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TREATMENT OF BEAMHOUSE EFFLUENT WITH AN AEROBIC FIXED-FILM REACTOR

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Abstract

An aerobic fixed-film pilot plant designed to treat high-strength waste was evaluated for treating beamhouse effluent. Its main advantage is a low space requirement compared to other aerobic systems. Its major drawback is that it must be supplied with oxygen rather than air for full efficiency.

The reactor consisted of a 6-in. ID, 8-ft-high column containing a bed of sand granules approximately 3 ft high. The waste was circulated into the column at a rate of flow that expanded the sand bed only a few inches. The aerobic organisms formed a film on the sand particles. As the density of the combined organisms and sand grains decreased, the particles became suspended in the circulating fluid in the column. The contents of the column were recycled into a second column containing oxygen under pressure. Dissolved oxygen levels between 5 and 30 ppm were maintained in the system.

Influent was added to the recycling contents of the column at a rate of 1 gal/hr. Column loading rates were changed by increasing or decreasing the strength of the waste added. Reduction of COD increased as the recycle rate increased from 2.75 to 4.75 gal/min. At the maximum loading rate, 1,300 lb/1,000 cu ft/day, COD removals of over 72 percent were obtained. Kjeldahl nitrogen removal varied, but was generally between 50 and 75 percent. Less than 20 percent of this removal was accounted for as nitrite or nitrate present in the effluent. Sulfide removal was over 98 percent regardless of the concentration in the influent. It is assumed that the sulfide was oxidized to sulfate.

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Introduction

Conversion of raw animal hides into leather is one of man's oldest industries. Although the final product is aesthetically pleasing, the effluent streams from the tanning process itself leave a great deal to be desired. This study was concerned with treatment of the waste stream from the beamhouse section of the tannery. One thousand pounds of hides processed here would produce about 2,500 gal of effluent with a typical composition (1) as follows (in lb of pollutant per 1000 lb of hide):

COD	101
Total solids	400
Suspended solids	105
Sulfide	8.5

This waste may be treated by a variety of methods, including aerated lagoons (2) and primary settling followed by activated sludge systems (3). These systems require relatively large land areas and are impractical for tanneries located in cities. Most urban tanneries now discharge to publicly owned treatment works, but proposed EPA pretreatment standards would necessitate major in-house treatment. In addition, in those situations where sewage surcharges are based on levels of certain parameters such as chemical oxygen demand, suspended solids, and sulfide, on-site treatment might be more economical. Since space limitations are critical in many urban tanneries, few options are available.

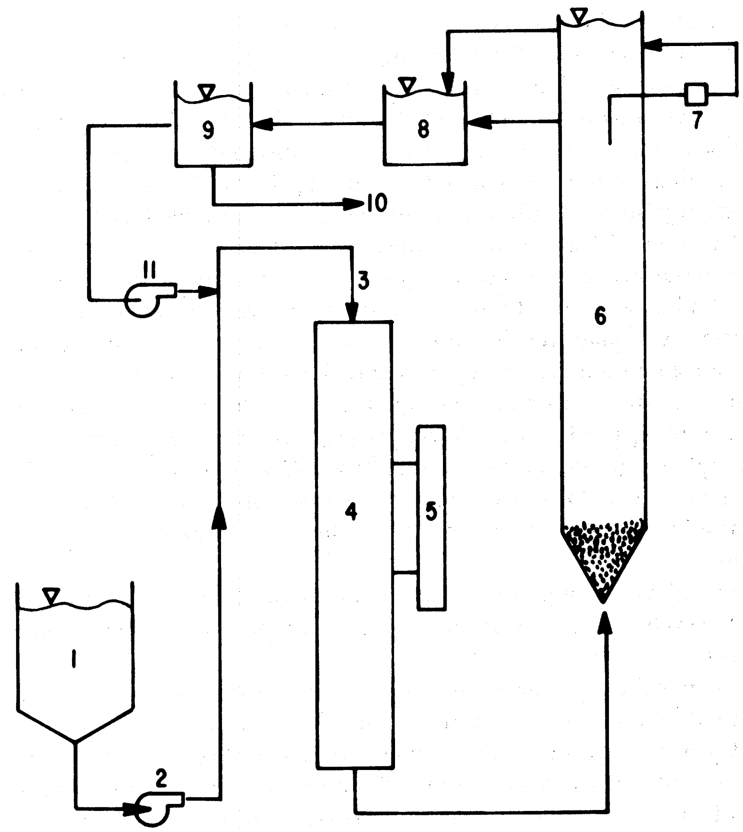
One method that might overcome these problems was described by Jeris and Owens (4). In this approach, sand granules are suspended in a column by the upward velocity of the incoming waste stream. The vast surface provided by the sand allows more microorganisms to grow per unit area than in suspended cultures. Therefore, the amount of pollutants that can be removed in a given volume of reactor is much greater. Since a high capacity for COD removal requires high levels of both organisms and supplies of oxygen for biocombustion, aeration with pure O_2 is necessary.

Materials and Methods

We obtained a pilot-plant reactor from Ecolotrol, Inc.*, Bethpage, N. Y., for this work. The reactor (Figure 1) consists of a clear PVC column, 6 in. ID, 8 ft high with a 17-in. cone at the base and the top open to the atmosphere. Sand grains, averaging 1 mm diameter, form a 3-ft high bed inside the column. As bacteria grow on the grains, the combined density of the growth and sand decreases to the point where the vertical velocity through the column is sufficient

* Reference to brand or firm name does not constitute endorsement by the U. S. Department of Agriculture over others of a similar nature not mentioned.

to cause the particles to rise. When this seeded sand reaches the top of the reactor, it is pulled into a small mechanical pump which strips the bacterial film from the grains. The film then becomes suspended in the flow and is eventually lost in the effluent while the sand granules are returned to the column and sink to the bed.



1	FEED TANK	6	REACTOR
2	FEED PUMP	7	MECHANICAL PUMP
3	O_2 INTAKE	8	SWIRL TANK
4	OXYGENATION COLUMN	9	RECYCLE TANK
5	LEVEL CONTROL	10	EFFLUENT
		11	RECYCLE PUMP

FIGURE 1.—Schematic diagram of beamhouse waste treatment unit.

The liquid in the system is continuously recirculated by a progressive cavity pump, powered by a 0.5 hp, 1725 rpm motor. The vertical velocity created by the recycle flow expands the sand volume by several inches. The sand grains with attached biomass are suspended throughout a 1,000-cu-in. volume above the bed. Fluidization of the bed also ensures better contact between the seeded sand and the waste to be treated and reduces clogging of the bed. Recycle rates are varied by changing the motor pulley.

Ocean Leather Co., Newark, N. J., supplied effluent from its unhairing operation. After removal of the floating fat layer, the waste was sent through a Moyno grinder pump where large particles were uniformly ground. The COD of this waste ranged from 32,000 to 58,000 ppm. The desired COD concentration was obtained by dilution with tap water. Since influent flow was kept constant, column loading rates were changed by varying the COD concentration of this feed. Microorganism phosphorus requirements were provided by 1 g of K_2HPO_4 dissolved in every 10 gal of feed solution. The feed solution was added continuously to the system at a rate of 1 gal/hr by a peristaltic pump. Pure oxygen, from a cylinder, was introduced to the influent line through a solenoid valve. Oxygenation took place inside a 6-in. ID, 5-ft high column. A liquid-level control mechanism on this column opened and closed the solenoid, thus controlling the input of O_2 into the system. The oxygenated influent entered the reactor at the bottom and passed upward through the biomass. The treated waste then went through a 4-gal swirl tank, which allowed CO_2 to be liberated, and then to a 4-gal recycle tank. Overflow from the recycle tank was the treated effluent, which passed out of the system. The remainder of the stream was pulled into the recycle pump.

Feed and effluent samples were taken automatically every 8 hr from the feed inlet and recycle tank, respectively. Reactor samples were taken through taps along the side of the column.

Total chemical oxygen demand (TCOD) was measured by the standard ampule method (5). COD was determined on the supernatants of settled samples without filtration and the value was taken to be soluble COD. Dissolved oxygen (DO) was analyzed by the azide modification method (6), and total organic carbon (TOC) was measured with a Beckman Model 915 TOC Analyzer. Suspended solids (SS) and volatile suspended solids (VSS) were determined by procedures in Standard Methods, 14th edition (6). Total Kjeldahl nitrogen (TKN) (7) and nitrate and nitrite levels (8) were measured on Technicon Auto Analyzers. Sulfide was analyzed by oxidation with $K_3Fe(CN)_6$ (9). Ammonia levels were not determined. Ammonia odors were not noticed during the treatment.

Results and Discussion

Start-Up. Attempts were made to seed the sand with microorganisms from municipal sludge, with a mixture of glucose and beamhouse waste used as feed.

We were not successful, however, as the microbial growth did not adhere to the sand particles in six months of experimentation. Previously seeded sand, from an anaerobic reactor, was then obtained from Ecolotrol and added to the column. The TCOD concentration of the feed was varied from 200 to 2,000 ppm at a feed rate of 1 gal/hr and a recycle rate of 2.75 gal/min. The feed consisted entirely of beamhouse waste; air, instead of pure O_2, was used for aeration. The net volume of biomass became 400 cu in. in approximately 3 weeks. Aeration was then continued with O_2, and the biomass reached its maximum net volume of 1,000 cu in. after another 4 weeks.

Standard Conditions. Once stable conditions were achieved at a recycle rate of 2.75 gal/min, an average TCOD removal of 72 percent was obtained (Figures 2 and 3). Simultaneously, TOC removals ranged from 40 to 50 percent. Loading rates were between 200 and 1,300 lb TCOD/1,000 cu ft/day. When the system was loaded above this range or when the pressure at the oxygen cylinder

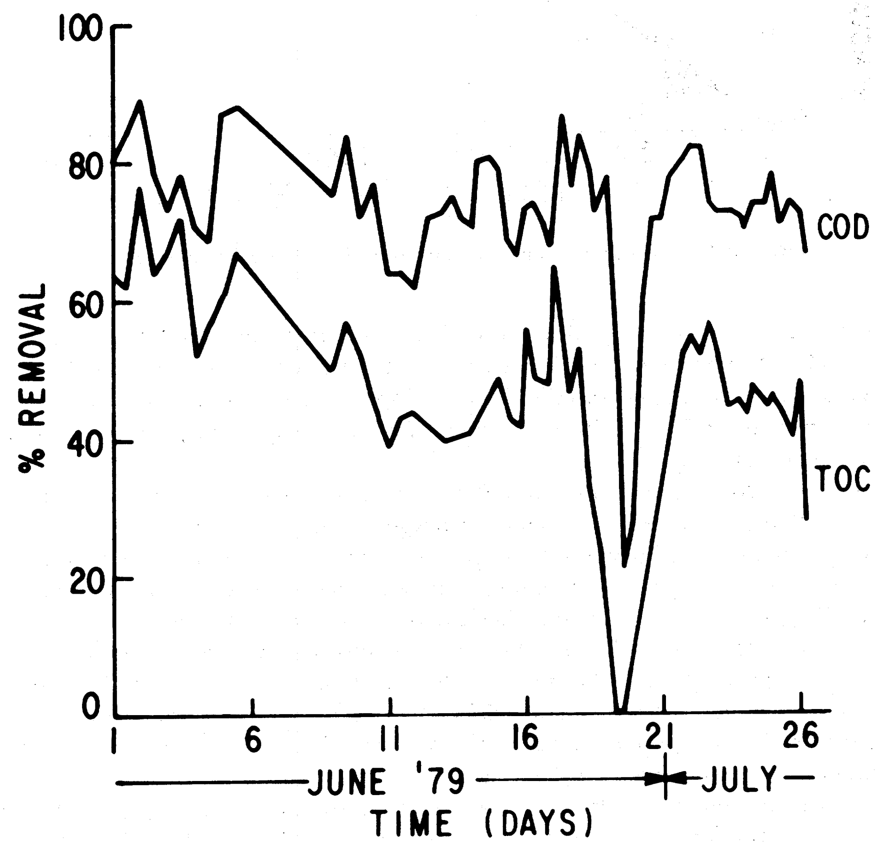


FIGURE 2.—Chronological variation of COD and TOC removal.

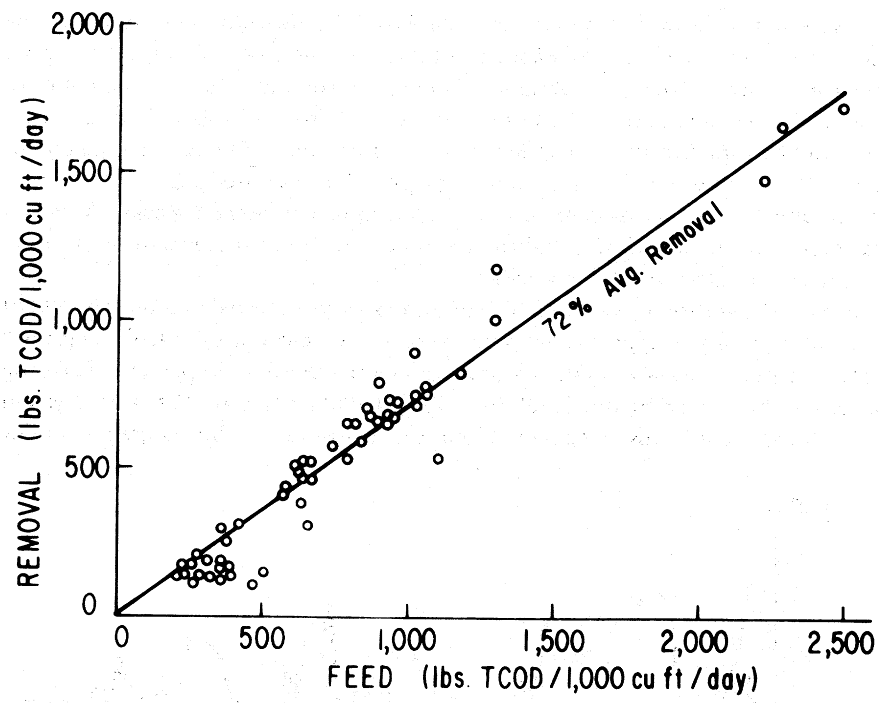


FIGURE 3.—Treatment of tannery beamhouse waste at 2.75 gal/min recycle rate.

regulator became too low, the DO level in the influent dropped below 3 ppm. The TCOD removal efficiency remained level for a day or two after the drop in DO but then decreased rapidly. The O_2 input was set to provide a DO concentration above 10 ppm in the influent. This probably resulted in some loss of O_2 from the system.

Effect of Recycle Rate on COD Removal. Adjustment of the recycle rate to 4.75 gal/min increased the amount of oxygenation. Consequently, the average TCOD removal was increased to 81 percent (Figure 4), and TOC removals improved to 60 to 80 percent. Loading rates tested were between 700 and 1,200 lb TCOD/1,000 cu ft/day. When a loading of 1,700 lb/1,000 cu ft/day was tried, efficiency decreased as before. No direct relationship was found between the oxygen applied (from 1,200 to 2,800 lb/1,000 cu ft/day) and COD removal (Figure 5). The concentration of TCOD that can be removed cannot surpass the concentration of O_2 applied. The limiting factor of the reactor appears to be the amount of O_2 available to the biomass.

Solids. Suspended solids (SS) levels in the feed varied from 1,200 to 2,000 ppm when the feed COD was between 3,000 and 4,000 ppm. The effluent contained almost as much SS as the feed. Similar results were obtained with VSS

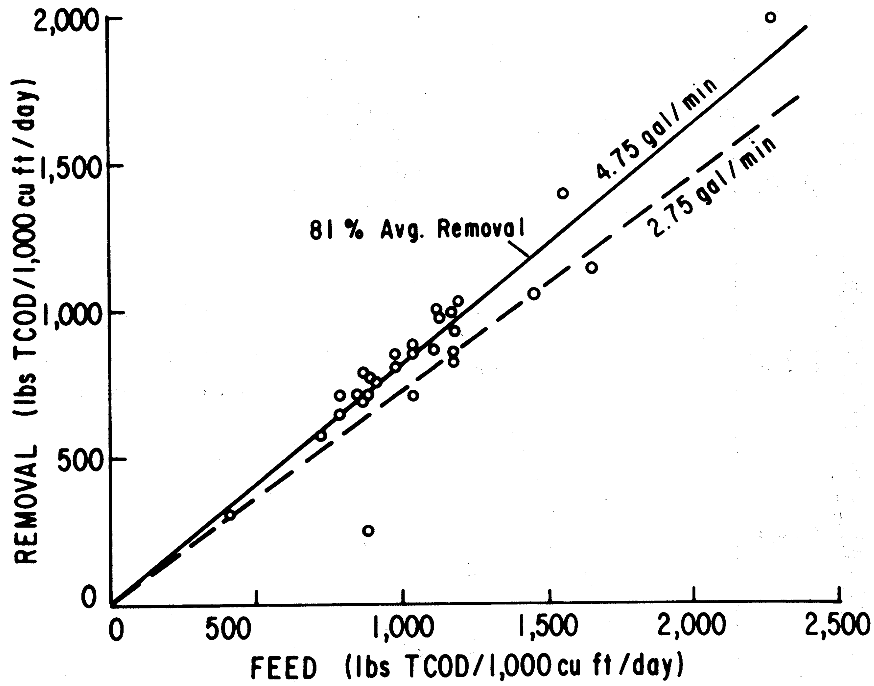


FIGURE 4.—Treatment of tannery beamhouse waste at 4.75 gal/min recycle rate.

values, which were generally about 90 percent of the corresponding SS figures. The lack of solids removal suggests that either the microorganisms generated as many solids as they consumed, or did not consume solids at all.

Feed was settled for 2 hr so that it contained less than 100 ppm SS. When this was used as feed for the pilot plant, average COD removal increased to 85 percent (Figure 6), and the soluble COD removals were constantly between 89 and 92 percent. This compares with soluble COD removals of 72 to 84 percent for feed containing normal SS levels.

TKN. Removal of TKN was usually between 50 and 75 percent regardless of feed composition or recycle rate. Nitrate and nitrite present in the effluent accounted for less than 20 percent of this removal. The balance of the TKN apparently was converted to protein in growing organisms.

Sulfide. Sulfide removal was consistently over 98 percent throughout the study. This result was also demonstrated in a previous aerobic system (3). The large removal is presumed to be due to oxidation to sulfate.

pH. The pH of the feed ranged from 9.5 to 11.5. In the reactor, the pH varied between 6.5 and 7.1. More acidic conditions would have resulted in the rapid liberation of H_2S. The effluent pH was between 6.7 and 7.2.

Operation. Mechanical difficulties affected continuous operation of the

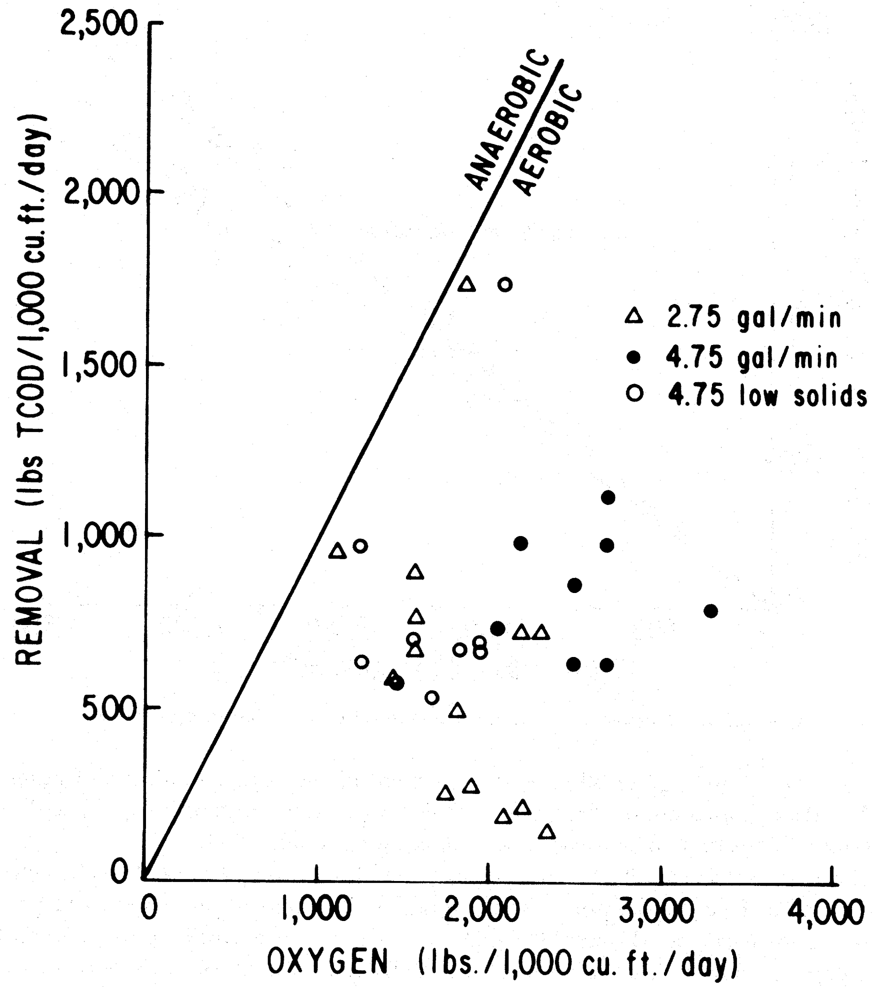


FIGURE 5.—Comparison of oxygen applied and COD removal.

system. Occasional leakage in the pumps caused partial draining of the reactor, poor recycling, and anaerobic conditions. This led to the loss of much of the seeded sand. When pump problems were corrected, the biomass usually recovered within 7-10 days. This rapid recovery is a particular virtue since start-up with unseeded sand takes much longer. The capability for rapid regrowth is probably due to the fact that the seeded sand was originally supplied from an anaerobic reactor. Therefore, the organisms were not killed when the system accidentally became anaerobic.

After 18 months of operation, the sand bed apparently became coated with nonbiodegradable substances which retarded the recycle flow. The bed then

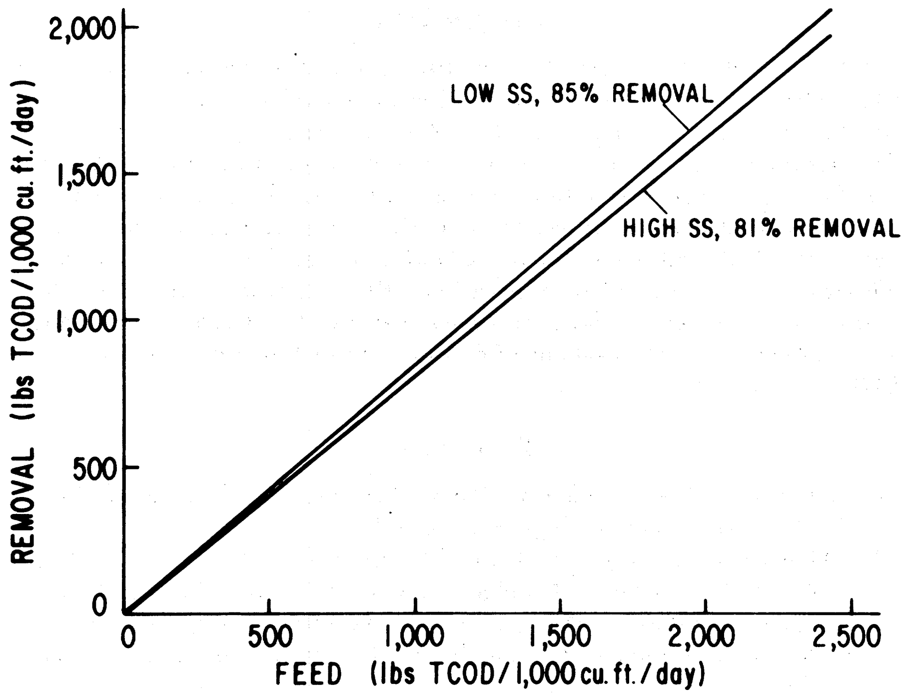


FIGURE 6.—Effect of 2-hr solids settling on treatment of tannery beamhouse waste at 4.75 gal/min.

clogged, preventing good fluidization and reducing efficiency. This may have been due to column design; however, it could have been prevented by periodic replacement of a portion of the bed with fresh sand.

Scale-Up. An average of 100 lb TCOD is generated by 1,000 lb of cattlehides. A tannery that processes 1,000 hides per day will produce around 6,000 lb TCOD/day. The type of reactor in this study would require a projected volume of 3,000 cu ft to achieve a 70 percent COD reduction in a day's worth of tannery waste. About 6,000 lb of pure O_2 would be used per day.

A 3,000-cu-ft reactor could consist of 10 columns, each 6 ft high and 8 ft in diameter.

Since a 1,000-cu-in. reactor removed 72 percent of applied COD at a recycle rate of 2.75 gal/min, a 3,000-cu-ft reactor would require a recycle rate of 14,300 gal/min to match that efficiency. The cost of electricity would be $210/day, based on a power requirement of 1 hp for every 50 gal/min and a charge of 4.1 ¢/kWh.

Liquid oxygen could be used as the O_2 source. Consumption by the unit of 6,000 lb O_2/day would cost about $270/day, based on a rate of $90/ton. The cost of recycling and oxygen would be approximately $100,000 in a year consisting of 200 working days.

Conclusions

An aerobic suspended fixed film reactor was tested for treatment of tannery beamhouse waste. Pure oxygen was used to meet the large oxygen demand of this substrate. A 1,000-cu-in. volume of microorganisms produced efficient (greater than 70 percent) removal of TCOD at loading rates between 200 and 1,700 lb/1,000 cu ft/day. Both increasing the recycle speed and decreasing the concentration of solids in the feed resulted in greater efficiency of removal. Over half of the TOC and TKN and virtually all of the sulfide were also removed. This type of reactor could have application to the treatment of wastewater where space is not available for other treatment systems. A 1,000 hide/day tannery would probably require a volume of reactor equivalent to 3,000 cu ft to reduce COD by 70 percent.

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Discussion

MR. MAX MAIRE (Discussion Leader): Thank you very much, Mike. I think one thing this paper demonstrates is that where there is a shortage of space, you can get the same treatment that we get from conventional plants, but you are going to pay for it either in terms of higher operating costs or in terms of greater capital expenditures.

Are there any questions?

DR. STANLEY SHUTTLEWORTH (South Africa): I would like to congratulate these workers on a fascinating piece of research. What I'm worried about is that normally a healthy aerobic system continually builds sludge. Now either you must be continually replacing the sand and increasing the sludge problem if the sand escapes, or you must have some way to return the sand and allow the accumulated sludge to escape separately from the sand, plus all of the normal sediment that comes in from the beamhouse. If you don't do something about separating the sand it's going to leave the system with the sludge which is normally developed. Normally with an aerobic system a good deal of the process consists in converting liquid or dissolved protein into microorganisms which form the sludge. So any healthy system will develop a considerable amount of sludge which becomes the disposable product.

Now, unless you do something to separate the sand, it's going to go along with the organisms. So from a practical point of view you have to find some way of preventing that. I'm interested to know how you solved that problem.

MR. TUNICK: We did not get much escape of the sand from the system. We had a small mechanical pump which put the sand grains back into the column after stripping the film from them. If any sand was carried over toward the effluent, it settled out in one of the two swirl tanks at the top. So we actually did not lose any sand. We could scoop out the sand from these tanks with a beaker and pour it back into the column. We found that the sludge goes out of the system along with the effluent. However, we did not determine exactly how much sludge was being produced.

DR. BERNARD VULLIERMET (Centre Technique du Cuir): Why did you choose the fluidized sand bed support in preference to activated carbon? I can see a lot of difference between the COD removal and the total organic carbon removal, which is caused by the nonfermentable matter. I have read of a number of experiments that were made with activated sludge in combination with activated carbon. Why did you choose sand in preference to activated carbon?

MR. TUNICK: We chose sand because of its density and its large surface area. Activated sludge would be removed rapidly from the system. There really isn't much reason why you could not use any other small particulate support of the proper density.

MR. RAY HAUCK (George Moser Leather Company): I would like to know what your starting material was when you speak of using a beamhouse waste material. Was this from a hair-burn or hair-save system?

MR. TUNICK: It was from a hair-burn system.

MR. HAUCK: I gathered that a great deal of the cost involved has to do with the feeding of oxygen to the system to help the microorganisms do their job. Is this correct?

MR. TUNICK: That is right.

MR. HAUCK: If sulfide is going to be one of the substances that uses some of the oxygen, would it be more economical to treat the sulfide with something like manganous sulfate in a regular air system, rather than to use the oxygen supplied to the microorganisms to cut down the costs?

MR. TUNICK: Yes, that is a definite possibility. If you remove the sulfide before you feed the effluent into the system, then you probably would not need as much oxygen.

MR. HAUCK: Was any work done along that line?

MR. TUNICK: No, we didn't do that. We just removed all of the sulfide in the column along with the COD.

DR. H. S. MURALIDHARA (Systems Consultants, Inc.): What advantages do you have using this system to a fixed bed trickling filter system?

MR. TUNICK: This is an alternative and its main advantage is the smaller space required.

DR. BAILEY: The fluidized sand presents a greater surface area as compared to the fixed bed trickling filter. A trickling filter requires a much larger installation; so it is a matter of size.

MR. MAIRE: From the standpoint that something like seventy percent of the tanneries in this country are indirect dischargers and are located in urban areas, treatment space becomes an extreme problem. I believe you will find that you will have to pay for compacting these operations through higher operating costs. But it may be that the only way you can do it is by paying a premium to get a treatment plant of the smallest possible physical size. I believe that's what they are trying to do here.

If there are no more questions, I thank you very much, Mike, for an interesting presentation.