Jaocs News Feature

SYMPOSIUM: ECOLOGY–PRACTICAL SOLUTIONS TO ENVIRONMENTAL PROBLEMS AS PRACTICED IN THE FATS AND OILS INDUSTRY

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Biological treatment of fatty acid and nitrogen derivative waste water[1]

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Armak Company's McCook, Ill., plant has installed an aerobic biological treatment system to handle a portion of its waste water flow prior to discharge to a municipal treatment plant operated by the Metropolitan Sanitary District of Greater Chicago. The waste includes a mixture of animal and vegetable fats and oils, fatty acids, nitrogen derivatives of fatty acids, and miscellaneous organic chemicals. The purpose of the treatment system is to reduce fats, oils, or greases as measured by a hexane soluble test to below 100 mg/liter, as required by Metropolitan Sanitary District ordinance. The biological treatment system achieved an average reduction of 92% in hexane solubles and an 82% reduction in chemical oxygen demand during the reporting period, when incoming hexane solubles average 760 mg/liter, and chemical oxygen demand average 4800 mg/liter. The hydraulic flow during this same period average 320,000 gpd. Odors associated with the operation required covering the aeration basins and treating the effluent air.

[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.

INTRODUCTION

The McCook, Ill., plant of Armak Company manufactures a broad line of fatty acids and nitrogen derivatives of fatty acids. This plant pioneered the commercial production of many fatty based chemicals, including amines, quaternary ammonium salts, and ethoxylated amines, and expanded Armak's use of vacuum fractionation of fatty acids.

Starting with a few simple raw materials–predominately tallow, coconut oil, and soybean oil–and using physical separations and chemical reactions involving mainly ammonia and hydrogen, a bewildering variety of fatty based products, numbering up to 250, is produced. The variety of products and the age of the plant have combined to produce a complex waste water problem.

The waste water from the plant is discharged into the interceptor sewers of the Metropolitan Sanitary District

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(MSD) of Greater Chicago and flows to the MSD's southwest treatment plant in Stickney, Ill., where it is treated along with water from other sources before being discharged to surface waters. The MSD's plant is the largest of its kind in the world and is capable of handling an average flow of 825 million gal/day and a maximum storm flow of 1.3 billion gal/day. By comparison, Armak's total flow normally does not exceed one million gal/day. The MSD has an ordinance governing the quality of the waste that may be discharged into its sewerage system. One portion of the ordinance prohibits water or wastes containing more than 100 mg/liter fats, oils, or greases, as measured by hexane solubles. The ordinance makes no distinction between fats, oils, or greases of animal or vegetable origin, which constitute Armak's waste load and which are readily biodegradeable, and those of petroleum origin which are quite refractory.

Primary waste water treatment in the form of settling and skimming has been part of the McCook plant's operation since its beginning and, in 1968, a new, improved clarifier was put into service. However, many of the products are surface-active and a fair amount of the waste is emulsified, reducing the effectiveness of the primary clarifier. The emulsification problem is aggravated by the variety of products and changes made in the plant and sewer system in the last 25 years which have resulted in the mixing of a number of waste water streams before entering the primary clarifier. Our experience tells us that separation is less effective under these conditions than if the streams are skimmed separately. As a result, primary clarification alone is not sufficient to produce a waste effluent with a hexane soluble below 100 mg/liter.

Given this situation, it was not considered practical to attempt to separate and skim each waste water stream, nor was it probable that this alone would result in an effluent that would meet the ordinance. Armak chose to implement in parallel a three pronged strategy which is certainly familiar to anyone who has seriously contemplated a similar problem. The company: (A) mounted an intensive, continuing effort to improve housekeeping and to make every employee keenly aware of how his actions affected the wasteload; (B) implemented projects and operating procedures aimed at eliminating waste at the source; and (C), on the assumption that the first two might be only partially successful or that upsets could cause a high effluent, decided to install some method of treatment for the effluent from the primary clarifier.

This paper deals only with the last item, namely, secondary treatment.

TABLE I

Design Loading for Biological Treatment System

Description	lb/day	mg/liter
Average hexane solubles	3,700	830
Average chemical oxygen demand	18,500	4,100
Average suspended solids	2,700	600
Maximum hexane soluble (90%)	6,700	1,500
Maximum chemical oxygen demand (90%)	32,000	7,200
Average flow	0.54 mgd	

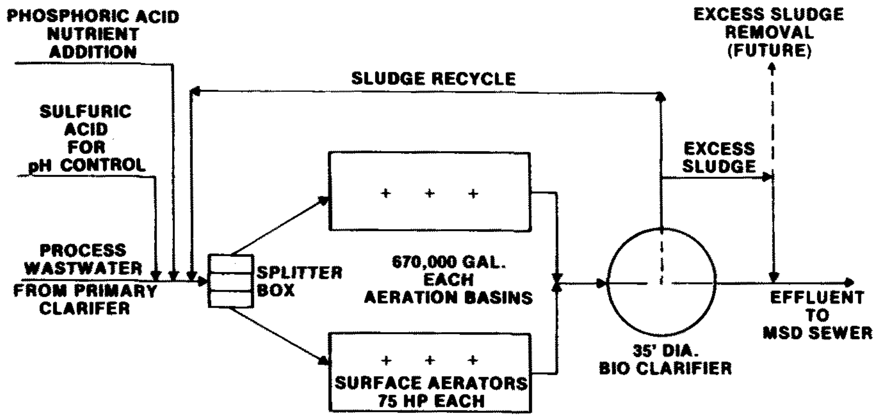

FIG. 1. Activated sludge system biological waste water treatment.

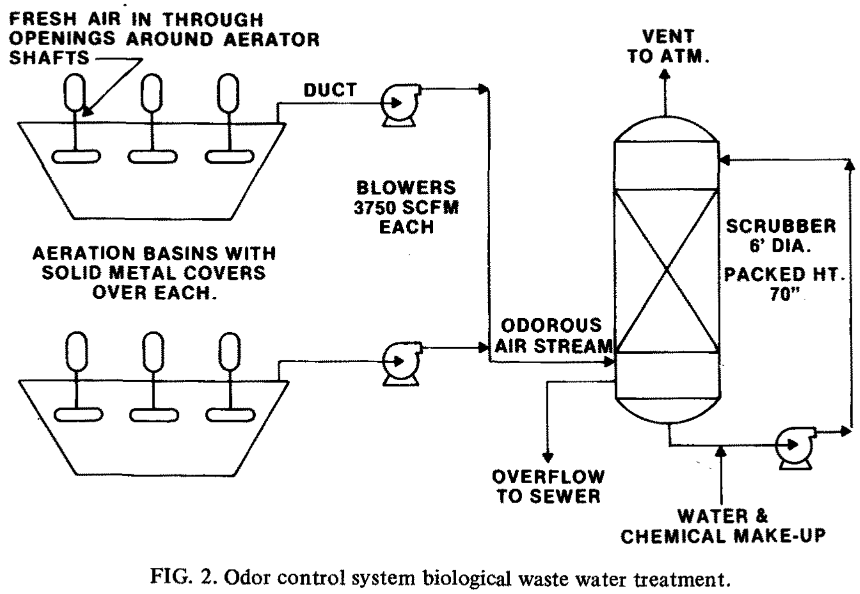

FIG. 2. Odor control system biological waste water treatment.

TREATMENT FOR PRIMARY CLARIFIER EFFLUENT

Armak had been working quite actively on this problem with its consultant Hydroscience, Inc., Westwood, N.J. Screening tests done by Hydroscience to find a suitable method for treating the primary clarifier effluent to reduce hexane solubles included foam separation, chilling, coagulation, acidification, solvent extraction, activated carbon, and both anaerobic and aerobic biological treatment. It was concluded that aerobic biological treatment of the effluent from the primary clarifier offered the best route to success. A search of the literature failed to disclose the operation of a biological treatment system on waste similar to that produced by the McCook plant. Because of the lack of a precedent, a federal Environmental Protection Agency grant was received in support of Armak's project to demonstrate on a full scale the suitability of biological treatment of fatty nitrogenous wastes, both because the application was sufficiently novel and because it would have a wider application in the industry.

A decision was made to pilot the operation both to demonstrate the feasibility of biological treatment of these variable waste waters and, at the same time, to obtain design data for the full scale treatment plant. The pilot unit was operated for over a year under all conditions during which time biological treatment was studied at various loading rates and detention times and the system characteristics, such as oxygen requirements and transfer, solids product, settling rates, and other needed information, was obtained.

The waste water stream from Arquad production, Armak's trade name for quaternary ammonium salts, was kept out of the stream destined for biological treatment because of the toxic effect upon biological activity at the concentrations that likely would be encountered. This stream is small and is being treatment separately by skimming followed by physical treatment.

DESIGN

The design basis selected for the full scale plant is shown in Table I.

An activated sludge system, shown in Figure 1, was designed to handle the above load.

The effluent from the primary clarifier is split between two aeration basins with a capacity of 670,000 gal each, providing a 2.5 day detention at design conditions. A loading of 0.3 lb biochemical oxygen demand (BOD)/day-lb of mixed liquor suspended solids (MLSS) was used; a loading rate normally found in municipal-industrial treatment plants. Each basin is equipped with three 75 horsepower surface aerators with a total oxygen transfer capability of 19,000 lb/day designed to maintain a dissolved oxygen of 2 mg/liter at the 90% occurrence loading level. Provision for pH adjustment and phosphorous feed is included, the latter to provide the required nutrient level for biological growth. Since the wastes are rich in ammonia, no additional nitrogen nutrient is required. The overflow from the basins flows by gravity to a 35 ft diameter bioclarifier in which the biological solids are allowed to settle and are recycled to the aeration basins. The clarified overflow from the bioclarifier is discharged to the MSD sewer along with any excess sludge. The system is designed to produce an effluent with a total hexane soluble of 102 mg/liter and a filtered hexane soluble of 35 mg/liter.

The full-scale system was completed in late 1971, and, after correcting some initial mechanical problems, the unit was started in the spring of 1972. The basins were seeded with sludge obtained from the MSD's plant. Acclimation to Armak's waste was rapid and proceeded without difficulty. Reduction of hexane soluble and chemical oxygen demand (COD) was good; the biological sludge settled well in the clarifier, and the whole startup appeared to be moving smoothly. However, the initial flush of satisfaction soon was shattered when it became apparent that there was an odor problem associated with the process. Even though no odors had been detected during the operation of the pilot unit, possibly because of its smaller scale, a mixed chemical-type and earthy-type odor could be detected when the full-scale plant was in operation. Under some circumstances, the odor would not have been considered a problem; however, in this case, the plant is in the midst of a residential-industrial community with many homes located within a few hundred yards of the treatment plant. Under this situation, the odors had to be brought under control. This was done by providing a rigid low profile cover over the basins and using fans to induce an air flow of ca. 7500 standard

TABLE II

Loading System Design Conditions vs Actual Loading[a]

Description	Design	Actual
Hexane soluble (total)		
Average		
mg/liter	830	760
lb/day	3,700	2,000
90% Occurrence		
mg/liter	1,500	1,900
lb/day	6,700	5,100
Chemical oxygen demand (total)		
Average		
mg/liter	4,100	4,800
lb/day	18,500	12,800
90% Occurrence		
mg/liter	7,100	9,500
lb/day	32,000	25,500
Average flow (mgd)	0.54	0.32
Detention time (days)	2.5	4.2
Average basin temperature (C)	30	37

[a]Both the actual flow rate and the load in terms of lb/day are lower than design indicating continuing improvement in housekeeping and reductions at the source. Temperatures are higher than design reflecting the influence of the basin covers in reducing heat loss. The effluent quality for the same period is shown in Table III.

TABLE III

Effluent Quality
System Design Conditions vs Actual Performance[a]

Description	Design	Actual
Hexane soluble (total)		
Average		
mg/liter	102	64
lb/day	460	170
90% Occurrence		
mg/liter	185	110
lb/day	834	290
Chemical oxygen demand (filtered)		
Average		
mg/liter	490	880
lb/day	2,200	2,400
90% Occurrence		
mg/liter	740	1,500
lb/day	3,300	4,000

[a]Removal of hexane solubles exceeds design, and chemical oxygen demand removal is slightly below design as the comparison in Table IV shows.

TABLE IV

Removal of Hexane Solubles and Chemical Oxygen Demand

Description	Design (%)	Actual (%)
Hexane soluble		
Average	88	92
90% Occurrence	88	94
Chemical oxygen demand		
Average	88	82
90% Occurrence	90	84

cubic feet per minute under the covers to provide the necessary oxygen for the biological process. The exit air was ducted into a wet scrubber. The scrubbing solution has alternated between an acid solution or an acidic potassium permanganate solution. Both have been found to be effective, though less than 100%, under different circumstances. Figure 2 is a sketch of the system.

There is one problem associated with a covered basin which is not encountered in open basins, namely, getting rid of the heat in the summer. This can be quite important when influent temperatures are high to begin with. Sources of heat gain include the mechanical work by the surface aerators, radiation, and the exothermic heat developed by the biological activity. One can calculate from heats of combustion, a heat of 5867 btu/lb COD reduced based on stearic acid. This can result in a sizable input when the organic load is high. Under normal circumstances, the heat losses from an open basis are adequate to prevent any problems. However, in a covered basin, heat losses are relatively low, and, while this may be a blessing in the winter, it is a problem during the warm weather. The result is a net heat gain to the aeration basins in the summer which raises the basin temperature to a critical level and requires artificial cooling.

Literature, laboratory tests, and our experience with the full-scale system all indicate that the efficiency of the biological system begins to drop above a certain temperature, and, in fact, it appears that the biological population is much more likely to be killed or retarded by a shock load or other stress at excessively high temperatures (above 45 C) than at low temperatures. Settling is also poorer at the higher temperature. Our experience, confirmed by laboratory tests, indicates that, for our particular system, temperatures should not exceed 38-40 C with optimum removal at ca. 32 C. With no heat removal, temperatures have, on occasion, reached 46 C.

PERFORMANCE

The performance of the system has been quite good, as can be seen from some of the following comparisons between design conditions and actual performance for a 4 month period from September-December 1973. The feed conditions are compared in Table II, and the effluent quality is compared with design conditions in Table III. Table IV compares actual percent removals of hexane solubles and COD with design. Actual removal of hexane solubles averaged 92% and design removal 88%. However, actual removal of COD at 82% was lower than the design of 88%.

Although the performance of the system meets the standards initially established for it in terms of hexane solubles, other factors dictate a further improvement in its performance. This will be accomplished by removing the biological solids from the effluent discharged to the MSD. The hexane solubles in the effluent are expected to be reduced by ca. one-third by removal of the biological solids.

Further work also is required to improve the effectiveness of the odor control system. Odors are unfortunately difficult to measure objectively and, in the end, depend upon subjective responses of individuals. While the odor situation with the covered scrubber is much improved over the bare basins, there is still occasionally some residual odor which is deemed objectionable in the long run. To handle this in a conclusive fashion, an incinerator currently is being added to destroy completely all odors from the basin.

This paper is but a brief summary of a very complex situation. It does, however, definitely show that a mixture of fats and oils of animal or vegetable origin, fatty acids, and nitrogen derivatives can be treated successfuly in a biological system.

The capital cost for the waste treatment system is almost $500,000 and the cost for the odor control system, as described, is ca. $170,000.

In view of the short supply of human resources and the constantly worsening energy situation, it is a pity that the regulations require the installations of the above system. The wastes are amenable to biological treatment, are compatible with the MSD's system, and could be treated effectively and efficiently in its large central plant. The present MSD surcharge ordinance which computes charges based upon flow, BOD, and suspended solids would have assured a fair payment for our load. The overall cost to the company, the consumer, and the country reckoned in any fashion you wish would have been less by utilizing the central plant for all compatible wastes than the situation which now exists with two biological systems in series. Situations similar to this represent a waste of resources which the country cannot accept indefinitely.

A statement by the federal EPA in its Pretreatment Standards (1) makes a sensible point:

> Where the joint treatment works was designed to and does achieve substantial removal of a pollutant, it is not appropriate to require the industrial user to achieve best practicable control technology currently available, since this would lead to an uneconomical duplication of treatment facilities. While the term 'substantial removal' is not subject to precise definition, it generally contemplates removals in the order of 80% or greater.

In discussing compatible pollutants, the regulation goes on to state: "Examples of such additional pollutants may include: . . .fats, oils, and greases of animal or vegetable origin except as prohibited under 128.131 (c)."

I believe that the information presented does show that the waste under discussion is amenable to "substantial removal" and could be handled by the MSD's central treatment plant. However, this cannot be done unless the ordinance is amended. This is not going to occur without a determined effort by the effected industries.

ACKNOWLEDGMENTS

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REFERENCE

1. Environmental Protection Agency, Fed. Reg. 38:30982 (1973).

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