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Project Summary

Full-Scale Evaluation of Activated Bio-Filter Wastewater Treatment Process

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The City of Helena, Montana, utilizes a relatively new biological treatment concept called the activated bio-filter (ABF) process* for secondary treatment of its municipal wastewater. The four major components of the ABF process are a redwood media trickling filter-type tower called a bio-cell, a bio-cell recirculation system, a short-term activated sludge aeration tank, and a conventional secondary clarifier.

A field evaluation study was initiated at Helena with the primary objective of developing year-round, full-scale operating and performance data on the ABF process. The experimental program was conducted so that organic and hydraulic loadings imposed during the winter months approached the manufacturer's recommended design criteria. Other objectives included defining process energy requirements and sludge production values.

Three different process loading regimens were investigated over a 17-month time frame. These regimens corresponded roughly to (1) one-half of the manufacturer's recommended loadings on both the tower and the aeration tank, (2) one-half of the recommended loading on the aeration tank and the full recommended loading on the aeration basin, and (3) the full recommended loadings on both the tower and aeration basin (winter months). Because of available wastewater flows and plant facility operating constraints, the desired 50 and 100 percent loadings in reality averaged closer to 40 and 80 percent of the manufacturer's recommended design criteria.

Excellent overall treatment performance was observed throughout the study. Phase-average final effluent BOD_5 and total suspended solids (TSS) concentrations ranged from 14 to 24 mg/L and from 10 to 27 mg/L, respectively. In general, effluent residuals increased with increasing process loadings. EPA's monthly-average, 30 mg/L secondary treatment requirement was exceeded during one 5-week stretch for TSS only because of operational procedures. Potential savings were indicated in the energy requirements of the ABF process as compared with those of the conventional activated sludge process. The ability to handle short-term peaks in the excess sludge production rate was determined to be a critical factor in the performance of ABF sludge treatment and disposal facilities.

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

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

Introduction

Biological wastewater treatment options are generally classified as either suspended growth processes or attached growth processes. The ABF process is a modification thereof combining characteristics of both types of processes. Marketed by Neptune Microfloc, Inc., the process can be designed to achieve carbonaceous removal, i.e., secondary treatment only or carbonaceous removal plus nitrification. This project evaluated a full-scale municipal ABF installation in a secondary treatment application.

The ABF process consists of a tower or bio-cell, a bio-cell recirculation system, a short-term aeration basin, and a secondary clarifier. The bio-cell contains redwood media stacked in a tower over which primary effluent is distributed in similar fashion to other stationary attached growth processes. In addition, settled sludge from the secondary clarifier is returned to mix with primary effluent and bio-cell underflow in the recirculation wet well, resulting in a "suspended growth" mixed liquor that is also continuously distributed over the redwood media. Originally, the bio-cell was the only biological unit in the ABF process. Later, a modification was incorporated that utilizes short-term aeration of the mixed liquor following the bio-cell, as at Helena. Intermediate clarification between the bio-cell and aeration basin is not provided.

Limited full-scale performance information was available for the ABF process operated at Neptune Microfloc's rated design conditions. This 2-year research study was undertaken at Helena to expand the existing data base.

Plant Description and Experimental Schedule

The Helena plant serves a population of about 28,000 and has no major industrial contributors. The plant's design flow rate is 22,700 m^3/day (6.0 mgd), and the plant was operating at about 11,350 m^3/day (3.0 mgd) during the study.

A schematic of a typical ABF system is depicted in Figure 1. The Helena plant flow diagram is shown in Figure 2. Of special note is the fact that the plant does not have any sludge treatment or disposal recycle streams, thereby eliminating this potential adverse effect on wastewater efficiency. The original Helena plant upgrade, incorporating just the bio-cell towers, bio-cell recirculation system, and secondary clarifiers, was completed in 1975. Subsequently, BOD_5 and TSS secondary treatment effluent limitations were violated during cold weather months (November-May). The addition of the short-term aeration basin in 1978 resulted in consistent permit compliance from then on. Research project data collection began in December 1978 per the schedule shown in Table 1.

The Helena ABF bio-cell consists of two towers, structurally and functionally independent. Valves are available to operate one tower at a time. The redwood-slat media dry specific surface area is 46 m^2/m^3 (14 ft^2/ft^3). A larger, undetermined operating specific surface area occurs because of biomass buildup. The flow distribution system uses fixed "vari-flow" nozzles manufactured by Neptune Microbloc, Inc.

The short-term aeration basin is divided into two compartments connected by an overflow opening. During Periods C and D, one aeration compartment was removed from service to approach design detention times with existing wastewater flow rates. Aeration is provided by three positive displacement blowers through a grid system of static tube diffusers. The identically-sized blowers were provided with various sized pulleys to change air supply possibilities.

Final clarifier settled sludge (suction sludge in Figure 1) is returned by gravity to the recirculation wet well. Waste sludge (hopper sludge in Figure 1) from each clarifier is diverted to a separate wet well and pumped to the primary clarifier for co-thickening with raw sludge and removal to the sludge handling system.

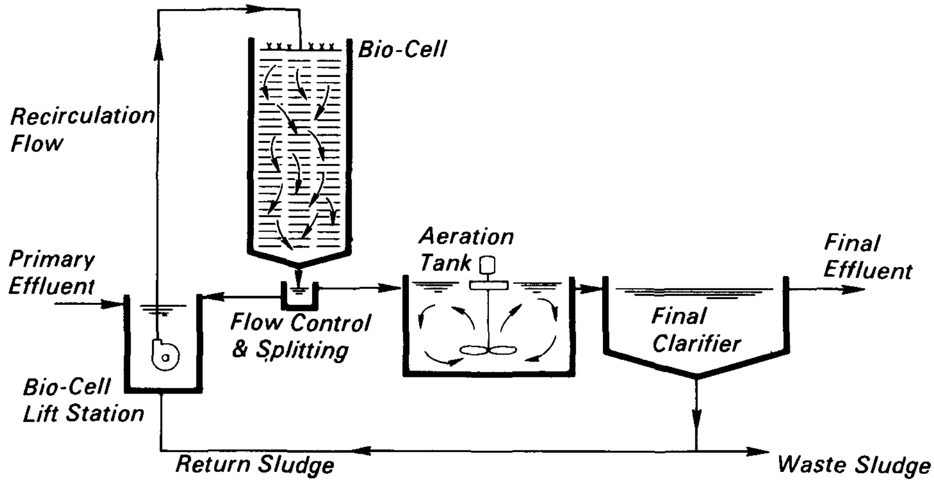

Figure 1. *Schematic of typical activated bio-filter system.*

Process Operational Controls

Special emphasis was made to achieve optimum process control to ensure that observed performance was not being limited by operational constraints. Numerous operational variables exist for the ABF process. Four controls that were believed to relate most directly to performance were selected for monitoring and adjustment during the research program: (1) volume of direct bio-cell mixed liquor recirculation, (2) aeration basin dissolved oxygen (DO) level, (3) secondary clarifier return sludge flow rate, and (4) system suspended sludge mass controlled by the sludge wasting rate. Direct bio-cell recirculation is an operational control typical of trickling filter systems. The other three are controls typically associated with activated sludge systems.

Control of the direct bio-cell recirculation rate was based on Neptune Microfloc's recommended bio-cell hydraulic loading range of 41 to 224 L/min/m^2 (1.5 to 5.5 gpm/ft^2). To stay within this range, limited recirculation adjustments were necessary. When both bio-cell towers were in service (Period A), the direct recirculation rate averaged 92 percent of the primary effluent flow rate and provided an average hydraulic loading of 81 L/min/m^2 (2.0 gpm/ft^2). No direct recirculation was used during all other periods when only one bio-cell tower was in service because the bio-cell hydraulic loading remained in the satisfactory range of 98 to 106 L/min/m^2 (2.4 to 2.6 gpm/ft^2) with just the mixed primary effluent and return sludge feed to the tower.

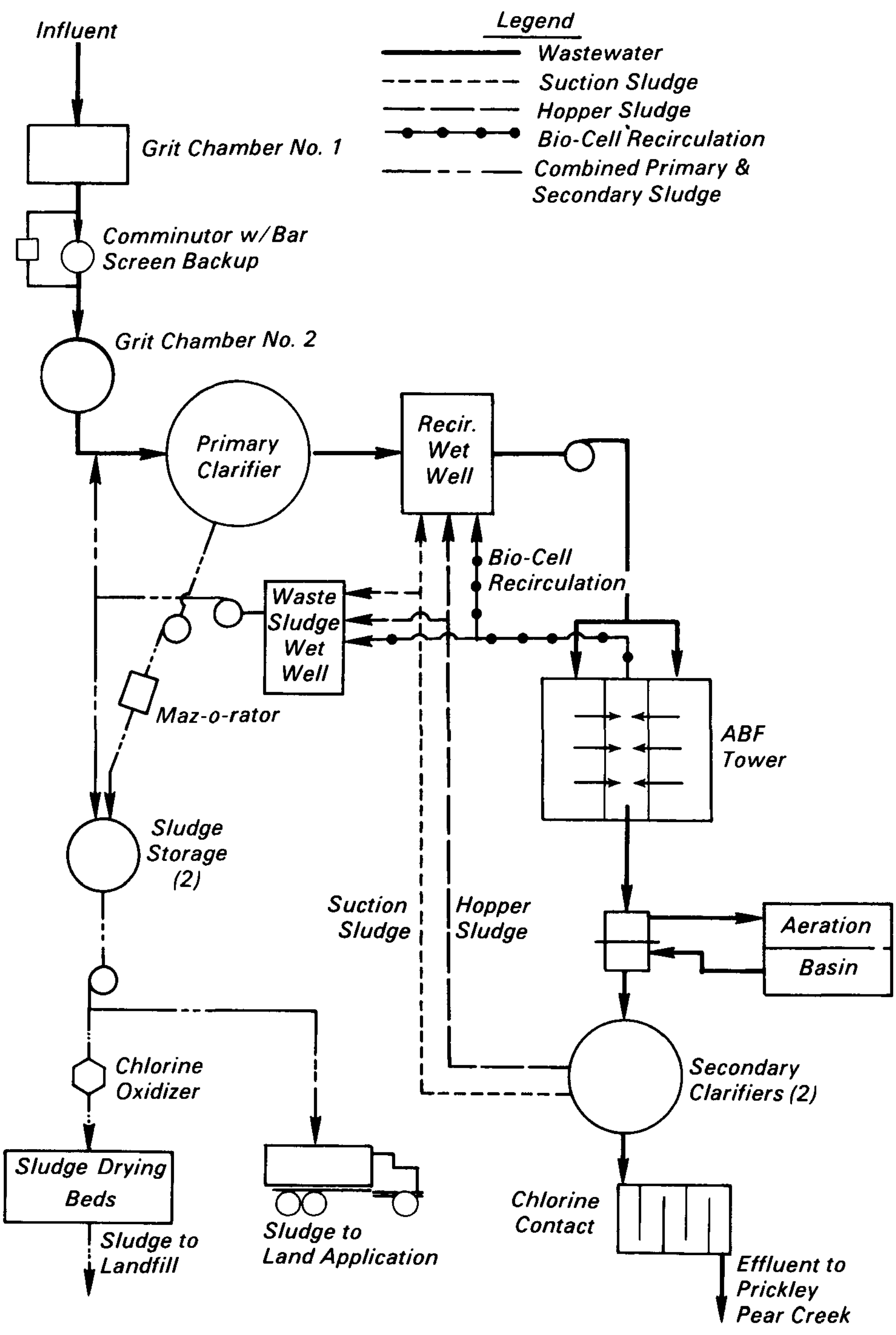

Figure 2. *Helena ABF plant flow diagram.*

The aeration basin DO concentration was maintained within Neptune Microfloc's recommendations of 1 to 3 mg/L by changing the speed or number of blowers used. The return sludge flow rate (R) was adjusted throughout the day, relative to wastewater flow (Q) variations, to maximize the MLSS concentrations in the aeration basin. Additionally, the daily average return rate was adjusted to maintain a preselected R/Q. Neptune Microfloc recommended a 50 percent R/Q. During the project, optimum solids distribution between the aeration basin and secondary clarifiers was obtained by maintaining the R/Q between 50 and 60 percent, supporting this recommendation.

To maintain a consistent inventory of suspended sludge solids in the Helena ABF system, special consideration had to be given to sludge wasting procedures. The relationship between MLSS concentration and mean cell residence time (MCRT) is shown in Figure 3. Prior to Week 29 of the project, selected amounts of sludge were wasted each day in an attempt to maintain a preselected suspended sludge inventory under aeration. During Period A, this approach was satisfactory in achieving a relatively uniform MLSS concentration. During Period B, however, with a smaller aeration basin volume in service, wide fluctuations in the MLSS concentration occurred and the approach to accomplishing suspended sludge inventory control was modified. The modification involved having the operators waste to achieve a preselected MCRT rather than a preselected sludge inventory. Using this procedure, less variation was observed in the MLSS concentration, as illustrated by Period C in Figure 3.

Process Performance

ABF process performance is dependent upon the individual and interrelated capabilities of the bio-cell, aeration basin, and secondary clarifier. The Helena ABF system achieved a sludge volume index that varied between 50 and 150 ml/gm and never developed the bulking sludge characteristics that are often associated with activated sludge processes. As such, clarifier performance never became a limiting factor in achieving good overall BOD_5 and TSS removals from the system.

Neptune Microfloc recommends a design organic loading rate for the bio-cell of 3.2 kg BOD_5/day/m^3 (200 lb/day/1,000 ft^3) and an aeration basin sized to achieve a system applied food-to-microorganism (F_A/M) loading of 1.43 kg BOD_5/day/kg MLVSS (based on a primary effluent BOD_5 (F_A) of 150 mg/L and an MLVSS (M) concentration of 3,000 mg/L). These design conditions will yield a nominal (i.e., excluding sludge recycle flow) aeration detention time of approximately 45 min. The actual loadings evaluated during the four data collection periods were less than Neptune Microfloc's recommended values, as illustrated in Figure 4. The highest combined loadings achieved during the project averaged 79 percent of the recommended bio-cell organic loading and 75 percent of the recommended system F_A/M loading during Period C. Nominal aeration detention times averaged 106, 103, 59, and 118 min, respectively, during Periods A, B, C, and B'.

A summary of Helena ABF process performance for Periods A, B, C, and B' is presented in Table 2. Weekly-average effluent BOD_5 variations are plotted in Figure 5. Effluent quality decreased slightly as process loadings increased with the exception of TSS removal during Period B. For this reason, Period B was retested (Period B'). Period B' results better reflect system capabilities at Period B loadings because operational procedures did not limit system performance during Period B' as they did in Period B. Operational procedures also did not limit system performance during Periods A and C.

Helena plant performance was evaluated based on its ability to meet federal secondary treatment standards. Weekly- and monthly-average effluent concentrations were not to exceed 45 and 30 mg/L, respectively, for both BOD_5 and TSS. Further, the plant was to achieve 85 percent overall removals of the raw wastewater BOD_5 and TSS concentrations on a monthly-average basis. Although not designed for nitrification, the ABF system was monitored to determine if nitrification occurred. At no time did the system nitrify at the loading conditions evaluated.

All standards were met during Periods A and B'. During Period B, all standards were met except for one 5-week stretch when TSS effluent limitation violations occurred because of operational procedures. All standards were met in Period C except the 85 percent removal requirements during a 10-week stretch when the influent raw wastewater concentrations were unusually low. It was concluded from these results that all federally defined standards can be met at the ABF loadings evaluated if good process control is exercised.

Process Energy Requirements

Energy to operate the Helena ABF system was consumed for pumping to the bio-cell and for oxygen transfer and mixing in the aeration basin. Calculated ABF process energy requirements for Period A, B, and C loadings versus theoretical energy consumption for a conventional activated sludge process are graphically illustrated in Figure 6. Similar treatment and oxygen transfer efficiencies were assumed for all systems in making the calculations. The energy requirements depicted for the ABF pro-

Table 1. *Experimental Schedule for Helena Project*

Period	*Date*	*No. of Weeks*	*Description*
A	*12/1/78 to 2/22/79*	*12*	*Total bio-cell and total aeration basin in service*
B	*2/23/79 to 7/12/79*	*20*	*Half bio-cell and total aeration basin in service*
Plant Modifications	*7/13/79 to 8/2/79*	*3*	*Half bio-cell in service. Aeration basin down for modification.*
C	*8/3/79 to 1/10/80*	*23*	*Half bio-cell and half aeration basin in service*
D	*1/11/80 to 2/28/80*	*7*	*Half bio-cell and half aeration basin in service. Primary clarifier out of service most of the time.*
B'	*3/21/80 to 7/10/80*	*16*	*Half bio-cell and total aeration basin in service.*

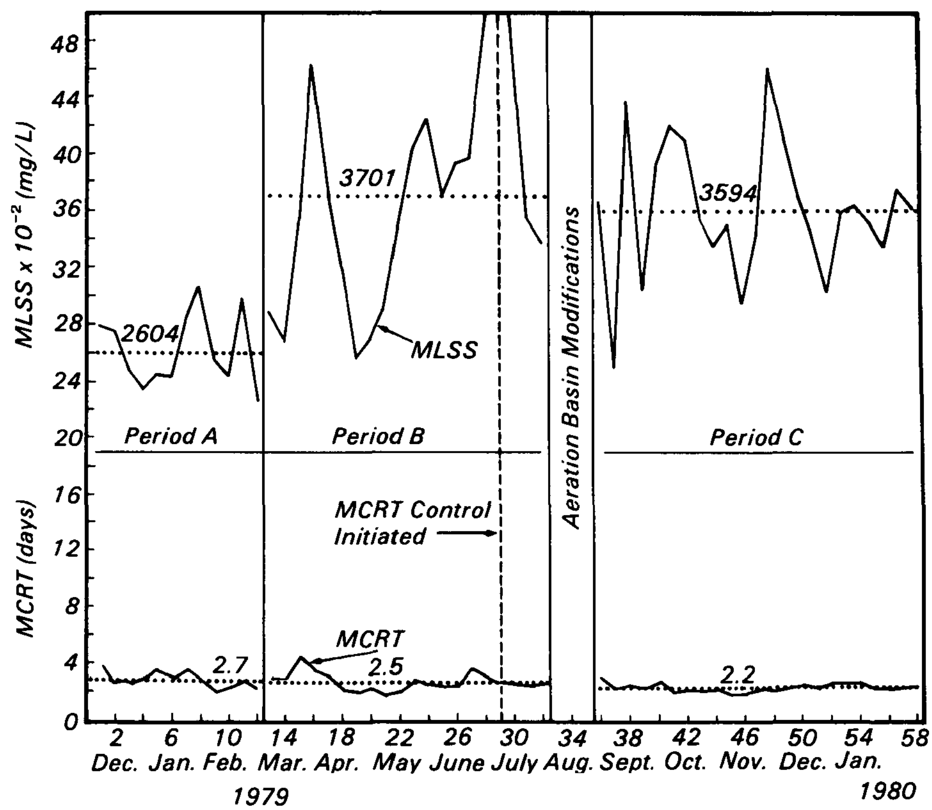

Figure 3. *Weekly variations in MCRT and MLSS concentration.*

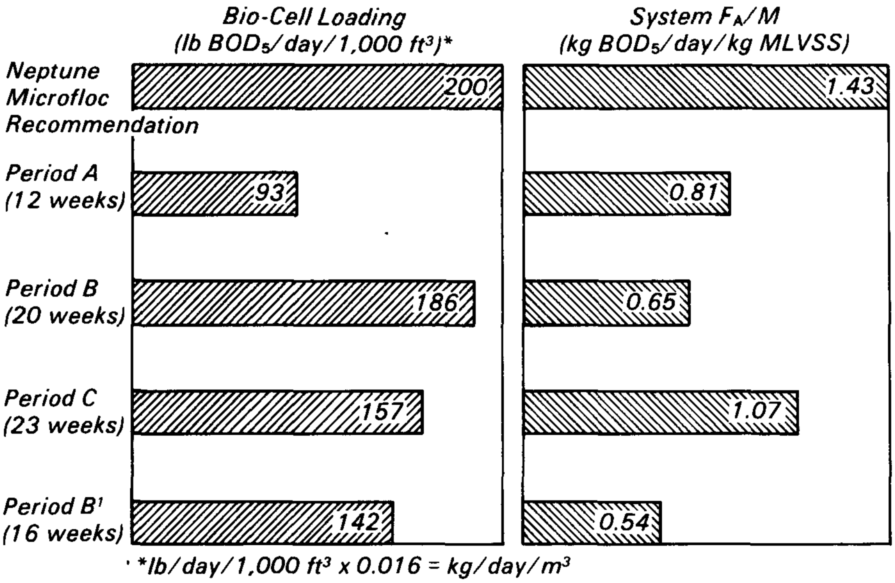

Figure 4. *Actual process loadings evaluated compared to manufacturer's recommended design loadings.*

Table 2. *Process Performance Summary*

Parameter	*Period A*	*Period B*	*Period C*	*Period B'*
BOD_5				
Raw (mg/L)	*175*	*148*	*152*	*164*
Primary (mg/L)	*130*	*128*	*124*	*112*
Secondary (mg/L)	*14*	*21*	*24*	*19*
Overall Removal (%)	*92*	*86*	*84*	*88*
TSS				
Raw (mg/L)	*130*	*194*	*214*	*196*
Primary (mg/L)	*73*	*111*	*109*	*102*
Secondary (mg/L)	*10*	*27*	*22*	*17*
Overall Removal (%)	*92*	*86*	*90*	*91*

cess indicate a potential energy savings when compared with those of the conventional activated sludge process. Several factors must be considered, however, when a design comparison is made:

- Aeration basin oxygen transfer efficiency
  - A higher efficiency, e.g., due to equipment selection, will favor the conventional activated sludge process.
  - A lower efficiency, e.g., due to elevation or equipment selection, will favor the ABF process.
- Bio-cell organic loading
  - A lower bio-cell loading reduces aeration basin oxygen demand and energy consumption, e.g., Period A versus the other periods.
- Bio-cell equipment selected
  - A smaller media depth will reduce bio-cell pumping and energy requirements.
- Unit process layout
  - Provision of gravity return sludge flow from the secondary clarifiers to the recirculation wet well will increase the bio-cell pumping total dynamic head.

ABF Sludge Production

The mass of secondary solids directed to the sludge handling system plus the mass of TSS contained in the secondary effluent were defined as the total amount of secondary sludge produced. Weekly-average secondary sludge production rates for Periods A, B, C, and B' are presented in Figure 7. Greater-than-anticipated quantities of secondary sludge were produced for all periods, and significant variations occurred from period to period. A partial explanation for the large secondary sludge production rates and variations may have been higher-than-normal quantities of pass-through solids in the primary effluent, which do not represent sludge grown but, nevertheless, sludge that must be wasted. This factor alone, however, could not totally account for the large variations noted among periods.

Because of higher process loadings, the secondary system sludge production rate was expected to be somewhat higher during Periods B and B' than during Period A, but the magnitude of the increases was surprising. At the same time, the highest process loading conditions evaluated, Period C, resulted in a lower sludge production rate than for either Period B or B'. The higher sludge production rates observed in Periods B and B' may have been due, in part, to the process testing arrangement, but it is unlikely that the arrangement caused such large variations.

Periods B and B' were both conducted during the months of March through July. Investigations at several activated sludge plants have shown that the sludge production rate typically varies from one season to another. Periods of high and low sludge production normally last for several months, and some plants demonstrate recurring high sludge production during the months of March through July. No definite cause has been isolated, but environmental changes are suspected. The variable sludge production rates at Helena may have been more influenced by environmental conditions than by process loadings, at least for the loading ranges evaluated.

This evaluation emphasizes the importance of sizing the sludge treatment and disposal facilities for the ABF process, like any process, to adequately handle short-term peaks in sludge production as well as long-term average values. Based on the Helena data, secondary sludge treatment and disposal facilities for an ABF system that should be designed to handle on the average about 1.1 kg TSS/kg $(BOD_5)_R$ and should be capable of handling as much as 160 percent of this production rate for several months at a time. Operational experience at Helena indicates that sludge handling is a high priority item for a well-operated ABF system.

Summary and Conclusions

The ABF process is an attractive, competitive secondary treatment alternative because of its operational stability, performance reliability, and energy savings potential. System design should take into account the following factors:

1. The potential exists for reducing energy consumption by more than 25 percent compared with that of the conventional activated sludge process.
2. Secondary sludge treatment and disposal facilities should be designed to handle both the average and peak rates of sludge produced (at Helena, an average rate of 1.1 kg TSS/kg $(BOD_5)_R$ with a peak rate of 160 percent of this value for several months).
3. Consideration should be given to increasing the detention time of the short-term aeration basin beyond that recommended by Neptune Microfloc, Inc., especially if the bio-cell loadings recommended by Neptune Microfloc are used in design.
4. The demonstrated stable sludge settling characteristics should be considered an advantage to system performance, but should not be considered a reason for providing minimal process control.
5. System operation and maintenance requirements should be considered as similar to those of an activated sludge process.

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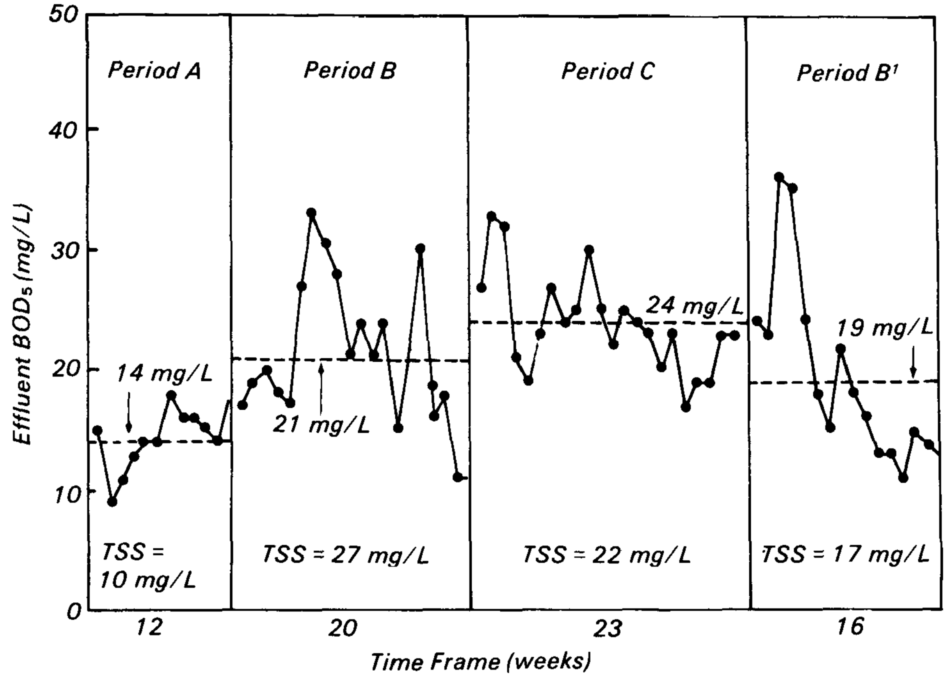

Figure 5. *Weekly variations in final effluent BOD_5 concentration.*

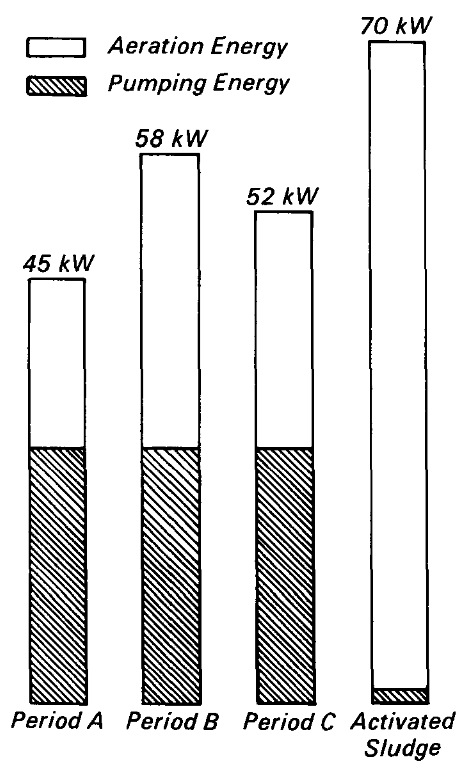

Figure 6. *Comparison of calculated energy requirements for the ABF process versus the conventional activated sludge process.*

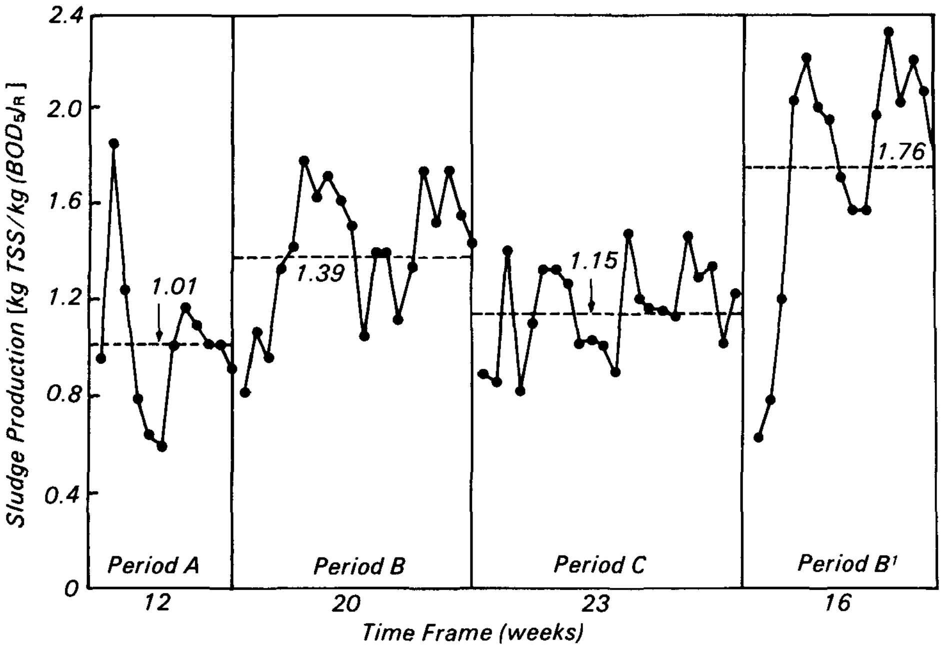

Figure 7. *Weekly variations in secondary system sludge production.*

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

The complete report, entitled "Full-Scale Evaluation of Activated Bio-Filter Wastewater Treatment Process," (Order No. PB 82-227 505; Cost: $12.00, subject to change) will be available only from:

National Technical Information Service
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