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Water Pollution Control in Slaughterhouses and Meat Processing Plants

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The U. S. Environmental Protection Agency requires packing plants and slaughterhouses that discharge into streams to meet stringent effluent standards. Effluent standards to be met by July 1, 1977, required a reduction in pollutant loads amounting to 98, 96 and 96 percent, respectively, for BOD_5, total suspended solids (TSS), and fats, oils and grease (FOG). The 1983 effluent standards require pollutant load reductions of 99 percent or more.

Federal, state and local requirements, as well as financial incentives for water pollution control from Texas slaughterhouses and meat packing plants, are explained in another Extension publication (MP-1371). To comply with water pollution control standards and to save money on sewer surcharges, slaughterhouses and meat processing plants need to apply a combination of in-plant waste reduction techniques, primary and secondary treatment. In many cases, land application also may be necessary to meet the 1983 EPA standards.

Waste Characterization

Wastewater from slaughterhouses and meat and poultry processing plants contains nutrients and organic pollutants with high oxygen demand. These wastewaters vary widely in amount and composition per unit of animal processed (see Table 1). Differences in waste quantity and characteristics are attributable primarily to plant designs, types of processing activities, animal species, waste management methods and employee habits.

Slaughterhouses generally produce lower effluent and pollutant quantities per 1,000 pounds of liveweight killed (LWK) than do packinghouses, which perform more meat handling operations. Poultry processing plants usually generate considerably greater pollutant and effluent quantities per 1,000 pounds LWK than either slaughterhouses or packinghouses.

Characteristics of waste flow must be known in order to select waste reduction steps and treatment processes, to determine size of treatment systems and to estimate costs. Because of large hourly and daily variations in flow volume and waste concentration, wastewater surveys should be conducted for individual plants.

A recommended survey procedure is to sample the wastewater discharge and measure the flow every hour for three days of normal slaughtering, processing and waste flow. Samples are not necessary for hours where nocturnal flow drops to near zero. Hourly samples are composited for each day in proportion to the flow at the time the sample was taken. Samples should be refrigerated and analyzed the following day.

Often these surveys reveal areas where major improvements can be made easily and cheaply. For example, a Texas poultry processing plant now saves $3,500 per month in sewer surcharges by identifying high-concentration waste streams and unnecessary water usage that were easily corrected.

In-Plant Waste Reduction

Water Conservation

Wastewater treatment costs are proportional to flow volume and quantity of pollutants treated. Flow volume accounts for 50 to 80 percent of the total cost of waste treatment. Excess water removes body fluids and tissue from the product as well as meat scraps. This is important since effluent standards are set on the basis of quantity per unit liveweight rather than con-

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Table 1. Typical Wastewater Characteristics (per 1,000 lbs. LWK).

Waste Parameter	Slaughter-houses	Packing-houses	Broiler processors	Hen processors
1. Flow, gallons				
average	640	940	2740	2530
minimum	160	240	1240	570
2. BOD_5, pounds				
average	6.0	8.1	9.9	15.2
minimum	1.5	2.3	3.3	11.8
3. Total suspended solids, pounds				
average	5.6	5.9	6.9	10.1
minimum	0.6	0.6	0.1	6.1
4. Fats, oils and grease, pounds				
average	2.1	3.0	4.2	2.3
minimum	0.2	0.8	0.2	0.7

centration. Thus, a reduction in water use reduces the quantity of pollutants. Limited water usage also reduces the size of waste treatment systems and improves their efficiency by concentrating the organic pollutants. Flow reduction also saves energy and water cost.

A survey of 11 small slaughterhouses in Texas and Oklahoma found some plants using three time more water than others (ranging from 200 to 786 gallons) per 1,000 pounds LWK. An Iowa plant reduced water use by 3 to 5 percent just through training employees to turn off hoses and sprays during breaks and other nonuse periods. Using high pressure (500 psi) and low volume (3 to 5 gpm) hoses and sprayers can cut water consumption for cleanup by more than 5 percent as compared to using conventional low pressure hoses. Automated solenoid valves on spray mechanisms and press-to-open valves on hand hoses can also give 5 percent water savings. Clean water from air conditioners, steam condensers and heat exchangers can be collected before it enters the waste stream and reused for floor cleanup.

A Wisconsin hog slaughtering plant reduced water use for cleanup by 56 percent by making simple process modifications. In most instances, the cost of process changes was paid for by savings which resulted the first year.

Reducing unnecessary water contact with meat products and waste materials is important. This includes dry cleanup of plant floors and livestock pens before water is turned on for final cleaning, a procedure which reduced BOD load by 40 percent in one study.

Blood Conservation

Blood is the major pollutant in wastewater from poultry and meat slaughtering plants, because of its extremely high biochemical oxygen demand of 160,000 mg/1, or 4.7 pounds BOD_5 per 1,000 pounds LWK. Blood from the bleeding operation and from those cutting operations which generate large quantities of blood should be kept out of the sewers by using blood collection troughs and separate storage containers. The sticking and bleeding area of the kill floor should be curbed and equipped with separate blood and water floor drains. During operation and before cleanup, blood should be squeeged to the blood drain. After an initial light, high-pressure rinse, the blood drain should be covered before washdown of the kill floor. For each 1 gallon of blood saved in this manner, 10 gallons of washwater are saved. Killing floors with sufficient bleeding area lose blood to the sewer because animals continue to bleed on the rail. Despite separate collection systems, as much as 30 percent of the blood can be lost to the sewer.

Blood from large slaughterhouses has many economic uses that can pay for its recovery. Various drying and centrifugation techniques have been developed. Rendering also has been employed. Recently, energy costs for blood dehydration were estimated at 19¢ per head. Capital cost requirements for blood processing may be excessive at small plants. Small plants can manually collect and store blood in 55-gallon drums for sale to renderers on a daily basis.

Paunch Manure Removal

Paunch manure contains a high BOD load of 50,000 mg/1, or 2.5 pounds BOD_5 per 1,000 pounds LWK. It should be kept out of sewers and waste treatment plants to avoid excessive treatment costs. There are three basic methods of paunch handling: no-dump, wet-dump and dry-dump.

The no-dump system involves removing the paunch sack and sending it unopened to the rendering operation to become part of the meal by-product. Unfortunately, this substantially lowers the meal protein content, increases moisture removal requirements, discolors grease and prevents tripe recovery. The renderer will pay less for offal that contains paunch.

The wet-dump system, consisting of washing paunch contents into the sewer, is poorest from the standpoints of pollution control and economics. Screens and grit chambers should be used for large solids removal before the paunch enters the collector sewer lines.

The dry-dump system has largely replaced wet-dumping. It involves slitting the rumen and dumping paunch contents into an under-floor hopper. The washed stomach is then reclaimed as tripe. Dry collection and transport of the paunch contents can reduce the waste load by 20 percent in beef slaughtering plants. Paunch manure containing 85 percent moisture can be transported by a screw conveyor to a grinder and then pneumatically conveyed from a blow tank into a loading hopper. Paunch contents have been successfully blown 700 feet at elevation differences of 45 feet.

Paunch can be applied to land by surface spreading or soil injection. Environmentally acceptable application rates of 19,000 to 75,000 gallons per acre per year as a 4 percent solids slurry will provide 125 to 500 pounds nitrogen per acre per year. Paunch can also be used as a cattle feed after treatment with chemical preservatives (acetic acid, formalyn, etc.) or by ensiling with other feedstuffs.

Holding Pens

Pen cleaning operations are another key area of in-plant waste reduction. Cattle in holding pens excrete 1.5 to 2.0 pounds BOD_5 per day, most of which is contained in the feces fraction. Manure from holding pens is relatively easy to segregate from other plant waste streams and should be disposed of on land.

Concrete-surfaced holding pens can be cleaned using two basic approaches:

(a) daily scrape, followed by daily washdown;

(b) daily washdown of all manure.

Dry cleanup of the concrete holding pens prior to washing can reduce the waste load significantly. The daily scrape system entails use of a tractor rear-mounted or front-end bucket to remove semi-solid manure (about 75 percent moisture) which contains most of the BOD. If bedding material is not used, the high moisture content of daily scraped manure dictates prompt land disposal before odors and flies develop. Washwater from scraped pens generally contains low enough solids and BOD load to allow economical treatment. Primary treatment with a settling chamber having 30- to 60-minute detention time, and/or with a stationary sloping or vibrating screen, will help reduce pollutant loadings and improve manure treatability. After primary treatment, conventional irrigation equipment can be used for direct land application.

Daily washdown of all manure will require more washwater and result in a higher BOD wastewater. Ordinarily, proper cleaning requires sufficient washwater that the resulting liquid manure slurry can be efficiently pumped and irrigated using big gun sprinklers. Another convenient means of disposal is transportation to agricultural land using tank wagons with surface spreading or subsoil injection. Tank wagons are useful for a wide range of moisture contents from less than 1 percent to more than 10 percent solids.

Hydraulic flush systems for automatic manure removal are rapidly gaining popularity in the swine and dairy industries. The flush system requires that holding pens have a 2 to 3 percent longitudinal slope for effective scouring and transport. Flushwater is suddenly released from holding tanks, rotating buckets or dams at the top of the slope. General water requirements are 70 gallons per day per 1,000 pounds animal liveweight. This produces an effluent with 1 to 1.5 percent solids concentration, ideal for direct slurry irrigation or lagooning.

Pen cleaning can be improved by using fan-shaped rather than rectangular pens. Fan-shaped pens optimize cattle flow and reduce pen-size requirements by 50 to 60 percent.

Holding pens can be roofed, guttered and curbed to eliminate rainfall runoff that otherwise enters manure handling systems. This also keeps livestock from getting wet just before slaughter.

Waste Treatment Processes

Primary treatment consists of physical and/or chemical reduction of organic solids. Combinations of the following primary treatment processes are often used in the meat processing industry: screening; centrifugation; gravity separation (sedimentation); air flotation; and flocculation/precipitation. Dissolved air flotation, for example, results in BOD reductions of 40 percent, with suspended solids and grease reduced to approximately 50 percent. The hydra-screen is a small, relatively inexpensive static screen with no moving parts. BOD removal efficiency can range as high as 40 percent for individual waste streams, depending on waste concentration, volume and particle size distribution. For efficient solids removal, the waste stream should be screened *before* pumping.

Mechanical primary treatment devices such as static and vibrating screens, hydracyclones (centrifugation), air flotation units for grease recovery and clarifiers are described in detail in other publications (see note p. 6). The remaining discussion will be concerned with secondary treatment with lagoon systems, which are widely used for meat packing plants in the south and southwest.

Secondary treatment processes provide bacterial decomposition of organic wastes, nitrogen removal and further solids settling. These processes include anaerobic lagoons, aerobic and aerated lagoons, extended aeration, activated sludge, trickling filters and rotating disk contactors. Combinations of these systems are needed since no single secondary treatment process will provide an effluent suitable for discharge. Even if terminal disposal on land is practiced, a second or third stage lagoon is needed for storage to allow proper irrigation scheduling.

Anaerobic Lagoons

Anaerobic lagoons are widely used at meat processing plants to provide bacterial digestion of organic wastes without free oxygen. The warm, highly concentrated effluent enhances decomposition, as does the mild Texas climate. Anaerobic lagoons can provide pollutant reductions of more than 90 percent BOD, 80 percent TSS and 95 percent FOG. Operational requirements and capital and operating costs with these units are minimal.

Anaerobic lagoons should be designed with a low surface area to volume ratio to conserve heat and minimize surface reaeration. Depths of 10 feet or more are desirable, but economic and groundwater considerations usually limit depths to less than 18 feet. The design liquid volume is critical and should be maintained during operation. Design organic loadings range from 12 to 25 pounds of BOD_5 per day per 1,000 cubic feet with 15 pounds recommended.

Anaerobic lagoon effluent typically contains less than 200 mg/1 BOD_5 and TSS, and less than 100 mg/1 FOG. Thus, it can be discharged to municipal sewage treatment plants but not to streams. Ammonia levels actually increase during anaerobic treatment as protein is converted to ammonia-nitrogen. For irrigation purposes, anaerobic lagoon effluent usually contains 20 to 25 pounds per acre inch of ammonia-nitrogen, which is readily available to crops.

Odors are the most prevalent problem associated with anaerobic lagoons. Establishment of a grease cover or floating sludge blanket over the lagoon drastically reduces odor emissions. Measured odor intensities alongside an anaerobic lagoon system have ranged from acceptable (0 to 7 dilutions to threshold) for a 95 percent scum cover, to unacceptable (31 to 170 dilutions to threshold) with only 10 percent scum cover. Efforts to induce formation of the floating grease layer include addition of straw and temporary bypassing of screening and air flotation units. High winds temporarily break up a lagoon scum cover.

The difficulty of forming and maintaining a scum cover for odor control has prompted development of a floating flexible membrane cover for anaerobic lagoons. Estimated cost of a lagoon cover for a 1.4-acre lagoon surface is $92,000, not including concrete, earth work, pipe, fittings and installation costs. Nevertheless, the membrane cover makes an anaerobic/aerobic lagoon system usable in an odor critical situation, and at a capital and operating cost savings of 40 and 42 percent, respectively, as compared to an aerated lagoon system. Biogas collected beneath the floating membrane cover can be collected for fuel.

The main cause of anaerobic lagoon odors is sulphate in the water supply. Under anaerobic conditions, sulphate is converted to hydrogen sulfide gas which has a characteristic "rotten egg" odor. Hydrogen sulfide in effluent forms sulphuric acid, which can cause severe damage to concrete sewers and structures. Atmosphere emissions of hydrogen sulfide are estimated at 1 percent of the sulphate loading in anaerobic lagoons.

Researchers have determined that wastewaters containing more than 100 mg/1 of sulphate will produce excessive hydrogen sulfide emissions. Therefore, anaerobic lagoons should not be used in odor critical locations unless the wastewater sulphate content is less than 100 mg/1.

Aerobic Lagoons

One or more natural aerobic lagoons or oxidation ponds are often used in series with anaerobic lagoons to provide further pollutant reduction and temporary storage. The surface area is critical to provide adequate oxygen diffusion and algal photosynthesis. Recommended design criteria are 3 to 5 feet deep with loading rates of 20 to 40 pounds BOD_5 per acre per day. Aerobic lagoons used for treatment of anaerobic lagoon effluent have provided BOD and TSS reductions of 50 percent and 30 percent, respectively. TSS discharges often exceed the EPA effluent guidelines, especially after rainfall. The TSS concentrations can actually increase in aerobic lagoons because of the seasonal production and die-off of algae. The EPA guidelines for pH and fecal coliforms also are frequently exceeded in aerobic lagoon effluent. Chemical treatment is a possibility for controlling these excesses.

Aerated Lagoons

Mechanically aerated lagoons can achieve BOD reductions of 50 to 60 percent, but suspended solids in the effluent remain high and require further settling to remove biological floc. Aerated lagoons are useful for pretreatment prior to discharge to municipal sewers or as an intermediate treatment step between anaerobic and aerobic lagoons. Mechanical aeration is often used to remove nitrogen from the effluent.

Aerated lagoons should be 8 to 15 feet deep with a detention time of 2 to 10 days. Complete mixing is required to prevent rapid sludge buildup. Aerator horsepower requirements are based on either the lagoon surface area (1 horsepower per 700 square feet) or the BOD loading rate (1 horsepower per 30 pounds BOD_5 entering the lagoon).

Extended Aeration Lagoon

This treatment process, an adaptation of the activated sludge process, was developed by EPA researchers for small meat and poultry processors. An extended aeration lagoon consists of a small, deep aerated lagoon specifically managed to retain bacterial floc and to discharge treated, clarified effluent. A unique feature of this system is timer control of the aerator and automated lagoon outlet valve. With a plant operating only one shift, lagoon inflow occurs only 10 to 12 hours daily. The aerator is operated 18 hours daily. The outflow valve is opened only 4 hours per day, usually late at night. This leaves 2 hours for settling bacterial floc and 4 hours for decanting the clarified liquid before restarting the aerator.

A main advantage of the extended aeration lagoon is high pollutant removal efficiencies, particularly for TSS and ammonia. Removal efficiencies in a 1-year EPA study were BOD_5—98 percent; TSS—88 percent; FOG—91 percent; and total nitrogen—87 percent. Extended aeration lagoons can be used where odor potential prevents use of anaerobic lagoons. In fact, anaerobic lagoons can be converted easily to extended aeration lagoons.

Disadvantages are increased power and equipment costs for aeration and frequent sludge removal, which is necessary whenever the mixed liquor suspended solids exceed 5,000 mg/1. This occurred five times per year in the EPA studies. Effluent still needs further treatment before release to a stream. A second stage lagoon appears necessary for storage of treated effluent prior to land disposal.

Land Application of Lagoon Effluent

The soil has an extremely high capacity for assimilating organic wastes. The upper few inches of the soil profile is an efficient medium for aerobic treatment of organic matter, along with nutrient uptake.

Where land is available, land disposal provides a highly effective, economical and versatile alternative to expensive treatment needed to meet the 1983 EPA effluent limitations for discharge. For a particular type of waste and site, application rates and land area requirements may be limited by one of three factors: hydraulic loading; nitrogen loading; or salt loading. Application techniques include irrigation, infiltration and overland flow.

For wastewaters from meat packing plants, hydraulic and nitrogen loading are more likely to be limiting. Nitrogen loading rates should be limited to 400 percent of annual crop uptake. Table 2 lists application rates (inches per day) and land disposal areas (acres per million gallons per day effluent) for situations where hydraulic loading is the governing factor.

Summary

Information in this publication can be used for preliminary planning of waste management methods and treatment systems for small meat processing plants. Tremendous progress toward water pollution abatement can be made through management attention to in-plant waste reduction featuring "dry" collection to keep blood, paunch, meat scraps and holding pen manure out of the wastewater stream as much as possible. Relatively simple means of wastewater treatment, such as lagoons, provide a high level of treatment. Terminal disposal through land application of solid and liquid wastes and lagoon effluent is recommended in lieu of expensive, high level treatment and discharge to streams.

Table 2. Characteristics of Land Application Processes.

Design factors	Infiltration	Irrigation	Overland flow
Loading (in./day)	0.6 to 19	0.1 to 0.6	0.25 to 1.0
Land area (acre/mgd)	Less than 60	60 to 370 plus buffer zone	50 to 150 plus buffer zone
Drainability, soil type	Rapid, sand to sandy loam	Moderate, loamy sand to clay	Slow, clay loam and clay
Application technique	Spray or surface	Spray or surface	Spray

NOTE: Additional information on mechanical primary treatment devices is available in References 11 and 16.

A detailed analysis of wastewater treatment needs and system design for each plant is critical. In many cases, engaging the services of a qualified consulting engineer is recommended.

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