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PRETREATMENT OF POULTRY PROCESSING WASTEWATER IN A PILOT-SCALE ANAEROBIC FILTER

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ABSTRACT

Wastewater from a typical poultry processing plant in the southeastern U.S.A. was treated on site with a pilot-scale anaerobic packed-bed reactor. The reactor had a working volume of 3.2 m^3, was filled with 15-cm diameter polyethylene random-pack media, and was operated at 35°C with a retention time of 21 hours and at a loading rate of 2.8 $kgCOD/m^3d^{-1}$. Under these conditions, treatment efficiencies were sufficient to meet typical surcharge-free municipal discharge requirements, with effluent soluble COD of 440 mg/L, soluble BOD_5 of 190 mg/L, fats, oil and grease (FOG) of 10 mg/L, and total suspended solids of 140 mg/L. Results from pilot operation are compared to those of previous laboratory-scale studies, where similar results were obtained with less than half of the hydraulic retention time. Differences in treatment on pilot vs. laboratory scale were largely due to differences in wastewater variability and reactor operation. Recommendations for future studies to reduce the costs of treatment, including emphasis on types of low-cost packing, amounts of packing media, and heating requirements are presented.

KEYWORDS

Poultry processing; anaerobic wastewater treatment; packed-bed reactors; biogas.

INTRODUCTION

The purpose of this paper is to present results of pilot-scale anaerobic wastewater treatment studies conducted at a North Georgia poultry processing plant[1], and to compare these results with previous laboratory-scale studies[2,3]. Upflow reactors were used in all cases; the characteristics of each reactor are listed in Table 1. The lab scale reactors were packed with ceramic 2.5-cm Berl saddles (Harper et al., 1987) and pea gravel (Yang et al., 1986). The pilot-scale reactor (Valentine et al., 1988) reported on here was filled with 15-cm diameter random-pack polyethylene media (Figure 1).

TABLE 1 Anaerobic Treatment Reactor Characteristics

	Harper et al., 1987	Yang et al., 1986	Valentine et al., 1988*
Volume (empty), L	5.6	5.8	3180
Depth, m	0.69	0.61	2.21
Diameter, m	0.10	0.10	1.63
Packing Material			
Type	Ceramic Berl Saddles	Pea Gravel	Polyethylene
Surface Area, m^2/m^3	256	(5-13 mm dia.)	98
Void Space, %	72.0	43.5	95.0

* This Study

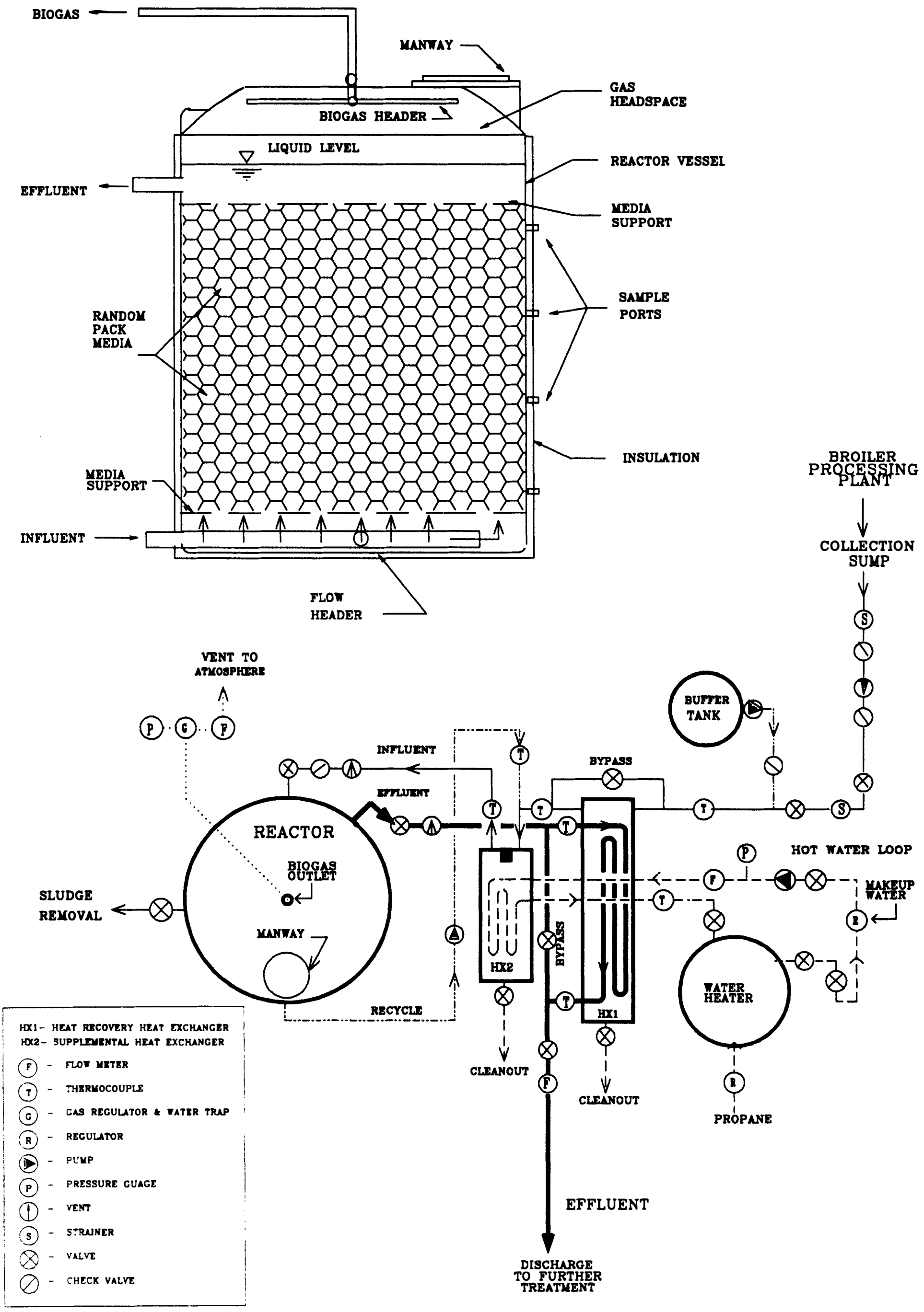

Figure 1. Schematic of pilot-scale anaerobic reactor used for poultry processing wastewater treatment

The compositions of the wastewaters used in each of these studies are given in Table 2. Harper et al. (1987) used a processing plant discharge collected weekly and stored at 10°C. The influent was buffered with a continuously fed solution of $NaHCO_3$. Yang et al. (1986) also used an actual processing plant wastewater, which was transported from the plant to the laboratory and stored until use. The wastewater used in this pilot study (Valentine et al. 1988) was pumped directly from the processing plant discharge during normal processing periods (10:00 pm to 4:00 pm) on weekdays only. This influent was also buffered with a solution of $NaHCO_3$.

TABLE 2 Poultry Processing Wastewater Characteristics

	Harper et al., 1987	Yang et al., 1986	Valentine et al., 1988*
Total COD, mg/L	2043	3482	2478
Soluble COD, mg/L	535	3071	1034
Total BOD_5, mg/L	1023	---	1016
Soluble BOD_5, mg/L	346	---	426
Total Suspended Solids, mg/L	703	1168	1177
Fats, Oils and Greases, mg/L	265	1316	169
NH_4-N, mg/L	53	24	9
pH	7.2	5.9-6.4	6.6

*Averages between Days 300 to 450

The processing plant wastewater was fairly constant with respect to COD and suspended solids concentrations between midnight and 4:00 pm, but these decreased sharply during the cleanup shift between 4:00 pm and 10:00 pm (Valentine et al., 1988). During the cleanup shift, the pilot plant feed pump was shut off and a recycle pump (Figure 1) was operated at a flowrate of 13 L/min until the end of the cleanup shift. Selected operational data from the pilot study are presented in Figures 2 and 3, and a summary of the treatment performance for all reactors (laboratory- and pilot-scale) is provided in Table 3.

RESULTS AND DISCUSSION

The pilot-scale reactor was not quite as efficient as the laboratory-scale reactors, despite the fact that the hydraulic retention time (HRT) was more than twice as long. COD removal efficiencies were on the order of 70% (66±2% between Days 300 and 450). Harper et al. (1987) had previously obtained more than 80% COD removal, and Yang et al. (1986) had achieved more than 90% COD removal. BOD_5 removal efficiencies were similar on both laboratory and pilot scale; more than 80% of the total BOD_5 was removed (86±11% for the pilot-scale reactor). TSS removal (84±9%) was better in the pilot unit than previously obtained by Harper et al. (1987), but similar to the laboratory-scale results of Yang et al. (1986). Likewise, FOG removal efficiencies were higher than previous laboratory-scale studies, and also similar to those obtained by Yang et al. (1986). Pilot-scale FOG removal efficiencies were 92±9% between Days 300 to 450.

Although it may be concluded that anaerobic treatment is a successful and attractive alternative for pretreatment of poultry processing wastewater, it is clear that operation on full-scale requires careful attention to problems not encountered in laboratory-scale studies. Among these, the influence of chemicals used during the cleanup shift has yet to be determined. In this pilot-scale study, the operational factors which most affected process efficiency were feed pump maintenance and buffering. As shown in Figure 2, a large number of pump failures were encountered, and for a different reason in each case. Many of these may have been unique to this project, arising from: a 4-5 meter suction head imposed by the necessity of bypassing DAF chemicals introduced into the wet well (i.e., the intake had to be placed further upstream); grit due to parking lot washing/runoff; freezing due to loss of power at the pump and its freeze protection devices; faulty wiring; and, general wear. In most cases, the pumps were replaced within one or two days, but on one occasion, several pumps were found to be unsuitable and the reactor was down while new pumps were ordered. The most reliable type of pump for this situation was a rotary-screw type with replaceable rubber stators. Screens and strainers were found to be essential, as was daily cleaning of these. Steady operation was finally achieved after 300 days of acclimation, and results are averaged between days 300 to 450 (Table 3).

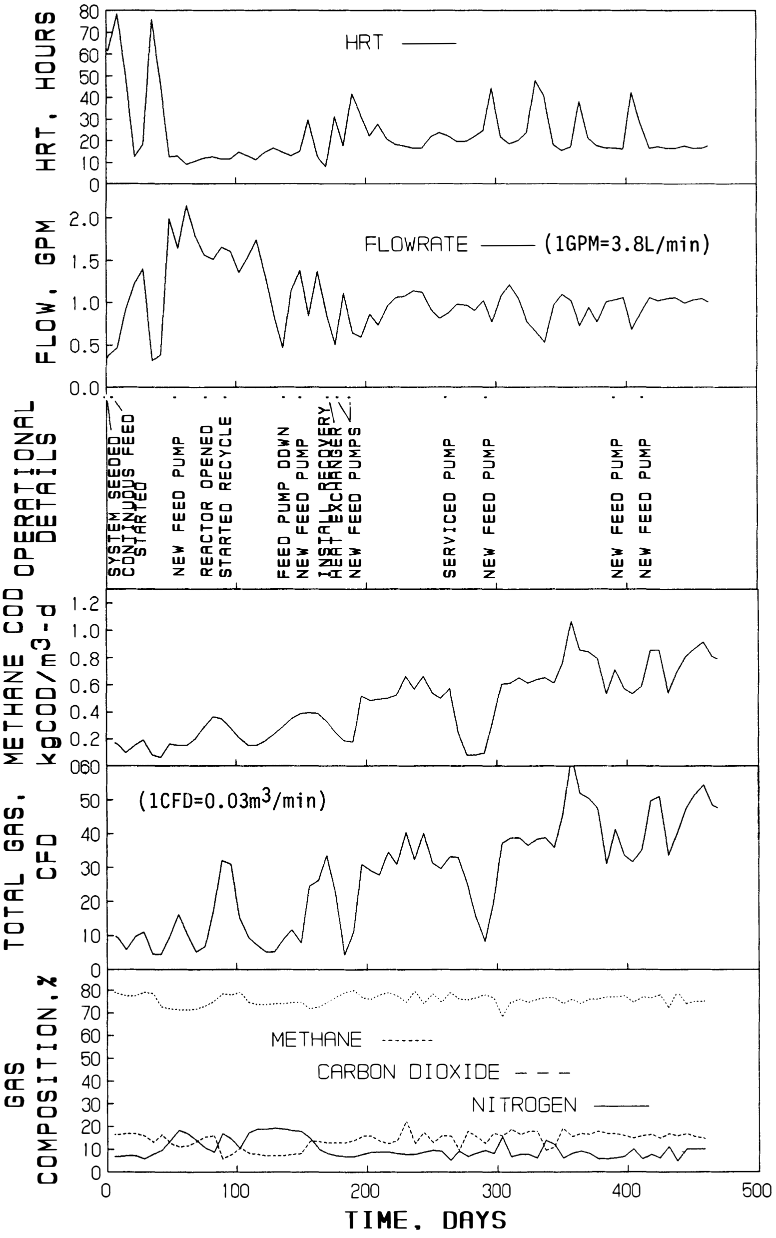

Figure 2. Pilot-scale HRT, flowrate, operational details, methane and gas production rates, and gas composition

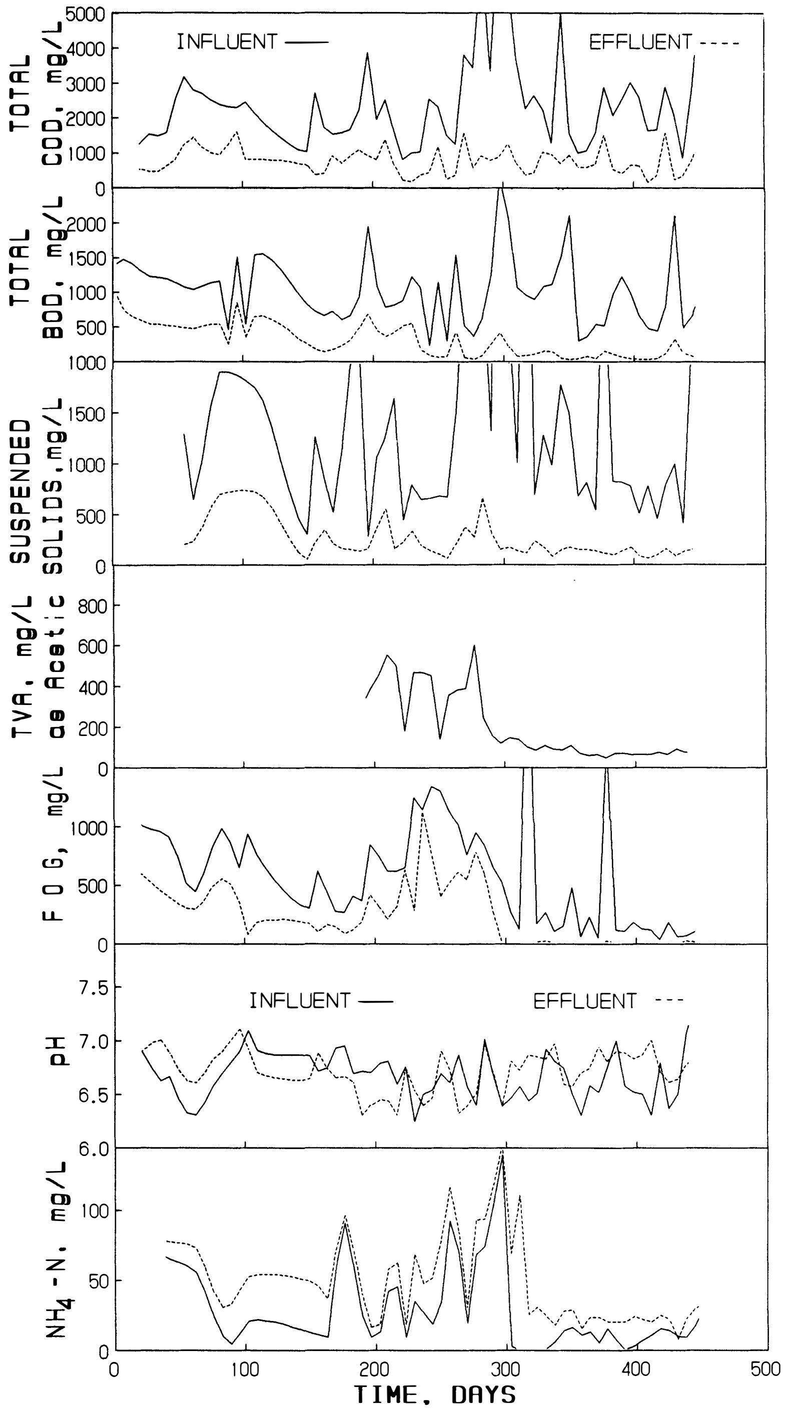

Figure 3. Pilot-scale reactor influent and effluent COD, BOD_5, TSS, total volatile acids (TVA), FOG, pH, and NH_4-N concentrations

TABLE 3 Comparison of Wastewater Treatment Performance

	Harper et al., 1987	Yang et al., 1986	Valentine et al., 1988
Average Effluent Characteristics			
Total COD, mg/L	371	332	733
Soluble COD, mg/L	87	215	436
Total BOD_5, mg/L	186	--	187
Soluble BOD_5, mg/L	29	--	112
Total Suspended Solids, mg/L	274	163	141
Fats, Oils and Grease, (FOG) mg/L	56	141	11
Total Volatile Acids (TVA), mg/L as acetic	11	--	89
Ammonia-N, mg/L as N	90	112	29
pH	7.0	--	6.8
Performance Characteristics			
COD Removal, %			
Total	82	90	66
Soluble	84	93	54
BOD_5 Removal, %			
Total	82	--	86
Soluble	92	--	63
TSS Removal, %	61	85	84
FOG Removal, %	79	88	92
Gas Production, v/vd^{-1}	1.3	1.2	0.4
Gas Composition, %			
Methane	80	89	75
Carbon Dioxide	14	11	16
Nitrogen	6		8
HRT, hours	10	12	21
OLR, kg COD/m^3d^{-1}	5.2	6.8	2.8

The second most influential problem was the loss of pH buffering which occurred on several occasions due to buffer pump failure or improper inventory of the buffer solution. Again, these operational influences may have been unique to this project, but they underscore the importance of control when buffers are used for this type of wastewater. In this study, when the pH of the effluent was allowed to drift below 6.8 by a loss of buffer control, process efficiency was observed to decline, with an increase in volatile acids at pH 6.6, a loss of COD and BOD_5 removal efficiency, as well as lower gas production rates. Although it was most often difficult to isolate buffer effects because these also occurred during recovery from feed pump failures, process performance was clearly superior above pH 6.8. However, it should be noted that this effect may also have been related to sulfide inhibition, because more than 2000 ppm of sulfides (as H_2S) were consistently detected in the gas. An attempt to remove H_2S was made by recycling the gas through an iron sponge, but this was only successful in reducing H_2S to slightly below 1600 ppm, and since the sponge was quickly saturated, these efforts were abandoned. However, this deserves further study with regard to potential process toxicity as well as its impact on corrosion of energy recovery equipment.[4]

Oil and grease were factors with respect to clogging of check valves, vents, and heat exchangers on the influent side of the system. Biological sludge was responsible for clogging on the effluent side. High-pressure cleanouts were found to be essential, as was semi-weekly flushing of heat exchangers and feed lines. The top of the reactor was caked with about a 5-cm crust of grease, and the heat recovery exchanger was also heavily caked with 2 to 5 cm of grease on all surfaces when the reactor was disassembled. It is suspected that a significant proportion of FOG removal occurred by accumulation in the reactor system, but the extent of this vs. biodegradation was not determined and remains deserving of further evaluation. Biological removal was also significant, because, despite low effluent BOD_5 concentrations, gas production remained active over the weekends when the processing plant was closed. It was possible that accumulated grease was serving as a substrate during these periods of no feed.

It was also suspected that the scum layer which had accumulated at the top of the reactor was negatively impacting the quality of the effluent. As shown in Figure 4, the COD of the reactor effluent was higher than that from Ports 2, 3, and 4 (upper region of reactor). Volatile acids, however, did not increase. It can also be shown from this figure that the majority of biological conversion occurred in the first section (bottom) of the reactor, where most of the biomass was contained (TSS of 28±3 g/L).

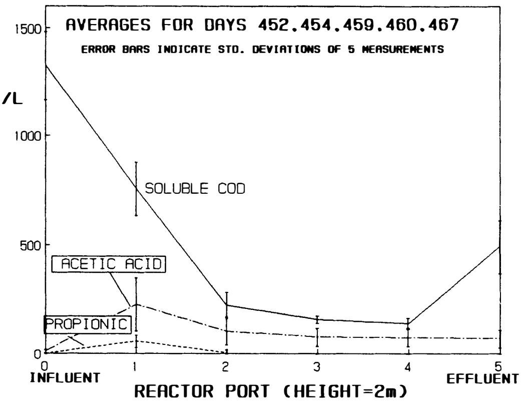

Figure 4. Profiles of COD and volatile acids in pilot-scale reactor

The influence of cleanup shift and weekend downtimes (when recycle was on) are depicted in Figure 5, where gas production continued over the weekend, regained 90% of maximum rates within the first day of continuous feeding and 100% by the second day. As shown in Table 3, biogas production rates for the two laboratory-scale studies were similar at about 1.2 v/vd^{-1}, while the pilot study maintained a production rate of only 0.4 v/vd^{-1}. Likewise, biogas production from the pilot unit accounted for only 40% of the theoretical production expected from the removal of COD (@ 0.38 L CH_4/g COD removed). Biogas methane content for the pilot-scale study (75%) was lower than the 80% and 89%, reported by Harper et al. (1987) and Yang et al. (1986), respectively.

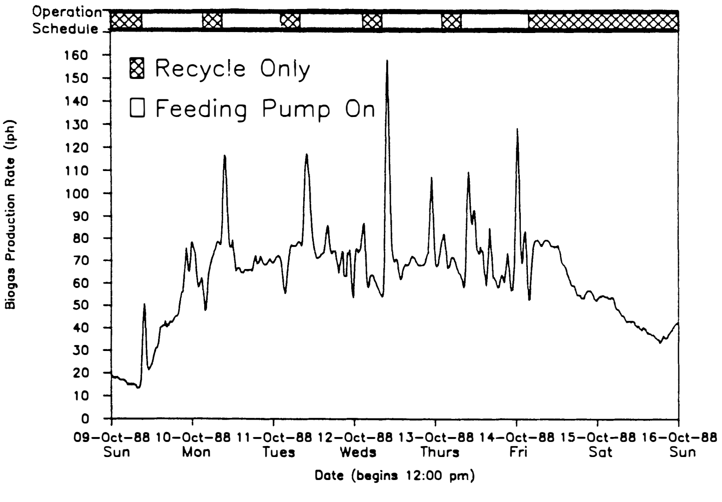

Figure 5. Weekly biogas production profile from pilot-scale reactor

In addition to pH buffering, the other major costs associated with anaerobic pretreatment are incurred from the need for supplemental heating to maintain mesophilic temperatures. The contributions of biogas, heat recovery, and supplemental fuel for the pilot unit are shown in Figure 6. Biogas accounted for only 11% and heat recovery only 13% of the total energy input (45.2 MJ/m^3 of wastewater) to the influent waste stream during the operational period from Days 300 to 450.

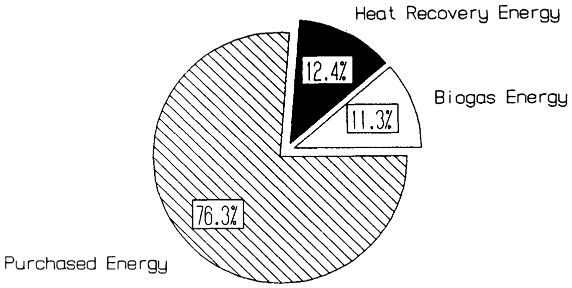

Figure 6. Distribution of energy requirement for pilot-scale reactor (45.2 MJ/m^3 of wastewater)

CONCLUSIONS AND RECOMMENDATIONS

Based on pilot-scale experiments, anaerobic treatment has proven to be an effective alternative to dissolved air flotation (DAF) for pretreatment of a poultry processing wastewater. The process, although effective, was not as efficient on pilot-scale as had previously been determined with laboratory-scale studies. Pilot-scale results suggest that HRTs on the order of one day are needed, as well as special attention to problems associated with oil and grease fouling, and strict buffer control. Heating requirements most affected the economics of the process, as the biogas produced accounted for only 12 % of the fuel needed to maintain operation at 35 °C. Efforts to reduce the costs associated with anaerobic treatment are recommended via studies on alternative packing materials and low-temperature operation. These studies are currently underway at Georgia Tech, and additional studies are recommended to evaluate the extent of oil and grease removal by accumulation, and the impacts of hydrogen sulfide and practical methods for sulfide control.

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