DISCUSSION

Of: **Effect of Anaerobic and Anoxic Selectors on Oxygen Transfer in Wastewater,** M.J. Fisher, W.C. Boyle, **71,** 84 (1999).

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The result of this study is interesting because a carefully planned and successfully executed experimental study did not find the result that was expected. The basic hypothesis was that degradation of surfactants is the primary reason for the typical observation that the α factor, which quantifies the dirty water effect on oxygen transfer efficiency, rises from the influent end to the effluent end in aeration tanks. Accordingly, it was expected that a bacterial population conditioned by anaerobic or anoxic selector zones in an activated-sludge system might degrade surfactants differently, either in mechanism or in speed, from the action of a population developed in a system without selectors. Moreover, the authors hoped that this difference would be reflected in differences in the α factors observed in the two types of systems.

The experimental situation was highly favorable for observing an effect of selectors. A modification program lasting a number of months at a large plant allowed the authors to observe full-scale serpentine aeration tanks that had been modified to include an anaerobic–anoxic selector zone for phosphorus removal and to observe another set of tanks in the same plant that differed only by not having the modification. In this way, they could be confident that the presence or absence of the selectors was likely to be the reason for any difference between the α observations in the two systems.

They also used a pilot-scale system with parameters that were as close as possible to those of the full-scale systems, operating the pilot-scale system both with and without a simulation of the selectors. However, the α values for the pilot-scale plants level off at approximately 0.5, whereas for the full-scale plants they continue upward into the range of 0.6 to 0.8, suggesting that the simulation performed by the pilot plant was in some respects imperfect.

No difference was observed between the systems with and without selectors. Not only did the two types of systems display α factors in the same ranges, as mentioned in the Abstract, but the authors' final plot shows how closely the α values in the systems with and without selectors match each other at all corresponding locations. The authors attribute this to the fact that nitrification was occurring in all these systems and raise the possibility that adding selectors in a nonnitrifying plant might measurably affect α.

A number of questions and comments are suggested by this study, as follows. Some additional information about the pilot-scale experimental situation would have been helpful for readers interested in doing similar work or in understanding this study in detail. For example, (a) How was the influent to the pilot-scale system obtained? Was it simply pumped out of the primary effluent channel at the Madison (Wisconsin) Metropolitan Sewerage District Nine Springs treatment facility (MMSD)? (b) Was a special small collecting hood used for the offgas measurements in the aerated tanks in the pilot-scale system? (c) Was any consideration given to making measurements of surfactant concentrations in addition to α? This would have tested the authors' hypothesis more directly than the measurements of oxygen uptake rate and dissolved oxygen. (d) Because a series of small tanks is hydraulically quite different from a long serpentine tank and might be expected to suffer some degree of settling of the mixed liquor, was some sort of mixing performed in the tanks of the pilot-scale plant, especially in the tanks that were not aerated? (e) The one diffuser in each aerated tank of the pilot-scale system resulted in a diffuser density of 11% there, but what was the density in the full-scale system? A few words about these topics, perhaps with indications of which thesis (Fisher's or Karlovich's) to consult for specific items, are appreciated.

In a similar spirit, is there a publicly available reference for the phosphorus removal process used at MMSD? The particular characteristics of this test evidently follow from having large anaerobic and small anoxic zones, as might be expected when achieving phosphorus removal is the purpose of establishing the selector system, but the combination of return activated sludge and denitrified recycle (ARCY) flows implies some degree of exchange of organisms between the aerobic and anaerobic zones through the anoxic zone, which might be expected to make the microbial population of these anaerobic zones intermediate between that of an anoxic zone and that of an anaerobic zone in which such mixing does not occur (as in some other processes for phosphorus removal).

Had the diffuser in tank 4 been cleaned since the start of operation in 1985? Likewise, have the authors considered the likelihood that the diffusers in grids 3 and 4 will suffer relatively rapid fouling by being immediately downstream of the unaerated zones?

Has any consideration been given to the possibility that surfactants may play a lesser role than is typically assumed? Admittedly, there is great intuitive appeal in the familiar picture of surfactant molecules collecting on the surface of a bubble and interfering with gas exchange, but it seems worth noting that the Hwang and Stenstrom (1985) cited by the authors found that surfactant concentration seemed to be less important, at least by statistical measures, than bacterial oxygen uptake rate as a predictor of α. Unfortunately, they did not present any mechanism to explain the observed correspondence.

Is it possible that the observations in plant 4 were influenced by some other component of the cannery waste instead of surfactants? What kind of cannery was it? Are there any plans to attempt comparable measurements in a nonnitrifying plant?

Please explain the footnote of Table 2; the Parameter column heading has a footnote explaining the TBOD and BOD abbreviations, although the table only lists the tests for total phosphorus, ammonia, and NO_x–N.

Let us close by saying that this excellent study seems to be strong evidence against the hypothesis with which the authors started and that it suggests that some other physical or chemical mechanism may be more important in explaining the variations of α.

Acknowledgments

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References

Hwang, H.J., and Stenstrom, M.K. (1985) Evaluation of Fine-Bubble Alpha Factors in Near Full-Scale Equipment. *J. Water Pollut. Control Fed.*, **57**, 11142.

Closure

M.J. Fisher, W.C. Boyle

The authors wish to thank these discussers for their comments and questions. It must be emphasized that this work was not conducted as a fundamental research effort, but rather took advantage of existing pilot-plant and full-scale operations to observe oxygen transfer with and without selectors designed to enhance phosphorus removal. The components in wastewater, both entering the system and produced by biomass within the process, that affect oxygen transfer are not clearly known. It is speculated that surface-active compounds play an important role in this phenomenon, but other chemical constituents may also be contributors. Clearly, whatever the components are, they remain present in small concentrations even in highly treated effluents. To date, there have been little data reported on the effect of selectors on downstream oxygen transfer. It can be speculated that selectors, which transform and sorb a variety of waste constituents, may enhance oxygen transfer.

The MMSD plant produced a high quality effluent before addition of selectors designed to enhance biological phosphorus removal. It was not anticipated that the addition of selectors would affect oxygen transfer efficiencies to any great extent insofar as the system already generated a high degree of wastewater stabilization. That, in fact, turned out to be the case.

The authors offer the following responses to specific questions raised about this study. The primary effluent was provided to the first tank of each plant from a splitter box (Fisher, 1996). A portion of the primary effluent from the pump that fed the MMSD autosampler was diverted to the splitter box. The splitter box was a 208-L (55-gal.) steel drum elevated above the pilot plants. Two pipes exited the splitter box at midheight and a third from the base of the drum. An overflow weir was placed just below the top of the splitter box. The two midheight pipes provided flow to the pilot plants, and the bottom pipe allowed the splitter box to be drained. Flow from the splitter box was caused by gravity, and flow rates were controlled using 1.3-cm (0.5-in.) polyvinyl chloride ball valves. Flow to the splitter box was in excess of that discharged to the pilot plants to maintain constant head, thus maintaining a constant flow to the pilot plants.

The hood used for collecting the offgas was constructed of 1.3-cm (0.5-in.) thick plywood with a diameter of 0.7-m (28 in.). This diameter was slightly larger than the diameter of the aeration basin, thus ensuring complete coverage of the aeration basin. The hood was lacquer sealed to protect the wood from the moisture from the aeration basins. The offgas collection line was located in the middle of the hood. Also located near the offgas collection line was a smaller air line for monitoring the air pressure under the hood. Flexible vinyl tubing was used for both lines. The connection points between the lines and hood were sealed with silicon caulking to prevent air leaks in the analyzer during operation. A schematic of the test setup is provided in Fisher (1996).

Mixing in the anaerobic and anoxic tanks was provided by 75 W (0.1 hp) Dayton gear motors operating at 66 r/min. A 6.3-mm (0.25-in.) stainless steel shaft with 16.5-cm (6.5-in.) propellers was attached to each motor. Each shaft had three propellers to ensure proper mixing. To prevent vortexing, two wooden baffles were placed opposite each other in each tank. The aeration equipment in the aeration basins provided the necessary mixing as determined by sampling suspended solids with reactor depth. No solids were found to accumulate within any of the pilot reactors.

The diffuser density in the pilot-scale system was 11%. Table 3 of the paper provides information regarding the diffuser density in the full-scale systems (with and without selectors). Typically, for fine-pore diffusers, the oxygen transfer efficiency will increase with increased diffuser density, all other parameters remaining constant.

Because the intent of the study was to evaluate the effect of biological phosphorous removal on oxygen transfer in WWTPs, the authors believed that the measurement of operational factors such as oxygen uptake rates and dissolved oxygen would be most beneficial for this purpose. However, a direct measurement of surfactant concentrations would prove useful in a more detailed study of the mechanism behind surfactant interference with oxygen transfer. The measurement of surfactant concentrations was beyond the intended scope of this investigation.

Both Fisher (1996) and Karlovich (1994) provide discussion regarding the operation of the pilot plants. Fisher's thesis also provides additional discussion pertaining to the performance of oxygen transfer studies in the pilot plant.

The full-scale plant at MMSD uses a modified University of Cape Town configuration for biological phosphorus removal whereby mixed liquor from the anoxic zone is recycled to the anaerobic selector (ACRY) and return activated sludge is recycled to the anoxic zone. No aerobic mixed liquor is recycled (see Figure 2 in paper). Reference to the description and performance of this system can be found in Barbeau et al. (1995).

The diffusers in tank 4 had not been cleaned since the start of operation in 1985. However, it should be noted that a separate study that was conducted concurrently with the oxygen transfer testing found that the diffusers in tank 3 had not been significantly fouled beyond the first two diffuser grids since the start of operation in 1985. It is reasonable to expect that the diffusers in tank 4 would have been in similar condition.

Diffuser fouling was considered during the course of the pilot-plant study. Before beginning operation of the pilot plant, dynamic wet pressure testing was performed on each diffuser to establish a clean diffuser performance baseline. It is expected that as a diffuser fouls, the diffuser dynamic wet pressure will increase. Dynamic wet pressure tests of the pilot-plant diffusers were performed periodically during operation of the pilot plant for approximately 1 year. In that short time, no significant increases in the diffuser dynamic wet pressures were observed. On the other hand, in situ testing of diffusers in grid 3 of the full-scale plant (Figure 2) indicated that dynamic wet pressure values initially increased to a range of 33 to 43 cm (13 to 17 in.) after startup of the enhanced biological phosphorus removal system but have held constant over the past 2 years. This matter is being further evaluated in a separate study of the full-scale facility.

The readily biodegradable substrate (simple sugars) available from beet processing cannery wastewater had a significant influence on the observations in plant 4. The cannery waste, combined with inadequate diffuser airflow, caused the rapid depletion of available oxygen in the first pass, resulting in an anaerobic zone in plant 4. The low dissolved oxygen concentrations and readily available biodegradable substrate created conditions favorable for enhanced biological phosphorous removal. Dissolved oxygen concentrations recovered, and enhanced biological phosphorous removal ceased in plant 4 once the cannery waste was no longer being received.

As discussed above, the intent of this study was not to validate or explore the mechanism behind surfactant interference with oxygen transfer. Rather the intent of this study was to evaluate the effect of biological phosphorous removal (anaerobic and anoxic selectors) on oxygen transfer and how the inclusion of selectors might affect the design and operation of wastewater treatment plants. The importance of surfactants in depressing oxygen transfer in fine-pore aeration systems is not yet clearly understood. It is known, however, that high quality effluents as measured by biochemical oxygen demand, suspended solids, nitrogen, and phosphorus concentrations still produce α values less than 1.0, and often less than 0.9 to 0.8. Two effluents with similar, and low, concentrations of these contaminants may exhibit distinctively different α values for comparable aeration systems. A more fundamental study is needed to better identify the constituents in wastewater effluents that may affect transfer in these highly stabilized effluents.

Table 2—Summary of analytical methods utilized.

Parameter	Method
$TBOD_5$	*Standard Methods* 5210
BOD_5 — inhibited	*Standard Methods* 5210
Total phosphorous	U.S. EPA Method 600/4-79-020, 365.1 colorimetric, automated ascorbic
NH_3—N	U.S. EPA Method 600/4-79-020, 350.1 automated phenate
NO_x—N	*Standard Methods* 4500
Suspended solids	*Standard Methods* 2540D

A study to evaluate oxygen transfer in parallel trains of a nonnitrifying plant with and without selectors would be interesting. None is planned at MMSD, and the authors are not aware of such a study being planned or executed. Such a study would provide more data on the influence of selectors on oxygen transfer, but a number of field investigations will be required to provide a confident database. There is no better way to find the answer, however, than through a carefully executed fundamental study to evaluate the role of trace components in wastewater that influence oxygen transfer.

Finally, Table 2 of the paper was in error. Please see the corrected Table 2.

References

Barbeau D.S.; Murphy, S.B.; Sprouse, G.B.; Reusser, S.; Boyle, W.C.; Karlovich, W.M.; and Rubens, T.F. (1995) The Use of Pilot Testing and EBPR Modeling for Alternative Development and Process Selection of an EBPR Retrofit. *Proc. Water Environ. Fed. 68th Annu. Conf. Exposition,* Miami Beach, Fla., 1, 535.