improvement to BOD_5 or NFR effluent quality
Lancaster/ Schuyler	1960	4 8-acre single cell	3	805 (1986)	NA	137	28	August 1986	1.9-acre 2° cell; 5-ft operating depth; multiple drawoffs at 2-, 4-, 5-ft depths; no sludge removed	NA	45	80	Significant improvement to lagoon discharge

TABLE 29 (Cont.)

City/ County	Date Original System Built	Type of Facility	Operating Depth (ft)	Estimated Population Served	Average Daily Flow	BOD_5 Loading (lb/day)	Lb BOD_5/ Acre	Date of Upgrade	Type of Upgrade	Added Aeration Capacity (lb O_2/lb BOD_5 Removed)	BOD_5 Permit Limit (mg/L)	NFR Permit Limit (mg/L)	Results
Maryville/ Nodaway	1969	2 37-acre parallel 1° cells; 20-acre 2° cell, 16-acre 3° cell	3	NA	1.6 MGD	1,267	17 (1° cells)	December 1985	Aerated cell; 3.4-acre surface area; 16-ft operating depth; 2 centrifugal aeration blowers each with a 2,000 scfm capacity; 80 static tube diffusers on lagoon floor; 8-day DTIME; no sludge removed	4	45	80	Improved BOD_5 reduction; solids concentration in lagoon effluent not sufficiently improved
Memphis/ Scotland	1969	15-acre single cell	5	2,100	NA	33	24 (1980-1988)	January 1986	Original lagoon divided into 10.7-acre 1° cell, 3.2-acre 2° cell, 1.1-acre 3° cell, by polymer-coated fabric material curtains; a submerged 20-ft long, 8-inch perforated pipe added to effluent structure; no sludge removed	NA	45	80	Definite improvements to BOD_5 and NFR effluent quality

TABLE 29 (Cont.)

City/ County	Date Original System Built	Type of Facility	Operating Depth (ft)	Estimated Population Served	Average Daily Flow	BOD_5 Loading (lb/day)	Lb BOD_5/ Acre	Date of Upgrade	Type of Upgrade	Added Aeration Capacity (lb O_2/lb BOD_5 Removed)	BOD_5 Permit Limit (mg/L)	NFR Permit Limit (mg/L)	Results
Smithville/ Clay	1960	9.4-acre single cell	3	2,200	.22 MGD; .25 MGD (1986)	374	40	November 1986	0.9-acre aerated cell; 12-ft operating depth; 3 5-hp aerators; 9.4-day DTIME; operating depth increased to 5 ft in original cell; no sludge removed	1.5	NA	NA	Marked improvement to BOD_5; NFR not improved
Southwest City/ McDonald	1969	2.3-acre 1° cell; 0.7-acre 2° cell	3.8	550	0.04 MGD	94	41 (1° cell)	March 1984	Added 4 1-hp and 1 3-hp aerator to 1° cell; 6.5-day DTIME; no sludge removed	1.9	30	60	BOD_5 and NFR were reduced in the effluent
Sweet Springs/ Saline	1960s	9.1-acre single cell	2-3	1,740 (1986)	90,000 gpd	296	38.5	Fall 1987	0.34-acre aeration cell; 6-ft operating depth; 3-hp floating mechanical aerators; existing cell divided into 5.0-acre 1° cell, 2.6-acre 2° cell, 1.5-acre 3° cell, with membrane partitions; 5.4-day DTIME; no sludge removed	1.6	4.5	70	BOD_5 and NFR effluent parameters improved

KEY
1° = primary
2° = secondary
3° = tertiary
BOD_5 = biological oxygen demand
DTIME = detention time
ft = feet/foot
gpd = gallons per day
hp = horsepower
NA = information not available or not applicable
NFR = nonfilterable residue
MGD = million gallons per day
O_2 = oxygen
scfm = standard cubic feet per minute

- The aerated lagoon typically had a 6- to 10-day detention time and significantly reduced the BOD_5 during the summer months. Designers should make sure that adequate aeration capacity is available during these months and that the aeration capacity can be lowered during the winter months.

- Modifying the outlet structure to provide multiple withdrawal elevations on facultative lagoons, without other modifications, will probably not provide the desired reductions in BOD_5 and NFR values.

Contact Terris Cates (see Appendix A) for a more complete report of this study which contains system schematics and monthly BOD_5 and NFR data.

CITY OF SANFORD, FLORIDA, WATER RECLAMATION FACILITY, RECLAIMED WATER SPRAY IRRIGATION SYSTEM, AND VACUUM SEWER COLLECTION SYSTEM

William A. Simmons, Engineering and Planning Department
Sanford, Florida

The City of Sanford is located in central Florida on Lake Monroe, about 20 miles north of Orlando. It has a population of about 30,000 with about 9,300 sewer accounts. The municipal wastewater treatment plant service area is 305 acres in an established downtown residential and commercial area. To comply with several Consent Orders from the Florida Department of Environmental Regulation (FDER), by the end of 1995, Sanford must stop discharging any nutrients into Lake Monroe and eliminate its combined sewer overflow (CSO) system.

Sanford's existing sewer collection system consists of a gravity interceptor, lift stations, and force mains, which convey the wastewater to a water reclamation area. Part of the older city is served by a combined sanitary/stormwater sewer system, which allows mixed overflow to discharge into the lake during high storm conditions. Based on technical and financial feasibility, cost effectiveness, and a review of other systems already in operation in other parts of the country, the city chose to install a new vacuum sewer collection system and rehabilitate the existing combined system for stormwater flow as the most appropriate plan for CSO elimination. The city chose the vacuum system because of its ability to bypass horizontal and vertical obstacles and overcome flat or adverse grade conditions.

After investigating numerous disposal options for eliminating effluent discharge into the lake, including deep-well injection, use of effluent as plant cooling water, ocean outfall, reuse of potable water, wetlands treatment, and land application, the city chose land application of reclaimed wastewater as the optimum solution. Because of the limited availability of suitable land in the area, the city must use a combination of low rate irrigation in both public access and restricted areas.

Vacuum sewer collection system. The design capacity of the vacuum collection system is about 1.2 MGD. The system consists of 42,526 lineal ft of vacuum line connected to 433 vacuum interface valves (AirVac) located predominantly in fiberglass pits with traffic-bearing covers (see Figures 36 and 37). There are 9 vacuum interface valves in concrete buffer tanks and 44 division valves. The system is divided into six separate vacuum mains arriving at the single vacuum collection station. The vacuum station will be able to accommodate a seventh line at a later date, if necessary.

The vacuum station (Figure 38) consists of a 5,000 gal vacuum collection tank placed under vacuum by three 430-cfm vacuum pumps. Dual 800-gpm sewage pumps convey sewage flows from the vacuum collection tank through a forcemain into the conventional gravity sewer system. There are also three tributary conventional 300 to 500 gpm lift stations.

Construction of the system is divided into three contracts by work type; one to build the vacuum main, one for the vacuum station, and for the lateral replacement work. Construction costs are $2,703,000 for the vacuum sewer collection main, $833,500 for the collection station, and $525,000 for the laterals contract.

Water reclamation facility. Improvements to the water reclamation facility include the addition of a flow splinter box; third secondary clarifier; another return/waste sludge pumping station; alum storage and pumping facilities; tertiary filtration; chlorine contact chamber for high level disinfection; reclaimed water transfer pump station, quality control building, and distribution pump station; chemical equipment building; and two 1.5-MG reclaimed water storage tanks.

Design wastewater flows for the facility are 7.3 MGD annual average daily flow and 15.5 MGD peak hourly flow. The "complete-mix" activated sludge process provides secondary treatment and filtration prior to effluent disposal by spray irrigation. The process operations used at the facility are as follows:

- Preliminary treatment, including screening with a coarse bar rack and aerated grit removal

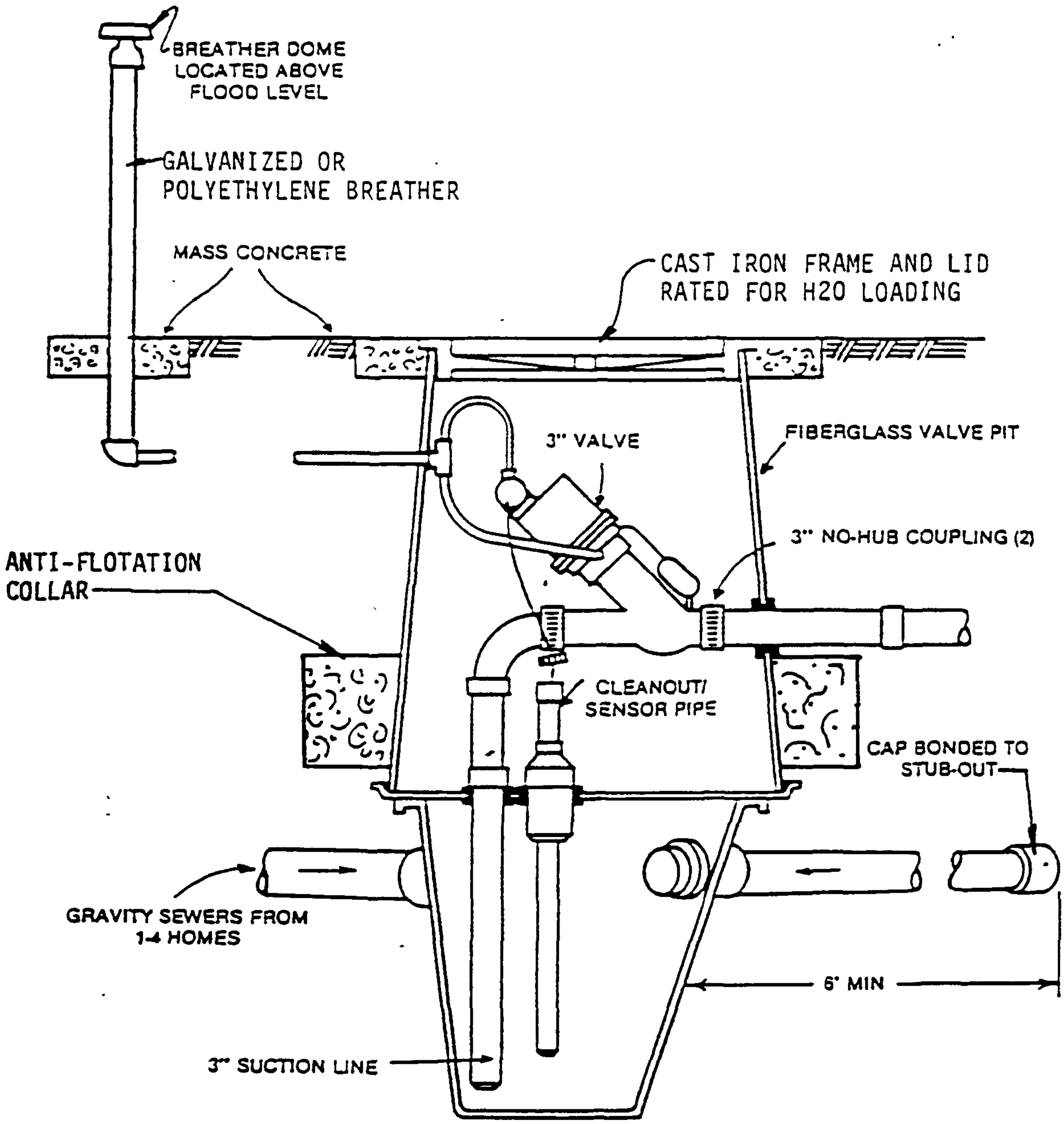

Figure 36. **Sanford, Florida, Vacuum Sewer Collection Valve Pit with Above-Ground Breather**

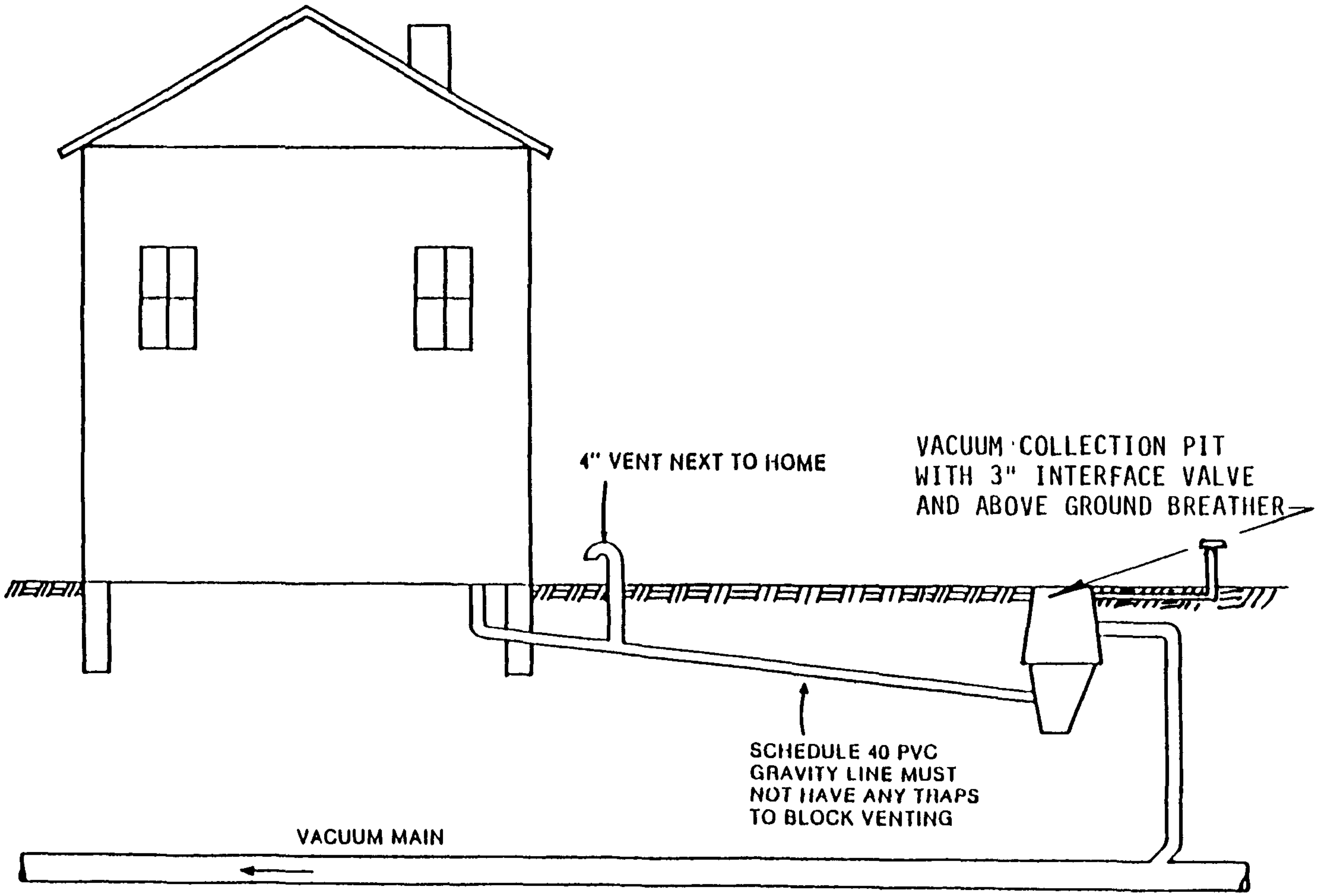

Figure 37. Sanford, Florida, Vacuum Sewer Collection System Gravity Line Connection to Vacuum Valve Pit

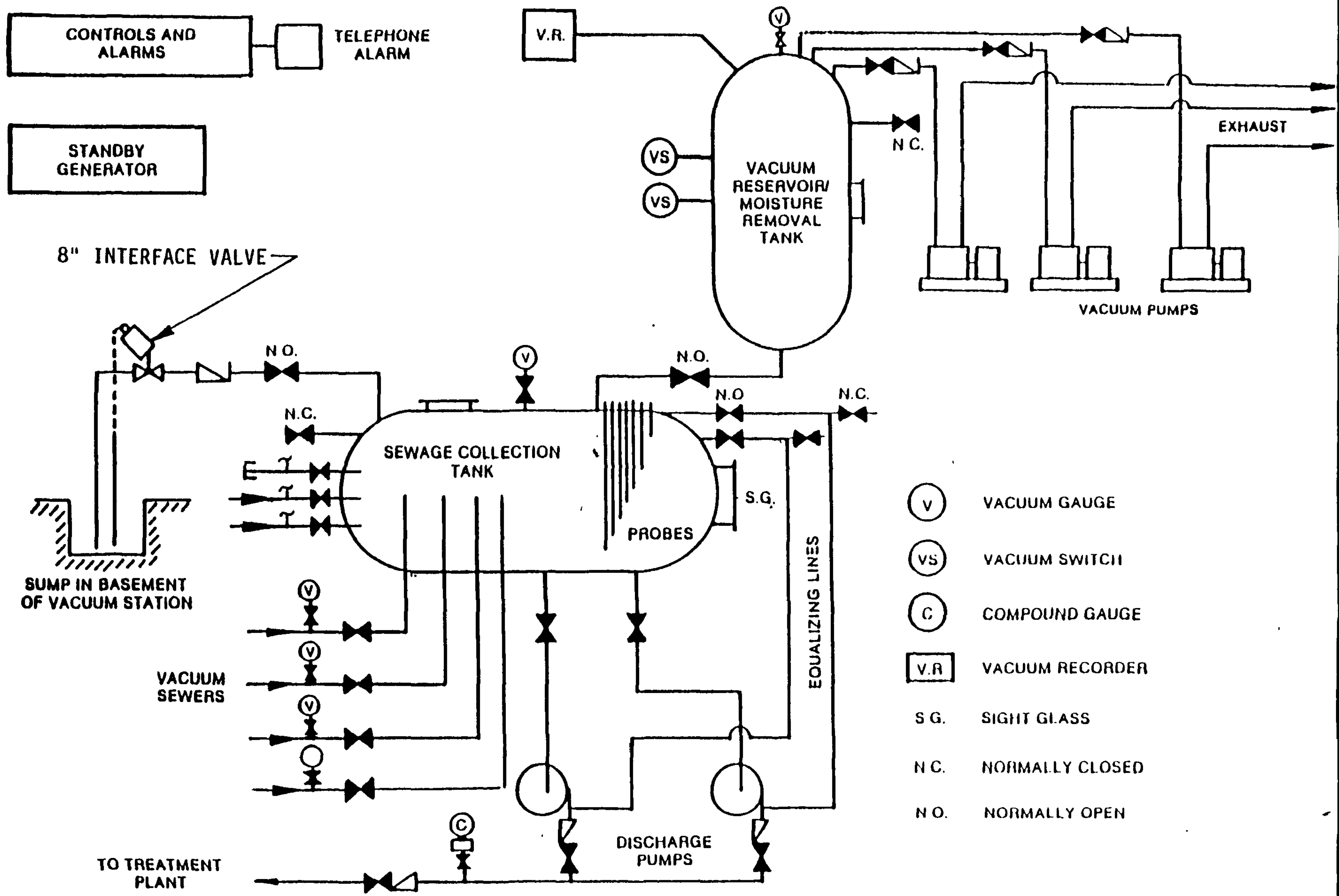

Figure 38. **Sanford, Florida, Vacuum Sewer Collection Station Line Diagram**

- Secondary treatment, including aeration of the mixed liquor, final clarification, and disinfection by chlorination
- Tertiary filtration, including alum addition, tertiary filtration (dual media), and high level disinfection
- Sludge treatment, including aerobic digestion and sludge dewatering (belt filter press system)
- Stormwater treatment, including sedimentation, detention in open, lined basins, and disinfection by chlorination

Figure 39 is a flow diagram of the facility.

Treatment efficiency in terms of BOD removal is expected to exceed 90 percent. The TSS removal process is designed to result in the average effluent suspended solids concentration of less than 5 mg/L, yielding a removal efficiency of 95 to 98 percent. Table 30 shows the expected influent and effluent characteristics for the Sanford Water Reclamation Facility.

Reclaimed water program. Following the water reclamation process, highly treated wastewater effluent called "reclaimed water," will be distributed throughout the planning area and used for spray irrigation in both public and restricted access sites. Public access areas include golf courses, city parks, school properties, residential neighborhoods, and commercial/industrial establishments. A 2,000-acre site owned by the city and referred to as "Site 10" will be developed as a "restricted access" agricultural reuse site to include orange groves and hay crops.

The original system contains about 85,000 linear ft of cement-lined ductile iron pipe (DIP) ranging in size from 8 to 18 inches. Gate valves and butterfly valves are located throughout the distribution system for isolating sections of the system and facilitating maintenance and future extensions. The system also includes a wet weather discharge system, which will be used when flows are high and irrigation use is low.

Reclaimed water is stored at the water reclamation facility, one of the golf courses, and Site 10. The storage at the main facility consists of two 1.5-MG prestressed concrete tanks.

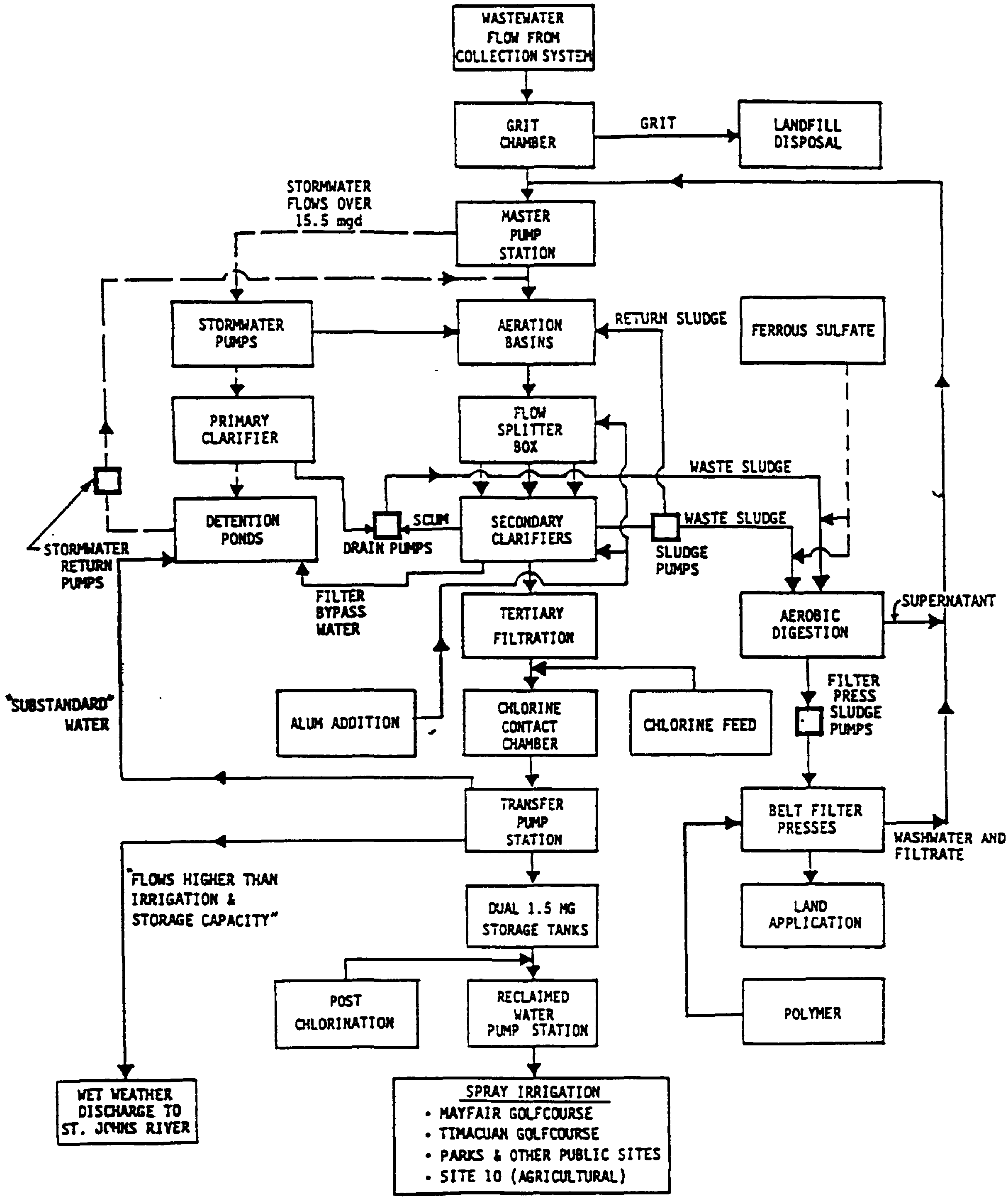

Figure 39. Flow Schematic of the Sanford, Florida, Water Reclamation Facility

TABLE 30

EXPECTED INFLUENT AND EFFLUENT CHARACTERISTICS FOR THE SANFORD WATER RECLAMATION FACILITY

			Current Year	Rerated Flow	Design Flow
Influent					
a.	Average Daily Flow (MGD)		5.3	6.5	7.3
b.	Maximum Daily Flow (MGD)		10.3	10.9	12.2
c.	Peak Hourly Flow (MGD)		11.3	13.8	15.5
d.	BOD_5 @ AADF[a] (lb/day)		4,420	6,780	7,610
e.	Suspended Solids (lb/day) @ AADF		5,300	7,590	8,520
Effluent					
a.	BOD_5 @ AADF	(mg/L)	10	5	5
		(lb/day)	442	271	304
b.	Suspended Solids @ AADF	(mg/L)	8	5	5
		(lb/day)	354	271	304

[a]Annual average daily flow.

Storage at the golf course consists of a lined pond incorporated into the landscape. Usable volume for irrigation is 750,000 gal. The storage capacity at Site 10 is still being designed.

A booster pump station provides adequate pressures for the points of connection. The station consists of two in-line turbine pumps set into the precast core structure located below grade. The pumps are actuated when the pressure in the distribution system falls below the set pressure.

The golf course uses new Rainbird sprinklers and controllers and an existing Toro hydraulic irrigation system interconnected to the new pipe system and Rainbird equipment. This course also installed a computer-operated irrigation system that can individually control each head in the new system using the precipitation rates entered into the computer and the Rainbird weather station information gathered from the golf course. The weather station measures rainfall and wind relativity. The city-owned properties and parks use Toro sprinklers with Rainbird controllers.

The city initiated a public awareness campaign that has included a public notice to determine customer interest regarding the future use of reclaimed water. Several neighborhoods showed an overwhelming response to the program and, as a result, the city already is designing an expansion system to allow residential irrigation to these areas. Agricultural sites have also requested to be included in the program. All future developments of the city must include provisions for irrigating with reclaimed water.

The City of Sanford Reclaimed Water Program is well underway. The response to the program has been very positive from the customers, regulatory agencies, and other interested parties. To obtain a more complete report about the Sanford water reclamation and vacuum sewer project, contact William Simmons (see Appendix A).

APPENDICES

APPENDIX A

AGENDA AND LIST OF SPEAKERS

U. S. ENVIRONMENTAL PROTECTION AGENCY
1990 MUNICIPAL WASTEWATER
TREATMENT TECHNOLOGY FORUM

March 20-22
Orlando, Florida

AGENDA

TUESDAY, MARCH 20, 1990

7:30 a.m. Registration

8:30 a.m. INTRODUCTION

- Opening Remarks
  Lee Pasarew, U.S. EPA Office of Municipal Pollution Control (OMPC), Washington, DC
  Irene Horner, Technology Network Coordinator, U.S. EPA OMPC, Washington, DC

- Region 4 Welcome

- State of Florida Welcome
  Robert Heilman, Department of Environmental Regulation, State of Florida

- Keynote Address
  Jack Lehman, U.S. EPA OMPC, Washington, DC

9:45 a.m. Break

10:00 a.m. SLUDGE MANAGEMENT TECHNOLOGIES
Session Chairman: Robert Bastian

- Trends in Municipal Sludge Management Practices
  Tim Shea, Engineering Science

- Organic Contaminants and Land Application of Municipal Sludge in Canada
  Melvin Webber, Wastewater Technology Center, Environment Canada

- Alkaline Pasteurization of Municipal Sludges for Beneficial Utilization
  David S. Sloan, N-Viro Energy Systems

- Odor Control for Composting
  Roy McIlwee, Smith Environmental Engineering

12:00 p.m. WORKING LUNCHEON
International Activities
Lehman-Baltay-Pasarew

1:15 p.m. SECONDARY TREATMENT TECHNOLOGIES
Session Chairman: James Kreissl

- ATAD - Auto Thermophilic Aerobic Digestion
  Kevin Deeney, Junkins Engineering

- Experience with CAPTOR
  Elbert Morton, West Virginia Department of Natural Resources

- Physical-Chemical Treatment for Secondary Effluent
  Robert Sparling, City of Tacoma

- BIOLAC - Biological Aerated Chain
  Karl Scheible, HydroQual

3:15 p.m. BREAK

3:30 p.m. O & M Issues for POTWs
John Flowers, U.S. EPA, Washington, DC

- Alternative Technologies at Iron Bridge Treatment Plant
  Philip Feeney, Post Buckley Schuh Jernigan

- Overview of National CSO Strategy
  Harry Thron, U.S. EPA, Washington, DC

- Combined Sewer Overflow Management for Region I
  Richard P. Kotelly, U.S. EPA, Region I

- Combined Sewer Overflow Plan for East Lansing MI
  Chuck Pycha, U.S. EPA, Region V

5:30 p.m. ADJOURN

WEDNESDAY. MARCH 21, 1990

8:00 a.m. CONSTRUCTED WETLANDS FOR WASTEWATER MANAGEMENT
Session Chairman: Robert Bastian

- Overview of Wetlands Treatment in the U.S.A.
  Robert Kadlec, The University of Michigan

- Design of Constructed Wetlands
  Robert Kadlec, The University of Michigan
  Randy Clarkson, State of Missouri

- Operational Performance of Reedy Creek Wetlands Treatment System and other Southern Wetlands
  Robert L. Knight, CH2M-Hill
  Bob Kohl, Reedy Creek Energy Services

- Constructed Wetlands at Iron Bridge Treatment Plant
  JoAnne Jackson, Post Buckley Schuh Jernigan

- Compliance with Permits for Natural Systems
  Bob Freeman, U.S. EPA, Region IV

10:15 a.m. BREAK

10:30 a.m. Inventory of Constructed Wetland Systems in U.S.A. and WPCF Manual of Practice on Natural Systems
Sherwood Reed, Consulting Engineer

11:00 a.m. DISINFECTION
Session Chairman: Robert Bastian

- U.V. Disinfection
  Karl Scheible, HydroQual

- Region V Special Evaluation Project of Chlorination-Dechlorination
  Chuck Pycha, U.S. EPA, Region V

12:00 p.m. LUNCH - On your own

12:00 p.m. I/A Coordinators Lunch and Meeting (12:00 - 2:30)

12:00 p.m. Small Flows Clearing House Demonstration of Bulletin Board (12:00 - 2:30)
Anish R. Jantrania, University of West Virginia

(Please choose one field trip to attend)

1:15 p.m. Leave hotel for Field Trip to Iron Bridge Treatment Plant, Orlando, Highlighting:
a. - Biological Treatment for Phosphorus Removal
b. - 1000 Acres of Constructed Wetlands
Host: JoAnn Jackson, Senior Project Engineer,
Post Buckley Schuh Jernigan, Consulting Engineers

2:30 p.m. Leave Hotel for Field Trip to Reedy Creek Energy Services,
Highlighting:
a. - 9 MGD Taulman-Weiss In-Vessel Composting
b. - 100 Acres of Constructed Wetlands
Host: Bob Kohl

4:30 p.m. Leave Field Trip sites

5:00 p.m. Arrive at the hotel

THURSDAY, MARCH 22, 1990

8:00 a.m. TOXICITY MANAGEMENT AT POTWs
Session Chairman: Atal Eralp

- Technologies for Toxicity Removal at POTWs
  Perry Lankford, Eckenfelder & Associates

- Development of Computer Based Model and Data Base for Predicting the Fate of Hazardous Wastes at POTWs
  John Bell, Wastewater Technology Center
  Environment Canada

- Plant Performance Evaluation
  Bill Cosgrove, U.S. EPA, Region IV

9:30 a.m. WASTEWATER TECHNOLOGIES FOR SMALL COMMUNITIES
Session Chairman: Arthur Condron

- EPA's Small Community Strategy
  Ann Cole, U.S. EPA, Regional Operations, State and Local Relations, Washington, DC

- SCOT - Small Communities Outreach Technologies
  Randy Revetta, U.S. EPA, Washington, DC

10:00 a.m. BREAK

10:15 a.m. New Developments for Small Community Sewer Systems
Dick Otis, Owen Ayres and Associates
Rich Naret, Cerrone & Associates
W.C. (Bill) Bowne, Bowne Associates

- Community Mound Systems
  Dick Otis, Owen Ayres and Associates

- Sequencing Batch Reactors
  James Heidman, U.S. EPA, Cincinnati, OH

- Application of Lagoons + Overland Flow to Small Communities
  Duke Martin, Emmitsburg, Maryland

- Review of Lagoon Upgrades in Missouri
  Terris Cates, State of Missouri

12:45 p.m. LUNCH-on your own

1:45 p.m.	Leave Hotel for Field Trip to Sanford Wastewater Treatment Plant, Featuring: a. - 0.3 MGD Vacuum Sewers b. - 5 MGD Advanced Treatment Plant for Water Reuse Host: William A. Simmons, City Engineer, City of Sanford
4:00 p.m.	Leave Sanford Wastewater Treatment Plant
5:00 p.m.	Arrive at Hotel
	END OF FORUM

U.S. ENVIRONMENTAL PROTECTION AGENCY

1990 MUNICIPAL WASTEWATER TREATMENT
TECHNOLOGY FORUM

Orlando, Florida
March 20-22, 1990

SPEAKER LIST

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Missouri Department of Natural Resources
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APPENDIX B

LIST OF NATIONAL CONTACTS FOR WASTEWATER TECHNOLOGY, SLUDGE TECHNOLOGY, AND OPERATIONS AND MAINTENANCE OPERATOR TRAINING

APPENDIX B

LIST OF NATIONAL CONTACTS FOR WASTEWATER TECHNOLOGY, SLUDGE TECHNOLOGY, AND OPERATIONS AND MAINTENANCE OPERATOR TRAINING

National Wastewater Technology Coordinator

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(FTS) 382-7292

Sludge Coordinator

John Walker
USEPA OMPC (WH-595)
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Washington, DC 20460
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(FTS) 382-7283

Wastewater Management Coordinator

Randy Revetta
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Wastewater Technology Contact

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National Small Flows Clearinghouse Manager

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(FTS) 382-7277

O&M Operator Training

John Flowers
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Washington, DC 20460
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APPENDIX C

LIST OF ADDRESSES FOR REGIONAL AND STATE WASTEWATER TECHNOLOGY, SLUDGE, AND O&M COORDINATORS

APPENDIX C

LIST OF ADDRESSES FOR REGIONAL AND STATE WASTEWATER TECHNOLOGY, SLUDGE, AND O&M COORDINATORS

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION I			
U.S. EPA Water Management Division JFK Federal Building Boston, MA 02203	Charles Conway (617) 565-3517 (FTS) 835-3517	Charles Conway (617) 565-3517 (FTS) 835-3517	Charles Conway (617) 565-3517 (FTS) 835-3517
Connecticut			
Connecticut Department of Environmental Protection 122 Washington Street Hartford, CT 06106	William Hogan (203) 566-2793	Warren Herzig (203) 566-3282	Roy Fredricksen (203) 393-2705
Maine			
Department of Environmental Protection State House (STOP 17) Augusta, ME 04333	Dennis Purington (207) 289-7764	Brian Kavanah (207) 582-8740	Don Elbert (207) 283-7800

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION I (Continued)			
Massachusetts			
Division of Water Pollution Control Massachusetts Department of Environmental Quality Engineering One Winter Street Boston, MA 02108	Robert Cady (617) 292-5713	Rick Dunn (617) 556-1130	Kim Simpson (508) 727-8882
New Hampshire			
New Hampshire Water Supply and Pollution Control Commission P.O. Box 95, Hazen Drive Concord, NH 03301	John Bush (603) 271-2508	Rich Vlanders (603) 271-2925	George Neill (603) 271-3325
Rhode Island			
Rhode Island Division of Water Resources 291 Promenade Street Providence, RI 02908	Warren Town (401) 277-3961	Chris Campbell (401) 277-3961	Ed Szymanski (401) 277-3961

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION I (Continued)			
Vermont			
Environmental Engineering Division Vermont Agency of Environmental Conservation 103 South Main Street, Bldg. 9 South Waterbury, VT 05676	Marilyn Davies (802) 244-8744	George Desch (802) 244-8744	Christine Thompson (802) 244-8744
REGION II			
U.S. EPA Water Management Division 26 Federal Plaza, Room 837 New York, NY 10278	John Mello (212) 264-5677 (FTS) 264-5677	Aristotle Harris (212) 264-4707 (FTS) 264-4707	John Mello (212) 264-5677 (FTS) 264-5677
New Jersey			
New Jersey Department of Environmental Protection P.O. Box CN-029 Trenton, NJ 08625	Robert Kotch (609) 292-6894	Helen Pettit Chase (609) 633-3662	Chris Hoffman (609) 984-4429

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
<u>REGION II (Continued)</u>			
New York			
Technical Assistance Section New York State Department of Environmental Conservation 50 Wolf Road Albany, NY 12233	Randy Orr (518) 457-3810	Rick Hammand (518) 457-2051	Arthur Warner (518) 457-5968
Puerto Rico			
Local Assistance Grants Section Puerto Rico Environmental Quality Board Banco Nacional Building 431 Ponce De Leon Blvd. Hato Rey, PR 00913	Baltazar Luna (809) 751-5540	Ava Hernandez (809) 751-5540	Baltazar Luna (809) 751-5540
Virgin Islands			
Natural Resources Management Office 179 Altoona and Welqunst Charlotte Amalie, St. Thomas Virgin Islands 00801	Phyllis Brin (809) 774-3320		

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION III			
U.S. EPA Water Management Division 841 Chestnut Building Philadelphia, PA 19107	Clyde Turner (215) 597-8223 (FTS) 597-8223	Kenneth Pantuck (215) 597-9478 (FTS) 597-9478	Jim Kern (215) 597-3423
Delaware			
Delaware Department of Natural Resources and Environmental Control Division of Environmental Control 89 Kings Highway, Box 1401 Dover, DE 19903	Roy R. Parikh (302) 736-5081	William Razor (302) 736-4781	
District of Columbia			
District of Columbia Department of Public Works Water and Sewer Utility Administration 5000 Overlook Avenue, S.W. Washington, DC 20032	Leonard R. Benson (202) 767-7603	Leonard R. Benson (202) 767-7603	James R. Collier (202) 767-7370
Maryland			
Department of Environment Water Management Administration 2500 Broening Highway Baltimore, MD 21224	John Milnor (301) 631-3726	Doug Proctor (301) 631-3375	Jake Bair (301) 934-2251 ex. 402

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION III (Continued)			
Pennsylvania			
Pennsylvania Department of Environmental Resources Division of Municipal Facilities and Grants P.O. Box 2063 Harrisburg, PA 17120	Charles Kuder (717) 787-3481	William Pounds (717) 787-7381	Ken O'Korn (717) 787-8184
Virginia			
Virginia State Water Control Board Box 11143 Richmond, VA 23230	Walter Gills (804) 367-8860	Cal M. Sawyer (804) 786-1755	Jack Vanderland (804) 257-6436
West Virginia			
West Virginia Department of Natural Resources Division of Water Resources 1201 Greenbrier Street Charleston, WV 25311	Elbert Morton (304) 348-0633	Clifton Browning (304) 348-2108	Richard Weigand (304) 348-3075 (304) 372-3400

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION IV			
U.S. EPA Water Management Division 345 Courtland Street, N.E. Atlanta, GA 30365	Bob Freeman (404) 347-4491 (FTS) 257-4491	Vince Miller (404) 347-3633 (FTS) 257-3633	Normand Colon (404) 347-3633 (FTS) 257-3633
Alabama			
Alabama Department of Environmental Management 1751 Federal Drive Montgomery, AL 36130	David Hutchinson (205) 271-7761	Cliff Evans (205) 271-7761	Larry Bryant (205) 277-3630
Florida			
Bureau of Wastewater Management and Grants Florida Department of Environmental Regulation Twin Towers Office Building 2600 Blair Stone Road Tallahassee, FL 32301	Bhupendra Vora (904) 488-8163	J.N. Ramaswamy (904) 488-8163	Barbara Mitchell (904) 392-9570
Georgia			
Environmental Protection Division Georgia Department of Natural Resources Floyd Towers East, Suite 1058 205 Butler Street, S.E. Atlanta, GA 30334	Ernest Earn (404) 656-4708	Mike Creason (404) 656-4887	Gaynell Hill (404) 656-7400

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION IV (Continued)			
Kentucky			
Kentucky Department of Environmental Protection Division of Water 18 Reilly Road Frankfort, KY 40601	Vince Borres (502) 564-3410	Art Curtis (502) 564-3410	Nancy Fouser (502) 564-3358
Mississippi			
Municipal Facilities Branch Mississippi Department of Natural Resources Bureau of Pollution Control P.O. Box 10385 Jackson, MS 39209	Sitaram Makena (601) 961-5171	Billy Warden (601) 961-5060	Glen Odom (601) 961-5159
North Carolina			
Division of Environmental Management North Carolina Department of Natural Resources and Community Development P.O. Box 27687 Raleigh, NC 27611	Allen Wahab (919) 733-6900	Dennis Ramsey/ Allen Wahab (919) 733-6900	Ted Cashin (919) 733-7015

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION IV (Continued)			
South Carolina			
Facilities Planning Environmental Quality Control South Carolina Department of Health and Environmental Control 2600 Bull Street Columbia, SC 29201	Sam Grant (803) 734-5279	Mike Montebello (803) 734-5262	Earl Hunter (803) 734-5300
Tennessee			
Tennessee Department of Health and Environment Terra Building, 3rd Floor 150 Ninth Avenue North Nashville, TN 37247-3301	Sam Gaddipati (615) 741-0638	Steve Sanford (615) 741-0638	James Coe (615) 898-8090
REGION V			
U.S. EPA Water Management Division 230 South Dearborn Street Chicago, IL 60604	Charles Pycha (312) 886-0259 (FTS) 886-0259	John O'Grady (312) 353-1938 (FTS) 353-1938	Eugene Chaiken (312) 353-2124 (FTS) 353-2124

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION V (Continued)			
Illinois			
Division of Water Pollution Control Illinois Environmental Protection Agency 2200 Churchill Road Springfield, IL 62706	James Leinecke Terry Zeal (217) 782-2027	Al Keller (217) 782-1696	William H. Busch (217) 782-1696
Indiana			
Special Projects Section Water Management Division Indiana Department of Environmental Management 105 South Meridian Street, P.O. Box 6015 Indianapolis, IN 46206-6015	Donald Dailey (317) 232-8659	Dan Strahl (317) 232-8736	Leonard Ashack (317) 633-0756
Michigan			
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APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION V (Continued)			
Minnesota			
Municipal Wastewater Treatment Section Community Assistance Unit #3 Minnesota Pollution Control Agency 520 Lafayette Road St. Paul, MN 55155	Lori Frekot (612) 296-8762	Jorja DuFresue (612) 296-9292	Bill Sexauer (612) 296-7218
Ohio			
Division of Construction Grants Ohio Environmental Protection Agency P.O. Box 1049 1800 Water Mark Drive Columbus, OH 43266-10349	Margaret Klepic (614) 644-2807	Stuart M. Blydenburgh (614) 644-2001	Scot Ankron (614) 644-2014
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Municipal Wastewater Section Wisconsin Department of Natural Resources P.O. Box 7921 Madison, WI 53707	Bob Steindorf (608) 266-0449	Tom Portle (608) 266-8343	Tom Kroehn (608) 267-7656

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
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Arkansas			
Arkansas Department of Pollution Control and Ecology, P.O. Box 9583 8001 National Drive Little Rock, AR 72219	Martin Roy (501) 562-8910	Mike Hood (501) 562-8910	James Bailey (501) 574-4550
Louisiana			
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New Mexico			
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APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION VI (Continued)			
Oklahoma			
Engineering Division Oklahoma State Department of Health 3400 North Eastern Avenue P.O. Box 53551 Oklahoma City, OK 73152	H.J. Thung (405) 271-7346	Denny Hodges (405) 271-7362	Dr. William Roach (405) 733-7364
Texas			
Texas Water Development Board P.O. Box 13087 Capital Station Austin, TX 78711-3231	Milton Rose (512) 463-8513	Milton Rose (512) 463-8513	Clark Benson (409) 845-6246
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U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION VII (Continued)			
Iowa			
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Water Pollution Control Program Division of Environmental Quality Missouri Department of Natural Resources P.O. Box 176 Jefferson City, MO 65102	Douglas Garrett (314) 751-5723	Ken Arnold (314) 751-6624	Lorene Boyt (417) 451-3583

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION VII (Continued)			
Nebraska			
Construction Grants Branch Water Quality Section Nebraska Department of Environmental Control P.O. Box 98922 Statehouse Station Lincoln, NE 68509-8922	Mahmood Arbab (402) 471-4236	Rick Bay (402) 471-2186	Rick Bay (402) 471-2186
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Colorado			
Water Quality Control Division Colorado Department of Health 4210 E. 11th Avenue Denver, CO 80220	Derald Lang (303) 331-4564	Phil Hegeman (303) 331-4564	Tom Feeley (303) 980-9165

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
<u>REGION VIII (Continued)</u>			
Montana			
Water Quality Bureau Montana Department of Health and Environmental Sciences Cogswell Building Helena, MT 59620-0522	Scott Anderson (406) 444-2406	Scott Anderson (406) 444-2406	Martha Ann Dow (406) 265 7821 ext. 3285
North Dakota			
Division of Water Supply and Pollution Control North Dakota Department of Health 1200 Missouri Avenue, P.O. Box 5520 Bismark, ND 58502-5520	Jeff Hauge (701) 224-4827	Jeff Hauge (701) 224-4827	Ralph Reidinger (701) 244-2354
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U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION VIII (Continued)			
Utah			
Utah Bureau of Water Pollution Control P.O. Box 16690 Salt Lake City, UT 84116-0690	Kiran L. Bhayani (801) 533-6146	Kiran L. Bhayani (801) 533-6146	Charles Tolson (801) 226-5000
Wyoming			
Water Quality Division Wyoming Department of Environmental Quality Herschler Bldg., 4 West 122 W. 25th Street Cheyenne, WY 82002	Mike Hackett (307) 777-7781	Mike Hackett (307) 777-7781	Bill Mixer (307) 268-2368
REGION IX			
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Arizona			
Arizona Department of Health Services 2005 North Central Avenue Phoenix, AZ 85004	Ron Frey (602) 257-2231	John McClain (602) 722-7872	John McClain (602) 722-7872

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION IX (Continued)			
California			
State Water Resources Control Board Division of Clean Water Programs P.O. Box 944212 Sacramento, CA 94224-2120	David Meza (916) 739-4315	Archie Mathews (916) 322-4567	Donald Proctor (916) 744-4150
Hawaii			
Construction Grants Program Hawaii State Department of Health 5 Water Front Plaza, Suite 250 500 Alamona Blvd. Honolulu, HI 96813	Dennis Tulang (808) 543-8288	Dennis Tulang (808) 543-8288	Dennis Tulang (808) 543-8288
Nevada			
Nevada Department of Environmental Protection - Construction Grants Capitol Complex 123 W. Nye Lane Carson City, NV 89710	James Williams (702) 687-5870	James Williams (702) 687-5870	Julian Bielawski (702) 687-4670

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
REGION X			
U.S. EPA Water Management Division 1200 Sixth Avenue Seattle, WA 98101	Bryan Yim (206) 442-8575 (FTS) 399-8575	Dick Hetherington (206) 442-1941 (FTS) 399-1941	Clarence Orimon (206) 442-2887 (FTS) 399-2887
Alaska			
Alaska Department of Environmental Conservation Division of Water Programs P.O. Box O Juneau, AK 99811	Richard Marcum (907) 465-2610	Stan Hungerford (907) 465-2610	Judy Urquart (907) 465-2673 Linda Taylor (907) 465-2610
Idaho			
Idaho Department of Health and Welfare Division of Environment State House Boise, ID 83720	Bob Braun (208) 334-5860	Susan Martin (208) 334-5855	Veronica Shawcroft (208) 888-1740
Oregon			
Oregon Department of Environmental Quality 811 SW 6th Street Portland, OR 97204	Francis Dzata (503) 229-5370	Richard Nichols (503) 229-5324	Thomas Gonzalez (503) 928-2361

APPENDIX C (Continued)

U.S. EPA REGION	TECHNOLOGY CONTACT	SLUDGE CONTACT	O&M CONTACT
<u>REGION X (Continued)</u>			
Washington			
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APPENDIX D

EPA REGIONAL WASTEWATER TREATMENT OUTREACH COORDINATORS

APPENDIX D

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APPENDIX E

SUMMARY OF INNOVATIVE AND ALTERNATIVE TECHNOLOGY PROJECTS BY STATE

SUMMARY OF INNOVATIVE TECHNOLOGY PROJECTS

EPA REGION	STATE	Aeration						Clarification					Collection	
		Counter Current Aeration	Draft Tube Aeration	Fine Bubble Diffusers	Aero-mod System	Intermittent Cycle Extended Aeration	Other Aeration	Flocculating Clarifiers	Integral Clarifiers	Intrachannel Clarifiers	Swirl Concentrators	Other Clarification	Small Diameter Gravity Sewers	Other Collection Systems
I	Connecticut			1										
	Maine		1				1				1	1		
	Massachusetts			1										
	New Hampshire													
	Rhode Island		1											
	Vermont													
II	New Jersey											1		
	New York		3						2				1	1
	Puerto Rico													
	Virgin Islands													
III	Delaware		1							1				
	Washington DC										1			
	Maryland									1				
	Pennsylvania	1	2									1		2
	Virginia	1	1						1	2			1	
	West Virginia		2				1		1	3		1		
IV	Alabama	5	4	2						4				
	Florida	1												
	Georgia	1												
	Kentucky	1								7			1	
	Mississippi									1				
	North Carolina	5	2		1		1							
	South Carolina	1								1				
	Tennessee	7				4				2	1			1
V	Illinois			1						2	1			
	Indiana			2						1	3			
	Michigan						1					1		
	Minnesota						1			1				
	Ohio			2	1					3	1	1	4	1
	Wisconsin			2				2						
VI	Arkansas						1			1				
	Lousiana	1					1			4				
	New Mexico		1											
	Oklahoma					2	1			1				
	Texas						2			2				
VII	Iowa						2			1				
	Kansas		1							1				
	Missouri				3					4				
	Nebraska													
VIII	Colorado													
	Montana							1					1	
	North Dakota													
	South Dakota									2				
	Utah							1						
	Wyoming													
IX	Arizona											1		
	California											2		
	Guam													
	Trust Territories													
	Hawaii													
	Nevada													
	N. Marianas Islands													
X	Alaska													
	Idaho		1							1				
	Oregon											1		
	Washington													
TOTAL		24	20	11	5	6	12	4	4	46	8	10	8	5

SUMMARY OF INNOVATIVE TECHNOLOGY PROJECTS (cont'd)

EPA REGION	STATE	Disinfection: Ultraviolet Disinfection	Disinfection: Other Disinfection	Disposal of Effluent: Other Disposal of Effluent	Energy Conservation and Recovery: Solar Heating	Energy Conservation and Recovery: Other Energy Conservation and Recovery	Filtration: Biological Aerated Filters	Filtration: Microscreens	Filtration: Other Filtration	Lagoons: Aquaculture	Lagoons: Hydrograph Controlled Release Lagoons	Lagoons: Single Cell Lagoon with Sand Filter	Lagoons: Other Lagoons
I	Connecticut	2											
	Maine	1	2		1				1		3		
	Massachusetts	1	1		1								
	New Hampshire	1											
	Rhode Island				1								
	Vermont	1			1								1
II	New Jersey												
	New York	4				1							
	Puerto Rico												
	Virgin Islands												
III	Delaware												
	Washington DC												
	Maryland	3	1										
	Pennsylvania								2				
	Virginia	1	1					1	2	1			
	West Virginia												
IV	Alabama	1					1				5		
	Florida			2									
	Georgia				1	1							
	Kentucky								1		2		
	Mississippi							1			8		
	North Carolina						1						
	South Carolina				1		1				1		
	Tennessee								1		2		
V	Illinois								2			10	2
	Indiana												
	Michigan								1				
	Minnesota	5	1		1	4			1				1
	Ohio	3	1		1	1			1				
	Wisconsin	1				3			1		1		
VI	Arkansas	1								2	1		
	Lousiana	4								1	1		2
	New Mexico			1									
	Oklahoma	4				1							1
	Texas			1						2			
VII	Iowa	1											
	Kansas	3									1		1
	Missouri	1	1			1			2				
	Nebraska					1		1					
VIII	Colorado	1						1					
	Montana	4	1										
	North Dakota												
	South Dakota												1
	Utah												
	Wyoming	4			1				2				1
IX	Arizona	1	1		1	1							1
	California		1	1		3			3				1
	Guam												
	Trust Territories												
	Hawaii												
	Nevada					1		1					
	N. Marianas Islands												
X	Alaska												1
	Idaho							1					1
	Oregon					1							
	Washington	1				1							
TOTAL		49	11	5	10	20	3	6	20	6	25	10	14

SUMMARY OF INNOVATIVE TECHNOLOGY PROJECTS (cont'd)

EPA REGION	STATE	Land Application of Effluent		Nitrification	Nutrient Removal				Oxidation Ditch		Fixed Growth		
		Overland Flow	Other Land Application of Effluent	Other Nitrification	Anoxic/oxic system (A/O)	Phostrip	Sequencing Batch Reactor (SBR)	Other Nutrient Removal	Barrier Wall Oxidation Ditch	Other Oxidation Ditch	Rotating Biological Contactors (RBC's)	Trickling Filter/Solids Contact	Other Fixed Growth
I	Connecticut												
	Maine		1										
	Massachusetts			2		1					1		
	New Hampshire												
	Rhode Island												
	Vermont		1										
II	New Jersey									1	1		
	New York			1		2			3	3		1	
	Puerto Rico												
	Virgin Islands												
III	Delaware								1				
	Washington DC												
	Maryland				1		1	2					
	Pennsylvania		1		1		3			2			
	Virginia		1	1				1		6			
	West Virginia									1			1
IV	Alabama									5			
	Florida		1		1			1					
	Georgia		1										
	Kentucky	2									1		
	Mississippi		1										
	North Carolina									2			
	South Carolina		1				2			1			
	Tennessee	1					1			3			
V	Illinois	1						1		1		2	
	Indiana			1									
	Michigan				1					2		1	
	Minnesota		1	1		1		2		1			
	Ohio							1		1		1	
	Wisconsin												
VI	Arkansas	3			1			1				1	
	Lousiana	1	1							5			
	New Mexico											1	
	Oklahoma	1					6			2	1	1	
	Texas	3								1	1	2	
VII	Iowa						3			1			
	Kansas									1			
	Missouri						3						
	Nebraska												
VIII	Colorado			2			1						
	Montana		1					2					
	North Dakota		1										
	South Dakota		1				1			1			
	Utah												
	Wyoming												
IX	Arizona							1					
	California			1				1					
	Guam												
	Trust Territories												
	Hawaii												
	Nevada					1							
	N. Marianas Islands												
X	Alaska						1						
	Idaho									1		1	
	Oregon		1		1							1	
	Washington												
TOTAL		**12**	**14**	**9**	**6**	**5**	**22**	**13**	**4**	**41**	**5**	**12**	**1**

SUMMARY OF INNOVATIVE TECHNOLOGY PROJECTS (cont'd)

EPA REGION	STATE	Sludge Technologies: Carver-Greenfield	Sludge Technologies: Composting	Sludge Technologies: Digestion	Sludge Technologies: Incineration	Sludge Technologies: Vacuum Assisted Sludge Drying Beds	Sludge Technologies: Other Sludge Technologies	Onsite Technologies: Other Onsite Technologies	Miscellaneous: Enclosed Impellor Screw Pump	Miscellaneous: Other Miscellaneous	Suspended Growth: Powdered activated Carbon/Regeneration	Suspended Growth: Other Suspended Growth
I	Connecticut		2									
	Maine		11							2		
	Massachusetts								1	1		
	New Hampshire											
	Rhode Island											
	Vermont											
II	New Jersey	1	1				4			1		
	New York		1		1					1		
	Puerto Rico											
	Virgin Islands											
III	Delaware		3									
	Washington DC									1		
	Maryland		6				1			1		
	Pennsylvania					1	1			1		
	Virginia					1				1		
	West Virginia			1								
IV	Alabama		1				2			1		
	Florida		14									
	Georgia		2									
	Kentucky		2				1					
	Mississippi											
	North Carolina			1	1	1						
	South Carolina		2				1					
	Tennessee									2		
V	Illinois					1					1	
	Indiana		2			2						
	Michigan						1			1	1	
	Minnesota			2		1		1				
	Ohio		1			1					2	
	Wisconsin							1				
VI	Arkansas						1	1		1		
	Lousiana					1						1
	New Mexico						2					
	Oklahoma			1		1						
	Texas					1	3			4		
VII	Iowa		1	1								
	Kansas		2				2		1			
	Missouri				2				2	1		
	Nebraska					1	1					
VIII	Colorado		4			1						
	Montana			1		1						
	North Dakota											
	South Dakota											
	Utah											
	Wyoming											
IX	Arizona						1					
	California	2	5			1	1			2		
	Guam											
	Trust Territories											
	Hawaii		1							1		
	Nevada											
	N. Marianas Islands											
X	Alaska		1		1		2			1		
	Idaho			1						1		
	Oregon						1					
	Washington											
TOTAL		3	62	8	5	15	25	3	4	24	4	1

SUMMARY OF ALTERNATIVE TECHNOLOGY PROJECTS

EPA REGION	STATE	ONSITE TREATMENT						SOLIDS TREATMENT						
		Septic Tank/Soil Absorption System (Single Family)	Mound System	Evapotranspiration Bed	Aerobic Unit	Sand Filter	Other Onsite Treatment	Septage Treatment and Disposal	Land Spreading of POTW Sludge	Composting	Preapplication Treatment	90% Methane Recovery from Anaerobic Digestion	Self-sustaining Incineration (Heat Recovery and Utilization)	Other Sludge Treatment or Disposal
I	Connecticut					1		7		1		4	1	
	Maine	4				5				6				
	Massachusetts					1		19	1	5		2	2	
	New Hampshire					4		7		1				
	Rhode Island							2		1			1	
	Vermont					2			12					
II	New Jersey							11	1	5	3			1
	New York	1	2			12	1	4	2	2		16	1	1
	Puerto Rico									1				
	Virgin Islands													
III	Delaware								2	2	1			
	Washington DC									1				
	Maryland	3	2			2	1	3	4	5		2		
	Pennsylvania	3	1		1	1			6	3		3		2
	Virginia							3	9	3	1	5	2	3
	West Virginia	1					1					2		
IV	Alabama								2	1		3		
	Florida									2	1	3		
	Georgia								4			4	1	
	Kentucky	1				2			13			2		
	Mississippi								3					1
	North Carolina								4			6		1
	South Carolina								5			1		
	Tennessee	2							5	1				1
V	Illinois	4	1			15	1	2	44		17	13		5
	Indiana	1	2					1	20		3	5	1	
	Michigan	2						1	16		3	4	1	
	Minnesota	10	9			2	1		24	2	3	6		
	Ohio	1	1			1		3	35	4	9	6	1	
	Wisconsin		3			1			13			3		1
VI	Arkansas	1						1	2			1		
	Lousiana				1				1					
	New Mexico										1	1		1
	Oklahoma						1		10	1	2		1	
	Texas	2			1				29	1	8	7		1
VII	Iowa					1			24		2	6		
	Kansas								20	1		5	2	2
	Missouri		1			1		1	34			1		8
	Nebraska								5	2	3	3		2
VIII	Colorado								2			1		
	Montana								9			2		1
	North Dakota		4											
	South Dakota								11		1	4		
	Utah								1	1		1		
	Wyoming								2			1		
IX	Arizona								1			3		1
	California		1					4	1	1	2	5	1	2
	Guam													
	Trust Territories						1							
	Hawaii													
	Nevada											3		
	N. Marianas Islands													
X	Alaska								1	1		1	1	1
	Idaho					2	1		6			3		
	Oregon			2		3			4	1	3	5		2
	Washington		1						1		1	2		
TOTAL		**36**	**28**	**2**	**3**	**56**	**8**	**69**	**389**	**55**	**64**	**145**	**16**	**37**

SUMMARY OF ALTERNATIVE TECHNOLOGY PROJECTS (cont'd)

EPA REGION	STATE	TREATMENT/DISCHARGE SYSTEMS										COLLECTION SYSTEMS			
		Overland Flow	Rapid Infiltration Land Treatment Systems	Slow Rate Treatment Systems	Other Land Treatment Systems	Septic Tank/Soil Absorption System (Multiple Families)	Preapplication Treatment or Storage	Total Containment Ponds	Aquaculture/Wetlands/ Marsh Systems	Aquifer Recharge	Direct Reuse	Pressure Sewers, Septic Tank Effluent Pump (STEP)	Small Diameter Gravity Sewers	Pressure Sewers, Grinder Pump (GP)	Vacuum Sewers
I	Connecticut		1			2									
	Maine			1		7						1		1	
	Massachusetts		2	1									1		
	New Hampshire	1			1	3								1	
	Rhode Island														
	Vermont			1		1							1	3	
II	New Jersey		1			1	1							2	2
	New York	2	3			2						3	16	16	3
	Puerto Rico														
	Virgin Islands														
III	Delaware		1			2							1	2	
	Washington DC														
	Maryland	2	1	5	2		4	1	2			2	3	27	6
	Pennsylvania		1	5	1	2	2		2			6	13	15	
	Virginia	3	1	1							5	3	2	2	2
	West Virginia											6	5	10	11
IV	Alabama			2								1	3	2	
	Florida	1	2	20						1	3				2
	Georgia	2	1	18								2	1		
	Kentucky	1		2		2			2			2	5	4	2
	Mississippi	11		2								1	1	3	
	North Carolina			21								1	1	2	
	South Carolina		1	9									2		1
	Tennessee	2		6			4					5	10	6	3
V	Illinois	4	1	3	1	1	3				5	4	21	3	
	Indiana			1		2						3	14	4	5
	Michigan	4	4	14		7	13		1				2	3	
	Minnesota		1	15		9	15					6	7	4	
	Ohio			1			1					3	2	6	
	Wisconsin		17	1	1		9					2	4	2	
VI	Arkansas			5	1		2					1	2	10	
	Lousiana	6		2			2		1			1	1	1	
	New Mexico			6			5								
	Oklahoma			31			16	29							
	Texas	1	1	11	2		10	1			4	3	1	6	
VII	Iowa			2			3		3			2	1	3	
	Kansas		1	16			9	27	1						
	Missouri	14		25					2			6	15	20	
	Nebraska		2	5				32	1						
VIII	Colorado			2	1		1			1				1	
	Montana		3	8				5							
	North Dakota			6				17				3	14	2	
	South Dakota		8	1			3	7	5		1	1	2	1	
	Utah			3			2								
	Wyoming		2	2				3							
IX	Arizona	1	1	12			1	1	4		1	1	1		
	California	2	14	20		3	25	1	3		2	7	4		1
	Guam		1			1									
	Trust Territories					5							2		
	Hawaii			2				1							
	Nevada		5	6			5	4	1						
	N. Marianas Islands														
X	Alaska					2	1					1	1		2
	Idaho		4	9	1	1	10	1	1			2	2		
	Oregon		1	6	1		9	1	2			5	4		1
	Washington			3	2	1	4	2	1			3	2	1	
TOTAL		**57**	**81**	**312**	**14**	**54**	**160**	**133**	**32**	**2**	**21**	**87**	**167**	**163**	**41**

APPENDIX F

CURRENT STATUS OF MODIFICATION/REPLACEMENT (M/R) GRANT CANDIDATES BY STATE

APPENDIX F

CURRENT STATUS OF MODIFICATION/REPLACEMENT (M/R) GRANT CANDIDATES BY STATE

STATE	COMMUNITY	TECHNOLOGY	M/R GRANT AWARDED	GRANT IN REVIEW	POTENTIAL M/R PROJECT	SUBJECT OF LITIGATION
Alabama	Littleville	Intrachannel clarifiers			X	
	Leighton	Intrachannel clarifiers			X	
	Phil Campbell	Intrachannel clarifiers			X	
Arizona	Flagstaff	Combined chlorination/clarification	X			
	Phoenix	Gas scrubbers			X	
Arkansas	Paragould	Aquaculture	X			
California	Fallen Leaf Lake	Vacuum collection system	X			
	Gustine	Aquaculture		X		
	Hayward	Fluidized-bed reactors		X		
	Manila	Community leach field		X		
	Nevada City	Vacuum-assisted sludge drying beds		X		
	Reedley	Rapid infiltration		X		
	San Lorenzo	Pressure leach field for effluent disposal	X			
	Ventura Nyeland Acres	Septic tank effluent pump collection system controllers and pumps		X		
	West Point	Community leach field				X
Colorado	Idaho Springs	UV disinfection			X	
	Longmont	Breakpoint chlorination			X	
Florida	Ft. Lauderdale	Mechanical composting		X		
Idaho	Grangeville	Draft tube aeration	X			

APPENDIX F (Continued)

CURRENT STATUS OF MODIFICATION/REPLACEMENT (M/R) GRANT CANDIDATES BY STATE

STATE	COMMUNITY	TECHNOLOGY	M/R GRANT AWARDED	GRANT IN REVIEW	POTENTIAL M/R PROJECT	SUBJECT OF LITIGATION
Illinois	Hanover	Sand filters	X			
	Sauget	Powdered activated carbon treatment (PACT)				X
Indiana	Portage	Vacuum-assisted sludge drying beds	X			
Kansas	Bonner Springs	Intrachannel clarifiers		X		
	Dodge City	Odor control			X	
Kentucky	Berea	Intrachannel clarifier	X			
	Elkton	Side channel clarifier	X			
Maine	Presque Isle	UV disinfection	X			
	Sabattus	UV disinfection	X			
Massachusetts	Fall River	Self-sustaining incineration	X			
	Southbridge	Sludge composting			X	
	Wayland	Septage treatment	X			
	Westboro	Sludge composting			X	
	Williamstown	Grinder pumps/pressure sewers	X			
Michigan	Ionia	Rotating biological contactors		X		

APPENDIX F (Continued)

CURRENT STATUS OF MODIFICATION/REPLACEMENT (M/R) GRANT CANDIDATES BY STATE

STATE	COMMUNITY	TECHNOLOGY	M/R GRANT AWARDED	GRANT IN REVIEW	POTENTIAL M/R PROJECT	SUBJECT OF LITIGATION
Minnesota	Moorehead	Active ozone disinfection	X			
	Northfield	UV disinfection	X			
	North Koochiching	UV disinfection	X			
	Pine River	Sludge composting and rotatating biological contactors			X	
	Rochester	Biological phosphorus removal		X		
Mississippi	Newton	Overland flow			X	
Missouri	Excelsior Springs	Overland flow	X			
	Gallatin	Intrachannel clarifiers		X		
	Little Blue Valley	Intrachannel clarifiers			X	
Montana	Bozeman	Rapid infiltration	X			
Nebraska	Scotts Bluff	Microscreen ponds	X			
Nevada	Henderson	Rapid infiltration basins			X	
	Incline Village	Wetlands	X			
New Jersey	Stafford	Vacuum collection system controllers				X
New Mexico	Santa Fe	Draft tube aerators	X			
New York	Lawrence	Community mound systems	X			
	Plattsburgh	In-vessel composting		X		
North Carolina	Washington	Draft tube aerators	X			
	Starr	Draft tube aerators	X			

APPENDIX F (Continued)

CURRENT STATUS OF MODIFICATION/REPLACEMENT (M/R) GRANT CANDIDATES BY STATE

STATE	COMMUNITY	TECHNOLOGY	M/R GRANT AWARDED	GRANT IN REVIEW	POTENTIAL M/R PROJECT	SUBJECT OF LITIGATION
	Burlington	Powdered activated carbon treatment	X			
	Greensboro	Starved air incinerator	X			
	Greenville	Counter current aeration		X		
	Henderson	Dual digestion	X			
	Pilot Mountain	Jet aeration oxidation ditches		X		
North Dakota	Antler	Community mound systems	X			
	Buchanan	Community mound systems		X		
	Churchs Ferry	Community mound systems	X			
	Clifford	Community mound systems	X			
Ohio	Akron	In-vessel composting	X			
	Bedford Heights	Powdered activated carbon treatment (PACT)	X			
	Clyde	Intrachannel clarifiers	X			
	Ironton	UV disinfection		X		
	Lake County	Composting	X			
	North Olmstead	Powdered activated carbon treatment	X			
Oregon	South Point	Rotating biological contactors	X			
	Cove Orchard	Community leach field	X			
	Dexter	Recirculating sand filter	X			
	Eugene	Spray irrigation		X		
Rhode Island	Cranston	Draft tube aerators	X			
South Carolina	Durban Creek	Intrachannel clarifier		X		
South Dakota	Mina Lake	Community mound systems		X		
	White Rivers	Total containment lagoons	X			

APPENDIX F (Continued)

CURRENT STATUS OF MODIFICATION/REPLACEMENT (M/R) GRANT CANDIDATES BY STATE

STATE	COMMUNITY	TECHNOLOGY	M/R GRANT AWARDED	GRANT IN REVIEW	POTENTIAL M/R PROJECT	SUBJECT OF LITIGATION
	Pollock	Rapid infiltration system			X	
Tennessee	Claiborne Co.	Counter current aeration		X		
	Memphis	Biofilters	X			
Texas	El Paso	Draft tube aerators	X			
	Levelland	Aeration/oxidation ponds	X			
Virginia	Buena Vista	Vacuum-assisted sludge drying beds		X		
Washington	Black Diamond	Wetlands	X			
	Elbe	Community mound systems	X			
West Virginia	Crab Orchard-MacArthur	Draft tube aerators				X
Wisconsin	Cambellsport	Rapid infiltration	X			
	Hayward	Rapid infiltration				X
	Wittenberg	Rapid infiltration	X			
	Whitewater	Rotating biological contactors		X		

APPENDIX G

LIST OF WASTEWATER TECHNOLOGY PUBLICATIONS

APPENDIX G

LIST OF WASTEWATER TECHNOLOGY PUBLICATIONS

TITLE	DOCUMENT ORDER SOURCE
Current Wastewater Technology Foldouts	
Alternative Wastewater Collections Systems: Practical Approaches	1,2,3,4
Aquaculture: An Alternative Wastewater Treatment Approach	1,2,3,4
The Biological Aerated Filter: A Promising Biological Process	1,2,3,4
Biological Phosphorous Removal: Problems and Remedies	1,2,3,4
Composting: A Viable Method of Resource Recovery	1,2,3,4
Counter-Current Aeration: A Promising Process Modification	1,2,3,4
Disinfection with Ultraviolet Light	1,2,3,4
Hydrograph Controlled Release Lagoons: A Promising Modification	1,2,3,4
Innovative and Alternative (I/A) Technology: Wastewater Treatment to Improve Water Quality and Reduce Cost	1,2,3,4
Innovations in Sludge Drying Beds: A Practical Technology	1,2,3,4
Intermittent Sand Filtration	1,2,3,4
Intrachannel Clarification: A Project Assessment	1,2,3,4
In-Vessel Composting	1,2,3,4
Land Application of Sludge: A Viable Alternative	1,2,3,4
Land Treatment Silviculture: A Practical Approach	1,2,3,4
Large Soil Absorption Systems: Design Suggestions for Success	1,2,3,4

TITLE	DOCUMENT ORDER SOURCE
Current Wastewater Technology Foldouts (Continued)	
Less Costly Wastewater Treatment for Your Town	1,2,3,4
Methane Recovery: An Energy Resource	1,2,3,4
Natural Systems for Wastewater Treatment in Cold Climates	1,2,3,4
Operation of Conventional WWTP in Cold Weather	1,2,3,4
Overland Flow An Update: New Information Improves Reliability	1,2,3,4
Planning Wastewater Facilities for Small Communities	1,2,3,4
Rapid Infiltration: Plan, Design, and Construct for Success	1,2,3,4
Rotating Biological Contactors	1,2,3,4
Sequencing Batch Reactors: A Project Assessment	1,2,3,4
Side-Streams in Advance Waste Treatment Plants: Problems and Remedies	1,2,3,4
Small Wastewater Systems: Alternative Systems for Communities and Rural Areas	1,2,3,4
Vacuum-Assisted Sludge Dewatering Beds: An Alternative Approach	1,2,3,4
Vacuum-Assisted Sludge Drying (Update)	1,2,3,4
Wastewater Stabilization Ponds: An Update on Pathogen Removal	1,2,3,4
Water Reuse Via Dual Distribution Systems	1,2,3,4
Wetlands Treatment: A Practical Approach	1,2,3,4

TITLE	DOCUMENT ORDER SOURCE
Wastewater Research Reports	
Alternative On-Site Wastewater Treatment and Disposal Systems on Severely Limited Sites; EPA/600/2-86/116; PB87-140992/AS	1,5,6
Alternative Sewer Studies; EPA/600/2-85/133; PB86-131224/AS	1,5,6
Alternative Sewer Systems in the United States; EPA/600/D-84/095; PB84-177815/AS	1,5,6
Autothermal Thermophilic Aerobic Digestion in the Federal Republic of Germany; EPA/600/D-85/194; PB85-245322/AS	1,5,6
Biological Phosphorus Removal - Technology Evaluation; EPA/600/J-86/198; PB87-152559	1,5,6
Characterization of Soil Disposal System Leachates; EPA/600/2-84/101; PB84-196229/AS	1,5,6
Costs of Air Pollution Abatement Systems for Sewage Sludge Incinerators; EPA/600/2-86/102; PB87-117743/AS	1,5,6
Control of Pathogens in Municipal Wastewater Sludge EPA 625/10-89/016	5
Design Manual Municipal Wastewater Stabilization Ponds; EPA/625/1-83-015	1,5,6
Determination of Toxic Chemicals in Effluent from Household Septic Tanks; EPA/600/2-85/050; PB85-196798	1,5,6
Emerging Technology Assessment of Phostrip, A/O and Bardenpho Process for Biological Phosphorus Removal; EPA/600/2-85/008; PB85-165744/AS	1,5,6
Evaluation of Anaerobic, Expanded-Bed Contactors for Municipal Wastewater Treatment; EPA/600/D-86/120; PB86-210648/AS	1,5,6

TITLE	DOCUMENT ORDER SOURCE
Wastewater Research Reports (Continued)	
Evaluation of Color Infrared Aerial Surveys of Wastewater Soil Absorption Systems; EPA/600/2-85/039; PB85-189074/AS	1,5,6
Fine Pore Aeration Systems; EPA 625/1-89/023	5
Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment; EPA 625/1-88/022	5
Forecasting On-Site Soil Absorption System Failure Rates; EPA/600/2-86/060; PB86-216744/AS	1,5,6
Full-Scale Studies of the Trickling Filter/Solids Contact Process; EPA/600/J-86/271; PB87-168134/AS	1,5,6
Handbook Estimating Sludge Management Costs; EPA/625/6-85/010; PB86-124542/AS	1,5,6
Handbook Septage Treatment and Disposal; EPA/625/6-84-009	1,5,6
Implemention of Sequencing Batch Reactors for Municipal Treatment; EPA/600/D-84/022; PB84-130400/AS	1,5,6
In-Vessel Composting of Municipal Wastewater Sludge; EPA 625/8-89/016	5
Innovative and Alternative Technology Assessment Manual; EPA/430/9-78/009; (MCD-53)	1,3,6
Land Application of Municipal Sludge; EPA/625/1-83/016	1,5,6
Large Soil Absorption Systems for Wastewaters from Multiple Home Developments; EPA/600/2-86/023; PB86-164084/AS	1,5
Municipal Sludge Composting Technology Evaluation; EPA/600/J-86/139; PB87-103560/AS	1,5,6

TITLE	DOCUMENT ORDER SOURCE
Wastewater Research Reports (Continued)	
Odor and Corrosion Control in Sanitary Sewerage Systems and Treatment Plants; EPA 625/1-85/018	5
Process Design Manual for Land Application of Municipal Sludge; EPA/625/1-83-016	1,5,6
Process Design Manual for Land Treatment of Municipal Wastewater; EPA/625/1-81-013 and Supplement; EPA/625/1-81-013a	1,5,6
Small Diameter Gravity Sewers: An Alternative Wastewater Collection Method for Unsewered Communities; EPA/600/2-86/0270; PB86-173622/AS	1,5
Start-up and Operation of Chemical Process Technologies in the Municipal Sector - the Carver-Greenfield Process for Sludge Drying; EPA 430/09-89/007; PB90-161902/AS; IRC 137U	1,6
Status of Porous Biomass Support Systems for Wastewater Treatment: An Innovative/Alternative Technology Assessment; EPA/600/2-86/019; PB86-156965/AS	1,5
Summary Report: Fine Pore (Fine Bubble) Aeration Systems; EPA/625/8-85/010	1,5,6
Technology Assessment of Aquaculture Systems for Municipal Wastewater Treatment; EPA/600/2-84/145; PB84-246347/AS	1,5,6
Technology Assessment of Sequencing Batch Reactors; EPA/600/2-85/007; PB85-167245/AS	1,5,6
Technology Assessment for Wetlands for Municipal Wastewater Treatment; EPA/600/2-84/154; PB85-106896/AS	1,5,6

TITLE	DOCUMENT ORDER SOURCE
Wastewater Research Reports (Continued)	
Technology Evaluation of Sequencing Batch Reactors; EPA/600/J-85/166	1,5,6
Technology Evaluation of the Dual Digestion System; EPA/600/J-86/150; PB87-116802/AS	1,5,6
The Lubbock Land Treatment System Research and Demonstration Project: Volume IV, Lubbock Infection Surveillance Study; EPA/600/2-86/027D; PB86-173622/AS	1,5
Toxic and Priority Organics in Municipal Sludge Land Treatment Systems; EPA/600/2-86/010; PB86-150208/AS	1,5
Trickling Filter/Solids Contact Process: Full-Scale Studies; EPA/600/2-86/046; PB86-183100/AS	1,5,6
Wastewater Treatment Plant Instrumentation Handbook; EPA/600/8-85/026; PB86-108636/AS	1,5,6
Other Wastewater Publications	
A Water and Wastewater Manager's Guide for Staying Financially Healthy; EPA/430-09-89-004	1,2,3
Building Support for Increasing User Fees; EPA/430/09-89-006	1,2,3
Design Manual: On-Site Wastewater Treatment and Disposal Systems; EPA/625/1-80-012	1,3,5
Is Your Proposed Wastewater Project Too Costly? Options for Small Communities	1,2,3
It's Your Choice - A Wastewater Treatment Handbook for the Local Official	1,2

TITLE	DOCUMENT ORDER SOURCE
Other Wastewater Publications (Continued)	
Looking at User Charges - A State Survey and Report	1,2,3
Management of On-Site and Small Community Wastewater Systems; EPA/600/8-82-009	1,2,3,5
Planning Wastewater Management Facilities for Small Communities; EPA/600/8-80-030	1,2,3,5
Touching All the Bases: A Financial Handbook for Your Wastewater Treatment Project	1,2
Value Engineering for Small Communities; EPA 430/09-87/011; PB88-184858/AS; IRC 122U	1,6
Wastewater Technology Videotapes	
Sand Filters (9 minutes)	1,2
Small Diameter Effluent Sewers (11 minutes)	1,2
Planning Wastewater Facilities for Small Communities (15 minutes)	1,2
Upgrading Small Community Wastewater Treatment (20 minutes)	1,2

TITLE	DOCUMENT ORDER SOURCE

Document Order Sources:

(1) Environmental Quality Instructional Resources Center (IRC)
The Ohio State University
1200 Chambers Road - Room 310
Columbus, OH 43212
314-292-6717

(2) National Small Flows Clearinghouse
258 Stewart Street
Morgantown, WV 26506
1-800-624-8301

(3) EPA-OMPC-MFD (WH-595)
401 M Street, S.W.
Washington, DC 20460

(4) EPA Regional Offices
For telephone numbers, see Appendix D

(5) EPA Center for Environmental Research Information (CERI)
26 West Martin Luther King Drive
Cincinnati, OH 45268
513-569-7562

(6) National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
703-487-4650

Note: Depending upon ordering source, there may be a charge for some documents.