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Development Document for Effluent Limitations Guidelines and Standards of Performance for the Meat Packing Industry

Prepared for the

United States Environmental Protection Agency
under Contract Number 68-01-0593

June 1973

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REVIEW NOTICE

This document presents conclusions and recommendations of a study conducted for the Effluent Guidelines Division, United States Environmental Protection Agency, in support of proposed regulations providing effluent limitations guidelines and new source standards for the meat packing industry.

The conclusions and recommendations of this document may be subject to subsequent revisions during the document review process, and as a result, the proposed guidelines for effluent limitations as contained within this document may be superceded by revisions prior to final promulgation of the regulations in the Federal Register on or before October 18, 1973, as required by the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500).

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ABSTRACT

This document presents the findings of an extensive study of the meat packing industry by the Environmental Protection Agency for the purpose of developing effluent limitations guidelines, Federal standards of performance, and pretreatment standards for the industry, to implement Sections 304(b) and 306 of the Federal Water Pollution Control Act Amendments of 1972 (the "Act").

The meat packing plants included in the study were slaughterhouses and packinghouses; plants that only process meat, but do no slaughtering, and rendering operations carried out off the site of the packing plant were not included.

Effluent limitations guidelines are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available", and the "Best Available Technology Economically Achievable", which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The "Standards of Performance for New Sources" set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives. The proposed regulations require the best secondary treatment technology currently available for discharge into navigable water bodies by July 1, 1977, and for new source performance standards. This technology is represented by anaerobic plus aerated plus aerobic lagoons, or their equivalent. The recommendation for July 1, 1983, is for the best secondary treatment and in-plant control, as represented by greatly reduced water use, air flotation with pH control and flocculant addition, and a final sand filter added to the 1977 technology. In addition, an ammonia removal system will be required. When suitable land is available, land disposal with no discharge may be a more economical option.

Supportive data and rationale for development of the proposed effluent limitations guidelines and standards of performance are contained in this report.

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SECTION I

CONCLUSIONS

NOTICE

This document is a preliminary draft. It has not been formally released by EPA and should not, at this stage, be construed to represent Agency policy. It is being circulated for comment on its technical accuracy and policy implications.

A conclusion of this study is that the meat packing industry comprises four subcategories:

Simple Slaughterhouses
Complex Slaughterhouses
Low-Processing Packinghouses
High-Processing Packinghouses

The major criterion for the establishment of the categories was the 5-day biochemical oxygen demand (BOD_5) in the plant wastewater. Other criteria were the primary products produced and the secondary (by-product) processes used. Information relating to other pollutants and the effects of such parameters as age and location of plants, kind of animal, and treatability of wastes all lent support to the categorization selected.

The wastes from all subcategories are amenable to biological treatment processes, and no materials harmful to municipal waste treatment processes were found.

Discharge limits that represent the average of the best treatment systems in the industry for the four subcategories are being met by about 25 percent of the plants for which data are available; these limits are recommended for 1977. The same limits are recommended for new sources. It is estimated that the costs of achieving these limits by all plants within the industry is less than $53 million. These costs would increase the capital investment in the industry by about three percent and would equal about 20 percent of the industry's 1971 capital investment.

For 1983, effluent limits were determined as the best achievable in the industry for 5-day biochemical oxygen demand (BOD_5) and suspended solids. Limits for Kjeldahl nitrogen, ammonia, nitrites and nitrates, and phosphorus were established on the basis of transfer of technology from other industries or of newly developing technology. It is also concluded that, where suitable and adequate land is available, land disposal is a more economical option.

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It is estimated that the costs above those for 1977 for achieving the 1983 limits by all plants within the industry are less than $107 million. These costs would further increase the capital investment in the industry by about six percent, and would equal about 44 percent of the industry's 1971 capital investment.

SECTION II

RECOMMENDATIONS

Guideline recommendations for discharge to navigable waters for July 1, 1977, are based on the characteristics of well operated secondary treatment plants. The guidelines for 5-day biochemical oxygen demand (BOD_5) range, for example, from 0.08 kg/1000 live weight killed (LWK) for simple slaughterhouses to 0.24 kg/1000 kg LWK for an average high-processing packinghouse. Other major parameters that are limited are suspended solids and grease. Total Kjeldahl nitrogen, ammonia, phosphorus, and nitrite-nitrate are also included.

Recommended New Source Standards are the same as the 1977 guidelines.

Guidelines recommended for 1983 are considerably more stringent. For example, BOD_5 limits range from 0.03 kg/1000 kg LWK for simple slaughterhouses to 0.09 kg/1000 kg LWK for an average high-processing packinghouse. Limits are also placed on the other parameters mentioned above, with particular attention to the ammonia discharge. The suspended solids range from 0.05 to 0.12 kg/1000 kg LWK; grease is below the limits of detection by standard analytical methods; and total Kjeldahl nitrogen, ammonia, nitrogen, phosphorus, and nitrite-nitrate are limited by the concentrations achievable by the technology rather than by a relation to the production level. In cases where suitable and adequate land is available, land disposal (no discharge) will be a practical option.

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SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Section 301(b) of the Federal Water Pollution Control Act Amendments of 1972 (the Act) requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 304(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the meat packing plant subcategory within the meat products source category.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b)(1)(A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources for the meat packing plant subcategory within the meat products source category, which was included in the list published January 16, 1973.

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SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

The effluent limitations guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first studied for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source category. This analysis included a determination of whether differences in raw material used, product produced, manufacturing process employed, age, size, wastewater constituents, and other factors require development of separate effluent limitations and standards for different segments of the point source category. The raw waste characteristics for each segment were then identified. This included an analysis of (1) the source and volume of water used in the process employed and the sources of waste and wastewaters in the plant; and (2) the constituents (including thermal) of all waste waters including toxic constituents and other constituents which result in taste, odor, and color in water or aquatic organisms. The constituents of wastewaters which should be subject to effluent limitations guidelines and standards of performance were identified.

The full range of control and treatment technologies existing within each category was identified. This included identification of each distinct control and treatment technology, including an identification in terms of the amount of constituents (including thermal) and the chemical, physical, and biological characteristics of pollutants, of the effluent level resulting from the application of each of the treatment and control technologies. The problems, limitations and reliability of each treatment and control technology and the required implementation time was also identified. In addition, the nonwater quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were also identified. The energy requirements of each of the control and treatment technologies was identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constituted the "best practicable control technology currently available", "best available technology economically achievable" and the "best available demonstrated control technology, processes, operating methods, or other alternatives". In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques process changes, nonwater quality environmental impact (including energy requirements) and other factors.

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The data for identification and analyses were derived from a number of sources. These sources included Refuse Act Permit Program data, EPA research information; data and information from North Star files and reports; a voluntary questionnaire issued through the American Meat Institue (AMI), the National Independent Meat Packers Association (NIMPA), and Western States Meat Packers Association (WSMPA); qualified technical consultation; and on-site visits and interviews at several exemplary meat packing plants and slaughterhouses in various areas of the United States. All references used in developing the guidelines for effluent limitations and standards of performance for new sources reported herein are included in Section XIII of this document.

GENERAL DESCRIPTION OF THE INDUSTRY

Meat packing plants carry out the slaughtering and processing of cattle, calves, hogs, and sheep for the preparation of meat products and by-products from these animals. The plants in this industry range from plants that carry out only one operation, such as slaughtering, to full-line plants that not only slaughter, but also carry out processing to varying degrees (manufacturing of meat products such as sausages, cured hams, smoked products, etc). The amount of processing varies considerably, because some process only a portion of their kill, while others process not only their kill, but also the kill from other plants. Most full-line plants (packinghouses) and many slaughterhouses also render by-products; edible and inedible by-products are rendered from edible scraps and trimmings and from inedible materials, respectively.

Reportedly, there were 5991 meat slaughtering plants in these 48 contiguous states and Hawaii on March 1, 1973.[1] Of these, 1364 were federally inspected. The industry produced about 37 billion pounds of fresh, canned, cured, smoked, and frozen meat products per year. Perhaps 85 percent of the plants in the industry are small plants, for which waste load data are almost universally unavailable. The remaining 15 percent of the plants account for by far the largest part--probably over 90 percent--of the production, and thus, of the waste load. In 1966, about 70 percent of all wastewater in the meat packing industry went to municipal systems; at that time it was projected that, by 1972, 80 percent would be discharged to municipal systems. It was estimated in 1962 that 65 percent of the waste from small plants discharged to municipal systems;[2] the figure is undoubtedly higher today.

While the industry is spread over much of the country, the states of Nebraska and Iowa led the nation in beef slaughter with nearly 4.7 million head each in 1972.[1] Between them, these two states accounted for over 26 percent of the beef production in the nation. The other states making up the first ten in beef slaughter, each with over one million head, are Texas, California, Kansas, Colorado, Minnesota, Illinois, Wisconsin, and Ohio.

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Iowa led in hog slaughter by a wide margin, slaughtering nearly 21 million animals in 1971 for nearly 25 percent of the national production. The second state, Illinois, slaughtered about 6.3 million; the rest of the first ten include, in order, Minnesota, Pennsylvania, Ohio, Michigan, Indiana, Wisconsin, Virginia, and Tennessee.

Colorado, California, and Texas led in sheep and lambs, with about 1.8, 1.7, and 1.5 million head, respectively. New York led in calves with 0.64 million head, followed by New Jersey with 0.28, Pennsylvania with 0.25, and Wisconsin with 0.23 million.

The total live weight of livestock slaughtered was about three percent lower in 1972 than in 1971, with only beef showing a small increase. Table 1 lists the 1971 and 1972 slaughter in terms of liveweight killed (LWK). Beef, with nearly 63 percent, and hogs, with over 34 percent, account for about 97 percent of the total slaughter.

Wastewaters from slaughtering of animals, and the processing of meat, and the associated facilities and operation (stock yards, rendering, and feed manufacturing) contain organic matter (including grease), suspended solids, and inorganic materials such as phosphates and salts. These materials enter the waste stream as blood, meat and fat, meat extracts, paunch contents, bedding, manure, curing and pickling solutions, and caustic or alkaline detergents.

Table 1. Commercial Slaughter in 48 States

	Live Weight Killed (millions of pounds) 1971	1972	Percent of Total in 1972	Percent Change Since 1971
Beef	36,588	37,126	62.7	+1.5
Hogs	22,535	20,249	34.2	-10.1
Calves	919	767	1.3	-16.6
Sheep & lambs	1,111	1,081	1.8	- 2.7
TOTAL	61,153	59,223	100.0	- 3.2

Source: *Livestock Slaughter, Current Summary, 1972.*[1]

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PROCESS DESCRIPTION

A general flowsheet of a typical full-line packing plant, or "packinghouse", is shown in Figure 1. Such a plant is a "packinghouse" rather than a "slaughterhouse" by virtue of the "processing" step. As a packinghouse, it may process a wide range and volume of products. For example, it may process no more than its own carcasses; that is, only what it kills, or even less. Such a packinghouse is termed "low processing". On the other hand, a packinghouse may bring in carcasses from other plants and process much more than it kills. Such a packinghouse is termed "high processing". Less complete plants would operate on appropriate parts of the flowsheet of Figure 1. For example, primary processes through cooling of carcasses are typical of all slaughterhouses, or abattoirs. The secondary processes of blood processing, hide processing, and rendering may or may not be carried out in the slaughterhouse. Most pork plants include processing to some extent; many beef plants, however, are only abattoirs. A slaughterhouse may have all of the operations of a packinghouse, except for the processing, cutting and deboning steps, as noted in Figure 1. Such a slaughterhouse, based on high waste load from secondary processes, would be termed a "complex" slaughterhouse. A slaughterhouse may also be extremely simple; the simplest kind, with no secondary processing, is shown in Figure 2. If the plant has relatively few secondary processes, and those processes are of a type that give a low waste load, the plant is termed a "simple" slaughterhouse.

The meat packing operations begin at the point at which animals arrive at the plant and carry through the shipping of the product to the wholesale trade (or sometimes directly to the retailer). In the case of very small operations, the product may go directly to the consumer. All processes and handling methods and their management are considered part of the plant system. These include not only the processes directed toward the production of food products, but also those involved in recovery of materials of value for by-product manufacture, such as animal feed ingredients. The latter processes, indicated as secondary processes in Figure 1, include those recovery steps such as screening and gravity separation for proteinaceous solids and grease, and also serve to reduce the plant waste load. Hence, processes often considered primary waste treatment are actually part of the plant system, even though their effectiveness will have a large bearing on the plant's raw waste load. For the purposes of this study, "primary" waste treatment refers to these in-plant control measures.

The number of processes carried out and the way in which they are carried out varies from plant to plant, and has an effect upon the effluent treatment requirements. It is convenient to discuss them in terms of the processes listed at the top of page 12.

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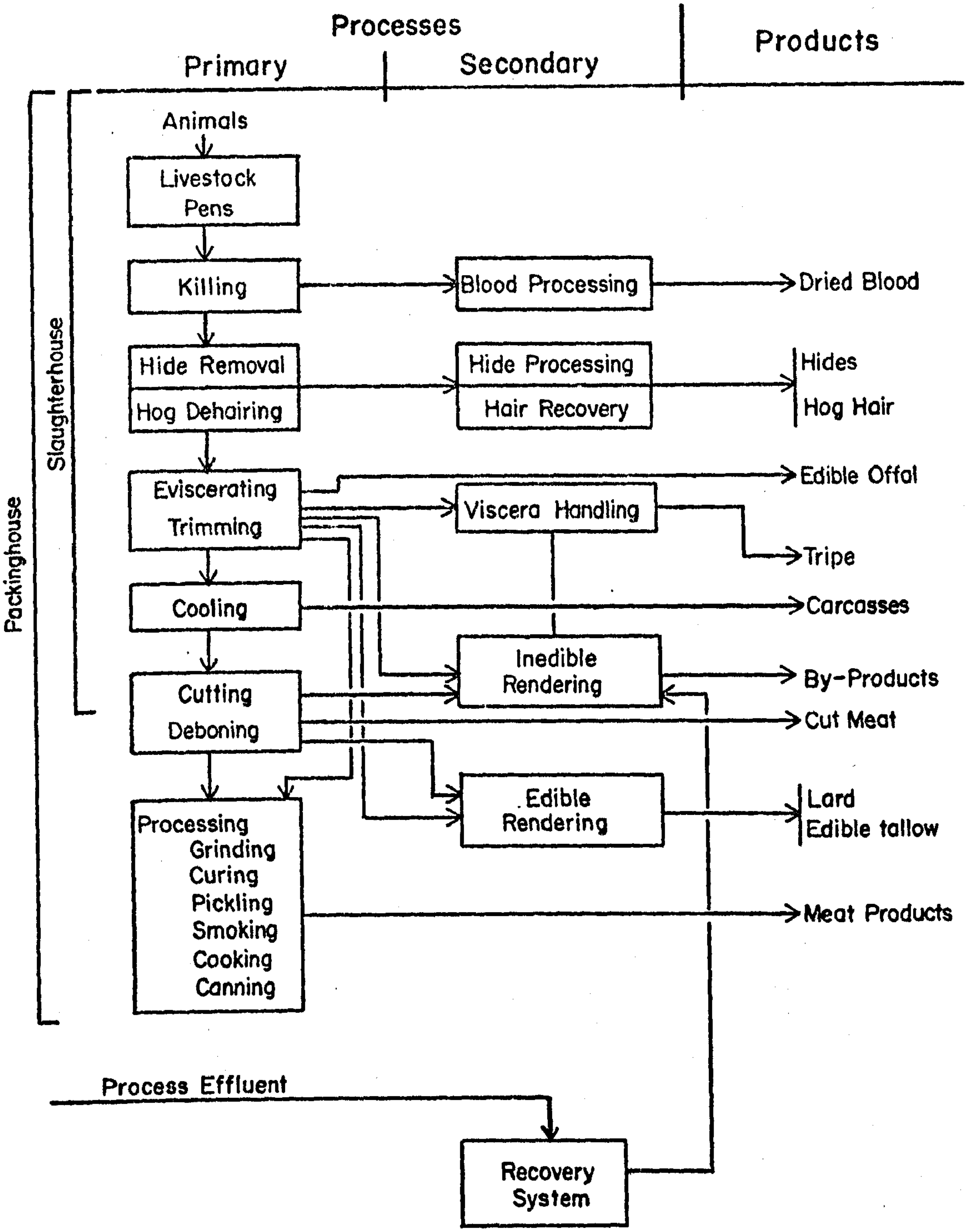

Source: *Industrial Waste Study of the Meat Product Industry*[3]

Figure 1. Process Flow in a Packing Plant

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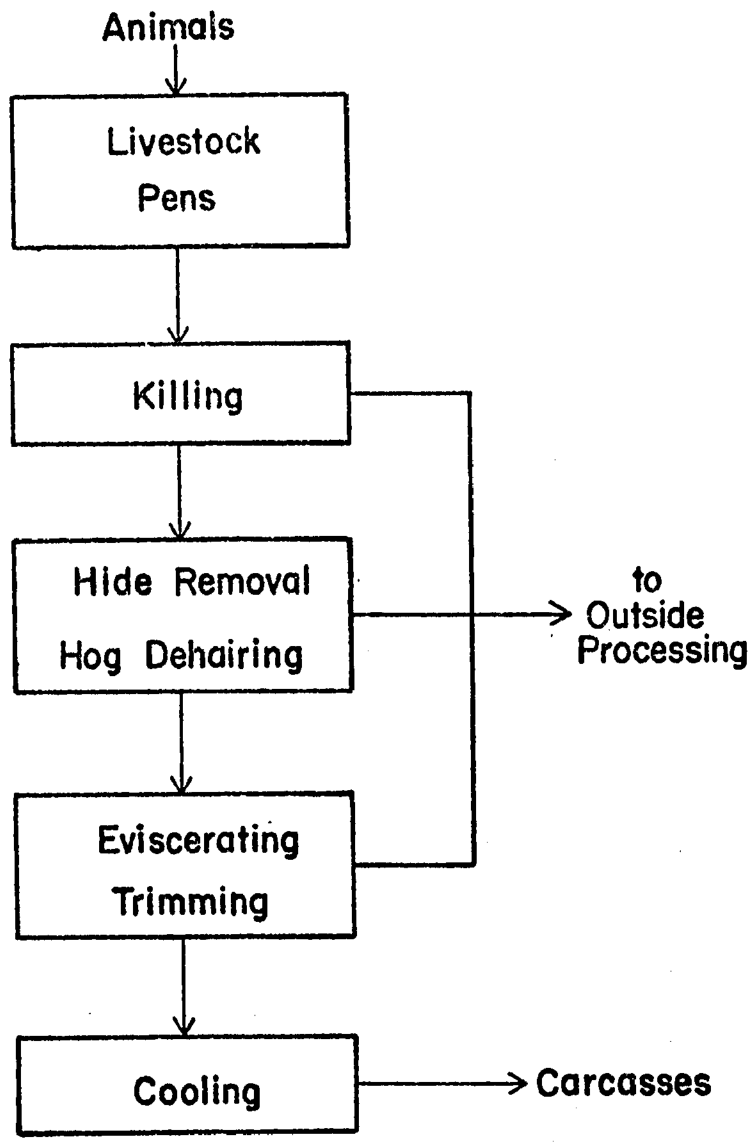

Figure 2. Process Flow for Simple Slaughterhouse

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MANUFACTURING PROCESSES

Meat packing processes include:

1. Animal stockyards or pens
2. Slaughtering, which in turn, includes:
   - Killing
   - Blood processing
   - Viscera handling and offal washing
   - Hide processing
3. Cutting
4. Meat processing
5. Rendering
   - Edible
   - Inedible
6. Materials recovery (primary separation)

As indicated in a general waste flow diagram for a packinghouse, Figure 3, all of these processes contribute to the raw waste load except the materials recovery or primary separation step; this removes material that would otherwise be lost to the sewer.

Stockyards and Pens

In most meat packing plants, animals are held in holding pens for less than one day. The animals are usually watered but not fed while waiting their turn for slaughter. The pens are often covered for protection from the elements, and sometimes are enclosed. In winter in northern climates, they may be heated enough to minimize condensation. A small volume of wastewater results from periodic washdown and from runoff; this enters the sewer downstream of any materials recovery processes.

Slaughtering

The slaughtering of animals includes the killing (stunning, sticking--cutting the jugular vein, bleeding) and hide removal for cattle, calves, and sheep, and scalding and dehairing for hogs; eviscerating; washing of the carcasses; and cooling. In the present context blood, viscera, and hide processing are included as subprocesses. Not all plants carry out all operations; for example, some only follow a narrower definition by shipping out blood, hides, and viscera for processing elsewhere.

Animals taken from the pens are immobilized upon entering the kill area by chemical, mechanical or electrical means. Cattle are usually stunned by a blow to the brain. A steel pin driven by a powder charge or by air pressure delivers the blow. Hogs are immobilized by an electric shock from electrodes placed on the head and back, or by running them through a tunnel where they breath a carbon-dioxide atmosphere. The latter is

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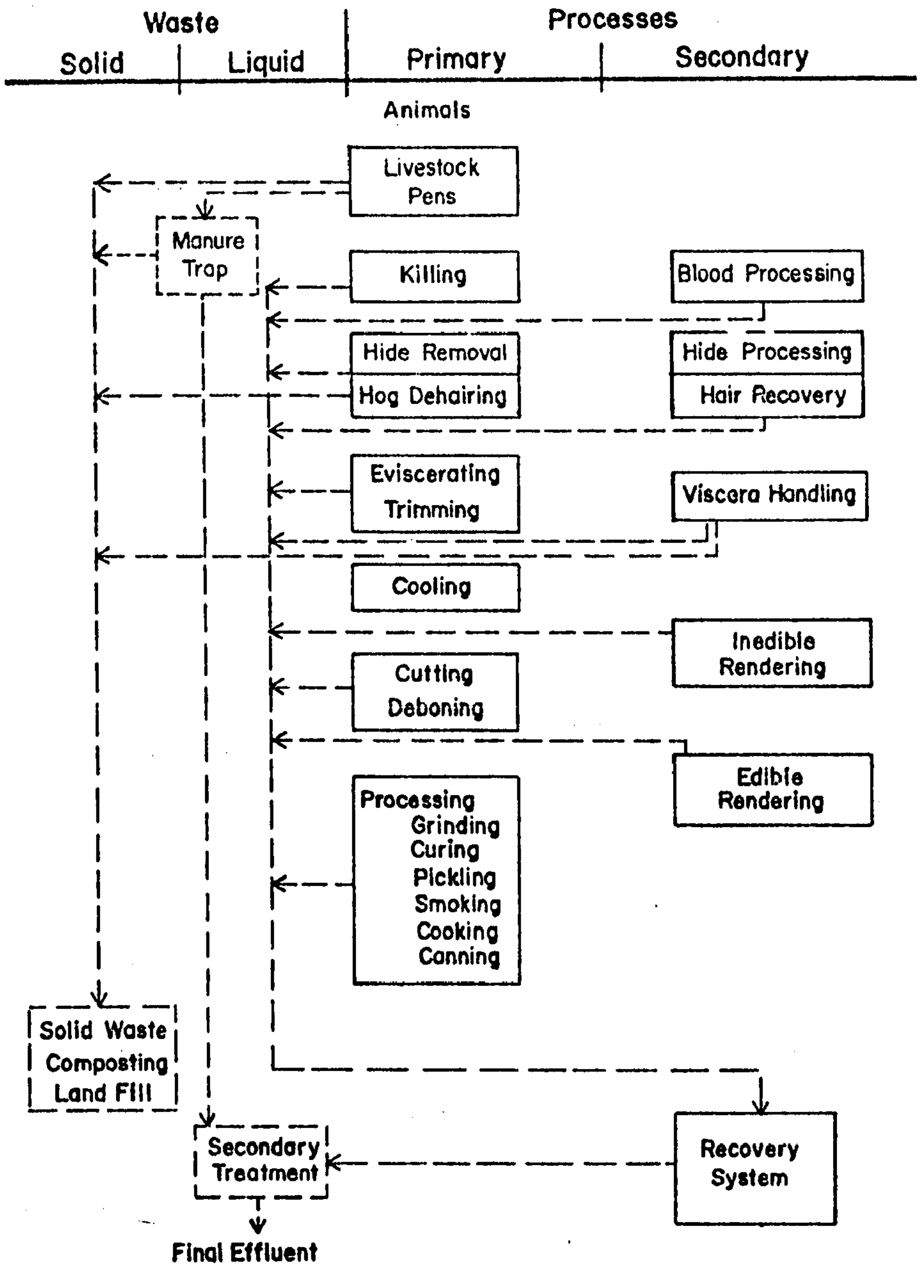

Figure 3. Waste Flow Diagram for a Packinghouse.

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becoming rare. Stunned cattle are suspended by their hind legs from an overhead rail for sticking and bleeding. Immobilized hogs are hung over a bleeding trough or are placed on a conveyor with their heads hanging over the bleeding trough. When they are stuck, the blood drains into the trough for collection. During bleeding, the conveyor carrying the animal moves slowly over the trough or gutter that catches the blood so it can be collected for blood processing. Sheep, lambs, and calves are generally handled like cattle. Some blood spills or splashes outside the collecting area, especially as the carcasses are conveyed to the next operation. Also, clean-up operations wash considerable blood into the sewer.

Following bleeding, the hides are removed from the cattle, usually by mechanical means. Before pulling, the hide is separated (by conventional or air-driven, hand-operated knives) sufficiently for fastening to the hide puller. Air knives are gaining favor because a skinner can be trained to use them very quickly and there is less chance of damaging the hide. The most common hide puller pulls the hide "up"; *i.e.*, from the neck to the tail, after the head is removed. A newer puller pulls downward, over the head. A traveling cage places the operator at the proper level for skinning and attaching the puller. Very small plants skin by hand. Some blood and tissue falls to the floor from this operation, or blood even splashes on walls. Much is collected, but some reaches the sewer, particularly during clean-up.

The hogs are usually not skinned, but are passed through a scalding tank of water at about 130°F, then dehaired. The dehairing machine is a rotating drum containing rubber fins. As the hog passes through the drum, the rubber fins abrade off the hair and water constantly flowing through the machine carries the hair to screens for recovery. In small plants, dehairing is often a hand operation. The hair is sometimes baled and sold for such uses as the manufacture of natural bristle brushes, and for furniture stuffing. Occasionally, it is hydrolyzed for animal feed. Often it is disposed of as solid waste. Following dehairing, hog carcasses are singed for final hair removal, and sprayed with water to cool and wash. They are inspected and trimmed to remove any remaining hair or other flaws. Scald water and dehairing and wash water contain hair, soil, and manure. The final carcass washwater is relatively clean. All are discharged to the sewer.

A trend appears to be developing for skinning hogs, much like cattle. This eliminates the scalding and dehairing.

Next, the carcass is opened by hand knives and the animal is eviscerated. The heart, liver, tongue(cattle), and kidneys are removed from the viscera and washed; these are sold as edible meat or are used in meat products. Lungs may be sold for pet food. The balance of the viscera is channeled to the viscera handling subprocess. The carcass is also trimmed and inspected. Scrap trimmings go to rendering for edible or inedible by-products. Blood and tissue from the evisceration find their way directly to the sewer and are washed into the sewer during clean-up.

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The carcasses, cut in half for beef and sheep, and left whole for hogs and calves, are hung in a cooler where they stay at least 24 hours. Materials recovered during clean-up, particularly by dry clean-up procedures, go to inedible rendering, either on- or off-site.

Blood Processing

Handling and processing of the blood is usually a part of the slaughterhouse operation. However, in some cases, the blood may be shipped out of a plant for processing elsewhere. The blood may be heated to coagulate the albumin; then the albumin and fibrin are separated from the blood water and forwarded for further processing such as pharmaceutical preparations. The blood water or serum remaining after coagulation may be evaporated for animal feed, or it may be sewered. In most cases, the whole blood is sent directly to blood dryers and used for animal feed. In small plants it is occasionally sewered.

Viscera Handling

The beef paunches may be handled either wet or dry. For wet handling, the contents of the paunches, 50 to 70 pounds of partially digested feed ("paunch manure") are washed out with water and passed over a screen. The separated solids go to solid waste handling. The liquor passing through the screen is generally sewered. In dry handling, paunches are dumped on a screen and the solids are sent either to a dryer or to a truck for removal from the plant. In some plants, the entire paunch contents are sewered; solids are later removed at the sewage treatment plant. A newer practice is to send the entire contents to processing or to haul out for disposal elsewhere. The paunch is then washed thoroughly if it is to be used for edible products. Hog stomach contents are normally wet processed.

The intestines may be sent directly to rendering or they may be hashed and washed and then sent to rendering. Often, the beef paunches and hog stomachs and the intestines are washed and saved for edible products. For example, it is common practice to bleach the paunches for marketing as tripe, and to recover hog casings and chitterlings (large intestines of hogs). Occasionally, paunches and stomachs are given only a brief washing and are sold for food for mink or pet food. Stomachs may be routed, unopened, directly to an inedible dryer. Hog intestines still find some market as sausage casings and for surgical sutures. Any viscera washing or cleaning operation results in the contents of stomachs, intestines, etc, as well as a considerable amount of grease being discharged to the sewer.

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Hide Processing

Hides may be processed wet or dry. Wet processing involves hide demanuring, washing, and defleshing, followed by a brine cure in a brine vat or raceway. The cure time may be as short as 12 hours. In dry curing, the washed, defleshed hides are packed with salt and stacked in the curing room. Often hides are only washed and hauled to other plants or to tanneries for defleshing and curing; sometimes they are hauled without even washing. Washing may be done by batches in a rotating screen or in a tumbler similar to a large concrete mixer. Defleshing is usually done by passing the hide through rotating scraper knives. In very small plants both may be done by hand. Some effort is being made toward transferring some of the tannery operations to the slaughtering plant; this allows better recovery and ensuing wastes to be channeled into animal feed. On the other hand, some specialty plants have come into being that take the green, unwashed hides from the slaughtering operation and deflesh, clean, and cure them as an intermediate step before they go to the tannery. Hide processing leads to significant loads of blood, tissue, and dirt being sewered. The curing operation contributes salt (sodium chloride) to the wastewater.

Cutting

Although meat cutting may be considered part of the "processing operation", it is often carried out in a separate part of the building, or may be carried out in plants that do no further processing. The latter is particularly true in the case of beef plants. In the cutting area, the carcasses are cut for direct marketing of smaller sections or individual cuts, or for further processing in the processing operations. Trimmings from this operation that do not go to products such as sausages and canned meats go to rendering of edible fats and tallows. Inedible materials are rendered for inedible fats and solids. There is always some material that reaches the floor, and a considerable amount that adheres to saw blades or conveyer systems, including meat, bone dust, fat tissues and blood that can be recovered for inedible rendering. Much of this, however, is washed to the sewer during clean-up.

Meat Processing

The edible portion resulting from slaughtering and cutting may be processed in a variety of ways. These include the manufacture of many varieties of sausages, hams, bacon, canned meats, pickled meats, hamburger, portional cuts, etc. Obviously, the processing of edible products is complex and varies from plant to plant. Some beef cuts are delivered to curing rooms for preparation of corned beef. Hog carcasses are cut up and hams, sides, and shoulders are generally sent to curing. Some loins may be deboned and cured for such products as Canadian bacon. (Most loins are packaged without curing for the retail market.)

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The curing operation involves injecting a salt and sugar solution into the meat, usually with a multineedle injection machine. Some curing is done by soaking in cure solution. Smoking is done in smokehouses at elevated temperatures. Smoked flavors are also obtained by soaking in or injecting a solution containing "liquid smoke". Spills from cooking equipment, excess cure solution spilled during injection, and materials washed into the sewer during clean-up all contribute to the waste load.

The processing operations may be carried out either in packing plants or in separate plants that do processing only. The "meat packing" industry concerns only the processing associated with packing plants.

Rendering

Rendering separates fats and water from tissue. Two types of rendering, wet or dry, may be used for either edible or inedible products. A type of dry rendering process called "low temperature" rendering is coming into common use, particularly for edible rendering. Edible trimmings from the cutting operations that do not go into products such as sausages and canned meats go to rendering for preparation of edible fats and tallows. The inedible processing is carried out in an area in the packing plant separate from the processing of edible products. Inedible products find use mainly in animal feed.

The materials to be rendered are normally passed through a grinder. For inedible rendering, this includes bones, offal (usually without cleaning), condemned animals, etc. From there it is fed to a continuous rendering operation, or to a blow tank that can be pressurized periodically to feed batch cookers. Economics usually dictate the type of process used.

Wet rendering is usually carried out in pressure tanks with 40 to 60 psi steam added directly. The fat phase is separated from the water phase after cooking. The solids in the water phase are screened out, leaving what is called tankwater. Tankwater is frequently evaporated to a thick material, rich in protein, known as stick, which is added to animal feeds.

Dry rendering is carried out either in vessels that are open to atmospheric pressure or are closed and under a vacuum. The material is cooked until all of the free moisture in the tissue is driven off. The liberated fat is then screened to remove the solid proteinaceous residue. Dry rendering can be either a batch or continuous operation, depending upon the equipment used. Batch operations are conducted in moderate-sized agitated vessels; continuous operations are conducted in either agitated vessels that are long enough to provide sufficient retention time to evaporate the water, or in multistage evaporators. Dry batch rendering is the most widely used rendering process.

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Low temperature rendering is a fairly recent development used primarily to produce edible products. In this process, the material to be rendered is first finely ground. The mass is then heated to just above the melting point of the fat. Centrifugation is used to remove the non-fatty material, and the fat is further clarified in a second centrifuge. The water phase may be further treated in other types of equipment for grease and solids recovery.

Spills from cooking equipment, collection tanks, and discharges from equipment washdown further contribute to total waste discharges. However, rendering operations serve to recover a number of materials, (*e.g.*, grease, fats, offal tissue) which might otherwise dramatically increase total plant waste loads. Moreover, since material such as grease that is less readily biodegradable is reduced in raw waste discharges, subsequent efficiencies in biological waste treatment are enhanced.

MATERIALS RECOVERY

The wastewater from the plant, excluding only the wastewater from the holding pens and, perhaps, paunch screening, usually runs through catch basins, grease traps, or flotation units. The primary purpose of these systems is usually the recovery of grease, which is sent to inedible rendering. The very important function of removal of pollutants is also served. Grease recovery most often has been the controlling factor, so the systems may be considered part of the manufacturing operation rather than a stage in pollution abatement. However, if the catch basin or grease trap is not adequate to meet the final effluent requirement, it may be necessary to further remove grease by an air flotation unit, with or without the addition of chemicals. This unit can be considered primary treatment because its main function is for pollution abatement rather than product recovery.

The most common method of solids recovery employs a catch basin. Solids settle to the bottom and are removed continously or periodically; grease floats to the top and is scraped off, often continuously. For effective recovery, these units usually have greater than a 20-minute detention time and are designed to minimize turbulence.

The best grease recovery is accomplished by employing dissolved air flotation in a tank. The tanks are usually large enough to retain the liquid for twenty minutes to one hour. Air is injected into a portion of the effluent, pressurized, and recycled, or is injected into the wastewater before it enters the tank. The liquid is pressurized to "supersaturate" it with air. The liquid then enters the tank where air bubbles coming out of solution rise to the surface, carrying grease particles with them. The grease is removed by skimmers. While the tanks are not designed for the most effective removal of settleable solids, some solids settle to the bottom and are scraped into a pit and pumped out. In some cases, flotation is added to other recovery systems for the primary purpose of pollution abatement.

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In addition to recovery systems above, some plants also recover part of the settleable solids before the waste streams enter the grease removal system by employing self-cleaning screens, either static, vibrating, or rotating. The solids that are recovered from these, as well as the solids recovered from the catch basins are returned to the plant's rendering system.

PRODUCTION CLASSIFICATION

The U.S. Bureau of Census, *Standard Industrial Classification Manual*[4] classifies the meat products industry under Standard Industrial Classification (SIC) group code number 201 (Major Group 20). Meat packing plants are classified as Industry No. 2011, which is defined as:

> "Establishments primarily engaged in the slaughtering, for their own account or on a contract basis for the trade of cattle, hogs, sheep, lambs, and calves for meat to be sold or to be used on the same premises in canning and curing, and in making sausage, lard, and other products."

Abattoirs on own account or for the trade; except nonfood animals
Bacon, slab and sliced, *mitsc**
Beef, *mitsc*
Blood meal
Canned meats, except baby foods, *mitsc*
Cured meats, *mitsc*
Lamb, *mitsc*
Lard, *mitsc*
Meat extracts, *mitsc*
Meat, *mitsc*
Meat packing plants
Mutton, *mitsc*
Pork, *mitsc*
Sausages, *mitsc*
Slaughtering plants: except nonfood animals
Variety meats (fresh edible organs), *mitsc*
Veal, *mitsc*

**mitsc* - made in the same establishment as the basic materials.

ANTICIPATED INDUSTRY GROWTH

Shipments of meat slaughtering and meat processing plants in 1972 was $23.8 billion and is expected to rise by about six percent to about $25.3 billion in 1973. *The U.S. Industrial Outlook:: 1973*[5] estimates that this annual growth rate of six percent per year will be substained through 1980 for American producers.

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Factors that should contribute to growth can be distinguished from those that act to restrain this growth.

A growing population and rising family incomes will continue to maintain consumer demand for meat products. Historically, as incomes of American families have grown, they have substituted higher priced food products such as meats for the bread and potatoes in their diets. Demand for beef, in particular, has continued to grow on a per capita basis as well as in total; for example, in 1972 the typical American consumed 115 pounds of beef, which was two pounds more than in 1971. In addition, larger quantities of portion-controlled meats are being processed in response to institutional demands by fast-food outlets, hotels, restaurants, and other institutions.

Several factors serve to restrain potential growth of the American meat industry, including higher meat prices, removal of import quotas, and the availability of synthetic substitutes. Two factors in higher meat prices may be the sharply reduced hog and calf slaughter in 1972, for an overall decrease of more than three percent from 1971. Supplies must increase sharply during the remainder of the decade to achieve the projected growth rates. Although firms in the industry have installed new plants and equipment, the resulting increased efficiency has been more than offset by higher costs for labor, livestock, packaging materials, and transportation--costs that have been passed on to consumers in the form of higher retail prices. On June 26, 1972, the U.S. eliminated all quantitative restrictions on meat imports to try to curb rising meat prices and to help meet the increased demand for beef; this effort was not completely successful, as indicated by the drastic price increases during the rest of the year.

Finally, synthetic meat substitutes, such as protein derivatives from soy beans, have been introduced into consumer markets. Although of minor importance in 1973, these substitutes may reduce growth in meat slaughtering and meat processing by 1980 if meat prices remain high and widespread consumer acceptance of the substitutes is achieved.

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SECTION IV

INDUSTRY CATEGORIZATION

CATEGORIZATION

In developing effluent limitations guidelines and standards of performance for the meat packing industry, a judgment was made as to whether limitations and standards are appropriate for different segments (subcategories) within the industry. To identify any such subcategories, the following factors were considered:

- Wastewater characteristics and treatability
- Final products
- Primary manufacturing processes
- Secondary manufacturing processes
- Raw materials
- Size, age, and location of production facilities.

After considering all of these factors, it was concluded that the meat packing industry consists of two major groups: slaughterhouses and packinghouses.

> A *slaughterhouse* is a plant that slaughters animals and has as its main product fresh meat, usually carcasses broken down no smaller than quarters.
>
> A *packinghouse* is a plant that both slaughters and processes fresh meat to cured, smoked, canned, and other prepared meat products.

Each of the above groups was further subdivided into two, giving a total of four subcategories:

I. Simple Slaughterhouse--is defined as a slaughterhouse that does a very limited amount of processing of by-products (*i.e.*, secondary processing). Usually, no more than two secondary processes, such as rendering, paunch and viscera handling, blood processing, or hide or hair processing are carried out.

II. Complex Slaughterhouse--is defined as a slaughterhouse that does extensive processing of by-products (*i.e.*, secondary processing). It usually carries out at least three of the secondary processes listed above.

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III. Low-Processing Packinghouse--is defined as a packinghouse that normally processes less than the total animals killed at the site, but may process up to the total killed.

IV. High-Processing Packinghouse--is defined as a packinghouse that processes both the total kill at the site and additional carcasses from outside sources.

The differences between the four subcategories and the relationships between them is shown schematically in Figure 4. The simplest plant is a *Simple Slaughterhouse,* and it does little secondary (by-product) processing. By adding substantial secondary processing, the plant becomes a *Complex Slaughterhouse*. By adding a meat processing operation, but processing less than produced in the plant as fresh meat, (processing less than the plant kills), the plant becomes a *Low Processing Packinghouse*. When the plant processes more than it kills (*e.g.*, brings in carcasses from outside in addition to processing its own), it becomes a *High Processing Packinghouse*.

RATIONALE FOR CATEGORIZATION

Wastewater Characteristics and Treatability

Industrial practices within the meat packing industry are diverse and produce variable waste loads. It is possible to develop a rational division of the industry, however, on the basis of factors which group plants with similar raw waste characteristics. The wastewater characteristic used in categorizing the industry is five-day biochemical oxygen demand (BOD_5) in units per 1000 units live weight killed: kg BOD_5/1000 kg LWK (lb BOD_5/1000 LWK). BOD_5 provides the best measure of plant operation and treatment effectiveness among the parameters measured, and more data are available than for all other parameters except suspended solids. Suspended solids data serve to substantiate the conclusions developed from BOD_5 in categorizing the industry.

The major plant waste load is organic and biodegradable: BOD_5, which is a measure of biodegradability, is the best measure of the load entering the waste stream from the plant. Furthermore, because secondary waste treatment is a biological process, BOD_5 also provides a useful measure of the treatability of the waste and the effectiveness of the treatment process. Chemical oxygen demand (COD) measures total organic content and some inorganic content. COD is a good indicator of change, but does not relate directly to biodegradation, and thus does not indicate the demand on a biological treatment process or on a stream.

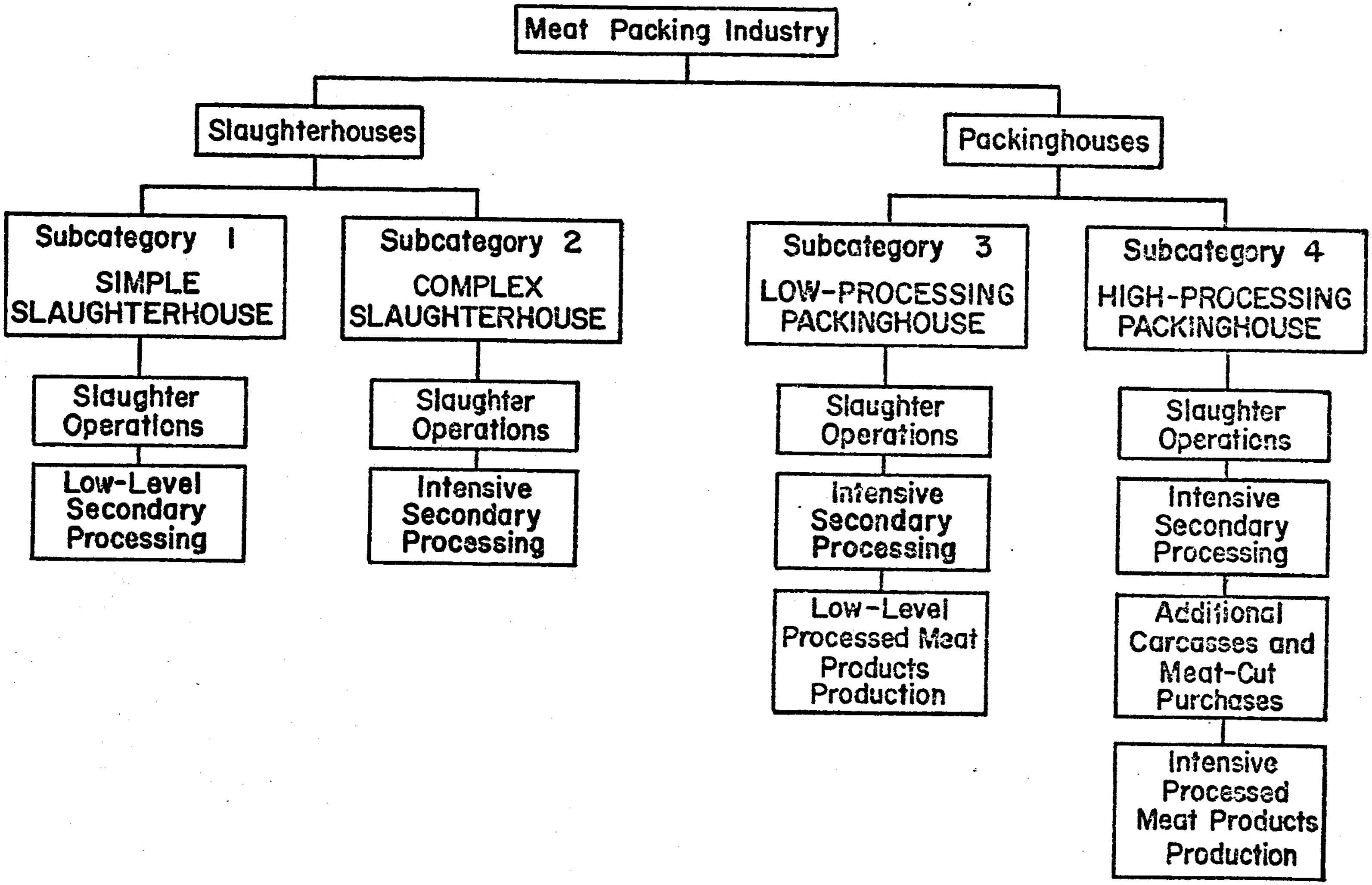

Figure 4. Categorization of Meat Packing Plants

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As developed in more detail in Section V, specific differences exist in the BOD_5 load for raw wastes for four distinct groupings of meat products operations. As defined above, these groupings (by plant type) are substantiated as subcategories on the basis of waste load.

A number of additional parameters were also considered. Among these were nitrites and nitrates, Kjeldahl nitrogen, ammonia, total dissolved solids, and phosphorus. In each case, data were insufficient to justify categorizing on the basis of the specified parameters; on the other hand, the data on these parameters helped to verify judgments based upon BOD_5.

Judging from secondary waste treatment effectiveness and final effluent limits, wastewaters from all plants contain the same constituents and are amenable to the same kinds of biological treatment concepts. It was anticipated that geographical location, and hence climate, might affect the treatability of the waste to some degree. Climate has occasionally influenced the kind of secondary waste treatment used, but has not had an influence on the ultimate treatability of the waste or the treatment effectiveness, given careful operation and maintenance.

Final Products

The final products of a meat packing plant provide further support for the selected subcategorization. Final products relate directly to processes employed, as discussed below. A plant that processes meat to products such as canned, smoked, and cured meats is significantly different from a plant that does no processing. Thus, there is a clear distinction between a packinghouse--a plant that both slaughters and processes--and a slaughterhouse.

Because of product differences, a further division of packinghouses is justified; some plants process no more than they kill, and others process far more by bringing in additional carcasses and meat cuts from other plants. Therefore, packinghouses divide into two subcategories, depending on the amount of final product that they produce.

> Low-Processing Packinghouse--has a ratio of weight of processed products to live weight killed less than 0.4. This numerical designation actually approximates the ratio of weight of processed products to live weight, when the entire carcass is processed (*i.e.*, forty percent of the weight of a live animal ultimately is processed into final products). In practice, these plants have an average ratio not of 0.4, but about 0.14. This low ratio indicates that low processing plants process only about a third of their kill.

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High-Processing Packinghouse--has a ratio of weight of processed products to live weight killed greater than 0.4. From the earlier definition, such a plant must bring in carcasses from outside sources for processing. For these type of plants the average ratio is about 0.65--high processing plants process about one-third more carcasses than are killed at the site.

The inedible by-products of a meat packing plant (*i.e.*, tallow, dried blood, tankage, dried solids) also affect categorization. However, the methods of by-product manufacture vary greatly, and the effect of recovered by-products upon categorization is discussed in "Secondary Manufacturing Processes".

Primary Manufacturing Processes

The primary manufacturing processes include the storage and slaughtering of animals and the dressing (evisceration), cutting, and processing of carcasses. As diagrammed in Section III, Figure 1, there is a distinct difference between the types and amounts of primary processes in various plants. Together with final products, this factor enhances the logic of the chosen subcategories.

Secondary Manufacturing Processes

Secondary manufacturing processes are those by-product operations for the handling, recovery, and processing of blood, trimmings, and inedible offal. This includes paunch and viscera handling, hide processing, hair recovery and processing, and edible and inedible rendering. Secondary processes used interrelate with both the final products and waste characteristics; however, the kind of manufacturing process is more relevant than the specific by-product. The process by which a by-product is made determines the waste load. Thus, it is the nature of the secondary processes rather than by-products themselves which define the categories. Unfortunately, there are a number of secondary manufacturing processes that can be used within each by-product area. Furthermore, there is no typical or usual combination of secondary manufacturing processes in the industry. Therefore, some other means of grouping plants by secondary manufacturing processes is required.

Computer analysis, literature, and experience suggested that empirical weighting factors (relative contributions to waste loads) assigned to each secondary processing technique would permit a further analysis of the slaughterhouse subcategory wherein the types and amounts of secondary processes prove critical.

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Therefore, waste loads in terms of kg BOD_5/1000 kg LWK (lb BOD_5/1000 lb LWK) were estimated for each secondary process that contributes materially to the raw waste load. Estimates were made from discussions with consultants, data obtained in this study, and from the experience of the investigators. As summarized in the subcategory, definitions and waste characteristics section above, the waste load factors are most important relative to each other rather than as absolute waste load values. The factors applied to the secondary processes were:

Process	Factor
Paunch handling:	
- wet dumping	1.0
Blood processing:	
- Steam coagulated and screened, with blood water sewered	1.2
- Whole blood dried	0.3
Rendering (edible or inedible)	
- Wet and low temperature, sewering water	2.0
Dry	0.5
Hide Processing	
- Defleshing, washing, curing	1.5
Hair processing	
- Hydrolyzing	1.0
- Washing	0.7
Viscera Handling	
- Casing saving, hashing and washing, or stomach and chitterling washing	0.6
- Tripe processing	0.4

The waste load factors for the secondary processes were summed for each slaughterhouse. The sum of the waste load factors divided the slaughterhouse sample into two distinct clusters, one group of slaughterhouses with totals below 4.0 and the other above 4.0 The plants with totals below 4.0 were relatively simple; *i.e.*, they had few secondary processes and those processes tended to be the types that were low waste load contributors. These "simple" slaughterhouses had relatively low total waste loads. The plants with waste load factors above 4.0 were much more complex; *i.e.*, they had many secondary processes. These "complex" slaughterhouses had distinctly higher waste loads.

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The waste load factors serve an additional purpose. Occasionally, a slaughterhouse in one of the subcategories carries out an unusually high amount of secondary processing. An example is a complex slaughterhouse that processes hides from several other plants. Its raw waste load is unusually high. However, when a waste load of 1.5 kg BOD_5/1000 kg LWK (1.5 lb BOD_5/1000 lb LWK, or about 1.5 lb BOD per hide processed) is taken into account for the extra hides processed, the waste load for the plant leads to logical assignment of this plant to its proper subcategory.

Raw Materials

Raw materials characteristics help to substantiate the above categorization. The raw materials include live animals (cattle, hogs, sheep, lambs, and calves), water, chemicals, and fuel. Although different kinds of animals vary greatly in size and require some different processing techniques, these effects are best handled by incorporation into other factors. For example, weight variations are accounted for by normalizing (dividing) waste parameter values by the daily live weight killed; this gives a waste load per unit of raw material independent of the kind of animal. The effects on waste load of differences in the plant processes that are dependent on the kind of animal are not significant.

A definite relationship was found between raw waste load and water use, both in individual plants and in the four subcategories. Variations in water flow between subcategories are caused by different process requirements. Highly varying water use in plants within the same subcategory are the result of varying operating practices.

Chemicals used in packing plants (*i.e.*, preservatives, cure, pickle, and detergents) do not serve as a basis for categorization. Differences in waste loads caused by chemicals are the result of different operating practices.

Fuels are usually natural gas or fuel oil. They have no effect on categorization.

Size, Age, and Location

Size, age, and location are not meaningful factors for categorization of the industry. Neither the information from this study, nor that from previous studies, reveals any discernible relationship between plant size and effluent quality or other basis for categorizing. Both high and low quality raw wastes were found at both ends of the plant size spectrum within the industry. Other factors perhaps related to plant size, such as degree of by-product recovery, are discussed elsewhere.

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Age as a factor for categorization might be expected to be at least amenable to quantitative identification and interpretation, but unfortunately age does not even achieve that degree of usefulness. The red meat industry is a relatively old industry, and some old plants incorporate early operating ideas and practices. Some plants, on the other hand, are very new and incorporate the latest operating ideas and practices. Nevertheless, most older plants have been updated by changes in plant processes and plant structure. Therefore, to say that a plant was built 50 years ago and is 50 years old is not particularly meaningful in terms of interpreting in-plant practices. In addition, no consistent pattern between plant age and raw waste characteristics was found.

Examination of the raw waste characteristics relative to plant location reveals no apparent relationship or pattern. The effect of manure and mud-coated animals processed in the winter by northern plants is not as significant as other factors. The type of animal handled, which is sometimes influenced by location, does not seem to affect the waste load either.

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SECTION V

WATER USE AND WASTE CHARACTERIZATION

WASTEWATER CHARACTERISTICS

Water is a raw material in the meat packing industry that is used to cleanse products and to remove and convey unwanted material. The principal operations and processes in meat packing plants where wastewater originates are:

- Animal holding pens
- Slaughtering
- Cutting
- Meat processing
- Secondary manufacturing (by-product operations) including both edible and inedible rendering
- Clean-up

Wastewaters from slaughterhouses and packinghouses contain organic matter (including grease), suspended solids, and inorganic materials such as phosphates, nitrates, nitrites, and salt. These materials enter the waste stream as blood, meat and fatty tissue, meat extracts, paunch contents, bedding, manure, hair, dirt, condenser water, losses from edible and inedible rendering, curing and pickling solutions, preservatives, and caustic or alkaline detergents.

Raw Waste Characteristics

The raw wasteload from all four subcategories of the meat packing industry discussed in the following paragraphs includes the effects of in-plant materials recovery (primary waste treatment).

The parameters used to characterize the raw effluent were the flow, BOD_5, suspended solids (SS), grease, chlorides, phosphorus, and Kjeldahl nitrogen. As discussed in Section VI, BOD_5 is considered to be, in general, the best available measure of the wasteload. Parameters used to characterize the size of the operations were the kill (live weight) and amount of processed meat products produced. All values of waste parameters are expressed as kg/1000 kg LWK, which has the same numerical value when expressed in lb/1000 lb LWK. In some cases, treated effluents are so dilute that concentration becomes limiting. In these cases, concentration is mg/l. Kill and amount of processed meat products are expressed in thousands of kg.

The data used to compute the values presented in Tables 2 through 5 were obtained through questionnaires distributed to their members by the three major trade associations--the American Meat Institute, the National Independent Meat Packers Association, and the Western States Meat Packers Association; through data provided directly by the companies; and through data obtained from state pollution control agencies and the Environmental Protection Agency. Some information on the kill and amount of processed products was obtained from the U.S. Department of Agriculture. Sufficient information was collected on 85 identifiable plants to allow the plants to be categorized and the data to be included in characterization of the raw waste. The information found in the open literature was not detailed enough to be included.

A summary of data including averages, standard deviations, ranges, and number of observations (plants) is presented in the following sections for each of the four subcategories of the industry. The four subcategories are:

1) Simple Slaughterhouse

2) Complex Slaughterhouse

3) Low-processing Packinghouse

4) High-processing Packinghouse

A detailed description of the subcategories was presented in Chapter IV.

Slaughterhouses

A typical flow diagram illustrating the sources of wastewaters in both simple and complex slaughterhouses is shown in Figure 5. It should be noted that a simple slaughterhouse normally conducts very few of the by-product operations (secondary processes) listed in Figure 5, whereas a complex slaughterhouse conducts most or all of them. Occasionally slaughterhouses may not have wastewaters from some of the operations shown, depending upon individual plant circumstances. For example, some slaughterhouses have dry animal pen clean-up with no discharge of wastewater, some have little or no cutting, and others may have a separate sewer for sanitary waste.

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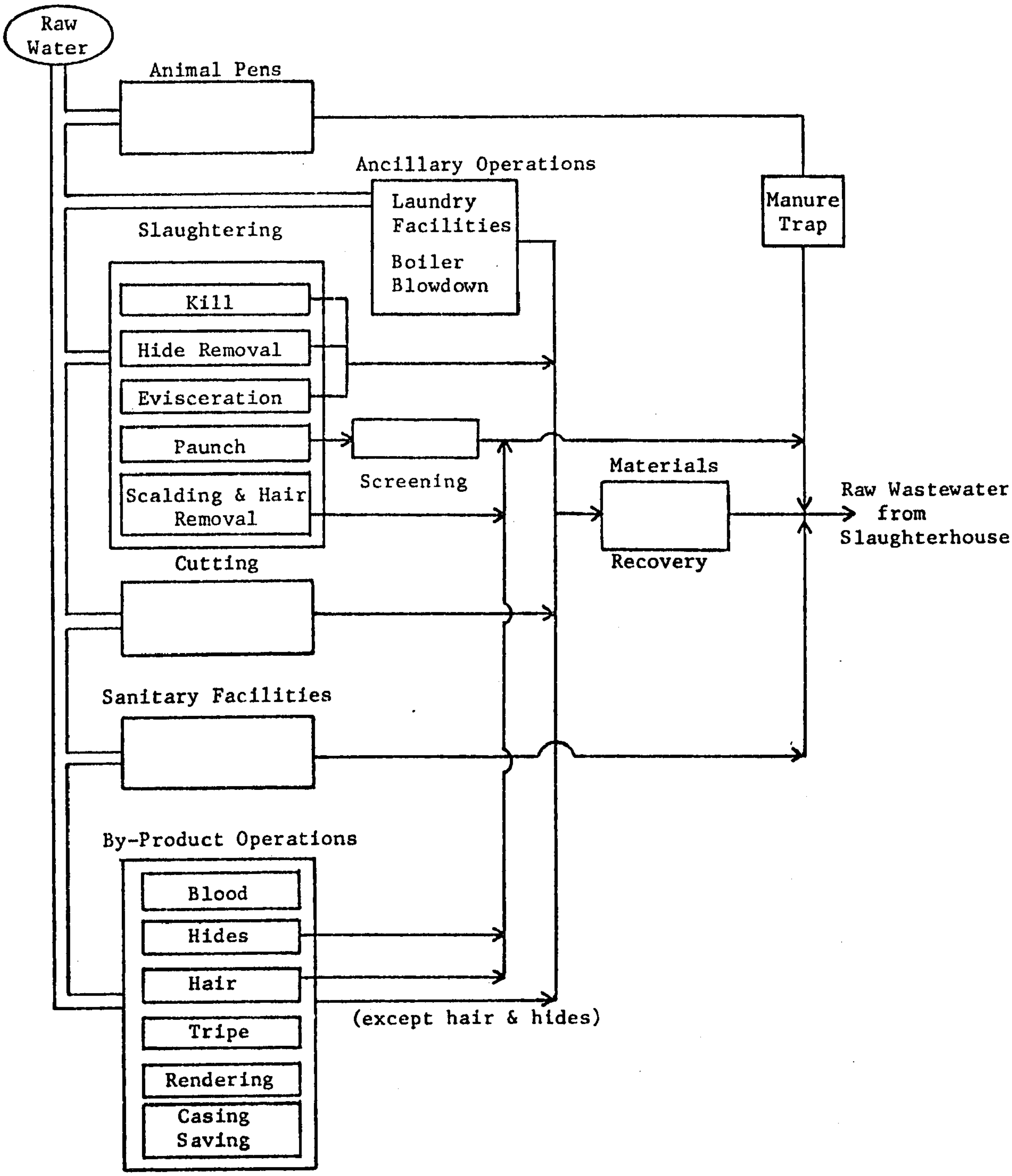

Figure 5. Operating and Wastewater Flow Chart for Simple and Complex Slaughterhouses

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The flow diagrams include both beef and hog operations. As noted in Section IV, no distinction was made in subcategories for the type of animal. It is recognized, however, that in some small plants there will be more significant differences in pollution wasteloads depending on the animal type. These cases, however, are still within the wasteloads cited for the subcategory.

Simple Slaughterhouses

Table 2 summarizes the plant and raw waste characteristics for a simple slaughterhouse. The table shows that 24 of the 85 plants analyzed were simple slaughterhouses (about one-half were beef and the others divided between hogs and mixed kill) and that the BOD_5 wasteload covers a range from 1.5 to 14.3 kg/1000 kg LWK (same value in lb/1000 lb LWK). Defining small plants as those with a LWK of less than 43,130 kg (95,000 lbs), and medium plants as those with a LWK between 43,130 kg and 344,132 kg (758,000 lb), it can be stated that only small and medium plants were included. In fact, two are small and twenty-two are medium.

Complex Slaughterhouses

Table 3 summarizes the plant and raw waste characteristics for complex slaughterhouses. Nineteen of the 85 plants analyzed were complex slaugherhouses (11 were beef; 6, hogs; and 2, mixed). Defining a large plant as one with a LWK of greater than 344,132 kg (758,000 lb), and a medium plant as in the paragraph above, the kill data of Table 3 shows all complex slaughterhouses included are either medium or large. Actually about one-third were large.

Packinghouses

A typical flow diagram illustrating the sources of wastewaters in both low- and high-processing packinghouses is shown in Figure 6. As defined in Section IV, the main difference between a low- and high-processing packinghouse is the amount of processed products relative to kill, *i.e.,* less than 0.4 for a low- and greater than 0.4 for a high-processing plant. As a result, the wasteload contribution from processing is less for a low-processing packinghouse. A comparison of Figures 5 and 6 shows that a packinghouse has the same basic processes and operations contributing to the wasteload as a slaughterhouse, with the addition of the meat processing for the packinghouse. Another difference is that the degree and amount of cutting is much greater for a packinghouse. In some cases, unfinished products may be shipped from one plant to another for processing, resulting in more products produced at a plant than live weight killed.

Table 2. Summary of Plant and Raw Waste Characteristics for Simple Slaughterhouses

Base	Flow 1/1000 kg LWK	Kill 1000 kg/day	BOD_5 kg/1000 kg LWK	Suspended Solids kg/1000 kg LWK	Grease kg/1000 kg LWK	Kjeldahl Nitrogen as *N* kg/1000 kg LWK	Chlorides as *Cl* kg/1000 kg LWK	Total Phosphorus as *P* kg/1000 kg LWK
(Number of Plants)	(24)	(24)	(24)	(22)	(12)	(5)	(3)	(5)
Average	5,328	220	6.0	5.6	2.1	0.68	2.6	0.05
Standard Deviation	3,644	135	3.0	3.1	2.2	0.46	2.7	0.03
Range, low-high	1,334- 14,641	18.5- 552.	1.5- 14.3	0.6- 12.9	0.24- 7.0	0.23- 1.36	0.01- 5.4	0.014- 0.086

Table 3. Summary of Plant and Raw Waste Characteristics for Complex Slaughterhouses

Base	Flow 1/1000 kg LWK	Kill 1000 kg/day	BOD_5 kg/1000 kg LWK	Suspended Solids kg/1000 kg LWK	Grease kg/1000 kg LWK	Kjeldahl Nitrogen as *N* kg/1000 kg LWK	Chlorides as *Cl* kg/1000 kg LWK	Total Phosphorus as *P* kg/1000 kg LWK
(Number of Plants)	(19)	(19)	(19)	(16)	(11)	(12)	(6)	(5)
Average	7,379	595	10.9	9.6	5.9	0.84	2.8	0.33
Standard Deviation	2,718	356	4.5	4.1	5.7	0.66	2.7	0.49
Range, low-high	3,627- 12,507	154- 1498	5.4 18.8	2.8- 20.5	0.7- 16.8	0.13- 2.1	0.81- 7.9	0.05- 1.2

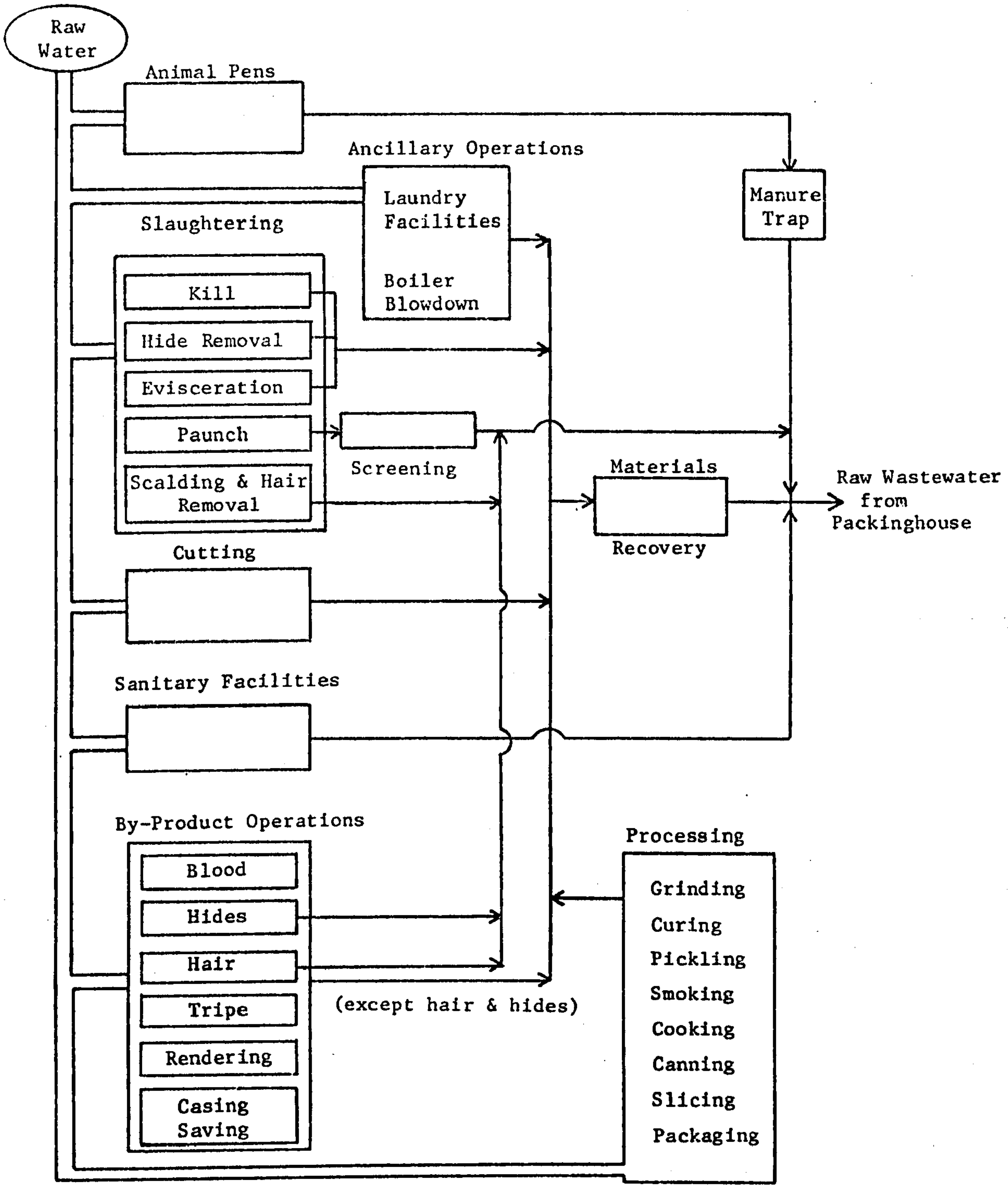

Figure 6. Operating and Wastewater Flow Chart for Low- and High-Processing Packinghouses

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Low-Processing Packinghouses

Table 4 summarizes the plant and raw waste characteristics for low-processing packinghouses. Twenty-three of the 85 plants analyzed were low-processing packinghouses. The average ratio of processed products to kill in these 23 plants is 0.14, with a standard deviation of 0.09. The low-processing packinghouses included in the analyses have a ratio of processed products to LWK well below the value of 0.4 used to distinquish between low- and high-processing plants. Using the above definitions of plant size, the kill data shows that all the packinghouses in the sample are medium or large in size.

High-Processing Packinghouses

Table 5 summarizes the plant and raw waste characteristics of high-processing packinghouses. Nineteen of the 85 plants analyzed were high-processing packinghouses. The range of data for the 19 plants is large for all wasteload parameters. The range of 0.4 to 2.14 for the ratio of processed products to LWK suggests that much of the wasteload variation caused by the wide variation in processing, relative to kill. Plant size as measured by kill ranges from small to large; two plants were small, 11 medium, and 6 large.

Discussion of Raw Wastes

The data in Tables 2 through 5 cover a wastewater flow range of 1334 to 20,261 l/1000 kg LWK (160 to 2427 gal/1000 lb LWK); a wasteload range of 1.5 to 30.5 kg BOD_5/1000 kg LWK (1.5 to 30.5 lb/1000 lb LWK); and a kill range of 18.5 to 1498 thousand kg LWK/day (40 to 3300 thousand lb/day). A comparison of the data from Tables 2 and 3 for simple and complex slaughterhouses shows that the averages of all the waste parameters are higher for a complex plant. This was expected because, by the method of categorization of slaughterhouses, complex slaugherhouses conducted more secondary (by-product) processes. In addition, the daily LWK for a complex slaughterhouse is notably larger, about 2.7 times based on averages.

The data listed in Tables 4 and 5 for low- and high-processing packinghouses show that high-processing plants have much higher average values for all waste parameters on a LWK basis.

Some variations in wastewater flow and strength within any one of the four subcategories can be attributed to differences in the amount and types of operations beyond slaughtering, such as by-product and prepared meat processing, and the effectiveness of material recovery in primary in-plant treatment. However, the major causes of flow and wasteload variations are variations in water use and in housekeeping practices.

Table 4. Summary of Plant and Raw Waste Characteristics for Low-Processing Packinghouses

Base	Flow 1/1000 kg LWK	Kill 1000 kg/day	BOD_5 kg/1000 kg LWK	Suspended Solids kg/1000 kg LWK	Grease kg/1000 kg LWK	Kjeldahl Nitrogen as *N* kg/1000 kg LWK	Chlorides as *Cl* kg/1000 kg LWK	Total Phosphorus as *P* kg/1000 kg LWK	Processed Products 1000 kg/day	Ratio of Processed Products to Kill
(Number of Plants)	(23)	(23)	(20)	(22)	(15)	(6)	(5)	(4)	(23)	(23)
Average	7,842	435	8.1	5.9	3.0	0.53	3.6	0.13	54	0.14
Standard Deviation	4,019	309	4.6	4.0	2.1	0.44	2.7	0.16	52	0.09
Range, low-high	2,018- 17,000	89- 1,394	2.3- 18.4	0.6- 13.9	0.8- 7.7	0.04- 1.3	0.5- 4.9	0.03- 0.43	3.0- 244.	0.016- 0.362

Tqable 5. Summary of Plant and Raw Waste Characteristics for High-Processing Packinghouses

Base	Flow 1/1000 kg LWK	Kill 1000 kg/day	BOD_5 kg/1000 kg LWK	Suspended Solids kg/1000 kg LWK	Grease kg/1000 kg LWK	Kjeldahl Nitrogen as *N* kg/1000 kg LWK	Chlorides as *Cl* kg/1000 kg LWK	Total Phosphorus as *P* kg/1000 kg LWK	Processed Products 1000 kg/day	Ratio of Processed Products to Kill
(Number of Plants)	(19)	(19)	(19)	(14)	(10)	(3)	(7)	(3)	(19)	(19)
Average	12,514	350	16.1	10.5	9.0	1.3	15.6	0.38	191	0.65
Standard Deviation	4,894	356	6.1	6.3	8.3	0.92	11.3	0.22	166	0.39
Range of low-high	5,444- 20,261	8.8- 1,233.	6.2- 30.5	1.7- 22.5	2.8- 27.0	0.65- 2.7	0.8- 36.7	0.2- 0.63	4.5- 631.	0.40- 2.14

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Excess water use removes body fluids and tissues from products and conveys them into the wastewater. The effect of wastewater flow on wasteload is discussed in more detail later in this Section.

In all four subcategories, a correlation analysis of the data revealed that the raw BOD_5 wasteload correlates very well with suspended solids, with grease, and with Kjeldahl nitrogen on a LWK basis. This means that an increase (decrease) in one parameter will account for a certain predictable increase (decrease) in another of the parameters.

The effect of plant size (kill) on wasteload as measured by BOD_5 for each category was assessed by a regression analysis. The results showed that larger plants tend to have slightly higher pollutional wasteloads. This trend is not caused by differences in processing. Rather, it results from some of the plants operating at ever increasing throughput, often beyond the LWK for which the plant was designed. Under these circumstances, housekeeping and water management practices tend to become careless. Often waste management personnel do not have the authority to enforce or change plant practices. Line speed-up overloads fixed operations such as inedible rendering and blood handling.

Only four small plants were included in the analysis; two were simple slaughterhouses and two were high-processing packinghouses. Three of the four were substantially below the average BOD_5 wasteload for their subcategory, suggesting that small plants can meet effluent limits of larger plants. The only other information available on small plants is that of Macon and Cote.[6] Accurate waste data were obtained on ten small packinghouses in 1961. Because there was insufficient information on these plants to subcategorize them as low- or high-processing packinghouses, and the plants were not identified, the results were not used in determining wasteloads for the various subcategories. Those plants that practiced blood recovery had BOD_5 wasteloads between 2.7 and 8.3 kg/1000 kg LWK; the other plants which sewered blood had considerably higher waste loads. Although some of the data did not include the waste load from clean-up, Macon determined that the clean-up could add from 0.35 to 3.0 kg BOD_5/1000 kg LWK. These results indicate that the waste load from small packinghouses not sewering blood are slightly less than those from larger packinghouses. This further substantiates that standards set for medium and large plants can be met, without special hardship, by a small plant, if the small plant is properly equipped for blood disposal, paunch handling, and similar high waste-related operations.

Data in Tables 2 through 5 shows that chlorides and phosphorus values are less frequently measured than are values for the other parameters. From the data reported, however, chlorides and phosphorus are dependent on in-plant operations and housekeeping practices. For example, large amounts of chlorides contained in pickling solutions and used in the processing of ham, bacon, and other cured products ultimately end up in the wastewaters. This explains the unusually high chloride values for high-processing packinghouses, *i.e.*, four to six times the values for the other subcategories, where relatively large amounts of products are cured.

Very little useful information on other waste parameters such as Kjeldahl nitrogen, nitrites, nitrates, ammonia, and total dissolved solids were reported by the 85 plants whose data were summarized by subcategory in this chapter. However, some information on these parameters was obtained from other sources[7] and from field verification studies conducted during this program. Typical ranges are given below for these waste parameters. It should be noted that the values for dissolved solids in the wastewater are also affected by the dissolved solids content of the plant water supply.

Nitrates and Nitrites as *N*, mg/l	0.01 - 0.85
Kjeldahl nitrogen, mg/l	50 - 300
Ammonia as *N*, mg/l	7 - 50
Total dissolved solids, mg/l	500 - 25,000

PROCESS FLOW DIAGRAMS

The most typical flow arrangement used in the meat packing industry is shown schematically in Figure 7. The system is used in about 70 percent of the plants studied. The figure shows that most of the wastewater flows through a recovery system which consists of screening followed by a catch basin. Frequently, the only waste streams to by-pass this system are the pen washing, sanitary wastes, hog scalding and dehairing wastewaters, and hide-processing wastewaters. Pen washing normally pass through a manure trap and then are mixed with the other wastewaters before entering further treatment for discharge to a watercourse or a municipal sewer. Only non-contaminated water, such as cooling water, completely by-passes treatment; they usually discharge directly to a stream. In plants in which barometric condensers are used, the water can become contaminated. Most of this water is sent to further treatment.

The second most frequently used wastewater arrangement is shown schematically in Figure 8. In this flow arrangement, several low grease-bearing streams by-pass the screen and catch basin. This permits an

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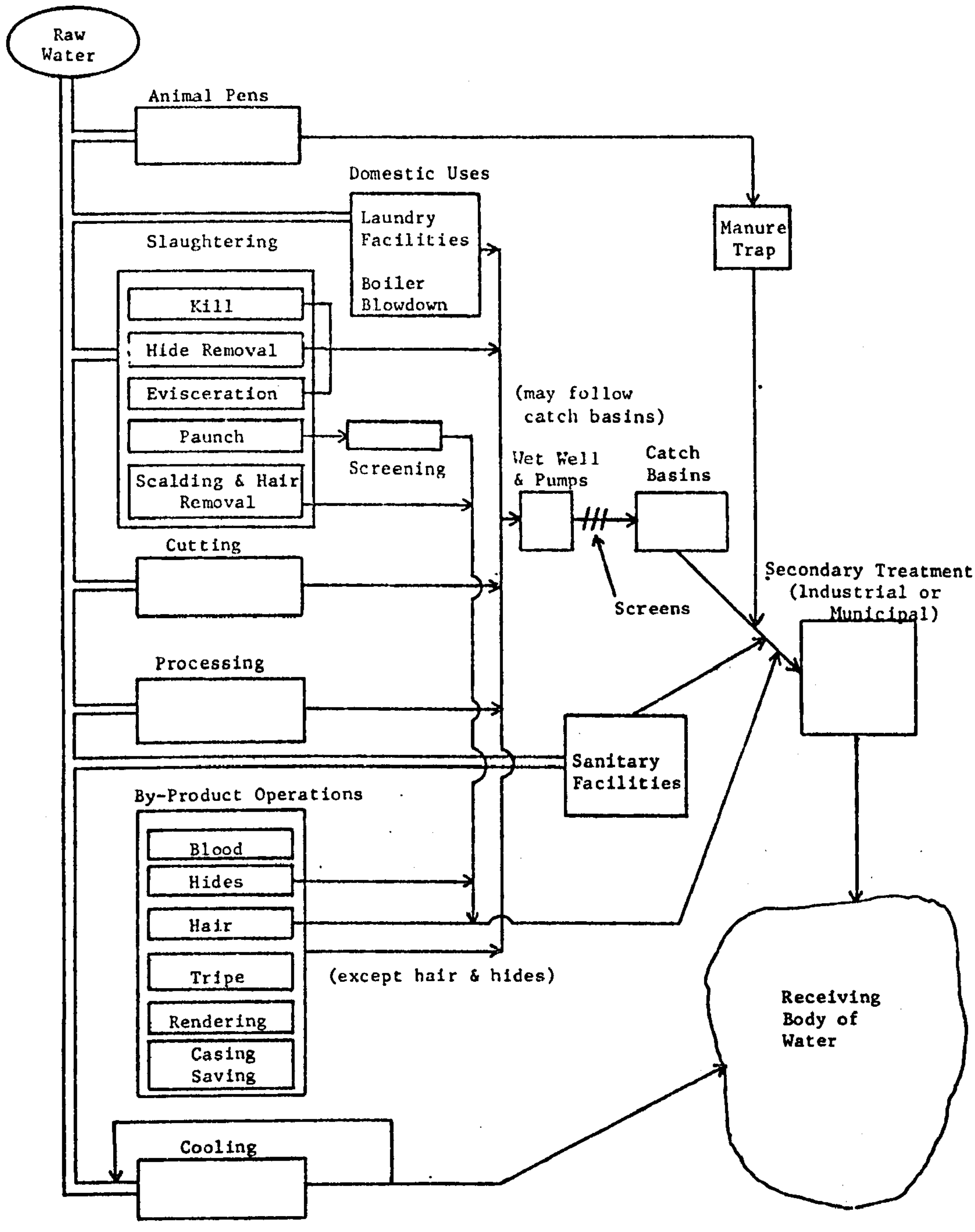

Figure 7. Typical Wastewater Treatment System Without Dissolved Air Flotation

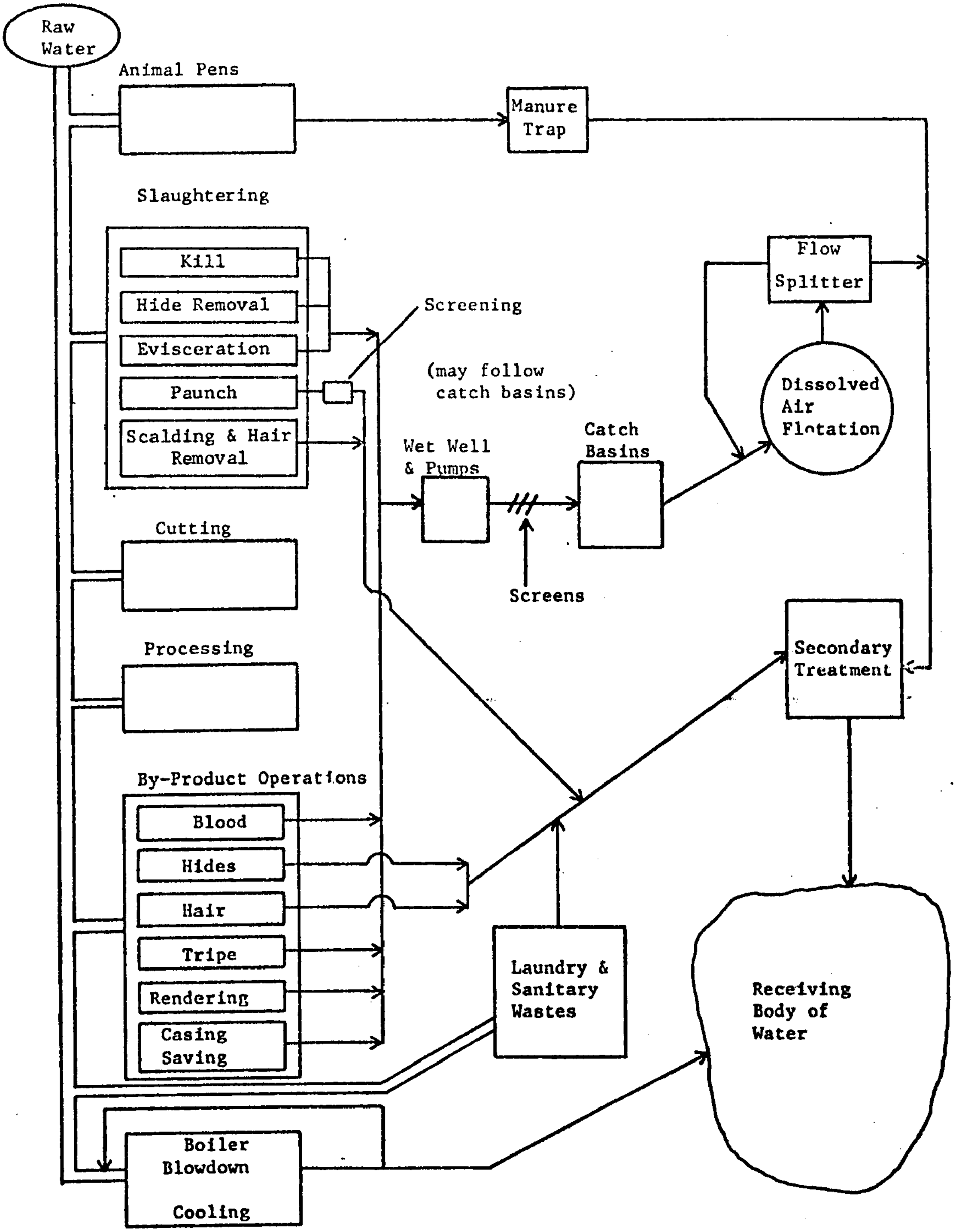

Figure 8. Typical Wastewater Treatment System Including Dissolved Air Flotation

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increase in the detention time of the grease-bearing stream in a grease recovery system because the system can now handle a lower wastewater flow. Low-grease-bearing wastewaters normally originate from the pens, some secondary (by-product) processing, and sanitary wastes. This arrangement is commonly used when dissolved air flotation is included in primary treatment. A portion of the effluent from the flotation unit is recycled to a pressurization tank where air is added for flotation.

Several modifications of the flow arrangement shown in Figure 8 are used by the industry. Some plants add chemicals to the waste stream via a mixing tank just prior to the flotation unit. This usually increases grease and solid recovery but it also may increase the moisture content of the skimmings to 85 to 95 percent, making the handling of skimmings more difficult. Other plants may have two dissolved air flotation units in series. Chemicals are usually added to the waste stream entering the second unit. Skimmings from the first unit are almost always rendered while those from the second unit, which contain chemicals, may be landfilled. A few plants add chemicals to both units to achieve a high wasteload reduction. Chemicals may reduce the rendering efficiency or produce a finished grease that is unacceptable on the market.

A third flow arrangement, which has been installed in a few recently built plants, is shown in Figure 9. The purpose of this arrangement is to segregate waste streams according to the type of treatment to be applied. In the scheme shown, the streams are divided into low and high grease-bearing streams, and manure-bearing streams. For example, floor drains located on the kill floor after the carcass is opened, are connected to the high grease-bearing streams; hide processing wastewater is directed to the manure-bearing streams. Segregation into the three major waste streams permits optimum design of each catch basin and flotation unit for recovery and waste load reduction, with minimum investment in equipment. A more detailed list of the segregated stream contents is given by Johnson.[8]

Although there are a number of operations where wastewater could be reused or recycled, the industry is generally recycling or reusing only non-contaminated cooling water, as illustrated in Figures 7, 8, and 9. One minor exception is reuse of lagoon water as cooling water.

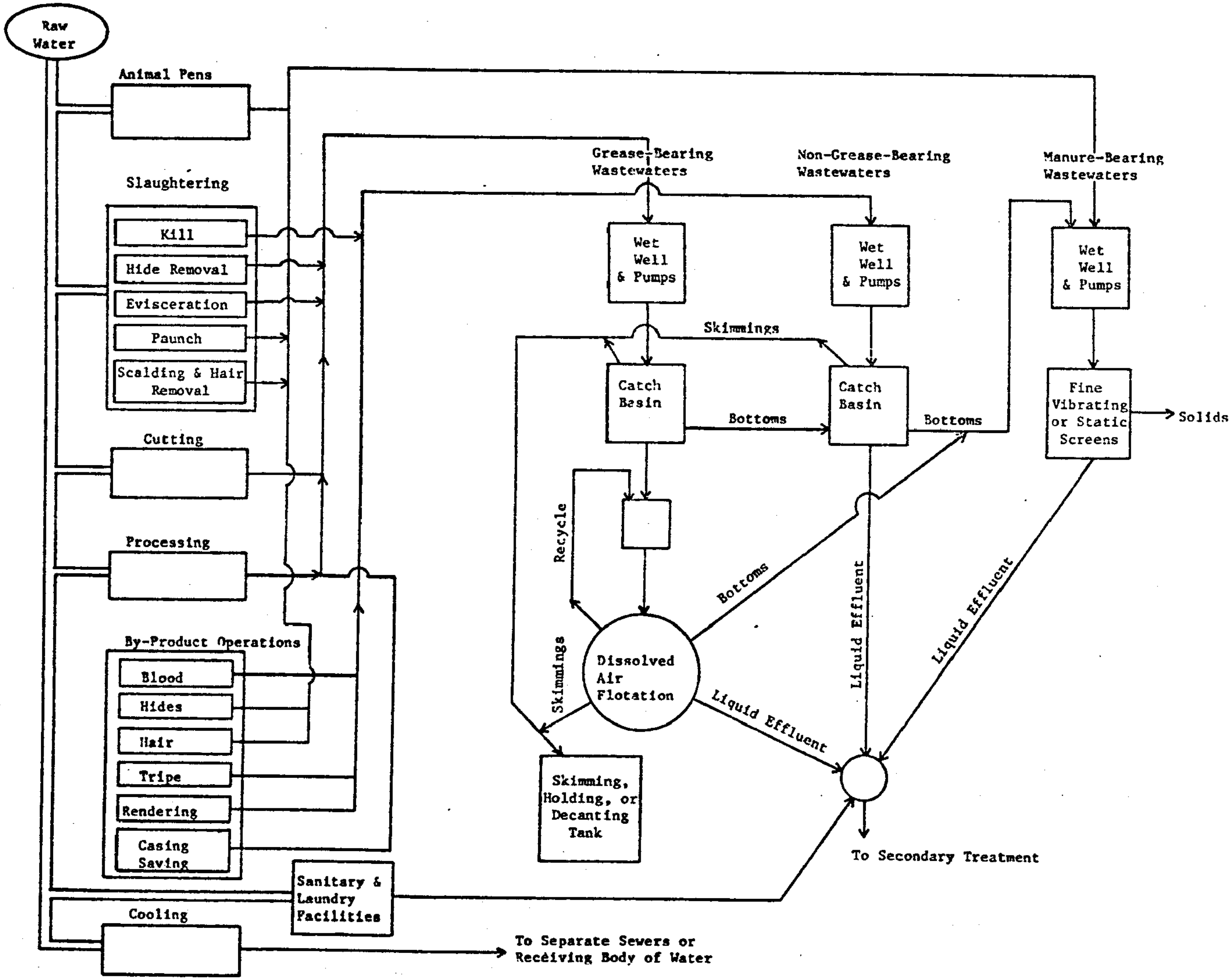

Figure 9. Separate Treatment of Grease-Bearing, Nongrease-Bearing and Manure-Bearing Wastewaters

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WATER USE - WASTELOAD RELATIONSHIPS

Increased water use causes increased pollutional wasteload in the meat packing industry. This was verified by regression and correlation analyses of individual plant data over long periods (up to two years), and also on the data for each of the four subcategories. For example, multiple regression analysis of the data relating BOD_5 wasteload to kill and flow revealed that a variation of one standard deviation would change the predicted BOD_5 for a simple slaughterhouse by 1.0 kg/1000 kg LWK (1.0 lb/1000 lb LWK); it would change the predicted load for a complex slaughterhouse by 2.8 kg/1000 LWK (2.8 lb/1000 lb LWK). Another regression analysis between BOD_5 and flow on a LWK bases showed that one standard deviation in flow changed the predicted BOD_5 by 5.6 and 5.3 kg/1000 kg LWK (5.6 and 5.3 lb/1000 lb LWK) for low- and high-processing packinghouses, respectively.

Figure 10 shows the average and range of the results of separate regression analysis on the flow-wasteload data from each of eleven plants. This figure clearly illustrates that water use strongly affects the pollutional wasteload. For example, the figures show that a 20 percent reduction in water use would, on the average, result in a BOD_5 reduction of 3.5 kg/1000 kg LWK (3.5 lb/1000 lb LWK).

Further evidence for the dependence of pollutional wasteload on water flow is that, in three of the four subcategories, the plant with the lowest wasteload also had the lowest water use. In the fourth subcategory, the plant with the lowest wasteload had the second lowest water use.

Low water use, and consequently low pollutional wasteload, requires good water management practices. For example, two simple slaughterhouses practice very good water use practices. The plants both had wasteloads of about 2 kg/1000 kg LWK (2 lb/1000 lb LWK); their wastewater flows ranged from 1333 to 2415 l/1000 kg LWK (166 to 290 gal/1000 lb LWK). One plant was an old beef slaughterhouse; the other, a new hog slaughterhouse. This outstanding performance was achieved in a subcategory for which the flows ranged to 21,000 l/1000 kg LWK (1750 gal/1000 lb LWK), and for which the BOD_5 loading ranged to over 14 kg/1000 kg LWK (14 lb/1000 lb LWK).

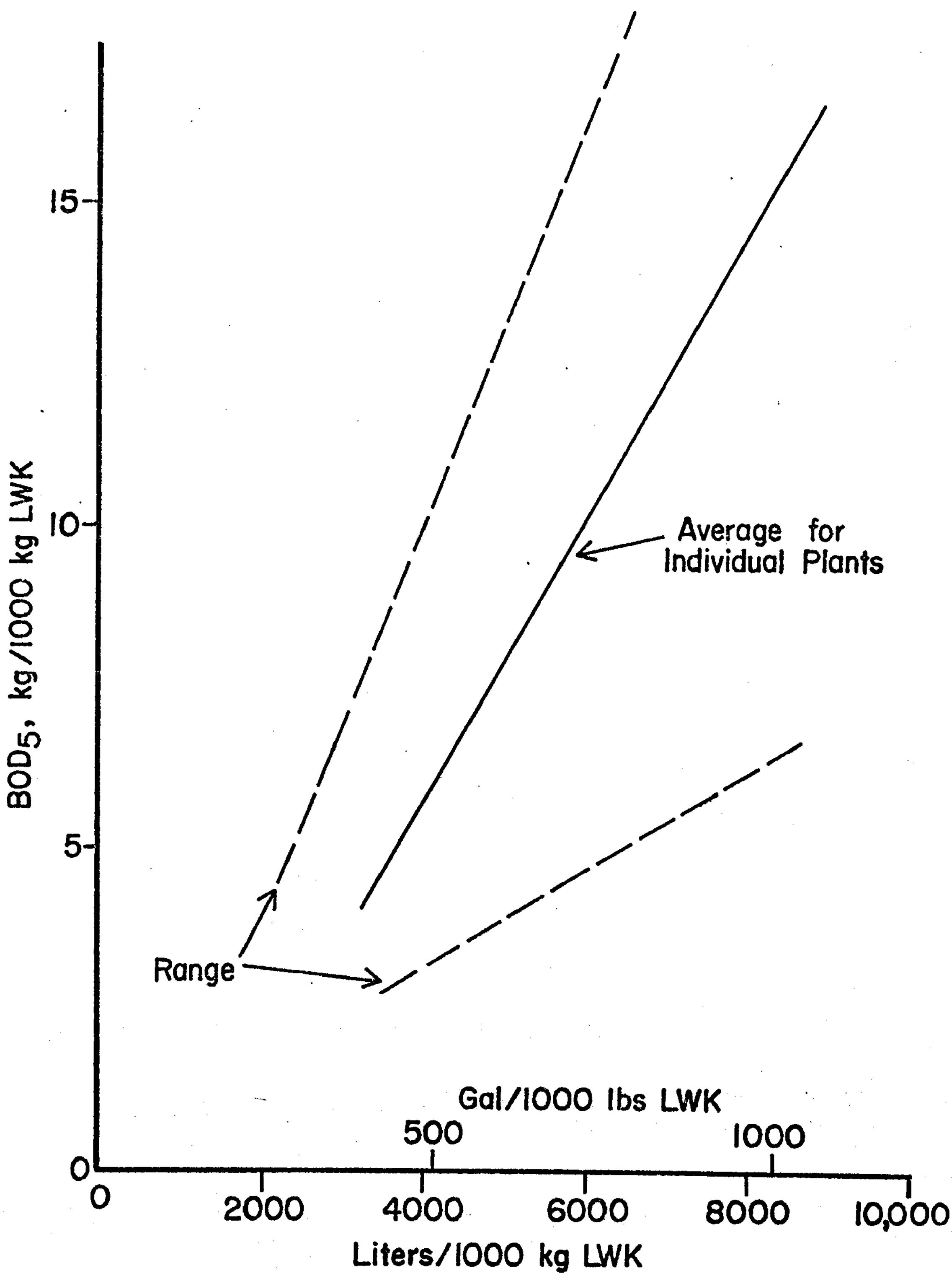

Figure 10. Effect of Water Use on Wasteload for Individual Plants

SOURCES OF WASTEWATER

Animal Pens

Although pen wastes only contain an estimated 0.25 kg of BOD_5/1000 kg LWK,[9] the wastes are high in nutrients.[10] Frequently, the solid wastes are removed by dry cleaning, followed by little or no washdown. If the pens are washed down, a manure trap is frequently used to recover solids rather than letting them enter a treatment system.

Another wastewater source in the pens is the watering troughs. Each trough may discharge 8 l/min (2.1 gal/min) or more. With perhaps 50 or more pens in a large plant, the water source becomes significant. The total waste from the pens, however, is a minor contributor to the waste load.

Slaughtering

The slaughtering operation is the largest source of wasteload in a meat packing plant, and blood is the major contributor. Blood is rich in BOD_5, chlorides and nitrogen. It has an ultimate BOD_5 of 405,000 mg/l and a BOD_5 between 150,000 to 200,000 mg/l.[11] Cattle contain up to 50 pounds of blood per animal, and typically only 35 pounds of the blood are recovered in the sticking and bleeding area. The remaining 15 pounds of blood are probably lost, and this represents a wasteload of 2.25 to 3.0 kg BOD_5/1000 kg LWK (2.25 to 3 lb/1000 lb LWK). Total loss of the blood represents a potential BOD_5 wasteload of 7.5 to 15 kg/1000 kg LWK (7.5 to 15 lb/1000 lb LWK). Because very few meat plants practice blood control outside of the bleeding area, the typical BOD_5 load from blood losses in the slaughtering operation is estimated to be 3 kg/1000 kg LWK. In beef plants, much of this loss probably occurs during hide removal, and particularly from the use of the automatic "down" hide puller.

Beef paunch or rumen contents is another major source of waste load. Paunch manure, which contains partially digested feed material, has a BOD_5 of 50,000 mg/l.[12] At an average paunch weight of 50 pounds per head, dumping of the entire contents can contribute 2.5 kg/1000 kg LWK. However, the common practices are to either screen the paunch contents, washing the solids on the screen (wet dumping), or to dump on a screen to recover the solids, allowing only the "juice" to run to the sewer (dry dumping). Because 60 to 80 percent of the BOD_5 in the paunch is water soluble, wet dumping of the paunch represents a BOD_5 loss of about 1.5 kg/1000 kg LWK. If dry dumping is practiced, the pollutional wasteload is much less than this. When none of the paunch is sewered but is processed or hauled out of the plant for land disposal, paunch handling does not contribute to the wasteload. Cooking of the rumen or paunch in a hot alkaline solution (tripe processing) will also add to the wasteload, particularly to the grease load. The strong alkalinity of these wastewaters may also make grease recovery more difficult.

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The hog scald tank and dehairing machine are other sources of pollution. The overflow from a hog scald tank is usually about 84 l/1000 kg LWK (10 gal/1000 lb LWK) at a BOD_5 concentration of about 3000 mg/l. This could represent a BOD_5 loss of about 0.25 kg/1000 kg LWK. Continuous overflow of water from the dehairing machine is estimated to contribute a maximum BOD_5 load of 0.4 kg/1000 kg LWK.

Other sources of waste from the slaughtering of animals and dressing of carcasses is from carcass washing, viscera and offal processing, and from stomach and peck flushing.

The offal operations such as chitterling washing and casing saving can contribute substantially to the pollution load. If the slime waste from the casing saving is not sewered, its pollutional wasteload would be greatly reduced.

The highest source of water use in slaughtering is from the washing of carcasses; an extreme example was 2915 l/min (350 gal/min). Flushing the manure from chitterling and viscera, or conveyer sterilizing, and the tripe "umbrella" washer are other high water use operations.

Meat Processing

The major pollutants from meat processing are meat extracts, meat and fatty tissue, and curing and pickling solutions. Loss of these solutions can be the major contributor to the waste load from processing. The results of a recent study showed that only 25 percent of the curing brine remained in the product.[11] The rest of the brine is lost to the sewer. This source of chlorides, plus others such as from hide curing and the use of salt on the floors to reduce slipperiness, explains why some packinghouse wastes have high chlorides. A content of 1000 mg/l of chlorides is not uncommon in the effluent from a packinghouse. Another constituent of the cure is dextrose; it has a BOD_5 equivalent of 2/3 kg/kg (lb/lb). Consequently, packinghouses with a sizeable curing facility will have high BOD_5 waste unless the wastes from curing are segregated or recycled. In one plant over 2000 pounds of dextrose was lost daily.[13] The pollution load from meat and fatty tissue can be substantially reduced by dry clean-up prior to washdown. The water use in meat processing should be primarily limited to clean-up operations and for product washing, and cooling, and cooking.

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Secondary Manufacturing Processes

Secondary manufacturing processes, as described in Section IV, are those by-product operations within the industry for the handling, recovery, and processing of blood, trimmings, and inedible offal. This includes paunch and viscera handling, hide processing, hair recovery and processing, and edible and inedible rendering. Those viscera and offal operations that occur on the slaughtering floor, such as paunch handling and tripe processing, were considered under slaughtering.

The hashing and washing of viscera, often performed prior to rendering, produces a strong waste load with a BOD_5 value of about 70,000 mg/l.[11] The waste conservation trend in the past few years has been toward not hashing and washing prior to rendering, but sending the uncleaned viscera directly to rendering. In one plant, removal of the hasher and washer reduced the BOD_5 to the waste treatment plant by 910 kg (2000 pounds) per day, with an attendant increase in the rendered animal feed production.

Efficient recovery of hog hair is now practiced widely within the industry, although the market for this by-product has been reduced in recent years. Very few plants hydrolyze hog hair, but rather wash and bale for sale or disposes of it directly to land fill. The waste load from the recovery and washing of the hair is estimated to contribute less than 0.7 kg/1000 kg LWK.

Hide curing operations are becoming increasingly involved at meat packing plants. Just a few years ago many plants were shipping hides green or in salt pack. Today, however, many beef slaughter operations include hide curing in tanks, vats, or raceways. The hides, prior to being soaked in brine, are washed and defleshed. These washings, which are sewered, contain blood, dirt, manure, and flesh. In most defleshing operations the bulk of the tissue is recovered. In addition to these wastes, soaking the hide in the brine results in a net overflow of approximtely 7.7 liters (2 gallons) of brine solution per hide. In a few plants the brine in the raceway is dumped weekly, whereas in others it is dumped yearly or whenever the solids build up to a point where they interfere with the hide curing operation. The life of the brine can be extended by pumping the recycled brine over a vibrating or static screen. The waste load from the overflow and washings in a typical hide curing operation, where the hide curing wastes are not frequently dumped, is about 1.5 kg/1000 kg LWK for BOD_5 and about 4 kg/1000 kg LWK for salt.

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Blood processing may be either wet or dry. Continuous dryers, which are quite common, use a jacketed vessel with rotating blades to prevent burn-on; this process results in low losses to the sewer (estimated to contribute about 0.3 kg BOD_5/1000 kg LWK). Continuous ring dryers are sometimes used: they produce a relatively small amount of blood water that, in some small plants, is discharged to the sewer. The old technique of steam sparging the blood to coagulate it is still frequently used. The coagulated blood is separated from the blood water by screening. The blood water has a BOD_5 of about 30,000 mg/l.[11] It is often sewered, contributing a waste load of about 1.3 kg/1000 kg LWK. This loss can be eliminated by evaporating the blood water, either by itself or by combining it with other materials in conventional inedible dry rendering operations.

Wet rendering and low temperature rendering are potentially large sources of pollution. Tank water from wet rendering can have a BOD_5 value of 25,000 to 45,000 mg/l, and the water centrifuged from low temperature rendering can have a BOD_5 of 30,000 to 40,000 mg/l. It is estimated that sewering of either of the waste streams produces a waste load of 2 kg BOD_5/1000 kg LWK. These waste loads can be eliminated by evaporation or combining with other materials used in dry inedible rendering. Triple-effect vacuum evaporators are often used to concentrate the "tankwater" from the wet rendering operation. The wasteload from wet rendering is primarily caused by overflow or foaming into the barometric leg of these evaporators and discharge to the sewer or, sometimes directly to a stream. From dry rendering the pollution comes from the condensing vapors, from spillage, and from clean-up operations. A recent study[10] revealed that a typical dryer used 454 to 492 l/min (120 to 130 gal/min) of water for condensing vapors, and that the effluent contained 118 mg/l of BOD_5 and 27 mg/l grease. The estimated wasteload from dry rendering is 0.5 kg/1000 kg LWK.

Cutting

The main pollutants from cutting operations are meat and fat scraps from trimming, and bone dust from sawing operations. Most of these pollutants enter the waste stream during clean-up operations. These wastes can be reduced by removing the majority of them by dry clean-up prior to washdown, and also by some form of grease trap in the cutting area. The collected material can be used directly in rendering. Bone dust is a large source of phosphorus and, when mixed with water, does not settle out readily; thus it is difficult to recover, and should be captured in a box under the saw.

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Clean-Up

Macon[6] found that clean-up contributes between 0.3 and 3 kg BOD_5/1000 kg LWK in small packinghouses. Data collected by the Iowa Department of Environmental Quality showed that anywhere from 27 to 56 percent of the total BOD_5 waste load is contained in the clean-up wastewaters. The clean-up operation thus is a major contributor to the waste load. It also leads to a significant loss of recoverable by-products. Detergents used in clean-up can adversely affect the efficiency of grease recovery in the plant catch basin.

The techniques and procedures used during clean-up can greatly influence the water use in a plant and the total pollutional waste load. For example, dry cleaning of floors prior to wash down to remove scraps and dry squeegeeing the blood from the bleed area into the blood sewer are first steps. A light wash down, again draining to the blood sewer, before the normal washdown definitely decreases the pollution load from clean-up.

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SECTION VI

SELECTION OF POLLUTANT PARAMETERS

SELECTED PARAMETERS

Based on a review of the Corps of Engineers Permit Applications from the meat packing plants, previous studies on wastewaters from meat packing plants,[3,15] industry data, questionnaire data, published reports,[14] and data obtained from sampling plant wastewaters during this study, the following chemical, physical, and biological constituents constitute pollutants as defined in the Act.

- BOD_5 (5 day, 20°C biochemical oxygen demand)
- COD (chemical oxygen demand)
- Suspended solids
- Dissolved solids
- Grease
- Ammonia nitrogen
- Kjeldahl nitrogen
- Nitrates and nitrites
- Phosphorus
- Chloride

On the basis of all evidence reviewed, there do not exist any purely hazardous or toxic pollutants (such as heavy metals or pesticides) in the waste discharged from the meat processing plants.

RATIONALE FOR SELECTION OF IDENTIFIED PARAMETERS

5-Day Biochemical Oxygen Demand (BOD_5)

This parameter is an important measure of the oxygen consumed by microorganisms in the aerobic decomposition of the wastes at 20°C over a five-day period. More simply, it is an indirect measure of the biodegradability of the organic pollutants in the waste. BOD_5 can be related to the depletion of oxygen in a receiving stream or to the requirements for waste treatment. Values of BOD_5 range from 300 to 3800 mg/l in the raw waste, although typical values range from 900 to 1500 mg/l.

If the BOD_5 level of the final effluent of a meat packing plant into a receiving body is too high, it will reduce the dissolved oxygen level in that stream to below a level that will sustain most fish life; *i.e.*, below about 4 mg/l. Many states currently restrict the BOD_5 of effluents

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to below 20 mg/l if the stream is small in comparison with the flow of the effluent. A limitation of 200 to 300 mg/l of BOD_5 is often applied for discharge to municipal sewer, and surcharge rates often apply if the BOD_5 is above the designated limit.

A 20-day biochemical oxygen demand (BOD_{20}), sometimes called "ultimate" BOD, is usually a better measure of the waste load than BOD_5. However, the test for BOD_{20} requires 20 days to run. so it is an impractical measure for most purposes.

Chemical Oxygen Demand (COD)

COD is yet another measure of oxygen demand. It measures the amount of organic and some inorganic pollutants under a carefully controlled direct chemical oxidation by a dichromate-sulfuric acid reagent. COD is a much more rapid measure of oxygen demand than BOD_5, and is potentially very useful. However, it does not have the same significance, and at the present time cannot be substituted for BOD_5 because COD:BOD_5 ratios vary with the types of wastes.

COD provides a rapid determination of the waste strength. Its measurement will indicate a serious plant or treatment malfunction long before the BOD_5 can be run. A given plant or waste treatment system usually has a relatively narrow range of COD:BOD_5 ratios, if the waste characteristics are fairly constant, so experience permits a judgment to be made concerning plant operation from COD values. In the industry, COD ranges from about 1.5 to 5 times the BOD_5; the ratio may be to the low end of the range for raw wastes, and near the high end following secondary treatment when the readily degraded material has been reduced to very low levels.

Suspended Solids

This parameter measures the suspended material that can be removed from the wastewaters by laboratory filtration, but does not include coarse or floating matter than can be screened or settled out readily. Suspended solids are a visual and easily determined measure of pollution and also a measure of the material that may settle in tranquil or slow-moving streams. Suspended solids in the waste from meat packing plants correlate quite well with BOD_5. A high level of suspended solids is an indication of high BOD_5. Generally, suspended solids range from one-third to three-fourths of the BOD_5 values in the raw waste. Suspended solids are also a measure of the effectiveness of solid removal systems such as clarifiers and fine screens.

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Dissolved Solids

The dissolved solids in the wastewater are mainly inorganic salts, and the salt present in the largest amount is sodium chloride (described below). Loadings of dissolved solids thus vary to a large extent with the amount of sodium chloride entering the waste stream. Frequently dissolved solids in the final effluent amount to about 500 mg/l; however, values of 1500 or more are not uncommon. The dissolved solids are particularly important in that they are relatively unaffected by biological treatment processes. Therefore, unless removed, they will accumulate on recycle or reuse of water within a plant. Further, the dissolved solids at discharge concentrations may be harmful to vegetation and preclude various irrigation processes.

Grease

Grease, also called oil and grease, or hexane solubles, is a major pollutant in the raw waste stream of meat packing plants. The source of grease is primarily from carcass dressing, washing, trimming, viscera handling, rendering and clean-up operations. Grease forms unsightly films on the water, interferes with aquatic life, clogs sewers, disturbs biological processes in sewage treatment plants, and can also become a fire hazard. The loading of grease in the raw waste load varies widely, from 0.25 to 27 kg/1000 kg LWK (0.25 to 27 lb/1000 lb LWK). This would correspond to an average concentration of about 650 mg/l. Effluent limitations of grease into receiving waters may be as low as 10 mg/l and into sewer systems, typically 100 mg/l. Grease may be harmful to municipal treatment facilities and to trickling filters.

Ammonia Nitrogen

Ammonia nitrogen in raw waste is just one of many forms of nitrogen in a waste stream. Anaerobic decomposition of protein, which contains organic nitrogen, leads to the formation of ammonia. Thus, anaerobic lagoons or digesters produce high levels of ammonia. Also, septic (anaerobic) conditions within the plant in traps, basins, etc., may lead to ammonia in the wastewater. Another source of ammonia can be leakage in ammonia refrigeration systems; such systems are still fairly common in meat packing plants.

Ammonia is oxidized by bacteria in a process called "nitrification" to nitrites and nitrates. This may occur in an aerobic treatment process and in a stream. Thus, ammonia will deplete the oxygen supply in a stream; its oxidation products are recognized nutrients for aquatic growth and for some toxic qualities (see below). Also, free ammonia in a stream is known to be harmful to fish.

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A typical concentration in the raw waste load is about 10 to 40 mg/l; however, after treatment in an anaerobic secondary system, the concentrations of ammonia can reach as high as 100 to 200 mg/l. Ammonia is limited in drinking water to 0.05 to 0.1 mg/l.[14] In some cases a stream standard is less than 2 mg/l.

Kjeldahl Nitrogen

This parameter measures the amount of ammonia and organic nitrogen; when used in conjunction with the ammonia nitrogen, the organic nitrogen can be determined by the difference. Under septic conditions, organic nitrogen decomposes to form ammonia. Kjeldahl nitrogen is a good indicator of the crude protein in the effluent and, hence, of the value of material being lost in the wastewater. The protein content is usually taken as 6.25 times the organic nitrogen. The sources of Kjeldahl nitrogen are basically the same as for ammonia nitrogen, above, except for the refrigeration system. The raw waste loading of Kjeldahl nitrogen is extremely variable and highly affected by blood losses. Typical loadings range from 0.04 to 6.76 kg/1000 lb LWK (0.04 to 6.76 lb/1000 lb LWK), and concentrations range from about 4 to 750 mg/l. Typical raw waste concentrations of Kjeldahl nitrogen are between 50 and 100 mg/l. Kjeldahl nitrogen has not been a common parameter for regulation and is a much more useful parameter for raw waste than for final effluent.

Nitrates and Nitrites

Nitrates and nitrites, normally reported as *N*, are the result of oxidation of ammonia and of organic nitrogen. They may also enter the waste stream from use in the plant as preservatives. Nitrates are important in the water supply used for human or livestock consumption, because high nitrate concentrations can lead to toxicity (methmoglobinemia or "blue babies",nitrate poisoning and death in young cattle). From investigation of this toxicity, nitrates as *N* should not exceed 20 mg/l in water supplies,[16] although the U.S. Public Health Service recommends a limit of 10 mg/l.[16] Nitrates are essential nutrients for algae and other aquatic plant life.

Phosphorus

Phosphorus, commonly reported as *P*, is a nutrient for aquatic plant life and can therefore cause eutrophication in water courses. The threshold concentration of phosphorus in receiving bodies that can lead to eutrophication is about 0.01 mg/l. The primary source of phosphorus in raw waste from meat packing plants are bones and detergents. The total phosphorus in the raw effluent ranges from about 0.01 to 0.63 kg/1000 kg LWK (0.01 to 0.63 lb/1000 lb LWK), or a concentration range of 15 to 50 mg/l.

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Chlorides

Chlorides in concentrations of the order of 5000 mg/l can be harmful to people and other animal life. High chloride concentrations in waters can be troublesome for certain industrial uses and for reuse or recycling of water. The major sources of chlorides from meat packing plants are the salt from animal tissues, hide curing operations, pickling and curing solutions, cleaning chemicals, blowdown water, and that used to prevent slipping on floors. The concentrations in raw waste are extremely variable from plant to plant, and are normally higher for plants killing cattle and treating hides than they are for other plants. The amount in the waste is an indicator of the way in which certain processes are being operated. The range of chloride loadings in raw waste effluents is from less than one to greater than 20 kg/1000 kg LWK (20 lb/1000 lb LWK). Chloride loadings are unaffected by secondary treatment systems used by the industry today, and once in the wastewaters they are very costly to remove.

Some other pollution parameters are of lesser significance. Color is related to waste strength, and is a visible indicator; it is useful only for qualitative purposes. Odor is only a problem in the wastewater in anaerobic treatment systems. A cover, usually of grease, will solve this; in some areas construction of anaerobic lagoons has been forbidden because of the odor problems. pH is of relatively minor importance. The usual pH for raw waste falls between 6.5 and 8; unusual processes such as hog hair hydrolyzing may raise this slightly, but not enough to significantly offset treatment effectiveness or effluent quality.

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SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

SUMMARY

The wasteload discharged from the meat packing industry to receiving streams can be reduced to desired levels, including no discharge of pollutants, by conscientious wastewater management, in-plant waste controls, process revisions, and by the use of primary, secondary, and tertiary wastewater treatment. Figure 11 is a schematic of a suggested waste reduction program for the meat packing industry to achieve high removal of pollutants in subsequent treatment.

This section describes many of the techniques and technologies that are available or that are being developed to achieve the various levels of waste reduction. In-plant control techniques and wastewater management suggestions are described first. Waste treatment technology normally employed as a primary treatment is then described. In the case of the meat packing industry this "primary" treatment is a materials recovery process, and is considered as part of the in-plant system, although many of these systems have been improved for reducing pollutional levels. The effluent from these processes is considered the "raw waste". Secondary treatment systems, which are employed in the treatment of the raw waste, are presented with a description of the process, the specific advantages and disadvantages of each system, and the effectiveness on specific wastewater contaminants found in packing plant waste. The tertiary and advanced treatment systems that are applicable to the waste from typical packing plants are described in the last part of this section. Some of these advanced treatment systems have not been used in full scale on meat packing plant waste; therefore, the development status, reliability, and potential problems are discussed in greater detail than for the primary and secondary treatment systems which are in widespread use.

IN-PLANT CONTROL TECHNIQUES

The wasteload from a meat packing plant is composed of a wastewater stream containing the various pollutants described in Section VI. The cost and effectiveness of treatment of the waste stream will vary with the quantity of water and the wasteload. In fact, as indicated in Section V, the pollutional wasteload increases as water use increases. In-plant control techniques will reduce both water use and pollutional wasteload. The latter will be reduced directly by minimizing the entry of solids into the wastewater stream and indirectly by reducing water use.

The in-plant control techniques described below have been used in packing plants or have been demonstrated as technically feasible.

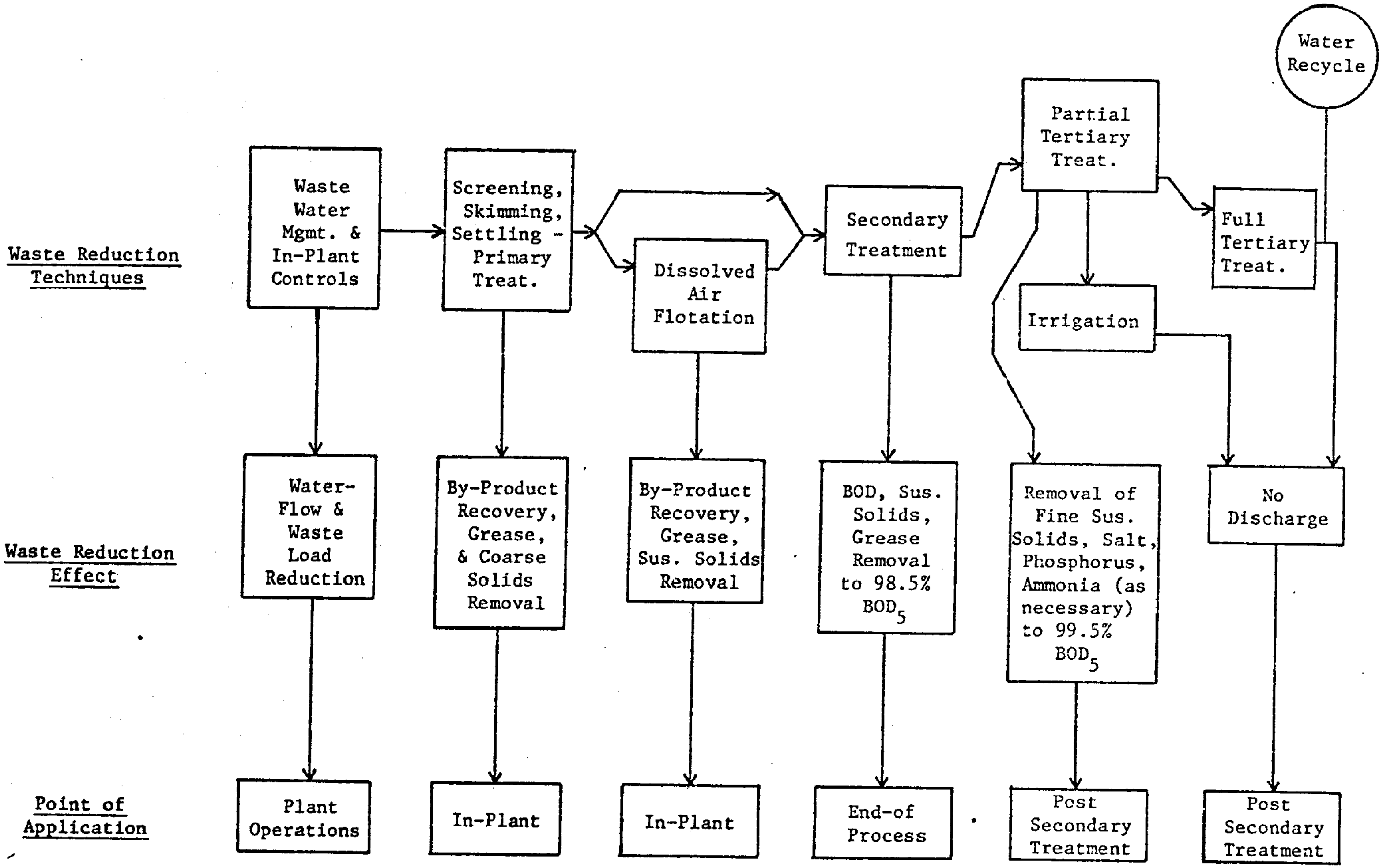

Figure 11. Suggested Meat Packing Industry Waste Reduction Program

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Pen Wastes

The best livestock holding pens are covered and dry cleaned with only occasional washdown. Bedding material and manure are readily disposed of on farm land as fertilizer. A separate sewer and manure pit are provided for liquid wastes from the pens; disposal is on land or to the secondary treatment system. Drinking water in the pens is minimized and based on need. Watering troughs should have automatic level controls.

Blood Handling

In good practice, blood is not sewered. Blood is almost totally contained and collected in a blood collection system. Water or steam are not necessary to operate such a system, and both should be avoided.[17] After dry cleaning the floors and walls exposed to blood flows and splashing, a first water wash, using a minimum amount of water, can be drained into the blood collection system.[18] Bloodwater can be avoided by installing a blood dryer. If a plant handles bloodwater, it should not be sewered, but can be rendered, evaporated, or mixed with paunch and cooked to produce a feed material.[18] Blood collection by a vacuum system may be a feasible process if markets for edible blood develop. Very limited amounts of edible blood are collected for pharmaceuticals. In general, improved blood collection methods need to be developed to match the high production rate of American plants.

Paunch

The use of water in the initial dumping of paunch material or in pumping it must be discontinued. Dumping the entire paunch contents (including the liquid) for disposal or treatment without sewering, followed by a high pressure but minimal water rinse of the paunch will minimize the pollutional wasteload from this operation. Consideration should also be given to vacuuming out the residual material instead of washing it outs. In each case the economics of recovery of the paunch and cost of the resulting waste treatment should be examined and compared to direct rendering of the paunch, as is.

Liquids screened from the paunch material should be collected and evaporated or rendered, not wasted. Plants that presently slurry the paunch with water for pumping should either install a solids handling pump, thus avoiding the need for a water slurry, or devise an alternate handling technique; *e.g.*, transporting the entire unopened paunch to rendering.

Viscera Handling

The inedible hashing and washing operation should be eliminated; there is no competitive reason to justify its continuation. Inedible viscera

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can be rendered without washing. A good quality grease may be obtained if the washings of edible viscera (*i.e.,* chitterlings) are collected in a catch basin in the immediate area before sewering.[17] The grease and solids wasteload from the viscera can be commensurately reduced through such by-product recovery techniques. Caustic washings from any viscera processing should be segregated before sewering to minimize grease saponification and to avoid a high pH in the wastewater.

Troughs

Troughs have been installed under the killing floor carcass conveying line to keep as much blood, trimmings, bone dust, and miscellaneous pieces off the floor as possible. The troughs have proven very effective in collecting and containing solids, blood, etc., that under ordinary circumstances would have ended up in the sewer. Substantial wasteload reductions are evident in the plants using these troughs. Variations in animal size may be a problem; however, if large variations are rare, some accomodation should be possible. A squeegee or scraper shaped to fit the trough is used in clean-up to move all collected materials to the inedible rendering system.

Rendering

Both wet and dry rendering are used for edible, as well as inedible, rendering processes; although the trend is toward dry rendering. In processing lard, low- or medium-temperature continuous rendering systems are common. The water centrifuged from this process can be sold as 50 to 60 percent edible "stickwater" and thus should be evaporated and not discharged to the sewer.

In dry rendering, sprays are commonly used to condense the vapors. In inedible dry rendering, catch-basin effluent can be reused as condenser water. In edible dry rendering, the vapors are commonly condensed with fresh water. A direct heat exchanger can be used to condense the vapors without increasing wastewater volumes.

In wet rendering, the greases are drawn off the top of the tank, then the water phase (tankwater) is removed. This tankwater has a BOD_5 ranging from 22,000 mg/l to as high as 45,000 mg/l and suspended solids as high as 2 percent. Under no circumstances can this type of waste be discharged to the sewer. It must be evaporated and the end product, commonly called stick or stickwater, is then blended into animal feed materials. The tankwater may also be dried directly with inedible solids in a dry rendering tank. The bottom sludge from wet rendering is pressed for recovery of residual grease, and the remaining solids (cracklings) are used as edible product from edible rendering, and as animal feed ingredient from inedible rendering.

Even if the tankwater is evaporated, pollution can occur. Triple-effect vacuum evaporation can readily foam over, further contaminating the wastewater.

Hide Processing

An overflow of water from the hide curing vat or raceway occurs because water is added to the curing solution and because hides dehydrate as they take on salt. This overflow could be contained and collected separately, allowing a more intensive treatment, at a reasonable cost, to achieve a higher quality effluent, especially in terms of salt concentrations. It is especially important to dump the raceway infrequently--perhaps only annually. When dumped, it should be drained gradually, over a period of 24 hours or more, to avoid an extreme shock load on the treatment system. The life of the solution can be extended by pumping it over a static or vibrating screen.

Scald Tank

The hog scald tank contains settled solids and wastewater with a high wasteload. Collection, treatment, and reuse of this water should be considered. Slow drainage of the tank will reduce any shock load on the waste treatment system and should be standard practice. Provision should be made for the removal of the solids through the bottom of the tank to a truck for land disposal.

Pickle and Curing Solutions

These solutions are high in salt content and, in many curing solutions, high in sugar content. Salt is a difficult pollutant to remove and sugar has a very high BOD_5. The operations involving injection or soaking of meat products in these solutions should be equipped to collect all of the solution presently wasted. The collection pans and equipment should be designed to permit reuse of these solutions.[17,18]

Water Conservation Practices

The following practices and equipment should be employed to reduce the water consumption in plants with coincidental reduction of the pollutional wasteload:[17,18]

1. Replace all drilled spray pipe systems with spray nozzles designed and located to provide a desired water spray pattern.

2. Replace all washwater valves with squeeze- or press-to-open valves wherever possible. Foot- or knee-operated

valve control is useful where operator fatigue is a problem or where the operation requires the operator to work with both hands.

3. Install foot-pedal operated handwashing and drinking fountain water valves to eliminate constantly running water.

4. Install automatic control for sprays which need to operate only about 50 percent of the time.

5. Product chillers using cold water may be economically replaced by chillers using a cryogenic liquid such as nitrogen, thus reducing water consumption and perhaps improving product quality.

6. Water waste from the boiler (blowdown) is soft water and should be considered for use in clean-up or in the plant laundry. Detergent use will be reduced as well as water conserved.

7. Plant clean-up as an operating procedure consumes a substantial quantity of water in most plants. Reduced water use can be achieved with equipment such as high pressure water spray systems, steam and water mix spray systems, or automated clean-in-place (CIP) systems. Management control is particularly vital in clean-up operations if water is to be conserved and cleanliness standards are to be maintained.

8. Whenever possible, water should be reused in lower quality needs. Examples include carcass washwater reused for hog dehairing, and lagoon water reused for cooling. The general axiom is: use the lowest quality of water satisfactory for the process.

Clean-Up Operations

In addition to water conservation practices, other steps can also be taken to reduce the wasteload from clean-up. Floors and other surfaces should be dry squeegeed or scraped wherever feasible, to keep a maximum amount of solids and grease out of the wastewater. Pull the drain basket only after cleanup has been completed. Use the minimum of water and detergent, consistent with cleaning requirements. Automate cleaning of conveyors, piping and other equipment wherever possible.[17,18]

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IN-PLANT PRIMARY TREATMENT

Flow Equalization

Equalization facilities consist of a holding tank and pumping equipment designed to reduce the fluctuations of waste streams. They can be economically advantageous whether the industry is treating its own wastes or discharging into a city sewer after some pretreatment. The equalizing tank will store wastewater either for recycle or reuse or to feed the flow uniformly to treatment facilities throughout the 24-hour day. The tank is characterized by a varying flow into the tank and a constant flow out.

The major advantages of equalization for the meat packer are that treatment systems can be smaller, since they can be designed for the 24-hour average rather than the peak flows, and secondary waste treatment systems operate much better when not subjected to shockloads or variations in feed rate.

Screens

Since so much of the pollutional matter in meat wastes is originally a solid (meat particles and fat) or sludge (manure solids), interception of the waste material by various types of screens is a natural first step. To assure best operation for application to the plant wastewater stream, a flow equalization facility should preceed it.

Unfortunately, when these pollutional materials enter the sewage flow and are subjected to turbulence, pumping, and mechanical screening, they break down and release soluble BOD_5 to the flow, along with colloidal and suspended and grease solids. Waste treatment--that is, the removal of soluble, colloidal and suspended organic matter--is expensive. It is far simpler and less expensive to keep the solids out of the sewer entirely.

Static, vibrating, and rotary screens are the primary types used for this step in the in-plant primary treatment. Whenever feasible, pilot-scale studies are warranted before selecting a screen, unless specific operating data are available for the specific use intended, in the same solids concentration range, and under the same operating conditions.

Static Screens

The primary function of a static screen is to remove "free" or transporting fluids. This can be accomplished in several ways and, in most older concepts, only gravity drainage is involved. A concavely curved screen design using high velocity pressure-feeding was developed and patented in the 1950's for mineral classification and has been adapted

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to other uses in the process industries. This design employs bar interference to the slurry which knives off thin layers of the flow over the curved surface.[18]

Beginning in 1969, United States and foreign patents were allowed on a three-slope static screen made of specially coined curved wires. This concept used the Coanda or wall attachment phenomena to withdraw the fluid from the under layer of a slurry which is stratified by controlled velocity over the screen. This method of operation has been found to be highly effective in handling slurries containing fatty or sticky fibrous suspended matter.[18]

The arrangement of transverse wires with unique singular curves in the sense of flow provides a relatively non-clogging surface for dewatering or screening. The screens are precisely made in No. 316 stainless steel and are extremely rugged. Harder, wear-resisting stainless alloys may also be used for special purposes. Openings of 0.025 to 0.15 cm (0.010 to 0.060 inches) meet normal screening needs.[18]

Vibrating Screens

The effectiveness of a vibrating screen depends on a rapid motion. Vibrating screens operate between 900 rpm and 1800 rpm; the motion can either be circular or straight line, varying from 0.08 to 1.27 cm (1/32 to 1/2 inch) total travel. The speed and motion are selected by the screen manufacturer for the particular application.

Of prime importance in the selection of a proper vibrating screen is the application of the proper cloth. The capacities on liquid vibrating screens are based on the percent of open area of the cloth. The cloth is selected with the proper combination of strength of wire and percent of open area. If the waste solids to be handled are heavy and abrasive, wire of a greater thickness and diameter should be used to assure long life. However, if the material is light or sticky in nature, the durability of the screening surface may be the smallest consideration. In such a case, a light wire may be necessary to provide an increased percent of open area.

Rotary Screens

One type of barrel or rotary screen, driven by external rollers, receives the wastewater at one open end and discharges the solids at the other open end. The liquid passes outward through the screen (usually stainless steel screen cloth or perforated metal) to a receiving box and effluent sewer mounted below the screen. The screen in usually sprayed continuously by means of a line of external spray nozzles. The screen is usually inclined towards the solids exit end. This type is popular as an offal screen but has not been used to any great extent in secondary "polishing"--that is, in removing solids from waste streams containing low solids concentrations.[18] (A screen of this type has been developed for recycle of hide brining waters.)

Another rotary screen commonly used in the meat industry is driven by an external pinion gear. The raw flow is discharged into the interior of the screen below center, and solids are removed in a trough and screw conveyor mounted lengthwise at the center line of the barrel. The liquid exits outward through the screen into a box in which the screen is partially submerged. The screen is usually 40 x 40 mesh, with 0.4 mm (1/64 inch) openings. Perforated lift paddles mounted lengthwise on the inside surface of the screen assist in lifting the solids to the conveyor trough. This type is also generally sprayed externally to reduce blinding. Grease clogging can be reduced by coating the wire cloth with teflon. Solids removals up to 82 percent are reported.[18]

Applications

A broad range of applications exist for screens as the first stage of in-plant primary treatment processes. These include both the plant wastewater and wastewater discharged from individual processes. The latter include paunch manure, hog stomach contents, hog hair recovery, stickwater solids, hide washing operations, hide curing brine recycle, and others.

Catch Basins

The catch basin for the separation of grease and solids from meat packing wastewaters was originally developed to recover marketable grease. Since the primary object was grease recovery, all improvements were centered on skimming. Many catch basins were not equipped with automatic bottom sludge removal equipment. These basins could often be completely drained to the sewer and were "sludged out" weekly or at frequencies such that septic conditions would not cause the sludge to rise. Rising sludge was undesirable because it could affect the color and reduce the market value of the grease.

In the past twenty years, with waste treatment gradually becoming an added economic incentive, catch basin design has been improved in the solids removal area as well. In fact, the low market value of inedible grease and tallow has reduced concern about quality of the skimmings, and now the concern is shifting toward overall effluent quality improvement. Gravity grease recovery systems will remove 20 to 30 percent of the BOD_5, 40 to 50 percent of the suspended solids and 50 to 60 percent of the grease (hexane solubles).[18]

The majority of the gravity grease recovery basins (catch basins) are rectangular. Flow rate is the most important criterion for design; 30 to 40 minutes detention time at one hour peak flow is a common

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sizing factor.[18] The use of an equalizing tank ahead of the catch basin obviously minimizes the size requirement for the basin. A shallow basin--up to 1.8m (6 feet)--is preferred.

A "skimmer" skims the grease and scum off the top into collecting troughs. A scraper moves the sludge at the bottom into a submerged hopper from which it can be pumped. Both skimmings and sludge go to by-product recovery.

Usually two identical catch basins, with a common wall, are desirable so operation can continue if one is down for maintenance or repair. Both concrete and steel tanks are used.

Concrete tanks have the inherent advantages of lower overall maintenance and more permanence of structure. However, some plants prefer to be able to modify their operation for future expansion or alterations or even relocation.

All-steel tanks have the advantage of being semiportable, more easily field-erected, and more easily modified than concrete tanks. The all-steel tanks, however, require additional maintenance as a result of wear from abrasion.

A tank using all-steel walls and concrete bottom is probably the best compromise between the all-steel tank and the all-concrete tank. The advantages are the same as for steel; however, the all-steel tank requires a footing underneath the supporting members, whereas, the concrete bottom forms the floor anu supporting footings for the steel wall tank.

Dissolved Air Flotation

This system is, by definition, a primary treatment system; thus the effluent from a dissolved air flotation system is considered raw waste. This system is normally used to remove fine suspended solids and is particularly effective on grease in wastewaters from meat packing plants. This is a relatively recent technology in the meat industry; however, it is in fairly widespread use and increasing numbers of plants are installing these systems.

Dissolved air flotation appears to be the single most effective device that a meat packing plant can install to reduce the pollutional wasteload in its wastewater stream. It is expected that the use of dissolved air flotation will become standard practice in the industry, especially as a step in achieving the 1977 or 1983 standards.

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Technical Description

Air flotation systems are used to remove any suspended material from wastewater with a specific gravity close to that of water. The dissolved air system generates a supersaturated solution of wastewater and compressed air by raising the pressure of the wastewater stream to that of the compressed air, then mixing the two in a detention tank. This supersaturated mixture of air and wastewater flows to a large flotation tank where the pressure is released, thereby generating numerous small air bubbles which effect the flotation of the suspended organic material by one of three mechanisms: 1) adhesion of the air bubbles to the particles of matter; 2) trapping of the air bubbles in the floc structures of suspended material as the bubbles rise; 3) adsorption of the air bubbles as the floc structure is formed from the suspended organic matter.[19] In most cases, bottom sludge removal facilities are also provided.

There are three process alternatives varying by the degree of wastewater that is pressurized and into which the compressed air is mixed. In the total pressurization process, Figure 12, the entire wastewater stream is raised to full pressure for compressed air injection. In partial pressurization, Figure 13, only a part of the wastewater stream is raised to the pressure of the compressed air for subsequent mixing. In the recycle pressurization process (Alternative B of Figure 13), treated effluent from the flotation tank is recycled and pressurized for mixing with the compressed air and then, at the point of pressure release, is mixed with the influent wastewater. Alternative A (Figure 13) shows a side-stream of influent entering the retention tank, thus reducing the pumping required in the system shown in Figure 12. Operating costs may vary slightly, but performance should be essentially equal among the alternatives.

Improved performance of the air flotation system is achieved by coagulation of the suspended matter prior to treatment. This is done by pH adjustment or the addition of coagulant chemicals, or both. A slow paddle mix will improve coagulation. It has been suggested that the proteinaceous matter in meat packing plant waste could be removed by reducing the wastewater to the isoelectric pH range of about 3.5.[19] The protein material would be coagulated at that point and readily removed as float from the top of the dissolved air unit. This is not being done in the meat industry in the United States at the present time.

However, a somewhat comparable practice involving by-product recovery is gaining acceptance. In this system, segregated sewers are required along with two stages of air flotation treatment of the wastewaters. A good quality grease product can be recovered from a grease-bearing wastewater without the addition of chemicals in the first dissolved air system. The effluent from the first dissolved air unit is mixed with effluent from the other waste streams in the plant and this is fed to the second dissolved air unit which may or may not include chemicals addition, as mentioned above.

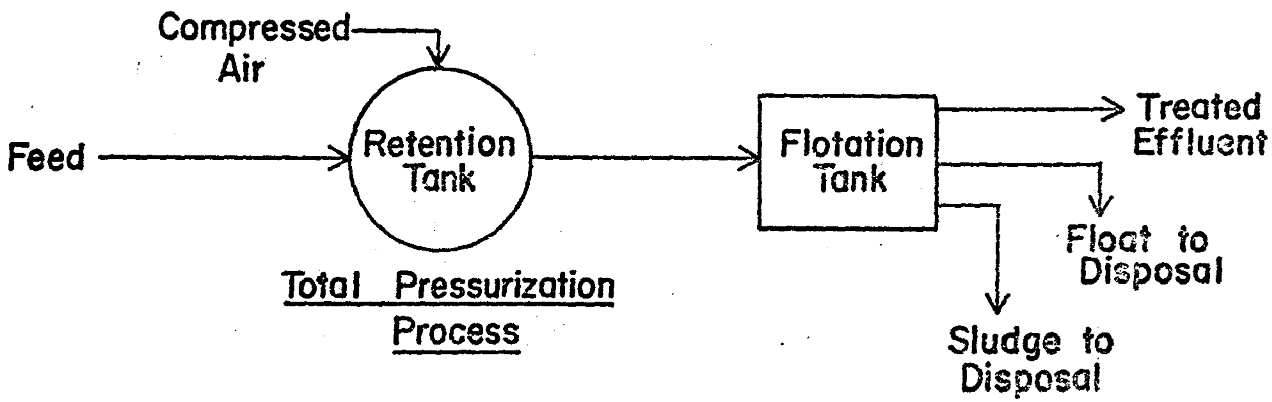

Figure 12. Dissolved Air Flotation

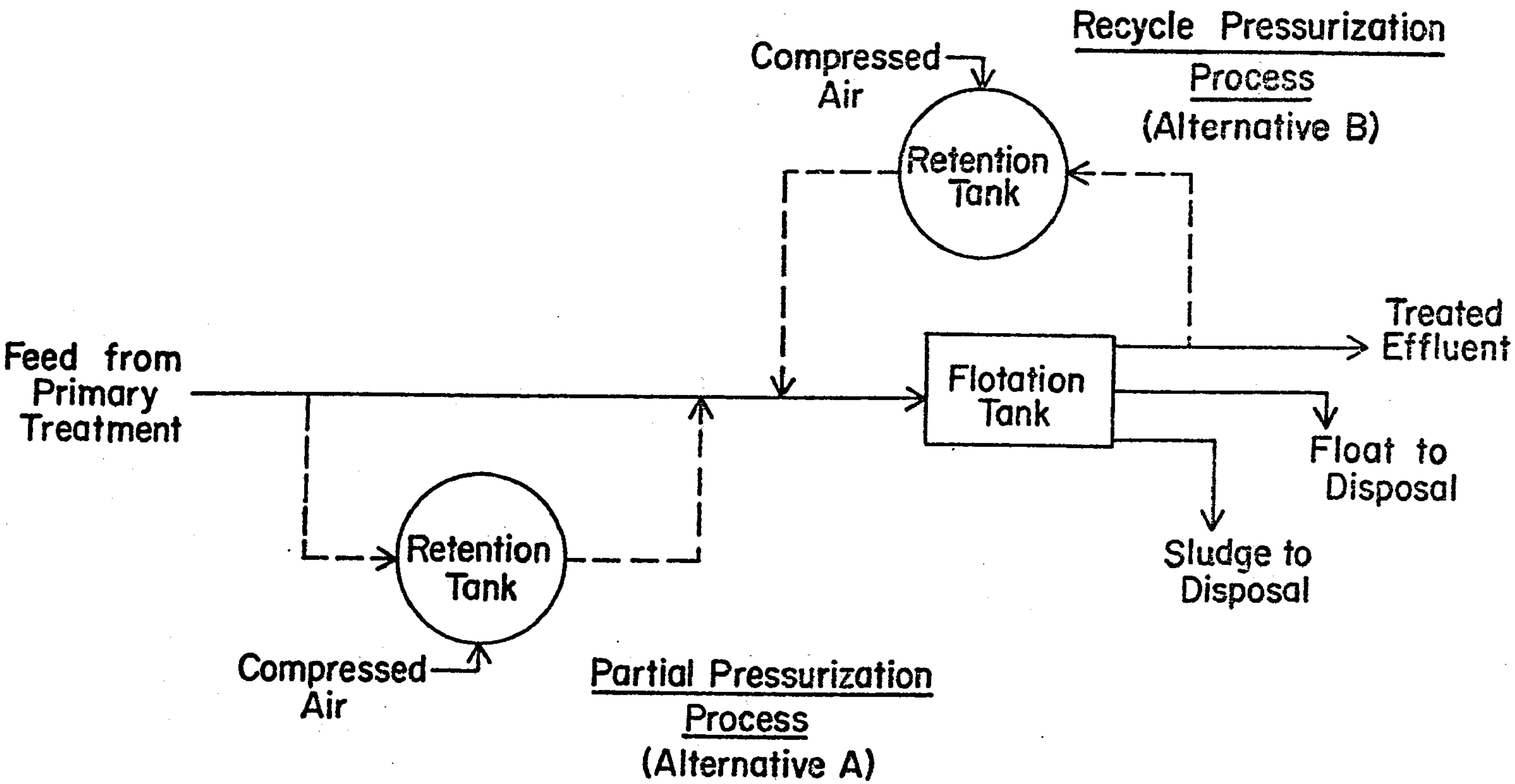

Figure 13. Process Alternatives for Dissolved Air Flotation

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One of the manufacturers of dissolved air flotation equipment indicated a 60 percent suspended solids removal and 80 to 90 percent grease removal without the addition of chemicals. With the addition of 300 to 400 mg/l of inorganic coagulants and a slow mix to coagulate the organic matter, the manufacturer says that 90 percent or more of the suspended solids can be removed and more than 90 percent of the grease.[20]

North Star's staff observed the operation of several dissolved air units during the verification sampling program and other plant visits. One plant that was visited controlled the feed rate and pH of the wastewater and achieved 90 to 95 percent removal of solids and grease. Other plants had relatively good operating success, but some did not achieve the results that should have been attainable. It appeared that they did not fully understand the process chemistry and were using erroneous operating procedures.

The Alwatec process has been developed by a company in Oslo, Norway, and uses a lignosulfonic acid precipitation and dissolved air flotation, recovering a high protein product that is valuable as a feed.[21] Nearly instantaneous protein precipitation is achieved when high protein-containing effluent, such as that from a meat packing plant, is acidified to a pH between 3 and 4, and high molecular weight fully sulphonated sodium lignosulphonate is added. BOD_5 reduction is reported to range from 60 to 95 percent. The effluent must be neutralized before further treatment by the addition of milk of lime or some other inexpensive alkali. This process is being evaluated on meat packing waste in one plant in the United States at the present time.

Problems and Reliability

The reliability of the dissolved air flotation process and of the equipment seems to be well established, although it is relatively new technology for the meat packing industry. As indicated above, it appears that the use of the dissolved air system is not fully exploited by some of the companies who have installed them for wastewater treatment. As in many other treatment systems, the problem seems to be limited training of operators.and perhaps some disinterest on the part of supervision and management in terms of the operating results expected from the process.

The sludge and float taken from the dissolved air system can be disposed of with the sludges obtained from secondary waste treatment systems. The addition of polyelectrolyte chemicals was reported to create some problems for sludge dewatering; however, this may have been the unique experience of one or two meat packing plants. The mechanical equipment involved in the dissolved air flotation system is fairly simple, requiring standard maintenance attention for such things as pumps and mechanical drives.

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SECONDARY WASTEWATER TREATMENT SYSTEMS

The secondary treatment methods commonly used for the treatment of meat packing wastes after in-plant primary treatment (solids removal) are the following biological systems; anaerobic processes, aerobic lagoons, variations of the activated sludge process, and high-rate trickling filters. Based on operational data from a pilot-plant system, the rotating biological contactor shows potential as a secondary treatment system. Several of these systems are capable of providing 70 to 97 percent BOD_5 reductions and 80 to 95 percent suspended solids reduction, while combinations of these systems can achieve reductions greater than 99 percent in BOD_5 and grease, and greater than 97 percent in suspended solids.

The selection of a secondary biological system for treatment of meat packing wastes depends upon a number of important system characteristics. Some of these are wastewater volume, equipment used, pollutant reduction effectiveness required, reliability, consistency, and resulting secondary pollution problems (*e.g.*, sludge disposal and odor control). The characteristics and performance of each of the above mentioned secondary treatment systems, and also for common combinations of them, are described below. Capital and operating costs are discussed in Section VIII. Since the treatment of wastes does not differ for the four subcategories of the meat packing industry (see Section IV), no distinction by subcategory is made in the following discussion.

Anaerobic Processes

Elevated temperatures (29° to 35°C or 85° to 95°F) and the high concentrations of carbohydrates, fats, proteins, and nutrients typically found in meat packing wastes make these wastes well suited to anaerobic treatment. Anaerobic or faculative microorganisms, which function in the absence of dissolved oxygen, break down the organic wastes to intermediates such as organic acids and alcohols. Methane bacteria then convert the intermediates primarily to carbon dioxide and methane. Unfortunately, much of the organic nitrogen present in the influent is converted to ammonia nitrogen. Also, if sulfur compounds are present (such as from high sulfated raw water--50 to 100 mg/l sulfate) hydrogen sulfide will be generated. Anaerobic processes are economical because they provide high overall removal of BOD_5 and suspended solids with no power cost (other than pumping) and with low land requirements. Two types of anaerobic processes are used: anaerobic lagoons and anaerobic contact systems.

Anaerobic Lagoons

Anaerobic lagoons are widely used in the industry as the first step in secondary treatment or as pretreatment prior to discharge to a municipal system. Reductions of up to 97 percent in BOD_5 and up to 95 percent in suspended solids can be achieved with the lagoons; 85 percent reduction is common. A usual arrangement is two anaerobic lagoons in parallel, although occasionally two are used in series. These lagoons are relatively deep (3 to 5 meters, or about 10 to 17 feet), low surface-area systems with typical waste loadings of 240 to 320 kg BOD_5/1000 cubic meters (15 to 20 lb BOD_5/1000 cubic feet) and a detention time of five to ten days. A thick scum layer of grease and paunch manure is frequently allowed to accumulate on the surface of the lagoon to retard heat loss, to ensure anaerobic conditions, and hopefully to retain obnoxious odors. Low pH and wind can adversely affect the scum layer.

Plastic covers of nylon-reinforced Hypalon, polyvinyl chloride, and styrofoam have been used on occasion in place of the scum layer; in fact some states require this. Properly installed covers provide a convenient means for odor control and collection of methane gas.

Influent wastewater flow should be near, but not on, the bottom of the lagoon. In some installations, sludge is recycled to ensure adequate anaerobic seed for the influent. The effluent from the lagoon should be located to prevent short-circuiting the flow and carry-over of the scum layer.

Advantages-Disadvantages. Advantages of an anaerobic lagoon system are initial low cost, ease of operation, and the ability to handle large grease loads and shock waste loads, and yet continue to provide a consistent quality effluent.[22] Disadvantages of an anaerobic lagoon are the hydrogen sulfide generated from sulfated waters and the typically high ammonia concentrations in the effluent of 100 mg/l or more. Incidentally, if the gases evolved are contained, it is possible to use iron filings to remove sulfides.

Applications. Anaerobic lagoons used as the first stage in secondary treatment are usually followed by aerobic lagoons. Placing a small, mechanically aerated lagoon between the anaerobic and aerobic lagoons is becoming popular. A number of plants are currently installing extended aeration units following the anaerobic lagoons to obtain nitrification. Anaerobic lagoons are not permitted in some states or areas where the ground water is high or the soil conditions are adverse (*e.g.*, too porous), or because of odor problems.

Anaerobic Contact System

The anaerobic contact system requires far more equipment for operation than do anaerobic lagoons, and consequently is not as commonly used. The equipment, as illustrated in Figure 14, consists of equalization tanks, digesters with mixing equipment, air or vacuum gas stripping units, and sedimentation tanks (clarifiers). Overall reduction of 90 to 97 percent in BOD_5 and suspended solids is achievable.

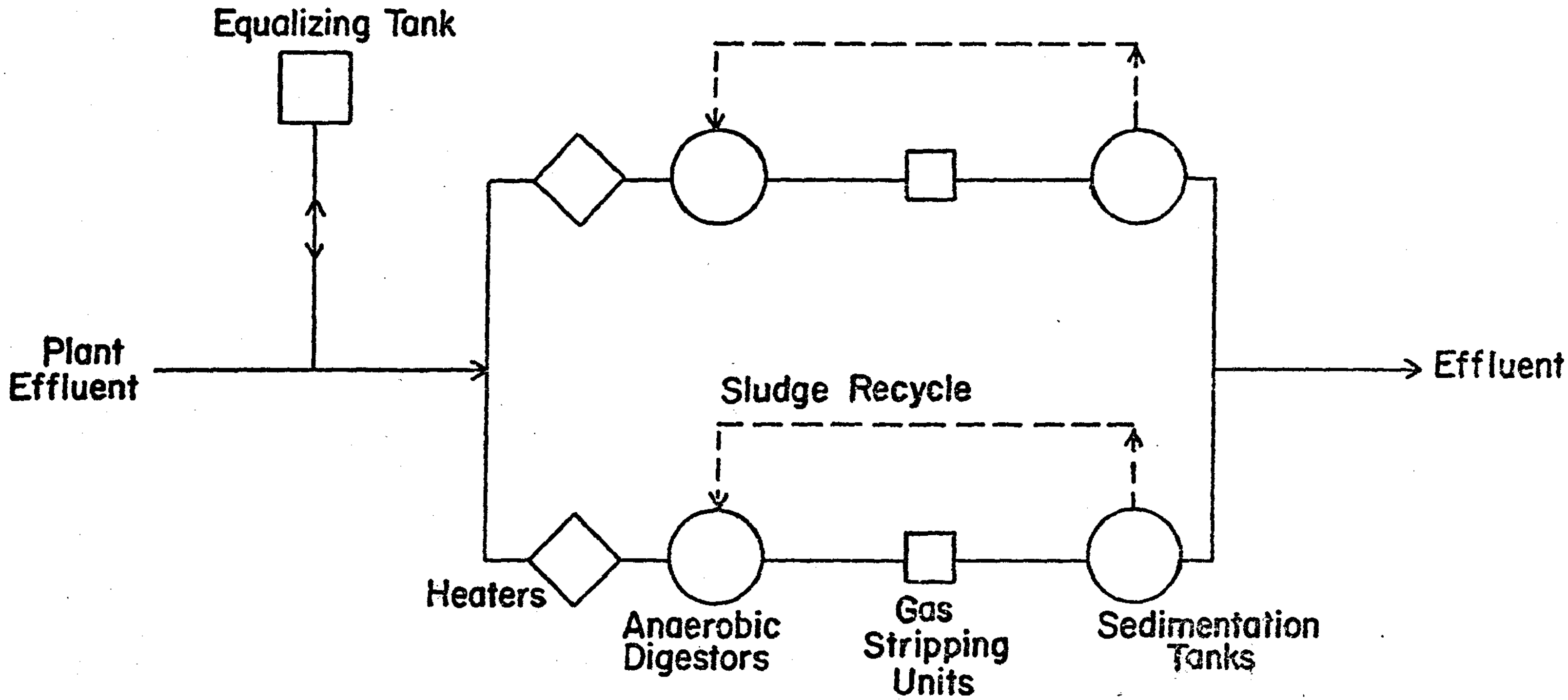

Figure 14. Anaerobic Contact Process

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Equalized wastewater flow is introduced into a mixed digester where anaerobic decomposition takes place at a temperature of about 33° to 35°C (90° to 95°F). BOD_5 loadings into the digester are between 2.4 and 3.2 kg/cubic meter (0.15 and 0.20 lb/cubic foot), and the detention time is between three and twelve hours. After gas stripping, the digester effluent is clarified and sludge is recycled at a rate of about one-third the raw waste influent rate. Sludge at the rate of about 2 percent of the raw waste volume is removed from the system.[7]

Advantages-Disadvantages. Advantages of the anaerobic contact system are high organic waste load reduction in a relatively short time; production and collection of methane gas that can be used to maintain a high temperature in the digester and also to provide auxillary heat and power; good effluent stability to grease and wasteload shocks; and application in areas where anaerobic lagoons cannot be used because of odor or soil conditions. Disadvantages of anaerobic contactors are higher initial and maintenance costs and some odors emitted from the clarifiers.

Applications. Anaerobic contact systems are restricted to use as the first stage of secondary treatment and can be followed by the same systems following anaerobic lagoons or trickling filter roughing systems.

Aerated Lagoons

Aerated lagoons have been used successfully for many years in a limited number of installations for treating meat packing wastes. However, with recent tightening of effluent limitations and because of the additional treatment aerated lagoons can provide, the number of installations is increasing.

Aerated lagoons use either fixed mechanical turbine-type aerators, floating propeller-type aerators, or a diffused air system for supplying oxygen to the wastewater. The lagoons usually are 2.4 to 4.6 m (8 to 15 feet) deep, and have a detention time of two to ten days. BOD_5 reductions range from 40 to 60 percent with little or no reduction in suspended solids. Because of this, aerated lagoons approach conditions similar to extended aeration without sludge recycle (see below).

Advantages-Disadvantages

Advantages of this system are that it can rapidly add dissolved oxygen (DO) to convert anaerobic wastewaters to an aerobic state; provide additional BOD_5 reduction; and require a relatively small amount of land. Disadvantages are the power requirements and that the aerated lagoon, in itself, usually does not reduce BOD_5 and suspended solids adequately to be used as the final stage in a high performance secondary system.

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Applications

Aerated lagoons are usually the second stage of secondary treatment and must be followed by an aerobic (shallow) lagoon to capture suspended solids and to provide additional treatment.

Aerobic Lagoons (also called Stabilization Lagoons)

Aerobic lagoons (or stabilization lagoons or oxidation ponds), are large surface area, shallow lagoons, usually 1 to 2.3 m deep (3 to 8 feet), loaded at a BOD_5 rate of 20 to 50 pounds per acre. Detention times will vary from about one month to six or seven months; thus aerobic lagoons require large areas of land.

Aerobic lagoons serve three main functions in waste reduction:

- Allow solids to settle out;
- Equalize and control flow;
- Permit stabilization of organic matter by aerobic and facultative microorganisms and also by algae.

Actually, if the pond is quite deep, 1.8 to 2.4 m (6 to 8 feet), so that the wastewater near the bottom is void of dissolved oxygen, anaerobic organisms may be present. Therefore, settled solids can be decomposed into inert and soluble organic matter by aerobic, anaerobic or facultative organisms, depending upon the lagoon conditions. The soluble organic matter is also decomposed by microorganisms. It is essential to maintain aerobic conditions in at least the upper 6 to 12 inches in shallow lagoons since aerobic microorganisms cause the most complete oxidation of organic matter. Wind action assists in carrying the upper layer of liquid (aerated by air-water interface and photosynthesis) down into the deeper portions. The anaerobic decomposition generally occurring in the bottom converts solids to liquid organics which can become nutrients for the aerobic organism in the upper zone.

Algae growth is common in aerobic lagoons; this currently is a drawback when aerobic lagoons are used for final treatment. Algae may escape into the receiving waters, and algae added to receiving waters are considered a pollutant. Algae in the lagoon, however, play an important role in stabilization. They use CO_2, sulfates, nitrates, phosphates, water and sunlight to synthesize their own organic cellular matter and give off free oxygen. The oxygen may then be used by other microorganisms for their metabolic processes. However, when algae die they release their organic matter in the lagoon, causing a secondary loading. Ammonia disappears without the appearance of an equivalent amount of nitrite and nitrate in aerobic lagoons. From this, and the fact that aerobic lagoons tend to become anaerobic near the bottom, it appears that some denitrification is occurring.

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Ice and snow cover in winter reduces the overall effectiveness of aerobic lagoons by reducing algae activity, preventing mixing, and preventing reaeration by wind action and diffusion. This cover, if present for an extended period, can result in anaerobic conditions. When there is no ice and snow cover on large aerobic lagoons, high winds can develop a strong wave action that can damage dikes. Riprap, segmented lagoons, and finger dikes are used to prevent wave damage. Finger dikes, when arranged appropriately, also prevent short circuiting of the wastewater through the lagoon. Rodent and weed control, and dike maintenance are all essential for good operation of the lagoons.

Advantages-Disadvantages

Advantages of aerobic lagoons are that they reduce suspended solids, oxidize organic matter, permit flow control and wastewater storage. Disadvantages are reduced effectiveness during winter months, the large land are required, the algae growth problem, and odor problems for a short time in spring, after the ice melts and before the lagoon becomes aerobic again.

Applications

Aerobic lagoons usually are the last stage in secondary treatment and frequently follow anaerobic or anaerobic-aerated lagoons. Large aerobic lagoons allow plants to store wastewaters from discharge during periods of high flow in the receiving body of water or to store for irrigation purposes during the summer. These lagoons are particularly popular in rural areas where land is available and relatively inexpensive.

Activated Sludge

The conventional activated sludge process is schematically shown in Figure 15. In this process recycled biologically active sludge or floc is mixed in aerated tanks or basins with wastewaters. The microorganisms in the floc adsorb organic matter from the wastes and convert it by oxidation-enzyme systems to such stable products as carbon dioxide, water, and sometimes nitrates and sulfates. The time required for digestion depends on the type of waste and its concentration, but the average time is six hours. The floc, which is a mixture of micro-organisms (bacteria, protozoa, and filamentous types), food, and slime material, can assimilate organic matter rapidly when properly activated; hence, the name activated sludge.

From the aeration tank the mixed sludge wastewaters, in which little nitrification has taken place, are discharged to a sedimentation tank. Here the sludge settles out, producing a clear effluent, low in BOD_5, and a biologically active sludge. A portion of the settled sludge, normally about 20 percent, is recycled to serve as an inoculum and to

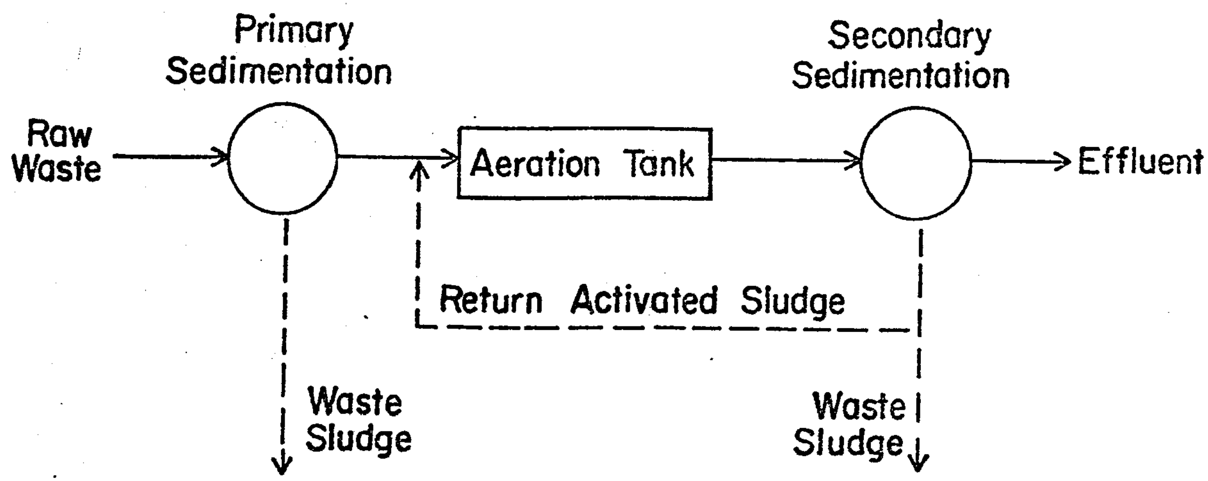

Figure 15. Activated Sludge Process

maintain a high mixed liquor suspended solids content. Excess sludge is removed (wasted) from the system, usually to thickeners and anaerobic digestion, or to chemical treatment and dewatering by filtration or centrifugation.

This conventional activated sludge process can reduce BOD_5 and suspended solids up to 95 percent. However, because it cannot readily handle the shock loads and widely varying flow common to meat packing wastewaters, this particular version of activated sludge is not a commonly used process for treating meat packing wastes.

Various modifications ofthe activated sludge process have been developed, such as the tapered aeration, step aeration, contact stabilization, and extended aeration. Of these, extended aeration processes are being used for treatment of meat packing wastes.

Extended Aeration

The extended aeration process is similar to the conventional activated sludge process, except that the mixture of activated sludge and raw materials is maintained in the aeration chamber for longer periods of time. The common detention time in extended aeration is one to three days, rather than six hours. During this prolonged contact between the sludge and raw waste, there is ample time for the organic matter to be adsorbed by the sludge and also for the organisms to metabolize the organic matter which they have adsorbed. This allows for a much greater removal of organic matter. In addition, the organisms undergo a considerable amount of endogenous respiration, and therefore oxidize much of the organic matter which has been built up into the protoplasm of the organism. Hence, in addition to high organic removals from the wastewaters, up to 75 percent of the organic matter of the microorganisms is decomposed into stable products and consequently less sludge will have to be handled.

In extended aeration, as in the conventional activated sludge process, it is necessary to have a final sedimentation tank. Some of the solids resulting from extended aeration are rather finely divided and therefore settle slowly, requiring a longer period of settling.

The long detention time in the extended aeration tank makes it possible for nitrification to occur. In nitrification under aerobic conditions, ammonia is converted to nitrites and nitrates by specific groups of nitrifying bacteria. For this to occur, it is necessary to have sludge detention times in excess of ten days.[22] This can be accomplished by regulating the amounts of sludge recycled and wasted each day. Oxygen enriched gas could be used in place of air in the aeration tanks to improve overall performance. This would require that the aeration tank be partitioned and covered, and that the air compressor and dispersion system be replaced by a rotating sparger system, which costs less to buy and operate. When cocurrent, staged flow and recirculation of gas

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back through the liquor is employed, between 90 and 95 percent oxygen utilization is claimed.[23] Although this modification of extended aeration has not been used in treating meat packing wastes, it is being used successfully for treating other wastes.

Advantages and Disadvantages

The advantages of the extended aeration process are that it is stable to shock loading and flow fluctuations because the incoming raw waste load is diluted, by the liquid in the system, to a much greater extent than in conventional activated sludge. Also, because of the long detention time, high BOD_5 reductions can be obtained. Other advantages of the system are the elimination of sludge digestion equipment and the capability to produce a nitrified effluent. Disadvantages are that it is difficult to remove most of the suspended solids from the mixed liquor discharged from the aeration tank; large volume tanks or basins are required to accommodate the long detention times; and operating costs for aeration are high.

Applications

Because of the nitrification process, extended aeration systems are being used following anaerobic lagoons to produce low BOD_5 and low ammonia-nitrogen effluents. They are also being used as the first stage of secondary treatment followed by polishing lagoons.

Trickling Filter

A trickling filter consists of a bed of rock or prefabricated plastic filter media on the surface of which the microbial flora develops; a rotary arm wastewater distribution system; and an under-drainage system. The distribution arm uniformly distributes wastewater over the filter media. The microflora adsorbs, and eventually metabolizes the organic matter in the liquid as it trickles down through the media. When the growth becomes fairly thick it begins to slough off the surface of the media as large pieces of solids which are carried with the liquid out through the under-drainage system. Consequently, the trickling filter must be followed by an appropriate sedimentation tank to remove the solids. To avoid clogging the trickling filter, the wastewater must be pre-treated (primary, in-plant treatment) to remove most solids and grease.

The high-rate trickling filter is used in treating meat plant wastewaters either as a roughing filter preceeding a conventional secondary treatment such as activated sludge or as complete secondary treatment in several stages. Hydraulic loading for high rate trickling filters is generally in the range of 93.5 to 187 million liters per hectare (10 to 20 million gallons per acre) per day.

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In treating high organic wastes with trickling filters there is a definite limit to BOD_5 removal by a single stage. Common practice has been to use a multistage filter system. The first stage filter can be fed at a BOD_5 rate of 0.016 to 0.024 kg/cubic meter of media (100 to 150 pounds/1000 cubic feet) and can result in 40 to 50 percent removal of BOD_5. If the second stage filter is the final filter to be used, the loading should not exceed 0.4 kg BOD_5/cubic meter of media (25 pounds of BOD_5 per 1000 cubic feet) of media. However, since the raw waste load of meat packing plants is relatively strong, this may mean that the size of the second filter will be excessively large. In this case, it might be better to provide still a third stage; then loadings can be higher in the second state--up to 0.8 to 1.2 kg BOD_5 per cubic meter of media (50 to 75 pounds of BOD_5/1000 cubic feet of media). The loading to the third stage should be limited to 0.32 kg of BOD_5/cubic meter of media (20 pounds/1000 cubic feet). The overall removal of such a system can be as high as 95 percent reduction in BOD_5. When staging of filters is used, it is desirable to provide a sedimentation tank for each stage. However, large rock or synthetic media can be used without intermediate sedimentation. Because of the size of second and third stage filters and because of the number of sedimentation tanks that may be required, this system is no longer generally used in the meat packing industry. Although single-stage filters alone result in considerably less BOD_5 reduction than staged trickling filter systems, they have found use in the meat industry, particularly as a pretreatment prior to some type of activated sludge system.

Advantages and Disadvantages

Advantages of the roughing trickling filter are that it can smooth out hydraulic and BOD_5 loadings; provide some initial reduction in BOD_5 (40 to 50 percent); and the fact that it is not injured materially by extended rest periods such as weekends. However, if there are long rest periods it is desirable to recirculate the effluent of one of the settling tanks through the filter to keep the floc moist. Another advantage of the roughing filter is its reliability with minimum care and attention. A disadvantage of the trickling filter system in general is that it is a costly installation, it may also be necessary to cover the filters in winter to prevent freeze-up and the effluent concentration fluctuates with changes in incoming wasteload.

Rotating Biological Contactor

Process Description

The rotating biological contactor (RBC) consists of a series of closely spaced flat parallel disks which are rotated while partially immersed in the wastewaters being treated. A biological growth covering the surface of the disk adsorbs dissolved organic matter present in the wastewater. As the biomass on the disk builds up, excess slime is sloughed off periodically and is removed in sedimentation tanks. The rotation of the disk carries a thin film of wastewater into the air where it absorbs the oxygen necessary for the aerobic biological activity of the biomass. The disk rotation also promotes thorough mixing and contact between the biomass and the wastewaters. In many ways the RBC system is a compact version of a trickling filter. In the trickling filter the wastewaters flow over the media and thus over the microbial flora; in the RBC system, the flora is passed through the wastewater.

The system can be staged to enhance overall wastewater reduction. Organisms on the disks selectively develop in each stage and are thus particularly adapted to the composition of the waste in that stage. The first couple of stages might be used for removal of dissolved organic matter, while the latter stages might be adapted to nitrification of ammonia.

Development Status

The RBC system was developed independently in Europe and the United States about 1955 for the treatment of domestic waste, but found application only in Europe. Currently, there are an estimated 1000 domestic installations in Europe.[22] However, the use of the RBC for the treatment of meat packing waste is relatively new. The only operational information available on its use on meat packing waste was obtained on a pilot-scale system, although a large installation was recently completed at the Iowa Beef Processors plant in Dakota City, Nebraska, for the further treatment of meat packing waste effluents from an anaerobic lagoon. The pilot-plant studies were conducted with a four-stage RBC system with four-foot diameter disks. The system was treating a portion of the effluent from the Austin, Minnesota, anaerobic contact plant used to treat meat packing waste. These results showed a BOD_5 removal in excess of 50 percent with loadings less than 0.037 kg BOD_5 per square meter (0.0075 lb BOD_5 per square foot) of disk area, based on an average BOD_5 influent concentration of approximately 25 mg/l. Data from Autotrol Corporation revealed ammonia removals of greater than 90 percent by nitrification in a multistage unit. Four to eight stages of disks with maximum hydraulic loadings of 61 liters per day per square meter (1.5 gallons per day per square foot) of disk area are considered normal for ammonia removal.

Advantages and Disadvantages

The major advantages of the RBC system are its relatively low installed cost; the effect of staging to obtain both dissolved organic matter reduction and removal of ammonia nitrogen by nitrification; and its good resistance to hydraulic shock loads. Disadvantages are that the system should be housed, if located in cold climates, to maintain high removal efficiencies and to control odors. Although this system has demonstrate its durability and reliability when used on domestic wastes, it has not yet been fully tested to treat meat packing plant wastes.

Uses

Rotating biological contactors could be used for the entire aerobic secondary system. The number of stages required depend on the desired degree of treatment and the influent strength. Typical applications of the rotating biological contactor, however, may be for polishing the effluent from anaerobic processes and from roughing trickling filters and as pretreatment prior to discharging wastes to a municipal system. A BOD_5 reduction of 98 percent is achievable with a four-stage RBC.[22]

Performance of Various Secondary Treatment Systems

Table 6 shows BOD_5, suspended solids (SS), and grease removal efficiencies for various secondary biological treatment systems used to treat meat packing wastewaters. Average values are presented for 10 systems; exemplary values for 5 systems. Exemplary values each represent one system (except for anaerobic plus aerobic lagoons, where they represent two systems) considered to be among the best for that kind of system and whose values were actually verified in the field sampling study conducted during this program.

The number of systems used to calculate average values, also shown in Table 6, clearly shows that the anaerobic plus aerobic lagoons are the most commonly used. In fact this system was used by about 63 percent of the plants included in the study that reported having secondary systems (see Section VIII).

The estimated value of BOD_5 shown for the anaerobic lagoons plus rotating biological contactor is based upon pilot plant results and is considered to be conservative.

The values shown for the anaerobic lagoons plus extended aeration are also estimated and are all below the values calculated by using average removal efficiencies for the two components of the system individually. For example, if the BOD_5 reduction for both the anaerobic lagoon and extended aeration were 90 percent , the calculated efficiency of the two systems combined would be 99 percent.

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Table 6. Performance of Various Secondary Treatment Systems.

Secondary Treatment System (number of systems used to determine averages)	Water Wasteload Reduction					
	Average Values			Exemplary Values		
	BOD_5	SS	Grease	BOD_5	SS	Grease
Anaerobic + Aerobic lagoon (22)	95.4	93.5	95.3	98.9	96.6	98.9
Anaerobic + aerated + Aerobic lagoon (3)	98.3	93.3	98.5	99.5	97.5	99.2
Anaerobic Contact Process + Aerobic lagoon (1)	98.5	96.0	99.0			
Extended Aeration + Aerobic lagoon (1)	96.0	86.0	98.0	96.0	86.0	98.0
Anaerobic lagoon + Rotating Biological contactor	98.5e	--				
Anaerobic lagoon + Extended Aeration + Aerobic lagoon	98e	93e	98e			
Anaerobic lagoon + Trickling filter (1)	97.5	94.0	96.0			
2-Stage Trickling filter (1)	95.5	95.0	98.0			
Aerated + Aerobic lagoon (1)	99.4	94.5	--	99.4	94.5	--
Anaerobic Contact (1)	96.9	97.1	95.8	96.9	97.1	95.8

e - estimated

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TERTIARY AND ADVANCED TREATMENT

Chemical Precipitation of Phosphorus

Phosphorus is an excellent nutrient for algae and thus can promote heavy algae blooms. As such it cannot be discharged into receiving streams and its concentration should not be allowed to build up in a recycle water stream. However, the presence of phosphorus is particularly useful in spray or flood irrigation systems as a nutrient for plant growth.

The effectiveness of chemical precipitation, Figure 16, is well established and has been verified in full scale during the North Star verification sampling program. One packing plant operates a dissolved air flotation system as a chemical precipitation unit and achieves a 95 percent phosphorus removal to a concentration of less than 1 mg/l.

Technical Description

Phosphorus occurs in wastewater streams from packing plants primarily as phosphate salts. Phosphates can be precipitated with trivalent iron and trivalent aluminum salts. It can also be rapidly precipitated by the addition of lime; however, the rate of removal is controlled by the agglomeration of the precipitate colloids and by the settling rate of the agglommerate.[19] Laboratory investigation and experience with in-plant operations have substantially confirmed that phosphate removal is dependent on pH and that this removal tends to be limited by the solubility behavior of the three phosphate salts mentioned above. The optimum pH for the iron and aluminum precipitation occurs in the 4 to 6 range, whereas the calcium precipitation occurs in the alkaline side at pH values above 9.5.[19]

Since the removal of phosphorus is a two-step process involving precipitation and then agglommeration, and both are sensitive to pH, setting the pH level takes on added significance. If a chemical other than lime is used in the precipitation-coagulation process, two levels of pH are required. Precipitation occurs on the acid side and coagulation is best carried out on the alkaline side. The precipitate is removed by sedimentation or by dissolved air flotation.[19]

Polyelectrolytes are polymers that can be used as primary coagulants, flocculation aids, filter aids or for sludge conditioning. Phosphorus removal may be enhanced by the use of such polyelectrolytes by producing a better floc than might occur without such chemical addition.[24]

The chemically precipitated sludge contains grease and organic matter in addition to the phosphorus, if the system is used in primary treatment. If it is used as a post-secondary treatment, the sludge volume will be less and it will contain primarily phosphorus salts. The sludge from either treatment can be landfilled without difficulty.

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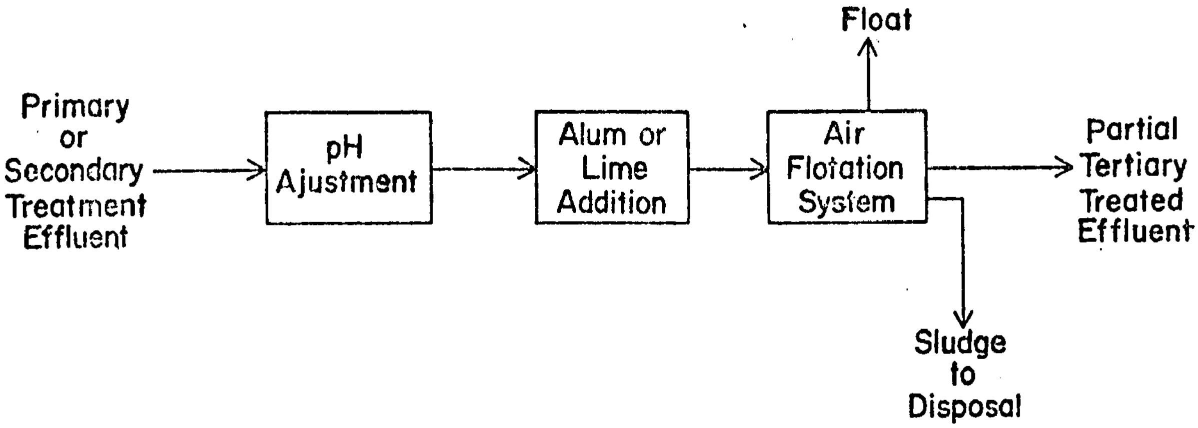

Figure 16. Chemical Precipitation

Development Status

This process is well-established and understood technically. Although its use on meat industry waste is very limited, it is gaining acceptance as a primary waste treatment process. Where it is in use, it is being operated successfully if the process chemistry is understood and the means to control the process are available.

Problems and Reliability

As indicated above, the reliability of this process is well established; however, it is a chemical process and as such requires the appropriate control and operating procedures. The problems that can be encountered in operating this process are those caused by a lack of understanding or inadequate equipment. Sludge disposal is not expected to be a problem. The use of polyelectrolytes and their effect on the dewatering properties of the sludge are open to some question at the present time.

Sand Filter

A slow sand filter is a specially prepared bed of sand or other mineral fines on which doses of wastewater are intermittently applied and from which effluent is removed by an under-drainage system, Figure 17; it removes solids from the wastewater stream. BOD_5 removal occurs primarily as a function of the degree of solids removal although some biological action occurs in the top inch or two of sand. Effluent from the sand filter is of a high quality with BOD_5 and suspended solids concentrations of less than 10 mg/l.[25] Although the performance of a sand filter is well known and documented, it is not in common use because it is not needed to reach current wastewater standards.

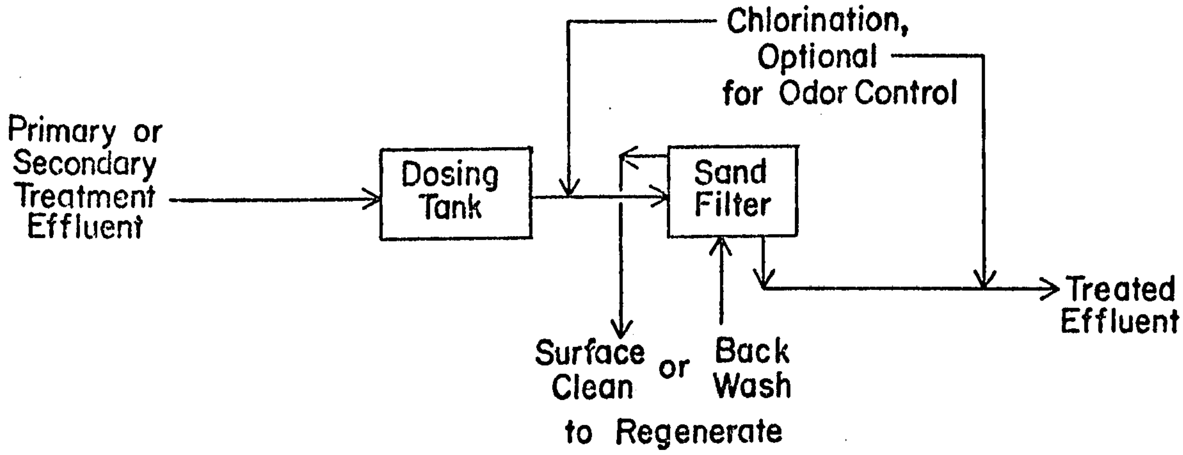

Figure 17. Sand Filter System

A rapid sand filter may operate under pressure in a closed vessel or may be built in open concrete tanks. It is primarily a water treatment device and thus would be used as tertiary treatment, following secondary treatment. Mixed media filters are special versions of rapid sand filters that permit deeper bed-penetration by gradation of particle sizes in the bed. Up-flow filters are also special cases of rapid filters.

Technical Description

The slow sand filter removes solids primarily at the surface of the filter. The rapid sand filter is operated to allow a deeper penetration of suspended solids into the sand bed and thereby achieve solids removal through a greater cross-section of the bed. The rate of filtration of the rapid filter is up to 100 times that of the slow filter. Thus, the rapid filter requires substantially less area than the slow filter; however, the cycle time averages about 24 hours in comparison with cycles of up to 30 to 60 days for slow filter. [26] The larger area required for the latter means a higher first cost. For small plants, the slow sand filter can be used as secondary treatment. In larger sizes, the labor in maintaining and cleaning the surface may operate against its use. The rapid sand filter on the other hand can be used following secondary treatment, but would tend to clog quickly and require frequent automatic backwashing if used as secondary treatment, resulting in a high water use. This washwater would also need treatment if the rapid sand filter is used following conventional solids removal.

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The rapid filters operate essentially unattended with pressure loss controls and piping installed for automatic backwashing. They may be enclosed in concrete structures or in steel tanks. [24]

Chlorination, both before and after sand filtering, particularly in the use of rapid filters, may be desirable to minimize or eliminate potential odor problems and slimes that may cause clogging.

Clean-up of the rapid sand filter requires backwashing the bed of sand with a greater quantity of water than used for the slow sand filter. Backwashing is an effective clean-up procedure and the only constraint is to minimize the washwater required in clean-up as this must be disposed of in some appropriate manner other than discharing it to a stream.

Development Status

The slow sand filter has been in use for 50 years and more. It has been particularly well suited to small cities and isolated treatment systems serving hotels, motels, hospitals, etc., where treatment of low flow is required and land and sand are available. Treatment in these applications has been a sanitary or municipal-type raw waste. The Ohio Environmental Protection Administration is a strong advocate of slow sand filters as a secondary treatment for small meat plants, following some form of settling or solids removal. As of early 1973, 16 sand filters had been installed and 8 were proposed and expected to be installed. All 24 of these installations were on waste from packing plants. [27] The land requirements for a slow sand filter are not particularly significant in relation to those required for lagooning purposes in secondary treatment processes. However, the quality and quantity of sand is important and may be a constraint in the use of sand filters in some local situations. It should also be recognized that this process requires hand labor for raking the crust that develops on the surface. Frequency of raking may be weekly or monthly, depending upon the quality of pretreatment and the gradation of the sand.

Problems and Reliability

The reliability of the slow sand filter seems to be well established in its long term use as a municipal waste treatment system. When the sand filter is operated intermittently there should be little danger of operating mishap with resultant discharge of untreated effluent or poor quality effluent. The need for bed cleaning becomes evident with the reduction in quality of the effluent or in the increase cycle time both of which are subject to monitoring and control. Operation in cold climates is possible as long as the appropriate adjustment in the surface of the bed has been made to prevent blanking off of the bed by freezing water.

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The rapid sand filter has been used extensively in water treatment plants and in municipal sewage treatment for tertiary treatment; thus its use in tertiary treatment of secondary treated effluents from meat plants appears to be a practical method of reducing BOD_5 and suspended solids to levels below those expected from conventional secondary treatment.

Microscreen-Microstrainer

A microstrainer is a filtering device that uses a fine mesh screen on a partially submerged rotating drum to remove suspended solids and thereby reduce the BOD_5 associated with those solids, Figure 18. The microstrainer is used as a tertiary treatment following the removal of most of the solids from the wastewater stream. The suspended solids and BOD_5 can be reduced to 3 to 5 mg/l [19] in municipal systems. There are no reports of their use in the tertiary treatment of meat plant wastes.

Technical Description

The microstrainer is a filtration device in which a stainless steel microfabric is used as the filtering medium. The steel wire cloth is mounted on the periphery of a drum which is rotated partially submerged in the wastewater. Backwash immediately follows the deposition of solids on the fabric, and in one installation, this is followed by ultraviolet light exposure to inhibit microbiological growth.[19] The backwash water containing the solids amounts to about 3 percent of the wastewater stream and must be disposed of by recycling to the secondary treatment system.[28] The drum is rotated at a minimum of 0.7 and up to a maximum of 4.3 revolutions per minute.[19] The concentration and percentage removal performance for microstrainers on suspended solids and BOD_5 appear to be approximately the same as for sand filters.

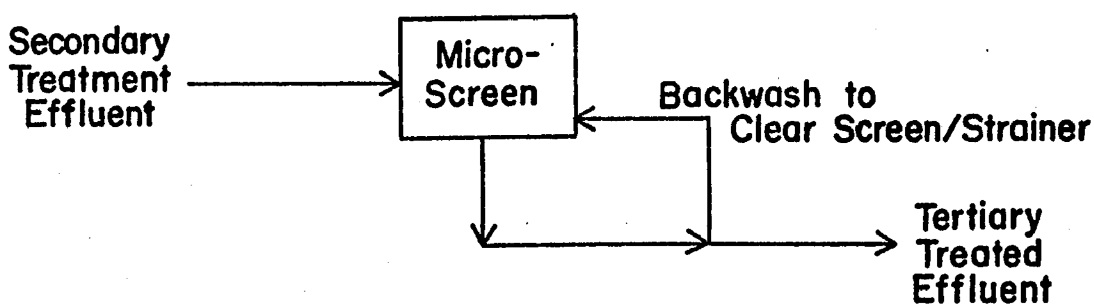

Figure 18. Microscreen/Microstrainer

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Development Status

While there is general information available on the performance of microstrainers and on tests involving the use of them, there appears to be only one recorded installation of a microstrainer in use on municipal waste; the requirements for effluent quality have not necessitated such installation. The economic comparisons between sand filters and microstrainers are inconclusive; the mechanical equipment required for the microstrainer may be a greater factor than the land requirement for the sand filter at the present time.

Problems and Reliability

The test performance of the microstrainer fairly well establishes the reliability of the device in its ability to remove suspended solids and the associated BOD_5. Operating and maintenance problems have not been reported; this is probably because, in large part, of the limited use of the device in full-scale application. As a mechanical filtration device requiring a drive system, it would have normal maintenance requirements associated with that kind of mechanical equipment. As a device based on microopenings in a fabric, it would be particularly intolerant to any degree of grease loading.

Nitrification-Denitrification

This two-step process of nitrification and denitrification, Figure 19, is a system to remove the nitrogen which appears as ammonia in treated meat plant wastewaters, and it is of primary importance for removal of the ammonia generated in anaerobic secondary treatment systems. Ammonia removal is becoming more important because of stream standards being set at levels as low as 1 to 2 mg/l.[7] Removal of ammonia is virtually complete, with the nitrogen gas as the end product.

Technical Description

The large quantities of organic matter in raw waste from meat packing plants is frequently and effectively treated in anaerobic lagoons. Much of the nitrogen in the organic matter, present mainly as protein, is converted to ammonia in anaerobic systems or in localized anaerobic environments. The following sets of equations indicate the nitrification of the ammonia to nitrites and nitrates, followed by the subsequent denitrification to nitrogen and nitrous oxide.[29] The responsible organisms are indicated also.

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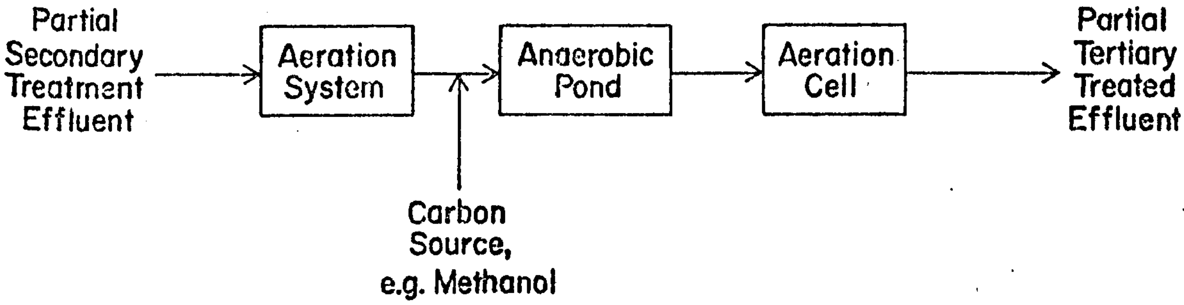

Figure 19. Nitrification/Dentrification

Nitrification:

$NH_3 + O_2 \longrightarrow NO_2^- + H_3O^+$ (Nitrosomonas)

$2NO_2^- + O_2 \longrightarrow 2NO_3^-$ (Nitrobacter)

Denitrification (using methanol as carbon source)

$6H^+ + 6NO_3^- + 5CH_3OH \longrightarrow 5CO_2 + 3N_2 + 13\ H_2O$

Small amounts of N_2O and NO are also found

(Facultative heterotrophs)

Nitrification does not occur to any great extent until most of the carbonaceous material has been removed from the wastewater stream. The ammonia nitrification is carried out by aerating the effluent sufficiently long to assure the conversion of all of the nitrogen in the raw effluent to the nitrite-nitrate forms prior to the anaerobic denitrification step.

The denitrification step, converting nitrates to nitrogen and nitrogen oxides, takes place in the absence of oxygen. It is thought to proceed too slowly without the addition of a biodegradable carbon source such as sugar, ethyl alcohol, acetic acid, or methanol. Methanol is the least expensive and performs satisfactorily. Investigators working on this process have found that a 30 percent excess of methanol over the stoichiometric amount is required. [24,31]

In current waste treatment practice using anaerobic and aerobic lagoons, ammonia nitrogen that disappears in the aerobic system does not show up to a large extent as nitrites and nitrates. Ammonia stripping

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is not likely to account for the loss. It appears that denitrification must actually be occurring in the bottom reaches of the aerobic lagoons, where anaerobic conditions are probably approached.

Presuming total conversion of the ammonia to nitrites or nitrates, there will be virtually no nitrogen remaining in the effluent from the denitrification process. Total nitrogen removal can be maintained at 90 percent over the range of operating temperatures; the rate increases with temperature to an optimum value of approximately 30°C for most aerobic waste systems. Temperature increases beyond 30° result in a decrease in the rate for the mesophilic organisms.[29]

The wastewater is routed to a second aeration basin following denitrification, where the nitrogen and nitrogen oxide are readily stripped from the waste stream as gases. The sludge from each stage is settled and recycled to preserve the organisms required for each step in the process.

Development Status

The specific nitrification-denitrification process has only been carried out at the bench- and pilot-scale levels. Culp and Culp [24] suggest that the "practicality of consistently maintaining the necessary biological reactions and the related economics must be demonstrated on a plant-scale before the potential of the process can be accurately evaluated." A pilot model of a three-stage system using this process was reportedly developed at the Cincinnati Water Research Laboratory of the EPA and is being built at Manassas, Virginia. [32] This work is also reported to be experimental. Thus, it can be concluded that this process is as of yet unproven. However, as mentioned above, observations of treatment lagoons for meat packing plants gives some indication that the suggested reactions are occurring in present systems. Also, Halvorson [33] reported that Pasveer is achieving success in denitrification by carefully controlling the reaction rate in an oxidation ditch, so that dissolved oxygen levels drop to zero just before the water is reaerated by the next rotor.

Problems and Reliability

In view of the experimental status of this process, it would be premature to speculate on the reliability or problems incumbent in a full-scale operation. It would appear that there would be not exceptional maintenance or residual pollution problems associated with this process in view of the mechanisms suggested for its implementation at this time.

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Ammonia Stripping

Ammonia stripping is a modificationof the simple aeration process for removing gases in water, Figure 20. Following pH adjustment, the wastewater is fed to a packed tower and allowed to flow down through the tower with a countercurrent air stream introduced at the bottom of the tower flowing upward to strip the ammonia. Ammonia-nitrogen removals of up to 98 percent and down to concentrations of less than 1 mg/l have been achieved in experimental ammonia stripping towers. [24]

Technical Description

The pH of the wastewater from a secondary treatment system is adjusted to between 11 and 12 and the wastewater is fed to a packed tower or to a cooling tower type of stripping tower. As pH is shifted above 9 the ammonia is present as the soluble gas in the wastewater stream rather than as the ammonium ion. [31] Ammonia-nitrogen removal of 90 percent was achieved with countercurrent air flows between 1.8 and 2.2 cubic meters per liter (250 and 300 cubic feet per gallon) of wastewater in an experimental tower with hydraulic loadings between 100 and 125 liters per minute per square meter (2.5 and 3 gallons per minute per square foot). [24] Ammonia removal was increased to 95 percent with the air rate increased to 3 cubic meters per liter (400 cubic feet per gallon) of wastewater and the hydraulic loading lowered to 85 liters per minute per square meter (2 gallons per minute per square foot). A maximum of 98 percent ammonia removal from a wastewater stream was reported with the air rate at 5.9 cubic meters per liter (800 cubic feet per gallon) and a hydraulic loading of 33 liters per minute per square meter (0.8 gallons per minute per square foot). The ammonia concentration was reduced to less than one part per million at 98 percent removal. The high percentage removal of ammonia-nitrogen is achieved only at a substantial cost in terms of air requirements and stripping tower cross sectional area. [24]

Because the system involves the stripping of ammonia from a water stream, ambient air temperatures below 0°C (32°F) present a problem; operation in cold climates may require housing inside a building or heating of the air prior to introducing it to the stripping tower. The residual pollution would be the ammonia stripped from the wastewater stream and mixed with the air, which is vented to the atmosphere. The maximum concentration of ammonia in the air stream prior to mixing with the ambient air would be about 10 milligrams per cubic meter, whereas the threshold for odor is about 35 milligrams per cubic meter. [24]

Development Status

The ammonia stripping process is a well-established industrial practice in the petroleum refinery industry. The only significant difference

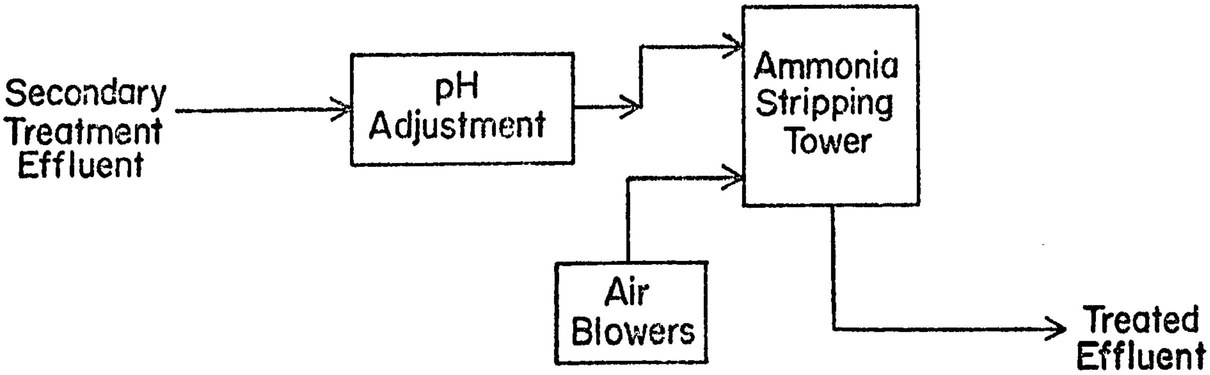

Figure 20. Ammonia Stripping

between petroleum refinery application and that on a meat packing plant waste would probably be the comparatively small size of stripping tower for the meat packing plant in comparison to the refinery. The air stripping of ammonia from secondary effluent is reported primarily on an experimental basis in equipment that is 1.8 meters (6 feet) in diameter with a packing depth of up to 7.3 meters (24 feet). Two large scale installations of ammonia stripping of lime treated wastewater are reported at South Tahoe, California, and Windhoek, South Africa.[24,19] The South Tahoe ammonia stripper was rated at 14.2 M liters per day (3.75 MGD) and was essentially constructed as a cooling tower structure rather than as a cylindrical steel tower which might be used in smaller sized plants.

Thus, although there is no reported use of ammonia stripping on meat packing plant waste, the technology is well established and implementation, when standards require it, should be without difficulty.

Problems and Reliability

The reliability of this process has been established by the petroleum refinery uses of the process over many years. Although the source of the ammonia may be different and there may be other contaminants in the water stream, none of this should affect the established reliability of this process. The experience of other users of the process will have pretty well identified potential problems and, presumably, the solutions for these problems. The maintenance requirements would be only those normally associated with the mechanical equipment involved in pumping the wastewater to the top of the tower, where the feed is introduced to the tower, and in maintaining the air blowers. The tower fill would undoubtedly be designed for the kind of service involved in treating a wastewater stream that has some potential for fouling.

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Spray/Flood Irrigation

A no discharge level for meat packing waste can be achieved by the use of spray or flood irrigation of relatively flat land, surrounded by dikes which prevent run-off and upon which a cover crop of grass or other vegetation is maintained. Wastewater disposal is achieved by this method to the level of no discharge. Specific plant situations may preclude the installation of irrigation systems; however, where they are feasible, serious consideration should be given to them.

Technical Description

Wastes are disposed of in spray or flood irrigation systems by distribution through piping and spray nozzles over relatively flat terrain or by the pumping and disposal through ridge and furrow irrigation systems which allow a certain level of flooding on a given plot of land, Figure 21. Pretreatment for removal of solids is adviseable to prevent plugging of the spray nozzles, or deposition in the furrows of a ridge-and-furrow system, or collection of solids on the surface, which may cause odor problems or clog the soil. Therefore, the BOD_5 would undoubtedly have already been reduced in the preliminary treatment in preparation for distribution through the spray system.

In a flood irrigation system the waste loading in the effluent would be limited by the waste loading tolerance of the particular crop being grown on the land, or it may be limited by the soil conditions or potential for vermin or odor problems.

Wastewater distributed in either manner percolates through the soil and the organic matter in the waste undergoes a biological degradation. The liquid in the waste stream is either stored in the soil or leached to a groundwater aquifer and discharges into the groundwater. Approximately 10 percent of the waste flow will be lost by evapotranspiration (the loss due to evaporation to the atmosphere through the leaves of plants).[29]

The following factors will affect the ability of a particular land area to absorb wastewater: 1) character of the soil, 2) stratification of the soil profile, 3) depth to groundwater, 4) initial moisture content, 5) terrain and groundcover.[29]

The greatest concern in the use of irrigation as a disposal system is the total dissolved solids content and particularly the salt content of the wastewater. A maximum salt content of 0.15 percent is suggested in Eckenfelder.[29] In order to achieve this level of salt content, 30 percent of the total wastewater stream from a typical plant was determined to require treatment in an ion exchange system upstream from the spray irrigation system.

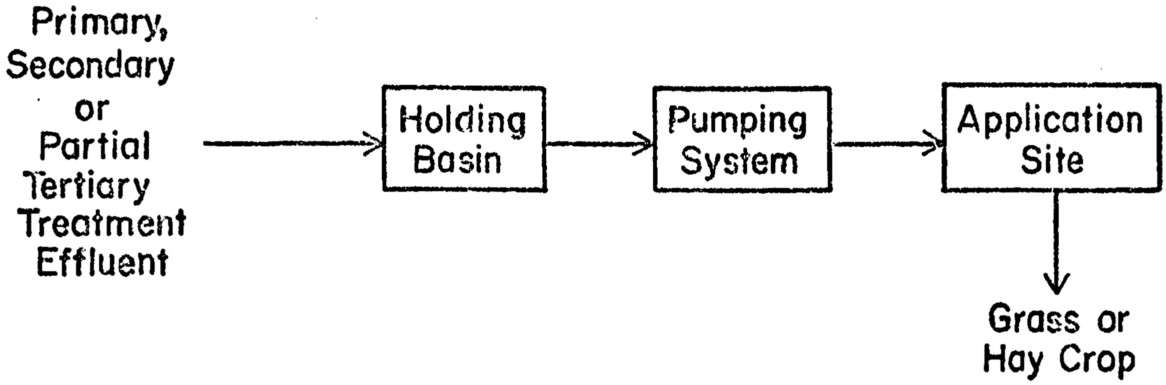

Figure 21. Spray/Flood Irrigation System

An application rate of 330 liters per minute per hectare (35 gallons per minute per acre) has been recommended in determining the quantity of land required for various plant sizes. This amounts to almost 5 cm (2 inches) of moisture per day and is relatively low in comparison with application rates reported by Eckenfelder for various spray irrigation systems.[29] However, soils vary widely in their percolation properties and experimental irrigation of a small area is recommended before a complete system is built.

The economic benefit from spray irrigation is estimated on the basis of raising one crop of grass hay per season with a yield of 13.4 metric tons of dry matter per hectare (six tons per acre) and valued at $22 per metric ton ($20 per ton). These figures are conservative in terms of the number of crops and the price to be expected from a grass hay crop. The supply and demand sensitivity as well as transportation problems for moving the hay crop to a consumer all mitigate against any more optimistic estimate of economic benefit.[30]

Cold climate uses of spray irrigation may be subject to more constraints and greater land requirements than plants operating in more temperate climates. However, a meat packer in Illinois reportedly operated an irrigation system successfully. Eckenfelder also reports that wastes have been successfully disposed of by spray irrigation from a number of other industries.[29]

North Star found in its survey that the plants located in the arid regions of the southwest were most inclined to use spray or flood irrigation systems.

Problems and Reliability

The long term reliability of spray or flood irrigation systems is a function of the ability of the soil to continue to accept the waste as it is disposed of through the irrigation system, and thus reliability remains somewhat open to question. Problems in maintenance are primarily in the control of the proper dissolved solids level and salinity content of the wastewater stream and also in climatic limitations that may exist or develop. Many soils are improved by spray irrigation.

Ion Exchange

Ion exchange, as a tertiary waste treatment, is used as a deionization process in which specific ionic species are removed from the wastewater stream, Figure 22. Ion exchange would be used to remove salt (sodium chloride) from waters. Ion exchange resin systems have been developed to remove specific ionic species, to achieve maximum regeneration operating efficiency, and to achieve a desired effluent quality. In treating meat packing waste, the desired effluent quality is a total wastewater salt concentration of 300 mg/l. Ion exchange systems are available that will remove up to 90 percent of the salt in a water stream.[19] They can also be used to remove nitrogen.

Technical Description

The deionization of water by means of ion exchange resin involves the use of both cation and anion exchange resins in sequence or in combination to remove an electrolyte such as salt.[(19)]

$$RSO_3H + NaCl \rightleftharpoons RSO_3Na + NCl$$

$$R\text{-}OH + HCL \longrightarrow R\text{-}Cl + H_2O$$

where R represents the resin

The normal practice in deionization of water has been to make the first pass through a strong acid column, cation exchange resin, in which the first reaction above occurs. Effluent from the first column is passed to a second column of anion exchange resin to remove the acid formed in the first step, as indicated in the second reaction. As indicated in the two reactions, the sodium chloride ions have been removed as ionic species. A great variety of ion exchange resins have been developed over the years for specific deionization objectives for various water quality conditions.

Wastewater treatment with ion exchange resins has been investigated and attempted for over 40 years; however, recent process developments in the treatment of secondary effluent have been particularly successful in achieving high quality effluent at reasonable capital and operating costs. One such process is a modification of the Rohm and Haas, Desal Process.[19] In this process a weak base ion exchange resin is converted to the bicarbonate form and the secondary effluent is treated by the resin to convert the inorganic salts. After the first step, the process includes a flocculation/aeration and precipitation step to

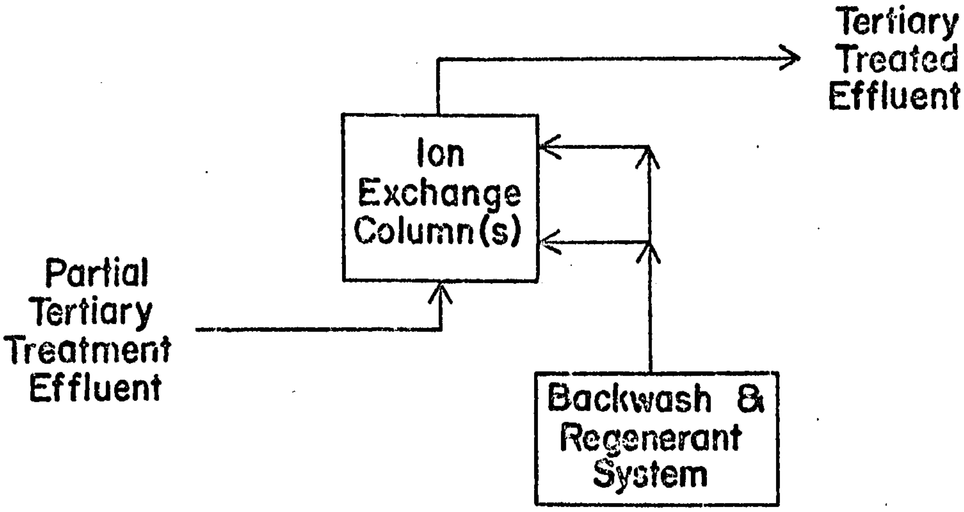

Figure 22. Ion Exchange

remove organic matter; however, this should be unnecessary if the sand filter and/or carbon adsorption system is used upstream of the ion exchange system. The effluent from the first ion exchange column is further treated by a weak cation resin to reduce the final dissolved salt content to approximately five mg/l. The anion resin in this process is regenerated with aqueous ammonia and the cation resin with an aqueous sulfuric acid. The resins did not appear to be susceptible to fouling by the organic constituents of the secondary effluent used in this experiment.

Other types of resins can be used for nitrate and phosphate removal, as well as color bodies, COD, and fine suspended matter. Removal of these various constituents can range from 75 percent to 97 percent, depending on the constituent.[24]

The cycle time on the ion exchange unit will be a function of the time required to block or to take up the ion exchange sites available in the resin contained in the system. Blockage occurs when the resin is fouled by suspended matter and other contaminants. The ion exchange system,is ideally located at the end of the wastewater processing scheme thus having the highest quality effluent available as a feedwater. The ion exchange system needed for irrigation purposes (mentioned earlier) based on an assumed inlet salt concentration of 2000 mg/l, was required to treat 30 percent of the wastewater stream. This inlet concentration is fairly conservative, based on the North Star survey data. Salt concentration should be easily reduced to 1000 mg/l and less with a minimal effort at controlling salt discharge into the wastewater.

To achieve a recyclable water quality, it may be assumed that less than 500 mg/l of total dissolved solids would have to be achieved. Of the total dissolved solids, 300 ppm of salt are assumed to be acceptable. To achieve this final effluent quality, 95 percent of the wastewater stream would be subjected to ion exchange treatment.

The residual pollution will be that resulting from regeneration of the ion exchange bed. The resin systems as indicated earlier, can be tailored to the ion removal requirements and efficient use of regeneration chemicals thus minimizing liquid wastes from the regeneration step.

Development Status

Ion exchange as a unit operation is well established and commonly used in a wide range of applications in water treatment and water deionization. Specific resin applications such as in wastewater treatment have not been widespread up to the present time, as there has not been a need for such a level of treatment. However, process development and experimental work have shown the capability of ion exchange systems to achieve the levels of salt removal required for the suggested irrigation and closed-loop water recycle systems examined in this report.

Part of the economic success of an ion exchange system in treating packing plant waste will probably depend on a high quality effluent being available as a feed material. This again, can be provided by an upstream treatment system including carbon adsorption or sand filtration to remove a maximum of the particularly bothersome suspended organic material. However, the affect of a lower quality feed would be primarily economic because of shorter cycle times, rather than a reduction in the overall effectiveness of the ion exchange system in removing a specific ionic species such as salt.

Problems and Reliability

Inasmuch as ion exchange is widely used, the reliability of the concept is well established. The application of the technology in waste treatment has not been tested and therefore the reliability in that application has yet to be firmly established. The problems associated with ion exchange operations would primarily center on the quality of the feed to the ion exchange system and its effect on the cycle time. The operation and control of the deionization-regeneration cycle can be totally automated, which would seem to be the desired approach.

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Carbon Adsorption

Carbon adsorption is a unit operation in which activated carbon adsorbs soluble and trace organic matter from wastewater streams, Figure 23. Either granular or powdered activated carbon can be used to remove up to 98 percent of colloidal and dissolved organics measured as BOD_5 and COD in a wastewater stream.[31] The organic molecules which make up the organic material attach themselves to the surface of the activated carbon and are thereby removed. Larger particles should be filtered from the wastewater in treatment systems upstream from carbon adsorption since the effectiveness of the latter will be substantially reduced by gross particles of organic matter. Total organic carbon removal efficiencies of about 50 to 55 percent have been reported for carbon adsorbers and 45 to 50 percent removal of soluble organic carbon is reported.[19] Carbon adsorption treatment of meat packing waste would be required only if a closed loop water recycle system were to be installed with a requisite low organic concentration.

Technical Description

Activated carbon in a granular or powdered form provides an active surface for the attachment and resultant removal of organic molecules from wastewater streams. This is a surface adsorption phenomenon and is not preferential for any particular molecule. Thus, in addition to trace organic matter, odors and color bodies will also be removed from the wastewater stream by carbon adsorption. The rate of adsorption is controlled by the rate of diffusion of the organic molecules within the capillary pores of the carbon particles. This rate varies inversely with the square of the particle diameter and increases with increasing concentration of organic matter and with increasing temperature. The implication of the particle diameter-adsorption rate relationship is that the smaller the carbon particle the larger the adsorption rate will be, in any given system. This factor is the basis for the interest in powdered activated carbon in preference to granular carbon.[24]

The granular carbon is effectively used in packed or expanded bed adsorbers. A number of processes have been experimentally attempted to utilize powdered carbon in various process systems such as the fluidized bed and carbon-effluent slurry systems.

Regeneration of the carbon is periodically required. A standard regeneration technique is incineration of the organic matter deposited on the surface of the carbon. It is economically important to regenerate and recover the carbon and regeneration has been a serious limitation to the use of powdered activated carbon up to the present time.

Carbon adsoption will remove up to about 98 percent of the colloidal and dissolved organic matter with resulting effluent COD's down to 12 mg/1 in any of the various physical systems devised for contacting

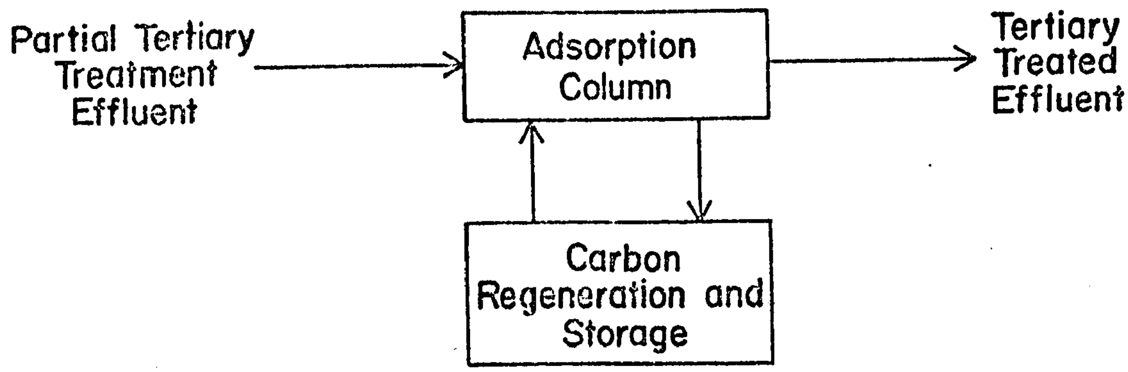

Figure 23. Carbon Adsorption

activated carbon and wastewater. This is a finishing treatment for wastewater intended to remove the trace organic material left after standard secondary and partial tertiary treatment. Essentially all of the gross organic particles must be removed from the wastewater before entering this treatment system.[24]

The residual pollution associated with carbon adsorption will be that due to regeneration and a properly operated low oxygen furnace achieving complete combustion of the organic matter should present no pollution problem for the surrounding air environment.

Development Status

Activated carbon treatment in water purification is common practice and well established. Several large scale pilot projects testing carbon adsorption as a treatment of wastewaters are presently underway. In addition carbon towers have been used for the removal of suspended solids in a small number of municipal treatment systems requiring high quality effluent. The treatment has not been applied specifically to meat packing plant effluent; however, at the point in a waste treatment system where an activated carbon system would be used, there should be no significant difference between municipal waste and meat packing waste. The effluent should be of high quality.

The primary question demanding the attention of research investigators in the use of this system is to find an economic method for the use of activated carbon in powdered form rather than granular form.

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Problems and Reliabilities

Since this technology is well established in the water treatment industry, it presumably can be operated with the proper type of feedstream on an efficient and reliable basis. While the treatment of wastewater for this system is largely limited to large scale pilot projects, the reliability and utility of such treatment should be clearly established within a relatively short time, certainly before the need for equipment to meet 1983 standards.

Operating and maintenance problems do not seem to be significant, particularly if the quality of the feedwater is maintained by appropriate upstream treatment systems. Regeneration is no problem in the packed and expanded bed systems and presumably can be worked out for powdered carbon systems before the mid 1980's.

Reverse Osmosis

The reverse osmosis process uses semi-permeable membranes to remove contaminants down to molecular size, Figure 24. It is capable or removing divalent ions at efficiencies of up to 98 percent and monovalent ions and small organic molecules at 70 to 90 percent.[34] Total solids concentrations between 25 mg/1 and 65 mg/1 have been obtained in reverse osmosis effluent.[34] Reverse osmosis would not be needed for applications other than a closed loop recycle water system. The application of reverse osmosis to date has been limited to capacities no larger than 190,000 liters (50,000 gallons) per day, and current operating costs are estimated to be $0.08 to $0.16/1000 liters ($0.30 to $0.60/1000 gallons).[24]

Technical Description

Several different kinds of semipermeable membranes are available for use in the reverse osmosis process. Data are available on the use of cellulose acetate membranes. These and other semipermeable membranes are more permeable to pure water than to dissolved salt and other ions and molecules. The process operates by reversing the normal osmotic process by increasing the pressure on the side of the membrane containing the contaminated water until pure water flows through the membrane from the contaminated side to the pure water side. Excellent rejection or removal of essentially all contaminants in a wastewater stream from a meat packing plant would be achieved through a reverse osmosis system. However, the rate at which pure water would be produced is still unacceptably low for economic application of this system. Current development work is aimed at improving the rate at which pure water can be produced, while retaining the high quality of the effluent.

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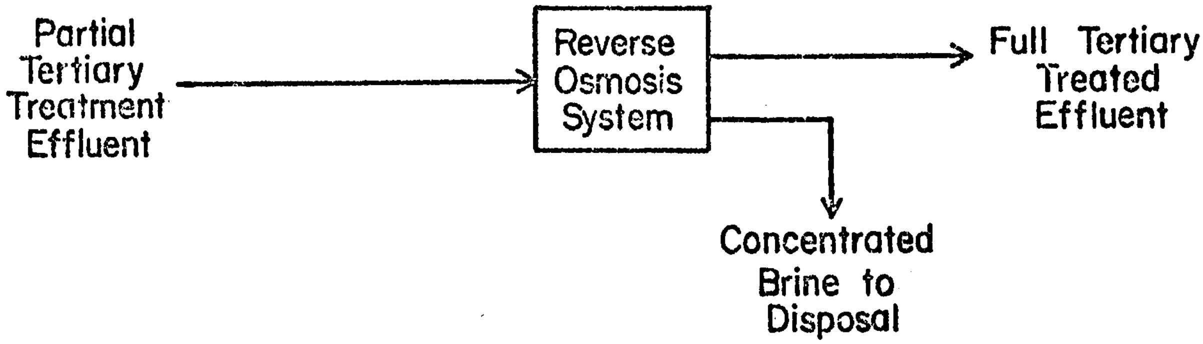

Figure 24. Reverse Osmosis

Development Status

The application of reverse osmosis to the treatment of wastewater streams has been confined to experiments on domestic sewage on a small scale. As a waste treatment process, the limited capacity of commercially available units and the high operating costs tend to limit the potential applicability of reverse osmosis wastewater treatment in the near future.

Problems and Reliability

The reliability of reverse osmosis remains open to question until larger scale and longer term experiments have been conducted on wastewater treatment. A very significant problem remains in the bacterial growth that has been observed on reverse osmosis membranes which seriously reduces their operating efficiency. Microbial growth has also been observed in the support structure under the membranes. Chlorine cannot be used because the membranes which are presently available are damaged by chlorination.[19]

Electrodialysis

Electrodialysis is a process that uses an applied electric current to separate ionic species in a solution, Figure 25. Membranes allow specific ions to pass from the wastewater stream on one side of the membrane to a highly concentrated solution of contaminants on the other side of the membrane. Electrodialysis is used to remove dissolved solids such as salt, which is of particular concern in meat industry waste. Single-pass removal efficiencies of up to 40 percent of the is the reported performance of the system.[31]

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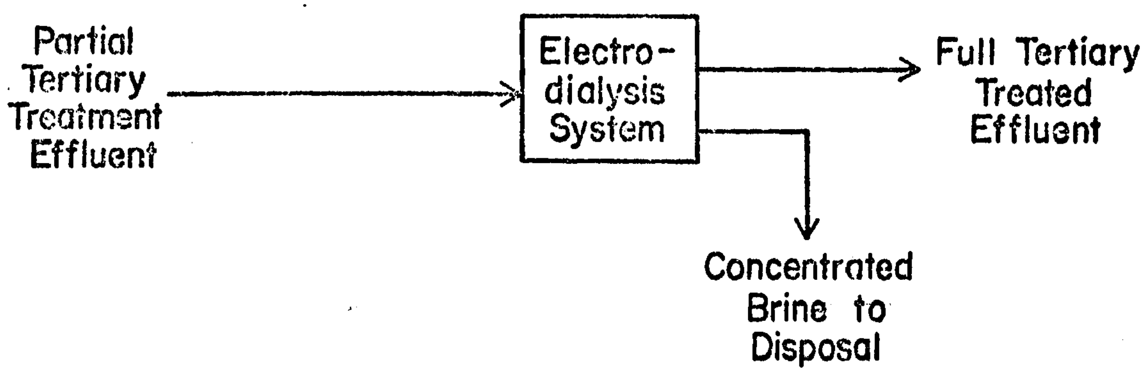

Figure 25. Electrodialysis

Technical Description

The electrodialysis process incorporates a number of chambers made by alternating anionic and cationic membranes that are arranged between two electrodes. A brine solution is alternated with contaminated wastewater solution in the chambers between the differing membranes. Electric current is applied across the membrane chambers causing the cations to move towards the cathode and the anions towards the anode. However, after passing from the chambers containing the wastewater into adjacent brine chambers, the ions can travel no further toward the electrodes. Their path is blocked by a membrane that is impermeable to that particular ionic species. In this manner, the wastewater stream is depleted while the adjacent brine stream is enriched in the ions which are to be removed.

Power costs limit the salinity of the effluent wastewater after treatment in the electrodialysis system to approximately 300 to 500 mg/l of salt.[35] This limitation is imposed because of the increase in electrical resistance in the treated wastewater that would occur at lower concentrations of salt.

The residual pollution from an electrodialysis unit would be the brine solution used and generated in the chambers of the unit. This brine solution might be handled by a blowdown system which removes the quantity of salt added per unit of time.

Development Status

Electrodialysis is an old process and in fairly widespread use for the purpose of desalting brackish water.[35] The treatment of wastewater in electrodialysis systems has not been done except on an experimental basis. There is no reported application of the process on wastewater

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from the meat industry which tends to have a fairly substantial salt content. The potential utility of the process is therefore speculative as to its use on wastewater, however, its widespread use in water desalting suggests that, if the need arises for its application, it is technically feasible to desalt wastewater in such a process.

Problems and Reliability

The reliability of the electrodialysis system in removing salt from wastewaters is only speculative based on the use of the system in desalting brackish waters. It has demonstrated its reliability in the desalting application. The problems associated with using this process in treating wastewater from meat packing plants is the substantial cost, the necessity of brine disposal, and the bacterial growth which occurs on the dialysis membranes.[19] Chlorine cannot be applied because it damages the membranes.

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SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

SUMMARY

The wastewater from meat packing plants is amenable to treatment in secondary and tertiary waste treatment systems to achieve low levels of pollutants in the final effluent. In-plant controls, by-product recovery operations, and strict water management practices can be highly effective in reducing the wasteload and wastewater flow from any industry plant. These water management practices will reduce the requisite size of secondary and tertiary treatment systems and improve their waste reduction effectiveness.

The waste treatment investment for a typical plant in each industry subcategory is listed in Table 7 to achieve each of four levels of treatment:

Level 1 - reduction of organics by the use of exemplary secondary treatment systems.
Level 2 - in-plant controls plus partial tertiary treatment.
Level 3 - no discharge via land disposal by irrigation.
Level 4 - wastewater recycle.

Assuming that 70 percent of the industry plants discharge to municipal sewers,[2] the total investment cost was calculated for the industry for the various effluent treatment levels. The total costs and per-installed capacity costs are reported in Table 8. The Level 3 alternative results in no discharge and costs less than Level 2. The critical requirements for irrigation are sufficient land availability within reasonable piping distance and a total salinity in the wastewater of less than 1500 ppm or 0.15 percent.[29] Total dissolved solids concentration may also be a consideration, depending on the type of soil.

Table 7. Average Total Waste Treatment Investment Costs per Plant to Achieve a Given Level of Effluent Quality.

Effluent Quality	Simple Slaughterhouse	Complex Slaughterhouse	Low-Processing Packinghouse	High-Processing Packinghouse
Level 1	$ 80,000	$ 139,000	$ 131,000	$ 148,000
Level 2	425,000	665,000	629,000	736,000
Level 3	268,000	487,000	451,000	544,000
Level 4	733,000	1,315,000	1,227,000	1,475,000

*Locker plants were not included in any subcategory, but were assumed to require an investment of $10,000 each to go to no discharge by 1977, which appears to be the most attractive choice other than municipal treatment.

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Table 8. Estimated Total Investment Cost to the Industry to Achieve a Given Level of Effluent Quality from Present Level of Treatment

Effluent Quality	Total Industry Investment, ($ millions)	Investment Cost per million kg LWK per year	Investment Cost per million lb LWK per year,
Level 1	52.8*	2,355	1,069
Level 2	159.7	7,119	3,232
Level 3	119.0	5,306	2,409
Level 4	252.2	11,240	5,103

*Includes $10,000 per plant for 2600 locker plants, totaling $26 million.

Table 9. Total Increase in Annual Cost of Waste Treatment, $/1000 kg ($/1000 lb) LWK.

Effluent Quality	Simple Slaughterhouse	Complex Slaughterhouse	Low-Processing Packinghouse	High-Processing Packinghouse
Level 1	0.35 (0.16)	0.26 (0.12)	0.33 (0.15)	0.46 (0.21)
Level 2	2.93 (1.33)	1.92 (0.87)	2.44 (1.11)	3.37 (1.53)
Level 3	2.00 (0.91)	1.34 (0.61)	1.74 (0.79)	2.42 (1.10)
Level 4	4.74 (2.15)	3.17 (1.44)	4.30 (1.95)	5.62 (2.55)

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The annual operating costs for a treatment system to achieve the indicated effluent quality are reported in Table 9. The costs to achieve Level 1 range from 12 to 21 cents per head of beef, depending on the subcategory. The costs to achieve Level 2 vary from $0.90 to $1.50 per head more than present waste treatment costs. Costs above present for Level 3 are about two-thirds of those for Level 2, and costs for Level 4 are nearly twice those for Level 2.

Energy comsumption associated with wastewater treatment in the meat industry is not a serious constraint, varying from 10 to 40 percent of present power consumption. The higher percentage is for the smaller packing plants that consume relatively small quantities of electric energy at the present time.

With the implementation of these standards, land becomes the primary waste sink instead of air and water. The waste to be land filled from packing plants can improve soils with nutrients and soil conditioners contained in the waste. Odor problems can be avoided or eliminated in all treatment systems.

"TYPICAL" PLANT

The waste treatment systems applicable to wastewater from the meat packing industry can be used by plants in all four subcategories of the industry. A hypothetical "typical" plant was constructed in each subcategory as a basis for estimating investment and total annual costs for the application of each waste treatment system within each subcategory. The costs were estimated, and, in addition, effluent reduction, energy requirements, and non-water quality aspects of the treatment systems were determined.

The waste treatment systems are applied on the basis of the following plant constructs for each subcategory:

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	Industry Subcategory			
	Simple Slaughter-house	Complex Slaughter-house	Low-processing Packing-house	High-processing Packing-house
Kill, kg LWK/day (lb LWK/day)	220,000 (484,000)	595,000 (1,310,000)	435,000 (900,000)	350,000 (800,000)
Wastewater flow liters/1000 kg LWK (gals/1000 lb LWK)	5,328 (639)	7,379 (885)	7,842 (941)	12,514 (1,500)
Raw waste, BOD_5 kg/1000 kg LWK (lb/1000 lb LWK)	6.0 (6.0)	10.9 (10.9)	8.1 (8.1)	16.1 (16.1)
Processed meat production kg/day (lb/day)	0	0	54,000 (119,000)	191,000 (422,000)

WASTE TREATMENT SYSTEMS

The waste treatment systems included in this report as appropriate for use on meat packing plant wastewater streams can be used by all plants in the industry. The treatment systems will work, subject to specific operating constraints or limitations. However, the cost of such treatment systems may be uneconomical or beyond the economic capability of some plants.

The waste treatment systems, their use, and the minimum effluent reduction associated with each are listed in Table 10.

The dissolved air flotation system can be used upstream of any secondary treatment system. When operated without chemicals, the by-product grease recovered in the floc skimmings has an economic value estimated at 11¢/kg (5¢/lb). The use of chemicals will increase the quantity of grease removed from the wastewater stream, but may reduce the value of the grease because of the chemical contaminants.

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Table 10. Waste Treatment Systems, Their Use and Effectiveness

Treatment System	Use	Effluent Reduction
Dissolved air flotation (DAF)	Primary treatment or by-product recovery	Grease, 60% removal, to 100 to 200 mg/l BOD_5, 30% removal SS, 30% removal
DAF with pH control and flocculants added	Primary treatment or by-product recovery	Grease, 95-99% removal, BOD_5, 90% removal SS, 98% removal
Anaerobic + aerobic lagoons	Secondary treatment	BOD_5, 95% removal
Anaerobic + aerated + aerobic lagoons	Secondary treatment	BOD_5, to 99% removal
Anaerobic contact process	Secondary treatment	BOD_5, 90-95% removal
Activated sludge	Secondary treatment	BOD_5, 90-95% removal
Extended aeration	Secondary treatment	BOD_5, 95% removal
Anaerobic lagoons + rotating biological contactor	Secondary treatment	BOD_5, 90-95% removal
Chlorination	Finish and disinfection	--
Sand filter,	Tertiary treatment & Secondary treatment	BOD_5, to 5-10 mg/l SS, to 3-8 mg/l
Microstrainer	Tertiary treatment	BOD_5, to 10-20 mg/l SS, to 10-15 mg/l
Electrodialysis	Tertiary treatment	TDS, 90% removal
Ion exchange	Tertiary treatment	Salt, 90% removal
Ammonia stripping	Tertiary treatment	90-95% removal
Carbon adsorption	Tertiary treatment	BOD_5, to 98% removal as colloidal & dissolved organic
Chemical precipitation	Tertiary treatment	Phosphorus, 85-95% removal, to 0.5 mg/l or less
Reverse osmosis	Tertiary treatment	Salt, to 5 mg/l TDS, to 20 mg/l
Spray irrigation	No discharge	Total
Flood irrigation	No discharge	Total
Ponding and evaporation	No discharge	Total

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The secondary treatment systems are generally land intensive because of the long retention time required in natural biological processes. Mechanically assisted systems have reduced the land requirements but increased the energy consumption and cost of equipment in achieving comparable levels of waste reduction. A final clarifier is included at the end of all secondary systems. Some of the tertiary systems are interchangeable. Any of them can be used at the end of any of the secondary treatment systems to achieve a required effluent quality. Chlorination is included if a disinfection treatment is required.

The most feasible system for no discharge at this time is flood or spray irrigation, or, in some cases, evaporation from a shallow pond. Closing the loop to a total water recycle or reuse system is technically feasible, but costly. The irrigation option does require large plots of accessible land--roughly 2.7 hectares/million liters (25 acres/million gallons) of wastewater per day; and limited concentrations of dissolved solids. More detailed descriptions of each treatment system and its effectiveness are presented in Section VII-Control and Treatment Technology.

Of all the plants in the study sample that reported wastewater treatment, 55 percent indicated discharging raw waste to a municipal treatment system. Thirty-eight plants reported some on-site secondary treatment. Of the 38 plants, 63 percent used the anaerobic plus aerobic lagoons system. This system was used to treat large and small wastewater streams alike, varying from 76,000 liters per day (0.2 MGD) to 4.8 million liters per day (1.3 MGD). The rest of the systems listed as secondary treatment were used by 1, 2, or 3 plants each, except the rotating biological contactor, which is now being evaluated at full-scale at one site.

Dissolved air flotation is used as a primary treatment, either alone or along with screens or a catch basin, by about 30 percent of the plants in the sample. About 5 percent use chemicals in the flotation system.

Chlorination is a rare practice, according to the information collected in the survey questionnaires; it appears to be used by about 5 percent of the plants.

Other than sand filters and spray irrigation, there is no reported use of any of the advanced treatment systems. Sand filters are used for secondary treatment in Ohio instead of anaerobic lagoons, which are discouraged by the Ohio Environmental Protection Administration. The few spray irrigation systems are located in arid regions of the Southwestern U.S.

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Among the industry subcategories, for which we have specific plant information, slaughterhouses have almost twice as many air flotation systems in use as do packinghouses. Municipal treatment and the anaerobic plus aerobic system for secondary treatment are used by the bulk of the industry. A breakdown of the sample by subcategory is as follows:

Secondary Treatment by Each Subcategory, %

	Simple Slaughter-house	Complex Slaughter-house	Low-Processing Packing-house	High-Processing Packing-house	North Star Sample of Industry
Municipal treatment, %	56	29	70	59	55
Anaerobic + aerobic lagoons, %	33	65	11	14	28
Other, %	11	6	19	27	17
TOTAL	100%	100%	100%	100%	100%

This tabulation does not take into account the large number of small plants in the industry. Depending on the source of information, the total number of plants in the industry varies from 4000 to 6000 and the approximate percentage of small plants varies from 85 to 90 percent. However, these small plants account for only 10 percent or less of the industry's output and, probably, a somewhat smaller proportion of the total wastewater load. Of the few small plants for which data were available, about 50 percent reported discharging wastewater into city sewers. The remaining 50 percent used a wide variety of secondary treatment systems. Based on all of the available information, it is estimated that 50 percent of the small plants use municipal treatment facilities, a small percent probably dump raw waste into local streams or use land disposal, and the remaining plants treat their own waste. Taken as single point sources of wastewater, these small plants represent an unknown but a very small fraction of the total wasteload on receiving streams.

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TREATMENT AND CONTROL COSTS

In-Plant Control Costs

The cost of installation of in-plant controls is primarily a function of the specific plant situation. Building layout and construction design will largely dictate what can be done, how, and at what cost in regard to in-plant waste control techniques. No in-plant control costs were included in the cost estimates for Level 1 and 2 technologies, although a dissolved air flotation system as primary treatment was included in the Level 2 costs. Rough approximations of the range of costs for the in-plant controls requiring capital equipment are listed in Table 11.

Table 11. In-Plant Control Equipment Cost Estimates

Plant Area	Item	Equipment Cost Range
Pen wastes	Roof on pens	$5000 - $10,000
	Manure sewer	$8 - $12/foot
Blood handling	Curbing & collection system	$10,000 - $50,000
	Blood dryer	$30,000 - $50,000
Paunch handling	Solids pumping system	$10,000 - $20,000
	Liquid screening & collection equipment	$5,000 - $10,000
Viscera handling	Localized catch basin	$6,000 - $12,000
Troughs	----	$5 - $10/foot
Rendering	Surface condensers	$15,000 - $20,000
	Tankwater evaporator	$50,000 - $200,000
Hide processing	Overflow collection & treatment	$5,000 - $20,000
Hog Scald Tank	Water treatment & reuse system	$10,000 - $25,000
Pickle & Curing solutions	Solution collection, treatment, reuse system	$10,000 - $30,000
Water Conservation	Install spray nozzles	$5,000 - $10,000
Water Conservation	Press-to-open & foot operated valves	$10,000 - $20,000

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Secondary and Tertiary Treatment Costs

The total investment cost and annual cost expressed in ¢/100 kg LWK (¢/100 lb LWK) are reported by subcategory for each secondary treatment system, air flotation, and chlorination in Table 12. These costs are listed on the same basis for each tertiary or advanced treatment system in Table 13.

The annual costs of secondary treatment for all categories vary from 6.0 to 17.8 ¢/100 kg LWK (2.7 to 8.1 ¢/100 lb LWK), excluding the highest figures. The 10-year (1962-1971) average earnings reported by the American Meat Institute is 75¢/100 kg (34¢/100 lb) LWK. These estimated annual costs of waste treatment, which are very conservative from an accounting viewpoint, represent between 8 and 24 percent of the 10-year average earnings.

Presuming an acceptable recycle water quality can be achieved through advanced waste treatment, including ammonia stripping, ion exchange, carbon adsorption, and chemical precipitation, the total estimated investment would vary from $700,000 to $1.6 million including secondary treatment costs. The annual costs would range from 26 to 55¢/100 kg LWK (12 to 25¢/100 lb LWK), or about 35 to 74 percent of the 10-year average earnings.

No discharge could be achieved by a spray irrigation system, incorporating partial treatment by ion exchange to reduce dissolved solids, and would result in total costs between $270,000 and $544,000 and annual costs between 13 and 24¢/100 kg LWK (6 and 11¢/100 lb LWK).

Investment Costs Assumptions

The waste treatment system costs are based on the kill, wastewater flow and BOD_5 figures listed previously for a "typical", but hypothetical, plant in each subcategory. Investment costs for specific waste treatment systems are largely dependent on the wastewater flow. Some of the lagoon systems are designed on BOD_5 loading, which has been shown to increase with increased water use.

In averaging the wastewater flow for each subcategory, it was found that one standard deviation for three subcategories was 100 percent of the average water flow, and 75 percent of the average for the other subcategory. Presumably, the capacity-cost relationships of waste treatment systems are similar to those of a typical process industry with a capacity-ratio exponent between 0.6 and 0.8. If so, specific plants will incur waste treatment investment costs which will differ from those reported for each category by $\pm$ 50 to 100 percent, and perhaps more.

Table 12. Secondary Waste Treatment System Costs
[Investment, $1000; Annual Costs, ¢/1000 kg LWK
(¢/1000 lb LWK)]

Waste Treatment System	Simple Slaughterhouse		Complex Slaughterhouse		Low-Processing Packinghouse		High-Processing Packinghouse	
	Total Investment	Annual Cost	Total Investment	Annual Cost	Total Investment	Annual Cost	Total Investment	Annual Cost
Pre-treatment and Finishing Systems								
Dissolved Air Flotation, pre-treatment	65	2.4 (1.1)	81	0.44 (0.2)	79	0.9 (0.4)	86	0.7 (0.3)
Chlorination, finishing	7.5	0.44 (0.2)	18.8	0.44 (0.2)	17.5	0.7 (0.3)	21.2	0.9 (0.4)
Secondary Systems								
Anaerobic + aerobic	238.	10.4 (4.7)	425.	6.0 (2.7)	400.	7.9 (3.6)	475	10.4 (4.7)
Anaerobic + aerated + aerobic	318.	13.9 (6.3)	564	8.8 (4.0	531	11.2 (5.1)	623	15.0 (6.8)
Aerated + aerobic	210	10.6 (4.8)	432	7.5 (3.4)	398	9.2 (4.2)	500	12.8 (5.8)
Anaerobic contact process	410	16.3 (7.4)	520	7.3 (3.3)	500	9.7 (4.4)	570	12.6 (5.7)
Activated sludge	438	17.2 (7.8)	1130	14.3 (6.5)	1000	17.8 (8.1)	1375	27.1 (12.3)
Anaerobic lagoon + extended aeration	308	14.3 (6.5)	370	8.6 (3.9)	364	10.1 (4.6)	373	13.2 (6.0)
Anaerobic lagoon + rotating biological contactor	198	10.6 (4.8)	364	6.6 (3.0)	334	8.4 (3.8)	375	10.6 (4.8)

Table 13. Advanced Waste Treatment System Costs
[Investment, $1000; Annual Costs, ¢/1000 kg LWK
(¢/1000 lb LWK)]

Waste Treatment System	Simple Slaughterhouse		Complex Slaughterhouse		Low-Processing Packinghouse		High-Processing Packinghouse	
	Total Investment	Annual Cost	Total Investment	Annual Cost	Total Investment	Annual Cost	Total Investment	Annual Cost
Sand Filter	140	6.0 (2.7)	195	2.9 (1.3)	188	3.7 (1.7)	215	4.8 (2.2)
Microstrainer	105	6.6 (3.0)	146	3.1 (1.4)	140	4.2 (1.9)	161	5.3 (2.4)
Reverse osmosis	640	28.4 (12.9)	1600	25.5 (11.6)	1470	32.6 (14.8)	1860	46.2 (21.0)
Electrodialysis	275	33.8 (15.4)	625	32.8 (14.9)	588	41.8 (19.0)	700	60.0 (27.3)
Ion exchange	57	4.4 (2.0)	102	2.4 (1.1)	92	3.1 (1.4)	122	4.4 (2.0)
Ammonia Stripping	75	5.3 (2.4)	112.5	2.6 (1.2)	106	3.5 (1.6)	119	4.2 (1.9)
Carbon adsorption	238	13.2 (6.0)	475	9.0 (4.1)	438	11.4 (5.2)	537	15.8 (7.2)
Chemical precipitation	65	8.8 (4.0)	81	6.2 (2.8)	79	7.7 (3.5)	86	11.0 (5.0)
Spray irrigation	91	4.2 (1.9)	254	3.1 (1.4)	229	4.0 (1.8)	297	5.3 (2.4)

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The investment cost data were collected from the literature, personal plant visits, equipment manufacturers, engineering contractors, and consultants. These costs are "ball-park" type estimates implying an accuracy of $\pm$ 20 to 25 percent. Rarely is it minus. All costs are reported in August 1971 dollars. Percentage factors were added to the basic system estimate for design and engineering (10%) and for contingencies and omissions (15%). Land costs were estimated to be $1000 per acre ($2470 per hectare).

In addition to the variation in plant water flows and BOD_5 loadings and the inherent inaccuracy in cost estimating, one additional factor further limits the probability of obtaining precise cost estimates for waste treatment systems. This factor was reported by a number of informed sources who indicated that municipal treatment systems will cost up to 50 percent more than comparable industrial installations. The literature usually makes no distinction between municipal and industrial installation in reporting investment costs.

Annual Costs Assumptions

The components of annual costs include capital cost, depreciation, operating and maintenance costs, and energy and power costs. The cost of capital is estimated to be ten percent of the investment cost for the meat packing industry. This cost should be a weighted average of the cost of equity and of debt financing throughout the industry. Neither individual companies nor industry associations have a known figure for this cost. Presuming that target and realized return-on-investment (ROI) or return-on-assets (ROA) figures incorporate some estimate of capital cost plus an acceptable profit or return, industry and corporate reports were used as a guide in selecting the 10 percent figure. One sample of companies reported earnings at 7.1 percent of total assets for 1971,[36] a recent business periodical reported earnings at 10.1 percent of invested capital,[37] and general industry sources report corporate target ROI or ROA figures at 12 to 15 percent for new ventures. The ten percent figure is probably conservative and thus tends to result in a high estimate of annual cost.

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The depreciation component of annual cost was estimated on a straight-line basis over the following lifetimes, with no salvage value:

Land costs -- not depreciated

Cost of improvements for land intensive treatment -- 25 years

Simple treatment systems without complex process equipment; *e.g.*, extended aeration, sand filter -- 25 years

Treatment systems requiring complex process equipment -- 10 years

The operating and maintenance costs include the cost of one man-year at $4.20/hr for each typical secondary treatment system plus 50 percent for burden, supervision, etc. One-half man-year was included in the annual cost for each tertiary treatment plus the 50 percent burden, etc. General and maintenance supplies, taxes, insurance, and miscellaneous operating costs were estimated as 5 percent of the total investment cost per year for process equipment based systems and 2.5 percent of the total investment cost for land intensive waste treatment systems. Specific chemicals use costs were added when such materials were consumed in the waste treatment system. By-product income, relative to waste treatment was credited only in the dissolved air flotation system for 160 mg/l of grease recovered per day and sold at $0.05 per pound, and in spray irrigation for 13,400 kg of dry matter (hay or grass) per hectare at $22/100 kg (6 tons/acre at $20/ton) and one crop per season.

ENERGY REQUIREMENTS

The estimated electrical energy consumption per plant based on 1967 Census of Manufactures[38] data is as follows:

Small plants -- 0.72 million KWH per year

Medium plants -- 5.5 million KWH per year

Large plants -- 18.6 million KWH per year

The meat packing industry consumes relatively small quantities of energy. The waste treatment systems require power primarily for pumping and aeration. The aeration horsepower is a function of the wasteload and that for pumping depends on wastewater flow rate.

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Power consumption for waste treatment varies from 0.8 to 3.4 million KWH per year for various secondary treatment systems. This consumption is between 10 and 40 percent of that indicated above for 1973. The larger plants with greater power consumption would tend toward the smaller percentage. The total additional power consumption to achieve Level 1 and Level 2 does not appear to raise serious power supply or cost questions for the meat packing industry.

Thermal energy costs roughly equal electrical energy costs for operations within the industry. Waste treatment systems impose no significant addition to the thermal energy requirements of plants. Wastewater can be reused in cooling and condensing service if it is separated from the process waters in non-barometric type condensers. These heated wastewaters improve the effectiveness of anaerobic ponds which are best maintained at 90°F or more. Improved thermal efficiencies are coincidentally achieved within a plant with this technique.

Wastewater treatment costs and effectiveness can be improved by the use of energy and power conservation practices and techniques in each plant. The wasteload increases with increased water use. Reduced water use therefore reduces the wasteload, pumping costs, and heating costs, the last of which can be further reduced by water reuse as suggested previously.

NON-WATER POLLUTION BY WASTE TREATMENT SYSTEMS

Solid Wastes

Solid wastes are the most significant non-water pollutants associated with the waste treatment systems applicable to the meat packing industry. Screening devices of various design and operating principles are used primarily for removal of large-scale solids such as hair, paunch manure, and hog stomach contents from wastewater. These solids may have some economic value as inedible rendering material, or they may be landfilled or spread with other solid wastes.

The solids material, separated from the wastewater stream, that contain organic and inorganic matter, including those added to aid solids separation, is called sludge. Typically, it contains 95 to 98 percent water before dewatering or drying. Both the primary and secondary treatment systems generate some quantities of sludge; the quantity will vary by the type of system and is roughly estimated as follows:

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Treatment System	Sludge Volume as Percent of raw wastewater volume
Dissolved air flotation	Up to 10%
Anaerobic lagoon	Sludge accumulation in these lagoons is usually not sufficient to require removal at any time.
Aerobic and aerated lagoons	
Activated sludge	10 - 15%
Extended aeration	5 - 10%
Anaerobic contact process	approximately 2%
Rotating biological contactor	unknown

The raw sludge can be concentrated, digested, dewatered, dried, incinerated, land-filled on-site, or spread in sludge holding ponds. The sludge from any of the treatment systems, except air flotation with polyelectrolyte chemicals added, is amenable to any of these sludge handling processes.

The sludge from air flotation with chemicals has proved difficult to dewater. A dewatered sludge is an acceptable land fill material. Sludge from secondary treatment systems is normally ponded by the meat industry plants on their own land or dewatered or digested sufficiently for hauling and deposit in public land fills. The final dried sludge material can be safely used as an effective soil builder. Prevention of run-off is a critical factor in plant-site sludge holding ponds. Costs of typical sludge handling techniques for each secondary treatment system generating sufficient quantities of sludge to require handling equipment are already included in the costs for these systems.

Air Pollution

Odors are the only significant air pollution problem associated with waste treatment in the meat packing industry. Malodorous conditions usually occur in anaerobic waste treatment processes or localized anaerobic environments within aerobic systems. However, it is generally agreed that anaerobic ponds will not create serious odor problems unless the process water has a sulfate content; then it most assuredly will. Sulfate waters are definitely a localized condition varying even from well to well within a specific plant. In nothern climates, however, the change in weather in the spring may be accompanied by a period of increased odor problems.

The anaerobic pond odor potential is somewhat unpredictable as evidenced by a few plants that have odor problems without sulfate waters. In these cases a cover and collector of the off-gas from the pond controls odor. The off-gas is then burned in a flare.

The other potential odor generators in the waste treatment are tanks and process equipment items for the anaerobic contact process that normally generate methane. However, with the process confined to a specific piece of equipment it is relatively easy to confine and control odors by collecting and burning the off-gases. The high heating value of these gases makes it worthwhile and standard practice to recover the heat for use in the waste treatment process.

Odors have been generated by some air flotation systems which are normally housed in a building, thus localizing, but intensifying the problem. Minimizing the unnecessary holdup of any skimmings or grease-containing solids has been suggested as a remedy.

Odors can best be controlled by elimination, at the source, in preference to treatment for odor control which remains largely unproven at this time.

Noise

The only material increase in noise within a packing plant caused by waste treatment is that caused by the installation of an air flotation system or aerated lagoons with air blowers. Large pumps and an air compresser are part of an air flotation system. The industry normally houses such a system in a low-cost building; thus, the substantial noise generated by an air flotation system is confined and perhaps amplified by the installation practices. All air compressors, air blowers, and large pumps in use on intensively aerated treatment systems, and other treatment systems as well, may produce noise levels in excess of the Occupational Safety and Health Administration standards. The industry must consider these standards in solving its waste pollution problems.

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SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within the industrial category and/or subcategory. This average is not based upon a broad range of plants within the meat packing industry, but based upon performance levels achieved by exemplary plants.

Consideration must also be given to:

- The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;
- The size and age of equipment and facilities involved;
- The processes employed;
- The engineering aspects of the application of various types of control techniques;
- Process changes;
- Non-water quality environmental impact (including energy requirements).

Also, Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process but includes the control technologies within the process itself when the latter are considered to be normal practice within an industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of start of construction of installation of the control facilities.

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EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Based on the information contained in Sections III through VIII of this report, a determination has been made that the quality of effluent attainable through the application of the Best Pollution Control Technology Currently Available is as listed in Table 14. Approximately 25 percent of the plants with secondary treatment systems for which effluent qualities were available are meeting these standards.

Exceptional cases may arise occasionally that require adjustment. An example is a plant that processes a large volume of hides or blood from other plants in addition to its own. Adjustments can be made to the effluent guidelines on the basis of information contained in Sections IV, V, and VII for BOD_5, suspended solids, Kjeldahl nitrogen, and ammonia. The adjustments for exceptions are listed in Table 15. It is assumed that the grease, phosphorus, and nitrite-nitrate levels are unaffected.

IDENTIFICATION OF BEST POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Best Pollution Control Technology Currently Available for the meat packing industry involves biological waste treatment following in-plant solids and grease recovery steps. To assure that treatment will successfully achieve the limits specified, certain in-plant practices should be followed.

1. Reduce water use by shutting off water when not in use, practicing extensive dry clean-up before washing, and exercising strict management control over housekeeping and water use practices. Water use should be controlled at least to the following values:

Class of Plant	liters/1000 kg LWK	gal/1000 lb LWK
Simple slaughterhouse	5,416	650
Complex slaughterhouse	7,497	900
Low-processing packinghouse	8,333	1000
High-Processing packinghouse*	12,495	1500

*This is for the average mix of kill and processing of about 0.65 kg processed meat products/kg LWK.

2. In-plant recovery systems should include, as a minimum, a gravity catch basin with at least a 30-minute detention time,

3. Blood recovery should be practiced extensively, with all major bleeding areas curbed and with separate drains to blood collection tanks. If blood is coagulated, blood water should be evaporated.

Table 14. Recommended Effluent Limit Guidelines for 1 July 1977

Plant Subcategory	BOD_5 kg/1000 kg LWK	Suspended Solids kg/1000 kg LWK	Grease* mg/1	Total Kjeldahl Nitrogen as *N* kg/1000 kg LWK	Ammonia as *N* kg/1000 kg LWK	Phosphorus as *P* kg/1000 kg LWK	Nitrite-Nitrate as *N*** mg/1
Simple Slaughterhouse	0.08	0.15	Trace	0.15	0.13	0.05	0.5
Complex Slaughterhouse	0.12	0.22	Trace	0.20	0.18	0.07	0.5
Low-Processing Packinghouse	0.12	0.18	Trace	0.20	0.18	0.07	0.5
High-Processing Packinghouse†	0.24	0.31	Trace	0.34	0.31	0.11	0.5

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*The grease should never be greater than the limit of sensitivity for the analytical procedure (5 mg/1).
**For waste treatment at this level, concentration becomes limiting.
†The values for BOD and suspended solids are for average plants; *i.e.*, plants with weight ratios of processed meat products to LWK of 0.65. Adjustments can be made for high-processing packinghouses at other ratios according to the following equations:

$$\text{kg } BOD_5/1000 \text{ kg LWK} = 0.21 + 0.23\ (\gamma - 0.4)$$

$$\text{kg SS}/1000 \text{ kg LWK} = 0.28 + 0.30\ (\gamma - 0.4)$$

where γ = kg processed meat products/kg LWK.

NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further review by EPA.

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Table 15. Adjustments for Exceptions in Plant Subcategories

	BOD_5	Suspended Solids	Total Kjeldahl Nitrogen as *N*	Ammonia as *N*
Processing hides from other plants in addition to own: Defleshing, washing, curing kg/1000 kg LWK* (~lb/hide)	0.02	0.04	0.03	0.03
Processing blood from other plants in addition to own: Steam coagulation and screening, sewering water kg/1000 kg LWK*	0.02	0.04	0.03	0.03
Rendering material from other plants in addition to own: Wet and low-temperature, sewering water kg/1000 kg LWK*	0.03	0.06	0.05	0.05
Dry kg/1000 kg LWK*	0.01	0.02	0.02	0.02

*Live weight killed (LWK) represented by blood, viscera, etc., brought in from outside.

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4. Water from low temperature rendering should be evaporated.

5. Barometric leg evaporators which tend to foam, such as for tankwater evaporation, should be equipped with foam breakers and demisters.

6. Uncontaminated cooling water should not be discharged to the secondary waste treatment system.

The above in-plant practices, in addition to good housekeeping, can readily produce a raw waste load below that cited as average in Section V. With an average waste load, the following secondary treatment systems are able to meet the stated guidelines:

1. Anaerobic lagoon + aerated + aerobic (shallow) lagoon
2. Anaerobic lagoon + extended aeration
3. Anaerobic contact process + aerobic (shallow) lagoons
4. Extended aeration + aerobic (shallow) lagoons

RATIONALE FOR THE SELECTION OF BEST POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Age and Size of Equipment and Facilities

The industry has generally modernized its plants as new methods that are economically attractive have been introduced. No relationship between age of plant and effectiveness of its pollution control was found. Also, size is not a significant factor, even though plants vary widely in size. Small plants are not mechanized to the extent of the rest of the industry; still they are able to achieve at least as effective control as larger plants. This is partly because the small-scale of operation permits options for simple paunch disposal, small low-cost in-plant equipment, viscera disposal, etc., that are not open to large operations because of the immense volume of materials concerned.

Total Cost of Application in Relation to Effluent Reduction Benefits

Based on the information contained in Section VIII of this report, the industry as a whole would have to invest up to an estimated maximum of \$52.8 million to achieve the effluent limitations described. This amounts to a cost of about \$2,355 for installed capacity of one million kg (\$1,069 per one million lb) per year. The cost increase will amount to about \$0.345/1000 kg LWK (\$0.157/1000 lb LWK). Based on an estimated overall investment of \$1.7 billion, the maximum increase in investment would be about 3 percent. This also represents about 20 percent of the capital expenditures reported for 1971.[36]

NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further review by EPA.

All plants discharging to streams can implement the Best Pollution Control Technology Currently Available. The technology is not affected by different processes used in the plants.

Engineering Aspects of Control Technique Applications

The specified level of technology is practicable because it is being practiced by plants in all subcategories. The level represents the averages for 13 plants (no less than two in any category). Eight of the plants are operating within this level, and all 13 could readily reach it. The levels at several plants were verified during this study. Further, several treatment facilities are currently under design that will enable other plants to meet the limits.

Process Changes

No major in-plant changes will be needed by most plants to meet the limits specified. Many plants will need to improve their water conservation practices and housekeeping, both responsive to good plant management control.

Non-Water Quality Environmental Impact

The major impact when the option of an activated sludge-type of process is used to achieve the limits will be the problem of sludge disposal. Nearby land for sludge disposal may be necessary--in some cases a sludge digester (stabilizer) may offer a solution. Properly operated activated sludge-type systems should permit well conditioned sludge to be placed in small nearby plots for drying without great difficulty.

Another problem is the odor that emits periodically from anaerobic lagoons. Covering with a plastic sheet and burning the off-gas offers a potential solution to this problem. It is necessary to avoid high-sulfate water supplies. The odor problem can be avoided with all-aerobic systems.

It is concluded that no new kinds of impacts will be introduced by application of the best current technology.

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SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE -- EFFLUENT LIMITATIONS GUIDELINES

INTRODUCTION

The effluent limitations which must be achieved no later than July 1,1983 are not based on an average of the best performance within an industrial category, but are determined by identifying the very best control and treatment technology employed by a specific point source within the industrial category or subcategory, or by one industry where it is readily transferable to another. A specific finding must be made as to the availability of control measures and practices to eliminate the discharge of pollutants, taking into account the cost of such elimination.

Consideration must also be given to:

- The age of the equipment and facilities involved;
- The process employed;
- The engineering aspects of the application of various types of control techniques;
- Process changes;
- The cost of achieving the effluent reduction resulting from application of the technology;
- Non-water quality environmental impact (including energy requirements).

Also, Best Available Technology Economically Achievable emphasizes in-process controls as well as control or additional treatment techniques employed at the end of the production process.

This level of technology considers those plant processes and control technologies which, at the pilot plant, semi-works, or other level, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities. It is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including "no discharge"

NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further review by EPA.

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of pollutants. Although economic factors are considered in this development, the costs for this level of control are intended to be the top-of-the-line of current technology, subject to limitations imposed by economic and engineering feasibility. However, there may be some technical risk with respect to performance and with respect to certainty of costs. Therefore, some industrially sponsored development work may be needed prior to its application.

EFFLUENT REDUCTION ATTAINABLE THROUGH APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Based on the information contained in Sections III through VII of this report, a determination has been made that the quality of effluent attainable through the application of the Best Available Technology Economically Achievable is as listed in Table 16. The technology to achieve these goals is generally available, although it may not have been applied as yet to a packing plant or on a full scale.

Exceptional cases may arise occasionally that require adjustment in the guidelines--these include the processing of large quantities of materials (*e.g.*, hides and blood) from other plants in addition to their own. Adjustments can be made on the basis of the information contained in Sections IV, V, and VII for BOD_5 suspended solids, Kjeldahl nitrogen, and ammonia. The adjustments for exceptions are listed in Table 17. It is assumed that phosphorus and nitrite-nitrate levels are unaffected.

It should be pointed out that a packer should consider land disposal, and hence no discharge, for 1983. Where suitable land is available, evaporation or irrigation is an option that not only is recommended from the discharge viewpoint, but also will usually be more economical than the system otherwise required.

IDENTIFICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The Best Available Technology Economically Achievable includes that listed under the Best Practicable Control Technology Currently Available. In addition, it includes improved pretreatment, such as dissolved air flotation with pH control and chemical flocculation; an ammonia control step which may involve ammonia stripping or a nitrification-denitrification sequence; and a sand filter or equivalent following secondary treatment.

Table 16. Recommended Effluent Limit Guidelines for July 1, 1983

Plant Subcategory	BOD_5 kg/1000 kg LWK	Suspended Solids kg/1000 kg LWK	Grease* mg/l	Total Kjeldahl Nitrogen** mg/l	Ammonia as *N*** mg/l	Phosphorus as *P*** mg/l	Nitrite-Nitrate as *N*** mg/l
Simple Slaughterhouse	0.03	0.05	Trace	4	4	2	0.5
Complex Slaughterhouse	0.04	0.07	Trace	4	4	2	0.5
Low-Processing Packinghouse	0.04	0.06	Trace	4	4	2	0.5
High-Processing Packinghouse†	0.08	0.10	Trace	4	4	2	0.5

*The grease should never be greater than the limit of sensitivity for the analytical procedures (5 mg/l).

**For treatment of these components, concentration becomes limiting at these levels.

†The values for BOD_5 and suspended solids are for average plants; *i.e.*, plants with a weight ratio of processed meat products to LWK of 0.65. Adjustments can be made for high-processing packinghouses at other ratios according to the following equations:

$$\text{kg } BOD_5/1000 \text{ kg LWK} = 0.07 + 0.08\ (\gamma - 0.4)$$

$$\text{kg SS}/1000 \text{ kg LWK} = 0.09 + 0.10\ (\gamma - 0.4)$$

where γ = kg processed meat products/kg LWK.

NOTICE: These are tentative recommendations based upon information in this report and are subject to change based upon comments received and further review by EPA.

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Table 17. Adjustments for Exceptions in All Plant Subcategories - 1983

Exception	BOD_5	Suspended Solids
Processing of hides from other plants in addition to own: Defleshing, washing, curing kg/1000 kg LWK* (∿ lb/hide)	0.007	0.013
Processing of blood from other plants in addition to own: Steam coagulation and screening, sewering blood water kg/1000 kg LWK*	0.007	0.013
Rendering of material from other plants in addition to own: Wet and low temperature, sewering water kg/1000 kg LWK*	0.01	0.02
Dry kg/1000 kg LWK*	0.003	0.007

*Based on the LWK of the animals which were the source of the material.

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In-plant controls and modifications are also required to achieve the specified levels. These include:

- Segregation of grease-bearing from nongrease-bearing waste streams;
- Water control systems and procedures to reduce water use to about 50 percent of that listed in Section IX;
- Dumping of entire paunch contents for processing or outside disposal;
- Installation of shell-in-tube or comparable systems for heat exchangers and evaporators;
- Provision for collection of excess pickle and cure solutions;
- Installation of dry rendering operations;
- General elimination of viscera washing operations;
- Design for extensive use of troughs under carcass conveying lines;
- Instigation and continuous enforcement of meticulous dry clean-up and materials recovery procedures.

To reduce the water use to the required levels, several changes in normal plant operations may be required. Push-to-open valves need to be used wherever possible. Spray nozzles can be redesigned for lower water flow. Automatic valves that close when the water is not in use should be installed; examples are in carcass washers and for washdown operations. Automatic level control should be used in pen watering troughs;. Pens should be covered in areas where rain and snow are significant; wood chips should be used for bedding and dry clean-up procedures should be used.

Water reuse should be practiced, reusing water for lower quality needs. For example, carcass washing water can be reused for hog dehairing and lagoon water can be reused for cooling waters (this latter has the advantage of heating a lagoon for greater biological activity).

Dissolved solids can be minimized by changing some current practices. Excess cure solutions should be collected immediately for reuse or treatment. Concentrated brine overflow from hide curing should be segregated for salt recovery, perhaps by evaporation. Salt should not be used on floors as an antislip material; other methods are available to counteract this problem. Reducing carcass and head washing water will reduce the body fluids(and thus the salts) washed into the sewer in this step.

If suitable land is available, land disposal is the best technology; it is no discharge. Depending on the amount and type of land, the above in-plant techniques and primary treatment, including dissolved air flotation with pH control, may be adequate before discharging to the land. On the other hand, a secondary treatment system may be required before disposal to soil. Any of the systems mentioned in Section IX, or even simpler ones, are suitable. The potential problem of dissolved solids in irrigation systems can usually be avoided by minimizing dissolved solids as described above; in some cases a part of the stream may need to be treated by ion exchange.

Technology is available for small plants for no discharge via the irrigation or evaporation or other land disposal methods. For example, a septic tank can be used with a drainfield or large cesspool. Strict in-plant controls are readily managed to minimize the raw waste load.

RATIONALE FOR SELECTION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Age and Size of Equipment and Facilities

Neither size nor age are found to affect the effectiveness of end-of-process pollution control. Although in-plant control can be managed quite effectively in older plants, some of the technologies required for reducing the raw waste loads to the low levels that are possible are costly to install in older plants. For example, rerouting of sewers to segregate waste streams is both very difficult and costly.

Small plants, for the reasons discussed in Section IX, have more options for waste control than do large plants. It is anticipated that most small plants will find land disposal the best choice.

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Total Cost of Application in Relation to Effluent Reduction Benefits

Based on information contained in Section VIII of this report, the industry as a whole would have to invest up to a maximum of $107 million above that required to meet the 1977 standards. This amounts to a cost of about $4760 for installed capacity of one million kg ($2160 for one million pounds) per year. The operating cost increase will amount to about $2.10/1000 kg LWK ($0.96/1000 lb LWK). The capital investment above that to meet the 1977 standards amounts to about six percent of the total investment of the industry, estimated at about $1.7 billion. It also equals about 44 percent of the capital investment reported for the industry for 1971.

All plants discharging to streams can implement the Best Available Technology Economically Achievable; the technology is not affect by different processes used in the plants.

Engineering Aspects of Control Technique Application

The specified level of technology is achievable. It is presently being met for BOD_5 and suspended solids by at least one plant in each of three of the industry subcategories. Both medium and large plants are included. The limits are not being met, however, for ammonia, Kjeldahl nitrogen, or phosphorus; newer technology is required for these parameters. Phosphorus is effectively removed by chemical treatment in air flotation, and by filtration of the final effluent from the secondary treatment. The greatest unknown is the nitrification-denitrification step. However, nitrification has been achieved in pilot units and on a limited extent in plant operations. Denitrification has been explored successfully on laboratory and pilot scales. Ammonia stripping may require pH adjustment and later neutralization; it is a technology transferred from other industries.

Each of the identified technologies, except ammonia removal, is currently being practiced in one or more packing plants. They need to be combined, however, to achieve the limits specified.

Technology for land disposal is being used by several plants in Texas; it is being planned for a plant in Iowa. Other industries, *e.g.*, potato processing, are using it extensively. Secondary treatment and large holding ponds may be required in the North to permit land disposal over only about one-half the year. Application of technology for greatly reduced water use will facilitate land disposal.

Process Changes

In-plant changes will be needed by most plants to meet the limits specified. These were outlined in the "Identification of the Best Available Technology Economically Achievable", above.

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Non-Water Quality Impact

The major impact will be when the option of land disposal is chosen. There is a potential, but unknown, long-term effect on the soil of irrigation of packing plant wastes. To date, impacts have been generally obviated by careful water application management.

Otherwise, the effects will essentially be those described in Section IX, where it was concluded that no new kinds of impacts will be introduced.

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SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

The effluent limitations that must be achieved by new sources are termed performance standards. The New Source Performance Standards apply to any source for which construction starts after the publication of the proposed regulations for the Standards. The Standards are determined by adding to the consideration underlying the identification of the Best Practicable Control Technology Currently Available a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, New Source Performance Standards are based on an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives are considered. However, the end result of the analysis is to identify effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed. A further determination made is whether a standard permitting no discharge of pollutants is practicable.

Consideration must also be given to:

- Operating methods;
- Batch, as opposed to continuous, operations;
- Use of alternative raw materials and mixes of raw materials;
- Use of dry rather than wet processes (including substitution of recoverable solvents for water);
- Recovery of pollutants as by-products

EFFLUENT REDUCTION ATTAINABLE FOR NEW SOURCES

The effluent limitation for new sources is the same as that for the Best Practicable Control Technology Currently Available (see Section IX). This limitation is readily achievable in newly constructed plants. However, the guidelines for the Best Available Technology Economically Achievable should be kept in mind; it may be a practical approach to design a plant which approaches the 1983 guidelines. Consideration should also be given to land disposal, which would be no discharge; in many cases this will be the most attractive and economical option.

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IDENTIFICATION OF NEW SOURCE CONTROL TECHNOLOGY

The technology is the same as that identified as the Best Practicable Control Technology Currently Available (see Section IX). However, certain steps that will be necessary to meet the 1983 guidelines should be considered and, where possible, incorporated. These include:

- In-Plant Controls
  - Segregation of grease-bearing streams from nongrease-bearing waste streams;
  - Water control systems and procedures to reduce water use considerably below those cited in Section IX;
  - Dumping of entire paunch contents for processing or outside disposal;
  - Installation of shell-in-tube or comparable systems for heat exchangers and evaporators;
  - Provision for collection of excess cure solutions;
  - Installation of dry rendering operations;
  - General elimination of viscera washing operations;
  - Design for extensive use of troughs under carcass conveying lines;
  - Installation of dissolved air flotation, with provision for a second unit to be added later;
  - Instigation and continuous enforcement of meticulous dry clean-up and materials recovery procedures.
- End-of-Process Treatment
  - Land disposal (evaporation, irrigation) wherever possible; this should be a prime consideration;
  - Sand filter or microscreen for effluent secondary treatment;
  - Solid waste drying, composting, upgrading of protein content.

PRETREATMENT REQUIREMENTS

No constituents of the effluent discharge from a plant within the meat packing industry have been found which would interfere with, pass through, or otherwise be incompatible with a well designed and operated publicly owned activated sludge or trickling filter wastewater treatment plant. The effluent, however, should have passed through materials recovery (primary treatment) in the plant to remove settleable solids and a large part of the grease. The concentration of pollutants acceptable to the treatment plant is dependent on the relative sizes of the treatment facility and the packing plant, and must be established by the treatment facility. It is possible that grease remaining in the packing plant effluent will cause difficulty in the treatment system; trickling filters appear to be particularly sensitive. A concentration of 100 mg/l is often cited as a limit, and this requires an effective air flotation system in addition to the usual catch basins. If the waste strength in terms of BOD_5 must be further reduced, various components of secondary treatment systems can be used--anaerobic contact, trickling filter, aerated lagoons, etc., as pretreatment.

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SECTION XII

ACKNOWLEDGMENTS

This Program was directed by Dr. E.E. Erickson; Project Engineers were Messrs John P. Pilney and Robert J. Reid. Special assistance was provided by North Star staff members: Mrs. Janet McMenamin, Messrs R.h. Forester and A.J. Senechal, and Drs. L.W. Rust and L.L. Altpeter.

The contributions and advice of Mr. A.J. Steffen of Purdue University, Mr. W.H. Miedaner of Globe Engineering, Mr. John Macon, and Dr. H.O. Halverson are gratefully acknowledged. Also, James and Paula Wells of Bell, Galyardt, and Wells made invaluable contributions in numerous telephone conversations.

Special thanks are due Mr. Jeffrey D. Denit, Effluent Guidelines Division for his guidance in the direction of the program and for his invaluable help in carrying out all aspects of the research program. Also, Mr. Richard Watkins of the same office was most helpful.

The cooperation of the meat packing industry is greatly appreciated. The American Meat Institute, the National Independent Meat Packers Association and the Western States Meat Packers Association deserve special mention, as do many companies that provided information and cooperated in plant visits and sampling programs.

Various Regional EPA offices were most helpful in arranging for site visits. The plant data provided by Dr. Wm. Garner and Mr. Ron Wantock of the Region VII office in Kansas City were especially appreciated.

The help of Dr. Dwight Ballinger of EPA in Cincinnati in establishing sampling and testing procedures used for the field verification studies was also appreciated.

Various offices in the United States Department of Agriculture, especially the Meat and Poultry Inspection Division, and many state and local agencies were also most helpful. Among these, special mention should go to the Iowa Water Quality Commission, the state of Ohio Environmental Protection Administration, and the City and County of Denver Water and Sanitation District.

Special thanks also go to Mr. Ross Frazier of the Minnesota Department of Health for periodically running duplicate sets of BOD_5 analyses.

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SECTION XIV

GLOSSARY

Abattoir: A slaughterhouse.

"Act": The Federal Water Pollution Control Act Amendments of 1972.

Activated Sludge Process: Aerated basin in which wastewaters are mixed with recycled biologically active sludge for periods of about six hours.

Aerated: The introduction and intimate contacting of air and a liquid by mechanical means such as stirring, spraying, or bubbling.

Aerobic: Living or occurring only in the presence of dissolved or molecular oxygen.

Algae: Major group of lower plants, single and multi-celled, usually aquatic and capable of synthesizing their foodstuff by photosynthesis.

Ammonia Stripping: Ammonia removal from a liquid, usually by intimate contacting with an ammonia-free gas such as air.

Anaerobic: Living or active only in the absence of free oxygen.

Bacteria: Primitive plants, generally free of pigment, which reproduce by dividing in one, two, or three planes. They occur as single cells, chains, filaments, well-oriented groups or amorphous masses. Most bacteria do not require light, but a limited number are photosynthetic and draw upon light for energy. Most bacteria are heterotrophic (utilize organic matter for energy and for growth materials), but a few are autotrophic and derive their bodily needs from inorganic materials.

Bedding: Material, usually organic, which is placed on the floor surface of livestock buidlings for animal comfort and to absorb urine and other liquids, and thus promote cleanliness in the building.

Biological Oxidation: The process whereby, through the activity of living organisms in an aerobic environment, organic matter is converted to more biologically stable matter.

Biological Stabilization: Reduction in the net energy level of organic matter as a result of the metabolic activity of organisms, so that further biodegradation is very slow.

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Biological Treatment: Organic waste treatment in which bacteria and/or biochemical action are intensified under controlled conditions.

Blood Water (Serum): Liquid remaining after coagulation of the blood.

Blowdown: A discharge of water from a system to prevent a buildup of dissolved solids in a boiler.

BOD_5: A measure of the oxygen consumption by aerobic organisms over a 5 day test period at 20°C. It is an indirect measure of the concentration of biologically degradable material present in organic wastes contained in a waste stream.

Capacity-Cost Relationship: The variation of investment cost for equipment or a total plant as a function of its size or capacity.

Capacity-Ratio Exponent (n): In capacity-cost relationships, cost usually increases at a slower rate than capacity. The ratio of capacities of two different size systems (C_1 and C_2) is therefore raised to an exponential power (n) in estimating investment cost at one capacity, given the cost at a different capacity; *e.g.*, $(C_1/C_2)^n$ (cost of C_2) = Cost of C_1.

Carbon Adsorption: The separation of small waste particles and molecular species, including color and odor contaminants, by attachment to the surface and open pore structure of carbon granules or powder. The carbon is usually "activated", or made more reactive by treatment and processing.

Category and Subcategory: Divisions of a particular industry which possess different traits that affect raw wastewater quality.

Chemical Precipitation: A waste treatment process whereby substances dissolved in the wastewater stream are rendered insoluble and form a solid phase that settles out or can be removed by flotation techniques.

Chitterling: Large intestine of hogs.

Clarification: Process of removing undissolved materials from a liquid. Specifically, removal of solids either by settling or filtration.

Clarifier: A settling basin for separating settlable solids from wastewater.

Cm: Centimeter.

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Coagulant: A material, which, when added to liquid wastes or water, creates a reaction which forms insoluble floc particles that adsorb and precipitate colloidal and suspended solids. The floc particles can be removed by sedimentation. Among the most common chemical coagulants used in sewage treatment are ferric sulfate and alum.

COD-Chemical Oxygen Demand: An indirect measure of the biochemical load imposed on the oxygen resource of a body of water when organic wastes are introduced into the water. A chemical test is used to determine COD of wastewater.

Composting: Present-day composting is the aerobic, thermophilic decomposition of organic wastes to a relatively stable humus. The resulting humus may contain up to 25% dead or living organisms and is subject to further, slower decay but should be sufficiently stable not to reheat or cause odor or fly problems. In composting, mixing and aeration are provided to maintain aerobic conditions. The decomposition is done by aerobic organisms, primarily thermophilic bacteria, actinomycetes and fungi. Heat generated provides the higher temperatures the microorganisms require.

Contamination: A general term signifying the introduction into water of microorganisms, chemical, organic, or inorganic wastes, or sewage, which renders the water unfit for its intended use.

Cracklings: The crisp solid residue left after the fat has been separated from the fibrous tissue in rendering lard or tallow.

Curing: A process, method, or treatment involving aging, seasoning, washing, drying, injecting, heating, smoking or otherwise treating a product, especially meat, to preserve, perfect, or ready it for use.

Denitrification: The process involving the facultative conversion by anaerobic bacteria of nitrates into nitrogen and nitrogen oxides.

Digestion: Though "aerobic" digestion is used, the term digestion commonly refers to the anaerobic breakdown of organic matter in water solution or suspension into simpler or more biologically stable compounds or both. Organic matter may be decomposed to soluble organic acids or alcohols, and subsequently converted to such gases as methane and carbon dioxide. Complete destruction of organic solid materials by bacterial action alone is never accomplished.

Dissolved Air Flotation: A process involving the compression of air and liquid, mixing to super-saturation, and releasing the pressure to generate large numbers of minute air bubbles. As the bubbles rise to the surface of the water, they carry with them small particles that they contact. The process is particularly effective for grease removal.

Dissolved Oxygen: The oxygen dissolved in sewage, water, or other liquid, usually expressed as milligrams per liter or as percent of saturation.

Effluent: Liquid which flows from a containing space or process unit.

Electrodialysis: A physical separation process which uses membranes and applied voltages to separate ionic species from water.

Eutrophication: Applies to lake or pond - becoming rich in dissolved nutrients, with seasonal oxygen deficiencies.

Evapotranspiration: Loss of water from the soil, both by evaporation and by transpiration from the plants growing thereon.

Extended Aeration: A form of the activated sludge process except that the retention time of wastewaters is one to three days.

Facultative Bacteria: Bacteria which can exist and reproduce under either aerobic or anaerobic conditions.

Facultative Decomposition: Decomposition of organic matter by facultative microorganisms.

Feed: A material which flows into a containing space or process unit.

Filtration: The process of passing a liquid through a porous medium for the removal of suspended material by a physical straining action.

Floc: A mass formed by the aggregation of a number of fine suspended particles.

Flocculation: The process of forming larger masses from a large number of finer suspended particles.

Floc Skimmings: The flocculent mass formed on a quieted liquid surface and removed for use, treatment, or disposal.

Full-Line Plant: A packinghouse that slaughters and produces a substantial quantity of processed meat products.

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Green Hides: Animal hides that may have been washed and trimmed, but have not been treated, cured, or processed in any manner.

Hydrolyzing: The reaction involving the decomposition of organic materials by interaction with water in the presence of acids or alkalies. Hog hair and feathers, for example, are hydrolyzed to a proteinacous product that has some feed value.

Influent: A liquid which flows into a containing space or process unit.

Ion Exchange: A reversible chemical reaction between a solid and a liquid by means of which ions may be interchanged between the two. It is in common use in water softening and water deionizing.

Kg: Kilogram or 1000 grams, metric unit of weight.

Kjeldahl Nitrogen: A measure of the total amount of nitrogen in the ammonia and organic forms in wastewater.

KWH: Kilowatt-hours, a measure of total electrical energy consumption.

Lagoon: An all-inclusive term commonly given to a water impoundment in which organic wastes are stored or stabilized or both.

Locker Plant: Very small meat packing plant that slaughters animals and may produce processed meat products, it stores meat in frozen form for its customers.

LWK: Live weight killed, a measure of production in a meat packing plant, commonly expressed in thousands of kilograms or pounds per day.

M: Meter, metric unit of length.

Mm: Millimeter = 0.001 meter.

Mg/1: Milligrams per liter; approximately equals parts per million; a term used to indicate concentration of materials in water.

MGD or MGPD: Million gallons per day.

Microstrainer/microscreen: A mechanical filter consisting of a cylindrical surface of metal filter fabric with openings of 20-60 micrometers in size.

Municipal Treatment: A city or community-owned waste treatment plant for municipal and, possibly, industrial waste treatment.

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New Source: Any building, structure, facility, or installation from which there is or may be a discharge of pollutants and whose construction is commenced after the publication of the proposed regulations.

Nitrate, Nitrite: Chemical compounds that include the NO_3^- (nitrate) and NO_2^- (nitrite) ions. They are composed of nitrogen and oxygen, are nutrients for growth of algae and other plant life, and contribute to eutrophication.

Nitrification: The process of oxidizing ammonia by bacteria into nitrites and nitrates.

No Discharge: No discharge of effluents to a water course. A system of land disposal with no run-off or total recycle of the wastewater may be used to achieve it.

Non-Water Quality: Thermal, air, noise and all other environmental parameters except water.

Offal: The parts of a butchered animal removed in eviscerating and trimming that may be used as edible products or in production of inedible by-products.

Off-Gas: The gaseous products of a process that are collected for use or more typically vented directly, or through a flare, into the atmosphere.

Organic Content: Synonymous with volatile solids except for small traces of some inorganic materials such as calcium carbonate which will lose weight at temperatures used in determining volatile solids.

Oxidation Lagoon: Synonymous with aerobic or aerated lagoon.

Oxidation Pond: Synonymous with aerobic lagoon.

Packinghouse: Meat packing plant that slaughters animals and also produces manufactured meat products such as weiners, sausage, canned meats, cured products, etc.

Paunch: The first stomach, or rumen of cattle, calves, and sheep. The contents are sometimes included in the term.

Paunch manure: Contents of the paunch.

Pens (Holding Pens): The area or building for holding live animals at meat packing plants prior to slaughter.

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<u>Percolation</u>: The movement of water through the soil profile.

<u>pH</u>: A measure of the relative acidity or alkalinity of water. A pH of 7.0 indicates a neutral condition. A greater pH indicates alkalinity and a lower pH indicates acidity. A one unit change in pH indicates a ten fold change in the concentration of hydrogen ion.

<u>Pickle Solution</u>: A water solution that may contain salt, sugar, curing or pickling agents, preservatives, and other chemicals. It is used for injection or soaking of meat to prepare finished meat products.

<u>Pollutant</u>: A substance which taints, fouls, or otherwise renders impure or unclean the recipient system.

<u>Pollution</u>: The presence of pollutants in a system sufficient to degrade the quality of the system.

<u>Polishing</u>: Final treatment stage before discharge of effluent to a water course, carried out in a shallow, aerobic lagoon or pond, mainly to remove fine suspended solids that settle very slowly. Some aerobic microbiological activity also occurs.

<u>Polyelectrolyte Chemicals</u>: High molecular weight substances which dissociate into ions when in solution; the ions either being bound to the molecular structure or free to diffuse throughout the solvent, depending on the sign of the ionic charge and the type of electrolyte. They are often used as flocculating agents in wastewater treatment, particularly along with dissolved air flotation.

<u>Ponding</u>: A waste treatment technique involving the actual holdup of all wastewaters in a confined space with evaporation and percolation the primary mechanisms operating to dispose of the water.

<u>Ppm</u>: Parts per million, a measure of concentration, expressed currently as mg/l.

<u>Pretreatment</u>: Wastewater treatment located on the plant site and upstream from the discharge to a municipal treatment system.

<u>Primary Waste Treatment</u>: In-plant by-product recovery and wastewater treatment involving physical separation and recovery devices such as catch basins, screens,and dissolved air flotation.

<u>Processing</u>: Manufacture of sausages, hams, canned meats, smoked meat products, etc., from fresh meat cuts or ground meats.

Process Water: All water that comes into direct contact with the raw materials, intermediate products, final products, by-products, or contaminated waters and air.

Raceway: Circular shaped vat containing brine, agitated by a paddle wheel and used for brine curing of hides.

Raw Waste: The wastewater effluent from the in-plant primary waste treatment system.

Recycle: The return of a quantity of effluent from a specific unit or process to the feed stream of that same unit. This would also apply to return of treated plant wastewater for several plant uses.

Rendering: Separation of fats and water from tissue by heat or physical energy.

Return-on-Assets (ROA): A measure of potential or realized profit as a percent of the total assets (or fixed assets) used to generate the profit.

Return-on-Investment (ROI): A measure of potential or realized profit as a percentage of the investment required to generate the profit.

Reuse: Water reuse, the subsequent use of water following an earlier use without restoring it to the original quality.

Reverse Osmosis: The physical separation of substances from a water stream by reversal of the normal osmotic process; *i.e.*, high pressure, forcing water through a semi-permeable membrane to the pure water side leaving behind more concentrated waste streams.

Riprap: A foundation or sustaining wall usually of stones and brush, so placed on an embankment or a lagoon to prevent erosion.

Rotating Biological Contractor: A waste treatment device involving closely spaced light-weight disks which are rotated through the wastewater allowing aerobic microflora to accumulate on each disk and thereby achieving a reduction in the waste content.

Rumen: The large first compartment of the stomach of a ruminant; see paunch.

Sand Filter: A filter device incorporating a bed of sand that, depending on design, can be used in secondary or tertiary waste treatment.

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Secondary Processes: Edible and Inedible rendering and the processing of blood, viscera, hide, and hair.

Sedimentation Tank: A tank or basin in which a liquid (water, sewage, liquid manure) containing settleable suspended solids is retained for a sufficient time so part of the suspended solids settle out by gravity. The time interval that the liquid is retained in the tank is called "detention period". In sewage treatment, the detention period is short enough to avoid putrefaction.

Secondary Treatment: The waste treatment following primary in-plant treatment, typically involving biological waste reduction systems.

Semipermeable Membrane: A thin sheet-like structure which permits the passage of solvent but is impermeable to dissolved substances.

Settling Tank: Synonymous with "Sedimentation Tank".

Sewage: Water after it has been fouled by various uses. From the standpoint of source it may be a combination of the liquid or water-carried wastes from residences, business buildings, and institutions, together with those from industrial and agricultural establishments, and with such groundwater, surface water, and storm water as may be present.

Shock Load: A quantity of waste water or pollutant that greatly exceeds the normal discharged into a treatment system, usually occuring over a limited period of time.

Slaughterhouse: Meat packing plant that slaughters animals to produce fresh meats. It does not produce manufactured meat products such as weiners, sausage, canned meats, etc.

Sludge: The accumulated settled solids deposited from sewage or other wastes, raw or treated, in tanks or basins, and containing more or less water to form a semi-liquid mass.

Slurry: A solids-water mixture, with sufficient water content to impart fluid handling characteristics to the mixture.

Stick or Stickwater: The concentrated (thick) liquid product from evaporating the tankwater from rendering operations. It is added to solids and may be further dried for feed ingredients.

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Stoichiometric Amount: The amount of a substance involved in a specific chemical reaction, either as a reactant or as a reaction product.

SS: Suspended solids; solids that either float on the surface of, or are in suspension, in water; and which are largely removable by laboratory filtering as in the analytical determinate of SS content of wastewater.

Surface Water: The waters of the United States including the territorial seas.

Tankwater: The water phase resulting from rendering processes, usually applied to wet rendering.

Tertiary Waste Treatment: Waste treatment systems used to treat secondary treatment effluent and typically using physical-chemical technologies to effect waste reduction. Synonymous with "Advanced Waste Treatment".

Total Dissolved Solids (TDS): The solids content of wastewater that is soluble and is measured as total solids content minus the suspended solids.

Tripe: The edible product prepared from the walls of the paunch or rumen.

Viscera: All internal organs of an animal that are located in the great cavity of the trunk proper.

Zero Discharge: The discharge of no pollutants in the wastewater stream of a plant that is discharging into a receiving body of water.

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CONVERSIONS

Multiply (English Units)		by		To Obtain (Metric Units)
English Unit	Abbreviation	Conversion	Abbreviation	Metric Unit
acre	ac	0.405	ha	hectares
acre-feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram-calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig + 1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meters

*Actual conversion, not a multiplier