WASTE DISPOSAL IN THE MEAT INDUSTRY (A COMPREHENSIVE REVIEW OF PRACTICE IN THE UNITED STATES)

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ABSTRACT

Meat industry waste waters are 5 to 10 times as strong (BOD) as domestic sewage and contain much higher nitrogen, phosphorus and grease concentrations. Conservation measures and pretreatment facilities are aimed principally at blood (or blood water), casing slimes, wet rendering (tank water), paunch manure, yard drainage and hog hair. The answers available are: dry rendering of blood and grease, coagulation of casing slimes, new processes for paunch manure dehydration, and sterilization and disposal of hog hair.

Washable trickling filters and conventional activated sludge treatment processes have both had some success, although the latter generally requires pretreatment. Extended aeration systems are in successful use, principally in lagoon-type plants. Disposal of raw meat packing wastes by irrigation has been successful in one installation in Illinois. This is a practical answer and warrants further study particularly to determine suitable crops. Some care is necessary to avoid high sodium concentrations to prevent soil damage.

Anaerobic ponds serve successfully as 'roughing' ponds for meat packing wastes principally because these wastes are warm (83 to 87°F), have high BOD and organic solids concentrations, and provide proper nutrient balance. Because aerobic ponds can accept anaerobic effluents at high BOD loadings, combinations of anaerobic ponds with various arrangements of aerobic ponds have become popular.

The anaerobic contact process can remove 90 to 96% of the BOD in a waste of 1400 mg/l, at a digester loading of 0.16 lb/day/cu. ft. with equalized flow. The gas-tight anaerobic digester is a completely mixed system. The mixed liquor is generally degasified by vacuum before gravity separation of sludge. The sludge is returned to the digesters at rates of 3 to 4 times the raw flow. The anaerobic effluent can be polished in aerobic ponds at loadings of 410 lb/day/acre, as well as in activated sludge and trickling filter systems.

The US meat industry is tending towards contracting with municipal agencies for waste treatment, often in spite of higher costs and with the danger of later escalation. However, municipal treatment eliminates the fixed costs of industry-owned facilities, and permits write-off of the annual costs as operating expenses. The meat packer will generally find that anaerobic pretreatment, either in a concrete digester or in a lagoon, prior to municipal treatment, will reduce his overall costs. Where land is expensive and odour control important, concrete digesters are preferred. The pretreatment facility may be owned by the city or the packer and, if owned by the latter, may be operated by the city.

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INTRODUCTION

Meat processing and abattoir operations produce highly organic, highly nitrogenous, biologically degradable waste water with relatively high concentrations of suspended and dissolved solids and grease. The waste characteristics do not vary as widely as might be expected from the industry's wide range of process and waste conservation operations. Because there are no average plants and no average conditions, the figures in *Table 1* should be used as a guide only where analytical data are not available.

The 2957 combined slaughtering and processing plants (hereafter termed 'packing plants') and abattoirs in the US discharge about 70 per cent of their waste water to city sewers. The other 30 per cent is treated prior to discharge into receiving streams. Treatment ranges from simple grease recovery by gravity separation to the recently developed anaerobic contact process.

Table 1. Approximate range of flows and analyses for abattoirs, packinghouses and processing plants†

Operation	Waste flow, gal/1000 lb live-weight slaughtered	Typical analysis, mg/l BOD 5-day	Suspended solids	Grease
Abattoirs	500–2000	650–2200	930–3000	200–1000
Packinghouse	750–3500	400–3000	230–3000	200–1000
Processing plant	1000–4000*	200–800	200–800	100–300

† From 'An Industrial Waste Guide to the Meat Industry'. Public Health Service Publication No. 386, Revised 1965, p. 6
* Per 1000 lb finished product

In a 1967 survey[1] of 219 plants representing 35 per cent of US federally inspected slaughtering, 153 plants discharged to city sewers. One hundred and eighteen had primary treatment (e.g. screening, sedimentation, and/or grease flotation) and 81, secondary treatment (4, channel aeration; 37 stabilization ponds; 7, trickling filter; 7, activated sludge; and 14, anaerobic contact processes).

Plant size affects the characteristics as well as the volume of the wastes. Some small abattoirs do not save blood or grease. Some may wet-render but may not have facilities for evaporating the tank water. Many plants heat-coagulate blood and run bloodwater to the sewer. The BOD_5 of tank water and blood water may run as high as 30000 mg per L. Most rendering plants are now dry-rendering, which produces no tank water, but 'skimmings' from grease recovery tanks are still often wet-rendered because of the large amount of entrained water.

CONSERVATION AND BY-PRODUCTS

In typical well-operated meat-packing operations, conservation measures are used to reduce solids, grease and BOD of waste water. Pens and floors are dry-cleaned before they are washed down. Kill blood is collected in a separate blood tank and the floor blood squeegeed to the blood sewer before clean-up hosing (dual floor drains are assumed). Blood represents 42 per cent of the gross waste load. In 1966, in the United States, over 95 per cent of the industry (live-weight basis) were recovering blood. Casing slimes are retained and dried.

Paunch manure, hog stomach contents, and other manure-bearing waste waters are screened with a rotary or vibrating screen, or a manure press. The resulting waste water is generally kept separate from the fat-bearing wastes because it contains very little fat but much partially digested hay, grass, and corn.

Paunch solids are usually disposed of directly to farmers as fertilizer or as land fill. Sometimes, as at South Saint Paul, Minnesota and Saint Joseph, Missouri, the solids are discharged with the plant wastes to the city sewer for segregation at the municipal treatment plant. Some success has been achieved dehydrating and sterilizing paunch manure for use as feed supplement. In any case, disposal has become a vexing problem.

In Omaha, Nebraska, the local packers joined with the City to finance a treatment plant for processing paunch manure. Paunch solids are removed by sedimentation and air flotation, and grease is extracted by the 3-stage Carver Greenfield Evaporation process[2]. The process vehicle is recirculated tallow which is removed by centrifuge from the water-free residue. Currently operating difficulties are being experienced.

Hog hair is also a disposal problem and is generally disposed of in land fills. The hydrolyzing of hog hair is not economical.

Grease is normally separated from all grease-bearing waste water by means of gravity or air flotation separators. The recovery basins are generally rectangular, 4 to 6 ft deep, and provide 20 minutes to 1 hour detention at maximum flow at a surface rate of one gallon per minute per square foot. The basins are mechanically skimmed, but may be hand-skimmed in small plants. They are also usually equipped for mechanical sludge removal, but some are designed to carry solids which will settle out with the effluent. The addition of polyelectrolytes has been found to improve grease yields.

Many plants use air flotation for grease recovery—some by direct aeration and some by pressurized air introduced into the influent or into a portion of recycled effluent. At the Beardstown, Illinois plant of Oscar Mayer & Co., flotation treatment[3] consists of 30 minute detention with 30 per cent recycle, of effluent which has been pressurized with air followed by primary settling with 50 minute detention. The percentage removal results are 49, BOD; 66, suspended solids; and 76, grease. A similar system at the same firm's main plant in Madison, Wisconsin receives 4.0 mgd flow at 1520 mg/l BOD, discharging a BOD of 850 mg/l (55.1 per cent efficiency)[4].

Other conservation measures include the evaporation and utilization of tank water and blood water (if blood is coagulated rather than dried). The newer and larger plants use continuous dry rendering, thus eliminating tank water. In water conservation, mechanical procedures can be applied. For example, water supply valves for hand operations can be self-closing, and sprays in 'line operations' can be mechanically linked with the process to shut off when not needed. Also, plant effluent can be recycled to provide process water for inedible purposes such as condensing in the tank house and spray cleaning of mechanical screens in inedible processing and waste water treatment.

WASTE WATER TREATMENT OTHER THAN PONDS

Activated sludge

The exodus of most packers from Chicago has reduced the significance of meat-packing wastes in the Chicago Sanitary District. In 1916, however, a study by the District with its then large complex of packing plants recommended the activated sludge process for joint treatment with municipal sewage. This process has proved to be successful when preceded by roughing filters[5] to reduce BOD and to iron out peaks. Conventional activated sludge systems, however, can be upset by spills of blood, casing slimes, or tank water. The modified systems that provide for extended aeration are more successful. For example, a Florida plant[6] treating 0.5 mgd of abattoir waste waters, is reported to be removing 95 per cent BOD at an aeration tank loading of 20 lb per 1000 cu. ft (30 hour detention), followed by an aerobic pond loaded at 50 lb BOD per day per acre.

Trickling filters

The work of Levine[7] and others in 1937 led to construction of large plants at Mason City, Iowa and South Saint Paul, Minnesota, which employed washable trickling filters in series. This system has also recently been applied at a Rochelle, Illinois packing plant where 95 per cent BOD removal is achieved with three-stage filters following grit removal, mechanical flocculation, and sedimentation. A conventional two-stage high-rate trickling filter plant in Madison, Wisconsin accomplishes 85 per cent removal. A disadvantage of this process is that high concentrations of proteins in meat processing wastes produce heavy biological growths that tend to clog trickling filters. Reversible washable filters are successful but relatively expensive.

Chemical treatment

Treatment[8] of packing plant wastes with chlorine and alum, chlorine and ferric chloride, and ferric chloride and lime[9] is no longer as popular as it was 20 years ago. Used today only by small plants prior to biological treatment, chemical treatment is expensive and provides only limited BOD removal. For example, chlorine will not precipitate hydrolyzed proteins from waste water produced in cooking processes. Chemical coagulation may be expected to reduce BOD 50 to 70 per cent by either the flow-through or batch process. In small plants the latter is generally preferred because variations in strength or solids concentration during the day can be accommodated by changes in the chemical dosage.

Irrigation

Although ridge-and-furrow, spray, and broad irrigation systems are successfully disposing of canning, dairy, paper mill and poultry waste waters, few such systems are handling wastes from the meat industry in the United States. One spray system in Rushville, Illinois disposes of the effluent from a lagoon receiving meat-packing waste waters. In Madison, Wisconsin, several types of flood and spray irrigation have been used to dispose effluent from a two-stage trickling filter plant (130 mg per L BOD) at a large packing plant. Application rates as high as 39000 gpd-acre are reported[10] with no leaching of nutrients into a drainage creek 30 ft away. The area is cropped with Reed canary grass and is currently irrigated by flooding. An eight-year study of the system shows that crop yields improved on Miama silt loam because of the nitrogen and on peat soils because of the phosphorus and potassium. Results were as follows:

	Percentage removal	
	Miami silt loam	Peat
Nitrogen	50	80
Phosphorus	40	50
Potassium	60	>55

The study also demonstrated that salt concentrations in packing-plant waste waters can be kept below the optimum allowable limits to prevent soil damage by means of conservation practices and treatment of meat-curing wastes.

Apparently, the only irrigation system in the United States treating raw waste waters from a meat-packing plant is at Elburn, Illinois. After grease recovery, 225 000 gpd are sprayed onto a 23-acre field of alfalfa and brome grass. There are 13 conventional irrigation-type spray nozzles, each discharge 14 gpm, on risers about 12 inches above aluminium distribution piping. The system, which covers one-sixth of the area, is moved daily, irrigating at 2 inches per day, with 6 days' rest. Crop yields have been so high that additional land had been purchased to make full use of the fertilizing potential of the wastes.

Irrigation warrants further study, especially regarding crop selection.

WASTE WATER TREATMENT: PONDS, LAGOONS AND STABILIZATION BASINS

The growing popularity of stabilization basins and lagoons for the treatment of meat industry wastes has been stimulated by developments in the pond treatment of municipal waste waters and by research in anaerobic fermentation. The kinds of lagoons and their use in both partial and complete treatment are as follows:

Pretreatment in anaerobic (deep ponds to reduce the strength of waste water prior to discharge to a municipal plant.

Complete treatment in aerobic (shallow) lagoons, generally in series, and preceded by good grease and solids recovery.

Complete treatment in anaerobic–aerobic systems in series, usually consisting of a single anaerobic pond, followed by one or more aerobic ponds in series or other aerobic process.

Tertiary treatment (effluent polishing) in aerobic lagoons, following conventional aerobic secondary treatment (no data available) or anaerobic contact.

Anaerobic ponds

In Union City, Tennessee, a full-scale anaerobic pond[11] pretreating packing plant wastes first overflowed (i.e. produced an effluent) in mid-September 1965 and showed 80 per cent BOD removal two weeks later at an average loading of 7.9 lb. BOD per day per 1000 cu. ft. After the pond was seeded with anaerobic sludge from a nearby pilot pond, the design loading of 15 lb per 1000 cu. ft was exceeded with no decrease in percentage BOD removal. Since 1968 the anaerobic pond has also been receiving all of the aerobically digested raw and waste activated sludge discharged from a municipal activated sludge plant which receives the pond effluent[12]. After two years of operation, and before adding the municipal aerobically digested sludge, the average BOD removal increased to 86 per cent (raw BOD 1560 mg/l, effluent 223 mg/l; suspended solids were 66 per cent (raw 690 mg/l, effluent 1257 mg/l; grease 88 per cent (raw 915 mg/l, effluent 108 mg/l). After adding the municipal sludge, amounting to 150,000 pounds monthly average weight, to the lagoons, effluent BOD rose to 405 mg/l, and suspended solids to 171 mg/l.

A system at Denison, Iowa[13], treats 800,000 gpd in two anaerobic ponds (in parallel) with 4 days detention in each, followed by a short aeration (4.5 cfpm), thence to two trickling filters, using synthetic media 30 ft deep, thence to two clarifiers with a theoretical detention time of 30 to 60 minutes, and chlorination. Effluent BOD was 30 mg/l during this past winter—20 mg/l is expected during the summer.

A report[14] on 29 anaerobic ponds pretreating meat and poultry plant waste water included median figures for area (1 acre), depth (7.3 ft), and detention (16 days). Based on data from 16 installations, BOD loadings ranged from 175 to 6060 lb per day per acre (median 1260), with removals of 65 to 95 per cent (median 80 per cent). It is unfortunate that these loadings were calculated on an area basis because anaerobic pond loading is governed by a volume factor, not surface area.

Anaerobic ponds are considered to be satisfactory for treating meat industry wastes if they are located in sufficiently remote areas. Odours were reported[15] to carry about a mile from three anaerobic cells treating such wastes in Edmonton, Canada, removing over 70 per cent of the BOD and about 75 per cent of the suspended solids. In another study[14], odours at nuisance levels were attributed to 9 out of 10 anaerobic ponds reporting, compared with 5 out of 13 aerobic pond systems. Hydrogen sulphide odours are generally attributed to high sulphate iron in the process water. It is believed that 200 mg/l or more sulphate in the process water will cause odours. Odour evaluations and comparisons depend, of course, on such variables as topography, weather, trees, and wind direction.

Aerobic ponds

In naturally aerobic pond systems not supplemented by aeration, reported loadings range from 50 lb per day per acre in South Dakota to 214 lb per day per acre in Delaware. The stabilization ponds in South Dakota[16] are used for the complete treatment of raw abattoir waste waters. while those in Delaware treat relatively dilute poultry processing waste waters (BOD, 175 mg/l) following flow equalization and primary sedimentation[17].

Porges[14] reports a median loading of 72 lb/day/acre (14 to 250 lb/day/acre) for 50 aerobic pond systems without supplementary aeration, treating waste waters from the meat and poultry industries. Depths ranged from 1.5 to 9.0 ft with a median of 3.0 ft and areas ranged from 0.04 to 75 acres, with a median of 1.3 acres, providing detention of 3 to 326 days, with a median of 70 days.

Extended aeration ponds include one in Plant City, Florida which utilizes mechanical surface aerators and two Pasveer systems (Ottumwa, Iowa and Arkansas City, Kansas) consisting of oval ditches and rotating metal 'brush' aerators.

Anaerobic–aerobic pond systems (complete treatment)

The first reported system of this type, at Moultrie, Georgia[18] has been operating since 1955, treating meat packing waste water in an anaerobic pond 14 ft deep, with a capacity of 4.6 mg, followed by an aerobic pond 19.2 acres in area and 3 ft deep. The detention time is 6 days in the anaerobic pond and 19 days in the aerobic pond, at a BOD loading of 0.011 lb/day cu ft in the anaerobic stage and 130 lb/day/acre in the aerobic stage (4-year average). Indicative of the space saving of this type of pond treatment, the overall BOD surface loading was 325 lb/day/acre. Sludge is recirculated in the anaerobic pond, and effluent is recirculated in the aerobic pond. The 4-year average BOD of the raw waste was 1100 mg/l and the effluent was 67 mg/l. A second system installed by the same firm at Wilson, North Carolina, consists of an anaerobic lagoon 17 ft deep with 3.5 days detention, followed by trickling filter treatment in the municipal plant. The effluent of the anaerobic lagoon, at 150 mg/l, BOD, is treated in the municipal plant without difficulty. At each of these plants, grease, paunch manure and gross solids are removed in pretreatment facilities. To reduce excessive solids concentration in the anaerobic pond, some sludge was removed after $2\frac{1}{2}$ years in service, and was dried in a nearby field without nuisance.

At Iowa Falls, Iowa[19], an anaerobic–aerated–aerobic lagoon system receiving hog abattoir wastes produces 99 per cent BOD removal at near design loading. The system is preceded by air flotation for grease recovery. The design was based upon loading of 15 lb BOD/1000 cu. ft/day in the anaerobic lagoons and 227 lb BOD/acre/day in the aerated lagoons (10 ft deep), aerated with diffused air at 0.5 cfm/lb BOD applied.

A system in Idaho intended to be aerobic, consisting of 3 ponds in series with a total area of 2.8 acres and 8 ft deep, is so overloaded with packing plant waste that includes paunch manure and other solids, that it is entirely anaerobic. However, the raw BOD of 1430 mg/l is reduced to 490 mg/l at a loading of 520 lb/day/acre. The reduction is only 66 per cent but the high capacity of anaerobic ponds for BOD removal is evident.

There is evidence that the discharge of paunch manure to anaerobic basins may be beneficial, presumably by forming a scum that resists penetration of air and sunlight and insulates in cold weather. Paunch manure, grease and blood are discharged with the raw wastes into three-stage pond systems at 12 small rural abattoirs in the southern state of Louisiana[20]. Each system consists of an anaerobic pond, a transitional pond, and an aerobic pond. Based upon an estimated BOD of 2000 mg/l and a flow of 800 gal per 1000 lb. live-weight kill, the anaerobic ponds were designed at 30000 lb live-weight kill/day/acre-foot, the transitional ponds at 150000 lb and the aerobic ponds at 75 000 lb. The anaerobic pond is 10 to 15 ft deep, and transition and aerobic ponds are about 4 ft deep. There is no recirculation or supplemental heating in the systems. An average of composite samples taken at three plants gave a raw BOD of 2270 mg/l, anaerobic effluent 183 mg/l, transition pond effluent 85 mg/l, and aerobic pond effluent 56 mg/l with an overall BOD removal of 98.5 per cent.

The treatment system at an abattoir at Harlan, Iowa[21], consists of an anaerobic lagoon 16 ft deep, providing 5 days detention; two mechanically aerated lagoons 8 ft deep with 2 days detention (2 aerators rated at 1800 lb oxygen input/day); and a final naturally aerobic lagoon 5 ft deep, with 15 to 20 days detention. Operations, begun in 1963, have expanded to such an extent that in 1967 the system was operating at organic loadings 150 per cent of the design and flows 180 per cent of design. In spite of these overloads, the plant was removing 93 per cent of the BOD in 1967. Under such overload conditions, however, gradual deterioration in conditions can be expected.

In operation since 1963, an Oscar Mayer Co. plant at Perry, Iowa[21,3], with anaerobic lagoons 14.5 ft deep providing 5 to 10 days detention, a transition lagoon (unaerated facultative) 7 ft deep with 19 days detention and a final aerobic lagoon 2.5 ft deep with 15 days detention, produces 99 per cent overall BOD removal, with a raw waste of 15 600 to 28 200 lb BOD. During 1966 and 1967, the BOD load on the anaerobic lagoons averaged 18 lb per 1000 ft^3, on the transition lagoon averaged 70 lb per acre and on the final lagoon averaged 15 lb per acre. A good scum cover in the anaerobic lagoons has maintained an average temperature of 78°F. Sludge accumulation in the anaerobic phase averages 7 inches per year.

Borrowing from American experience, a plant in New Zealand[22] consisting of grease recovery and sedimentation of solids, an anaerobic pond loaded at 20 to 70 lb BOD/1000 cu. ft/day, an aeration tank with 7 to 10 minutes detention (for degasification—see Austin, Minnesota under Anaerobic Contact Process), sludge blanket clarifiers providing one hour detention (the latter two steps remove the anaerobic sludge), and an oxidation pond treating about 65 lb BOD/acre/day, receives raw wastes averaging 2000 mg/l and discharges a final effluent of 30 mg/l. The Meat Industry Research Institute of New Zealand has recently established a small pollution research unit to study effluent improvement and treatment. Their initial interest is directed towards anaerobic treatment.

Design criteria for anaerobic–aerobic systems vary. State regulatory agencies in Illinois, Iowa, Nebraska, Tennessee, Pennsylvania and Minnesota accept design loadings of 15 lb BOD per 1000 cubic ft of anaerobic ponds, allowing 60 per cent BOD removal, followed by some form of aerobic treatment. BOD removals can exceed 95 per cent in properly designed and operated systems.

Wastes from a Wilson plant at Cherokee, Iowa[23] are treated in a four-stage plant designed as follows: anaerobic pond at 9.7 lb per 1000 cu. ft, 60 per cent BOD reduction (detention time 6.7 to 8.3 days); a mechanically aerated lagoon at 26 lb per 1000 cu. ft., allowing 50 per cent BOD removal; and two natural aerobic stabilization ponds, the first at 113 lb BOD per acre, and the second at 56 lb per acre, allowing 60 per cent removal for each, resulting in a design for 97 per cent removal. Operating data during the latter half of 1966 produced 84.5 per cent BOD removal in the anaerobic pond, 50 per cent in the aerated pond, and 50 per cent in the first aerobic stabilization pond (second not in use), resulting in 95.5 per cent overall removal, with 1600 mg/l raw waste water and 75 mg/l effluent. Total flow averaged 1 000 000 gallons per day. Suspended volatile solids averaged 1200 mg/l raw and 85 mg/l final.

The behaviour of an anaerobic–aerobic pond sustem treating abattoir wastes under cold winter conditions was reported[24]. At an ambient air temperature of 25°F and raw waste temperature of 82°F, the coefficient of conductivity in the first of two anaerobic ponds in series was 8.0 BTU/h/sq ft of surface/Δ°F (water–air) while the second was 23.4. The difference was attributed to an 8 inch scum layer on the first pond, while the liquid surface of the second pond was exposed directly to the air. BOD loading, with a raw BOD concentration of 940 mg/l, was 16.1 lb per 1000 cu. ft with 58.2 per cent removal. Subsequent treatment of the anaerobic effluent in aerobic ponds at 34 lb/day/acre resulted in 13 to 30 mg/l BOD in the final effluent. Under ice cover, the BOD in the aerobic ponds exceeded 200 mg/l.

Anaerobic contact process

The anaerobic contact process is similar in many respects to the activated sludge process. The first phase of treatment in both is largely stabilization by contact between anaerobic organisms and nutrient in a favourable environment. After contact the sludge, made up of organisms and agglomarated organic matter, is separated from the treated liquid and returned to the process to serve as seed for incoming wastes. The organisms digest the organic matter in the sludge mass during the recycling and treating process.

When digested anaerobically at 90° to 95°F, packing plant wastes produce methane gas which, when used for heating, raises the raw waste water temperature about 6°F, from a norm of 83° to 87°F.

The first full-scale modified anaerobic contact process for the treatment of meat packing plant wastes was placed in operation in December 1959, at Albert Lea, Minnesota[25–28]. Since then, other plants of this type have been built, notably one at Momence, Illinois[12–29].

The plants at Albert Lea (*Figures 1* and *2*) and at Momence are similar. Each is designed to equalize the flow over a full 24-hour period. Preliminary treatment consists of gravity grease and solids removal ($\frac{1}{2}$ to 1 hour detention). The raw wastes, preheated to 90° to 95°F, are discharged into totally mixed concrete digesters where the detention time is 12 to 15 hours. As it leaves the digesters, the mixed liquor†, containing suspended solids ranging from 7000 to 12 000 mg/l, digests actively. It is discharged through vacuum degasifiers to gravity sludge separation tanks.

The degasifiers are gastight vessels elevated to receive the digester effluent, which is drawn up under 20 in. of mercury vacuum by wet vacuum pumps. In the vessels, the liquid cascades down over slatted trays to enhance gas separation. As drawn off by the vacuum pumps, the gas is wet, contains 40 to 60 per cent carbon dioxide, and is thus highly corrosive. Corrosion

† At Albert Lea, the sludge age is about 5 days and the loading is about 0.25 mg BOD per day per mg mixed liquor suspended solids.

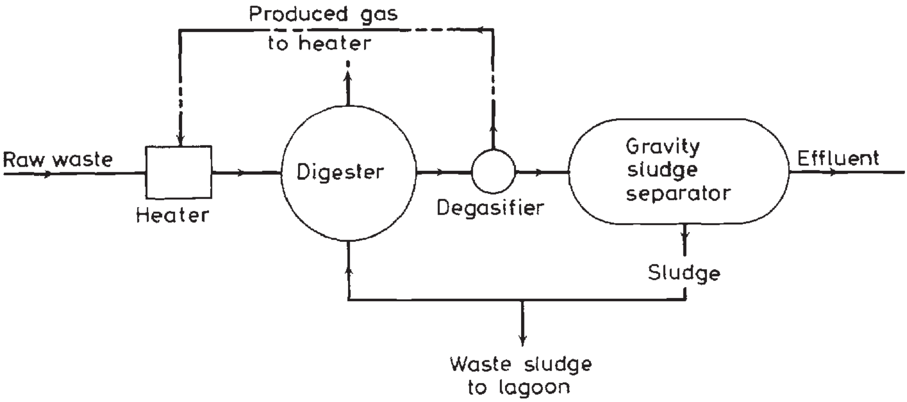

Figure 1. Flow diagram—anaerobic contact process

Figure 2. Full scale anaerobic contact waste treatment plant, Wilson & Co. Inc., Albert Lea, Minnesota USA

protection consists of a baked phenolic lining and galvanized slats in the degasifier, stainless steel pumps, and plastic piping. This 'vacuum gas' is mixed with the gas generated in the digesters, which contains about 85 to 90 per cent methane and 10 to 15 per cent carbon dioxide, and is burned in the boiler.

A plant at Austin, Minnesota utilizes air to purge the residual gases and operates at a lower BOD loading, removing 90 per cent of the raw BOD of 1400 mg/l at 0.06 to 0.1 lb/day/cu ft loading.

In each case, the sludge is returned to the digesters as seed to maintain the anaerobic culture. The detention time in the separators is about one hour, based on total flow and including sludge circulating at 3 to 4 volumes per volume of incoming raw waste. The surface settling rate is about 300 gpd per sq. ft, based on raw flow only. Despite the fact that the residual gases are removed in the degasifiers, the sludge is still flocculent and must be removed with a suction-type rather than scraper-type mechanism.

The treated effluent overflows into weir troughs and is discharged for final polishing to oxidation ponds at Albert Lea, and to an activated sludge plant at Momence.

The ponds at Albert Lea occupy 3.7 acres and are 3 to 4 ft deep. They reduce the BOD of the anaerobic effluent 50 to 70 per cent, producing an oxygenated effluent suitable for discharge into an adjoining lake. Because of increased loading and reduced BOD removal during the winter months, additional ponds were recently constructed to dispose of most of the effluent by soil percolation.

Table 2. Anaerobic contact process treating meat packing wastes (Albert Lea, Minnesota)†

	Raw waste		Anaer. proc. effl.		Pond effluent	Loss in ponds
Flow gal.	1410000		1410000		772000	638000
	Raw waste		Anaer. proc. effluent		Pond effl. corrected for seepage	
	ppm	lb	ppm	lb	ppm	lb
BOD	1381	16220	129	1517	26	304
Suspended solids	938	11610	198	2325	23	268
	Percentage removal					
	Through anaerobic unit		Through ponds		Through entire plant	Digester loading lb/day/cu. ft
BOD	90.8		79.8		98.2	0.156
Suspended solids	80.2		88.4		97.6	0.112

† Average operating data; all killing days in 1960

Operating data for the Albert Lea plant, based on daily analyses of samples composited automatically in proportion to the flow, are shown in *Table 2*. Comparative results for the process are as follows:

Through	Removal (%) BOD	SS
Anaerobic unit	90.8	80.2
Ponds	79.8	88.4
Plant	98.2	97.6

The relative capacity of the anaerobic process in removing BOD is shown graphically in *Figures 3* and *4*. *Figure 3* shows that the process regularly removed 1000 to 1450 mg/l of BOD, while the oxidation ponds removed

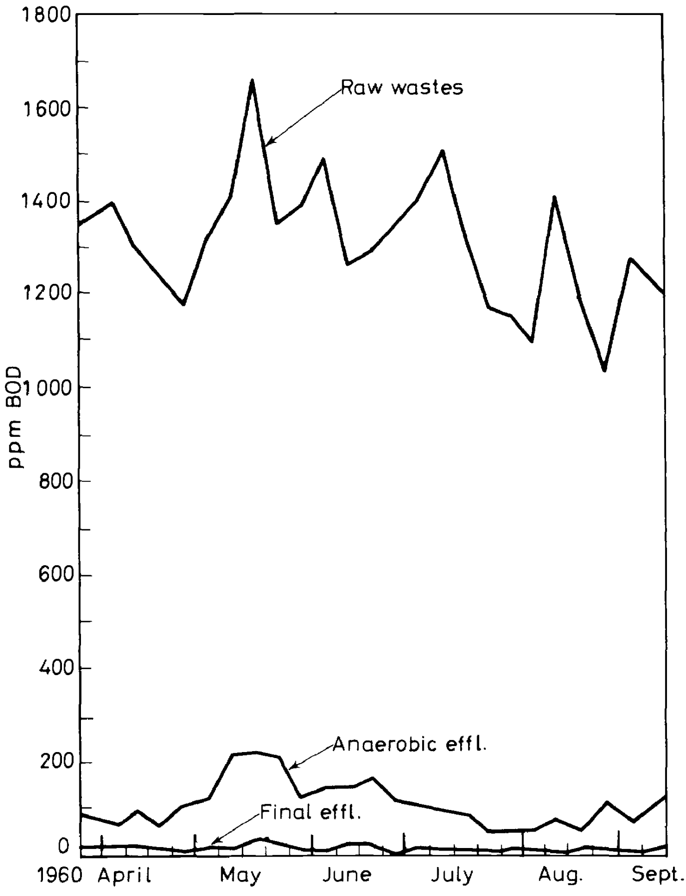

Figure 3. BOD data (weekly averages), Albert Lea Plant

a much smaller proportion. The oxidation ponds, however, act as shock absorbers, producing a final effluent of relatively uniform quality under a wide range of loading. The first pond, which is usually anaerobic, accounts for most of the BOD removal in the pond system. The average BOD loading to the ponds was 410 lb per day per acre, averaging 129 mg/l BOD and 198 mg/l suspended solids. Loading to the digester averaged 0.156 lb per day per cubic ft BOD and 0.112 for SS.

Results at Momence show 86 per cent BOD removal through the anaerobic unit and 77 through the activated sludge plant, yielding 97 per cent overall BOD removal.

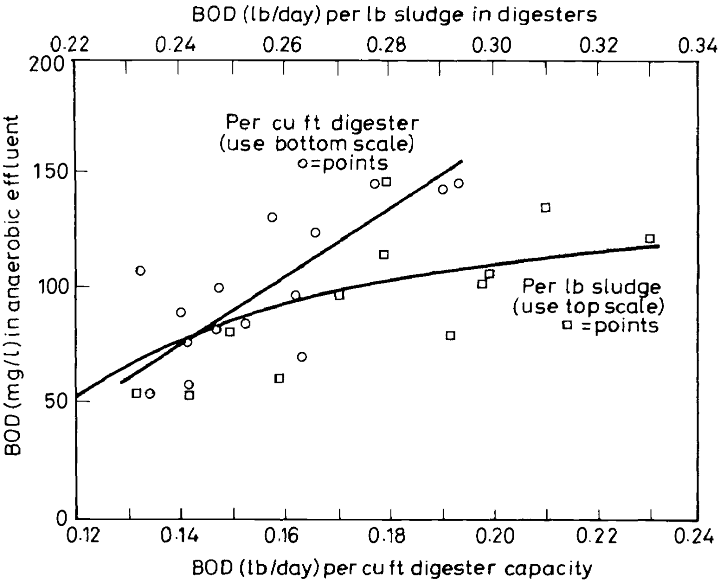

Figure 4. BOD applied per lb of sludge and per cu. ft of digester capacity vs BOD in effluent (Albert Lea, Minn.)

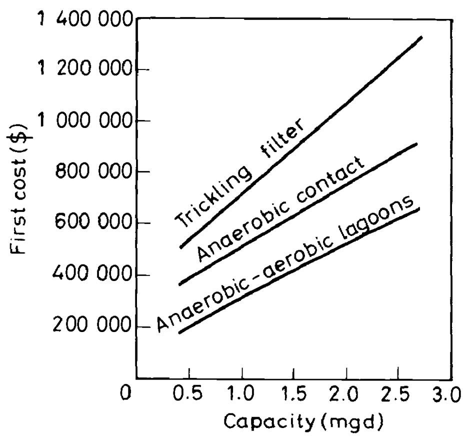

Figure 5. Initial costs, including land, for three treatment systems[29]

Costs

Cost comparisons[29] for the anaerobic-contact process, anaerobic–aerobic lagoons, and trickling filter system are shown in *Figures 5* and *6*. The curves are based on flows of 0.5, 1.5, and 2.5 mgd and costs as of 1964 (e.g. land costs in *Figure 4* at $500 per acre). In *Figure 5*, annual costs include insurance, taxes, depreciation, power and labour.

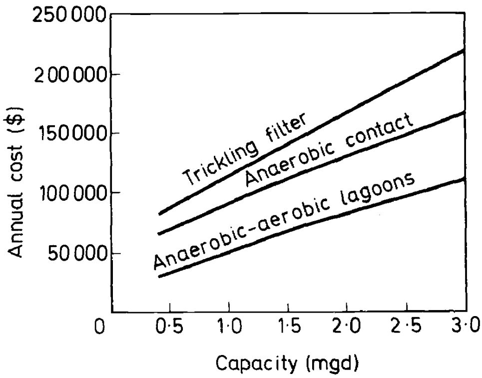

Figure 6. Annual costs, including fixed and operating costs, for three treatment systems[29]

Units and sizes for the three systems represent standards modified according to comparable plant data and expected design loadings and should be acceptable to most state reviewing agencies.

Waste loading and flows were assumed to be as follows:

Shift plus clean up, h	Flow, mgd	BOD, lb
1–8	0.50	5000
2–8	1.50	12000
2–8	2.50	15000

Other assumptions were that treatment facilities were located 1000 ft from the processing plant and 1000 ft. from the receiving stream and that wastes were passed through a 20-mesh screen and a grease recovery unit prior to discharge to treatment facilities. A 10 per cent contingency was included in the estimate.

A brief description of the three types of treatment at 0.5 mgd flow follows.

Trickling Filter

Bar screens
Grit chamber
Flocculators
One primary settling tank, 12 ft × 50 ft, 7 ft depth
Three roughing filters, 50 ft diameter, 6 ft depth
One clarifier, 46 ft dia., 6 ft depth
One final filter, 100 ft dia., 6 ft depth
One final clarifier, 40 ft dia., 9 ft depth
Sludge lagoons, 2.5 acres

Anaerobic contact

One equalizing tank, 40 ft dia., 15 ft depth
One digester, 45 ft dia., 21 ft depth
One separator, 14 ft × 51 ft, 10 ft depth
Sludge holding tank, square 13.5 ft, 10 ft depth
Polishing lagoons, 10 acres water area
Sludge lagoons, one, 80 ft × 120 ft
Wet sludge hauling facilities

Anaerobic–Aerobic lagoons

Two anaerobic ponds at 20 lb BOD per 1000 cu. ft:
first pond, 155 ft × 190 ft, 15 ft depth;
second pond, 120 ft × 135 ft, 11 ft depth

The first pond to be covered with insulation with underwater heater plus sludge recirculation

Three aerobic ponds, two ponds in parallel with recirculation, with the third pond in series. Total water area, 30 acres.

SUMMARY AND TRENDS

Miscellaneous treatment processes

Chemical treatment aroused some interest 20 to 30 years ago but is currently limited to pretreatment, producing 50 to 70 per cent BOD removal in adequately designed and properly operated small plants.

As for aerobic processes, washable trickling filters and conventional activated sludge treatment have both has some success, although the latter generally requires pretreatment. Extended aeration systems are in successful use, principally in lagoon-type plants.

Disposal of raw meat-packing wastes by irrigation has been successful in one installation in Illinois. This is a practical answer and warrants further study, particularly to determine suitable crops. Some care is necessary to avoid high sodium concentrations to prevent soil damage.

Pond systems

Anaerobic ponds serve successfully as 'roughing' ponds for meat packing wastes principally because these wastes are warm (83 to 87°F), have high BOD and organic solids concentrations, and provide proper nutrient balance. These ponds are generally about 12 to 16 ft deep and, at average loadings of 12 to 15 lb BOD per 1000 cu. ft, require far less land area than aerobic stabilization lagoons. Sludge is often recirculated to the inlet to seed the raw wastes. Because aerobic ponds can accept anaerobic effluents at high BOD loadings, combinations of anaerobic ponds with various arrangements of aerobic ponds have become popular. However, a word of caution: anaerobic and anaerobic–aerobic pond systems treating meat industry waste water should be located with due regard to possible odour problems.

Anaerobic contact process

This process can remove 90 to 96 per cent of the BOD in a waste of 1400 mg/l, at a digester loading of 0.16 lb/day/cu. ft, with equalized flow. The gas-tight anaerobic digester is a completely mixed system. The mixed liquor is generally degasified by vacuum before gravity separation of sludge. The sludge is returned to the digesters at rates of 3 to 4 times the raw flow. The process can be shut down for extended periods without loss of treatment efficiency.

The anaerobic effluent can be polished in aerobic ponds at loadings of 410 lb/day/acre (with additional removal of about 80 per cent of the BOD and 88 per cent of the suspended solids), as well as in activated sludge and trickling filter systems.

Trends

The US meat industry, discouraged by operating problems, difficulties with regulatory agencies and the cost of competent technical help to operate the separate treatment plants, is tending towards contracting with municipal agencies for waste treatment, often in spite of higher costs and with the danger of later escalation. But municipal treatment eliminates the fixed costs of industry-owned facilities, and permits write-off of the annual costs as operating expenses.

The meat packer will generally find that anaerobic pretreatment, either in a concrete digester or in a lagoon, prior to municipal treatment, will reduce his overall costs. Where land is expensive and odour control important, concrete digesters are preferred. The pretreatment facility may be owned by the city or the packer and, if owned by latter, may be operated by the city.

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