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Project Summary

Protein Recovery from Beef Packing Effluent

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The wastewater from a large beef packing plant, containing 3000 mg/l BOD_5 and 2,500 mg/l of suspended solids was treated in a physiochemical process that recovers protein. This process removed 58% of the total nitrogen, 80% of the oxygen demand and suspended solids, and 94% of the fat, oil and grease. The discharge of BOD_5 was reduced to less than 3 pounds per head of beef slaughtered. For every pound of BOD_5 entering the wastewater treatment plant, 0.77 pounds of product was recovered with a composition of 38% protein, 11% grease and oil, 27% inorganic solids, and 24% other solids (dry weight basis). About 2 pounds of protein were recovered per head. Total cost was $3 per 1,000 gallons (44% capital costs). A price of 42¢ per pound of protein would pay all costs. The figures given above were observed in a full scale plant and should not change significantly with different size wastewater treatment plants. This wastewater treatment process can be used as a pretreatment process for beef packing effluent prior to discharge to a sewage treatment plant.

Seven different beef packing wastewater treatment processes including other methods of protein recovery are discussed and compared in the full report.

This Project Summary was developed by EPA's Industrial Environmental 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

Beef packing effluents pose a considerable challenge to wastewater treatment technology. Several water quality parameters are listed below in Table 1 along with their average concentrations in domestic wastewater and the average concentrations observed in the effluent from this beef packing plant.

Clearly the oxygen demand of beef packing effluent is 20 to 30 times that of domestic wastewater, so that at least 95% removal would be necessary to reduce the oxygen demand of beef packing effluent to that of untreated domestic wastewater. In addition, the quantity of suspended solids is over 10 times that of domestic wastewater. As a final complication, beef packing plants are not usually operated continuously, so that conventional biological wastewater treatment techniques leave a great deal to be desired.

This lack of continuous operation indicates the desirability of a physiochemical wastewater treatment process. In addition, it would be highly desirable if some cost recovery were possible from the sale of the relatively large quantities of sludge that can be expected.

The Alwatech process is a physiochemical wastewater treatment process that also recovers protein (from the beef packing effluent) which can be sold to partially recover the cost of wastewater treatment. The process uses sulfuric acid, H_2SO_4, for pH reduction, calcium lignosulfonate for protein precipitation,

Table 1 *Comparison of Beef Packing and Domestic Wastewaters*

	Average Concentration, mg/l	
Water Quality Parameter	*in domestic wastewater*	*in beef packing effluent*
COD	*150*	*4,610*
5-Day, 20°C BOD	*140*	*2,940*
Suspended Solids	*235*	*2,460*

and calcium hydroxide, $Ca(OH)_2$, for both effluent and sludge neutralization.

This report gives the results of a full scale evaluation of the Alwatech process installed at a large beef packing plant in the United States. While the Alwatech process is not necessarily limited to treatment of and protein recovery from beef packing effluents, this report is based on beef packing effluent treatment and protein recovery. Other effluents treated by the Alwatech process include those from poultry and pig abattoirs.

Unit Waste Production

Table 2 shows the unit waste production rates for 6 different waste products. From this table, it is clear that the quantities of the last 3 wastes listed are minor when compared to the quantities of the first 3 wastes listed. Because the average live weight of beef killed at this plant is 1,040±15 pounds, the quantity of waste produced per 1000 pounds live weight killed is close to the quantity produced per head of beef. About 350 gallons of wastewater are produced per head.

Brief Description of the System Evaluated

The plant wastewaters, excluding those from the stock pens and condensers, are sent to an existing clarifier which was modified to also balance flow volumes. The pH of the effluent from this clarifier is reduced with H_2SO_4 to between 2 and 3. Calcium lignosulfonate is added to the wastewater in quantities that are directly proportional to the COD concentration. Following this protein precipitation step, the resulting floc containing protein, fat, and suspended material is separated in two dissolved air flotation tanks.

Following this separation, the pH of the liquid effluent is raised to about 4 with $Ca(OH)_2$ and then mixed with other wastewater streams that are not treated by this process. The pH of the resulting mixture is about 7 and consequently is suitable for additional treatment by biological wastewater treatment processes.

The sludge is also neutralized with $Ca(OH)_2$ to an initial pH of 9.1 which eventually drops to a pH of 7.6. The sludge is dewatered in a centrifuge, dried and sold.

Table 2. *Unit Waste Production*

Waste Produced	*lb / 10³lb LWK**
5-day, 20°C BOD	*6.51*
Total suspended solids	*5.44*
Grease and oil	*1.26*
Organic nitrogen	*0.28*
Ammonia nitrogen	*0.18*
Phosphate	*0.04*

**lb/10³ lb live weight killed*

Scope of This Project

The major water quality parameters used to measure the effectiveness of this process are (listed in order of decreasing concentration):

COD
BOD_5
Total suspended solids
Total volatile solids
Volatile suspended solids
Grease and oil
Organic nitrogen
Ammonia nitrogen
Phosphate

The data summarized in this report cover a period of 8 months of operation. Because both the BOD_5 and suspended solids loadings were 50% greater than the values used in the initial design, a certain amount of additional research and development work was necessary during this 8 month period. Near the end of the 8 month data logging interval, 2 performance tests of 2 weeks each were conducted. The results obtained during these 2 trial periods may be a better indication of the capabilities of this process than the averages observed during the 8 month duration of the data collection summarized in this report.

Conclusions

For a beef packing effluent with an initial BOD_5 averaging 3,000 mg/l, the Alwatech process is capable of removing over 80% of the oxygen demand, about 86% of the suspended solids, and 94% of the fat, oil, and grease. Average removals of 41% of the ammonia N and 63% of the organic N were observed. The solids concentration of the sludge produced by this flotation process averages about 9%.

The optimum calcium lignosulfonate dose is about 5% of the influent COD concentration although additional work may later show that this dose can be reduced somewhat. While the optimum pH range varies from about 2 to less than 3, for incoming COD concentrations greater than about 1,800 mg/l, it is less expensive to use pH values nearer 2 because lower calcium lignosulfonate doses can be used. While chemical costs increase as the influent COD concentration increases, the rate of increase is less at pH values near 2.

While the centrifuge efficiency was about 94% for water, it was only 52% for total solids, 66% for protein and 21% for oil and grease. When the centrifuge reject solution is recirculated back to the plant influent, the incoming COD is increased 32%, the influent suspended solids are increased 29%, and the influent grease and oil is increased 36% to 52%.

Total observed operating costs were 47¢ per head or $1.68 per 1,000 gallons of wastewater treated. About 2 pounds of protein were recovered per head, so this protein would have to sell for 23.5¢ per pound in order to cover all operating costs. However, operating costs could be reduced to 40¢ per head by using less calcium lignosulfonate. Calcium lignosulfonate accounted for 39% of the total operating costs followed by 25% for labor, 15% for H_2SO_4, 10% for $Ca(OH)_2$, 9% for energy (1979), and 2% for repairs.

Biological activity in the clarifier balancing tank preceding the Alwatech plant had an influence on oxygen demand and nitrogen removal efficiencies. This biological activity is believed due to the paunch and gut contents, relatively long detention time (1.5-2 hours), and high effluent temperatures (100° to 125°F). However, the detention time cannot be reduced below 1.5 hours as fat skimming and bottom sludge removal would both suffer.

The discharge of 5-day, 20°C BOD from this beef packing plant has been reduced to less than 3 pounds per head. For every pound of 5-day, 20°C BOD entering the Alwatech plant, an average of 0.77 pounds of product was recovered with an average composition of 38% protein, 11% grease and oil, 27% fixed solids, and 24% other solids on a dry weight basis.

Monthly Average Effluent Concentrations

The monthly average effluent concentrations were 806± 413 mg/l BOD, 46± 24 mg/l organic nitrogen, 41 ± 13 mg/l ammonia nitrogen, and 15 ± 11 mg/l phosphate where the first figure is the average (arithmetic mean) and the second figure is the arithmetic standard deviation. Both the grease and oil and the total suspended solids effluent concentrations were so variable (coefficient of variation >1) that they were better represented by a log normal (geometric) frequency distribution. Accordingly, the suspended solids effluent concentration geometric mean was 309 mg/l with a geometric mean standard deviation of 2.2. The grease and oil effluent concentration geometric mean was 40 mg/l with a geometric standard deviation of 4.8.

Ammonia and Organic Nitrogen

The ratio of the standard deviation/mean for both the influent ammonia and organic nitrogen concentrations was the same (0.48). The total nitrogen concentration averaged 210 mg/l with a standard deviation of 74 mg/l giving a standard deviation/mean ratio of 0.35 which indicates that the total influent nitrogen concentration was less variable. The average removal of total nitrogen was 58% with a standard deviation of 21% giving a standard deviation/mean ratio of 0.36 which indicates that the % removal of total nitrogen was also less variable. Total nitrogen = ammonia + organic nitrogen because it is assumed that nitrate plus nitrite nitrogen is negligible in comparison in this wastewater.

On the average, 41% of the influent ammonia nitrogen concentration of 82 mg/l was removed and 63% of the influent organic nitrogen concentration of 128 mg/l was removed. Consequently, the ammonia and organic nitrogen concentrations in the effluent were both about 48 mg/l each so that the nitrogen effluent concentration was 95 mg/l.

An equation developed during the course of a laboratory investigation of protein recovery using chitosan was modified so that the % removal of organic nitrogen could be predicted as a function of temperature, pH, calcium lignosulfonate dose, and the COD concentration in the wastewater influent. Comparison of the % organic nitrogen removals calculated by this equation with the observed data gave a correlation coefficient of 0.84. Percent COD removal and % organic nitrogen removal are linearly related with a correlation coefficient of 0.82.

Phosphate and Fecal Coliforms

The average removal of phosphate was 49% which reduced the average influent concentration of 17 mg/l P to 9 mg/l P. A concentration of 6,600 fecal coliforms per 100 ml were observed in the effluent.

Solids

Bottom sludge from the air flotation tanks is 28% of the total wet sludge volume produced. Total dried sludge production averaged 5 pounds per 1,000 pounds live weight killed. The dried sludge was 38% protein, 27% inorganic solids, 11% grease and oil, and 24% other. The solids concentration of the dried sludge was 88% and therefore the water concentration was 12%. The dried sludge is sold for use in animal feeds.

Material Balances of Pollutants

On the average, 27.5 gallons of wet sludge were produced per 1,000 gallons of wastewater treated. Ninety percent of the wet sludge becomes centrifuge reject solution and 10% becomes dewatered sludge. The concentrations of COD, grease and oil, and suspended solids in the centrifuge reject solution averaged 50,000 mg/l, 5,860 mg/l, and 21,000 mg/l, respectively. Consequently, pumping the centrifuge reject solution back into the plant influent increased the incoming COD 32%. Eighty-three percent of the incoming COD is removed, and of the amount removed, 62% winds up in the dewatered sludge and the remaining 38% leaves in the centrifuge reject solution.

Based on separate disposal of the centrifuge reject solution, 81% of the suspended solids is removed, and of the amount removed, 64% winds up in the dewatered sludge and the remaining 36% leaves in the centrifuge reject solution. Consequently, pumping the centrifuge reject solution back into the plant influent would increase the influent suspended solids 29%.

Again based on separate disposal of the centrifuge reject solution, 94% of the grease and oil is removed, and of the amount removed, 53% winds up in the dewatered sludge and the remaining 47% leaves in the centrifuge reject solution. The grease and oil concentration in the dewatered sludge is about 6%. Recirculation of the centrifuge reject solution back to the plant influent would increase the influent grease and oil by roughly 44%.

Filter Belts

Initially it was attempted to dewater the wet sludge using filter belts, but these were found to perform unsatisfactorily on the wet sludge produced, so they were replaced with a centrifuge.

Economics

Virtually all cost inputs to the process were measured including labor, cost of repairs and maintenance, energy, and chemicals. Operating costs were $1.68 per thousand gallons treated. The capital costs for an 800,000 gpd plant are an additional $1.32 per thousand gallons treated, so the total cost is $3.00 per 1,000 gallons treated. The capital costs (and consequently the total costs) include property taxes, interest recovery of principal, and insurance. These costs do not give any credit for the protein recovered and sold.

About 2 pounds of protein are recovered per head. The average quantity of wastewater treated in the Alwatech plant was 276 gallons per head. Therefore the average cost of treating this wastewater was 83¢ per head, so that the protein recovered would have to sell for about 42¢ per pound of protein in order to recover all costs.

The wastewater treatment plant effluent pH averaged 3.7, but the wastewater discharged to the sewage treat-

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ment plant averaged 7 because of the effect of mixing the plant effluent with other wastewater streams from the beef packing plant. If the Alwatech wastewater treatment plant effluent had been raised to pH 7, this would have resulted in a needless increase of 10% in total costs.

Recommendations

Means of reducing the operating cost of the Alwatech process should be investigated. While the pH should be near 2 for minimum operating cost, the calcium lignosulfonate dose need not exceed 5% of the influent COD concentration. The effect of doses less than 5% on COD removal, and especially protein recovery should be studied.

The results of a detailed laboratory investigation of the use of chitosan are summarized. A similar study should be done for calcium lignosulfonate, because of the potential for significant reduction in operating costs. In addition, it is virtually impossible in a full scale operation (such as the one described in this report) to evaluate the effect of various plant operating practices on the sludge produced. Where protein recovery and hence financial recovery is possible, it is essential to know the effect of changes in operating variables on sludge production and characteristics.

Ways to increase the centrifuge efficiency for total solids as well as protein need to be investigated. The low protein efficiency (66%) of the centrifuge precludes separate treatment of the centrifuge reject solution unless one is willing to accept a 34% loss of potentially recoverable protein.

Before treatment by the Alwatech process, it may be desirable to have heavy solids and readily floatable grease removed by an efficient continuous screening system followed by a balancing tank with a relatively short detention time (30 minutes) to even out rapid variations in flow and concentration. This might improve solids handling and sludge product quality.

While additional investigation of this process has been recommended, the process is ready to be used in its present state of development.

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***Kenneth Dostal** and **Jack Witherow** are the EPA Project Officers (see below).*

The complete report, entitled "Protein Recovery from Beef Packing Effluent," (Order No. PB 81-224 362; Cost: $15.50, subject to change) will be available only from:

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