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TREATMENT OF LOW STRENGTH DOMESTIC WASTEWATER USING THE ANAEROBIC FILTER

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Abstract—A laboratory scale anaerobic filter packed with synthetic high surface area trickling filter media was used to treat a low strength domestic wastewater averaging 288 mg l^{-1} COD. The filter was operated for 60 days after reaching steady-state at 20, 25, 35°C at a loading rate of 0.02 lb COD ft^{-3} day^{-1} and 24 h hydraulic retention time. Filter effluent BOD_5 averaged 38 mg l^{-1} providing an average removal rate of 79%, and effluent COD averaged 78 mg l^{-1}, corresponding to a 73% removal rate. Removal efficiencies showed very little sensitivity to daily fluctuations in influent wastewater quality. The filter performance at 25 and 35°C was not significantly different, but BOD and TSS removal efficiency declined at 20°C. Gas production averaged 0.027 ft^3 of gas per ft^3 of influent wastewater, or 1.875 ft^3 of gas per pound of influent COD. Gas composition averaged 30% nitrogen, 65% methane, and 5% carbon dioxide. Ammonia nitrogen and sulfides both increased during treatment. It is concluded that the anaerobic filter is a promising candidate for treatment of low strength wastewaters and that post treatment for sulfides and ammonia may be necessary.

INTRODUCTION

Anaerobic treatment requires a unique microbiological balance of fast growing acid-forming bacteria and sensitive, slow growing methane-producing bacteria. To increase the growth rates of the slow growing methane bacteria, most anaerobic processes operate at elevated temperatures in the mesophilic or thermophilic ranges. Therefore almost all anaerobic processes have heretofore required some type of heating to achieve efficient and economical operation. The methane gas produced by the process is normally used, hence limiting the process to treatment of wastes with high potential for gas production. Consequently, the anaerobic digestion process has almost always been restricted to high strength wastes which are not inhibitory or toxic in nature, and to climates where digesters can be successfully heated. Undoubtedly the greatest single application of anaerobic treatment is in the digestion of biological sludges derived from wastewaters. In many respects the process is ideal for this purpose due to the low cell yield which results in low excess sludge production. The process would also be useful for treating wastewater with low potential for gas production, such as domestic wastewater treatment, if inexpensive heat were available, or if the process could be made efficient at ambient temperatures.

Two important developments in the application of anaerobic processes to lower strength wastewaters are the development of the anaerobic contact process (Schroepfer *et al.*, 1955; Schroepfer & Ziemke, 1959) and the development of the anaerobic filter (Coulter *et al.*, 1957; McCarty, 1968; Young & McCarty, 1969). The key concept of both processes relates to the ability to control mean cell retention (MCRT) independently of hydraulic retention time. This feature permits anaerobic treatment at lower temperatures than previously thought possible or economical. Without some method of increasing MCRT independently of hydraulic retention time, very large reactor volumes are required, making anaerobic treatment techniques too costly. Since heating is not required at lower operating temperatures due to long MCRT, low strength wastes, which produce only small quantities of gas per unit volume of waste treated, can be effectively treated by the anaerobic filter or anaerobic contact process.

Young & McCarty (1969) demonstrated the importance and potential of the anaerobic filter process by successfully treating a medium strength (1500–6000 mg l^{-1} COD) synthetic waste at 25°C, at loading rates ranging from 0.06 to 0.212 lb COD ft^{-3} of filter volume. Their work stimulated numerous investigations to determine the suitability of the process for treating a variety of types of medium to high strength industrial wastes and synthetic wastes. Table 1 summarizes the recent fingings of investigations using anaerobic filtration.

Several investigators in addition to Young and McCarty have examined the theory and kinetics of the anaerobic filter. DeWalle & Chian (1976) evaluated a first-order steady-state kinetic model. El Shafie & Bloodgood (1973) investigated the progressive breakdown of a synthetic waste to volatile fatty acids

Table 1. Studies using anaerobic filter process on wastewater

Waste	Scale and temperature	Organic loading rate* (lb per 1000 cf per day)	Efficiency (%)	Retention time† (h)	Reference
Food processing (8500 mg l^{-1})	Lab scale 11–16 in. high 35°C	100–640	30–86	13–83	Plummer *et al.* (1980)
Potato processing (3000 mg l^{-1})	Lab scale 4 × 8 ft column 19–22°C	33–145	41–79	13–59	Mueller *et al.* (1975)
Wheat starch (8800 mg l^{-1})	Full scale 20 × 30 ft column 32°C	237	64	22	Taylor (1972)
Synthetic organic alcohols, aldehydes, acids, amines, glycol phenol (2000 mg l^{-1})	Lab scale 25 × 35 in. column 34°C	35–130	64–76	17–46	Hovius *et al.* (1972) Mueller *et al.* (1975)
Petrochemical (2000–8000 mg l^{-1})	Pilot scale 6 × 1 ft 34°C	40–145	10–13 Failure	72	Hovius *et al.* (1972) Mueller *et al.* (1975)
Brewery press (6000–24,000 mg l^{-1})	Lab scale 6 ft × 6 in. column 35°C	50	>90	15–330	Lovan & Foree (1971)
Pharmaceutical waste 95% methanol (1250–16,000 mg l^{-1})	Lab scale 3 ft × 5.5 in. column 37°C	14–220	94–98	12–48	Dennis *et al.* (1975)
Sulfite liquor (1300–5300 mg l^{-1})	Lab scale 19 ft × 5.7 in. column 35°C	125–375 BOD	27–58 Failure	89–95	Mueller *et al.* (1975)
Sewage (60–220 mg l^{-1} BOD)	Pilot scale 18.3 × 5 ft column 15–20°C	3–38 BOD	55	2.5–10.5	Genung *et al.* (1979)
(44–573 mg l^{-1} BOD)	Lab scale	3–34 BOD	76	24	This study
Guar (9140 mg l^{-1})	Full scale 30 × 40 ft column 36.6°C	470	60	24	Witt *et al.* (1979)
Acetate + formate + 2-butanone (5000–10,000 mg l^{-1})	Lab scale	380–500	86–94	—	Witt *et al.* (1979)
Acetate + aldehyde + glycol + acetate (7000–10,000 mg l^{-1})	Lab scale	380–500	86–94	—	Witt *et al.* (1979)
Formate + acetate + methanol + formaldehyde (17,000–24,000 mg l^{-1})	Lab scale	690–910	72–92	—	Witt *et al.* (1979)
Acrylic acid + acrylate esters (79,000–85,000 mg l^{-1})	Lab scale	500–600	94–97	—	Witt *et al.* (1979)
Evaporated milk (24,000 mg l^{-1})	Lab scale	450–550	80–90	—	Witt *et al.* (979)
Leachate from solid waste landfill (30,000 mg l^{-1})	Lab scale 7 ft × 7 in. column 25°C	49	95	> 7 days	DeWalle *et al.* (1976)
Shellfish process wastewater (466–121 mg l^{-1})	Lab scale 5 ft × 6 in. column 9.8–26°C	2–23	46–81	8–74	Hudson *et al.* (1978)
Effluent from heat treatment of activated sludge (9500 mg l^{-1})	Lab scale 6 ft × 5 in. column 32°C	300	76	48	Hauge *et al.* (1977)

+ mg l^{-1} COD if not otherwise indicated.
*Based on empty bed volume. COD unless otherwise indicated.
†Based on unseeded void volume unless otherwise indicated.

by sampling a system of filters operated in series Clark & Speece (1973) experimentally investigated the effect of low pH on anaerobic filter performance and stability. Mueller & Mancini (1975) investigated the effects of inhibition due to unionized volatile acids and low pH, for steady-state conditions, using the inhibition model proposed by Andrews (1969) for completely mixed anaerobic digesters. Jennings *et al.* (1976) theoretically investigated the effects of diffusion in a plug flow reactor under steady-state conditions using Monod kinetics.

With the exception of the work of Hudson *et al.* (1978), the previously cited investigations were restricted to medium to high strength wastewaters. Very few researchers have investigated the anaerobic treatment of low strength wastewaters, such as domestic wastewaters. Pretorious (1971) investigated the use of an anaerobic filter preceded by a modified, upflow digester, very similar in principle to equipment used originally by Coulter *et al.* (1957). In contrast to findings of Coulter and co-workers, Pretorious reported that most of the gas production and COD reduction occurred in the filter and not the upstream digester. The work of Genung *et al.* (1979) involved treatment of 5000 gallons day^{-1} of domestic wastewater directly in an anaerobic filter. The influent was heated during the coldest period of their investigations. Treatment efficiency was on the average low (55%) and considerable post-treatment was necessary. Their economic analysis of the system showed however that an unheated anaerobic filter was competitive to the activated sludge process with respect to capital costs and far better with respect to energy requirements, for hypothetical wastewater treatment plants sized at 0.05 MGD and 1.0 MGD. Jewell *et al.* (1979) have described a modified anaerobic filter treating domestic wastewater using an expanded bed of polyvinylchloride particles. They report COD removal efficiencies averaging approx. 80% for hydraulic retention times as low as 1 h.

The previously cited work indicates that the anaerobic filter is a promising alternative for wastewater treatment and has applications for a broad range of wastewaters. The advantages of this process make it especially useful for low maintenance wastewater treatment applications where freedom from "high technology" equipment such as aeration equipment is desired. The objective of this investigation was to evaluate the suitability of the anaerobic filter for low maintenance wastewater treatment, and to determine the potential for producing a useful energy by product. At the time the experiment was initiated, no work demonstrating the suitability of a fixed-bed anaerobic filter (without preliminary digestion) to treat low strength domestic wastewaters had been reported. It is anticipated that low volume, low maintenance wastewater treatment processes will be especially useful in the western United States, where predicted water shortages will stimulate water conservation and wastewater recycle. Undoubtedly there are many other worldwide applications for this technology.

EXPERIMENTAL EQUIPMENT AND METHODS

An anaerobic filter was used which was similar in design to those used by Young & McCarty (1969). The filter was constructed from a 6 in i.d. × 37 in. tall acrylic pipe. The filters were packed with PVC packing material manufactured by B.F. Goodrich (Koro-Z), having a specific surface area of 44 $ft^2\ ft^{-3}$ and 97% porosity. The packed column had a void volume of 4.4 gallons. The entire length of the column was packed, with the exception of the bottom most 2 in., and the top 4 in. The bottom space served as a distribution and sludge collection chamber, while the top portion of the column provided gas storage space, and a zone where gas bubbles could separate from suspended solids. Even flow distribution was confirmed visually by injecting methylene blue and observing the flow patterns.

The column was heated with electrical heating tapes wrapped around the outside and temperature was controlled manually. The temperature was maintained in the range of 35°C (32–35°C), 25°C (23–27°C) and 20°C (18–23°C) for three periods of operation. Influent wastewater feed was obtained daily from a sewer running through the UCLA campus which serves a portion of the school and the surrounding neighborhood. Sewer flow rates and concentrations show diurnal fluctuations typical of domestic wastewaters. Collected wastewater was stored in a refrigerator and pumped at a rate of 11 ml min^{-1} to the anaerobic filter. Figure 1 shows the experimental set-up.

The anaerobic filter effluent was sampled approximately three times weekly and was analyzed for chemical oxygen demand (COD), five day biochemical oxygen demand (BOD_5) volatile fatty acids (VFA), alkalinity, total and volatile suspended solids (TSS and VSS), ammonia, orthophosphate, turbidity, fecal coliforms, sulfides and pH. Gas production was measured daily and analyzed periodically for composition. Sulfides were measured using the method of Pachymar as described by Brock *et al.* (1971), and VFA and gas composition were determined using gas chromatography. In order to determine only the COD resulting from organic compounds, sulfides were stripped from by acidification and gas purging prior to analysis. All other procedures were Standard Methods (1975). Fecal coliforms were determined using the membrane filter method on MFC media incubated at 44.5°C for 24 h.

START-UP PROCEDURE

The anaerobic column was initially filled with a swine waste which had been prescreened and adjusted to

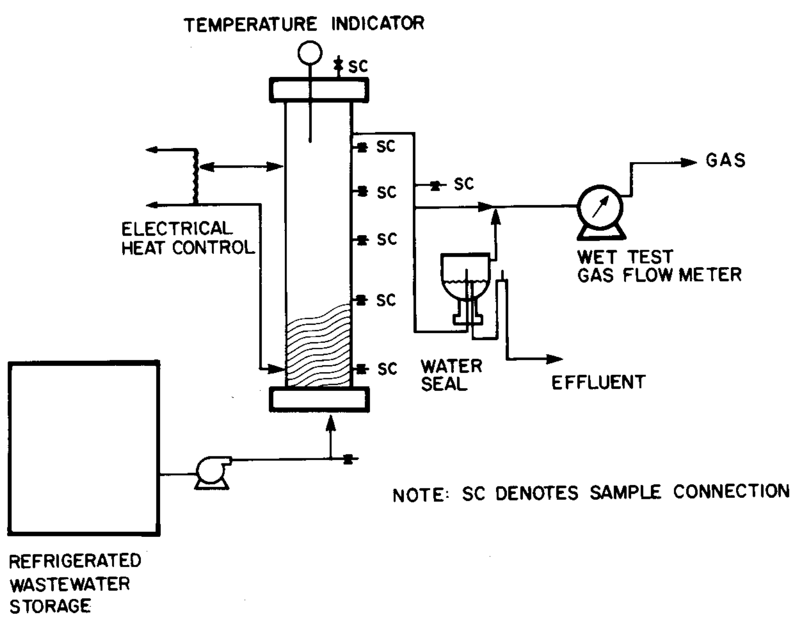

Fig. 1. Experiment equipment schematic diagram.

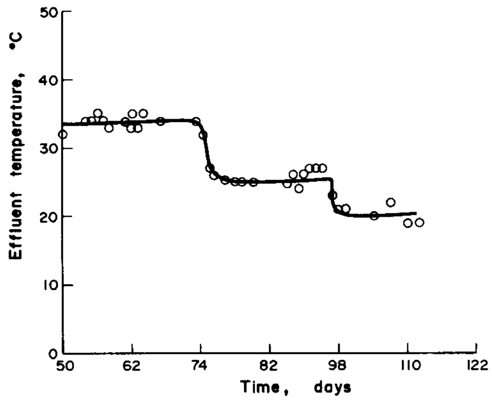

Fig. 2. Anaerobic filter effluent temperature.

pH = 7.5, and had a total COD of 5820 mg l^{-1}. This initial feed was inoculated with digesting sludge obtained from a mesophilic sludge digester at the Los Angeles City Hyperion wastewater treatment plant. The column was operated as a batch for the next 5 weeks. Gas production was monitored and observed to gradually decline to nearly zero at the seventh week, indicating that the initial feed was exhausted. The column was next operated for 52 days on the domestic wastewater until steady state was obtained. The temperature was maintained at approx. 35°C during start-up. Figure 2 shows the temperatures which were maintained during the study.

RESULTS AND DISCUSSION

Figure 3 shows the influent and effluent COD time series profiles for the 60 days of filter operation. Influent COD ranged from a low of 80 to over 1100 mg l^{-1}. Effluent COD averaged 74 mg l^{-1} in all three temperature periods. In some cases the influent COD was higher than the values shown on the graph. It was discovered at approx. day 75 that COD and BOD reductions were occurring in the refrigerated influent container and the reduction is reflected in the data since samples were not necessarily collected when the wastewater was collected. In some instances the samples were collected 8–24 h later. After the influent wastewater degradation was discovered, samples of the fresh wastewaters and the wastewater

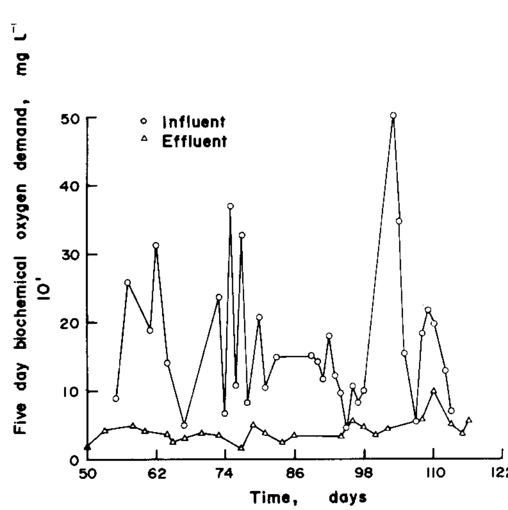

Fig. 4. Influent and effluent five-day biochemical oxygen demand concentration.

remaining just prior to collection were collected and analyzed. In this manner the average influent water quality was measured.

Figure 4 shows the influent and effluent BOD_5 time series data. The immediate dissolved oxygen demand (IDOD) was determined separately from the BOD_5. The IDOD was quite high and was proportional to the effluent sulfide concentration, which ranged from 5 to 19 mg l^{-1}. This concentration of sulfides is similar to the results found by Coulter *et al.* (1957). The BOD_5, after IDOD removal, ranged from 13 to 97 mg l^{-1} which is in excess of that allowed for secondary treatment in the United States. One would expect the BOD_5 from organic material alone to be significantly less than that shown in Fig. 4, since not all the sulfide oxygen demand was removed in the IDOD test.

Influent and effluent TSS are shown in Fig. 5. The influent TSS varied widely with peaks as high as 543 mg l^{-1}. Nevertheless, effluent suspended solids ranged from 15 to 50 mg l^{-1}, averaging 32 mg l^{-1}. The figure shows slightly higher effluent TSS in the 20°C period of operation. The increasing trend at the

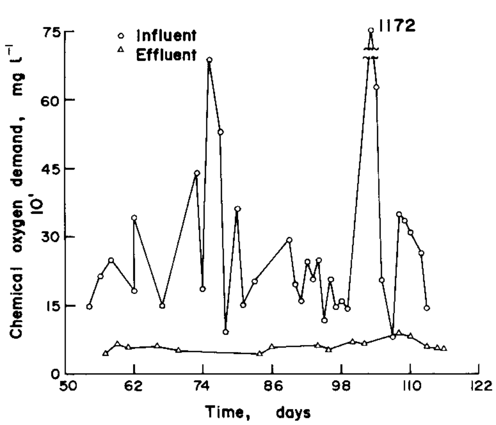

Fig. 3. Influent and effluent chemical oxygen demand concentration.

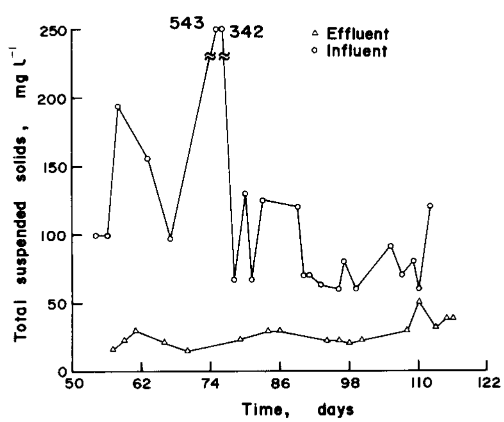

Fig. 5. Influent and effluent total suspended solids concentration.

Table 2. Influent and effluent characteristics

Parameter	Influent Range	Av.	Effluent Range	Av.	% Change
BOD_5* (mg l^{-1})	44–573	163	13–97	40	−75
COD† (mg l^{-1})	77–1170	288	55–121	78	−73
Soluble COD (mg l^{-1})	—	—	31–71	46	—
Ammonia (mg l^{-1})	8–70	33	13–70	44	+33
Phosphate (mg l^{-1})	1–6	3	3–6	5	+67
Sulfide (mg l^{-1})	—	—	5–19	11	Increases significantly
Alkalinity (mg l^{-1} $CaCO_3$)	190–354	225	115–343	245	−4
Turbidity (NTU)	16–71	37	8–54	18	−51
pH	5.72–8.95	7.51	6.85–8.2	7.28	−3
Volatile suspended solids (mg l^{-1})	33–400	98	7–43	20	−80
Suspended solids (mg l^{-1})	60–543	118	15–50	32	−73
Fecal coliforms (cells 100 ml^{-1}	—	1.2×10^6	—	4.1×10^5	−66
Volatile fatty acids	—	—	Not detectable		—
Organic loading rate (lbs BOD per 1000 cf per day)	3–34	—	—	—	—

*Influent BOD data for 75–122 days on sewage.
†Total Effluent COD = Soluble COD + 1.5 VSS.

lower temperatures may be significant and would be expected since sedimentation in the filter is an important TSS removal mechanism.

Ammonia nitrogen was not removed, as expected, and increased due to the conversion of organic nitrogen to ammonia. Orthophosphate also showed an increase for the same reason. Effluent turbidity ranged from 18 to 54 NTU. The range and average value of all influent and effluent parameters are summarized in Table 2.

Biogas production is shown in Fig. 6 and ranged from a low of 150 ml day^{-1} to over 1500 ml day^{-1}. Gas production rates were highly variable due to the size of the system. Gas pockets were observed in the filter, head space, and gas collection tubing. It appeared that the gas pockets tended to grow until they reached a limiting size when they would break loose and rise through the filter. Therefore gas production tended to occur in "spurts" rather than at regular rates. Actual microbiological gas production probably occurred at a much more even rate than Fig. 6 shows. The high gas production rates during the 20°C part of the study can be attributed to higher influent organics concentration. Gas analysis revealed that the biogas always contained nitrogen, averaging approx. 30%. The source of nitrogen was probably due to nitrogen stripping of the influent or diffusion of nitrogen through the plastic tubing. It is unlikely that air entered through leaks since the system always operated slightly greater than atmospheric pressure. The digester gas composition, ignoring the nitrogen fraction, ranged from 92 to 98% methane. This high methane concentration is similar to the results obtained by Pretorius (1971) who obtain 92% methane concentration in the biogas. The high methane percent, as compared to methane content of digester gas, can be expected from the alkalinity, pH and COD loading rate. Anaerobic processes treating low strength wastes will have high methane concentration since carbon dioxide is much more soluble than methane.

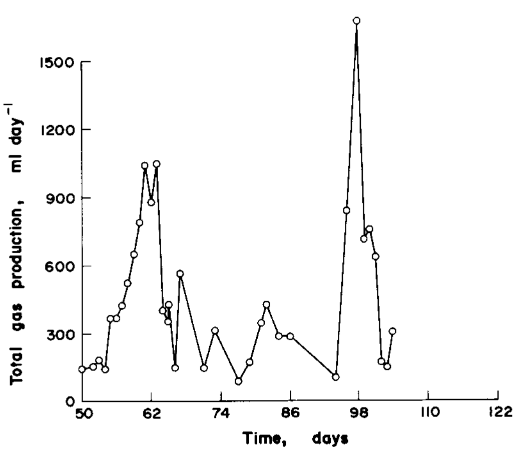

Fig. 6. Biogas production rate.

It is interesting to note the effects of methane solubility on gas production rates. At 30°C, the saturation methane concentration, at partial pressure of 496 mm-Hg (estimated methane partial pressure of an anaerobic filter operating at 2 in. water pressure with 30% nitrogen, 65% methane and 5% carbon dioxide gas fraction) is approx. 15.1 mg l^{-1}. For the flow rate used in this study (11 ml min^{-1}) approx. 0.24 g of methane or 334 ml at STP is lost in the effluent daily. In many cases this quantity of methane is greater than the gas collected. From this analysis is appears that energy recovery potential for filters operating at low loading rates is further diminished due to soluble methane loss in the filter effluent. At extremely low loading rates it is conceivable that all the gas would be lost in the effluent.

Sludge production was measured at the end of the study and found to average 60 mg VSS day^{-1}, not including solids lost in the effluent. Undoubtedly, sludge production is higher than this amount due to sludge accumulation in the filter packing. Nevertheless this very low sludge production rate (0.05 mg VSS mg^{-1} in influent COD) is indicative of the anaerobic filter and is one of its important advantages.

Temperature effects

From the preceding discussion and analysis of the data several conclusions can be made about the effect of temperature on filter operation. The BOD_5 and COD removal efficiencies and effluent concentrations for the first two periods of operation (35 and 25°C) are not significantly different at the 5% ($\alpha = 0.05$) level of confidence. The biogas production is also not significantly different. During the third period the effluent BOD_5, COD, and TSS concentrations all increased, and the increasing trend is significantly different ($\alpha = 0.05$) for BOD and TSS, but not for COD and the other measured parameters. Although the mean gas productions for the three periods are quite varied, they are not significantly different. Any difference in gas production rate is masked by the high variability in day-to-day rates.

Organic loading rate

This experiment was operated at approx. 0.02 lb COD ft^{-3} day which is well below the rates reported for other anaerobic filter investigations. The low rate results from the desire to treat dilute wastewaters. Other investigators have attempted to determine maximum organic loading rates for specific wastes, but in the case of dilute wastes, such as municipal wastewater, the organic loading rate will always be very low and will not approach the maximum loading rates observed in other investigations. A more important indicator of filter performance is hydraulic detention time, and it appears that it will govern filter design. From the limited samples taken at different column depths in this investigation, it appears that a reduction in retention time from the 24 h used here is possible. The minimum feasible retention time will undoubtedly depend on operating temperatures. Several very long term studies at reduced temperatures will be required to fully evaluate the effects of retention time, especially at reduced temperatures.

Kinetics

As mentioned previously, several investigators have evaluated anaerobic filter kinetics. Performing a kinetic analysis on a filter such as the one used in this study would undoubtedly produce highly variable and questionable results due to the variability of influent wastewater characteristics. Kinetic evaluations of filter performance having a uniform synthetic wastewater would undoubtedly produce more satisfactory results. Nevertheless it is possible to evaluate the results obtained with the model proposed by Young & McCarty (1968). Young & McCarty proposed the following relationships:

$$\% E = 100\left(1 - \frac{e}{t}\right)$$

where

$\% E$ = ultimate soluble BOD removal efficiency
t = hydraulic retention time (h)
e = experimentally determined coefficient.

Using COD as an approximation of ultimate BOD, the value which best fits the results reported for the 35 and 25°C periods is approx. 2.0, which compares favorably with the value of 1.8, as reported by Young & McCarty (1968). The value of e increases to approx. 4.0 for period at 20°C, which is indicative of the declining efficiency indicated earlier.

CONCLUSION

It has been shown that an aerobic filter operating a low loading rate can successfully treat domestic wastewaters over a range of temperatures from 20 to 35°C. The filter sustained a variety of changes in influent wastewater quality including peak influent COD concentrations almost three times the average concentration. These variations did not appear to affect effluent quality.

Effluent quality did not achieve secondary effluent standards but came very close. Figure 7 shows probability plots of influent and effluent BOD_5 and COD, and is useful for estimating effluent quality. Mean effluent BOD_5. was only slightly higher than 30 mg l^{-1} and part of this can be attributed to sulfides. Mean effluent COD, less the COD contribution of sulfides, was approx. 40 mg l^{-1}. Although insufficient data were collected to determine ninety-eight percentile limits, extrapolation from the ninety-fifth percentile indicates that these values would be approx. 70 and 60 mg l^{-1} for COD and BOD_5 respectively.

There was no statistically significant difference in filter operation at 25 and 35°C at the 5% level of

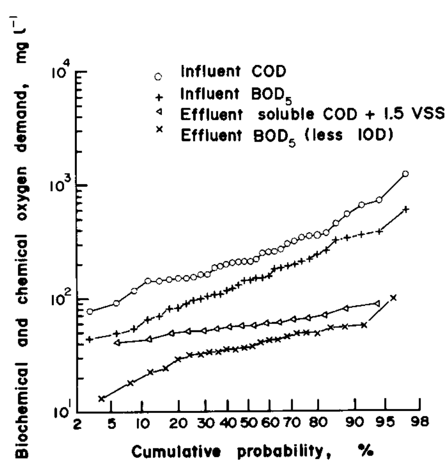

Fig. 7. Probability plots of influent and effluent chemical oxygen demand and five-day biochemical oxygen demand.

confidence, but filter performance declined for BOD and TSS removal efficiency at 20°C.

Effluent sulfides produced by the filter would be unacceptably high for discharge, and some type of post treatment technique will be necessary. Coulter *et al.* (1957) also found unacceptably high effluent sulfide concentration. Presently an anaerobic photosynthetic filter is being investigated for sulfide removal. Effluent ammonia concentrations may also be too high for direct discharge and may require post-treatment.

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COMMENT

Comments by V. RAMAN on "Treatment of Low Strength Domestic Wastewater Using the Anaerobic Filter" by H. A. KOBAYASHI, M. K. STENSTROM and R. A. MAH, *Water Research* **17**, 903–909 (1983).

The writer carried out experiments in laboratory and field conditions on anaerobic upflow filtration of raw macerated sewage, settled sewage and septic tank effluent since 1967. These results are in agreement with those of the authors, and show that increased loading rates are also possible, giving the same efficiency when the detention time is 12 h. Also the filter can work under intermittent flow conditions, and it becomes blocked, normally after 12–18 months of continuous operation, after which it has to be downflushed with water. The author has also carried out field scale studies on a filter of size 1.6 × 1.6 m filled with media (25 mm size) for treating directly raw degritted macerated domestic sewage. This was carried out for nearly 4 years and based on the findings, a period of 12–18 months interval for clogging has been arrived at. The BOD removal efficiency was around 75–80% at a detention time of 6–8 h.

Contrary to the authors' remark on p. 905 that no such work has previously been reported, the writer's work has been published (Raman V., Khan A. N., Patkie S. A. and Swarnkar N. G. *IAWPC Tech. Annual* **IX**, 73–79, 1982), which also contains references to 5 other publications by the writer.

Would the authors comment on the removal of soluble BOD and COD?

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AUTHOR'S REPLY

Reply to Comments by V. Raman on "Treatment of Low Strength Domestic Wastewater Using the Anaerobic Filter" by H. A. KOBAYASHI, M. K. STENSTROM and R. A. MAH, *Water Research* **17**, 903–909 (1983).

The authors are appreciative of discusser's comments, providing further evidence that anaerobic filtration of low strength wastewater is a viable treatment technique. Unfortunately the manuscript referred to in the comments was published after our manuscript was accepted. Also the majority of the Professor Raman's publications, including his recent manuscript, are not readily available in the United States.

Our remark on p. 905 specifically addressed anaerobic filtration of effluents without prior sedimentation or digestion, as occurs in a septic tank. Most of Professor Raman's research, especially the earlier work, addresses treatment of septic tank effluents, and is similar in concept to Coulter's and Pretorius's research. For treatment of single or multiple family dwellings, using a septic tank prior to anaerobic filtration should be preferable to straight anaerobic filtration.

Raman's comments on clogging are especially meaningful, and the need for flushing is significant. The work reported in our manuscript was conducted over too brief a period and at too small a scale to evaluate clogging. Raman's research (1.6 m scale device) is also probably too small to be indicative of clogging in full scale devices. We have operated two larger scale filters (0.6 m in diameter by 2.6 m high) and have experienced no clogging problems in three years of operation, but we believe additional work is still required to evaluate clogging and distribution problems. This work also supports Raman's findings that operation is possible at reduced retention times and higher organic loading rates.

We are encouraged by our current and previous results, as well as the results of others. We believe that anaerobic filtration will become a viable treatment alternative for small to medium size wastewater treatment plants, and will also become a useful technique for expanding exiting treatment plants, by reducing the organic load to the down stream treatment processes.

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