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Project Summary

Status of Porous Biomass Support Systems for Wastewater Treatment: An Innovative/Alternative Technology Assessment

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A study was conducted to assess the emerging wastewater treatment technology of porous biomass support systems (PBSS). These systems use large numbers of small, open-cell or reticulated polyurethane foam pads to support high concentrations of biomass in an aeration basin. The technology is being marketed by Simon-Hartley Ltd. in England (CAPTOR) and Linde AG (Linpor) in West Germany.

Visits were made to laboratories of the original process developers in the United Kingdom and in West Germany. Data were gathered through interviews with academic and commercial investigators in both countries and through a review of all available literature and data, both published and unpublished.

The study concluded that PBSS technology does not presently qualify as a fully developed technology, but that it does offer some attractive potential benefits and very little risk for some intended applications. Thorough pilot-plant and full-scale studies are needed to answer many remaining questions about the process and to provide design data and guidance.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Clean Water Act of 1977 and the Municipal Construction Grant Amendments of 1981 include provisions that encourage the use of innovative and alternative (I/A) wastewater treatment technologies. One emerging technology is the use of porous biomass support systems (PBSS) for biological wastewater treatment. These systems use large numbers of small, open-cell or reticulated polyurethane foam pads to provide surface area for high concentrations of biomass growth in the aeration basin. As the pads move through the wastewater, the wastewater also moves through the pads, bringing nutrients, oxygen, and particulate matter into contact with the biological growth, which may either be attached to the pad material or entrapped within the pores.

The basic technology has been developing along two different lines. The British developer, Simon-Hartley Ltd.,* has concentrated on external pad cleaning devices to waste excess biomass and avoid the use of secondary clarification (the CAPTOR process). The West German developer, Linde AG, uses no pad cleaning and has developed their process for secondary treatment along the lines of conventional activated sludge using a combination of suspended and attached

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

biomass with final clarifier and sludge recirculation for suspended biomass control (the Linpor process).

To evaluate this emerging technology, visits were made to the laboratories of the original process developers in the United Kingdom and in West Germany, and the status of research and development efforts was discussed with both academic and commercial investigators in both countries. Several pilot- and full-scale development projects were also visited in the United Kingdom, West Germany, and the United States. All available literature, both published and unpublished, was reviewed. The final report is the result of these efforts, most of which took place during the spring and summer of 1984.

CAPTOR Process Description

CAPTOR is a proprietary process marketed by Simon-Hartley Ltd. The CAPTOR system uses 25- x 25- x 12.5-mm pads of reticulated polyurethane foam. Pore size is controlled at approximately 11.8 pores/lineal cm (30 pores/in.), with a pad porosity of 97%. The normal design level for pad concentration is 40,000/m^3, a volume concentration of 31%. This concentration has been determined to be near the practical limit for consistent mixing. Screens are used to prevent the pads from leaving the aeration basin. Trial and error development has resulted in the adoption of 4-mesh screens (5.13 mm square apertures) large enough to limit the peak hydraulic loading to less than 78 $m^3/m^2 \cdot hr$ based on gross submerged screen area.

Pads are withdrawn from the aeration basin as desired, and most of the accumulated biomass is removed by a pad cleaner (Figure 1). As the pads move up the conveyor, some interstitial water drains by gravity. Additional water is removed by a pre-squeeze roller followed by a tight squeeze between two rollers, which removes the biomass as a concentrated waste stream.

Aeration system design has proved to be a critical element. The development work has shown the necessity of producing discrete upward and downward currents that are strong enough to ensure adequate mixing and keep the pads suspended and moving through the liquid. These currents are critical where fine bubble aeration systems are used and in aeration basins of high aspect ratios.

Linpor Process Description

The Linpor process is being developed by Linde AG. The pads used in the Linpor process are more heterogeneous in size and shape than those used in the CAPTOR process. An average pad is a parallelepiped with dimensions of about 12 mm x 12 mm x 12 mm. Some pads may be as small as 10 mm, and others may have a dimension up to 17 mm. The pads are of open cell type foam and have about 15 to 20 pores/lineal cm (38 to 50/in.). The Linpor process may use a 10% to 40% concentration of pads (by volume), with most of the present investigations being carried out near the 40% level. Screens are placed across the aeration basin exit to prevent loss of pads. The Linpor process uses no external pad cleaning device, relying instead on the turbulence and shearing action in the aertion basins to control the amount of excess biomass.

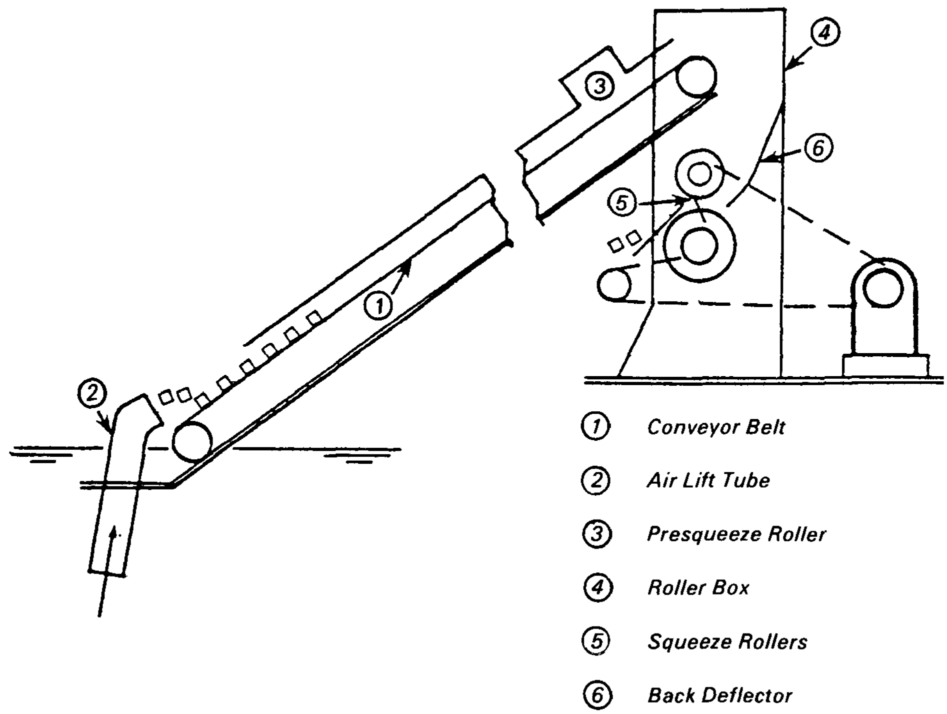

Figure 1. Diagram of CAPTOR pad cleaner.

In the Linpor-C process for carbonaceous BOD removal, biomass is grown both on the pads and in suspension. The pads retain a large quantity of biomass in the aeration basin, reducing the solids loading on the secondary clarifier and maintaining a higher effective mixed liquor solids concentration. A portion of the settled biomass is recirculated to the aeration basin as in a conventional activated sludge process.

The Linpor-N process for effluent polishing and nitrification was the first application conceived for the foam pads. Linpor-N is operated with a feed BOD of 20 to 30 mg/L, dissolved oxygen (DO) levels of 4 to 5 mg/L, and no final clarifier or sludge recirculation.

CAPTOR Development Status

The early development with PBSS was performed at the University of Manchester, United Kingdom. As a result of this early work, a patent for the CAPTOR process was applied for and granted in the United Kingdom and later in the United States.

At the time of this report, CAPTOR experience in the United States was limited to two pilot plants and one small-scale industrial system. The pilot units at Marion, Illinois, had a pad concentration of 40/L for only 2 of the 8 weeks for which usable data exist. Pad biomass solids during the entire period ranged from 45 to 70 mg/pad. Total BOD removals at 40 pads/L were near 50% at loadings to the CAPTOR system of roughly 0.6 to 0.9 kg BOD/kg pad solids·day. The pilot system at Downingtown, Pennsylvania, contained an average of 42 pads/L and operated at a hydraulic residence time of about 1 hr. Pad solids averaged 71 mg/pad resulting in an effective mixed liquor suspended solids

(MLSS) concentration of only 2990 mg/L. Comparison of the data from the CAPTOR section alone with those at Marion showed a worse performance at Downingtown at about the same F/M loading and strength of feed. The industrial system was equipped with a final clarifier because of the amount of growth anticipated from the 1000 to 2500 mg/L COD in the influent wastewater. During the period for which most of the analytical data are available, sludge was being recycled, and pad mixing conditions within the reactor were very poor, with the majority of the pads collected in a large floating raft at the surface of the aeration basin. Most of the treatment (except on occasions that are not well documented) was being accomplished by the suspended biomass from the recycled sludge. Though some valuable lessons can be learned from the U.S. experience, it would be grossly unfair to judge the potential of the CAPTOR process on this basis alone.

The most comprehensive full-scale investigation of the CAPTOR process was at Freehold, United Kingdom. This plant has two two-stage CAPTOR lanes, with CAPTOR in the first quarter, and activated sludge in the final three quarters. CAPTOR was intended to allow upgrading of the existing plant to provide nitrification. The CAPTOR units were predicted to remove 75% of the incoming BOD of 144 mg/L, allowing the activated sludge systems to operate at increased solids retention times while keeping acceptable solids loadings to the existing final clarifiers. The study began in September 1982, and data have been available from early November 1983 to the time of this report. Throughout the course of the study, plastic strips in the incoming primary effluent have caused problems with the pad cleaners and effluent screens. Pad distribution within the basins was poor, with frequent periods of large rafts of floating pads. The CAPTOR system did not receive the design complement of pads (40/L) until March 1985, when the aeration and flow patterns were modified. Before this time, one lane operated with 28 pads/L, and the other operated with only 16/L.

The BOD removal correlation developed by Simon-Hartley Ltd. from previous pilot-scale work was as follows:

$$\text{Percent BOD Removal} = 100 \exp(-0.67\ F/M)$$

This correlation has appeared in several of their publications, but the effluent BOD values represent BOD remaining after 1 hr of settling, which is not indicative of CAPTOR operation without a final clarifier.

Linpor Development Status

The first application of PBSS by Linde AG was for the purpose of nitrification in a 1-m^3 reactor receiving secondary effluent from a domestic wastewater treatment process. These studies did not use final clarification or sludge return, and they achieved a substantial degree of nitrification at hydraulic residence times of less than 2 hr. Other pilot studies to assess nitrification of secondary effluent at Poing, West Germany, have shown that dissolved oxygen (DO) played an important role, probably because of diffusional limitations. DO values below 5 mg/L were observed to affect nitrification rates.

Pilot-plant studies have also been conducted with the Linpor-C process at several treatment facilities in West Germany. Biomass growth and attrition within the pads reached equilibrium with good biomass activity, as measured by the specific oxygen uptake rate within the pads. Visual examination of the pads during the site visits revealed that the particle biomass was fresh and dark brown throughout the particle volume, with no signs of anaerobosis within the pad structure. Parallel tests in activated sludge units with and without pads revealed lower sludge volume indices and improved effluent quality in two different pilot studies at 30% and 40% pad volumes.

Currently, at least two full-scale studies using Linpor-C are being conducted in West Germany. At Freising, Linpor pads (25% by volume) have been added to one tank for the primary purpose of reducing sludge volume index. Other research at Munich I is being conducted in both pilot plants and full-scale tanks. Results of this work were not available at the time this assessment was written.

Conclusions

Visits to operating facilities and a review of the available data indicated that PBSS technology is not fully developed. The manufacturers and suppliers of this technology would not recommend installation of a system at present without thorough pilot-plant investigation to provide design data and guidance. The promising applications of this technology appear to include:

a) Pretreatment systems for high-strength waste,
b) Upgrading of overloaded activated sludge plants, especially those that are habitually plagued by filamentous bulking, and
c) Additions to existing systems to produce nitrification without the need for additional clarifiers.

A tremendous number of questions about PBSS technology remain. Fundamental research questions on the characteristics of the PBSS biomass exist. Evaluation of the effect of pad cleaning rates on biomass physiology, specific substrate uptake, sludge yields, sludge dewaterability, biomass hold-up, and free suspended solids would yield further insights into CAPTOR performance. Both CAPTOR and Linpor require extra attention to the quality and reliability of preliminary and primary treatment processes to avoid severe operation and maintenance problems with the pad cleaners (CAPTOR) and retaining screens (both processes). Furthermore, design requirements to ensure proper pad mixing and distribution need to be better defined.

Linpor-C is almost ready to become classified as one of the regular members of the available spectrum of treatment systems capable of consistently meeting secondary treatment requirements. The CAPTOR process, used as the sole biological process without final clarifiers, is not ready to become so classified. PBSS should be treated as an innovative technology with a degree of risk that varies with the specific application. PBSS projects receiving consideration for I/A funding should be those for which the risks are minimized through careful consideration of the specific details of the project. As the technology continues to evolve and be better understood, it should be possible to attempt some projects with higher risk factors, provided that high potential benefits are possible as well.

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The complete report, entitled "Status of Porous Biomass Support Systems for Wastewater Treatment: An Innovative/Alternative Technology Assessment," (Order No. PB 86-156 965/AS; Cost: $16.95, subject to change) will be available only from:
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