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Project Summary

Design Information on Fine Pore Aeration Systems

Field studies were conducted over several years at municipal wastewater treatment plants employing fine pore diffused aeration systems. These studies were designed to produce reliable information on the performance and operational requirements of fine pore devices under process conditions. The results of the studies provided critical input to a comprehensive treatise on the subject entitled "Design Manual - Fine Pore Aeration Systems." This document, prepared by the American Society of Civil Engineers' (ASCE) Oxygen Transfer Committee, was published in 1989 and is available to the public.

The above studies resulted in 16 separate contractor reports as part of a cooperative research agreement with ASCE. Abstracts of each contractor report are given here.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of field studies that are fully documented in separate reports (see Project Report ordering information at back).

Introduction

In 1985, the U.S. Environmental Protection Agency (EPA) funded a cooperative research agreement with ASCE to evaluate the existing data base on fine pore diffused aeration systems in both clean and process waters, conduct field studies at a number of municipal wastewater treatment facilities employing fine pore aeration, and prepare a comprehensive design manual on the subject. This manual, entitled "Design Manual - Fine Pore Aeration Systems," was completed in September 1989 and was first distributed at the 62nd Annual Water Pollution Control Federation Conference in San Francisco, CA, October 1989. Copies of the Design Manual (EPA report no. EPA/625/1-89/023) are available from the EPA Center for Environmental Research Information (CERI), Cincinnati, OH 45268. An earlier "Summary Report - Fine Pore (Fine Bubble) Aeration Systems" was published in October 1985 to document the early findings of this study and summarize the state-of-the-art at that time. This Summary Report is also available from CERI (EPA/625/8-85/010).

Data generated on the field studies conducted at municipal wastewater treatment plants were important sources of information for the Design Manual. These studies were undertaken as contracts under the cooperative research agreement. They were selected primarily to address technical issues and data base inadequacies identified in the 1985 Summary Report.

The field studies were composed primarily of investigations on the performance of various fine pore diffuser generic types in process waters (i.e., under field conditions), diffuser operating characteristics and fouling rates, and operation and maintenance requirements including cleaning of partially fouled diffusers. In addition, an interplant diffuser fouling evaluation was carried out to relate observations and trends to wastewater characteristics and process operating conditions. A corollary interplant study used microbiologically based procedures to describe biofouling phenomena on fine pore aeration devices and to determine whether biofilm characteristics could be related to diffuser performance parameters. Several studies were conducted at facilities having sufficient prior information to enable case histories to be developed. Finally, a survey of European experience with fine pore rigid porous plastic diffusers provided additional information to supplement the North American data base on this class of diffusers.

Each of the above field studies resulted in a separate contractor report. These reports are referenced throughout the Design Manual.

A brief abstract of each contractor field report is given below. These abstracts are intended to provide sufficient information to identify those reports that may be of individual interest as supplements to the Design Manual.

Abstract of Reports

1. *"Fine Pore Diffuser System Evaluation for the Green Bay Metropolitan Sewerage District" (EPA/600/R-94/093) by J.J. Marx*

The Green Bay Metropolitan Sewerage District retrofitted two quadrants of their activated sludge aeration system with fine pore ceramic disc and plasticized PVC perforated membrane tube diffusers to evaluate and compare the savings in energy use with that of the sparged turbine aerators originally installed. Because significant diffuser fouling was expected, the two diffuser types were closely monitored over an 18-mo period. The oxygen transfer efficiencies (OTEs) of the full-scale systems were measured by using off-gas techniques. The effects of diffuser fouling and the effectiveness of diffuser cleaning procedures were evaluated in the laboratory with the use of dynamic wet pressure (DWP) and steady-state clean water oxygen transfer tests.

Although significant fouling was encountered on both types of diffusers, cost-effective cleaning procedures were developed. The ceramic disc diffusers provided better long-term performance with periodic cleaning than did the plasticized PVC membrane tube diffusers, which irreversibly lost OTE with time in use. Collectively, the fine pore diffuser systems provided a 30% savings in electrical power use compared with that of the original sparged turbine aerators.

2. *"Oxygen Transfer Efficiency Surveys at the Jones Island Treatment Plants, 1985-1988" (EPA/600/R-94/094) by R. Warriner*

Ceramic plate diffusers were among the earliest forms of fine pore diffusers used for oxygen transfer in activated sludge treatment. They have been successfully used for over 60 yr in the Jones Island West Plant of the Milwaukee Metropolitan Sewerage District (MMSD) and in the MMSD Jones Island East and MMSD South Shore Plants since 1935 and 1974, respectively. Results of off-gas sampling surveys carried out at the original Jones Island West Plant, which was scheduled for rehabilitation in 1988-90, and in the newly rehabilitated East Plant are reported. Twenty-one (21) basin surveys were carried out in the West Plant and 30 in the East Plant.

For the West Plant basins, equipped with the original ceramic plate diffusers installed in 1923 and 1924, the median value of standardized oxygen transfer efficiency under field conditions, αF(SOTE), was 11.8% at 15 ft of submergence. For the East Plant basins, which contained new plate diffusers installed in 1983, the median value of αF(SOTE) was 15.3% at a submergence of 14 ft.

Cleaning history was noted for each basin at the time of each off-gas survey. A relationship between time-in-service since cleaning and OTE was not established in these surveys; however, a short-term improvement in OTE following cleaning was indicated in the East Plant. Because alpha was unknown and varied widely between surveys, and possibly during surveys, it was difficult to separate alpha effects from fouling effects on OTE. For the most part, extended periods of basin operation had no measurable effect on performance.

3. *"Fine Pore Diffuser Fouling: The Los Angeles Studies" (EPA/600/R-94/095) by M.K. Stenstrom and G. Masutani*

Fine pore diffuser evaluations conducted at three different wastewater treatment plants located in the greater Los Angeles area are described. The overall goal of the study was to evaluate the performance of fine pore diffusers by using selected cleaning methods for extended periods of time at selected treatment plants. The major part of this study was conducted at the Whittier Narrows Water Reclamation Plant, operated by the Los Angeles County Sanitation Districts. This study evaluated fine pore ceramic disc and dome aeration systems using HCl acid gas cleaning and a ceramic dome aeration system without acid gas cleaning over a 25-mo period. A second study, smaller in scope and effort, was conducted at the Valencia Water Reclamation Plant (also operated by the Districts). This study evaluated fine pore rigid porous plastic disc diffusers over a 13-mo period. A third study, also smaller in scope and effort than the Whittier Narrows study, was conducted at the Terminal Island Wastewater Treatment Plant, operated by the City of Los Angeles. In this study, the performance of a perforated membrane tube system and a parallel nonrigid porous plastic tube system was evaluated over a 12-mo period.

The principal indicator of the performance of the different aeration systems was OTE, as measured by off-gas analysis. For the Whittier Narrows study, changes in diffuser characteristics were also reported.

The fine pore ceramic disc aeration system at Whittier Narrows, which was acid gas cleaned, performed better than both the ceramic dome system that was acid gas cleaned and the control ceramic dome aeration system that received no cleaning. Part of the differences in performance between the disc system and the two dome systems was attributable to mechanical problems with the domes. The cleaned and uncleaned dome systems had comparable OTEs during the study. Relatively consistent performance was observed for the rigid porous plastic disc system at Valencia over the 13-mo study period. The tube systems at Terminal Island exhibited high variability because of operational differences, and one tube system experienced significant fouling over a relatively brief period. The variability in performance of the several aeration systems during day-to-day changes in plant load and operating mode was an important finding of the study.

4. *"Oxygen Transfer Studies at the Madison Metropolitan Sewerage District Facilities" (EPA/600/R-94/096) by W.C. Boyle, A. Craven, W. Danley, and M. Rieth*

Field studies at the Madison Metropolitan Sewerage District facilities were conducted over a 3-yr period to obtain long-term data on the performance of fine pore aeration equipment in municipal wastewater service. The studies were conducted on several basins in the East Plant containing ceramic domes installed in 1977 and two sets of first-pass basins in the West Plant containing newly installed ceramic discs.

The performance of the domes was excellent even after 10 yr of service. This conclusion was based on OTE as measured by off-gas analysis, alpha calculations, and diffuser characterization. Reasons for excellent performance included routine maintenance of the diffusers and the use of high quality ceramic diffusers and hardware. Evidence was presented for this plant that operation at high solid retention times (SRTs), i.e., low food-to-microorganism loadings, which produced complete nitrification, resulted in higher αF(SOTE) values than did operation at low SRTs. Results of studies on the impact of diffuser cleaning and hydraulic flow patterns on performance are also reported.

The ceramic discs in the West Plant were monitored for 800 days. In that period, no perceptible decrease in diffuser performance was observed based on αF(SOTE) measurements. The mean first-pass αF(SOTE) values over 800 days were about 11.5% at a submergence of approximately 15 ft. The mean-weighted αF(SOTE) for all three passes ranged from 12.1% to 15.3%. The West Plant aeration system was operated at high SRT values to achieve complete nitrification. As seen in the East Plant, some evidence of improved aeration performance [αF(SOTE)] with increased SRT was noted. Brief examinations of diffusers in these low-loaded basins suggested that fouling was not a problem in this plant.

5. *"Long-Term Performance Characteristics of Fine Pore Ceramic Diffusers at Monroe, Wisconsin" (EPA/600/R-94/097) by D.T. Redmon, L. Ewing, H. Melcer, and G.V. Ellefson*

A study of the fine pore aeration system at the Monroe, WI, Wastewater Treatment Facility was conducted over a 2-yr period to monitor the OTE and fouling tendencies of ceramic discs with four different permeabilities. The plant, which treats a mixture of municipal and industrial wastewaters, consisted of three two-pass aeration tanks, each containing two independent aeration grids per pass. In 10 of the 12 passes, disc diffusers with a specific permeability of 26 were employed. The remaining two grids contained disc diffusers with specific permeabilities of 38 and 50. OTE was monitored by off-gas analysis. Fouling tendencies and effectiveness of cleaning were determined by using diffusers obtained from separate pilot test headers, which were then analyzed in the laboratory.

Results of this study indicated that the clean diffuser bubble release vacuum (BRV) and its coefficient of variation were better measures of effective pore size of ceramic diffusers than was permeability. Although OTE increased with decreasing permeability (increasing clean diffuser BRV) in clean water, the operating conditions of the plant and its wastewater characteristics appeared to influence αF(SOTE) more than did effective pore size. Although fouling was visually observed on the ceramic discs under certain operating conditions, it had little apparent effect on αF(SOTE), BRV, or DWP. Little correlation was shown between fouling tendencies and permeability at this plant over the range of permeabilities tested.

Inexpensive cleaning procedures were used in the laboratory. These involved a combination of high pressure water spraying with or without liquid acid treatment and/or brushing, followed by additional spraying. Laboratory cleaning resulted in nearly complete restoration of the diffusers' original characteristics.

6. *"Case History of Fine Pore Diffuser Retrofit at Ridgewood, New Jersey" (EPA/600/R-94/098) by J.A. Mueller and P.D. Saurer*

In April 1983, the Ridgewood, NJ, Wastewater Treatment Plant was partially retrofitted from a coarse bubble to a fine pore ceramic dome diffused aeration system. The process was also modified from a contact stabilization to a tapered aeration activated sludge treatment regime. A case history of plant and aeration system performance from 1981-1986 is presented. Extensive aeration studies were conducted on the fine pore system in 1985 and 1986 to observe changes in OTE with time and evaluate cleaning frequency requirements to maintain efficiency at a viable level. An economic evaluation including bid prices, maintenance costs, and payoff period based on power savings is included. Over the 6 yr of study, the coarse bubble system exhibited an average αF(SOTE) of 4.8% (at a submergence of approximately 13 ft) with an average αF value of 0.55. Over 3.75 yr of operation, the fine pore dome diffusers produced an average αF(SOTE) of approximately 9.5% (at a submergence of approximately 14 ft) during normal operation with an average αF value of 0.4. A significant improvement in effluent quality with respect to nitrification in the summer months was observed with the fine pore system when compared with the coarse bubble system, which achieved no nitrification.

7. *"Oxygen Transfer Efficiency Surveys at the South Shore Wastewater Treatment Plant, 1985-1987" (EPA/600/R-94/099) by R. Warriner*

Ceramic plate diffusers were among the earliest forms of fine pore diffusers used for oxygen transfer in activated sludge treatment. They have been successfully used for over 60 yr in the Jones Island West Plant of the Milwaukee Metropolitan Sewerage District (MMSD) and in the MMSD Jones Island East and MMSD South Shore

Plants since 1935 and 1974, respectively. Twenty basin off-gas sampling surveys were carried out at the South Shore Plant, yielding a median αF(SOTE) value of 18.9% at a submergence of 15 ft. When evidence of nitrification was present, αF(SOTE) values were higher than on other survey dates. A diffuser cleaning history was obtained at the time of each off-gas survey; however, no correlation between the number of months-in-service since cleaning and αF(SOTE) could be identified.

8. *"Fine Pore Diffuser Case History for Frankenmuth, Michigan" (EPA/600/R-94/100) by T.A. Allbaugh and S.J. Kang*

In 1986, the Frankenmuth, MI, Wastewater Treatment Facility, which treats a mixture of municipal and industrial wastewaters, was retrofitted with fine pore ceramic discs. Significant flows received by the plant from a brewery and a large restaurant produced high soluble organic loadings on the aeration tanks. Off-gas tests were conducted over a 1-yr period on 13 different days to determine the effects of acid gas cleaning and operation at elevated airflow rates on the performance of the fine pore system.

The rate of diffuser fouling at the plant was significant. Acid gas cleaning was typically initiated when the DWP reached 16 to 18 in. (water gage). Gas cleaning was effective in controlling the DWP at this plant, but little effect was observed on OTE.

9. *"Off-Gas Analysis Results and Fine Pore Retrofit Information for Glastonbury, Connecticut" (EPA/600/R-94/101) by R.G. Gilbert and R.C. Sullivan*

The Town of Glastonbury, CT, retrofitted one of its two aeration tanks in 1983 with rigid porous plastic tube fine pore diffusers in a spiral roll configuration. These tubes were placed on existing swing arms used for the original coarse bubble spargers. An extensive aeration system performance evaluation using off-gas analysis was conducted involving six separate investigations over a 35-mo period. The αF(SOTE) measurements averaged 6.6.% at a submergence of approximately 12 ft; this represents a 57% increase in OTE compared with the average 4.2% αF(SOTE) value estimated for the original coarse bubble spargers. The retrofit simple payback period was less than 18 mo.

10. *"Off-Gas Analysis Results and Fine Pore Retrofit Case History for Hartford, Connecticut" (EPA/600/R-94/105) by R.G. Gilbert and R.C. Sullivan*

In 1986, the Hartford Water Pollution Control Plant in South Meadows, CT, was retrofitted from a coarse bubble, spiral roll system to a fine pore ceramic dome, grid-configured system. Four of six aeration tanks were involved in the retrofit. Extensive off-gas studies were conducted over 18 mo to evaluate the performance of the new system and to determine the effectiveness of diffuser cleaning. The αF(SOTE) measurements averaged 10.0%; this is more than double the average αF(SOTE) value estimated for the original coarse bubble, spiral roll aeration equipment. The retrofit simple payback period was less than 3 yr.

11. *"The Measurement and Control of Fouling in Fine Pore Diffuser Systems" (EPA/600/R-94/102) by E.L. Barnhart and M. Collins*

The purposes of this study were to define the efficiency of various methods of cleaning fine pore diffusers and to develop a methodology that could be used to evaluate the efficiency of several cleaning techniques. Fouled ceramic dome diffusers from the North Texas Municipal Water District were cleaned with these techniques, and the improvement in OTE was measured.

The domes were reinstalled in the aeration tanks and withdrawn at various time intervals thereafter. The deterioration in OTE was then noted. The cleaning techniques were repeated, and the improvement in transfer was recorded.

Overall, the domes from the North Texas Plant did not exhibit severe fouling. Low-pressure hosing appeared to be as effective as any other method in cleaning the domes. The domes deteriorated promptly after they were reintroduced into the aeration tank, and αF(SOTE) stabilized.

The technique of using an offline aeration tank for studying diffuser cleaning techniques provided mixed results. The comparative effectiveness of cleaning techniques appeared to be properly described in this small test tank. The breakdown of slimes and fouling materials during dome transportation and handling, however, may have caused an underestimation of the degree of fouling.

12. *"Fouling of Fine Pore Diffused Aerators: An Interplant Comparison" (EPA/600/R-94/103) by C.R. Baillod and K. Hopkins*

The objective of this study was to assess the relative fouling tendencies of fine bubble diffusers at nine activated sludge treatment plants. A secondary objective was to relate fouling to mixed liquor and process parameters. A standardized diffuser test header containing four removable diffusers was installed at each of the participating plants. Diffusers were periodically removed and tested for OTE, BRV, DWP, foulant accumulation, and increase in OTE after acid cleaning.

The results of this study showed that an increase in BRV was generally accompanied by a decrease in OTE, an accumulation of foulant, and an increase in DWP loss through the diffuser. The plants were classified according to their degree of fouling (as measured by BRV). The classifications were heavily fouling (Jones Island West, WI and Frankenmuth, MI), moderately fouling (Green Bay, WI, North Texas, TX, and Whittier Narrows, CA), fouling (South Shore, WI and Portage Lake, MI), and lightly fouling (Madison, WI and Monroe, WI). Observations at individual plants suggested that high organic loads enhanced fouling, although interplant comparisons suggested a weak association between fouling and organic load.

13. *"Case History Report on Milwaukee Ceramic Plate Aeration Facilities" (EPA/600/R-94/106) by L.A. Ernest*

Ceramic plate diffusers were among the earliest forms of fine pore diffusers used in activated sludge treatment. They have been used for 60 yr in the Jones Island West Plant of the Milwaukee Metropolitan Sewerage District (MMSD) and in the MMSD Jones Island East and MMSD South Shore Plants since 1935 and 1974, respectively. The Jones Island East Plant aeration basins were completely rehabilitated in 1982-83, and the West

Plant basins were scheduled for rehabilitation in 1989-90. In both cases, alternative fine pore systems were evaluated and ceramic plate diffusers were again selected. Three separate case history reviews are presented: the Jones Island East Plant, the Jones Island West Plant, and the South Shore Plant.

All of the historical reviews discuss the conceptual designs and selection processes involved for each of the plants. The review of the Jones Island West Plant covers the period from the start-up of the activated sludge plant in 1915 through the planned rehabilitation in 1989-90. The Jones Island East Plant history begins with start-up in 1930 and discusses in some detail the comparisons of optional fine pore diffuser layout patterns with the original ridge-and-furrow full floor diffuser coverage pattern. The East Plant review also includes the history of the 1982-83 retrofit to diffuser plates installed in concrete containers placed at right angles to the basin flow and with the diffuser surface flush with the floor. In the South Shore history, the concept of the layout and design of the concrete containers is discussed. The South Shore Plant history covers the time from initial plant start-up in 1974 to 1988 and describes how the results at South Shore formed the basis for the Jones Island East and West Plant rehabilitations.

14. *"Survey and Evaluation of Porous Polyethylene Media Fine Bubble Tube and Disk Aerators" (EPA/600/R-94/104) by D.H. Houck*

Historically, although alternative media materials have been employed over the years with varying degrees of success, the principal fine pore diffuser medium has been porous ceramic. In the early to mid-1970s, diffusers with rigid porous plastic media were installed in secondary treatment plants in Europe, primarily in Finland and Sweden. To document operation and maintenance experiences with rigid porous plastic media diffusers, 11 plants in Europe were visited.

Observations made at each site and the review of on-site, long-term operation and maintenance information are discussed. In general, it was concluded that the rigid porous plastic diffusers were performing satisfactorily. It was also concluded that the use of ferrous sulfate for precipitation of phosphorus in wastewater treatment facilities was the most adverse fouling condition encountered in applications of these diffusers. The most effective cleaning method for this type of fouling was found to be formic acid gas treatment followed by an air/water backwash with specialized equipment. The effectiveness of similar cleaning for biofouling was inconclusive. The design and application of aeration systems using rigid porous plastic media diffusers appeared to be similar to those employing ceramic media diffusers.

15. *"Investigations Into Biofouling Phenomena in Fine Pore Aeration Devices" (EPA/600/R-94/107) by W. Jansen, J.W. Costerton, and H. Melcer*

Microbiologically based procedures were used to describe biofouling phenomena on fine pore aeration devices and determine whether biofilm characteristics could be related to diffuser process performance parameters. Fine pore diffusers were obtained from five municipal wastewater treatment plants in Wisconsin, one in Michigan, and one in California. Biofilm thickness and carbohydrate content were measured as was each film's ability to retain air bubbles. Scanning electron microscopy (SEM) procedures were used to examine biofilm structure. The effect of four different laboratory cleaning procedures on diffuser characteristics was also measured. A parallel laboratory-scale investigation simulated microbially induced fouling of small-scale diffusers and the effects of bleach and acid cleaning.

Microbial fouling of the diffusers occurred irregularly at all seven sites. The thickness of a biofilm and its distribution over a diffuser appeared to vary randomly. Highly structured biofilms were observed by SEM and were thought to interfere with the passage of air bubbles such that the size of the bubbles released from a fouled diffuser surface was probably not the same as those from a cleaned and unfouled diffuser surface. Two types of biofoulant were observed. One appeared to reduce OTE with minimal impact on diffuser headloss as measured by DWP. The second appeared to increase DWP with minimal impact on OTE. Although measurements of biofilm thickness and carbohydrate content did not appear to be directly related to measurements of OTE, DWP, and BRV, the microbiological measurements contributed to an improved understanding of diffuser operation and performance.

The laboratory investigations showed that the progressive development of a bacterial biofilm on the surface of a fine bubble diffuser could increase the size of bubbles released from the fouled surface. Five-percent bleach was found to be more effective in removing the biofilm than 14% HCl on both artificially induced and naturally occurring biofilms, and a combination of bleach followed by acid returned the diffusers to their original condition.

16. *"Characterization of Clean and Fouled Perforated Membrane Diffusers" (EPA/600/R-94/108) by L. Ewing and J. Kitzinger*

Laboratory analyses were conducted on plasticized PVC perforated membrane tube diffusers after varying periods in service at two different municipal wastewater treatment facilities. One set of diffusers from Cedar Creek, NY, was in service for 26 mo. The other set from the Green Bay Metropolitan Sewerage District facility was in service for approximately 47 mo. Tests on the membranes included DWP, flow uniformity, weight, dimensions, tensile modulus of elasticity, hardness, and OTE.

Results of this brief study indicate a significant increase in DWP and decrease in flow uniformity and OTE after service. Following membrane cleaning, measurements indicated: a nonrecoverable reduction in DWP below that of a new membrane; an increase in specific gravity, durometer hardness, and circumferential modulus of elasticity; and a decrease in weight, length, and strain at failure. These findings were in good agreement with other field tests performed with these diffusers.

The full reports were submitted in partial fulfillment of Cooperative Research Agreement CR812167 by the American Society of Civil Engineers under the partial sponsorship of the U.S. Environmental Protection Agency.

This Project Summary was authored by The Steering Subcommittee of the ASCE Committee on Oxygen Transfer. ASCE headquarters are in New York, NY 10017.

***Richard C. Brenner** is the EPA Project Officer (see below).*

The complete reports are entitled:

"Fine Pore Diffuser System Evaluation for the Green Bay Metropolitan Sewerage District," (Order No. PB94-200813; Cost: $27.00, subject to change) ;

"Oxygen Transfer Efficiency Surveys at the Jones Island Treatment Plants, 1985-1988," (Order No. PB94-200821 Cost: $19.50, subject to change) ;

"Fine Pore Diffuser Fouling: The Los Angeles Studies," (Order No. PB94-200839; Cost: $27.00, subject to change) ;

"Oxygen Transfer Studies at the Madison Metropolitan Sewerage District Facilities," (Order No. PB94-200847; Cost: $27.00, subject to change) ;

"Long-Term Performance Characteristics of Fine Pore Ceramic Diffusers at Monroe, Wisconsin," (Order No. PB94-200854; Cost: $27.00, subject to change) ;

"Case History of Fine Pore Diffuser Retrofit at Ridgewood, New Jersey," (Order No. PB94-200862; Cost: $27.00, subject to change) ;

"Oxygen Transfer Efficiency Surveys at the South Shore Wastewater Treatment Plant, 1985-1987," (Order No. PB94-200870; Cost: $17.50, subject to change) ;

"Fine Pore Diffuser Case History for Frankenmuth, Michigan," (Order No. PB94-200888; Cost: $19.50, subject to change) ;

"Off-Gas Analysis Results and Fine Pore Retrofit Information for Glastonbury, Connecticut," (Order No. PB94-200896; Cost: $27.00, subject to change) ;

"Off-Gas Analysis Results and Fine Pore Retrofit Case History for Hartford, Connecticut," (Order No. PB94-200938; Cost: $27.00, subject to change) ;

"The Measurement and Control of Fouling in Fine Pore Diffuser Systems," (Order No. PB94-200904; Cost: $27.00, subject to change) ;

"Fouling of Fine Pore Diffused Aerators: An Interplant Comparison," (Order No. PB94-200912; Cost: $19.50, subject to change) ;

"Case History Report on Milwaukee Ceramic Plate Aeration Facilities," (Order No. PB94-200946; Cost: $19.50, subject to change) ;

"Survey and Evaluation of Porous Polyethylene Media Fine Bubble Tube and Disk Aerators," (Order No. PB94-200920; Cost: $19.50, subject to change) ;

"Investigations into Biofouling Phenomena in Fine Pore Aeration Devices," (Order No. PB94-200953; Cost: $19.50, subject to change) ; and

"Characterization of Clean and Fouled Perforated Membrane Diffusers," (Order No. PB94-200961; Cost: $17.50, subject to change).

These reports will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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