Resume of total operation of waste treatment facility for animal and vegetable oil refinery[1]

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A 2 year study in cooperation with the U.S. Environmental Protection Agency has been conducted to define and treat effluent from one of Swift's edible oil refineries. As a result of this study, the existing treatment system was modified to produce effluent suitable for discharge to the Kankakee, Ill., sanitary district and at the same time eliminate surcharges and the need for a lagoon. The treatment system consists of a skim tank which is cathodically protected, automatic pH and chemical addition control, and an air flotation cell also cathodically protected. Provisions also were made to recover the inedible oil for sale as a by-product. The skimmings from the skim tank and from the air flotation cell are acid treated, heated, and centrifuged to recover 7-10,000 lb/day of inedible oil. Sale of recovered inedible oil can cover 60-80% of the direct costs of operation of the waste treatment system. Recent improvements in the system have reduced the cost of treatment even further and rasied effluent quality. With impressed current and chemicals, the biochemical oxygen demand is reduced from 3300 to 150, fats, oils, and greases from 2500 to 75, and suspended solids from 3000 to 150 ppm.

INTRODUCTION

On July 10, 1968, Swift & Company accepted an Environmental Protection Agency research and development grant (12060-DQV) of $250,000 to study the removal and recovery of fatty materials from edible fat and oil refinery effluents at our Bradley, Ill., plant.

The Bradley refinery is a modern high volume edible fat and oil refinery engaged in all types of processing. Before the grant, the plant was equipped with standard sewage treatment facilities consisting of a large rectangular skim tank and a circular air flotation unit.

Under the grant, full-scale new equipment and modifications were installed providing a flexible and complete effluent treatment facility. Then, studies were made on coagulants, synthetic polymers, cathodic protection devices, proper pH control, and other instrumentation to produce an effluent containing 400 ppm, or less, of biochemical oxygen demand (BOD), ether solubles and suspended solids.

Also a centrifugal system was installed and evaluated to separate and upgrade the quality of the recovered fatty materials to obtain a more salable by-product to offset part of the cost of the waste treatment. Finally, a complete survey of individual plant waste streams was made.

IN-PLANT SURVEY

Details of the in-plant survey cannot be covered here. In summary it showed that the great bulk of waste flow and loading results from general cleaning operations indoors and outdoors. Relatively small amounts come from the basic refining, hydrogenation, bleaching, and deodorizing operations.

PROCESS DESCRIPTION

Figure 1 is a simplified process flow diagram for both the water clarification and the oil recovery systems.

Water Clarification System

All the plant waste drains into a concrete sump (upper left hand corner, Figure 1). Typical plant flow rate is 300 gal/min. From there, it is pumped to the skim unit.

Before reaching the skim tank, the waste flow passes through a "chemical mixing loop" of Teflon lined and 316 stainless steel pipe. Near the inlet end, the water phase from the DeLaval centrifuge (oil recovery system) is recycled and injected into the waste stream. Next, 66° Baume sulfuric acid is injected under automatic control for adjustment of the raw waste pH.

The waste flow then proceeds through a magnetic flow meter to the skimmer unit which has an overall retention time of 46 min at 300 gpm and surface scraper blades to skim off the grease to a steam coil heated tank. No provisions were made in the skimmer for continuous removal of settled solids. It must be cleaned out ca. once a month.

The water then is pumped through a small tank under 40 psi pressure, then through a back pressure value to the air flotation unit. On the way, it passes through an in-line blender. Air is injected directly into the bottom of the mixer under pressure at a rate equivalent to at least 4% by volume of the water processed. A 20% alum solution is injected 20 ft upstream from the in-line mixer.

A polymer at 0.2% solution is injected just downstream of the back pressure valve.

The air flotation cell has a retention time of 36 min at 300 gal/min. Skimmings are discharged by gravity into

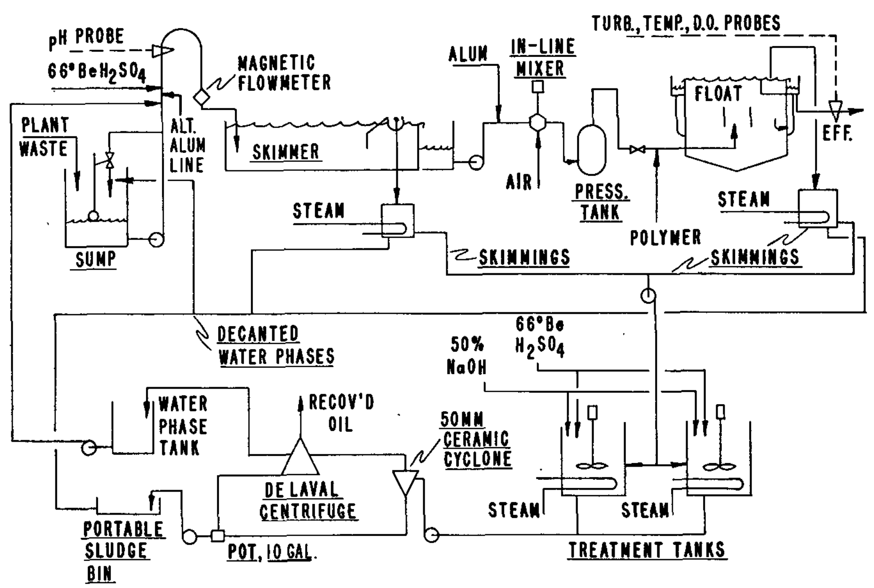

FIG. 1. Bradley waste treatment flow diagram.

[1]One of seven papers presented in the symposium, "Ecology—Practical Solutions to Environmental Problems as Practiced in the Fats and Oils Industry" at the AOCS Spring Meeting, Mexico City, Mexico, April 1974.

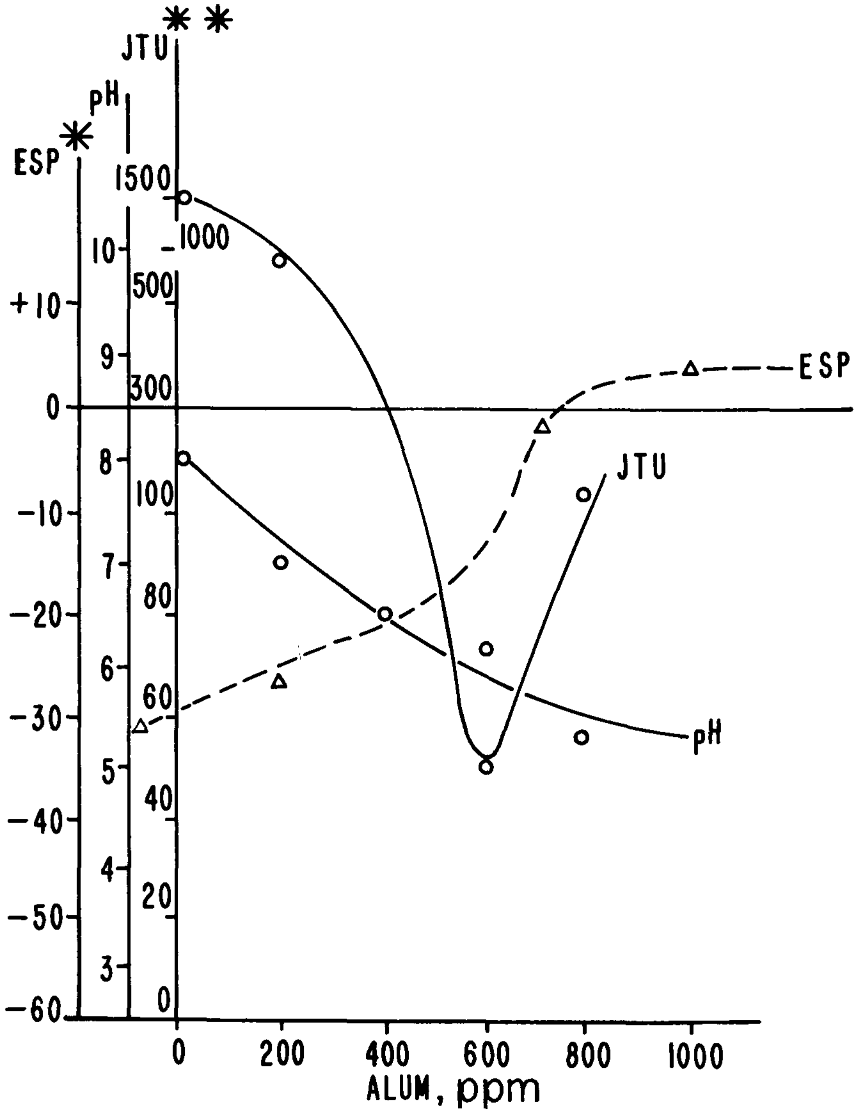

FIG. 2. Effects of initial pH and alum dosage upon clarified phase final pH, turbidity, and effective surface potential (ESP). Sample: Bradley composite, pH adjustment: to pH 8.0 with sulfuric acid, pre-floc: alum, and collector: X400 2.0 ppm. Minimum turbidity: point C, Figure 3. JTU = Jackson turbidity units.

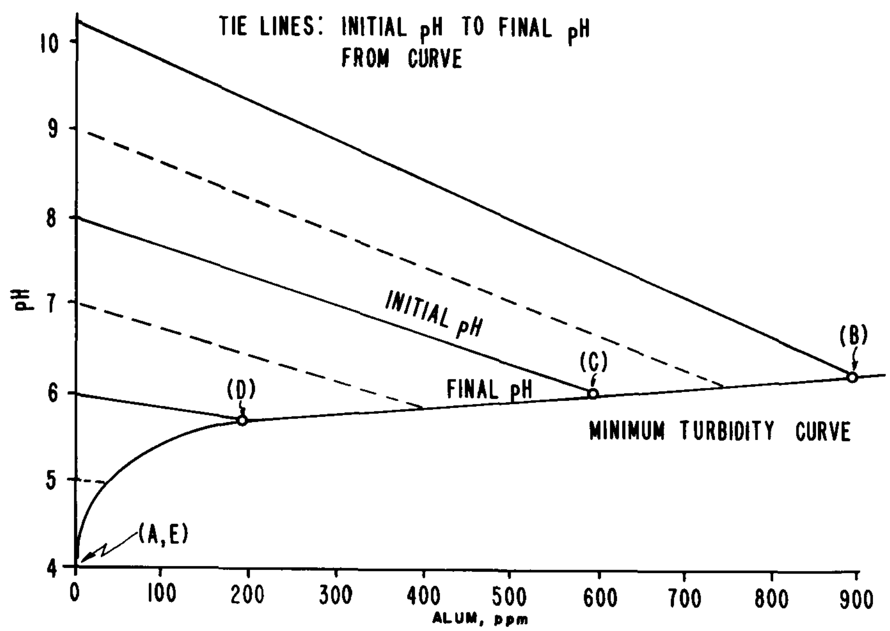

FIG. 3. Minimum turbidity curve; and initial pH, final pH, and alum dosage required. Minimum turbidity curve: letters in parentheses indicate data from other figures, such as Figure 2.

steam coil heated steel tank. The clarified effluent discharges by gravity into an underground sump from where it was formerly pumped to a 200 ft by 300 ft aerated lagoon on the premises and then to the Kankakee Municipal Waste Treatment Plant. The lagoon has been eliminated as a result of the new system and its performance.

Dissolved oxygen, turbidity, and temperature instruments and a continuous total carbon analyzer were used to monitor the air flotation cell effluent.

The turbidity probe was found unsatisfactory primarily because of prism failure. When the unit was operative, it did track the process quite well.

Usually the dissolved oxygen content of the plant effluent was at saturation, so this instrument is not needed.

The automatic total carbon analyzer was found unacceptable, mainly because its input disc filter and sample measurement orifices became plugged rapidly with grease.

Oil Recovery System

Skimmings from the skimmer and air flotation units are pumped to either one of the two 6500 gal large agitated treatment tanks. They can accept 24 hr collection of waste grease. While one is being used to collect the grease, the contents of the other is heated to 170 F, treated with sulfuric acid to 2.5 pH.

The two treatment tanks are of fiberglass reinforced polyester resin, with direct steam injection and temperature controls. Both tanks have failed after 3-1/2 years and will be replaced with wooden tanks.

After treatment, the waste grease is pumped through a 50 mm ceramic cyclone and then to a bowl opening, disk stack type centrifuge. The ceramic cyclone removes most of the sand and grit from the feed to the centrifuge, but significant wear of the bowl still occurs. The sludge underflow from the centrifuge and the underflow grit stream from the ceramic cyclone are pumped into a portable scavenger bin for disposal.

Centrifuge acid water is stored and recycled continuously to the chemical mix loop of the water clarification system where it partially acidifies the raw waste.

EVALUATION OF FLOCCULANTS

In general, coagulants, such as alum, produce a pinpoint sized particle. The role of the polymer is to produce a further agglomeration of these pinpoint particles to a size that will be more amenable to separation.

Laboratory Screening Tests

Many polymers were screened in

laboratory tests in combination with coagulants.

Anionic and nonionic polymers generally performed better than cationic polymers, especially at lower pH levels. However, they all performed well, lowering turbidity 10-50% more than when using coagulant alone.

Also the relationships between surface charge, pH, and turbidity were investigated. A typical set of curves obtained (Fig. 2) is given where the sample was adjusted initially to 8 pH, then alum treated, followed by addition of 2 ppm Swift X-400 polymer

It shows that the point of maximum clarity (or minimum Jackson turbidity units) appears as the effective surface potential (ESP) approaches zero but is not necessarily maintained, even though the ESP may remain near zero as the curves move from left to right or in the direction of increasing the alum dosage.

To summarize the relationships between initial and final waste pH, alum dosage, and turbidity, when using 2 ppm of Swift X-400, the curve in Figure 3 was constructed. It connects all points of minimum turbidity for the corresponding initial and final pHs. This figure was used as a guide to the best range of conditions to be explored in the Bradley waste treatment system evaluations and was substantiated by the longer term plant tests made.

Bradley Waste Water Clarification Tests

Based upon the laboratory screening tests, several manufacturers' polymers and coagulants were studied in continuous tests in the new treatment facility over a period of months.

In summary: (A) best results were achieved when operating conditions conformed to Figure 3, (B) alum was found to be the best coagulant, and (C) all the polymers performed well with no more than 2 ppm needed.

Average test data for the 4 pm-midnight shift, which are actually typical of all shifts, are given in Table I.

Flow rates actually varied from 100 to over 600 gpm, and raw waste contaminant concentrations were up to 10 times the average shown.

Removal efficiencies for the air flotation cell were generally 2.5 times as high as for the skimmer unit, i.e. 70-88% compared with 20-40%.

Air flotation effluent contained an overall average of 401 ppm suspended solids, 357 ppm ether solubles, and 741 ppm BOD. During subsequent nontest operations, levels were maintained substantially lower.

Overall removals of contaminants shown in Table II were 84.0-89.4% for suspended solids, 87.2-92.4% for ether solubles, and 74.9-81.6% for BOD. Overall BOD removals were typically 10% lower than for suspended solids and ether solubles. This is explained, in part, because 50-150 ppm soluble BOD are contained in the raw waster which the system does not remove.

Influence of Cathodic Protection Devices

The technology of cathodic protection for corrosion control is well known, and such equipment was installed as part of the project in the skim tank and air flotation units for corrosion control. However, it also was evaluated relative to its benefit for improving flocculation clarification efficiency based upon tests made previously at a Swift & Company packing plant and in the laboratory.

Corrosion was brought under control in the skimmer and air flotation tanks. Further, all metal surfaces below the water line remained free of adhering deposits of fat and scale, whereas previously a thick, firm cake would form and, subsequently, fall off at random. However, during the project a beneficial effect of impressed current on flocculation efficiency was not demonstrated clearly. Nevertheless, based upon extensive laboratory and field work in other and similar applications, particularly in recent months, impressed current does produce very valuable benefits on flocculation and clarification of waste waters.

Several months ago, the Bradley impressed current arrangement was revised in accordance with our continuing research program to develop this technology further. As a result, less chemical is being used, and the effluent now averages 75 ppm hexane solubles and ca. 150 ppm each for suspended solids and BOD.

OIL RECOVERY SYSTEM EVALUATION

Table III gives typical operating and analytical data for the oil recovery system when using proper conditions. The recovered oil phase contained an average of 0.3% mositure, 98.9% ether solubles, 0.3% ether insolubles, and

TABLE I

Averages, All Data, Afternoon Shift
Bradley Flocculant Tests

Raw waste	
gal	138,407
gpm	288
pH	9.0
Suspended solids, ppm	3,679
Ether solubles, ppm	3,984
Biochemical oxygen demand, ppm	4,012
Skimmer effluent	
pH	6.5
Suspended solids, ppm	2,706
Suspended solids, % removed	32.6
Ether solubles, ppm	3,195
Ether solubles, % removed	25.3
Biochemical oxygen demand ppm	2,439
Biochemical oxygen demand % removed	38.3
Air flotation effluent	
Temperature	111
Alum, ppm	452
Polymer, ppm	2.59
pH	5.0
Suspended solids, ppm	401
Suspended solids, % removed	84.3
Ether solubles, ppm	357
Ether solubles, % removed	88.3
Biochemical oxygen demand, ppm	741
Biochemical oxygen demand, % removed	70.3

TABLE II

Percent Overall Contaminant Removals[a]

Analysis	Shift: Midnight	Morning	Afternoon
Suspended solids	84.0	86.7	89.4
Ether solubles	87.2	92.4	91.2
Biochemical oxygen demand	74.9	77.0	81.6

[a]Given in percentage.

TABLE III

Typical Oil Recovery System Data[a]

Parameter	Feed	Oil	Water	Cyclone sludge	DeLaval sludge	Total sludge
Rate, lb/min	114	29	44	15	26	41
Analyses						
Moisture,	67.0	0.8	95.0	90.6	93.1	92.1
Ether soluble	28.3	98.9	1.3	4.4	2.3	2.7
Ether insoluble	4.7	0.3	3.7	5.0	5.1	5.2
Ash	1.7	0.13	1.9	2.4	2.3	2.4
Distribution						
Ether soluble to:		88.9	1.8	2.0	1.8	3.4
Ash to:		1.9	43.1	18.6	30.9	50.8

[a]Given in percentage

TABLE IV

Average Additional Quality Analysis for DeLaval Recovered Oil

Free fatty acid, %	Fat Analysis Committee color	Titer	Saponifiable	Unsaponifiable	Iodine value
21.9	21	34.9	198.2	2.5	05.2

0.13% ash.

Neither oil quality nor oil recovery are affected significantly by the typical range for grease feed rate and composition.

Table III also shows 88.9% of the oil in the feed, as ether solubles were recovered in the oil phase. Actually, over 95% of the ether solubles are recovered since only half the sludge is lost after dewatering.

Additional oil quality analysis are given in Table IV. The overall oil quality is such that the oil has a minimum market value of at least 4.25 cents/lb.

ECONOMIC EVALUATION

Direct operating costs for the Bradley water clarification are shown in Table V, based upon 500,000 gal/day. Annual depreciation charges are not included.

The total daily direct operating cost for the water clarification system is $328, of which 38% is for chemicals, 5% for utilities, 46% is for direct labor, and 11% is for maintenance.

Total direct operating cost for the oil recovery system, Table VI, is $171, of which 5% is for sulfuric acid, 29% for disposal of the combined centrifuge and grit cyclone sludge, 10% for utilities, 44% for direct labor, and 12% for maintenance. The 7000 lbs reclaimed oil obtained each day or 1,750,000 annually (250 days) with a value of 4.25 cents/lb in soap or animal feed would yield $300/day and $74,000 annually. This is 60% of the grand total waste treatment direct operating costs of $500/day.

The installation at Bradley was conceived and installed a number of years ago. This installation has been extremely successful, in that the operation of the lagoon was eliminated and its associated odor problems; the plant effluent meets the sanitary district's requirements without the generation of surcharge payments, and a sizable quantity of salable inedible grease is recovered from the sewer.

Since our work at Bradley, we have continued to do research on waste treatment and by-product recovery, particularly in the area of electrochemical floc formation. We have been intrigued by this because of the apparent synergistic effects from impressed current and chemical treatment. The use of impressed current is considerably less expensive than the use of chemicals, and it is advantageous to reduce chemical costs wherever possible. In addition, it is desirable from the by-product recovery standpoint to recover materials uncontaminated with chemicals. This is true especially in the areas of fats, oils, and greases where the presence of alum or ferric sulfate interferes with subsequent rendering and recovery of the fats and oils.

Our research over the last several years has resulted in the design of four different types of electrochemical cell geometries, each with a specific purpose in mind. One of these involves recovery of fats and oils from waste streams without the use of any chemical whatsoever. This design is more efficient than the one which was installed at our Bradley Edible Oil Refinery. We have had great success in recovering all types of fats, oils, and greases from a wide variety of sources.

After primary removal of fats, oils, and greases, the residual material, which is suspended solids, BOD, and any residual oily matter which escaped the first treatment, then can be treated chemically and caused to rise.

Part of our study in the fundamentals of cleaning up waste systems involves the study of the effectiveness of bubble formation from an electric grid.

The rise-rate of bubbles can be demonstrated as a function of size. If a bubble is large, the rise-rate is more rapid than if the bubble is very small. Larger bubbles have points of attachment to floc particles which are weak relative to the pulling powers of larger bubbles. This means that the bubble may lose a particle before it has been pulled to the surface. Also, the larger bubbles, by rising at a faster rate, do not remain long enough for effective collisions with suspended matter.

We have determined the parameters of an electric cell which are necessary to produce an extremely fine cloud of bubbles much smaller than can be achieved with dissolved air principles. By the judicious use of a cloud of microbubbles generated electrolytically, we can affect the clarification of waste water more efficiently than is possible by any other means.

We also have come to realize the value of field testing. The advantage of field testing is on-site characterization of any given waste stream and enables one to collect engineering data, as well as to demonstrate the effectiveness of electrocoagulation techniques for not only nonchemical removal of fats, oils, and greases, but final clarification of the waste water as well.

We also have a mobile laboratory which we take to the plant site for in situ characterizations of waste streams.

Electrochemical techniques are not

TABLE V

Direct Operating Costs for Water Clarification[a]

Item	Dollar/day	Percent
Alum, 500 ppm, $0.03/lb	62	19
Swift X–400 polymer, 2 ppm, $1.65/lb	13	4
Sulfuric acid, 66 C, Ee, 1700 ppd, %0.03/lb	51	15
Power, 1370 Iw hr, %0.0094/Mw hr	13	4
Steam, 3000 ppd, %1.00/1000 lb	3	1
Labor, 1 man/shift, $6.25/hr (includes fringes but not supervision or material handling)	151	46
Maintenance (excluding depreciation)	5	11
Total	328	100

[a]Basis: 500,000 gpd waste flow, Monday-Friday.

TABLE VI

Direct Operating Costs for Oil Recovery[a]

Item	Dollar/day	Percent
Sulfuric acid, 66 C, $0.03/lb	8	5
Sludge disposal, $150/2100-gal load/3 days	50	29
Steam, 3000 ppd, $1.00/1000 lb	3	2
Power, 1440 per hr, $0.0094/Rw hr	14	8
Direct labor, 1.5 men/day, %6.29/hr	76	44
Maintenance (excluding depreciation)	20	12
Total	171	100

[a]Basis: 500,000 gpd waste flow, Monday-Friday.

limited strictly to edible oils but are applicable also to petroleum-type oils. We have installed a two stage system at a refinery in Oklahoma, where the first stage is designed to, and in fact does, remove hydrocarbon-type oils from the waste stream without the use of chemicals, and the second stage is used to clarify the waste water. The first stage returns essentially all of the available hydrocarbon materials to the refinery where they are reprocessed. The second stage has effectively eliminated a large ponding system for final treatment of the waste water before it discharged to a federal system.

The electrochemical process has proven effective in removing fats and oils without the aid of chemicals at a large packing plant. The flow at this plant is 1200 gal/min. Even though the waste stream is contaminated with manure, blood, and has a fluctuating pH, it is still possible to recovery fat down to a level of 20 ppm, and this fat then is augured directly to a melter for rendering.

A fat recovery system also has been designed for an edible renderer. The fats, oils, and greases are removed in this case in a single stage operation from a level of 3000-5000 ppm to less than 100 ppm. The recovered fat then is passed through a skimmings thickener where the concentration is increased from 10-45% of hexane extractables. Control equipment which is installed at this plant enables the system to operate essentially without attention.

The process also has been installed in an inedible rendering operation which was not in trouble with the sanitary district. This installation was made at the request of the owner strictly for economic reasons: the fats and oils are money and the recovery from the sewer is profits.

Treatment of vegetable oil refining wastes to conform to government regulation[1]

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Historical and conventional methods for the treatment of vegetable oil waste water are described. The results obtained and the economics of the various processes for oil-water separation are reported. A process utilizing selective adsorption filtration is described. The new regeneration procedure for cleaning the filter media allows for its total reuse. The process produces effluent water which will conform to existing government regulations for oil content. Development of the filtration/regeneration process is described up to full-scale installation with test results.

INTRODUCTION

Food processing plants have, in general, been designed to include one or more effective methods for removing gross amounts of such pollutants as biological oxygen demand (BOD); solids; fats, oils, and greases (FOG); acids; and alkalies. In reference to the plant waste water stream; however, the main technological emphasis has been given to the recovery of valuable by-products, i.e. the pollution-control achievements have been a desirable, but nonessential, effect of the attempt to recover these reusable by-products.

SKIMMING

Gravity separation is employed as a by-product recovery and pollution control method almost universally by industries which have significant amounts of fats and oils in their waste water streams. The method usually involves the combining of the various plant waste water streams and dumping into a common separation station. The separation station consists of a large pit equipped with bottom sludge removal equiment and a mechanical skimmer for removing the floating oils and fats. There is also a drain for taking off excess water. This recovery method is subject to overloading during peak production periods, is quite frequently a source of offensive odors, and produces neither high quality reusable products nor acceptably clean water.

Operating costs for this type of equipment are relatively low, but, as seen in Table I, the effluent water is far outside current limits for concentration of pollutants.

DISSOLVED AIR FLOTATION

A much more recent improvement in the treatment of food processing wastes is a method known commonly as dissolved air flotation. This method is more effective than skimming but less effective than some other known methods. Basically, the treatment consists of releasing pressurized air into a nonpressurized tank containing the waste water. The tiny air bubbles formed by this action will attach themselves to the dispersed grease and oil droplets and to the suspended solids (SS). This will tend to rise to the surface more rapidly and completely than in a simple skimming tank. Heavier solids will still fall to the bottom.

The results, shown in Table II,

TABLE I

Typical Results of Skimming Method (1)[a]

Impurity:	BOD	SS	FOG
Input	4010	3680	3985
Output	2440	2700	3200
Percent removal	38	33	25

[a]BOD = biological oxygen demand, SS = suspended solids, and FOG = fats, oils, and greases. These are given in ppm.

TABLE II

Typical Results Using Dissolved Air Flotation (1)[a]

Impurity:	BOD	SS	FOG
Input	2625	2225	1485
Output	1760	1507	560
Percent removal	33	32	62

[a]BOD = biological oxygen demand, SS = suspended solids, and FOG = fats, oils, and greases. These are given in ppm.

TABLE III

Results Using Alum and Polymer Combined with Dissolved Air Flotation[a]

Impurity:	BOD	SS	FOG
Input (from skimmer)	2440	2706	3195
Output	740	400	360
Percent removal	70	84	88

[a]BOD = biological oxygen demand, SS = suspended solids, and FOG = fats, oils, and greases. These are given in ppm.

[1]One of seven papers presented in the symposium, "Ecology–Practical Solutions to Environmental Problems as Practiced in the Fats and Oils Industry" at the AOCS Spring Meeting, Mexico City, Mexico, April 1974.