DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

RENDERER
SEGMENT OF THE
MEAT PRODUCTS AND RENDERING PROCESSING POINT SOURCE CATEGORY

Russell E. Train
Administrator

James L. Agee
Assistant Administrator for Water and
Hazardous Materials

Allen Cywin
Director, Effluent Guidelines Division

Jeffery D. Denit
Project Officer

January, 1975

Effluent Guidelines Division
Office of Water and Hazardous Materials
U. S. Environmental Protection Agency
Washington, D. C. 20460

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $2.70

DEVELOPMENT DOCUMENT

for

EFFLUENT LIMITATIONS GUIDELINES

and

NEW SOURCE PERFORMANCE STANDARDS

for the

RENDERER
SEGMENT OF THE
MEAT PRODUCTS AND RENDERING PROCESSING POINT SOURCE CATEGORY

Russell E. Train
Administrator

James L. Agee
Assistant Administrator for Water and
Hazardous Materials

Allen Cywin
Director, Effluent Guidelines Division

Jeffery D. Denit
Project Officer

January, 1975

Effluent Guidelines Division
Office of Water and Hazardous Materials
U. S. Environmental Protection Agency
Washington, D. C. 20460

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $2.70

ABSTRACT

This document presents the findings of an extensive study of the renderer segment of the meat products industry by the Environmental Protection Agency (EPA) for the purpose of developing effluent limitations guidelines, standards of performance for new sources, and pretreatment standards for the industry, to implement Sections 301, 304(b), 306 and 307(b) and (c) of the Federal Water Pollution Control Act Amendments of 1972 (the "Act").

The rendering plants included in the study were those plants specifically processing animal by-products at an independent plant (i.e., a plant located, operated and managed separately from meat or poultry slaughtering and packing plants). Plants processing fish by-products and rendering operations carried out as an adjunct to meat packing plants 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 regulations are based upon efficient biological treatment for existing sources to discharge into navigable water bodies by July 1, 1977, and for new source performance standards. This technology is represented by anaerobic plus aerobic lagoons, or their equivalent. The recommendation for July 1, 1983, is for biological treatment and in-plant control, as represented by in-plant containment and separate treatment or recycle of high strength waste waters, and an advanced waste water treatment process (i.e., nitrification and/or filtration) added to the 1977 technology. When suitable land is available, land disposal with no discharge may be a more economical option, particularly for plants in rural locations.

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

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

FIGURES

FIGURES (Continued)

TABLES

TABLES (Continued)

SECTION I

CONCLUSIONS

The study presented herein is a part of an overall investigation of the meat processing (no slaughtering of animals accomplished in the plants) and rendering (accomplished independent of slaughterhouses, packinghouses, and poultry processors) industry segments of the meat products and rendering processing point source category.

Because of evidence developed early in the investigation, it became apparent that meat processing operations differed materially from rendering operations as to raw materials, processes, products, and other factors. As a result, an initial categorization which split the two industry segments was utilized to facilitate a thorough analysis with a separate study report for each, with the rendering industry segment presented herein. Unless otherwise specifically designated, all subsequent discussions of the rendering industry, or references to the rendering industry, deal with the independent rendering operation or plants not included as a part of livestock or poultry slaughtering, packing, or processing.

A conclusion of this study is that the rendering industry constitutes a single subcategory. Using BOD5 as the basis for the analysis, the variables of raw material, processing methods, plant age and size, water use, and treatability of wastes were analyzed and found to demonstrate this conclusion.

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

The 1977 discharge limits for BOD5, suspended solids, and grease, representing the average of the best treatment systems in the rendering industry, are currently being met by a number of plants included in the survey. Several of the plants meeting the limits discharge waste water to receiving waters, while a number of other plants, particularly small plants, meet the limits by irrigation or impoundment of waste waters. These limits, plus limits on pH and fecal coliforms can be met by 1977. The same limits plus limitations on ammonia can be met by new sources. The ammonia standard for new sources coincides with the performance already achieved by plants with the best treatment systems. It is estimated that there will be about $2.6 million in capital costs required to achieve the 1977 limits by the industry.

For 1983, effluent limits were determined on the basis of best available technology economically achievable in the industry for

BOD_5, suspended solids, ammonia, oil and grease, pH, and fecal coliforms.

It is estimated that the cost to achieve the 1983 limits by the industry will be $6.75 million. The 1977 cost for the industry represents about 8 percent, and the 1983 cost approximately 22 percent of the $30 million spent by the industry in 1972 on new capital expenditures.

It is also concluded that, where suitable and adequate land is available, land disposal is a more economical option for meeting the effluent limitations.

SECTION II

RECOMMENDATIONS

Limitations recommendations for discharge to navigable waters by rendering plants for July 1, 1977, are based on the characteristics of well-operated biological treatment plants being used by the industry. The limitations are for 5-day biochemical oxygen demand (BOD_5), total suspended solids, oil and grease, and fecal coliform. These limitations are 0.17 kg BOD_5/kkg raw material (RM); 0.21 kg TSS/kkg RM; 0.10 kg grease/kkg RM; and 400 counts fecal coliform/100 ml. Adjustments in the BOD_5 and TSS limitations are provided for plants curing hides. In all cases, pH is established at a range of 6.0 to 9.0.

Recommended New Sources Standards include the 1977 limitations plus limitations on ammonia (NH_3). The additional limitations are also based on the performance characteristics of well-operated biological treatment plants. The new source standard for ammonia is recommended at 0.17 kg/kkg RM.

Limitations recommended for the industry for 1983 are more stringent and are based upon the performance characteristics of the best operated biological treatment systems being used to treat rendering waste waters. These limitations include the same pollutant parameters as included in the new source standards. The 1983 limitations are: 0.07 kg BOD_5/kkg RM; 0.10 kg TSS/kkg RM; 0.05 kg grease/kkg RM; and 0.02 kg NH_3 as N/kkg RM. Again, there is established a pH range of 6.0 to 9.0 and a fecal coliform count of 400/100 ml. Also, adjustments in the BOD_5 and TSS limitations are provided for plants curing hides; however, these adjustments are smaller than those for the 1977 limitations.

The limitations summarized above are applicable as an average of daily values for any period of 30 consecutive days. Recommended daily maximum limitations are based on a variability factor of 2.0; or daily limitations are recommended as 2.0 times the average for 30 consecutive days.

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 301(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 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 independent renderers subcategory of the meat products point source category designated in Section 306.

Section 306 of the Act requires the Administrator, within 1 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 performance 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 based upon best available demonstrated technology applicable to new sources of the rendering segment of the meat products and rendering processing point source category, which was included in the list published January 16, 1973.

Section 307(c) of the Act requires the Administrator to promulgate pretreatment standards for new sources at the same time that standards of performance for new sources are promulgated pursuant to Section 306. Similarly, Section 307(b) requires the establishment of pretreatment standards for pollutants introduced into publicly owned treatment works. The regulations set forth pretreatment standards for new sources and existing sources pursuant to Sections 307(b) and (c) of the Act for the renderer segment of the meat products and rendering processing point source category.

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

The effluent limitations guidelines and standards of performance set forth 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, equipment, age, size, waste water 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 source of waste and waste waters 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 waste waters which should be subject to effluent limitations guidelines and standards of performance were identified. (See Section VI.) The result of this analysis was that there was no reason for separate limitations and standards for different segments of the industry.

The full range of control and treatment technologies existing within the point source 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, and 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 were 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 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. The data for identification and analysis 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 National Renderers Association (NRA); qualified technical consultants; and on-site visits and interviews at several exemplary rendering plants in various areas of the United States. Questionnaires provided information on 49 plants; 12 of these were also included in the field sampling survey. Two other plants that did not submit questionnaires were also sampled and were included in the "questionnaire" data base. Thus, the total number of plants included in this study was 51, or about 11 percent of the rendering industry. All principal 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.

The reviews and analyses of data described above were performed using accepted methodology. The "questionnaire" data base (51 total plants) served as the principal source of information for all analyses. Field verification sampling data was used principally in support of the derivation of effluent limitations. Subjective information (plant practices, processes, equipment, etc.) gained from the site visits was also used to complement industry submissions. Because of the apparently representative nature of the industry questionnaire information, these data were used for analyses to categorize and characterize the industry processes, waste water discharges, and operating conditions. The analyses involved both rigorous mathematical procedures (using computer statistical methods) and subjective judgments and observations using experience from site visits, consultant comments, information from trade publications, and similar sources as more fully described in Sections IV and V. Similarly, cost information was developed on the basis of data supplied by plants in the industry with supporting information as developed for other segments of the meat products industry.

The effluent limitations and standards of performance were derived from available data on the actual performance of existing plants. Limitations for 1977 (BPCTCA) were derived as the average of the performance for the best plants. (Some data were excluded due to plant malfunctions, etc., as noted in Section IX.) The same procedure was used to establish new source performance standards (NSPS); limitations for 1983 were derived on the basis of the very best performance achieved by plants in the industry (between 3 and 5 plants depending upon the availability of data for all limited parameters).

Table 1. Inedible Tallow and Greases: Use, By-Products, 1960-1970[4]

Year Beginning October	Soap	Animal Feeds	Fatty Acids	Lubricants and Similar Oils	Other	Exports	Total
	Million Pounds						
1960	732	443	351	70	151	1769	3516
1961	702	732	402	79	177	1710	3802
1962	688	774	433	78	151	1738	3862
1963	660	861	478	91	230	2338	4658
1964	690	714	530	102	203	2155	4394
1965	649	855	575	107	208	1962	4356
1966	665	972	547	98	283	2214	4779
1967	631	990	576	89	291	2212	4789
1968	637	1061	585	98	289	2009	4679
1969	601	1093	610	97	320	2051	4772
1970*	615	1140	568	89	214	2591	5217

*Preliminary data; based on census reports.

GENERAL DESCRIPTION OF THE INDUSTRY

The rendering industry falls within Industry No. 2077, Animal and Marine Fats and Oils.[1] SIC 2077 includes;

> "Establishments primarily engaged in manufacturing animal oils, including fish oil and other marine animal oils and fish and animal meal; and those rendering inedible grease and tallow from animal fat, bones, and meat scraps. Establishments primarily engaged in manufacturing lard and edible tallow and stearin are classified in Group 201; those refining marine animal oils for medicinal purposes in Industry 2833; and those manufacturing fatty acids in Industry 2899.

"Fish liver oils, crude	Oil, neat's-foot
Fish meal	Oils, animal*
Fish oil and fish oil meal	Oils, fish and marine animal: herring, menhaden, whale (refined), sardine
Meat meal and tankage*	Rendering plants, grease and tallow*
Neat's-foot oil	Stearin, animal: Inedible"
Oil and meal, fish	

*The rendering industry covered in this report includes only meat-meal and tankage; oils, animal; and rendering plants, grease and tallow.

Rendering is a process to convert animal by-products into fats, oils, and proteinaceous solids. Heat is used to melt the fats out of tissue, to coagulate cell proteins and to evaporate the raw material moisture. Rendering is universally used in the production of proteinaceous meals from animal blood, feathers, bones, fat tissue, meat scraps, inedible animal carcasses, and animal offal. The rendering industry consists of off-site or independent renderers and on-site or captive renderers. The independent renderers reprocess discarded animal materials such as fats, bones, hides, feathers, blood, and offal into saleable by-products, almost all of which are inedible for human consumption, and "dead stock" (whole animals that die by accident or through natural causes). Captive rendering operations, on the other hand, are usually conducted as an adjunct to meat packing or poultry processing operations and are housed in a separate building on the same premises. Consequently, captive renderers produce almost all of the edible lard and tallow made from animal fats in addition to producing inedible by-products. Two usual process differences between rendering edible or inedible materials are the composition and freshness of the materials, and, second, the process used. Edible rendering requires fresh (inspected) fats and usually is conducted by a wet or low temperature process. These processes do not evaporate raw material moisture during cooking, and therefore require an additional step to separate water from the edible products. Inedible rendering is accomplished exclusively by dry rendering where the raw material is cooked with no addition of steam or water.

Rendering of animal by-product materials is one of the original recycling industries; it began as an industry over 150 years ago. During the past two decades the production of inedible tallow and grease (the major products of rendering plants) has increased from 2.3 billion pounds, worth $150 million in early 1950, to an estimated 5.4 billion pounds, worth $430 million for 1971-72.[2] This increase is largely caused by an expansion in livestock and poultry production. The increase resulting from increased plant efficiency is negligible.

The United States is the world's leading producer, consumer, and exporter of tallow and grease. Since the early 1950's, the United States has accounted for 55 to 60 percent of the world's tallow and grease output. The export market has been the largest single outlet for inedible tallow and grease, consuming about 50 percent of the domestic output. Table 1 lists the various markets for inedible tallows and greases and shows the current use of tallow and grease in both soap and fatty acid manufacturing to be about one-half of that for animal feeds. It also shows that between 1960 and 1970 there was a slight decrease in their use for soap manufacturing, which is more than offset by a 2.5 times increase in their use for animal feeds.

Renderers send out trucks daily on regular routes to collect discarded fat and bone trimmings, meat scraps, bone and offal, blood, feathers, and entire animal carcasses from a variety of sources: Butcher shops, supermarkets, restaurants, poultry processors, slaughterhouses and meat packing plants, farmers, and ranchers. Each day the rendering industry, including both on-site and independent plants, processes more than 80 million pounds of animal fat and bone materials, in addition to dead stock, that would otherwise have to be suitably disposed of to prevent its becoming a national public health problem.[3]

The independent renderer pays for the raw material he collects and he manufactures usable products, such as tallow for soap and for derivatives for the chemical industry, and meal and inedible grease for animal and poultry feed. Because of the perishable nature of the raw material collected, renderers must process the material without delay. This normally restricts the collection area to a 150-mile radius around the plant. However, if the renderer is only picking up restaurant grease, which is more stable, it is possible that he may travel greater distances.

Renderers are located in both urban and rural areas. The urban renderer normally has more modern equipment, shorter routes for pickup of raw materials, a better grade of raw materials, and high production rates that enable his operation to run more efficiently. The urban renderer usually has access to municipal sewers and has the option of either providing his own treatment system or buying into the municipal plant. The country renderer, on the other hand, normally has older equipment, longer routes, picks up dead stock, and has a lower capacity system. The location of the rural renderer does not permit him to tie into a sewer facility and, therefore, he normally has his own waste treatment facilities.

Figure 1 provides a general idea of the distribution of all rendering plants throughout the country; it includes both edible and inedible rendering plants, on-site as well as independent. Also, fish rendering plants are included in the state totals. Judging from Figure 1, the number of rendering facilities is greatest in the central states. However, the National Renderers Association indicated that production from facilities along the Atlantic seaboard equals that from facilities located between the Appalachian Mountains and the Rockies.

Data from the 1967 Census of Manufactures[4] is summarized in Table 2. These data provide some information regarding the size of existing rendering plants. However, since the data reflect only 69 percent of the industry, the distribution of plant sizes should be considered only approximate. Plants range in size from small operations employing one to four persons with annual sales of about $100,000 to large operations employing over 100 persons with sales from $5 to $10 million. An average plant could be characterized as employing 23 people and having annual sales of approximately $1 million. Judging from our recent observations of the industry, it would appear that these figures are no longer correct, since many companies have consolidated their plants and installed more modern gear with larger capacities. However, because size was measured not in terms of products, but rather by amount of raw material handled, it is difficult to make an exact comparison. In any event, based on the assumption that the average size plant is as found in this study--a plant handling 59,000 kg (130,000 pounds) per day of raw material--and based on average yield values and on current market prices, the average plant would have annual sales of about $1.5 million.

As of 1968, there were 770 firms operating in 850 facilities engaged in the rendering of inedible animal matter.[2] Of this number, some 460 were operated by independent renderers (off-site), 330 were controlled by the meat packing and poultry industries (on-site), and the remainder were owned by a variety of concerns. It is estimated that some 275, or about 83 percent, of the plants controlled by the meat industry are also involved in edible rendering. The industry estimates that the number of independent renderers is now around 350.

PROCESS DESCRIPTION

A general flowsheet of the processes of a typical inedible rendering plant is shown in Figure 2. (A general flowsheet for edible rendering would be similar.) The bulk material (offal, bones, and trimmings) collected by renderers is normally dumped into a pit from which it is conveyed to a grinder. Liquid wastes collected on the bottom of the pits are usually sewered, although in a few cases the liquid, if not an excessive amount, is pumped

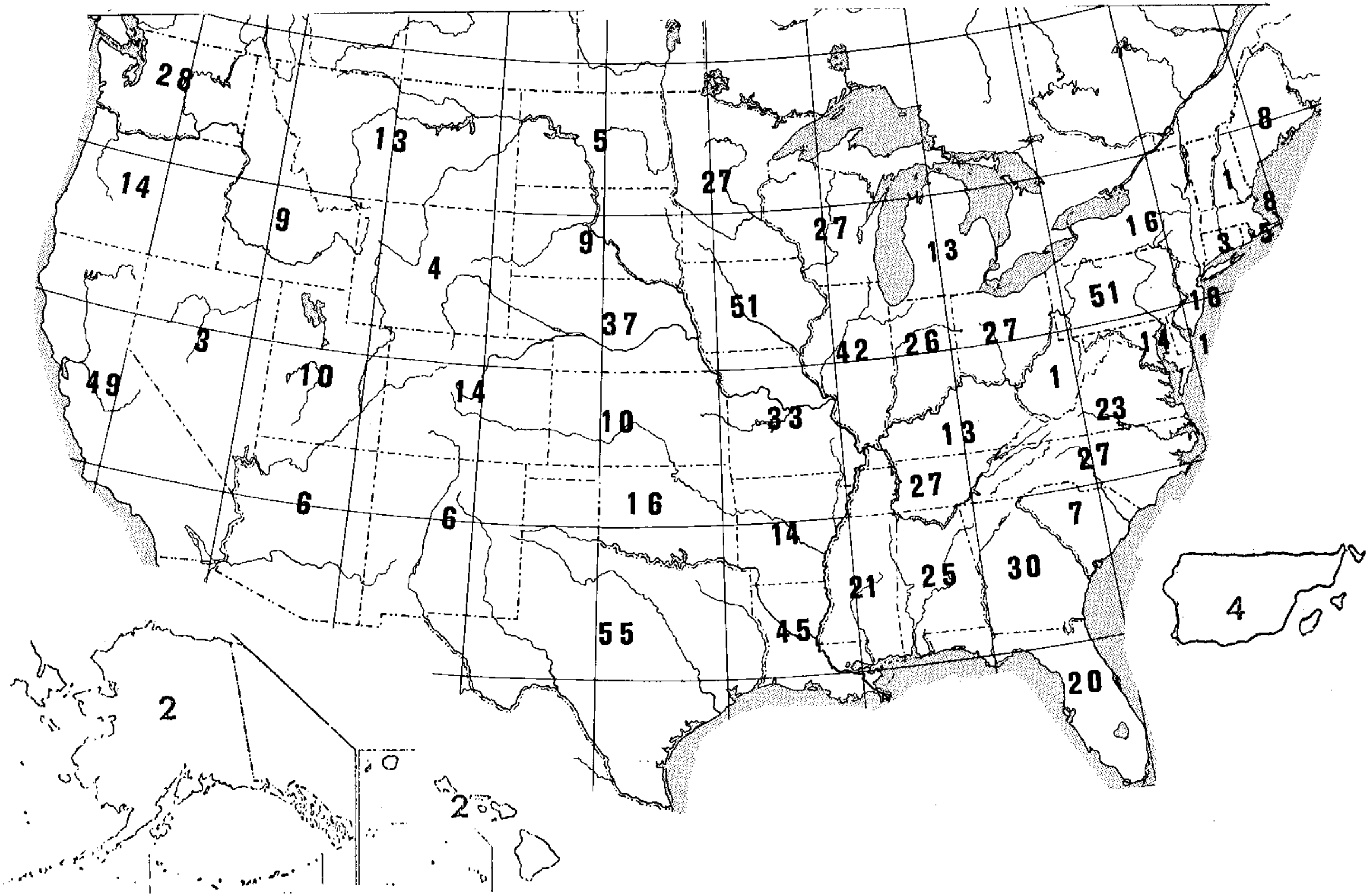


Figure 1. Distribution of Rendering Plants by State[2]

on top of the materials being conveyed to the grinder or the cooker. In the case of poultry offal, it is not always necessary to grind the raw material before cooking unless it contains a large number of whole birds. Feathers, if they are not mixed with poultry offal, are dumped directly on a floor to allow excess liquid to drain off. Rendering plants normally process feathers separately from poultry offal. Oils are poured into receiving tanks and from there go directly to cookers.

The process of rendering consists of two essential steps. First, the raw material is heated or cooked to melt the tallow or grease and permit the phases to separate and, in the dry inedible process, to evaporate the moisture. Also, the animal fibrous tissues are conditioned. The second step is a separation of tallow or grease from the solid proteinaceous material. Proper conditioning of the fibrous tissue is important to accomplish the second step efficiently. In edible rendering little, if any, of the raw material moisture is evaporated; the cooking is normally conducted at a lower temperature (49° to 82°C, or 120° to 180°F) to improve the quality of the grease and tallow. However, since this is done almost exclusively by on-site renderers, it will not be discussed in great detail in this report.

The product yields and process control of the cookers are very dependent on the nature of the raw materials. For example, the moisture content of raw materials ranges from 20 percent moisture for beef fats to 87 percent moisture for blood. Tables 3 and 4 give the percentage of yield of a number of common materials processed by independent rendering plants. The percentage of moisture, of course, can be calculated by subtracting the total percentage of yield of fat and solids from 100 percent. Additional information on the amount and type of animal by-products processed for various animal sources and on product yields can be found in reference 6 which is also the source of the information presented in Tables 3 and 4.

INEDIBLE RENDERING

Batch System

Note: Throughout the discussion of production methods and concepts which follows, the use of trade names is included as necessary to facilitate the explanations presented and understanding by the reader. Use of such trade names, however, should in no way be construed as a product endorsement or recommendation by the U.S. Environmental Protection Agency.

Batch rendering, a dry process, is a cooking and moisture-evaporation operation performed in a horizontal steam jacketed cylindrical "cooker" equipped with an agitator. It is referred to as a dry rendering process because the raw material is cooked with no addition of steam or water and because the moisture in

Table 2. Statistics by Employment Size of Establishment, 1967[2]

Establishment With an Average of:	Number of Establishments	Number of Employees	Value of Shipments (millions of dollars)
1 to 4 employees	132	300	12.0
5 to 9 employees	103	700	27.9
10 to 19 employees	127	1800	62.2
20 to 49 employees	157	4800	207.1
50 to 99 employees	51	3500	117.1
100 to 249 employees	18	2600	131.0
TOTALS	588	13,700	557.9*

*Total value of shipments from all sources.

the material is removed from the cooker by evaporation. It is a batch process because it follows the repetitive cycle of charging with raw material, cooking under controlled conditions, and finally discharging of the material. A typical modern batch rendering process is illustrated schematically in Figure 3. Although only one cooker is shown, the usual installation will have from three to ten cookers.

Before charging the dry batch cookers, the raw material is usually reduced in size by crushers (sometimes called grinders, prebreakers, or hoggers) to a size of 1.0 to 2.0 inches to provide for efficient cooking. Cooking normally requires 1.5 to 2.5 hours, but may run as long as 3.5 to 4 hours. The cookers are charged with raw material by either a screw conveyor or by blowing the material in under pressure from a "blow tank." The raw materials used are quite variable, depending on the source, and adjustments in cooking time, temperature, and speed of agitation are usually required to properly process the material. For example, shop fat and bone from butcher shops may yield 37 percent tallow and have an initial moisture content of only 40 percent; dead beef cattle, when processed, may yield only 12 percent tallow and have an initial moisture content of 63 percent. Then again, poultry feathers, which yield no grease, and may have an initial moisture content of 75 percent, require cooking under pressure (about 3.7 atmospheres or 40 psig) for 30 to 45 minutes in a batch cooker for hydrolysis, prior to cooking under normal or atmospheric pressure for an additional 30 to 40 minutes to reduce the moisture content to 40 to 50 percent. Finally, the feathers are dried in a rotary or ring dryer to reduce the moisture content to 5 percent.

The general practice in determining the end point of the cooking operation is by previously established cook cycles and by periodic withdrawal of samples by the operator to determine the consistency by touch of the cooked material. A less frequently used method is to measure the moisture content of the material with an electrical conductivity device, but this approach has not been generally successful; it is ineffective when cooking blood or a variety of other materials. Temperature is used to follow the progress of the cooking. The temperature of the material being processed remains substantially constant until the moisture level has dropped to 5 to 10 percent. At this point the temperature begins to rise rather rapidly and the cooking process should then be stopped to prevent product degradation and odor problems. Throughout the cook, the jacket steam pressure usually is maintained constant, between 2.7 and 6.1 atmospheres (25 and 75 psig), although a few use a pressure as great as 7.8 atmospheres (100 psig) or a temperature of 170°C (334°F).

The cooked material is discharged from the batch cooker into a percolation pan and left standing until all free-draining fat has run off. The solids are then conveyed to a press (usually screw press) to further reduce the fat content. Finally, the solids are conveyed to grinding and screening operations.

Table 3. Raw Material and Product Yields for Inedible Rendering by Type of Animal[6]

By-Products from Animals	Offal and Bone per Head, kg (lb)	Tallow and Grease, Percent	Cracklings at 10-15% Fat, Percent
Steers	41-45 (90-100)	15-20	30-35
Cows	50-57 (110-125)	10-20	20-30
Calves	6.8-9.1 (15-20)	8-12	20-25
Sheep	3.6-4.5 (8-10)	25-35	20-25
Hogs	4.5-6.8 (10-15)	15-20	18-25
Broilers (offal & feathers)	0.45 (1)	4	26

Table 4. Product Yields for Inedible Rendering by Type of Raw Material[6]

By-Products from Materials	Tallow and Grease, Percent	Cracklings at 10-15% Fat, Percent
Shop fat and bones	37	25
Dead cattle	12	25
Dead cows	8-10	23
Dead hogs	30	25-30
Dead sheep	22	25
Poultry offal (broiler)	14	4
Poultry feathers	--	12 (meal)
Blood	--	12-14 (meal)

Prior to 10 years ago, essentially all inedible rendering at independent rendering plants was conducted using the dry batch cookers. In recent years, however, a number of plants have replaced batch cookers with continuous systems because these systems offer inherent advantages: Improved product quality control; better confinement of odor and fat aerosol particles within the equipment, thereby requiring less cleanup; less space; and less labor for operation and maintenance. Also, continuous systems permit increased throughput and occasionally result in consolidation of two or more plants. It is currently estimated, however, that 75 to 80 percent of the plants still use dry batch cookers. The percentage of batch cookers is expected to continue to decrease in the near future for economic reasons, but it is very doubtful that it will ever be entirely replaced by continuous systems. This is because most small plants could not afford continuous sytems and because some materials such as feathers and blood are better handled in a dry batch system.

Continuous Systems

Continuous rendering systems, as mentioned above, have replaced some batch systems. A continuous system has the ability to provide an uninterrupted flow of material and to produce a product of more constant quality. In addition, the residence time in some continuous systems is much less than in batch systems, ranging between 30 and 60 minutes; as a result of less exposure to heat, product quality is improved. An inherent disadvantage of the continuous system is that when a component breaks down, the entire plant is shut down. Hence, it is important that a thorough preventive maintenance program be rigidly followed to keep the plant in operation.

Unlike batch systems, the manufacturers of continuous systems do not use the same basic design. Currently there are at least three major manufacturers of continuous systems being used by independent renderers. These three companies are the Duke continuous system, manufactured by the Dupps Company; the Anderson C-G (Carver-Greenfield) system, manufactured by Anderson-Ibec; and the Strata-Flow System manufactured by Albright-Nell Co.

Duke Rendering System

The Duke system was designed to provide a method of cooking similar to that of batch systems except that it operates continuously. This system is illustrated in Figure 4. The cooker, called the Equacooker, is a horizontal steam-jacketed cylindrical vessel equipped with a rotating shaft to which are attached paddles that lift the material and move it horizontally through the cooker. Steam-heated coils are also attached to the shaft to provide increased heat transfer. The Equacooker contains three separate compartments which are fitted with baffles to restrict and control the flow of materials through the cooker.

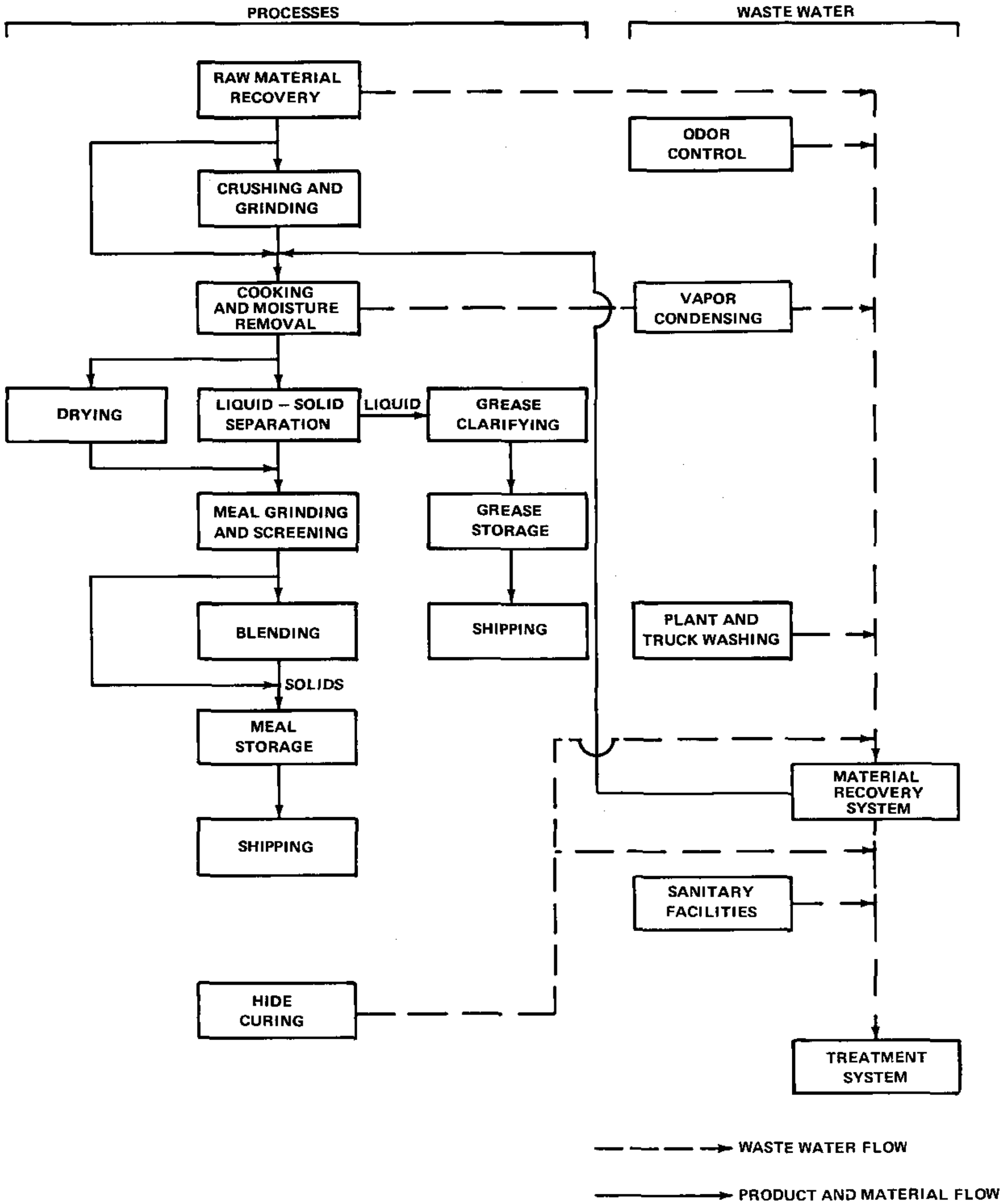


Figure 2. General Flowsheet of Operations for a Typical Inedible Rendering Plant

The feed rate to the Equacooker is controlled by adjusting the speed of the variable speed drive for the twin screw feeder; this establishes the production rate for the system. The discharge rate for the Equacooker is controlled by the speed at which the control wheel rotates. (See Figure 4.) The control wheel contains buckets similar to those used in a bucket elevator that pick up the cooked material from the Equacooker and discharge it to the Drainor. Next to the control wheel is located a site glass column which visually shows the operating level in the cooker. A photoelectric cell unit is provided to shut off the twin screw feeder when the upper level limit is reached.

The Drainor performs the same function as a percolator pan in the batch cooker process. It essentially is an enclosed screw conveyor that contains a section of perforated troughs allowing the free melted fat to drain through as the solids are conveyed to the Pressor or screw press for additional separation of tallow. The Pressor is similar to any other screw press used along with a batch cooker to reduce the grease level of the crackling.

A central control panel consolidates the process controls for the Duke system. The control panel houses a temperature recorder, steam pressure indicators, equipment speed settings, motor load gages, and stop and start buttons, allowing one person to operate the Equacooker part of the Duke system.

C-G (Carver-Greenfield) Continuous System

The C-G continuous process is of a considerably different design than the Duke system. Figure 5 is a schematic diagram of a one-stage evaporator C-G system. In the C-G system, the partially ground raw material is fed continuously by a triple screw feeder at a controlled rate to a fluidizing tank. Fat recycled through the C-G system at 104°C (220°F) suspends the material and carries it to a disintegrator for further size reduction--the final range is from about 1.0 inch to 1/4-inch pieces. This slurry is then pumped to an evaporator. The evaporator can be a single- or double-stage unit, and is held under vacuum. The vacuum, which facilitates moisture removal, allows the C-G system to operate at a lower temperature than some other systems. The evaporator system is basically a vertical shell-and-tube heat exchanger connected to a vacuum system. The slurry of solids and fat flows by gravity through the tubes of the heat exchanger (evaporator), while steam is injected into the shell. The water vapor is then separated from the slurry in the vapor chamber, which is under a vacuum of 660 to 710 mm (26 to 28 inches) of mercury. Water vapor then passes through a shell and tube condenser connected to a steam-ejection vacuum system. The condensed vapors are removed from the condenser through a barometric leg, which helps maintain the vacuum in the system. In the case of a two-stage evaporator system, the vapor evaporated from the second stage serves as a heating medium for the first stage. Two-stage evaporators provide steam economy, and are especially useful for raw

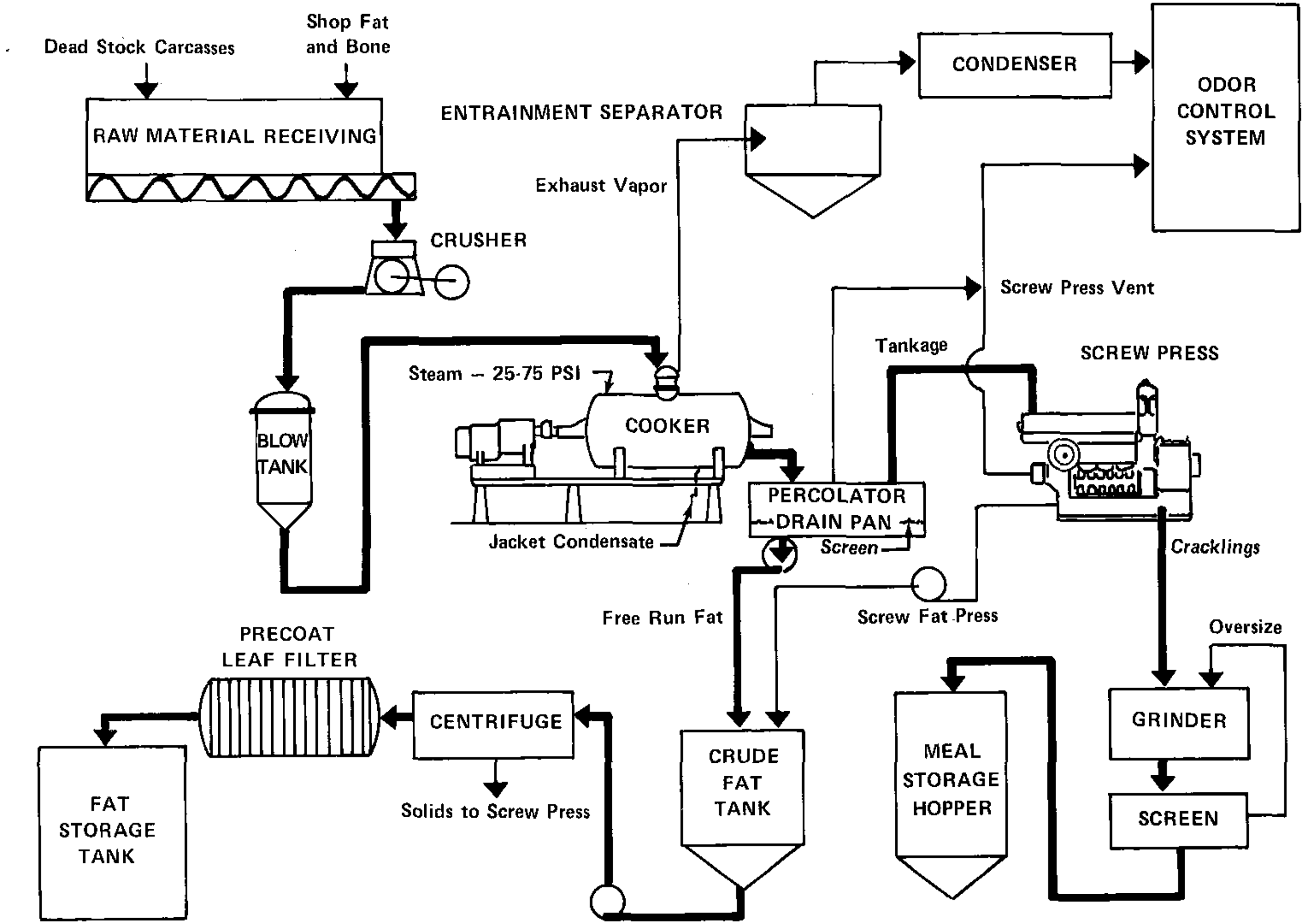


Figure 3. Batch Cooker Rendering Process

materials with a high moisture content. The dried slurry of fat and cracklings is then pumped from the evaporator to a centrifuge which separates the solids from the liquid. Part of the fat is removed from the system at this point, while the remainder is recycled back to the fluidizing tank. The solids discharged from the centrifuge are screw conveyed to expellers (screw presses) that reduce the fat content of the solids from about 26 percent by weight to 6 to 10 percent.

A central control panel allows one operator to control the entire cooking process. Level indicators and controls are provided to stabilize the flow through the fluidizing and other process tanks and also for the vacuum chamber. Evaporator vacuum and temperature are also monitored. Equipment speed settings, motor current readings and start/stop push buttons are also located on this panel.

Strata-Flow Continuous System

The third system, ANCO-Hormel Strata-Flow continuous system, manufactured by the Albright-Nell Company, is basically a series of batch cookers stacked one above the other. Normally five or six stages are provided in series. Each cooker stage is vented to a common manifold that is connected to a condenser for removing vapors.

The crushed raw material from the prebreaker is blown continuously to the first stage cooker. This eliminates screw conveying and pumping of the raw material. The cooked material discharges from the last stage to a percolation pan called an Autoperc. A drag conveyor located in this pan continuously removes material after the free run fat has drained off.

EDIBLE RENDERING

Edible rendering is estimated to be conducted by less than two percent of the independent renderers.[7] However, these plants do both edible and inedible rendering, and probably less than 1.0 percent of the raw material handled by independent renderers is used for edible rendering.

Edible rendering of inspected fats can be conducted by either a wet- or a low-temperature process. The wet process is conducted in a vertical tank with injection of live steam under a pressure of about 3.7 atmospheres (40 psig) and a large volume of "tank water," which should be evaporated. The quality of the lard and tallow thus produced is quite low. For this reason, this once common process is rarely used any more and no independent rendering plants surveyed in this study use the wet rendering process. Low-temperature rendering of fats is the most commonly used method for edible rendering. Fats, after being finely pulverized in a grinder, are placed in a melter and heated to a temperature of 49° to 82°C (120° to 180°F). When the cooking

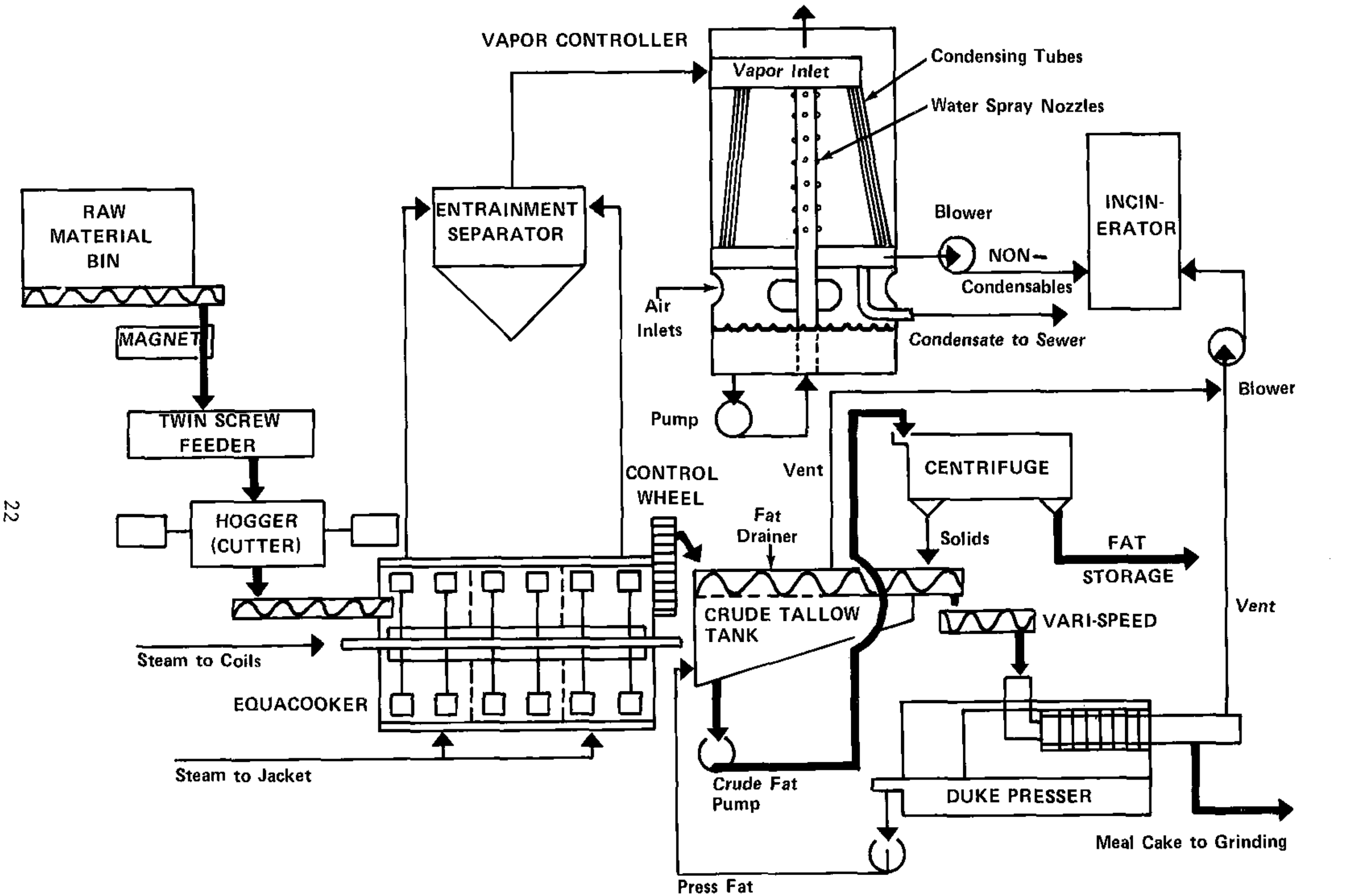


Figure 4. Continuous Cooker - Duke Process

temperature is maintained at or below 49°C (120°F), the cracklings or solids may also be used as an edible product. Cooking at these low temperatures does not evaporate the raw material moisture. Hence, after the fat has separated from the solids and water in the melter, the cooked material is desludged by screening or centrifuging. The water phase is also separated during desludging. The remaining water entrained in the hot fat is then removed in a second centrifuge. The separated water, called tank water, can be further evaporated to a thick material known as stick, which can be used as tankage for inedible rendering.

The general practice in either wet- or low-temperature edible rendering is to directly sewer the tank water. However, this is a poor practice from a pollutional standpoint because tank water can have a BOD_5 of anywhere from 30,000 to 45,000 mg/l[8] and a grease value as high as 20,000 to 60,000 mg/l. If, instead, the tank water is evaporated and the stick used for tankage, the waste water load from wet- or low-temperature rendering would be similar to that from a dry process.

COOKER USES AND PROCESS VARIATIONS

The type of inedible cooker chosen--batch or continuous--is in some instances very dependent upon the material handled and, of course, on the size of the plant. Poultry feathers and hog hair, for example, are handled in most plants in batch systems. This is because these materials must first be cooked under pressure of about 4.4 atmospheres (50 psig) to hydrolize the proteinaceous material (primarily keratin) to usable protein before being cooked and dried in the same way as other materials are in a batch system. A continuous processing system is now available for materials that require hydrolysis, such as feathers, in which the material passes through a hydrolyzer and then into a cooker.

Blood is another material normally handled in batch cookers. However, in some cases, the final drying and conditioning of blood, feathers, and hog hair is carried out in a ring or rotary dryer. This method of drying following batch cooking permits a higher production rate for a plant with a given number of batch cookers. This is because of poor heat transfer during the later stages of drying in batch cookers as the material passes through a "glue stage." In a few cases, blood is processed by steam sparging, which coagulates the albumin; then the albumin and fibrin are separated from the blood water by screening and are processed in a batch cooker or ring dryer. The blood water, which can have a BOD_5 up to 16,000 mg/l, is usually sewered.

The ring dryer system, as the name implies, is in the shape of a flattened ring or race track, positioned vertically. The material to be dried is first pulverized and then blown into the ring where it is conveyed around the ring by furnace gases of 314° to 425°C (600° to 800°F). Centrifugal force, recirculation rates, and control dampers permit the material to recirculate

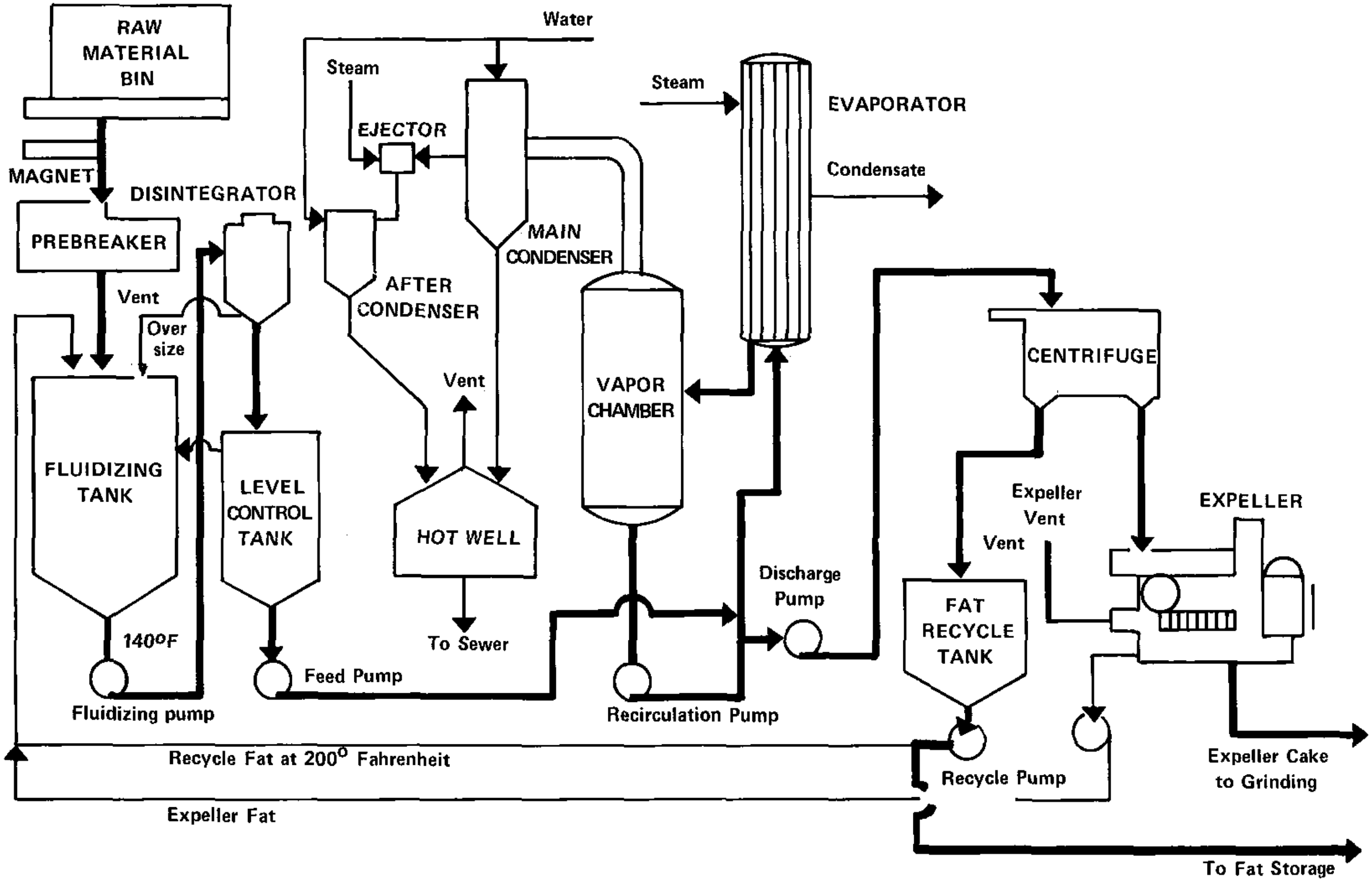


Figure 5. Continuous Cooker by Carrier - Greenfield Process

until the particles of the material become light enough because of drying to escape along with the exhaust gases. A cyclone separates the material from the exhaust gases, which are conveyed away by an exhaust fan. This exhaust fan is necessary to ensure a slight negative pressure in the ring dryer and thus to prevent material from leaking out of the dryer. The high temperature of the furnace gases can cause scorching of the proteinaceous material, resulting in strong odors. Consequently, the exhaust gases are frequently ducted through a spray scrubber.

Rotary (air) dryers are also used to further dry blood, feather, and hoghair meals. The dryer is a horizontal cylindrical vessel equipped with longitudinal steam tubes. The material cascades through the dryer as it rotates. Rotary dryers create less of an odor problem than ring dryers because of the lower temperatures involved and the lower volumes of air required for drying.

VAPOR CONDENSING

Cooking vapors from dry batch processes and also from evaporating tank water are condensed by one of three methods: barometric leg, air condenser, and shell-and-tube heat exchanger. Prior to five or ten years ago, all vapors were condensed with the use of a barometric leg.

In a barometric leg, the cooking vapors are contacted with condensing waters and together flow gravimetrically out through a standpipe. A barometric leg condenser is basically a water-powered ejector located on top of a standpipe. As the high velocity water passes through the ejectcr, it creates a vacuum on the downstream side. The vacuum draws the cooking vapors into the high velocity water where the vapors are cooled and condensed. The vacuum is usually very slight for batch cookers, whereas for several continuous systems using barometric leg condensers the vacuum may be quite high, thus requiring a long standpipe. The standpipe serves two purposes. First, it provides a confined space for contact between the vapor condensing water. Second, it acts as a reverse water trap. This prevents condensed vapors and cooling waters from being accidentally sucked back into a sealed cooker as it cools. To ensure against backup even under a nearly perfect vacuum, the standpipe should be slightly over 10 meters (33 feet) high. This is because a 1.0-atmosphere vacuum can lift water to a height of only about 10 meters. In general, it was observed that very few barometric leg condensers used in the industry are near 33 feet in height. However, a few plants with barometric legs protect against backup by installing an air check valve in the standpipe. Hence, before a vacuum can lift water to the top of the standpipe, the air valve will open and reduce the vacuum.

Air condensers and shell-and-tube heat exchangers are rapidly replacing the barometric leg for condensing water vapors. Probably the major reason for this is that air condensers and shell-and-tube heat exchangers do not dilute the waste waters.

Barometric legs, on the other hand, highly dilute the waste waters resulting from the condensing of vapors. Usually a barometric leg is used on each batch cooker, and each requires 57 to 151 liters (15 to 40 gallons) per minute of water for condensing. In plants that are continuing to use barometric legs, the trend is to recycle treated or partially treated water through the barometric leg.

Air condensers force ambient air across a bank of externally finned tubes. A typical unit has a horizontal section containing finned tubes, a steel supporting structure with plenum chambers and fan ring, axial-flow fan, drive assembly, and miscellaneous accessories such as louvers, fan guards, and temperature-operated fan speed controls.

Shell-and-tube heat exchangers are basically cylindrical vessels containing a bundle of parallel tubes. The tubes are enclosed in such a manner that they isolate the liquid inside the tubes from the liquid surrounding the tubes. Normal flow arrangement is to have the condensate inside the tubes. The cooling water is recirculated through a cooling tower to dissipate the heat collected in condensing the cooking vapors. Water is continuously added to the cooling water to make up for that lost by evaporation.

GREASE AND TALLOW RECOVERY

Grease and tallow recovery is normally accomplished in two steps. The first step is draining in percolation or drain pans just after the material is dumped or removed from cookers. For batch systems, the material may be allowed to drain for up to 2.0 hours. This normally reduces the fat content of the solids to 25 percent. The second step in fat reduction involves the pressing of solids to reduce the residual tallow content to 6 to 10 percent. The usual practice is to use a screw press to allow for continuous throughput, although some small or old plants may still use hydraulic batch-operated presses. The screw press consists of a cylindrical barrel of metal bars that are spaced with narrow openings between to allow the fat to be squeezed through by the action of a rotating screw. Hence, the pressure within the screw press is maintained by friction and the fat present in the solids provides a lubricating effect. It is important that overpressing of the tallow from the solids be avoided; otherwise overheating and scorching can result in producing smoke and strong odors. Frequently, the smoke generated by screw presses is drawn through an odor control system that uses either wet scrubbing or incineration.

In possibly 1.0 percent of the plants, the second step in grease and tallow reduction involves solvent extraction. In this process a solvent such as hexane is used to remove the excess grease. Heat is then required to separate the solvent from the grease and to remove it from the solids. The solvent is recovered for recycle. This process reduces the tallow and grease content of the solids to 1.0 percent or less. The increased income derived from the additional fat recovered by solvent extraction, however, is usually too small to encourage widespread use of solvent recovery.

Tallow and grease recovered in the two steps of drainage and pressing are normally combined and then further clarified. This usually involves screening, centrifuging, or filtering, or combinations thereof. Solids recovered from clarification are returned to the cracklings prior to the second step of tallow and grease recovery. The tallow and grease are then pumped into storage tanks and held for later shipment.

SOLIDS PROCESSING

The solid proteinaceous material discharged from the screw press, known as cracklings, is normally screened and ground with a hammer mill to produce a meat and bone meal product that passes through a 10- to 12-mesh screen. The finely divided solids are usually stored in bulk handling systems for later shipment. Occasionally this material is blended with another, such as blood or feather meal, to ensure a high level of crude protein. Frequently, the blood and/or feather meal are bagged prior to shipment, although this operation is normally a relatively small one.

ODOR CONTROL

Odor control is practiced in nearly all rendering plants today. Although rendering odors are not necessarily harmful to health, they may be very offensive to people because of their distinct nature and the complexity of the odor compounds present. A recent study[9] identified a number of odorous compounds present in rendering plant emissions. The important categories of compounds identified were sulfides, amines, aldehydes, ketones, alcohols, and organic acids. The major methods of odor control basically involve using scrubbers with or without chemical oxidant solutions (the most commonly used chemical is sodium hypochlorite), and incinerators. Condensers and temperature control of cooking vapors involve rendering plant operations which should be adequately controlled to minimize odors. Excellent discussions of the control of odors from inedible rendering plants can be found in references 2 and 10.

The primary sources of odor are from the cooking and pressing operations because, in both cases, the material is heated to temperatures of 105°C (220°F) or higher. Of course, aged or deteriorated raw materials will appreciably increase the intensity of odors from these operations. Furthermore, if the raw materials are not particularly fresh, it may be necessary to control this odor source by covering screw conveyors and venting them to the odor control system.

The condenser plays a very important part in controlling odors from cookers. One of the best ways of controlling any odors from the cookers is to ensure that the final temperature of the condensed cooking vapors is below 52°C (125°F), or preferably below 38°C (100°F). In addition, the noncondensable vapors from the cooker, which give high-intensity odors, can be controlled by venting directly to the boiler used for generating the plant steam. This is feasible only under certain circumstances. If the odorous stream is used as primary combustion air, the necessary precautions must be taken to remove solid and fat aerosol particles before passing this air through the boiler and controls. Also, the boiler must be equipped with suitable burner controls to ensure that the minimum firing rate is sufficient to incinerate the maximum volume of effluent gas passing through the boiler firebox, regardless of the steam requirements. Press odors are treated by venting these vapors through a scrubber or incinerator. The intensity of the smoke and odor from the presses is occasionally high enough that the scrubbing water cannot be recycled.

Using water without chemicals in a scrubber usually does not permit high recirculation rates, and thus requires large water use; the effect is that the waste waters from the plant are diluted. When chemicals such as sodium hypochlorite are used, it is normal to recycle up to 95 percent of the scrubber waters; this minimizes chemical and waste water treatment costs. Wasting 5.0 percent of chemical scrub water should not affect either the volume of the waste water or its treatability to any noticeable degree.

Direct-fired incineration units could be used anywhere in place of the scrubber, although they are normally used only for low-volume, high-intensity odors. However, in recent months, the use of incinerators has been reduced drastically because of the difficulty in obtaining the necessary fuel. Even before there was difficulty in obtaining fuels, scrubbers were believed to be the most economical method of odor control.[9]

WASTE WATER SOURCES

Waste waters from the rendering of raw materials contain the condensate or moisture evaporated from the raw materials and wash water from cleaning the plant and the raw materials pickup trucks. In some cases, the waste water contains additional condenser water and liquid drainage from the raw materials. The strength of these waste waters, which contain organic materials including soluble and insoluble protein, grease, suspended solids, and inorganic materials, can be greatly increased as a result of rundown and poorly maintained equipment. Also, poor housekeeping practices can result in accidental spills of raw and finished materials into the waste waters and the foaming over of material from the cookers. A detailed discussion of the waste water characteristics, sources, and contributing factors is presented in Section V.

Trucks and barrels used for picking up raw materials are carefully washed after each use. The amount of water used for this is probably insignificant, although these operations can contribute significantly to the waste load, particularly to the grease load. Barrel washing, however, is not as common a practice as it once was in rendering plants, since most barrels are emptied at the pickup site and are not brought to the plant. Barrels are primarily used to transport restaurant grease.

Washdown in inedible rendering plants is not nearly as intensive as it is in meat processing and packing plants. In fact, washdown usually occurs at the end of a day's operation when rendering has been completed. Normally only the areas for receiving, grinding, and cooking of raw materials and the product separating and grinding areas are washed down. The other areas of the plant are generally drycleaned. Washdown does occur within the plant, however, whenever there is an accidental spill. Washdown of accidental spills without prior dry cleanup obviously adds significantly to the waste load from inedible rendering plants. The most common accidental spills observed, that were entirely cleaned up by washdown, were of tallow and grease. Fortunately, a properly operated materials recovery system (primary or in-plant treatment) can recover a large portion of these materials for recirculation to the cookers.

MATERIALS RECOVERY

Materials recovery from the waste water streams (primary or in-plant treatment) is conducted in essentially all rendering plants. The most common materials recovery system used by independent renderers is a catch basin or skimming device. Basically, this device is a large rectangular tank in the effluent stream to allow grease and oil to float to the surface and solids to settle to the bottom, thus separating them from the waste water. Grease and oil that float to the surface in catch basins are normally removed manually once or twice a day and blended in with the raw materials for recycling, or are processed separately. With automatic skimming devices, the materials may be collected for recycle once or twice a day or they may be continuously recycled using screw conveyor systems. Solids collected from catch basins are less frequently recycled; however, it is becoming more common practice today to occasionally pump out solids and recycle them through the rendering equipment.

Some rendering plants (15 out of 49 plants included in the survey) have air flotation systems in place of catch basins or skimming devices. However, these systems are normally not operated under optimum conditions for either materials recovery or waste water treatment. Optimum conditions might require flow equalization, pH control, temperature control, and the addition of chemical flocculating agents. The temperature of rendering plant waste waters is often somewhere between 70° and 85°C (125° and 150°F), which is too high for effective grease removal by air flotation systems or by other gravity separation methods. At these temperatures, grease is too soluble in water for the required phase separation. Further, chemicals are not normally added to the air flotation system because the resulting sludge collected would be very high in water (85 to 95 percent) and, consequently, this excess water would add considerably to the heat load if recycled through the cookers. The addition of chemicals could also change the nature of the grease and thus lower its market value. One solution to this is to have two materials recovery systems in series, where the second one is an air flotation device to which chemicals have been added.

HIDE CURING (ANCILLARY OPERATION)

Hide curing occurs in a number of rendering plants, essentially as a separate operation from rendering. In many cases, slaughterhouses and packinghouses from which the renderers collect their material are either too small to handle hide curing or do not have the necessary equipment. Consequently, for the renderer to obtain these sources as users of his "services," he must also pick up the hides along with his raw materials. In addition, many rendering plants handling a large number of dead animals will find it economically favorable to remove the hides from dead carcasses for curing.

The older method of curing hides was to dry-pack hides in salt. However, in recent years the trend has been to replace this operation with brine curing in raceways or brine vats. Essentially, the hide curing is a dehydration process, and in the brine-curing process there results a net overflow of approximately 2.0 to 3.0 gallons of brine cure for each hide handled. These wastes are nearly saturated with salt and also contain other dissolved solids plus blood, tissue, and fats and oils. The overall contribution of this waste load to that from the rendering plant is usually relatively small. However, a high salt load can cause problems in the treatment of the waste waters and in some cases may make it very difficult for a plant to obtain a final chloride content that would meet some State and local regulations. A possible solution to this problem might be to blend the curing effluent with the raw material as it enters a dry cooker.

SECTION IV

INDUSTRY CATEGORIZATION

CATEGORIZATION

In developing effluent limitations guidelines and standards of performance for the rendering 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:

- Waste water characteristics and treatability
- Raw materials
- Final products
- Manufacturing processes (operations)
- Processing equipment
- Size, age, and location of production facilities.

After considering all of these factors, no justification could be found for subdividing the industry. Hence, the industry as a whole constitutes a single subcategory, and the effluent limitations and standards of performance recommended in this report are intended to apply to all independent rendering plants except those processing fish by-products which are evaluated as part of the studies of the Seafood Processing point source category.

As described above, the typical plant representative of the subcategory is one that collects animal by-products such as bone, offal, fat, and dead animals from such sources as slaughterhouses, processing plants, butcher shops, restaurants, feed lots, and ranches, and processes them into products such as fats, oils, and solid proteinaceous meal. The products may be either edible or inedible. Plants processing fish by-products are not included in this study. In addition, rendering plants that are an adjunct to meat and poultry operations and are located on the same premises are not included in the subcategory of renderers. An independent rendering plant may also cure hides as an ancillary operation. The manufacturing processes in an independent rendering plant are shown in Figure 6.

RATIONALE FOR CATEGORIZATION

Waste Water Characteristics and Treatability

Basic processes in independent rendering plants are essentially the same, although such factors as equipment type, raw materials, size, and age of the plant may differ. Hence, it was possible to

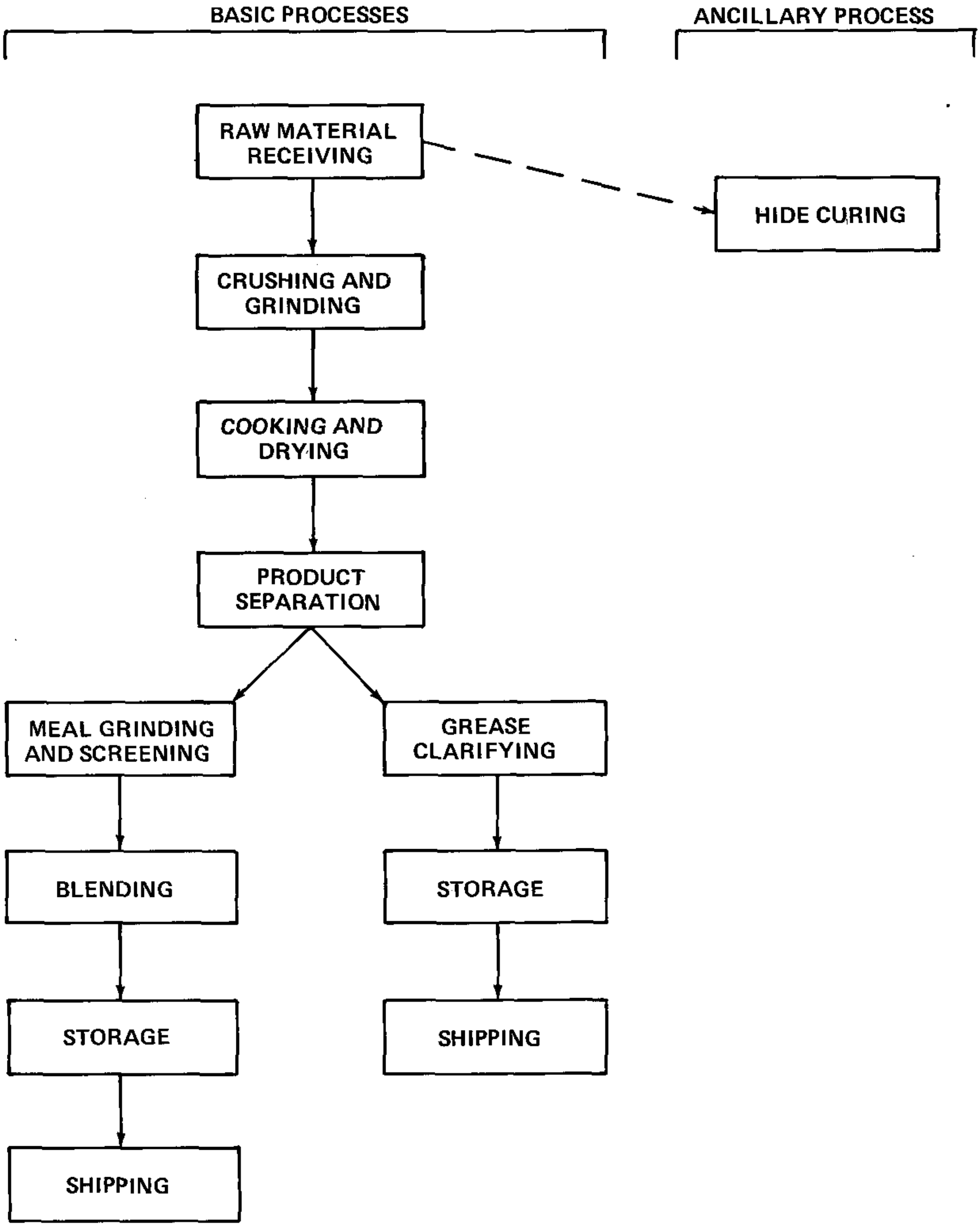


Figure 6. Manufacturing Processes of a Rendering Plant

consider division of the industry on the basis of those factors which might group plants with similar raw waste water characteristics. The waste water characteristic used in analyses of possible subcategorization of the industry was the 5-day biochemical oxygen demand (BOD_5) in units per 1000 units raw material (RM) handled or processed: kg BOD_5/kkg RM (lb BOD_5/1000 lb RM). BOD_5 provides the best measure of plant operation and treatment effectiveness among the parameters studied, and more data are available than for any other waste parameters. Suspended solids, grease, and COD data substantiate the conclusions developed from using BOD_5 in characterizing both the industry and the raw waste (Section V). The raw waste was evaluated and is herein discussed as that waste water discharged subsequent to materials recovery operations--catch basins, skimming tanks, etc.

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.

A number of additional parameters were also considered for use in categorization besides BOD_5, suspended solids, grease, and COD. Among these were nitrites and nitrates, Kjeldahl nitrogen, ammonia, total dissolved solids, total volatile 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 the judgments based on BOD_5.

Waste Waters from all plants contain the same general constituents and are amenable to treatment by a variety of biological treatment concepts. Geographical location, and hence climate, does not affect the treatability of the waste. Climate may influence the selection or design of biological waste treatment concepts employed. However, the ultimate treatability of the waste is not affected by the biological process used if treatment effectiveness can be sustained at the highest levels by adhering to sound principles of design and operation as outlined in Section VII. Judging from biological waste treatment effectiveness and final effluent limits, waste waters from all plants contain the same constituents and are amenable to the same kinds of biological treatment concepts. Geographical location, and hence climate, affects the treatability of the waste to some degree. All biological activity slows at lower temperatures; hence, biological waste treatment systems do not perform as well in the winter months in northern areas as they do when the weather is warm. Climate has occasionally influenced the kind of secondary waste treatment used. However, the ultimate treatability of the waste or the treatment effectiveness can be maintained at the highest levels by using a variety of alternatives including not discharging during the coldest months of the year. The time period for no discharge will vary with location, but should never exceed 6 months. This is the same practice that is used by plants that dispose of their waste water by irrigation.

Raw Materials

The type and nature of raw materials processed is meaningful in substantiating a single subcategory. A clear independent relationship was disclosed that all types of raw materials may be expected to result in similar BOD_5 discharges. In addition, the range (low and high) and average of BOD_5 waste water values for plants processing greater than 50 percent poultry by-products could not be differentiated from those plants processing less than 50 percent poultry by-products or from those for the total industry. This is illustrated by bar graphs in Figure 7.

For the purposes of conducting a rigorous analysis of possible effects due to this factor, raw materials (as waste animal by-products) were classified as follows:

- o Packinghouse (slaughterhouse) materials which are primarily animal offal
- o Shop fat and bones
- o Grease
- o Blood
- o Dead animals
- o Poultry offal
- o Feathers and hair.

Multiple regression analysis techniques described in Section III were used to correlate the percent of raw material in each of these classes with the raw BOD_5 load for each set of data. Information from questionnaires and other data sources for 29 independent renderers was sufficiently complete with flow, BOD_5, and raw material data to permit this analysis. Some of this data represented the average of data over a period of several months; other data represented grab or composite values over short periods such as one or two days. The result of the regression analysis is best indicated by the multiple correlation coefficient. This coefficient was found to be 0.39. The square of this number, or 0.16, is a measure of the predictability of the change in BOD_5 load caused by a change in raw materials. In other words, 16 percent of a BOD_5 load change could be accounted for by a change in raw materials. For the dependence between animal by-products and BOD_5 load to be explained with reasonable

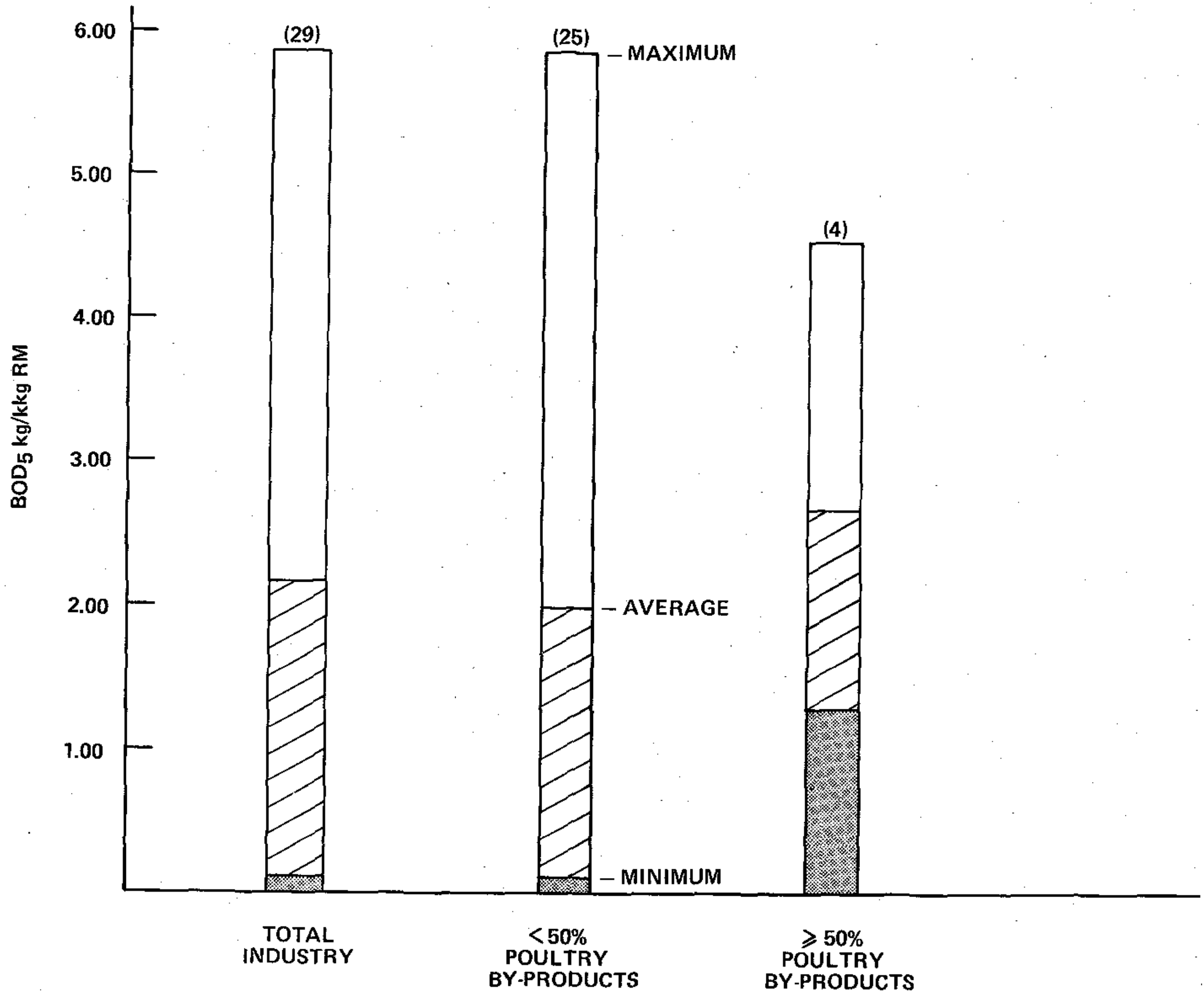


Figure 7. Average and Range of BOD5 Data by Raw Material Type

certainty as a basis for subcategorization, the square of the multiple correlation coefficient should be greater than 0.5. That is, it could be predicted that at least half of the changes or differences in raw BOD_5 were attributable to raw material characteristics. The lack of dependence between BOD_5 load and raw materials is somewhat surprising since the raw materials in each of the classes have different initial moisture contents and product yields of solids and of tallow and grease. But then a simple regression analysis between BOD_5 load and waste water flow, both expressed in units per 1000 units of raw material processed, also did not reveal a correlation. The correlation coefficient for this analysis was -0.027.

Final Products

The final products are generally the same for all plants. The factor was found to be closely related to overall manufacturing processes and equipment thus supporting subcategorization based on these factors as described below.

Manufacturing Processes

The manufacturing processes in rendering were shown in Figure 6. Those processes considered as basic--raw materials receiving, crushing and grinding, cooking and drying, product separation, meal grinding and blending, grease clarifying, and storage and shipping--are conducted in most plants. In a few cases, such as plants processing poultry byproducts (offal and feathers mixed together), the only product is meal, and no grease is separated and clarified. These plants may have more complex meal grinding and screening processes. Coupled with the analysis of processing equipment and methods described below, the basic manufacturing processes were found to be consistent throughout the industry thus substantiating the single subcategory conclusion first discovered when analyzing raw materials.

The ancillary manufacturing process (hide curing) is not practiced by all plants, but the process can contribute additional waste to the raw effluent when the waste load is only based upon the amount of raw material used for the basic manufacturing processes, as it is in this report. But to create a separate category for rendering plants that cure hides would not result in a separate set of fixed effluent standards. This is because the additional waste load caused by hide curing is dependent on the relative amounts of raw materials processed in the basic and ancillary manufacturing processes.

The most equitable method of accounting for the additional raw waste load caused by hide curing, therefore, was found to be the use of an adjustment factor. The adjustment factor for hide curing is presented in detail in Sections IX and X.

Processing Equipment and Methods

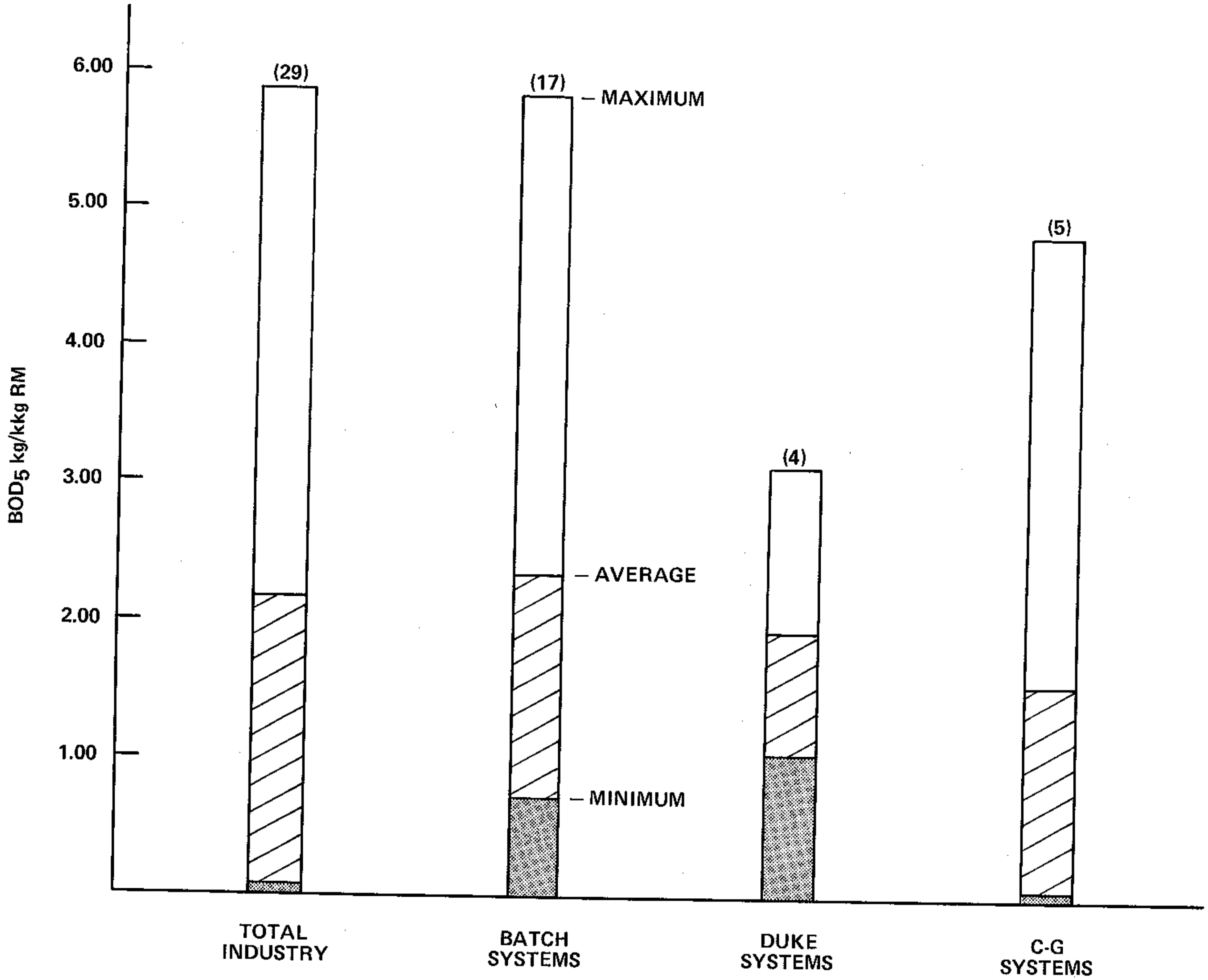


Figure 8. Average and Range of BOD5 Data by Cooker Type

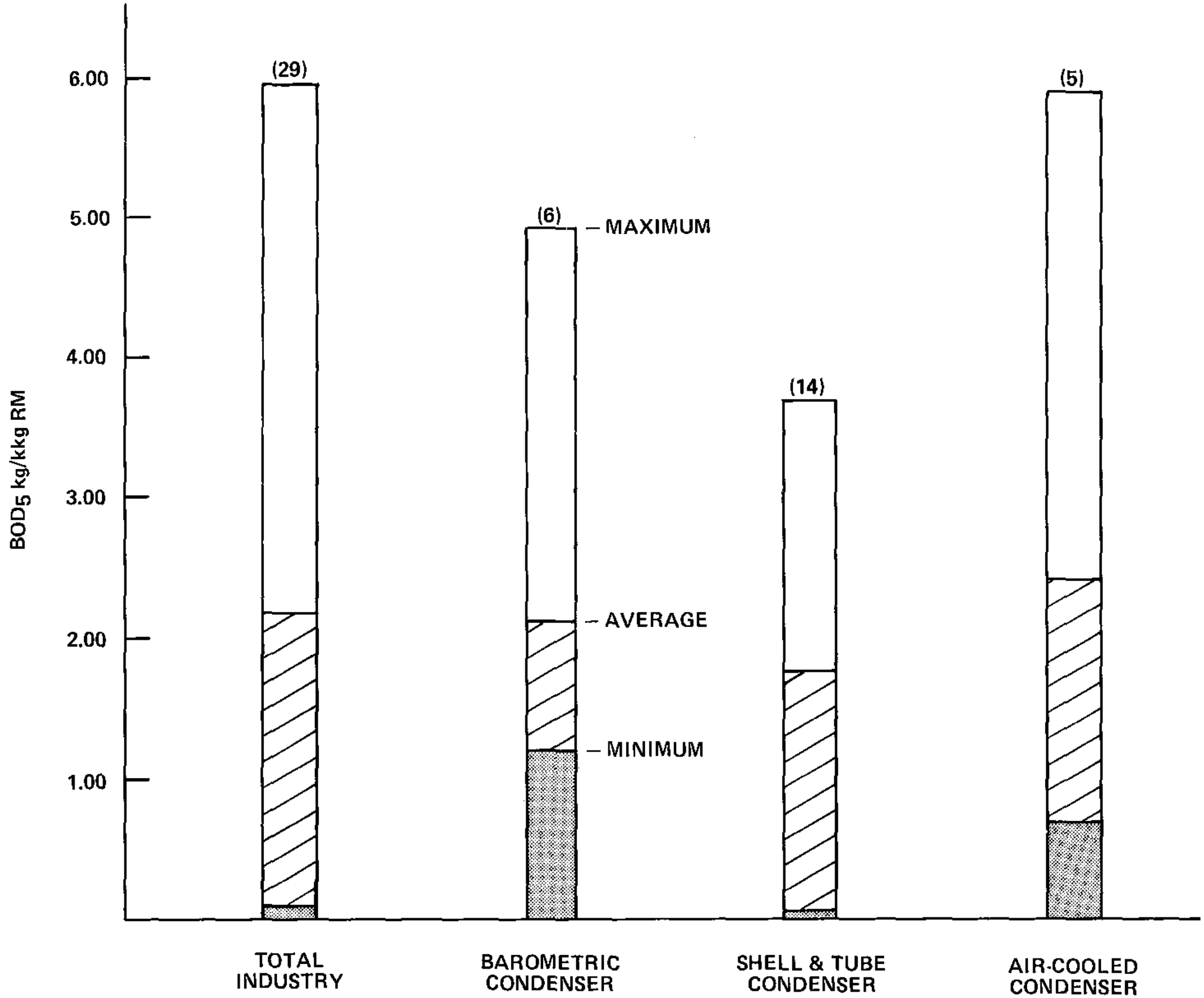


Figure 9. Average and Range of BOD5 Data by Condenser Type

Table 5. Raw Waste Data on Rendering Plants by Equipment Type

Parameter	Equipment Type*	Number of Observations	Average Value	Standard Deviation	High Value	Low Value
BOD_5 kg/kkg RM (lb/1000 lb RM)	Total	29	2.15	1.34	5.83	0.10
	Batch	17	2.31	1.34	5.83	0.72
	Duke	4	1.92	0.99	3.15	1.07
	C-G	5	1.56	1.97	4.83	0.10
	Baro	6	2.10	1.39	4.83	1.20
	S & T	14	1.78	0.95	3.64	0.10
	Air	6	2.42	2.00	5.83	0.72
SS kg/kkg RM (lb/1000 lb RM)	Total	26	1.13	1.39	5.18	0.03
	Batch	14	1.06	0.91	3.33	0.03
	Duke	4	1.54	2.44	5.18	0.05
	C-G	5	0.97	1.87	4.32	0.06
	Baro	3	1.79	2.20	4.32	0.39
	S & T	14	0.98	1.44	5.18	0.05
	Air	5	0.56	0.65	1.45	0.03
Grease kg/kkg RM (lb/1000 lb RM)	Total	16	0.72	1.14	4.18	0.00
	Batch	9	0.44	0.48	0.92	0.00
	Duke	2	1.66	1.82	2.94	0.37
	C-G	5	0.90	1.83	4.18	0.04
	Baro	2	2.09	2.96	4.18	0.00
	S & T	9	0.55	0.96	2.94	0.04
	Air	4	0.41	0.43	1.07	0.04

*Values listed as:

- "Total" is a summary of all data, regardless of equipment type and included four plants using more than one type of cooker or condenser.
- Batch, Duke, or C-G: Summary of the information on plants using one type of these cookers, respectively.
- Baro, S & T, or Air: Summary of the information on plants using one of the following types of condensers: barometric leg, shell-and-tube, and air condensers, respectively.

The processing equipment considered as factors for categorization were the type of cookers--batch versus continuous--and the type of condensers used for condensing cooking vapors--barometric leg, shell-and-tube, and air condensers. Other types of equipment such as grinders, presses, etc., were not considered because the basic operating principles were generally quite similar for each type of equipment, regardless of the manufacturer, and because there was no significant difference in the contribution to the waste water load from different equipment designs within a given equipment type (e.g., all batch cookers or all continuous cookers).

Table 5 summarizes the raw waste data on 51 rendering plants (49 from questionnaires, 2 from field survey) comparing various kinds of cookers and condensers with resultant raw waste BOD_5, suspended solids, grease, flow, and amount of raw materials handled. Figures 8 and 9 graphically illustrate the conclusion to group the industry into single segment because of close similarities in waste load regardless of processes or equipment employed. These data show that there are no distinct raw waste water load differences when the data are grouped by the types of cookers and condensers used. Thus, it was concluded that the factor of process equipment proved consistent with findings regarding manufacturing process and substantially supported designation of a single category for the rendering industry.

Size, Age, and Location of Production Facilities

Size, age, and location are not meaningful factors for developing subcategories. Size as a factor was evaluated by a simple regression analysis between raw BOD_5 waste load and the amount of raw material processed per day using the data collected in this study. This analysis revealed no discernible relationship between BOD_5 waste load and size, as measured by the daily amount of raw materials processed. This was indicated by the value of the correlation coefficient, 0.062, showing a very low degree of correlation. The same data were also separated into three data groups based on amount of raw material used. The data groups represented approximately equal numbers of plants. Analysis of the data in each of the groups showed no correlation of plant size with BOD_5 waste load. Figure 10 shows the average and range values of BOD_5 for the three size groups and for all the plants included in the study (indicated in Figure 10 by total).

The scatter diagram of raw BOD_5 wasteload versus plant size (Figure 10A) shows that the raw wasteload is not a function of the plant size. That is, several plants of the same size will have different wasteloads depending on plant practices. This is further substantiated by the results of a regression analysis of the wasteload and plant size data in that the linear model obtained from the analysis is not statistically significant.

Age is often reflected by the type of processing equipment used. Plants over ten years old were originally equipped with batch

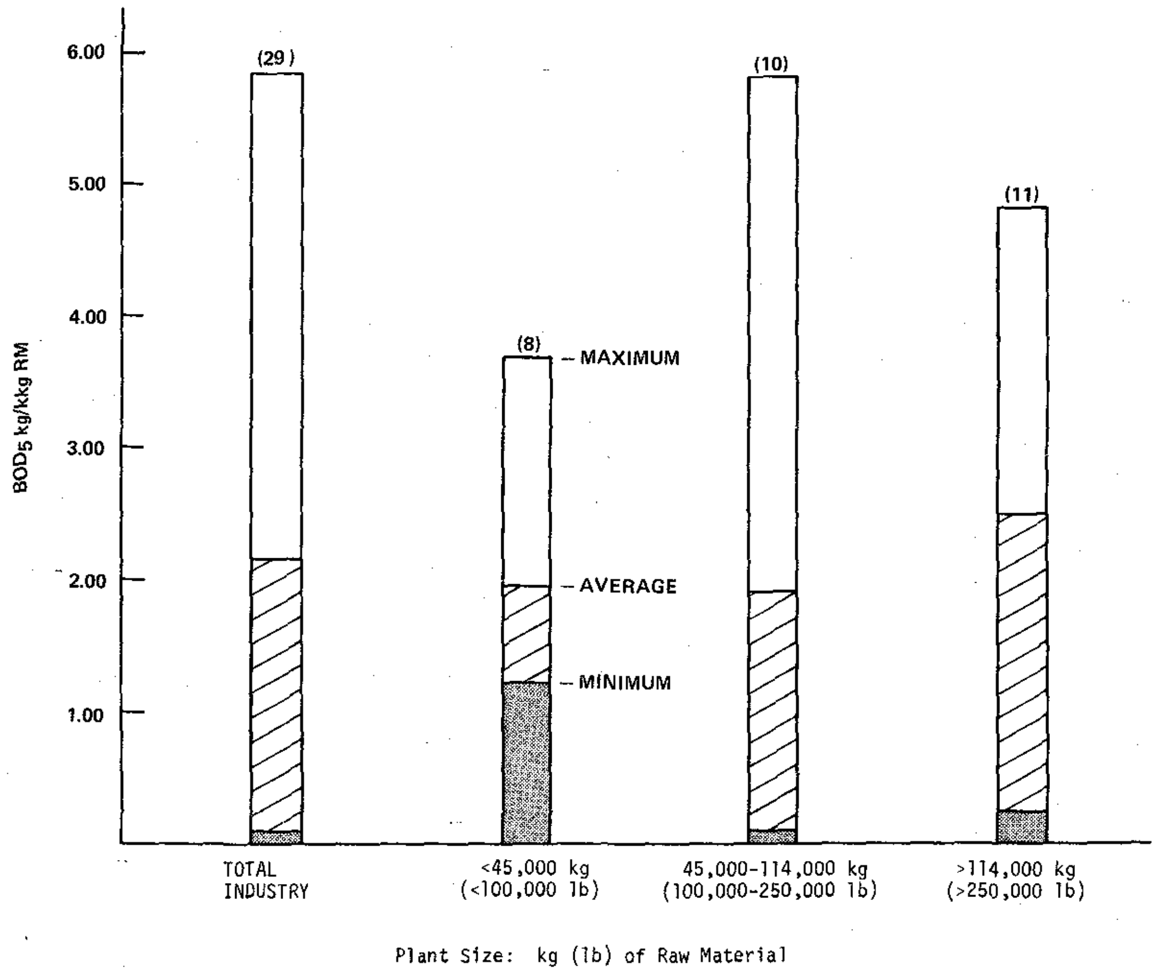
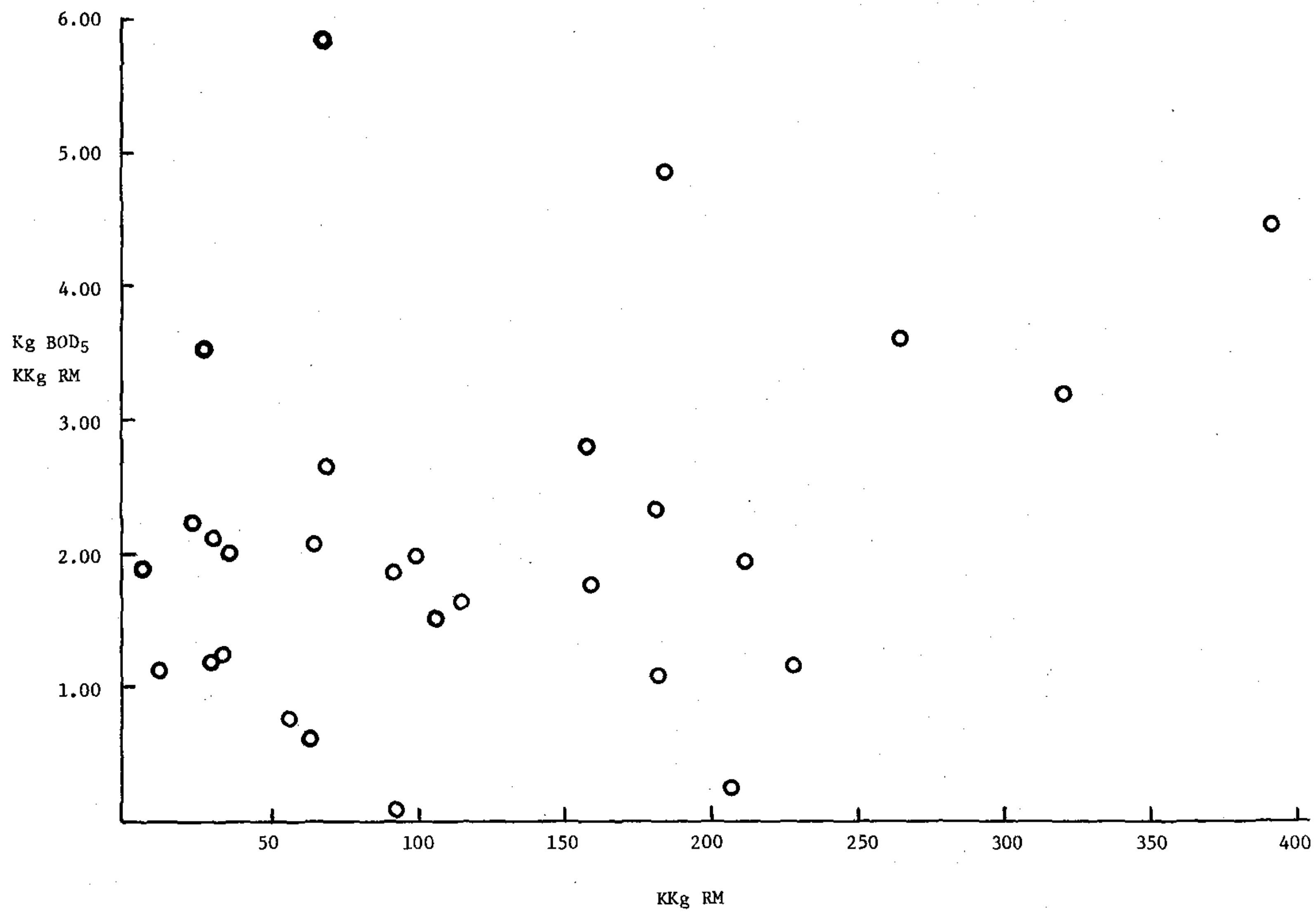


Figure 10. Average and Range of BOD_5 Values for Three Size Groups of Plants and for All Plants Studied (Total)

Figure 10A - Scatter Diagram of Raw Wasteload *versus* Plant Size



cookers and barometric leg condensers. However, in recent years some older plants have replaced batch systems with continuous systems and barometric leg condensers with air or shell-and-tube condensers. Newer plants use both batch and continuous systems and also use shell-and-tube and air condensers more frequently than barometric legs. Therefore, the major difference, from a raw waste load standpoint between old and new plants is the type of processing equipment. Since processing equipment served to indicate a single discrete subcategory, the close correlation between age of facilities and equipment means that age helps to reiterate this conclusion.

Examination of the raw waste water characteristics relative to plant location revealed no apparent relationship or pattern. Variations in raw waste load were observed to be as large or larger during a given month as they were between different months for a specific location. The same pattern also existed when comparing data for plants in different locations. This "pattern of randomness" for location is to be expected, however, and is in agreement with similar results encountered in other segments of the meat industry. As discussed in Section V, it is such factors as materials recovery practices, production spills, clean-up practices, and disposition of condensates which most clearly affect raw waste for any specific plant. The type of animal by-products being processed is sometimes influenced by location (e.g. more poultry in southern areas, more livestock in midwest), but as mentioned previously, the type of raw material processed had no discernible effect on raw waste.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

WASTE WATER CHARACTERISTICS

Water is used in the rendering industry for condensing cooking vapors, plant cleanup, truck and barrel washing, odor control, and for boiler makeup water. The principal operations and processes in rendering plants where waste water originates are:

- Raw material receiving
- Condensing cooker vapors
- Plant cleanup
- Truck and barrel washing.

Waste waters from rendering plants 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, body fluids, hair, dirt, manure, hide curing solutions, tallow and grease, and meal products (such as meat, bone, blood, feathers, hair, and poultry meal), and caustic or alkaline detergents.

Raw Waste Characteristics

The raw waste load characteristics from the rendering industry discussed in the following paragraphs include the effects of the materials recovery process (considered the primary waste treatment system such as catch basins, skimming tanks, and air flotation).

The parameters used to characterize the raw effluent were the flow, BOD_5, suspended solids (TSS), grease, COD, total volatile solids (TVS), total dissolved solids (TDS), Kjeldahl nitrogen, ammonia, nitrates, nitrites, chlorides, and phosphorus. As discussed in Section IV, BOD_5 is considered to be the best available measure of the waste load. The parameter used to characterize the size of the operations was the amount of raw materials processed. All values of waste parameters are expressed as kg/kkg of raw materials (RM), which has the same numerical value when expressed in lb/1000 lb RM. Amount of raw materials processed is expressed in units of kkg RM.

Table 6 summarizes the plant and raw waste water characteristics for independent rendering plants. The summary includes averages, standard deviations, ranges (high and low values), and number of observations (plants).

The data used to compute the values presented in Table 6 were obtained through questionnaires distributed to their members by the National Renderers Association (NRA), through supplementary data submitted by the companies (such as laboratory analysis reports and consulting engineers' reports), and through data obtained from the field sampling survey. Questionnaires provided information on 49 plants; 12 of these were also included in the field sampling survey. Two other plants that did not submit questionnaires were also sampled. Thus, the total number of plants included in this study was 51, or about 11 percent of the industry. Data were not available for all plants for all pertinent parameters. Thus, the number of observations used to develop averages or other characteristics may not conform to the sample total even for such parameters as waste water flow or pounds of raw materials processed. The data in Table 6 for flow, raw materials, BOD5, suspended solids, and grease are primarily based on questionnaire data; data on the other variables were largely based on supplementary and field sampling information. While the sampling data generally verified questionnaire information, a number of presumably atypical conditions existed for four or five plants during the field visits which clearly caused unusual results for raw waste loads. As summarized in Table 8A, the conditions included spills from cookers, emergency use of old equipment, and malfunctions of certain in-plant controls. Wherever helpful for the purposes of industry and process descriptions, however, the data or circumstances reflecting these conditions are included to provide as much thoroughness as possible in the presentation. Thus, the general waste load characteristics (for BOD5, TSS) were derived from submissions by the industry itself.

Discussion of Raw Wastes

The data in Table 6 cover a waste water flow of 467 to 20,000 l/kkg RM (56 to 2400 gal./1000 lb RM); a BOD5 waste load range of 0.10 to 5.83 kg BOD5/kkg RM (0.10 to 5.83 lb BOD5/1000 lb RM); and a production range of 3.6 to 390 kkg RM/day (8000 to 860,000 lb RM/day).

Variations in waste water flow per unit of raw material are largely attributable to the type of condensers used for condensing the cooking vapors and, to a lesser extent, on the initial moisture content of the raw material. (See Section III.) Table 7 shows that the average waste water flow for plants using barometric leg condensers is much higher, by at least a factor of 2, than for those using either shell-and-tube or air condensers. The range and standard deviation in the flow values are large, however, for all three types of condensers, which undoubtedly is partially caused by the type of raw materials processed. The volume of water used for cleanup can be a significant portion of the flow per unit of RM; typically it amounts to 30 percent of the total flow.

Table 6. Summary of Raw Waste Characteristics for Rendering Industry[a]

Parameter*	Number of Observations	Average Value	Standard Deviation	High	Low
Flow, l/kkg RM (gal./1000 lb RM)	47[b]	3261 (403)	— —	20,000 (2400)	467 (56)
Raw Material, kkg/day (1000 lb/day)	48	94 (206)	94 (206)	390 (860)	3.6 (8)
BOD_5, kg/kkg RM	29	2.15	1.34	5.83	0.10
SS, kg/kkg RM	26	1.13	1.39	5.18	0.03
Grease, kg/kkg RM	18	0.72	1.14	4.18	0.00
COD, kg/kkg RM	16	8.04	8.32	37.03	1.59
Total Volatile Solids, kg/kkg RM	18	3.34	3.09	13.12	0.04
Total Dissolved Solids, kg/kkg RM	17	3.47	3.05	11.67	0.01
Total Kjeldahl Nitrogen, kg/kkg RM	17	0.476	0.313	1.200	0.120
Ammonia, kg/kkg RM	16	0.299	0.196	0.740	0.080
Nitrate, kg/kkg RM	14	0.008	0.016	0.060	0.0001
Nitrite, kg/kkg RM	13	0.003	0.011	0.040	0.00002
Chloride, kg/kkg RM	14	0.793	0.767	2.56	0.080
Total Phosphorus, kg/kkg RM	17	0.044	0.064	0.280	0.003

*kg/kkg RM = lb/1000 lb RM

a. All raw waste data is for effluent following in-plant materials recovery (catch basins, skimmers etc.).

b. Excludes one plant reporting water use at nearly 10,000 gal/1000 lb RM.

Table 7. Waste Water Flow and Raw Material Data Summary as Shown

Parameter	Equipment Type*	Number of Observations	Average Value	Standard Deviation	High Value	Low Value
Flow, 1000 liters (1000 gal.)	Total	51	326(86)	643(170)	3028(800)	3.8(1)
	Batch	35	314(83)	708(187)	3028(800)	3.8(1)
	Duke	6	276(73)	166(44)	488(129)	64(17)
	C-G	6	110(29)	42(11)	170(45)	68(18)
	Baro	15	443(117)	764(202)	2952(780)	7.6(2)
	S & T	21	185(49)	174(46)	628(166)	7.6(2)
	Air	9	64(17)	38(10)	121(32)	19(5)
Raw Material, kkg/day (1000 lb/day)	Total	48	94(206)	94(206)	390(860)	3.6(8)
	Batch	34	60(132)	80(176)	390(860)	3.6(8)
	Duke	5	195(430)	90(198)	318(700)	68(150)
	C-G	5	128(282)	61(135)	204(450)	61(135)
	Baro	14	37(82)	44(98)	182(400)	5.4(12)
	S & T	19	132(291)	89(195)	318(700)	11(25)
	Air	9	62(137)	37(82)	114(250	11(25)

*Values listed as:

- "Total" is a summary of all data, regardless of equipment type and included four plants using more than one type of cooker or condenser.

- Batch, Duke, or C-G: Summary of the information on plants using one type of these cookers, respectively.

- Baro, S & T, or Air: Summary of the information on plants using one of the following types of condensers: barometric leg, shell-and-tube, and air condensers, respectively.

A regression analysis of the field sampling data revealed that the raw BOD5 waste load correlates very well with oil and grease and COD waste loads. Raw BOD5 waste load also correlates with total volatile solids (TVS), total dissolved solids (TDS), and total Kjeldahl nitrogen (TKN). This means that an increase (decrease) in one of these waste load parameters will account for a certain predictable increase (decrease) in one of the other parameters. In fact, the square of the correlation coefficient (called the coefficient of determination) is a measure of the predictability. Consequently, the high degree of correlation between BOD5 and oil and grease waste load implies that much of the variation in BOD5 waste load is caused by variations in the oil and grease load. The correlation coefficients from these analyses are presented in Table 8.

Table 8. Correlation Coefficients of Several Raw Waste Load Parameters with BOD5 from the Field Sampling Results

Parameter	Correlation Coefficient
Oil and Grease	0.905
COD	0.933
Total Volatile Solids	0.789
Total Dissolved Solids	0.796
Kjeldahl Nitrogen	0.580

The basic manufacturing processes in independent rendering (See Section IV) should have no influence on the raw waste load, because they are universal. However, some processing equipment, such as cookers and condensers, do differ significantly in operating principles. However, a comparison of data for batch versus Duke and C-G continuous cookers and for the three types of condensers--barometric leg, shell-and-tube, and air--revealed no discernible difference in raw BOD5 waste load. These data were presented in Section IV and Figures 8 and 9, along with a further discussion. As was previously mentioned and further illustrated with the data from Table 7, it may be oberved that water use rates per unit of raw material associated with barometric condensers are higher than for other condensers. At the same time, the amount of water used for condensing does not affect the raw waste load per unit of RM processed. In fact, a regression analysis for raw BOD5 waste load and waste water flow per unit of RM processed revealed no correlation. The correlation coefficient for this analysis was -0.027. Earlier studies on meat packing plants[8] and poultry slaughterhouses[11] revealed a strong positive relationship between raw waste load and water use.

The effect of plant size (amount of raw materials processed per day) on waste load as measured by BOD_5 was assessed by a multiple regression analysis. This analysis showed no discernible relationship between BOD_5 per unit of RM processed and plant size. The correlation coefficient was 0.062 and the square of this coefficient, which is the coefficient of determination, is only 0.0038.

Plant size does, however, appear to be related to the type of cooker and condenser used. Table 7 shows that the average amount of raw material processed is smaller for plants using batch cookers and barometric leg condensers than for plants using continuous cookers (Duke and C-G) and shell-and-tube air condensers. Plants with batch cookers and barometric leg condensers frequently are older plants--built more than ten years ago. Plant age, although apparently related to both size and equipment type, is not related to waste load. Size and age were factors considered in categorizing the industry and were discussed in more detail in Section IV.

Sources of Waste Water

The most typical process and waste water flow arrangement used by the independent rendering industry is shown schematically in Figure 11. Hide curing is shown in this figure (even though the majority of the plants do not handle hides) because it can represent a significant portion of the total raw waste load.

Some plants, rather than using the exact sequence of manufacturing processing illustrated in Figure 11, use slight variations of it. A plant processing poultry by-products, for example, will usually have two complete processing operations on the same premises. One operation is for poultry offal and dead birds, which will be very similar to the arrangement shown in Figure 11; the other operation will be for the feathers and blood. The feather and blood operation will not include the liquid-solid separation process nor any of the grease processes. Other rendering plants may not have blending and bagging processes if, for example, they do not handle blood or feather meal and their meat and bone is consistently of a high crude protein level. Still others may not have a size reduction process; these include plants that handle grease only, or a high percent of poultry offal. Plants that have large grease operations probably vary more from the process flow arrangement of Figure 11 than do any other plants. In these operations, there is receiving, cooking (or heating), separation of the water and solids from the grease, storage, and shipping. Yet these operations still have the same characteristic waste loads as the other rendering plants. In addition, there are very few plants with large grease operations, and most of these usually have a separate operation schematically similar to that of Figure 11 for processing of fats and other raw materials.

Figure 11 also shows the major sources of waste water as indicated by the dashed line. The sources include auxiliary operations in addition to manufacturing processes. The auxiliary operations are odor control, spills, and plant and truck cleanup; the manufacturing processes are receiving, vapor condensing from cooking and drying, and hide curing. Total plant waste loads including the effects of materials recovery were presented in Table 6 and discussed in this section.

Raw Materials Receiving

Liquid drainage from raw materials receiving areas can contribute significantly to the total raw waste load. Frequently throughout the processing period large amounts of raw materials accumulate in receiving areas (either in bins or on floors) allowing strong liquors to drain off and enter sewers. This is especially true of plants processing poultry feathers because of the manner in which feathers, offal, and blood are sometimes handled at their source (poultry slaughterhouses). As a result, the feathers or combined feathers and offal often contain much blood and excess water. At one such plant that was sampled, this drainage amounted to roughly 20 percent of the original raw material weight and had an average BOD_5 value of 12,500 mg/l. This BOD_5 loss amounted to 2.5 kg BOD_5/kkg RM (2.5 lb/1000 lb RM) and 43 percent of the total plant raw BOD_5 waste load. In another plant that had a dual operation for poultry offal and for feathers and blood, the loss caused by drainage from the feather operation was calculated from field sampling information; it was about 1.4 kg BOD_5/kkg RM, or about 39 percent of the waste load prior to materials recovery processes. In these examples, the waste load caused by drainage of liquors from raw materials is obviously very significant. A partial remedy for these losses, which was practiced in a plant included in the field survey, is to isolate, steam sparge, and screen these waste waters.

Vapor Condensing

Condensate from the cooking and drying process typically contributes about 30 percent of the total raw BOD_5 waste load. The field sampling condensables was from 0.049 to 1.53 kg BOD_5/kkg RM (0.049 to 1.53 lb BOD_5/1000 lb RM), with an average value of 0.73 kg/kkg RM. A summary of concentrations and waste loads of undiluted condensed cooking vapors is presented in Tables 9 and 10, respectively. Of course, being undiluted means the vapors were condensed in a closed system: air or shell-and-tube condensers. A number of factors, such as rate of cooking, speed of agitation, cooker overloading, foaming, lack of traps, etc., are probably responsible for much of the variation in values. Raw materials could also have a direct effect on the values, although no discernible difference between raw materials

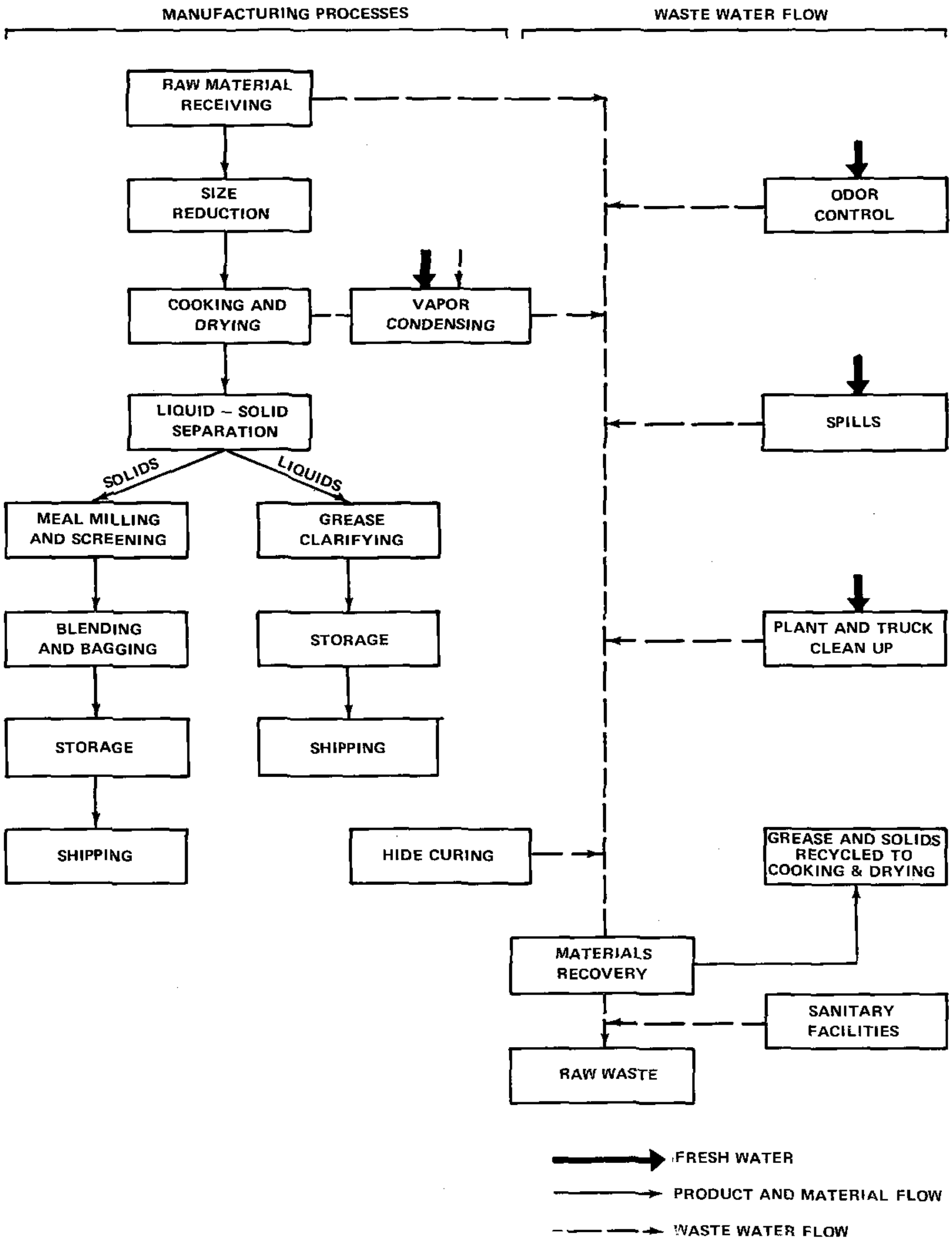


Figure 11. Typical Rendering Process and Waste Water Flow Arrangement

and total plant raw waste load was revealed by a multiple regression analysis, as discussed in Section IV.

The pH of the condensables averaged 8.7 for 11 observations with a standard deviation of 1.12 and with low and high values of 6.8 and 9.7, respectively. Incidentally, the number of observations for the waste parameters in these tables is frequently less for the waste load values than for the concentration values. This is because some of the data were lacking to permit the calculation of the waste load; e.g., the amount of raw material processed was not always known.

The use of barometric leg condensers will dilute the condensables and thus lower the concentrations from those listed in Table 9. In many cases, treated waste waters are recycled through barometric legs for condensing cooking vapors and to allow a high water throughput to lower the barometric leg effluent temperature to at least 38°C (100°F) for odor control. This practice may increase the actual waste load slightly; however, an analysis of the data by type of condenser (See Section IV.) did not reveal any distinct differences in waste loads caused by type of condenser.

Spills and Plant and Truck Cleanup

Washdown (cleanup) of the plant, trucks, and spills can contribute significantly to the total plant raw waste load. In one plant that was sampled, the waste waters from cleanup were isolated from the condensables. Analysis of this source revealed that cleanup in this plant added 16.2 kg BOD_5/kkg (lb BOD_5/1000 lb) RM to the raw waste load, an extraordinarily high value. The reasons for this high value were that the plant used a constant flow of hot water throughout the entire production period; it constantly cleaned up spills from worn, leaking equipment, and frequently shut off the automatic skimmer of the materials recovery systems, resulting in large amounts of grease carry-over. The large amounts of hot water helped maintain the cleanup effluent temperature above 52°C (125°F), thus preventing efficient grease separation. Needless to say, the plant was clean. In another plant, the BOD_5 and suspended solids load just from cleanup were 43 and 50 percent of the total, respectively.

It was observed on the field survey studies that spills caused by equipment breakdown occurred frequently and that leaks from worn equipment were not uncommon. This does not mean that spills cannot be prevented or limited; however, the common practice when equipment breaks down is to open it and dump materials directly on the floor. This allows free draining grease and liquors to enter the sewers. Also, after the bulk of the solids have been shoveled up, the remainder is washed off. More effort could be made to contain materials when equipment breaks down and to better maintain equipment by use of regularly scheduled maintenance programs on equipment during downtime. (See Table 8A)

Table 8A

Observed Housekeeping and Operating Procedures Adversely Affecting Raw Waste Control and Treatment Plant Performance 1/

- Barrel washing and standpipe water discharge with water temperature in excess of 130°F.
- Excessive hot water cleanup without preliminary dry cleanup.
- Improper operation of materials recovery systems leading to grease spills into aerated lagoons.
- Spill from cookers and dump of entire cooker contents to sewer.
- Severe treatment plant overload due to plant production overload.
- Pumping non-contaminated, non-process water into treatment facilities.
- Drainage or discharge of detrimental chemical substances to treatment facilities.

1/ Developed from information compiled during field survey, September to November, 1973.

Table 9. Concentrations of Undiluted Condensed Cooking Vapors

Parameter	mg/l				
	Number of Observations	Average Value	Standard Deviation	Low Value	High Value
BOD_5	11	1723	1165	80	3950
COD	10	2207	1383	192	4212
Total Volatile Solids	10	185	169	15	579
Total Dissolved Solids	7	201	143	59	413
Total Phosphorus	7	6.3	6.3	2.45	20.4
Chlorides	7	196	212	13	593
Total Kjeldahl Nitrogen	7	493	317	36	1005
Nitrate	7	263	238	14	750
Nitrite	7	0.11	0.08	0.01	0.02
Grease	7	109	76	63	271
Suspended Solids	10	60.9	94.3	11	327

Odor Control

Air scrubbers are common in the rendering industry for odor control. The relative volume of water used, however, varies greatly, although the waste load caused by scrubbing is insignificant. The reason for the variation in water flow is that scrubbers for plant air and other low-aerosol-containing emissions (smoke and grease particulates) can tolerate recycling of up to 95 percent of the scrubbing waters. However, air heavily laden with odorous aerosols is usually scrubbed with fresh water to prevent grease buildup and clogging of the equipment. For example, one dual operation (one batch operation and one continuous operation) plant contained a total of nine scrubbers. Although some scrubbers did use partial recycle of scrubbing water, the volume of scrubbing waters was about 75 percent of the total plant effluent volume. Typically, plants will have only two or three scrubbers: one for total plant air, one for the presses, and possibly one for the ring or rotary dryers. Most of the scrubbing waters then are recycled, and the relative waste water volume from scrubbing is small. For example, one plant that was sampled had two scrubbers--one for plant air and one for a dryer--and the volume of waste water from the scrubbers amounted to only 6.0 percent of the total effluent volume.

Hide Curing

Hide curing is conducted in a number of independent rendering plants. The waste water from this operation is high in strength but relatively low in volume, particularly when the curing solution is only dumped a few times each year. Data from previous studies[12,8] indicate that about 7.7 liters (2 gallons) is the waste water overflow volume for brine curing each cattle hide.

The waste load for just curing hides at an independent rendering plant is, however, considerably less than the waste load for curing at a packing plant. This is because curing of hides at a packing plant includes a number of additional operations. These are washing, demanuring, and defleshing. In addition, the time differential between hide removal and hide delivery at a rendering plant allows for much of the blood and other fluids to seep from the hides. This time differential ranges from several hours to a few days. Also, hides and accompanying flesh removed from dead animals at a rendering plant do not appear to contain anywhere near the amount of blood and fluid that a hide removed at a packing plant from an animal killed just moments earlier contains.

Data from the recent study of packing plants[8] states that the average waste load for handling and curing hides of a packinghouse is 1.5 kg BOD5/kkg LWK (live weight killed). Since the average LWK for beef is about 454 kg (1000 pounds), this can be equivalently expressed as 0.68 kg BOD5/hide. On the other hand, a study of tannery effluents[12] lists the waste load for

Table 10. Waste Loads for Undiluted Condensed Cooking Vapors

Parameter	kg/kkg RM or lb/1000 lb RM				
	Number of Observations	Average Value	Standard Deviation	High Value	Low Value
BOD_5	10	0.73	0.50	1.53	0.049
COD	7	1.10	0.75	2.23	0.12
Total Volatile Solids	7	0.086	0.093	0.31	0.0032
Total Dissolved Solids	6	0.21	0.25	0.73	0.0013
Total Phosphorus	6	0.0021	0.00015	0.0043	0.00081
Chloride	6	0.056	0.078	0.21	0.0046
Total Kjeldahl Nitrogen	6	0.17	0.12	0.35	0.022
Nitrate	6	0.081	0.067	0.16	0.0086
Nitrite	6	0.0018	0.0038	0.0096	0.000008
Grease	7	0.14	0.25	0.70	0.015
Suspended Solids	9	0.018	0.017	0.056	0.0058

Table 11. Waste Load Characteristics for Hide Curing at an Independent Rendering Plant Versus Those for a Tannery[12]

Parameter	kg/hide	
	Rendering Plant	Tannery
BOD_5	0.11	0.12
COD	0.21	0.24
Total Volatile Solids	0.17	
Suspended Solids	0.064	0.08
Kjeldahl Nitrogen	0.014	
Ammonia	0.0013	
Nitrate	4.4×10^{-5}	
Nitrite	4.1×10^{-6}	
Total Phosphorus	0.0021	
Total Dissolved Solids	2.9	
Chloride	1.26	
Grease	0.0011	0.32

Table 12. Measured Waste Strengths of Tank Water and Blood Water

Parameter	mg/l	
	Tank Water	Blood Water
BOD_5	31,390	18,950
COD	49,152	27,200
Total Volatile Solids	36,739	17,516
Total Dissolved Solids	54,791	315
Total Phosphorus	1,350	3,498
Chloride	8,638	1,813
Total Kjeldahl Nitrogen	2,187	
Ammonia	81	
Nitrate	3.43	
Nitrite	0.35	
Grease	9,901	
Suspended Solids	6,647	

just hide curing at a tannery as 3.9 kg BOD5/kkg hides (3.9 lb/1000 lb). Using an average hide weight of 32 kg (70 pounds), this value can be expressed as 0.12 kg (0.26 lb) BOD5 per hide. This latter example should also typify the waste load for hide curing at an independent rendering plant. In fact, analysis of only the hide curing effluent at one independent rendering plant yielded a BOD5 waste load of 0.11 kg (0.24 lb) per hide. The results of this analysis are summarized in Table 11. For comparison, the value recalculated from reference 12, assuming 32 kg/hide (70 pounds), is also included.

Miscellaneous Sources

Sewered tank water and blood water are major sources of waste load. The sources of tank water are grease processing and wet- and low-temperature rendering; the source of blood water is from processing blood by steam sparging and then separating the blood water from the coagulated blood by screening. Fortunately, not many independent rendering plants have the processes that generate these sources of waste. Also, some plants that do generate tank water eliminate it as a waste source by evaporating it down to stick, which is used for tankage in dry inedible rendering. As mentioned in Section III, the BOD5 and grease concentrations of tankwater can be as high as 30,000 to 45,000 mg/l and 20,000 to 60,000 mg/l, respectively.

Table 12 shows the measured waste strengths of tank water from a grease operation and of blood water from steam sparging and screening of blood. The waste load resulting from the sewering of the tank water was 9.4 kg BOD5/kkg (9.4 lb BOD5/1000 lb) grease before primary treatment (materials recovery process). However, much of this waste load was removed by primary treatment, since the amount of grease processed was about 63 percent of the total plant RM and since the total plant waste load was only 2.2 kg BOD5/kkg (2.2 lb/1000 lb) RM. Likewise, the sewering of blood water added 16.3 kg BOD5/kkg blood before primary treatment. Judging from the values of the total plant raw waste load and the waste loads of the other sources, it would appear that the primary treatment recovered very little, if any, of the waste load from the sewering of blood water; this is as expected. It should be pointed out, however, that the blood screening process was not very efficient and that a pilot study at that plant revealed that an improved screening process would significantly lower the load from sewering blood water.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

SELECTED PARAMETERS

Based on a review of the Corps of Engineers' Permit Applications from the independent renderers, previous studies on similar waste waters such as from the meat packing plants, industry data, questionnaire data, and data obtained from sampling plant waste waters during this study, the following chemical, physical, and biological constituents constitute pollutants as defined in the Act.

- BOD5 (5-day, 20°C biochemical oxygen demand)
- COD (chemical oxygen demand)
- Total suspended solids (TSS)
- Total dissolved solids (TDS)
- Total volatile solids (TVS)
- Oil and grease
- Ammonia nitrogen
- Kjeldahl nitrogen
- Nitrates and nitrites
- Phosphorus
- Chloride
- Bacteriological counts (total and fecal coliform)
- pH, acidity, and alkalinity
- Temperature

On the basis of all evidence reviewed, there do not exist any extremely hazardous pollutants (such as heavy metals or pesticides) in the waste discharge from the independent rendering plants. While all of the above parameters are in present renderer plant waste water, the amount and reliability of available data, costs for treatment or control, and availability of technology were factors which resulted in limitations only for the primary parameters BOD5, TSS, oil and grease, fecal coliforms, ammonia, and pH.

RATIONALE FOR SELECTION OF IDENTIFIED PARAMETERS

5-Day Biochemical Oxygen Demand (BOD5)

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. BOD5 can be related to the depletion of oxygen in the receiving stream or to the requirements for the waste treatment. Values of BOD5 range from 100 to 9000 mg/l in the raw waste, although typical values range from 1000 to 5000 mg/l. Low BOD5 values in the raw waste are frequently the result of the dilutional effects of using a barometric condenser; high values are due to a combination of factors, such as undiluted condenser waters, frequent spills, and a relatively large amount of drainage of high-strength liquids from the raw material.

If the BOD5 of the final effluent of a rendering 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 BOD5 effluents 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 BOD5 is often applied for discharge to a municipal sewer, and surcharge rates often apply if the BOD5 is above the designated limit. BOD5 is included in the effluent limitations recommended because its discharge to a stream is harmful to aquatic life since it depletes the oxygen supply.

A 20-day biochemical oxygen demand (BOD20), sometimes called "ultimate" BOD, is usually a better measure of the waste load than BOD5. However, the test for BOD20 requires 20 days to run, so it is an impractical measure for most purposes.

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

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. The COD measures more than only those materials that will readily biodegrade in a stream and hence deplete the stream's dissolved oxygen supply.

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 rendering industry, COD ranges from about 1.5 to 6 times the BOD_5 in both the raw and treated wastes, with typical ratios between 1.5 and 3.0. Although the nature of the impact of COD on receiving waters is the same as for BOD_5, BOD_5 was chosen for inclusion in the effluent limitations rather than COD because of the industry's frequent use and familiarity with BOD_5.

Total Suspended Solids (TSS)

This parameter measures the suspended material that can be removed from the waste waters by laboratory filtration. 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. A high level of suspended solids is an indication of high BOD_5. Generally, suspended solids range from 1/3 to 3/4 of the BOD_5 values in the raw waste. Suspended solids are also a measure of the effectiveness of solids removal systems such as clarifiers and fine screens.

Suspended solids frequently become a limiting factor in waste treatment when the BOD_5 is less than about 20 mg/l. In fact, in highly treated waste, suspended solids usually have a higher value than the BOD_5, and in this case, it may be easier to lower the BOD_5 even further, perhaps to 5 to 10 mg/l, by filtering out the suspended solids. Suspended solids in the treated waste waters of rendering plants correlate well with BOD_5, COD, and total volatile solids. The same is not true, however, for the raw wastes.

Suspended solids also may inhibit light penetration and thereby reduce the primary productivity of algae (photosynthesis).

Because of the strong impact suspended solids can have on receiving waters, suspended solids were included in the effluent limitations recommended in this report.

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, State and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low.

Total Dissolved Solids (TDS)

The total dissolved solids in the waste waters of most independent rendering plants contain both organic and inorganic matter. A large source of organic dissolved solids is blood. Inorganic salts can be a major part of the dissolved solids if hide curing is conducted at the plant. The amount of dissolved solids will also vary to a large extent with the type of in-plant operations and the housekeeping practices. Dissolved solids are of the same order of magnitude and correlate well with the total volatile solids in both the raw and treated waste waters. The inorganic dissolved solids are particularly important because they are relatively unaffected by biological treatment processess. Therefore, unless removed, they will accumulate within the water system on total recycle or reuse, or build up to high levels with partial recycle or reuse of the waste water.

Dissolved solids affect the ionic nature of receiving waters and are usually the nutrients for bacteria and protozoans. Thus, they may increase the eutrophication rate of the receiving body of water. Total dissolved solids were not included in the effluent limitations recommended in this report because the organic portion would be substantially limited by BOD_5 limitations and the nutrient portion by the ammonia nitrogen limitations.

In natural waters the dissolved solids consist mainly of carbonates, chlorides, sulfates, phosphates, and possibly nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese, and other substances.

Many communities in the United States and in other countries use water supplies containing 2000 to 4000 mg/l of dissolved salts, when no better water is available. Such waters are not palatable, may not quench thirst, and may have a laxative action on new users. Waters containing more than 4000 mg/l of total salts are generally considered unfit for human use, although in hot climates such higher salt concentrations can be tolerated whereas they could not in temperate climates. Waters containing 5000 mg/l or more are reported to be bitter and act as bladder and intestinal irritants. It is generally agreed that the salt concentration of good, palatable water should not exceed 500 mg/l.

Limiting concentrations of dissolved solids for fresh water fish may range from 5,000 to 10,000 mg/l, according to species and prior acclimatization. Some fish are adapted to living in more saline waters, and a few species of fresh water forms have been found in natural waters with a salt concentration of 15,000 to 20,000 mg/l. Fish can slowly become acclimatized to higher salinities, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil well brines. Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on metals.

Waters with total dissolved solids over 500 mg/l have decreasing utility as irrigation water. At 5,000 mg/l water has little or no value for irrigation.

Dissolved solids in industrial waters can cause foaming in boilers and cause interference with cleanness, color, or taste of many finished products. High contents of dissolved solids also tend to accelerate corrosion.

Specific conductance is a measure of the capacity of water to convey an electric current. This property is related to the total concentration of ionized substances in water and water temperature. This property is frequently used as a substitute method of quickly estimating the dissolved solids concentration.

Total Volatile Solids (TVS)

Total volatile solids is a rough measure of the amount of organic matter in the waste water. Actually it is the amount of combustible material in both the total dissolved solids and total suspended solids. Total volatile solids in the raw waste waters of rendering plants correlates quite well with total dissolved solids and COD, and fairly well with BOD5, SS, and grease; total volatile solids in the final waste waters correlates well with total dissolved solids and BOD5, and fairly well with SS, grease, and COD. Because of these correlations and because total volatile solids is a relatively easy parameter to determine, it could be used as a rapid method to determine a serious plant or treatment system malfunction.

Effluent limitations for total volatile solids were not established because TVS will be limited by limitations on other pollutant parameters such as BOD5 and suspended solids.

Oil and Grease

Oil and grease, or grease, is a major pollutant in the raw waste stream of rendering plants. The source of grease is primarily from spillages of processed tallow and grease and cleanup of equipment, floors, barrels, and trucks. 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. It is also a food source for microorganisms. The loading of grease in the raw waste load varies widely, from less than 0.1 to about 15 kg/kkg RM. The average raw waste loading of grease is about 0.7 kg/kkg RM, which corresponds to an average concentration of about 1660 mg/l. Grease correlates well with BOD5 and COD in the raw wastes, but not in the treated wastes. Because grease appears to constitute a major portion of the waste load from rendering plants, effluent limitations were established for it.

Oil and grease exhibit an oxygen demand. Oil emulsions may adhere to the gills of fish or coat and destroy algae or other plankton. Deposition of oil in the bottom sediments can serve to prohibit normal benthic growths, thus interrupting the aquatic food chain. Soluble and emulsified material ingested by fish may taint the flavor of the fish flesh. Water soluble components may exert toxic action on fish. Floating oil may reduce the re-aeration of the water surface and in conjunction with emulsified oil may interfere with photosynthesis. Water insoluble components damage the plumage and coats of water animals and fowl. Oil and grease in water can result in the formation of objectionable surface slicks preventing the full enjoyment of the water. Oil spills can damage the surface of boats and can destroy the aesthetic characteristics of beaches and shorelines.

Ammonia Nitrogen

Ammonia nitrogen in the 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 waste water. Another source of ammonia can be liquid drainage from raw materials containing manure, and also from proteinaceous matter such as blood that has been "aged."

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. Also, free ammonia in a stream is known to be harmful to fish.

Typical concentrations in the raw waste range from 25 to 300 mg/l; however, after treatment in an anaerobic system, the concentrations of ammonia can reach 100 to 500 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. Effluent limitations for new sources and the 1983 limits were established for ammonia because of the strong impact it can have on receiving waters.

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate (NO_3) by nitrifying bacteria. Nitrite (NO_2), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when nitrification is not complete. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

In most natural water the pH range is such that ammonium ions (NH_4^+) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present. Because of the significance of ammonia as a pollutant and as an important parameter in the effluent from rendering plants, limitations have been established for 1983 and for new sources.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

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 proteinaceous material being lost in the waste water. 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. The raw waste loading of Kjeldahl nitrogen is extremely variable and is highly affected by blood losses from raw material drainage and blood and feather operations, and by liquid entrainment in the cooking vapors. Typical raw loadings range from 0.12 to 1.20 kg/kkg (0.12 to 1.20 lb/1000 lb) raw material; concentrations range from about 60 to 800 mg/l, with the lower values usually caused by the dilutional effects of barometric leg condensers. 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. Moreover, control of ammonia leads to substantial reductions of Kjeldahl nitrogen.

Nitrates and Nitrites

Nitrates and nitrites, normally reported as N, are the result of oxidation of ammonia and of organic nitrogen. Nitrates as N should not exceed 10 mg/l in water supplies.[14] They are essential nutrients for algae and other aquatic plant life. Nitrites ranged from a trace to 0.040 kg/kkg RM in the raw wastes and from a trace to 0.08 kg/kkg RM in the treated wastes;

nitrates ranged from a trace to 0.06 kg/kkg RM in the raw and from a trace to 0.012 kg/kkg RM in the treated wastes.

Concentrations of nitrites varied from 0.02 to 26 mg/l in the raw and from 0.04 to 1.2 mg/l in the final; nitrate concentrations varied from 0.02 to 13 mg/l in the raw and from 0.02 to 3.25 mg/l in the treated waste. Low values are primarily caused by the dilutional effects of barometric leg condensers.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen (NO_3-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. Nitrates and nitrites are important measurements, along with Kjeldahl nitrogen, in that they allow for the calculation of a nitrogen balance on the treatment system. The field sampling data verified that when there was a substantial nitrogen reduction by the treatment system, it was accompanied by good BOD_5, TSS, and oil and grease reductions.

Phosphorus

Phosphorus, commonly reported as P, is a nutrient for aquatic plant life and can therefore cause an increased eutrophication rate in water courses. The threshold concentration of phosphorus in receiving bodies that can lead to eutrophication is about 0.01 mg/l. The primary sources of phosphorus in raw waste from rendering are bone meal, detergents, and boiler water additives. The total phosphorus in the raw effluent ranges from about 0.007 to 0.28 kg/kkg RM (0.007 to 0.28 lb/1000 lb RM), or a typical concentration range of 3 to 50 mg/l as P. Final effluent concentrations of phosphorus are usually even lower and limitations have not been established for this parameter.

During the past 30 years, a formidable case has developed for the belief that increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man, frequently are caused by increasing supplies of phosphorus. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. Phosphorus is not the sole cause of eutrophication, but there is evidence to substantiate that it is frequently the key element required by fresh water plants and is generally present in the least amount relative to need. Therefore, an increase in phosphorus allows use of other, already present, nutrients for plant growths. Phosphorus is usually described, for these reasons, as a "limiting factor."

When a plant population is stimulated in production and attains a nuisance status, a large number of associated liabilities are immediately apparent. Dense populations of pond weeds make swimming dangerous. Boating and water skiing and sometimes fishing may be eliminated because of the mass of vegetation that serves as a physical impediment to such activities. Plant populations have been associated with stunted fish populations and with poor fishing. Plant nuisances may emit vile stenches, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a desired substrate and breeding ground for flies.

Phosphorus in the elemental form is particularly toxic, and subject to bioaccumulation in much the same way as mercury. Colloidal elemental phosphorus will poison marine fish (causing skin tissue breakdown and discoloration). Also, phosphorus is capable of being concentrated and will accumulate in organs and soft tissues. Experiments have shown that marine fish will concentrate phosphorus from water containing as little as 1 ug/l.

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 rendering plants are the salt from animal tissues, hide curing operations, and blood. The concentrations in raw waste are extremely variable from plant to plant, and are normally much higher for plants treating hides or sewering blood waters (e.g., drainage from poultry feathers) than they are for other plants. For example, chloride concentrations from liquid drainage of cured hides were measured at 80,000 mg/l as Cl; from drainage of bloody waters from poultry offal, at 691 mg/l as Cl; and from sewered blood waters from a blood operation, at 3500 mg/l as Cl. The range of chloride loadings in raw waste effluents is from 0.08 to greater than 2.56 kg/kkg RM (2.56 lb/1000 lb RM). Chloride loadings are unaffected by biological treatment systems used by the industry today, and once in the waste waters they are very costly to remove. While high chloride concentrations in biological treatment systems and receiving waters can upset the metabolic rate of organisms, effluent concentrations are probably too low to have a serious impact.

Fecal Coliforms

The coliform bacterial contamination (total and fecal) of raw waste is substantially reduced (by a factor of 100 to 200) in the larger waste treatment systems used in the industry, such as anaerobic lagoons followed by several aerobic lagoons. Chlorination will reduce coliform counts to less than 400 per 100 ml for total, and to less than 100 per 100 ml for fecal. Data indicate that the total coliform of the raw waste from rendering plants is in the 0.65- to 500-million per 100 ml range with a median value of about 7 million per 100 ml; for fecal coliform, the range is 0.05- to 75-million per 100 ml, with a median value of about 0.7 million per 100 ml. Typically, States require that the total coliform count not exceed 50-200 MPN (most probable number) per 100 ml for waste waters discharged into receiving waters. Hence, most final effluents require chlorination to meet state standards. When waters contain 200 counts of fecal coliform per 100 ml, it is assumed that pathogenic enterobacteriacea, which can cause intestinal infections, are present. Consequently, effluent limitations were established for fecal coliforms.

Fecal coliforms are used as an indicator since they have originated from the intestinal tract of warmblooded animals. Their presence in water indicates the potential presence of pathogenic bacteria and viruses.

The presence of coliforms, more specifically fecal coliforms, in water is indicative of fecal pollution. In general, the presence of fecal coliform organisms indicates recent and possibly dangerous fecal contamination. When the fecal coliform count exceeds 2,000 per 100 ml there is a high correlation with increased numbers of both pathogenic viruses and bacteria.

Many microorganisms, pathogenic to humans and animals, may be carried in surface water, particularly that derived from effluent sources which find their way into surface water from municipal and industrial wastes. The diseases associated with bacteria include bacillary and amoebic dysentery, Salmonella gastroenteritis, typhoid and paratyphoid fevers, leptospirosis, cholera, vibriosis, and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of Salmonella, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops, and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 ml, the occurrence of Salmonella was 53.5 percent.

pH, Acidity, and Alkalinity

pH is of relatively minor importance, although waters with pH outside the 6.0 to 9.0 range can affect the survival of most organisms, particularly invertebrates. The usual pH for raw waste falls between 6.0 and 9.0; although the pH of the condensables tends to be higher (7.2 to 9.6). This pH range is close enough to neutrality that it does not significantly affect treatment effectiveness or effluent quality. However, some adjustment may be required, particularly if pH adjustment has been used to lower the pH for protein precipitation, or if the pH has been raised for ammonia stripping. The pH of the waste water then should be returned to its normal range before discharge. The effect of chemical additions for pH adjustment should be taken into consideration, as new pollutants could result.

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH, water tastes "sour." The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousandfold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Temperature

Because of the long detention time at ambient temperatures associated with typically large biological treatment systems used for treating renderer plant waste water, the temperature of the treated effluent from most rendering plants will be virtually the same as the temperature of the receiving body of water. Therefore, temperature effluent limitations were not established. Temperatures of the raw waste waters are, however, between 29° and 66°C (85° and 150°F), with a typical value of about 52°C (125°F); temperatures, of course, run higher during summer months than winter months. The major source of high-temperature waters is the condensed cooking vapors. These high temperatures, along with the high-strength wastes are an asset for biological treatment of the wastes, maintaining high growth rates of microorganisms required for good treatment. However, if the temperature of the raw wastes is too high--greater than 52°C, the raw wastes may create a strong odor problem. Raw waste temperatures below 38°C (100°F) rarely cause odor problems.

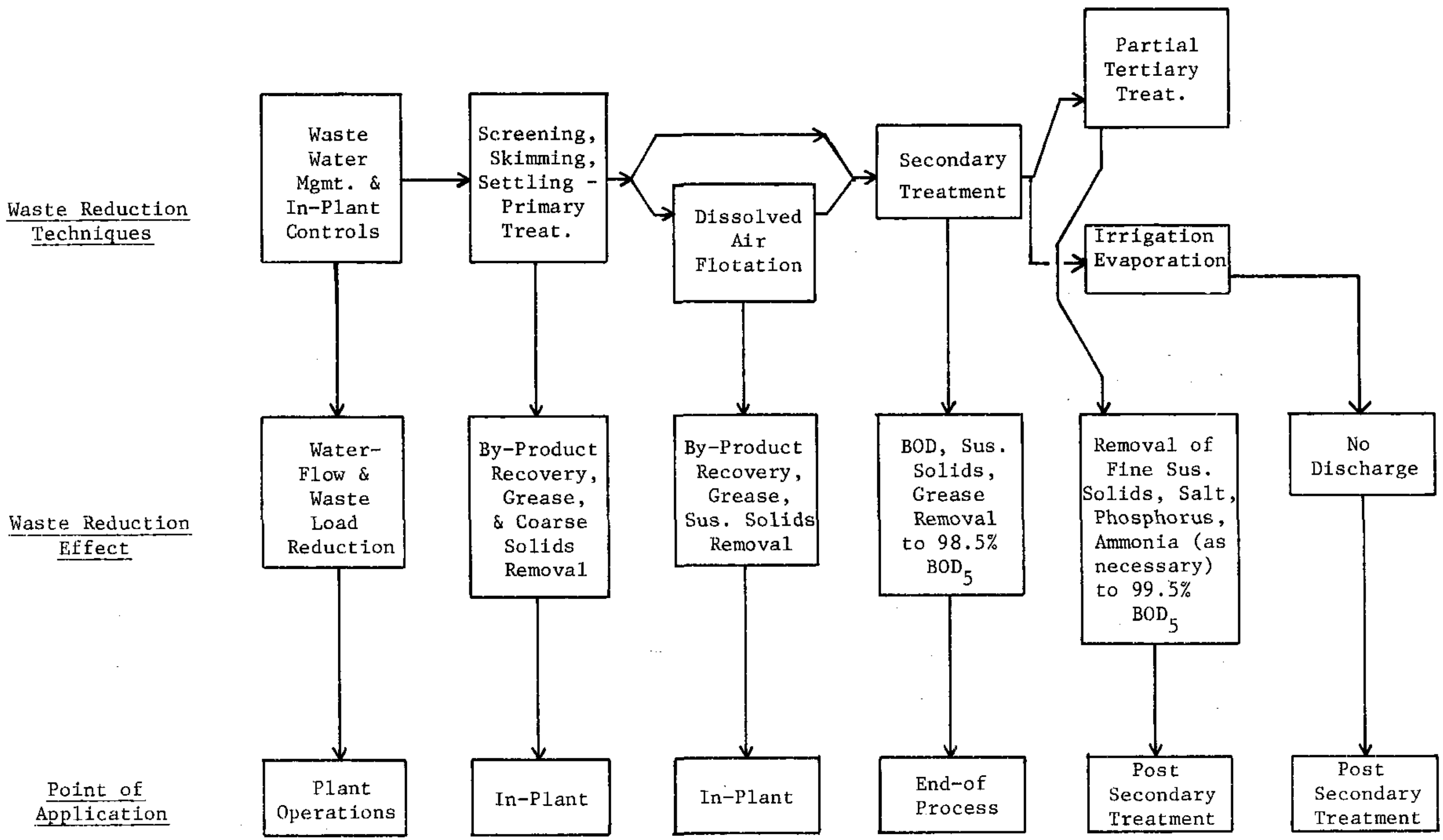
Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic plant nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Figure 12. Suggested Waste Reduction Program for Rendering Plants



The in-plant control techniques described below have been used in offsite rendering plants or are technically feasible.

Condensables

Condensables typically are high in BOD_5, phosphorus, suspended solids, dissolved solids, TKN, ammonia, nitrates, and grease. (See Table 9.) However, a number of plants are able to minimize the strength of condensables in several ways. These include:

- Avoid overloading cookers;
- Provide and maintain traps in the vapor lines;
- Control the speed of agitation;
- Provide bypass valves for controlling pressure bleed-down on cookers used for hydrolyzing raw material; and
- Control cooking rate.

The volume of condensables is dependent upon the type of raw material being processed and on the type of condenser used. From the standpoint of waste treatment, condensables should not be diluted with fresh water. Treated waters should be recycled for use in operating barometric leg condensers.

Control of High-Strength Liquid Wastes

Liquid drainage from raw materials can contribute significantly to the total raw waste load. These sources can be controlled or eliminated by containing them and then mixing the drainage with the raw materials as they enter a cooker, screening, or steam sparging and screening. Containing drainage may require plugging drains in the raw materials receiving area and in wet wells below receiving bins.

Blood water and tank water, both of which are high-strength wastes (See Section V.), can be eliminated by evaporating to stick and using as tankage for dry inedible rendering. Whole blood drying processes do not generate any blood water and should be considered as an alternative method to steam sparging and screening, followed by evaporation of blood water.

Hide curing waste waters are of high strength (See Section V.) and can be a significant part of the total raw waste load. This source can be eliminated by blending the hide curing wastes in relatively small amounts with raw materials being charged to cookers.

Truck and Barrel Washings

Solids, including grease, should be scraped or squeegeed from the trucks and barrels prior to washdown. Truck washings should be screened.

Odor Control

Although odor control by scrubbing does not contribute significantly to the raw waste load, it can add significantly to the waste water volume. This large contribution to the waste water volume can be avoided by using chemically conditioned and recycled scrubbing water or by reusing treated water.

Plant Cleanup and Spills

Cleanup of the plant and spills should include dry cleanup by squeegeeing or scraping prior to washdown. Plant cleanup is usually required only once daily. Accidental spills and leaky equipment can, however, necessitate more frequent plant cleanup. Thus, considerable effort should be expended to avoid spills and to prevent leaks. A regularly scheduled maintenance program will minimize leaks; it will minimize the spills caused by equipment failure.

IN-PLANT PRIMARY TREATMENT

Flow Equalization

Equalization facilities consist of a holding tank and pumping equipment designed to reduce the fluctuations of waste water flow through materials recovery systems. 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 should have sufficient capacity to provide for uniform flow to treatment facilities throughout a 24-hour day. The tank is characterized by a varying flow into the tank and a constant flow out.

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

Many plants do not require any special tanks to achieve flow equalization because of the manner in which they are operated. For example, plants with large continuous systems or a number of batch systems (10 to 20) with staggered cooking cycles that operate most of the day are inherently achieving a near-constant flow of waste water.

Screens

Since so much of the pollutant matter for some sources of rendering plant wastes is originally solid (meat and fat particles), interception of the waste material by various types of screens is a natural first step. To assure the best performance on a plant waste water stream, flow equalization may be needed preceding screening equipment.

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

Static, vibrating, and rotary screens are the primary types used for this step in the in-plant primary treatment. Whenever possible, 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 to other uses in the process industries. This design employs bar interference to the slurry which knives off thin layers of the water as it flows over the curved surface.[15]

Beginning in 1969, United States and foreign patents were allowed on a three-slope static screen made of specially curved wires. This concept used the Canada or wall attachment phenomenon to withdraw the fluid from the underlayer 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.[15]

Vibrating Screens

The effectiveness of a vibrating screen depends on a rapid motion. Vibrating screens operate between 99 rpm and 1800 rpm; the motion can be either 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 least consideration. In such a case, a light wire may be desired to provide an increased percent of open area.

Rotary Screens

One type of barrel or rotary screen, driven by external rollers, receives the waste water at one open end and discharges the solids at the other open end. The screen is inclined toward the exit end to facilitate movement of solids. The liquid passes outward through the screen (usually stainless steel screen cloth or perforated metal) to a receiver and then to the sewer. To prevent clogging, the screen is usually sprayed continuously by a line of external spray nozzles.

Another rotary screen commonly used in various industries, such as the meat industry, is driven by an external pinion gear. The raw waste water is fed into the interior of the screen, below the longitudinal axis, and solids are removed in a trough and screw conveyor mounted lengthwise at the axis (center line) of the barrel. The liquid exits outward through the screen into a tank under the screen. The screen is partially submerged in the liquid in the tank. 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 removal up to 82 percent is reported.[15]

Applications

A broad range of applications exists for screens as the first stage of in-plant waste water treatment. These include both the plant waste water and waste water discharged from individual sources, especially streams with high solids content such as raw material drainage.

Catch Basins

The catch basin for the separation of grease and solids from independent rendering waste waters was originally developed to recover marketable grease. Since the primary objective 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).[15]

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 design sizing factor.[15] The use of an equalizing tank ahead of the catch basin obviously minimizes the size requirement for the basin. A shallow basin--up to 1.8 meters (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 or carries it up and deposits it into a hopper. Both skimmings and sludge can be recycled as a raw material for rendering.

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 and corrosion.

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 the waste waters from independent rendering plants. It is a relatively recent technology in the rendering industry; therefore, it is not in widespread use, although increasing numbers of plants are installing these systems.

Dissolved air flotation appears to be the single most effective device currently available for a plant to use to reduce the pollutant waste load in its raw waste water stream. It is expected that the use of dissolved air flotation will become more common in the industry, especially as a step in achieving the 1983 limitations.

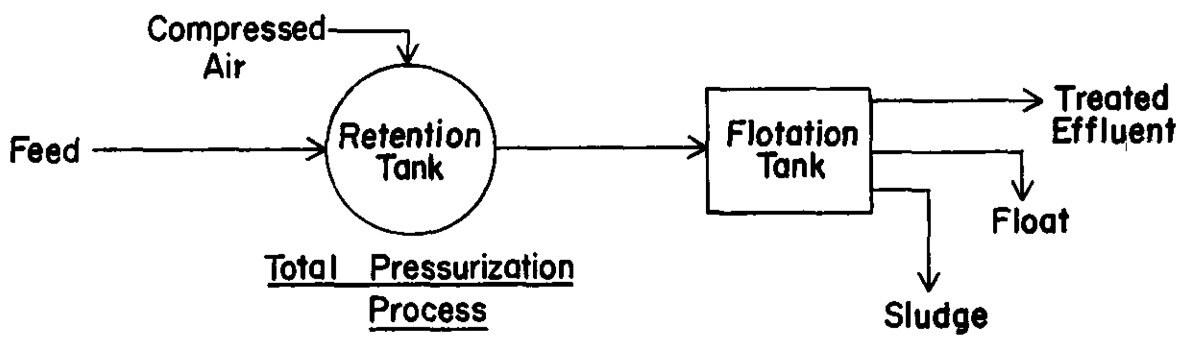


Figure 13. Dissolved Air Flotation

Technical Description

Air flotation systems are used to remove any suspended material from waste water with a specific gravity close to that of water. The dissolved air system generates a supersaturated solution of waste water and air by pressurizing waste water and introducing compressed air, then mixing the two in a detention tank. This "supersaturated" waste water 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; and 3) adsorption of the air bubbles as the floc structure is formed from the suspended organic matter.[16] In most cases, bottom sludge removal facilities are also provided.

There are three process alternatives that differ by the proportion of the waste water stream that is pressurized and into which the compressed air is mixed. In the total pressurization process, Figure 13, the entire waste water stream is raised to full pressure for compressed air injection.

In partial pressurization, Figure 14, only a part of the waste water stream is raised to the pressure of the compressed air for subsequent mixing. Alternative A of Figure 14 shows a sidestream of influent entering the detention tank, thus reducing the pumping required in the system shown in Figure 13. In the recycle pressurization process, Alternative B of Figure 14, 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 waste water. 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. Aluminum sulfate, iron sulfate, lime, and polyelectrolytes are used as coagulants at varying concentrations up to 300 to 400 mg/l in the raw waste. These chemicals are essentially totally removed in the dissolved air unit, thereby adding little or no load to the downstream waste treatment systems. However, the resulting float and sludge may become a less desirable raw material for recycling through the rendering process as a result of chemical coagulation addition. Chemical precipitation is also discussed later, particularly in regard to phosphorus removal, under tertiary treatment; phosphorus can also be removed at this primary (in-plant) treatment stage. A slow paddle mix will improve coagulation. It has been suggested that the proteinaceous matter in rendering plant waste could be removed by reducing the pH of the waste water to the isoelectric point of about 3.5.[16] The proteinaceous material would be coagulated at that point and readily removed as float from the top of the

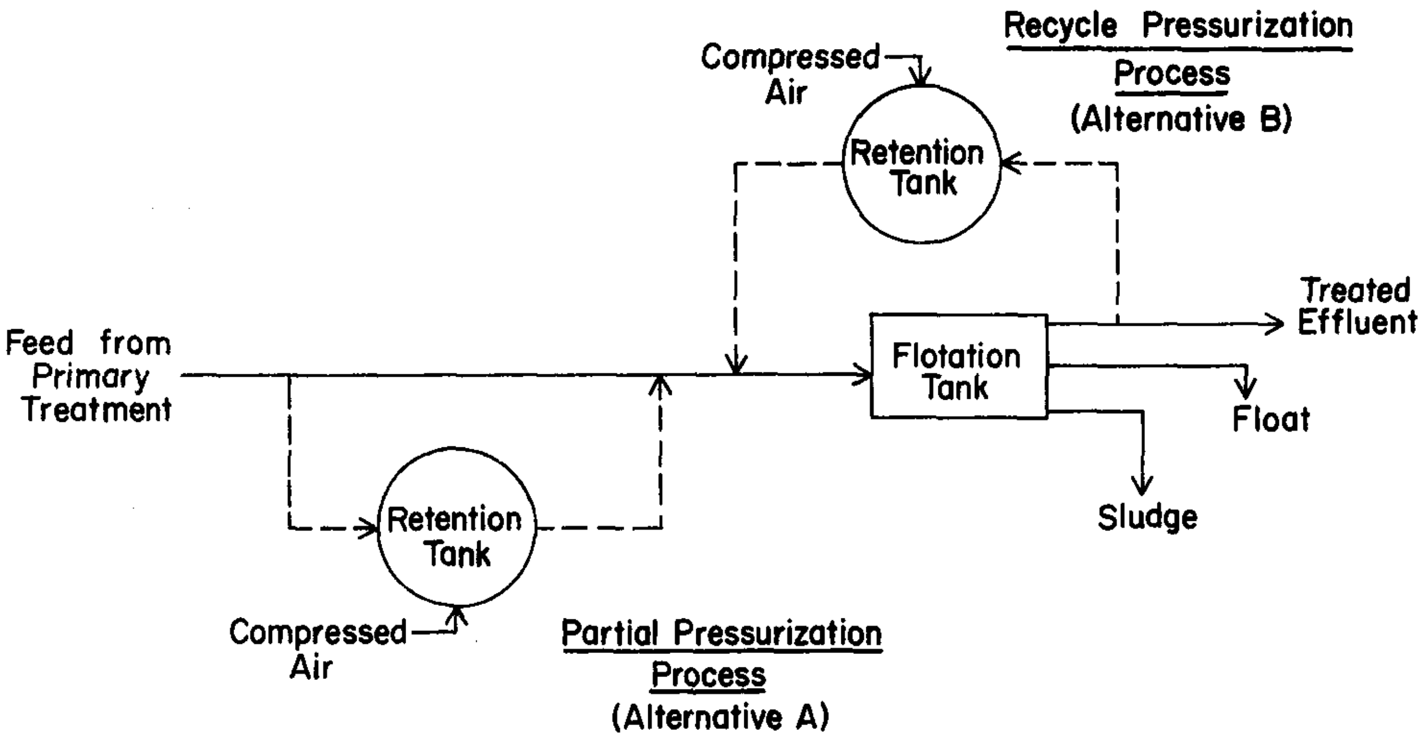


Figure 14. Process Alternatives for Dissolved Air Flotation

dissolved air unit. This is not being done commercially in the rendering industry in the United States at the present time.

Similarly, the Alwatec process has been developed by a company in Oslo, Norway, using a lignosulfonic acid precipitation and dissolved air flotation to recover a high protein product that is valuable as a feed.[16] Nearly instantaneous protein precipitation and hence, nitrogen removal, is achieved when a high protein-containing effluent is acidified to a pH between 3 and 4 with a high molecular weight lignosulfonic acid. 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 or 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.[18]

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 and more than 90 percent of the grease can be removed.[19] Total nitrogen reduction between 35 and 70 percent was found in dissolved air units surveyed in the meat packing industry.[8]

The operation of several dissolved air units has been observed during the verification sampling program and plant visits of the rendering and meat packing industries. One meat packing plant that was visited controlled the feed rate and pH of the waste water 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.

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 rendering 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 it for waste water treatment. The potential reliability of the dissolved air process can be realized by proper installation and operation. The feed rate and process conditions must be maintained at the proper levels at all times to assure this reliability. This fact does not seem to be fully understood or of sufficient concern to some companies, and thus full benefit is frequently not achieved.

The sludge and float taken from the dissolved air system can both be recycled through the rendering process. The addition of polyelectrolyte chemicals was reported to create some problems for sludge dewatering and for subsequent use as a raw material for rendering. 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.

WASTE WATER TREATMENT SYSTEMS

The secondary treatment methods commonly used for the treatment of rendering plant wastes after in-plant primary treatment (solids removal) are the following biological systems: anaerobic process, aerated and aerobic lagoons, and variations of the activated sludge process. Several of these systems individually are capable of providing up to 97 percent BOD_5 reductions and 95 percent suspended solids reduction, as observed primarily in the meat packing industry.[8] Combinations of these systems can achieve reductions up to 99 percent in BOD_5 and grease, and up to 97 percent in suspended solids for rendering plant waste water. Based on operating data from pilot-plant systems for packing plant wastes and sludge supernatant, the rotating biological contactor also shows potential.

The selection of a biological system for treatment of rendering plant wastes depends upon a number of important system characteristics. Some of these are waste water volume, waste load concentration, equipment used, pollutant reduction effectiveness required, reliability, consistency, and resulting ancillary pollution problems (e.g., sludge disposal and odor control). The characteristics and performance of each of the above-mentioned biological treatment systems, and also for common combinations of them, are described below. Capital and operating costs are discussed in Section VIII.

Anaerobic Processes

The combination of normally warm raw waste water (20° to 35°C, or 65° to 95°F) and the high concentrations of readily digested organic nutrients associated with independent rendering-plant wastes make these wastes well suited to anaerobic treatment. Anaerobic or facultative 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. Much of the organic nitrogen (protein materials) present in the influent is converted to ammonia nitrogen. Also, if sulfur compounds are present (such as from high-sulfate raw water--100 to 200 mg/l sulfate), hydrogen sulfide will be generated. Acid conditions are undesirable because methane formation is suppressed and noxious odors develop. Anaerobic processes are economical because they provide high overall removal of BOD_5 and suspended solids with low power cost and with low land requirements. Two types of anaerobic processes are used in this industry segment or in other meat products industry segments: anaerobic lagoons and anaerobic contact systems.

Anaerobic Lagoons

Anaerobic lagoons are widely used in the rendering industry as the first step in biological 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. Occasionally two anaerobic lagoons are used in parallel and sometimes 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 detention times of five to ten days. A thick scum layer of grease may be 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. Paunch manure and straw are sometimes added to help maintain the physical structure of the scum layer.

Plastic covers of nylon-reinforced Hypalon, polyvinyl chloride, and styrofoam have been used on occasion by other industries 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 the by-product methane gas.

The waste water flow inlet should be located near, but not on, the bottom of the lagoon. In some installations, sludge is recycled to ensure adequate anaerobic seed for the influent. The outlet from the lagoon should be located to prevent short circuiting of the flow and carryover of the scum layer.

For best operation, the pH should be between 7.0 and 8.5. At lower pH, methane-forming bacteria will not survive and the acid formers will take over to produce very noxious odors. At a high pH (above 8.5), acid-forming bacteria will be suppressed and lower the lagoon efficiency.

<u>Advantages-Disadvantages.</u> 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.[20] Disadvantages of an anaerobic lagoon are the hydrogen sulfide generated from sulfate-containing waters and the typically high ammonia concentrations in the effluent of 100 mg/l or more. If acid conditions develop, severe odor problems result. If the gases evolved are contained, it is possible to use iron filings to remove sulfides and methane gas could serve as a fuel source.

<u>Applications.</u> Anaerobic lagoons used as the first stage in biological treatment are usually followed by aerobic lagoons or other aerobic treatment process. Placing a small, mechanically aerated lagoon between the anaerobic and aerobic lagoons is becoming popular. Anaerobic lagoons are not permitted in some

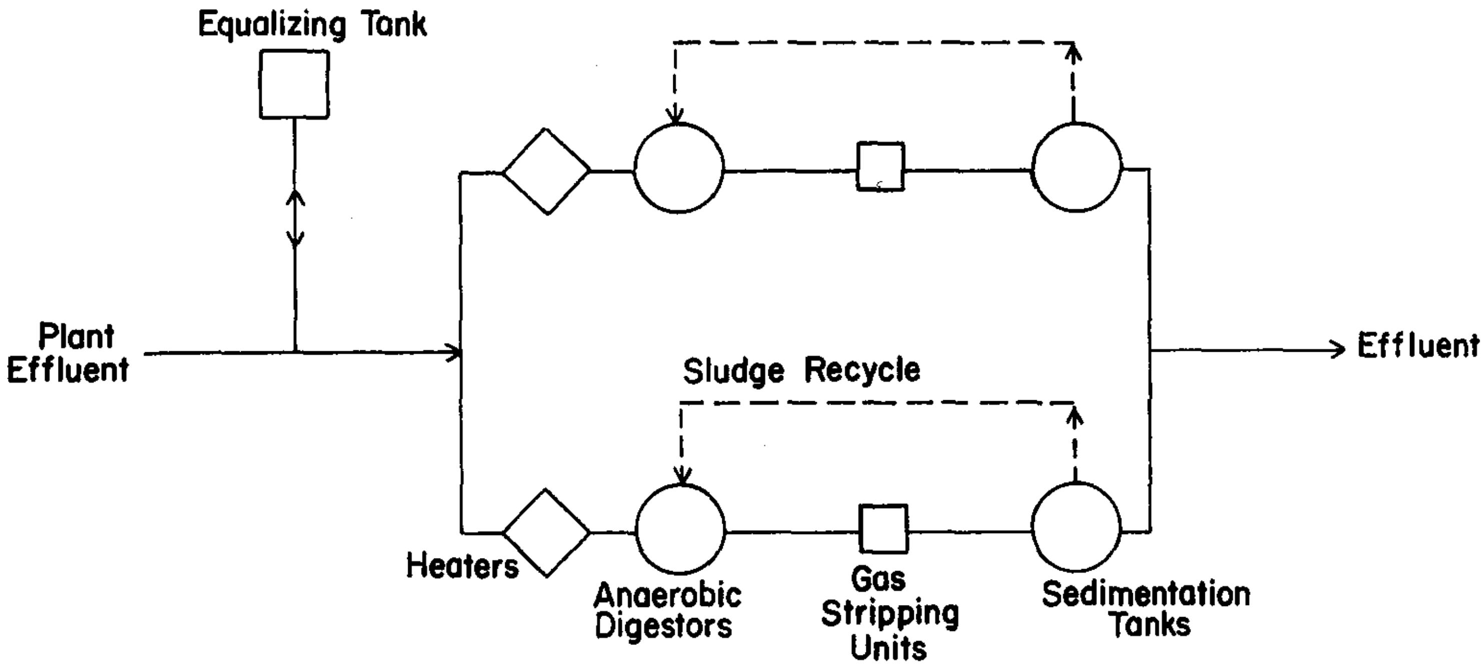


Figure 15. Anaerobic Contact Process

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 Systems

Anaerobic contact systems require more equipment for operation than do anaerobic lagoons. These systems are not known to be in use by the rendering industry, however, their use by some meat packing plants has demonstrated their applicability to rendering plant waste waters because of the similarity in waste characteristics. The equipment, as illustrated in Figure 15, 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.

Equalized waste water flow is introduced into a mixed digester where anaerobic decomposition takes place at a temperature of 33° to 35°C (90° to 95°F). BOD_5 loading into the digester is between 2.4 and 3.2 kg/cubic meter (0.15 and 0.20 lb/cubic foot) and the detention time is between 3.0 to 12.0 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 is removed from the system at the rate of about 2 percent of the raw waste volume.

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 auxiliary heat and power; good effluent stability to grease and waste load shocks; and application in areas where anaerobic lagoons cannot be used. Disadvantages of anaerobic contactors are higher initial cost and maintenance costs and potential odor emissions from the clarifiers.

Applications. Anaerobic contact systems are restricted to use as the first stage of biological treatment and can be followed by the same systems as follow anaerobic lagoons.

Aerated Lagoons

Aerated lagoons have been used successfully for many years in a small number of installations treating meat packing and rendering plant wastes. However, with the tightening of effluent limitations, and because aerated lagoons can provide the additional treatment, 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 waste water. The lagoons usually are 2.4 to 4.6 meters (8 to 15 feet) deep, and have a detention time of from several hours up 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 effluent to an aerobic state; provide additional BOD_5 reduction; and it requires a relatively small amount of land. Disadvantages include the power requirements and the fact 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 biological treatment system.

Applications

Aerated lagoons are usually the first or second stages of secondary treatment, and must be followed by a solids separation unit such as aerobic (shallow) lagoons to reduce suspended solids and to provide the required final treatment.

Aerobic Lagoons

Aerobic lagoons (stabilization lagoons or oxidation ponds) are large surface area, shallow lagoons, usually 1 to 2.3 meters (3 to 8 feet) deep, loaded at a BOD_5 rate of 20 to 50 pounds per acre. Detention times 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:

- o Allow solids to settle out;
- o Equalize and control flow; and

- o 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 meters (6 to 8 feet), the waste water near the bottom may be void of dissolved oxygen and 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 6.0 to 12.0 inches in shallow lagoons, since aerobic microorganisms cause the most complete removal of organic matter. Wind action assists in carrying the upper layer of liquid (aerated by air-water interface and photosynthesis) into the deeper portions. The anaerobic decomposition generally occurring in the bottom converts solids to liquid organics, which can become nutrients for the aerobic organisms 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 in the effluent may be reduced by drawing off the lagoon effluent at least 30 cm (about 14 inches) below the surface, where concentrations are usually lower, maintenance cleaning of the lagoon, installation of a "polishing" clarifier, or combination of these actions. 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 oxygen. The oxygen may then be used by other microorganisms for their metabolic processes. When algae die they either settle out or become part of the overall food supply (substrate) for other microorganisms.

It has been frequently observed that ammonia is reduced without the appearance of an equivalent amount of nitrite and nitrate in aerobic lagoons as evidenced by the results of field sampling surveys at various meat products treatment facilities. From this, and the fact that aerobic lagoons tend to become anaerobic near the bottom, it appears that considerable nitrification and denitrification can occur.

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. If necessary, it has been shown that the adverse effects of this condition can be substantially overcome by supplemental aeration using submerged aerators or by the use of effluent storage.[74,79] When there is no ice and snow cover on large aerobic lagoons, high winds can develop a 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 waste water 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 the suspended solids and colloidal matter, and oxidize the organic matter of the influent to the lagoon; they also permit flow control and waste water storage. Disadvantages are reduced effectiveness during winter months that may require supplemental aeration, increased design capacity, possible requirements to include provisions for no discharge for periods of three months or more. In addition, there are relatively large land requirements, the potential algae growth problem leading to higher suspended solids, 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 biological treatment and frequently follow anaerobic or anaerobic-plus-aerated lagoons. Large aerobic lagoons allow plants to store waste waters for 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 16. In this process, recycled biologically active sludge or floc is mixed in aerated tanks or basins with waste water. 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, or nitrogen gas (denitrification). The time required for digestion depends on the type of waste and its concentration, but the average time is 6.0 hours. The floc, which is a mixture of microorganisms (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 and waste water, 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 settled biologically active sludge. A portion of the settled sludge, normally about 20 percent, is recycled to serve as an inoculum and to maintain a high mixed liquor suspended solids content. Excess sludge is removed (wasted) from the system, to thickeners and anaerobic digestion, to chemical treatment and dewatering by filtration or centrifugation, or to land disposal where it is used as a fertilizer and soil conditioner to aid secondary crop growth.

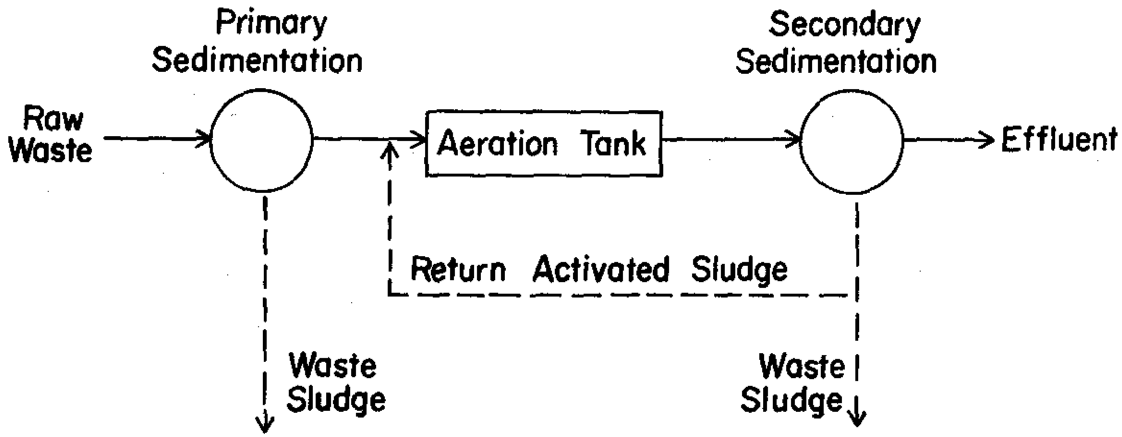


Figure 16. Activated Sludge Process

This conventional activated sludge process can reduce BOD_5 and suspended solids up to 95 percent. However, it cannot readily handle shock loads and widely varying flows and therefore might require upstream flow equalization.

Various modifications of the activated sludge process have been developed, such as the tapered aeration, step aeration, contact stabilization, and extended aeration. Of these, extended aeration processes are most frequently being used for treatment of meat processing, meat packing and rendering 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 usual detention time in extended aeration ranges from one to three days, rather than six hours as in the conventional process. 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. 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 waste waters, 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 nitrifying bacteria. For this to occur, it is necessary to have sludge detention times in excess of ten days.[20] This can be accomplished by regulating the amounts of recycled and wasted sludge. Oxygen-enriched gas may be substituted for 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. When countercurrent, staged flow and recirculation of gas back through the liquor are employed, between 90 and 95 percent oxygen use is claimed. Although this modification has not been used in treating rendering plant wastes, it is being used successfully for treating other wastes. The concept of nitrification and the treatment systems involved are discussed later in greater detail under the heading "Nitrogen Control."

Advantages-Disadvantages. One advantage of the extended aeration process are that it is immune 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 the conventional activated sludge. Also, because of the long detention time, high BOD_5 reductions can be attained. 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 high efficiency in reduction of organic waste load and the additional benefit of the nitrification process, extended aeration systems are being used by some meat products plants in lieu of, or in conjunction with, anaerobic processes or lagoons to produce low BOD_5 and low ammonia-nitrogen effluents. They are also being used as the first stage of biological treatment, followed by polishing lagoons.

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 waste waters being treated. A biological growth covering the surface of the disk adsorbs dissolved organic matter present in the waste water. As the biomass on the disk builds up, excess slime is sloughed off periodically and is settled out in sedimentation tanks. The rotation of the disk carries a thin film of waste water 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 waste waters. In many ways the RBC system is a compact version of a trickling filter. In the trickling filter, the waste waters flow over the media and thus over the microbial flora; in the RBC system, the flora is passed through the waste water.

The system can be staged to enhance overall waste load 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 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; it found application only in Europe, where there are an estimated

1000 domestic installations.[20] However, the use of the RBC for the treatment of meat plant waste is being evaluated at the present time. The only operating information available on its use on meat packing waste is from a pilot scale system; no information appears to be available on its use for treating rendering plant wastes. 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 unit area on an average BOD_5 influent concentration of approximately 25 mg/l.[21]

Data from Autotrol Corporation, one of the suppliers of RBC systems, revealed ammonia removal of greater than 90 percent by nitrification in a multistage unit.[21] 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 with final ammonia concentrations as low as 2.0 mg/l or less.[55]

A large installation was recently completed at the Iowa Beef Processors plant in Dakota City, Nebraska, for the further treatment of the effluent from an anaerobic lagoon.[22] No data are available on this installation, which has been plagued with mechanical problems.

Advantages-Disadvantages

The major advantages of the RBC system are its relatively low first cost; the ability to stage to achieve dissolved organic matter reduction with the potential for removal of ammonia by nitrification; and its 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 demonstrated its durability and reliability when used on domestic wastes in Europe and on several industrial wastes in the United States, it has not yet been proved on rendering plant wastes.

Uses

Rotating biological contactors could be used as a substitute for the entire aerobic 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, nitrification of effluents, and as pretreatment prior to discharging wastes to a municipal system. A BOD_5 reduction of 98 percent is reportedly achievable with a four-stage RBC.[20]

Performance of Various Biological Treatment Systems

Table 13. Performance of Various Biological Treatment Systems

	Secondary Treatment System (number of systems used to determine averages)	Water Wasteload Reduction, Percent					
		Average Values			Exemplary Values		
		BOD_5	SS	Grease	BOD_5	SS	Grease
Rendering Plants	Anaerobic + Aerobic Lagoon (4)	97.7	97.3	89.2	99.0	99.9	99.4
Rendering Plants	Activated Sludge (2)	93.7	86.1	92.2	96.6	97.1	99.4
Rendering Plants	Aerated + Aerobic Lagoon (2)	96.9	88.2	77.5	97.7	93.8	78.8
Meat Packing Plants[8]	Anaerobic + Aerobic Lagoon (22)	95.4	93.5	95.3	98.9	96.6	98.9
Meat Packing Plants[8]	Anaerobic + Aerated + Aerobic Lagoon (3)	98.3	93.3	98.5	99.5	97.5	99.2
Meat Packing Plants[8]	Anaerobic Contact Process + Aerobic Lagoon (1)	98.5	96.0	99.0			
Meat Packing Plants[8]	Extended Aeration + Aerobic Lagoon (1)	96.0	86.0	98.0	96.0	86.0	98.0
Meat Packing Plants[8]	Anaerobic Lagoon + Rotating Biological Contactor	98.5e	--				
Meat Packing Plants[8]	Anaerobic Lagoon + Extended Aeration + Aerobic Lagoon	98e	93e	98e			
Meat Packing Plants[8]	Anaerobic Lagoon + Trickling Filter (1)	97.5	94.0	96.0			
Meat Packing Plants[8]	2-Stage Trickling Filter (1)	95.5	95.0	98.0			
Meat Packing Plants[8]	Aerated + Aerobic Lagoon (1)	99.4	94.5	--	99.4	94.5	--
Meat Packing Plants[8]	Anaerobic Contact (1)	96.9	97.1	95.8	96.9	97.1	95.8

e = estimated

Table 13 shows BOD_5, suspended solids (SS), and grease removal efficiencies for various biological treatment systems on rendering plant and meat packing plant waste waters. Exemplary values each represent results from an actual treatment system, except for the data on the anaerobic plus aerobic lagoon system under treatment on meat packing waste waters, which includes an average for two plants.

The number of systems used to calculate average values is shown in Table 13. It is apparent that the anaerobic plus aerobic lagoon system is the one most commonly used by meat packing and rendering plants.

The estimated reduction of BOD_5 for meat packing waste waters shown for the anaerobic lagoon plus rotating biological contactor is based on preliminary pilot-plant results. The values shown for the anaerobic-lagoon plus extended aeration system are based on estimates of their combined effectiveness that are below the value calculated by using the average removal efficiency for the two components of the system, individually. For example, if the BOD_5 reduction for the anaerobic lagoon and the extended aeration were each 90 percent, the calculated efficiency of the two systems combined would be 99 percent.

The data of Table 13 show that, for rendering plants, the anaerobic plus aerobic lagoons are the most effective system of those studied for BOD_5, SS, and grease removal. Furthermore, the anaerobic plus aerobic lagoon system appears, by percent reductions, to be more effective on rendering than on meat packing waste waters. This conclusion could be the result of an insufficient number of observations; however, it most likely is because the rendering waste loadings to the treatment system are generally lower in absolute amounts than in the more complex operations at meat packing plants. In fact, the BOD_5 waste loadings to this type of system for three of the rendering plants were 12.8; 125, and 35.3 kg BOD_5/1000 cubic meters (15 to 20 lb BOD_5/1000 cubic feet). All of the treatment systems listed in Table 13 are capable of treating typical rendering plant waste waters to a degree sufficient to meet the 1977 limitations recommended in Section IX. In fact, the data presented in Section X show that at least three of these systems alone--anaerobic plus aerobic lagoon, activated sludge, or aerated plus aerobic lagoon--are already producing rendering plant effluent that meets the majority of pollutant parameter limitations for 1983.

ADVANCED WASTE WATER TREATMENT

Chemical Precipitation

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 for removing phosphorus, Figure 17, has been verified in full scale during the verification sampling program of the meat packing industry.[8] One packing plant operates a dissolved air flotation system as a chemical precipitation unit and achieves 95 percent phosphorus removal, to a concentration of less than 1 mg/l.

Chemical precipitation can be used for primary (in-plant) treatment to remove BOD_5, suspended solids, and grease, as discussed earlier in conjunction with dissolved air flotation. Also, it can be used as a final treatment following biological treatment to remove suspended solids in addition to phosphorus.

Technical Description

Phosphorus occurs in waste water streams from rendering 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 precipitated colloids and by the settling rate of the agglomerate.[16] 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--calcium, aluminum, and iron. The optimum pH for the iron and aluminum precipitation occurs in the 4 to 6 range, whereas the calcium precipitation occurs on the alkaline side at pH values above 9.5.

Since the removal of phosphorus is a two-step process involving precipitation and then agglomeration, and both are sensitive to pH, controlling 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.[16]

Polyelectrolytes are polymers that can be used as primary coagulants, flocculation aids, filter aids, or for sludge conditions. Phosphorus removal may be enhanced by the use of such polyelectrolytes by producing a better floc than might occur without such chemical addition.[23]

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.

Development Status

This process is well established and understood, technically. However, its use on rendering plant waste waters, normally as a primary waste treatment system, is very limited and is not expected to gain widespread acceptance. This is because most rendering plants do not have high phosphorus levels in their total waste waters and have other effective primary treatment processes for BOD_5, SS, and grease removal.

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 frequently the result of a lack of understanding or inadequate equipment. Sludge disposal is not expected to be a problem, although the use of polyelectrolytes and their effect on the dewatering properties of the sludge are open to some question at the present time. In addition, the use of the recovered sludge as a raw material for rendering may be less desirable as a result of chemical addition.

Sand Filter

A slow sand filter is a specially prepared bed of sand or other mineral fines on which doses of waste water are intermittently applied and from which effluent is removed by an under-drainage system (Figure 18); it removes solids from the waste water stream. A variety of filters can be used to remove the solids in a treated waste water: intermittent sand filters, slow sand filters, rapid sand filters, and mixed media filters. BOD_5 removal occurs primarily as a function of the degree of solids removal. The effluent from the sand filter is of a high quality. A summary of available information indicates that effluent suspended solids concentrations of less than 10 mg/l can be met. Although the performance of a sand filter is well known and documented, it is not in common use in the meat products industry because use of refinements of this type has not been needed to reach current waste water standards.

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 for final 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 sand filter. Thus, the rapid sand filter requires substantially less area than the slow sand filter; however, the cycle time averages about 24 hours in comparison with cycles of up to 30 to 60 days for a slow sand filter.[25] The larger area required for the latter means a higher initial cost. For small plants, the slow sand filter can be used as tertiary treatment. The rapid sand filter can be more generally applied following secondary treatment for all plant sizes. If a rapid sand filter were used as secondary treatment it would tend to clog quickly and require frequent backwashing, resulting in a high water use. This wash water would also need treatment prior to discharge particularly if the rapid sand filter were used in secondary treatment applications with only conventional solids removal upstream in the plant. Thus, its use is generally confined to applications for "polishing" final effluents.

The rapid sand filters operate essentially unattended with pressure loss controls and piping installed for automatic backwashing. They are contained in concrete structures or in steel tanks.

In a rapid sand filter, as much as 80 percent of the head loss can occur in the upper few inches of the filter. One approach to increase the effective filter depth is the use of more than one media in the filter. Other filter media have included coarse coal, heavy garnet or ilmenite media, and sand. There is no one mixed media design which will be optimum for all waste water filtration problems. As an example, "removal of small quantities of high-strength biological floc often found in activated sludge effluents may be satisfactorily achieved by a good dual media design. With a weaker floc strength or with an increase in applied solids loading, the benefits of the mixed, tri-media bed become more pronounced."[23]

Although a mixed media filter can tolerate higher suspended solids loadings than can other filtration processes, it still has an upper limit of applied suspended solids at which economically long runs can be maintained. With activated sludge effluent suspended solids loadings of up to 120 mg/l, filter runs of 15 to 24 hours at 5 gpm/ft have been maintained when operating to a terminal head loss of 15 feet of water.[23]

The effluent quality produced by plain filtration of biological effluents is essentially independent of filter rate within the range of 5-15 gpm/ft primarily due to the high strength of the biological floc. The following quality of filter effluents are presented as general guides to the suspended solids concentration which might be achieved when filtering a secondary effluent of reasonable quality, without chemical coagulation: high rate trickling filter, 10-20 mg/l; two stage trickling filter, 6-15 mg/l; contact stabilization; 6-15 mg/l; conventional activated sludge plant, 3-10 mg/l; activated sludge plant with a load factor less than 0.15, 1-5 mg/l.

Development Status

The slow sand filter has been in use for more than 50 years. 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 of sanitary- or municipal-type raw waste. The Ohio Environmental Protection Administration is a strong advocate of slow sand filters in lieu of biological treatment for small meat plants. As of early 1973, 16 sand filters had been installed and eight were proposed and expected to be installed in Ohio. All 24 of these installations were on waste from meat plants.[31] The land requirements for a slow sand filter are not particularly significant in relation to those required for lagooning purposes in biological 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. Rapid sand filters have received most attention as the principal method to treat water supplies. More recently, applications as an advanced waste treatment mode for municipal and joint municipal-industrial waste water facilities have proven successful. Multi-media filters were developed for general use in the mid 1960's and these filters also have been used for potable water treatment and final treatment of waste water since that time. A summary of results using filtration on a variety of treated effluents is given in Table 13A.

Problems and Reliability

The reliability of all principal types of filters seems to be well established in its long-term use as a principal component of water treatment systems. When the sand filter is operated intermittently there should be little danger of operating mishap with resultant discharge of untreated effluent or poor quality

Table 13A. Effluent Quality from Conventional Filtration of Various Biologically Treated Wastewaters*

Influent Source	Filter Type	Filter Influent (mg/l) BOD	Filter Influent (mg/l) TSS	Filter Effluent (mg/l) BOD	Filter Effluent (mg/l) TSS	Reference
Activated Sludge	Gravity mixed media	15-20	10-25	4-10	2-5	67
Activated Sludge	multi-media	11-50	28-126	3-8	1-17	67
Extended Aeration plus settling	pressure, multi-media	7-36	30-2180	1-4	1-20	67
Trickling Filter	Gravity, Sand	15-130	8-75	2-74	1-27	60,62
Activated Sludge with Clarifier	multi-media	-	18 (AVE)	-	2.4 (AVE)	61
Contact Stabilization (raw waste includes cannery)	mixed-media	-	-	2-4	2-8	65
Miscellaneous	sand (slow and rapid)	10-50	15-75	2-6	3-10	59,61 0
Trickling Filter with Nitrification	sand	-	-	9-28	3-7	54

*See also, performance data in references 23, 24, 62, 63, and 66.

effluent. The need for bed cleaning becomes evident with the reduction in quality of the effluent or in the increased cycle time, both of which are subject to monitoring and control. Operation in cold climates is possible as long as the appropriate precautionary measures are taken to prevent "blanking off" of the bed by freezing water.

With larger sized slow sand filters, the labor in maintaining and cleaning the surface should receive adequate consideration. Cleanup of the rapid sand filter requires backwashing of the bed of sand with a greater quantity of water than used for the slow sand filter. Backwashing is an effective cleanup procedure and the only constraint is to minimize the washwater required in cleanup, since this must be disposed of in some appropriate manner other than discharging it to a stream. 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.

The rapid sand filter has also been receiving more extensive application in municipal sewage treatment for tertiary treatment; thus, its use in tertiary treatment of secondary treated effluents from any type of meat or rendering processing plants appears to be a practical method of reducing BOD5 and suspended solids to levels below those expected from conventional secondary treatment.

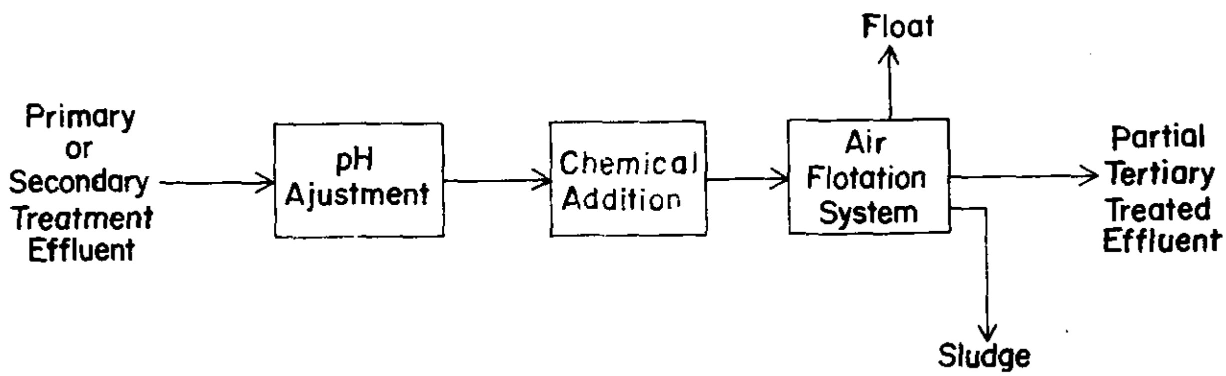
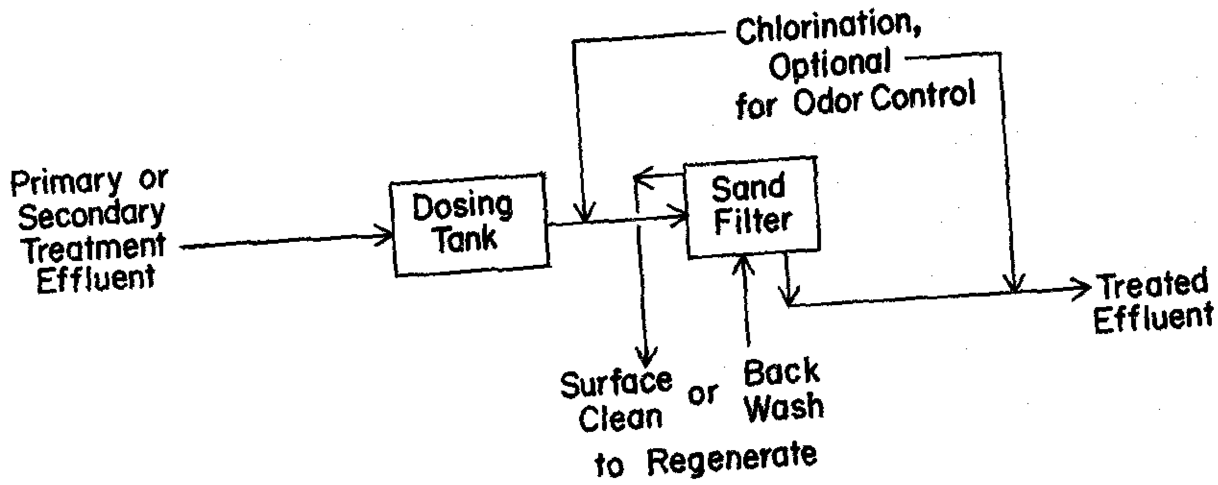


Figure 17. Chemical Precipitation Schematic

Figure 18. Sand Filter System



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 19. The microstrainer is used as tertiary treatment following the removal of most of the solids from the waste water stream, and suspended solids and BOD_5 have been reduced to 3 to 5 mg/l in applications on municipal waste.[15 70] One poultry processing plant using microscreens as tertiary treatment consistantly achieves a BOD_5 in the effluent of less than 15 mg/l and frequently below 5 mg/l. The effluent quality obtained by the microstrainer at the poultry processing plant is consistent with data reported by other situations in which microstrainers have been used to remove solids from secondary effluents. The percent removal of suspended solids by a microstrainer are related to the size of the aperture of the screen. Fifty to 60 percent removals can be anticipated with a 23 micron strainer and 40-50 percent removals with a 35 micron strainer. The microstrainer effluent quality from a number of studies indicated suspended solids concentrations of 6 to 8 mg/l when activated sludge effluent was tested, and 15 to 40 mg/l when a trickling filter effluent was treated.[24]

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 waste water. Backwash immediately follows the deposition of solids on the fabric, and in one installation, this is followed by ultra-violet light exposure to inhibit microbiological growth. The backwash water containing the solids amounts to about 3 percent of the waste water stream and must be disposed of by recycling to the biological treatment system.[27] The drum is rotated at a minimum of 0.7 and up to a maximum of 4.3 revolutions per minute. The concentration and percentage removal performance for microstrainers on suspended solids and BOD_5 appear to be approximately the same as for sand filters.

Development Status

While applications of microscreens for filtration are more recent than conventional filters, there is general information available on the performance of microstrainers and on tests involving the use of them. In addition to its use on poultry processing waste, there has been a substantial increase in full-scale applications at municipal facilities. As with conventional filters, the requirements for effluent quality imposed by State and Federal regulatory agencies have not necessitated such installations in the past. The economic comparisons between sand filters and

Table 13B. Performance of Microstrainers
in Advanced Treatment of Biologically Treated Wastewater

Influent (mg/l)		Effluent (mg/l)		Reference
BOD	TSS	BOD	TSS	
15-20	20-25	3-5	6-8	23
10-30	10-40	3-8	3-10	70
-	6-54	-	2-14	67*
15-25	15-30	4-5	3-7	poultry plant

*Data from 22 municipal installations including several with wasteload contributions from unidentified industrial sources.

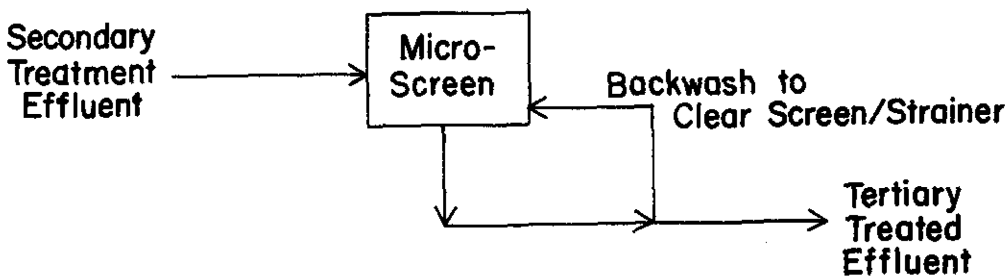


Figure 19. Microscreen/Microstrainer

microstrainers are inconclusive; the mechanical equipment required for the microstrainer may be a more relevant factor than the space requirement for the sand filter at the present time. Table 13B provides a brief summary of the general performance achieved by microstrainers on biologically treated waste water.

Problems and Reliability

The reported performances of the microstrainer fairly well establishes the reliability of the device and its ability to remove suspended solids and associated BOD_5. Operating and maintenance problems have not been reported; this is probably because of the limited use of the device in full-scale applications. 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 substantial degree of grease loading.

NITROGEN CONTROL

Nitrification

Nitrification is the biological conversion of nitrogen in organic or inorganic compounds from a more reduced to a more oxidized state. In the field of water pollution control, nitrification usually is referred to as the process in which ammonium ions (NH_4) are oxidized to nitrite and nitrate sequentially. When aeration systems are used to treat an industrial waste water, some nitrification and ammonia stripping can be expected to occur naturally and thus reduce the quantity of ammonia requiring further removal. This "incidental" treatment has been observed for treated effluents from several types of meat products plants where concentrations of about 10 to 50 mg/l of ammonia have been found while partially treated wastes have concentrations of 100 mg/l or more. Ammonia removal is becoming more important since it is recommended that the concentration of un-ionized ammonia (NH_3) in surface water be no greater than 0.02 mg/l at any time or place to assure protection of some aquatic organisms. Because ammonia may be indicative of pollution, it is recommended that ammonia nitrogen in public water supply sources not exceed 1.5 mg/l.[39]

Technical Description

Nitrification can be used to reduce the ammonia concentration of waste waters. Figure 20 indicates a schematic of the nitrification process. The equations following the figure indicate the nitrification sequence and organisms involved.

Adequate process design and operating control are necessary for consistent results. Factors that affect the nitrification process include concentration of nitrifying organisms, temperature, pH, dissolved oxygen concentration, and the concentration of any inhibiting compounds.[40] The nitrifying organisms of significance in waste management are autotrophic with Nitrosomonas and Nitrobacter being the major bacterial genera that are involved. Nitrifying bacteria are ubiquitous in the soil although they may not be part of untreated wastes.

Nitrifying organisms are aerobic and adequate dissolved oxygen (DO) in the aeration system is necessary. DO concentrations should be above 1 to 2 mg/l to assure consistent nitrification. Nitrification is affected by the temperature of the system. Available information provides conflicting data on the performance of nitrification systems at low temperatures. Although detailed studies are lacking, it should be possible to achieve nitrification at low temperatures and compensate for slower nitrifying organism growth rates by maintaining a longer solids detention time and hence larger nitrifying active mass in the system.[41]

The optimum pH for nitrification of municipal sewage has been indicated to be between 7.5 and 8.5. Nitrification can proceed at low pH levels, but at less than optimum rates. During nitrification, hydrogen ions are produced and the pH decreases, the magnitude of the decrease being related to the buffer capacity of the system. A decrease in pH is a practical measure of the onset of nitrification.

High concentrations of un-ionized ammonia (NH_3) and un-ionized nitrous acid (HNO_2) can inhibit nitrification. These compounds can be in the influent waste water or can be generated as part of the nitrification process. The concentrations of un-ionized ammonia and nitrous acid that are inhibitory and operational approaches to avoid such inhibition have been documented. Using these approaches it should be possible to operate nitrification systems that produce consistent results even with waste waters having high nitrogen concentrations.

Development Status

While research on nitrification has been conducted for a number of years, most pilot and full-scale studies have been initiated since 1970. Even though there has been a relatively short time frame of evaluation, nitrification is already a very readily described process for which treatment system designs can be implemented. Most of the applications have been on municipal effluents, but concentrations of ammonia in these effluents ranged between 20 mg/l and 800 mg/l. Ammonia concentrations in biologically treated effluents from various types of meat and poultry packing and processing plants have been found to range between 10 mg/l and 200 mg/l, or more, and thus fall within the limits of the nitrification investigations cited below in Table 13C. Like any other "tertiary" level of treatment, nitrification

Table 13C. Selected Results for Nitrogen Control in Effluents

Nitrogen Control[a] Mode	Parameter(s) Measured	Effluent Concentration (mg/l)	Reference
Extended aeration(N)	Total Kjeldahl Nitrogen	0.5-10.0	57
Clarification(DN)	Total Nitrogen	5.0	44
Denitrification Tower	Ammonia	0.8-1.2	44
Nitrification	Ammonia	1.7 June- 1.9 January	44
Single Stage (DN)	Total Nitrogen	3.8-5.9	44
Submerged Filter(N)	Ammonia	0.3-1.2	56
Rotating Disc(N)	Ammonia	1.6-2.5	55[b]
Trickling Filter Tower(N)	Ammonia	1.2-1.9	54[c]
Aerated sludge and anaerobic reactor(DN)	Ammonia nitrates	0.0-1.5 0.0	50
Breakpoint(N) chlorination	Ammonia	1.0	68
Activated Sludge(N)	Ammonia	0.0-2.7	69

[a] Note (N) refers to nitrification system and (DN) refers to nitrification-denitrification

[b] Influent ammonia concentrations range of 450-800 mg/l

[c] Range of data for 18 month period; test site in Michigan with seasonal data collected for approximately two weeks each season.

requires more operational attention than has generally been given to simple biological treatment, but the applicability of the process to all types of meat product effluents appears very reasonable.

Problems and Reliability

As discussed above, emphasis on nitrification as a treatment process has been relatively recent. Except for incidental ammonia removal facilities, nitrification processes have not been specifically applied in this industry. Water temperature, particularly below 10°C, is an apparent constraint for which an increase in sludge age or solids retention time (via sludge recycle) may compensate. Maintenance of adequate dissolved oxygen levels is also important since nitrification activity effectively ceases at DO levels below 1.0 mg/l. The process is relatively delicate and requires attentive operation.

Nitrification/Denitrification

This two-step process of nitrification and denitrification, Figure 20, is of primary importance for removal of the residual ammonia and nitrites-nitrates in secondary treatment systems. Removal of the above soluble nitrogen forms can be virtually complete, with the nitrogen gas as the end product. This process differs from ammonia stripping and nitrification in that the latter processes convert or remove only the ammonia content of a waste water. Table 13C shows a summary of results in removing both ammonia and other nitrogen from waste waters.

Technical Description

As described in an earlier section, nitrification is carried out under controlled process conditions by aerating the waste water sufficiently to assure the conversion of the nitrogen in the waste water to the nitrite-nitrate forms. The denitrification process reduces the oxidized nitrogen compounds (nitrites and nitrates) to nitrogen gas and nitrogen oxides thereby reducing the nitrogen content of the waste water as the gases escape from the liquid.

Denitrification takes place in the absence of dissolved oxygen. Additional important factors affecting denitrification include carbon source and temperature. Denitrification is brought about by heterotrophic

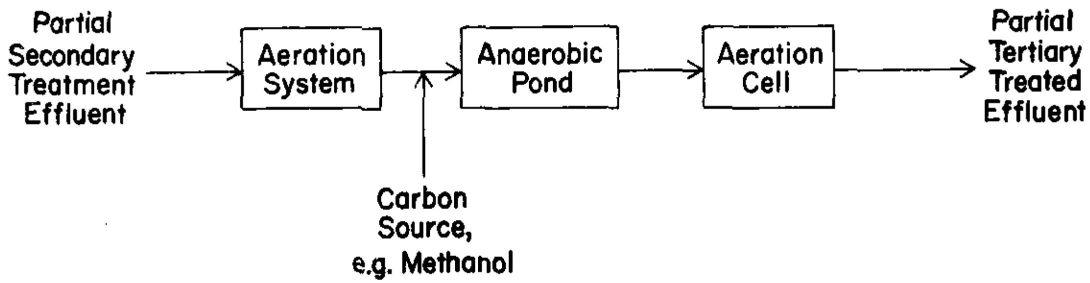


Figure 20. Nitrification/Denitrification

Nitrification:

$NH_3 + O2 \longrightarrow NO_2^- + H_3O^+$ (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 formed

(Facultative heterotrophs)

facultative bacteria. Generally, high denitrification rates require 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.[23 29]

Denitrification does not take place until the dissolved oxygen concentration of the waste water is near or at zero. The organisms responsible for denitrification are ubiquitous and can adapt to pH levels within the range of about 6.0 to 9.0. As with any biochemical process, denitrification exhibits a temperature dependency although within the range of 20°C to 30°C, little effect has been observed. Denitrification activity decreased when the temperature decreased to 10°C. Denitrification can be operated at low temperatures by designing systems with long solids retention times (SRT). For denitrification systems, an SRT of at least 3 to 4 days at 20°C and 30°C and 8 days at 10°C has been recommended. Nitrate reduction efficiency in denitrification can be controlled by adjusting the SRT of the process to assure adequate numbers of denitrifying organisms and adequate denitrification rates as environmental conditions change.

In a sequential nitrification-denitrification process (Figure 20), the waste water from the denitrification step may be sent to a second aeration basin following denitrification, where the nitrogen gases are stripped from the waste stream. The sludge from each stage is settled and recycled to preserve the organisms required for each step in the process. The processes of nitrification and denitrification can occur simultaneously in aeration systems in which both aerobic and anaerobic portions occur.

Development Status

Although, nitrification-denitrification has not been applied to rendering processing waste waters as yet, the process has been evaluated in a number of bench and pilot scale studies on a variety of wastes.[40 42] Anaerobic processes evaluated as part of the denitrification sequence have included anaerobic ponds, an anaerobic activated sludge system, and anaerobic filters. Efficient nitrogen removals from agricultural subsurface drainage water were accomplished with an anaerobic filter. In Germany, the successful elimination of nitrogen from sewage and digester supernatant was achieved by first nitrifying the wastes and then denitrifying in a separate vessel. Two and three sludge systems have been shown to be feasible for the nitrification-denitrification process.[44] A pilot model of a three-stage system using this process was developed at the Cincinnati Water Research Laboratory of the EPA and is being built at Manassas, Virginia. Observations of treatment lagoons indicate that the suggested reactions are occurring in present systems. Also, Halvorson reported that Pasveer achieved success in denitrification by carefully controlling the reaction rate in an oxidation ditch, so that dissolved oxygen levels drop to near zero just before the water is reaerated by the next rotor.[26 31] Denitrification of animal wastes has been evaluated and shown to be feasible.[42] Depending upon how a biological system such as an oxidation ditch is operated, the nitrogen total loss can range from 30 to about 90 percent.[43]

Problems and Reliability

It would appear that there would be no exceptional maintenance or residual pollution problems associated with this process in view of the mechanisms suggested for its implementation. For some of the newer concepts, i.e., denitrification by fluidized bed reactors, operational difficulties due to biological matting of the carbon filter bed have been encountered in bench scale tests. Completely mixed reactors with methanol addition appear to be favored from the standpoints of operational control and long term reliability in nitrogen removal. However, a final aeration chamber may be required to offset increases in effluent BOD due to methanol leakage from the denitrification reactor. As with nitrification, sludge return has also been shown to assist system stability in the denitrification mode.[44]

Ammonia Stripping

Ammonia stripping is a physical process and amounts to a modification of the simple aeration process for removing gases in water, Figure 21. Following pH adjustment, the waste water 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.

Technical Description

Because of the chemistry of ammonia, the pH of the waste water from a secondary treatment system should be adjusted to between 11 and 12 and the waste water fed to a packed or cooling tower type of stripping tower.[40] As pH is shifted to above 9, the ammonia is present as a soluble gas in the waste water stream, rather than as the ammonium ion. Ammonia-nitrogen removal of 90 percent has been achieved on a municipal effluent with countercurrent air flows between 1.8 and 2.2 cubic meters per liter (250 and 300 cubic feet per gallon) of waste water 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). The best performance was achieved with an air rate of 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.[23]

Development Status

The ammonia stripping process (using both steam and air as the stripping medium) has been practiced on "sour water" in the petroleum refinery industry.[86] Differences between the petroleum refinery application and that on rendering or meat processing waste would be the comparatively small size of stripping tower and higher pH required for the meat plants, compared to the refinery. The air stripping of ammonia from secondary effluent is reported primarily on a pilot plant basis using various equipment.[48] Two large-scale installations of ammonia stripping of lime-treated waste water are reported at South Tahoe, California, and Windhoek, South Africa. 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 rendering or meat processing plant waste, the technology is established and implementation, when standards require it, would be a possible alternative particularly for well stabilized secondary effluents.

Problems and Reliability

The reliability of this process has been found reasonable in petroleum refinery and pilot plant applications 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, this should not affect the established reliability of this process. Among the maintenance requirements would be those normally associated with the mechanical equipment involved in pumping the waste water 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 waste water stream that has some potential for fouling. Problems with temperature and tower scaling are also documented. Recent advances in possible anti-scale chemicals appear promising.[47] It has also been observed that efficiency losses due to low temperature can be at least partially overcome by breakpoint chlorination, by housing the stripping tower, or heating the water or air with waste steam. The most recent advance in the process includes an ammonia recovery step and preliminary results indicate that most problems with stripping towers have been overcome.[71]

DISINFECTION

The disinfection of domestic and industrial waste water is usually achieved through chlorination. While not discussed in detail herein, another disinfection process, ozonation, has received some attention for several years and may become more popular in the future as costs (compared with chlorination) become competitive and there is somewhat more widespread use.[23]

Chlorine, when added to waste waters, forms various compounds including HOCl, OCCl, and chloramines. The germicidal effect is believed due to the reaction of the chlorine compounds achieved with essential enzymes of the bacterial cell, thereby stopping the metabolic process. Among the conditions affecting germicidal effectiveness are pH, temperature, contact time, and chlorine concentration. Residual pH affects germicidal power through its relation to the formation of HOCl which is many times more effective than OCCl and chloramines.

Chlorine is used principally to disinfect treated effluent prior to its discharge into surface waters. To be effective, chlorine requires a contact time of not less than fifteen minutes at maximum flow rates at which time there should remain a residual of not less than 0.2 to 1.0 mg/l. Under these conditions, chlorination of effluent from secondary treatment will generally result in more than a 99.9 percent reduction in the coliform content of the effluent. The range of chlorine dosage generally required for disinfection varies from 3 to 30 mg/l depending upon the quality of the effluent.

BOD can be reduced by the use of chlorine. Approximately two mg/l of BOD is satisfied by each mg/l of chlorine absorbed up to the point at which orthotolidine residual is produced. Chlorine alone can reduce BOD by as much as 15 to 35 percent.

An important potential use for chlorine is to kill algae prior to algae removal operations performed on lagoon effluent. Dead algae are much easier to remove by flotation, sedimentation, and filtration than are live algae, according to experience with removal of algae from domestic waste water lagoon effluents. Chlorination of algae laden lagoon effluents requires high dosages of chlorine (up to 25 mg/l) because chloramines are formed. Chloramines are not as effective a killing agent as the other chlorine compound forms in water.

Chlorine is also effective in the oxidation of hydrogen sulfide and is used for odor control. It may be applied whenever there is a decomposition odor problem. In general, control will result from the application of four to six mg/l and without the production of a residual.

Chlorine is available as liquified chlorine, in powdered form, and in solutions. Liquified chlorine in 68 kg (150 pound) and 970 kg (1 ton) cylinders is generally used for all but the smallest facilities. Chlorination facilities include chlorinators, chlorine handling and storage, mixing, and detention facilities for effluent. Since chlorine is a hazardous substance, special safety precautions in storage and handling are required.

Chlorination is utilized for final waste water disinfection at several meat products plants in the U.S., in each case on a secondary effluent prior to direct discharge to surface waters.

Breakpoint Chlorination

When waste water containing ammonia is treated with chlorine, a chemical reaction toward the formation of chloramines is observed. Further chlorination to the "breakpoint" (free chlorine residuals predominate) converts the chloramines to nitrogen gas which is lost to the atmosphere.

Technical Description

A detailed discussion of the chemistry of breakpoint chlorination is readily found in numerous textbooks and references on disinfection.[40 71] In summary, chlorine is added (as a gas or liquid) to waste waters containing ammonia in amounts sufficient to cause the release of nitrogen gas. For each part of ammonia, about nine parts of chlorine are required to drive the chemical reactions from monochloramines through to nitrogen gas. At proper chlorine feed rates, a contact time of 30 minutes or less is necessary.

Development Status

Breakpoint chlorination is a well understood and well documented technology. Applications have centered on tertiary treatment of secondary municipal wastes, although the concept has been found to be useful as a "polishing" mode in conjunction with ammonia stripping. It appears from the literature that the process offers a possible alternative for ammonia control of ammonia concentrations similar to those encountered in municipal secondary effluents.

Problems and Reliability

Under low pH (less than 6.0) conditions, chlorination of ammonia may produce nitrogen trichloride which is highly odorous. The removal of ammonia is not adversely affected if it becomes necessary to add a base (sodium hydroxide) to overcome acid conditions. Under field conditions described in the literature, the natural alkalinity of the waste water being treated proved to be sufficient to preclude depression of pH below 6.0. The process operates equally well in the temperature range of 5°C to 40°C; more chlorine may be needed at lower temperatures. Process efficiencies consistently range between 95 and 99 percent and the process is easily adapted to complete automation which helps assure quality and operational control. Excessive use of chlorine can result in substantial relative increases in dissolved solids (choride salts) in effluents.

Spray/Flood Irrigation

A no-discharge level for rendering waste water can be and is being achieved by the use of spray or flood irrigation of relatively flat land, surrounded by dikes to prevent runoff. A cover crop of grass or other vegetation is maintained on the land. Specific plant situations may preclude the installation of irrigation systems; however, where they are feasible, the economics can be very favorable and 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 the ridge and furrow irrigation systems which allow a certain level of flooding on a given plot of land, Figure 22. Pretreatment for removal of solids is advisable 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 will usually have already been reduced in prior treatment (primary plus some degree of secondary treatment) upstream from the distribution system.

In flood irrigation, 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.

Waste water 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. Approximately 10.0 percent of the waste flow will be lost by evapotranspiration (the loss caused by evaporation to the atmosphere through the leaves of plants).[28]

Spray runoff irrigation is an alternative technique which has been tested on the waste from a small meat packer[32] and on cannery waste.[28] With this technique, about 50 percent of the waste water applied to the soil is allowed to run off as a discharge rather than no discharge. The runoff or discharge from

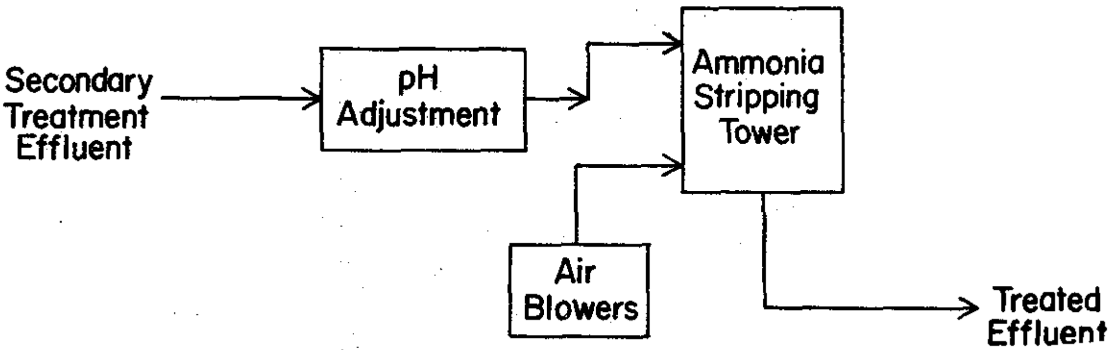


Figure 21. Ammonia Stripping

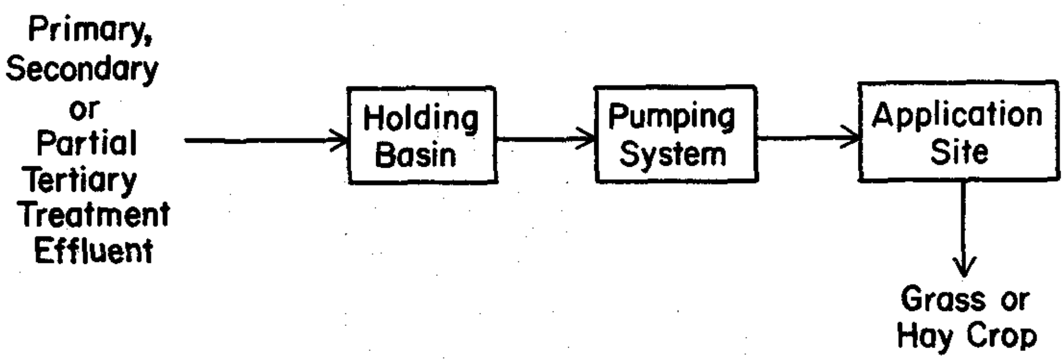


Figure 22. Spray/Flood Irrigation System

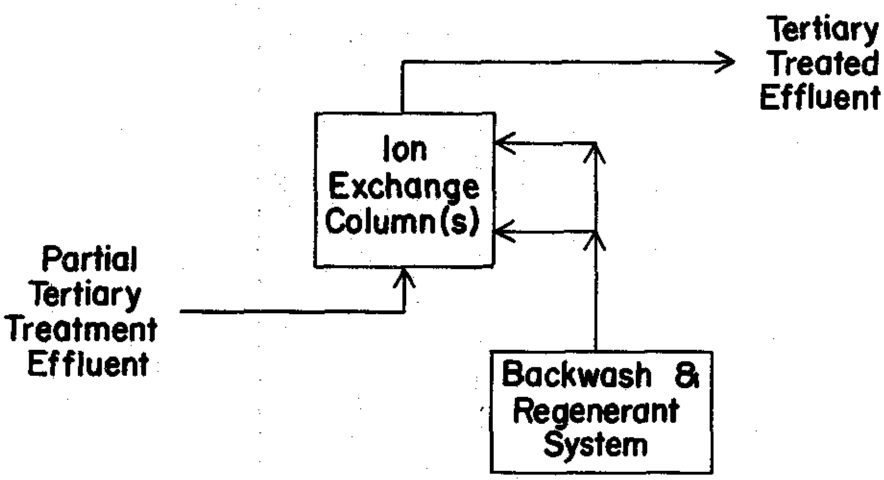


Figure 23. Ion Exchange

this type of irrigation system is of higher quality than the waste water as applied, with BOD_5 removal of about 80 percent; total organic carbon and ammonia nitrogen are about 85 percent reduced, and phosphorus is reduced about 65 percent.[32]

The following factors will affect the ability of a particular land area to absorb waste water: 1) character of the soil, 2) stratification of the soil profile, 3) depth to groundwater, 4) initial moisture content, and 5) terrain and ground cover.[28]

The potentially greatest concern in the use of irrigation as a disposal system is the total dissolved solids content and particularly the salt content of the waste water. A maximum salt content of 0.15 percent has been suggested.[28] However, the average plant should have no problem with salt, since the average salt content of rendering waste waters is about a factor of six less than this suggested limit.

An application rate of up to 330 liters per minute per hectare (35 gallons per minute per acre) has been suggested in determining the quantity of land required for various waste water flows. This amounts to almost 5 cm (2 inches) of moisture per day, and is relatively low in comparison with application rates reported for various spray irrigation systems.[40] However, solids vary widely in their percolation properties and experimental irrigation of a small area is recommended before a complete system is built. In this report, land requirements were based on 2.5 cm (one inch) applied per operating day for six months of the year with lagoon storage for six-months' accumulation of waste water.

Waste water application rates currently used by rendering plants with spray irrigation systems are less than 4.0 cm (1.6 inches) water per two weeks for a six-month irrigation period. If rendering plant waste waters were being used as the sole nitrogen source for corn growth, the waste waters would probably have to contain 250 to 500 mg/l nitrogen. For lower nitrogen concentrations, the corn crop would probably be damaged by flooding or by heavy overwatering before the corn received sufficient nitrogen from the waste waters. This is based on the assumptions that one bushel of corn requires 454 gm (1 pound) of nitrogen; that the yield is 120 bushels of corn per acre, and that the corn would require from 25 to 75 cm (10 to 30 inches) of water per season.[34] This water rate amounts to 3.1 to 9.5 cm (1.2 to 3.7 inches) of water per two weeks, over a four-month season. Thus, treated waste water from rendering is a small enough volume so it can be used as a supplementary nutrient source for corn rather than a sole resource of nutrients. Data were not discovered for any cases in which waste water treated only by primary systems was used for irrigation.

The economic benefit from spray irrigation is estimated on the basis of raising two crops of grass or hay per season with a yield of 13.4 metric tons of dry matter per hectare (six tons per acre) and values at $22 per metric ton ($20 per ton). These figures are reportedly conservative in terms of the number of crops and the price to be expected from a grass or hay crop. The supply and demand sensitivity as well as transportation problems for moving the crop to a consumer all mitigate against any more optimistic estimate of economic benefits.[33]

Cold climate uses of spray irrigation may be subject to more constraints and have greater land requirements than plants operating in more temperate climates. Rendering plants located in cold climates or short growing areas should consider two crops for spray irrigation. One could be a secondary crop such as corn and the other a grass crop. The grass crop could tolerate heavier volume loadings without runoff and erosion and also would extend the irrigation season from early spring to possibly late November. Corn, although a more valuable crop, tolerates irrigation in cold climate areas only during the summer months.

North Star found in its survey of the rendering industry 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, and thus reliability remains somewhat open to question. Problems in maintenance are primarily in the control of the dissolved solids level and salinity content of the waste water stream and also in climatic limitations that may exist or develop. Many soils may be 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 waste water stream, Figure 23. 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 rendering waste, the desired effluent quality would be a waste water with a salt concentration of less than 300 mg/l. Ion exchange systems are available that will remove up to 90 percent of the salt in a water stream.[16] 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.

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 shown in the equations 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.

Waste water 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.[16] 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 remove the inorganic salts. After this step, the process includes a flocculation/aeration and precipitation step to remove organic matter; however, this should be unnecessary if a sand filter or comparable system is used upstream of the ion exchange unit. 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 5 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 are available for ammonia, nitrate, or phosphate removal as well as for color bodies, COD, and fine suspended matter. Removal of these various constitutents can range from 75 percent to 97 percent, depending on the constituent.[23]

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 waste water processing scheme, thus having the highest quality effluent available as a feedwater.

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 mg/l of salt are assumed to be acceptable. To achieve this final effluent quality, some portion or all of the waste water 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 specific ion removal 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. Water softening for boiler feed treatment and domestic and commercial use is probably the most widespread use of ion exchange in water treatment. Deionization of water by ion exchange is used to remove carbon dioxide; metal salts such as chlorides, sulfates, nitrates, and phosphates; silica; and alkalinity. Specific resin applications such as in waste water treatment have not been widespread up to the present time, since 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 water quality that may be required for irrigation and closed-loop water recycle systems.

Part of the economic success of an ion exchange system in treating rendering 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 such as sand filtration to remove a maximum of the particularly bothersome suspended organic material. However, the effect of a low-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

The application of the technology in waste treatment has not been tested and therefore the reliability in that application has yet to be 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. Regeneration solution is used periodically to restore the ion exchange resin to its original state for continued use. This solution must be disposed of following its use and that may require special handling or treatment. The relatively small quantity of regenerant solution will facilitate its proper disposal by users of this system.

SECTION VIII

COST, ENERGY, AND NONWATER QUALITY ASPECTS

SUMMARY

The waste water from rendering plants is amenable to treatment in biological and advanced waste treatment systems to achieve low levels of pollutants in the final effluent. In-plant controls, product recovery operations, and strict water management practices can be highly effective in reducing the waste load and waste water flow from any rendering plant. The water management practices will reduce the requisite size of secondary and tertiary treatment systems and improve their waste reduction effectivenesss.

For purposes of estimating treatment costs, the rendering industry can be divided into small, medium, and large size plants. The plant size is based on the weight of raw material processed per day. This division of the industry does not imply the need to categorize the industry according to size; the primary categorization criterion--raw waste load--does not vary with size. Total investment costs and unit operating costs for waste treatment, on the other hand, will vary with plant size. Costs that represent the industry situation could not be determined on the basis of one "typical" plant size, with the wide range of production and waste water flow for plants in the industry. Therefore, the three rendering plant sizes that are relatively closely grouped in production and waste water flow are used to describe the waste treatment economics for the entire rendering industry and for plants within the industry.

Waste water treatment investment cost is primarily a function of waste water flow rate. Cost per unit of production for waste treatment will vary with total investment cost and the production rate. Therefore, the rendering industry treatment costs have been estimated on the basis of "typical" plants for each size. A "typical" plant is a hypothetical plant with an average production rate and the indicated waste water flow rate as shown in Table 13D.

The average $BOD\underline{5}$ raw waste load is the same for each plant size, as indicated by the single industry category, described in Section IV.

The additional capital expenditures required of a "typical" plant in each size group to upgrade or install a waste water treatment system to achieve the indicated performance are indicated in Table 14. Table 15 shows comparative costs as related to expanding the hydraulic capacity of existing treatment facilities if barometric condenser recirculation is not practiced. The estimated total investment cost to the industry is also reported for the proposed 1977 and 1983 limitations.

Table 13D. Profile of Typical Plants by Size

	Rendering Plant Size		Average Raw Materials Processed		Average Waste Water Flow Rate	
	Ranges					
	kg/day	lb/day	kg/day	lb/day	liters/day	gal/day
Small	<33,800	<75,000	16,800	37,000	37,700	10,000
Medium	33,800 - 113,500	75,000 - 250,000	76,300	168,000	91,000	24,000
Large	>113,500	>250,000	240,600	530,000	288,000	76,000

The estimate of the cost of achieving the proposed 1977 limitations is based on the following assumptions and criteria, which reflect the data collected on the industry in the study survey, and additional information developed in the course of this study.

- o Because an analysis of economic impact revealed that small rendering plants would be subject to closure with the imposition of costs to achieve the 1977 limitations, cost estimates for these plants (processing 75,000 pounds of raw material per day or less) is included for information purposes only.

- o There are about 76 medium and large plants with a direct discharge to streams.

- o For purposes of total industry cost estimates all medium and large plants with a direct discharge were assumed to need to improve treatment by expanding aerobic lagoons or comparable cost alternatives such as adding aerated lagoons.

- o 50 percent of all medium and large plants with a direct discharge will need to install chlorination.

- o All plants currently have installed primary treatment (materials recovery in the form of a catch basin or mechanical skimmer/settler) and a single lagoon system of 30 days holding capacity.

- o On the basis of water use rates, the medium and large plants are distributed as approximately 85 percent achieving low water use rates (typically about 150 gallons per 1000 pounds of raw material) and 15 percent at high rates (averaging about 400 gallons per 1000 pounds of raw material).

The rendering industry waste treatment practices are estimated to conform closely to survey data supplied by the industry and specific questionnaire data for 49 plants. The data reveals a 45 to 55 split between plants with a municipal discharge and those that treat or control their own waste waters. Thus, of the approximately 350 plants encompassed by this study, slightly less than half are municipal discharges, about 15 percent achieve no discharge of pollutants, and over 150 treat waste waters and discharge to streams. A further discussion of the relevance of this distribution is presented below under the heading, "Waste Treatment Systems."

Using the same assumed distribution of medium and large plants by water use rate, the 1983 limitations are estimated to require the following additions to the existing treatment systems, incremental to the additions for 1977:

- o 15 percent of all plants with a direct discharge

Table 14. Likely Capital Expenditures by Plant Size to Meet Limitations Shown For Plants with Condenser Recirculation

	1977 Limitation ($)	1983 Limitation ($)	New Source Standard ($)	Irrigation System Only** ($)	Percolator & Evaporation Pond ($)
Small Plant	26,500	53,000	38,000	5,000	14,000
Medium Plant	27,000	63,000	78,000	14,000	32,000
Large Plant	52,000	119,000	133,000	37,000	62,000
Total Rendering Industry	2,000,000*	6,750,000	--	--	--

*Approximately 85% of medium and large plants have flows (150 gal/1000 lb RM) reflecting recirculation (i.e., those at high rates of water use) must add sand filters, or the equivalent;

- 50 percent of all plants with a direct discharge will have to make capital improvements in their primary treatment facilities;

- 12 percent of all plants with a direct discharge will have to eliminate direct blood drainage to the sewer and recover it in their product streams; and

- 95 percent of all plants with a direct discharge will have to install ammonia control (nitrification) systems.

The costs for irrigation and for ponding are included in Table 14 to indicate the economic advantages of both approaches. The no-discharge options are particularly advantageous to those plants with relatively low effluent volumes.

The investment costs for new point sources are derived from cost estimates of treatment systems presently in use in the industry based on the average flow for the plant size, as indicated in Table 14.

The cost estimates for a plant to achieve the recommended limitations are predicated upon additions to existing facilities which are presently installed at most plants discharging directly to streams. The investment cost for a given plant will vary depending upon the extent to which investments have already been made in pollution control equipment. A "most likely" investment cost was computed for each plant size based on the cost of the combination of treatment system additions with the highest probability of occurrence. The most likely and maximum costs are presented in Table 16. All operating and total annual costs are based on the "most likely" investment cost rather than the minimum or maximum cost.

Tables 15, 15A, and 15B are also presented to provide an indication of the approximate cost of waste treatment for plants with waste water volume per unit of raw material processed equivalent to the average batch process renderer without the use of water conservation or recirculation systems (3300 liters/1000 kgs or 400 gal/1000 lb RM). Investment costs would be higher for such a plant. Operating costs would increase in comparison with the low waste water volume plant by 18 to 75 percent depending on plant size and annual costs would increase by 12 to 125 percent. The medium size plants would experience the largest increase in the per unit annual cost for 1977 of 0.03¢/lb RM and small plants would incur the largest increase in annual cost for 1983 of 0.28¢/lb RM, again in comparison with the plant using only 143 gal/1000 lb RM.

The additions to plant operating cost and total annual cost, in total dollars and in dollars per unit of raw material processed, for the indicated type or level of waste treatment performance

Table 15. Estimated Waste Treatment Investment Costs for Renderers with High Waste Water Volume (3300 liters/1000 kgs RM or 400 Gals/1000 lbs RM)*

Plant Size	1977 Limitations	1983 Limitations	Irrigation System, Only
Small	20,700	135,000	13,100
Medium	47,600	202,000	34,000
Large	94,000	337,000	90,000

*Approximately 15% of medium and large plants are at this flowrate

Table 15A. Total Annual and Operating Costs for a Rendering Plant with High Waste Water Volume to Meet the Indicated Performance, $/Year

Plant Size	Cost	1977 Limitations	1983 Limitations	Irrigation System, Only
Small	Annual	16,600	61,100	6,200
	Operating	12,400	30,000	4,000
Medium	Annual	24,400	86,200	9,800
	Operating	14,900	36,300	4,200
Large	Annual	36,800	132,900	16,300
	Operating	18,000	46,700	2,000

Table 15B. Annual and Operating Costs Per Unit Weight of Raw Material for a Rendering Plant with High Waste Water Volume to Meet Indicated Performance

Plant Size	Cost	1977 Limitations		1983 Limitations	
		¢/kg	¢/lb	¢/kg	¢/lb
Small	Annual	0.39	0.18	1.45	0.66
	Operating	0.30	0.13	0.71	0.32
Medium	Annual	0.13	0.06	0.46	0.21
	Operating	0.08	0.035	0.19	0.09
Large	Annual	0.06	0.03	0.20	0.09
	Operating	0.03	0.014	0.07	0.03

are listed in Tables 17 and 18. The additional costs for the 1977 limitations include the payroll and burden (at 50 percent of payroll) for the equivalent of one-half man-year. This assumed cost of manpower for the treatment system accounts for between 70 and 82 percent of the annual operating cost and between 45 and 60 percent of the total annual cost. This allocation of manpower cost would be highly discretionary within each rendering plant. Therefore, the reported operating and total annual costs are very conservative estimates of expected real plant experience, the estimates probably are higher than what will actually occur.

The maximum annual costs per unit weight of raw material occur in the small plants. The 1977 limitations would add 0.35¢/kg (0.16¢/lb) to the annual operating cost of an average small plant, and the 1983 limitations would add 0.84¢/kg (0.38¢/lb). In comparison with the operating margin of a rendering plant, these are significant additions to their costs. The costs for irrigation or ponding are at least a factor of six less than the cost for other treatment methods for small plants. The additional cost for the medium or large rendering plant to meet the 1983 limitations is no greater than 0.2¢/kg (0.1¢/lb), no matter which treatment system is used.

The total rendering industry spent approximately $30 million in 1972 on new capital expenditures. This estimate is based on a projection of the capital expenditures reported for 1958 through 1967 in the 1967 Census of Manufacturers and generally verified by more recent comments supplied by industry.* The total industry waste treatment expenditures reported in Tables 14 and 15 of $2.6 million for 1977 limitations and $6.75 million for the 1983 limitations, amounting to about 8.0 percent and 22 percent of the $30 million estimate, respectively. The waste treatment expenditures can be programed over a number of years, thus the requisite investment appears reasonable and achievable. The small rendering plant is put in the most difficult financial position, however, this can be minimized by the use of irrigation or ponding.

The electrical energy consumption in waste water treatment by the rendering industry amounts to less than 2 percent of their current total use of electrical energy, and less than 0.1 of one percent of their total (heat plus electrical) energy consumption. Thus, in absolute terms and comparatively speaking, waste treatment energy use is of little consequence.

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

Table 16. Comparison of Most Likely and Maximum Investment, with Condenser Recirculation, By Plant Size

Performance	Small Plant		Medium Plant		Large Plant	
	Most Likely Cost ($)	Maximum Cost ($)	Most Likely Cost ($)	Maximum Cost ($)	Most Likely Cost ($)	Maximum Cost ($)
1977 Limitations	26,500	26,500	27,000	47,600	52,000	94,000
1983 Limitations	53,000	100,000	63,000	202,000	119,000	337,000

Table 18. Annual And Operating Costs Per Unit Weight of Raw Material for a Rendering Plant with Condenser Recirculation to Meet Indicated Performance

Plant	Cost	1977 Limitation		1983 Limitation		New Source Standards	
		¢/kg	¢/lb	¢/kg	¢/lb	¢/kg	¢/lb
Small	Annual Cost	0.35	0.16	0.84	0.38	0.42	0.19
	Operating Cost	0.24	0.11	0.53	0.24	0.31	0.14
Medium	Annual Cost	0.07	0.03	0.20	0.10	0.13	0.06
	Operating Cost	0.04	0.02	0.13	0.06	0.09	0.04
Large	Annual Cost	0.03	0.014	0.09	0.04	0.07	0.03
	Operating Cost	0.02	0.01	0.04	0.02	0.04	0.02

Table 17. Total Annual and Operating Costs for a Rendering Plant with Condenser Recirculation to Meet the Indicated Performance, $/Year

Plant Size	Cost	1977 Limitation	1983 Limitation	New Source Standard	Irrigation System	Ponding
Small	Annual Cost	16,500	40,300	20,500	1,500	2,700
	Operating Cost	11,900	25,100	14,700	500	750
Medium	Annual Cost	16,200	42,700	30,600	3,500	6,100
	Operating Cost	12,200	26,200	18,800	700	1,600
Large	Annual Cost	21,600	62,600	44,100	7,600	11,800
	Operating Cost	14,000	31,300	24,100	230	3,100

"TYPICAL" PLANT

The waste treatment systems applicable to waste water from the rendering industry can be used effectively by all plants in the industry. Irrigation or ponding with no discharge is most widely used by small plants, and is usually the most attractive treatment option for small plants. A hypothetical "typical" plant was determined for each plant size as the basis for estimating investment cost and total annual and operating costs for the application of each waste treatment system for each plant size. The costs were estimated, and in addition, effluent reduction, energy requirements, and nonwater quality aspects of the treatment systems were determined.

The waste treatment systems are applied on the basis of the "typical" plants described in Table 19 for each plant size.

Table 19. "Typical" Plant Parameters for each Plant Size

Plant Parameter	Average Value of Plant Parameter by Plant Size		
	Small	Medium	Large
Average Raw Material Processed, kg/day, (lbs/day)	16,800 (37,000)	76,300 (168,000)	240,000 (530,000)
Standard Deviation of Average R. M. Processed kg/day, (lbs/day)	9,100 (20,000)	26,300 (58,000)	74,900 (165,000)
Total Waste Water Volume, liters/day (gals/day)	37,700 (10,000)	91,000 (24,000)	288,000 (76,000)
Waste Water Volume per unit of R. M. Processed liter/1000 kgs, (gals/1000 lb RM)	2,240 (268)	1,191 (143)	1,191 (143)

The small rendering plant generally has a lower production limit of about 4500 to 6800 kg (10,000 to 15,000 lb) of raw material processed per day. This estimate is based on the industry sample data and involves the use of one batch cooker operating on two batches per day. This level of operation would be at the low end of economic viability. The sample included one plant that processed about 3600 kg (8000 lb) per day of only dead animals.

This type of raw material enabled the plant to operate at that production level, however, it was unique in the sample.

Individual, "typical" plant costs have been derived on the basis of production characteristics so that equal emphasis is given to each plant type. Thus, costs for plants with low rates of water use (characteristic of plants with continous cookers and condenser recirculation) and with high rates of water use (characteristic of plants with batch cookers and little or no condenser recirculation) have been derived for achieving both the 1977 and the 1983 limitations.

WASTE TREATMENT SYSTEMS

The waste treatment systems included in this report as appropriate for use on rendering plant waste water streams can be used, subject to specific operating constraints or limitations as described later, by most plants in the industry. The use of some treatment systems may be precluded by physical or economic impracticability for some plants.

The waste treatment systems, their use, and the minimum effluent reduction associated with each are listed in Table 20.

The dissolved air flotation system can be used upstream of any secondary treatment system. The use of chemicals should increase the quantity of grease removed from the waste water stream, but may reduce the value of the grease because of chemical contaminants.

The biological 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 to achieve comparable levels of waste reduction. 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 since disinfection treatment is probably necessary for at least half of the plants. A final clarifier has been included in costing out all biological treatment systems that generate a substantial sludge volume; e.g., extended aeration and activated sludge. The clarifier is needed to reduce the solids content of the final effluent.

The most feasible system to achieve no discharge at this time is flood or spray irrigation or ponding. Closing the loop to a total water recycle or reuse system is technically feasible, but far too costly for consideration. The irrigation option does require large plots of accessible land--roughly 2.0 hectares/million liters (0.2 acres/thousand gallons) of waste water per day and limited concentrations of dissolved solids. More detailed descriptions of each treatment system and its

Table 20 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 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
Ammonia stripping	Tertiary treatment	90-95% removal
Chemical precipitation	Tertiary treatment	Phosphorus, 85-95% removal, to 0.5 mg/l or less
Spray irrigation	No discharge	Total
Flood irrigation	No discharge	Total
Ponding and evaporation	No discharge	Total
Nitrification and Denitrification	Tertiary treatment	N, 85% removal

effectiveness are presented in Section VII--Control and Treatment Technology.

Of the 49 plants responding to the study questionnaire, about one-half reported having either their own waste water treatment system or no discharge; the others indicated discharging their waste to a municipal treatment system. Twelve plants reported on-site secondary treatment with lagoon systems or other combinations of secondary treatment processes. Twelve plants also reported treatment systems with no discharge. Chlorination is used by five plants, according to the data. A summary of the distribution of the type of treatment or control used by plants in the study survey is as follows:

	Discharge to Municipal System	Secondary Treatment With Discharge	No Discharge
Small plants	7	4	8
Medium plants	7	5	3
Large plants	9	3	1
TOTALS	23	12	12

TREATMENT AND CONTROL COSTS

In-Plant Control Costs

The purchase and installation cost of in-plant control equipment is primarily a function of each 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. Approximations of the range of costs for the in-plant controls requiring capital equipment are listed in Table 21 and are incorporated into investment cost estimates for meeting 1983 limitations. These cost ranges are based somewhat on plant size variation, but are primarily based on the expected cost that might be incurred by any rendering plant, depending on the plant layout, age, type of construction, etc.

Investment Costs Assumptions

The waste treatment system costs are based on the average plant production capacity and waste water flow listed previously for a "typical," but hypothetical, plant of each size. Investment costs for specific waste treatment systems are primarily dependent on the waste water volume.

Table 21. Estimates of In-Plant Control Costs

Plant Area	Item	Equipment Cost Range
Raw Materials Storage	Steam sparge and screen for high blood containing waters.	$10,000-$15,000
Cookers	By-pass controls on vapor lines from cookers	$100-$300 per cooker
Air Scrubbing	Recycle system for scrubber water	$10,000-$20,000
Hide Curing	Pipe curing waste waters to cookers	$1,000-$3,000
Materials Recovery	Flow equalization tank	$2,000-$5,000

The investment cost data were collected from data included on questionnaires from rendering plants, the literature, personal plant visits, equipment manufacturers, engineering contractors, and consultants. The costs are "ball park"-type estimates, implying an accuracy of ±20 to 25 percent. Rarely is it minus. All costs are reported in August 1973 dollars. Percentage factors were added to the treatment system equipment cost for design and engineering (10 percent) and for contingencies and omissions (15 percent). Land costs were estimated to be $2470 per hectare ($1000 per acre).

The irrigation system costs are based on application and storage assumptions to take into consideration geographic and climatic variables throughout the country. These assumptions are as follows:

- o Application rate is one inch of waste water applied per operating day during six months per year.

- o Storage capacity for six months accumulation of waste water in a lagoon 1.2 m (4 feet) deep plus land for roads, dikes, etc.

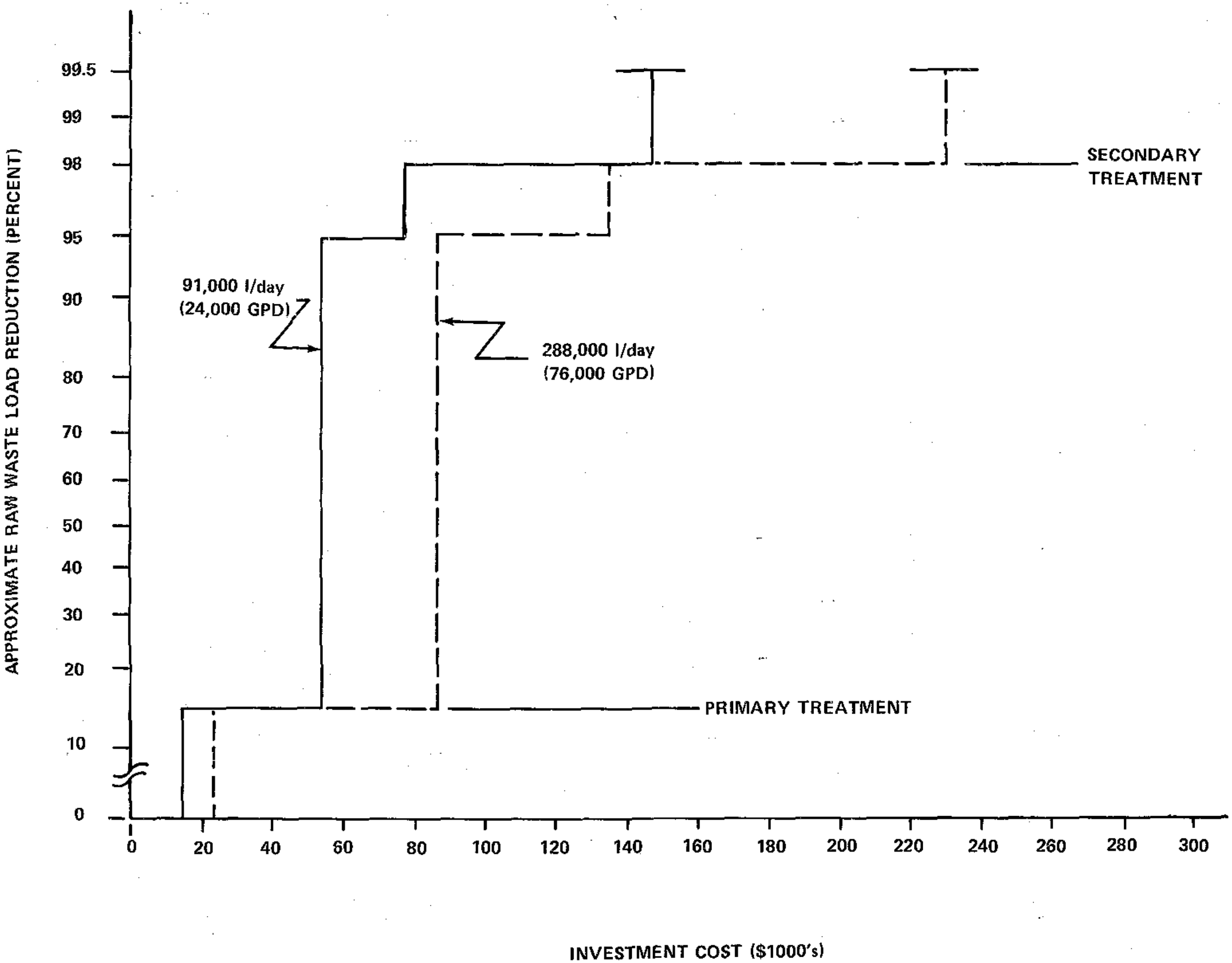
- o Irrigation equipment includes pumps, piping, and distribution system; dikes to prevent all runoff at a reference cost of $70,000 for 21 hectares (52 acres).

The chlorine costs are based on chlorinating the waste water to 8 mg/l. The assumed cost of 18¢ per kg (8¢ per lb) for chlorine results in a cost of 0.1¢ per 1000 liters (0.4¢ per 1000 gal.) of waste water chlorinated.

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 specific 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.

Cost effectiveness data are presented in Figure 24, as investment cost required to achieve the indicated BOD_5 removal with the typical lagoon waste treatment system at two levels of waste water flow. The low flow is the average for the medium size rendering plant and the high flow is the average for the large plants. The raw waste reduction is based on the construction of waste treatment systems with the incremental waste reduction achieved by adding treatment components to the system as indicated below (a catch basin is assumed to be standard practice and the raw waste is that discharged from the catch basin).

Figure 24. Waste Treatment Cost Effectiveness



Component	Cumulative BOD5 Removal
+ Catch Basin	0
+ Improved Primary Treatment	15
+ Anaerobic and Aerobic Lagoons	95
+ Aerated Lagoon	98
+ Sand Filter	99+

Annual Cost Assumptions

The components of total annual cost are capital cost, depreciation, operating and maintenance costs, and energy and power costs. The cost of capital is estimated to be 10.0 percent of the investment cost for the rendering industry--the same as in 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 10.0 percent figure for the meat packing industry. One sample of companies reported earnings at 7.1 percent of total assets for 1971;[35] a recent business periodical reported earnings at 10.1 percent of invested capital,[36] and meat packing industry sources report corporate target ROI and ROA figures at 12 to 15 percent for new ventures. The 10.0 percent figure is probably high, and thus tends to contribute to a high estimate of total annual cost. Operating cost includes all the components of total annual cost except capital cost and depreciation.

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

Land intensive treatment systems; e.g., lagoons -- 25 years

All other treatment systems -- 10 years.

The operating and maintenance costs for the 1983 system include the cost of one man-year at $4.20/hour plus 50 percent for burden, supervision, etc. One-half man-year was used for the annual cost for the 1977 limitations 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. Specific chemical-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 irrigation system for 13,400 kg of dry matter (hay or grass) per hectare at $22/100 kg (6 tons/acre at $20/ton) and two crops per year.[37]

ENERGY REQUIREMENTS

The electrical energy consumption by the rendering industry--SIC 2077, including marine fats and oils--was reported for 1967 (then under SIC 2094) to be 362 million KWH and total heat and power energy consumption at the equivalent of 8108 KWH.[4] The rendering industry consumes relatively small quantities of electrical energy but large quantities of fuel. The waste treatment systems require power primarily for pumping and aeration. The aeration horsepower is a function of the waste load and the horsepower for pumping depends on waste water flow rate.

Total power consumption to achieve the 1977 limitations is estimated to be 7 million KWH per year for the rendering industry. This amounts to about 2 percent of electrical energy consumption, and roughly 0.1 percent of the total (heat and electrical) energy consumption of the industry reported for 1967. The same approximate percentage would apply to current power consumption. The additional power needed to achieve 1983 limitations amounts to about 4 percent and 0.2 percent of electrical and the total energy, respectively, and does not appear to raise serious power supply or cost questions for the industry. However, widespread use of chlorine as a disinfectant may pose some energy problems in the future, or, conversely, the future supply of chlorine may be seriously affected by the developing energy situation.

Waste treatment systems impose no significant addition to the thermal energy requirements of plants. Waste water can be reused in cooling and condensing service. These heated waste waters improve the effectiveness of anaerobic ponds, which are best maintained at about 90°F. Improved thermal efficiencies are also achieved within a plant when waste water is reused in this manner.

Waste water treatment costs and effectiveness can be improved by the use of energy and power conservation practices and techniques in plant operations. Reduced water use therefore reduces the pumping costs and heating costs, the last of which can be further reduced by water reuse as suggested above.

NONWATER POLLUTION FROM WASTE TREATMENT SYSTEMS

Solid Wastes

Solid wastes are the most significant nonwater pollutants associated with the waste treatment systems applicable to the rendering industry. Screening devices of various design and operating principles are used primarily for removal of large-scale solids from waste water. These solids have economic value as inedible rendering raw material and can be returned to the feed end of a plant.

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

Treatment System	Sludge Volume as Percent of Raw Waste Water Volume
Dissolved air flotation	Up to 10%
Anaerobic lagoon	Sludge accumulation in these lagoons is usually not sufficient to require removal.
Aerobic and aerated lagoons	
Activated sludge	10 to 15%
Extended aeration	5 to 10%
Anaerobic contact process	Approximately 2%
Rotating biological contactor	Unknown

The raw sludge can be concentrated, digested, dewatered, dried, incinerated, land-filled 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 proven difficult to dewater in a couple of plants. A dewatered sludge is an acceptable land fill material. Sludge from secondary treatment systems is normally ponded by plants on their own land or dewatered or digested sufficiently for hauling and depositing in public land fills. The final dried sludge material can be safely used as an effective soil builder. Prevention of water runoff 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 included in the costs for these systems.

For those waste materials considered to be non-hazardous where land disposal is the choice for disposal, practices similar to proper sanitary landfill technology may be followed. The principles set forth in the EPA's Land Disposal of Solid Wastes

Guidelines (CFR Title 40, Chapter 1; Part 241) may be used as guidance for acceptable land disposal techniques.

For those waste materials considered to be hazardous, disposal will require special precautions. In order to ensure long-term protection of public health and the environment, special preparation and pretreatment may be required prior to disposal. If land disposal is to be practiced, these sites must not allow movement of pollutants such as fluoride and radium-226 to either ground or surface water. Sites should be selected that have natural soil and geological conditions to prevent such contamination or, if such conditions do not exist, artificial means (e.g., liners) must be provided to ensure long-term protection of the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located.

Air Pollution

Odors are the only significant air pollution problem associated with waste treatment in the rendering 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 a northern climate, 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 without sulfate waters that have odor problems. In these cases a cover and collector of the off-gas from the pond controls odor. The off-gas is burned in a flare.

The other potential odor generators in waste water treatment are leaking tanks and process equipment items used in 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 a frequent 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, rather than resorting to treatment for odor control, which remains largely unproven at this time.

Noise

The only material increase in noise within a rendering 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 compressor are part of an air flotation system. The industry frequently 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 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.

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 by July 1, 1977, are to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. This technology 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 was not based upon a broad range of plants within the independent rendering industry, but based upon performance levels achieved by exemplary plants.

Consideration was also 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; and
- Nonwater 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.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE 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 Practicable Control Technology Currently Available is as listed in Table 22. Of the ten plants with materials recovery systems and secondary treatment systems for which information on effluent quality was available, two are meeting these standards. An additional four of the plants come close to meeting these standards.

Hide curing at an independent rendering plant requires an adjustment in the limitation for BOD_5 and SS (Table 23). An adjustment does not become significant, however, unless the number of hides handled is quite large.

For example, an average size plant, as found in this study, is one handling 94,000 kg (206,000 pounds) RM (raw materials) per day, and also curing 100 hides, and would have the following adjustment factors (AF):

$$AF\ (BOD_5) = \frac{11 \times 100}{94{,}000} = 0.0085 \text{ kg/kkg RM (lb/1000 lb RM); and}$$

$$AF\ (TSS) = \frac{11 \times 100}{94{,}000} = 0.012 \text{ kg/kkg RM (lb/1000 lb RM).}$$

From Table 22 and the above correction, the effluent limitations for this pollutant would be 0.15 + 0.0085, and 0.17 + 0.012 or 0.182 kg/kkg (lb/1000 lb) RM (a 5 and 7 percent increase) for BOD_5 and SS, respectively. An adjustment for grease was not included because there was no correlation between the raw and final waste loads for grease. For instance, for the six plants meeting the grease limit (of the nine plants for which final effluent data on grease were available) only two of the six plants had raw grease loads less than the industry average (which was 0.72 kg/kkg RM). The other four plants had raw grease loads that were 1.5, 1.6, 4.3, and 7.6 times greater than the average value of 0.72. Yet, five of the six plants had final grease concentrations that were within a range of 2 to 23 mg/l; the sixth had a final grease concentration of 54 mg/l. It thus appears that the treatment system used can reduce grease in the final effluent to relatively low values, independent of the grease in the raw waste.

Table 22. Recommended Effluent Limitations for July 1, 1977*

Effluent Parameter	Effluent Limitation
BOD_5	0.17 kg/kkg RM (lb/1000 lb RM)
Suspended solids (TSS)	0.21 kg/kkg RM (lb/1000 lb RM)
Grease	0.10 kg/kkg RM (lb/1000 lb RM)
pH	6.0 - 9.0
Fecal coliform	400 counts/100 ml

*Applicable for any period of 30 consecutive days; daily maximum is 2.0 times values except pH and coliforms

Table 23. Effluent Limitations Adjustment Factors for Hide Curing

Effluent Parameter	(kg/kkg RM or lb/1000 lb RM)
BOD_5	$= \dfrac{8.0 \times (\text{no. of hides})}{(\text{kg of RM})} = \dfrac{17.6 \times (\text{no. of hides})}{(\text{lb of RM})}$
Suspended solids (SS)	$= \dfrac{11 \times (\text{no. of hides})}{(\text{kg of RM})} = \dfrac{24.2 \times (\text{no. of hides})}{(\text{lb of RM})}$

IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Best Practicable Control Technology Currently Available (BPCTCA) for the independent rendering industry involves biological waste treatment following a materials recovery process for grease and solids. The following housekeeping activities will help prevent slug loads to treatment systems and greatly assist overall waste control programs:

1. Materials recovery system--catch basins, skimming tanks, air flotation, etc.--should provide for at least a 30-minute detention time of the waste water.

2. Removal of grease and solids from the materials recovery system on a continuous or regularly scheduled basis to permit optimum performance.

3. Scrape, shovel, or pick up by other means, as much as possible, material spills before washing the floors with hot water.

4. Minimize drainage from materials receiving areas. One possibility is to pump the liquid drainage back onto the raw materials as it is conveyed from the area.

5. Repair equipment leaks as soon as possible.

6. Provide for regularly scheduled equipment maintenance programs.

7. Avoid overfilling cookers.

8. Contain materials when equipment failure occurs and while equipment is being repaired.

9. Try to prevent spills and provide supervision when unloading or transfering raw blood.

10. Do not add uncontaminated water to the contaminated water to be treated.

The following secondary biological treatment systems should produce an effluent that meets the recommended effluent limitations:

1. Anaerobic lagoon + aerobic (shallow) lagoons

2. Anaerobic + aerated + aerobic lagoons

3. Activated sludge

4. Aerated lagoons + aerobic (shallow) lagoons.

Plants with a higher-than-average raw waste load or an undersize treatment system may require a solids removal stage or chlorination as the final treatment process.

RATIONALE FOR THE SELECTION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The rationale used in developing the effluent limitations presented in Table 24 was based upon the actual performances of ten plants having what was considered to be complete secondary treatment and for which sufficient information was available. A complete secondary treatment system would include any properly sized system mentioned in the preceding paragraph.

Size, Age, Processes Employed, and Location of Facilities

The ten plants used for developing the effluent limitations cover operations using different processes, equipment, raw materials, and are of different size, age, and location of facilities. Data presented in Section IV showed that these factors did not have a distinct influence on the raw waste characteristics from independent rendering plants. Furthermore, the final effluent data from these ten plants reveal that the raw waste loads can be readily reduced by secondary treatment to a similar level regardless of in-plant operations, raw materials used, and size, age, and location of facilities.

Total Cost of Application in Relation to Effluent Reduction Benefits

Based on information contained in Section VIII of this report, the total investment cost to the independent renderer industry to implement the waste treatment to achieve the 1977 effluent limitations is estimated to be $2.6 million. This expenditure will be incurred only by the medium and large plants in the industry with a discharge to navigable waters. It amounts to about 20 percent of the estimated total capital expenditures made in 1972 by this segment of the industry.

This capital expenditure is associated with a substantial reduction in pollution discharged directly to navigable waters. Using BOD_5 as a basis for calculations, it is estimated that this segment of large and medium size plants is discharging about 1.4 million lbs of BOD_5 to streams each year at present levels of pollution control. Full implementation of the 1977 effluent limitations for BOD_5 by these plants is estimated to provide a reduction of BOD_5 to approximately one-half million lbs per year. The investment cost for the 1977 limitations per unit weight of BOD_5 reduction amounts to $0.35 per year per lb of BOD_5 removed when evaluated over the six year period during which the 1977 limitations are applicable.

The additional operating cost associated with achieving 1977 limitations varies from 1.4¢/lb of raw material for a large rendering plant to 3.5¢/lb for a medium size plant. The estimated increase in total annual cost, which includes operating costs, depreciation, and capital recovery amounts to 3¢/lb of raw material for large plants and 6¢/lb for medium size plants.

Data Presentation

Table 24 presents the data for the ten plants. Included in Table 24 are the plant size (kkg or 1000 lb RM/day), effluent flow, raw and final waste loads for BOD5, SS, and grease, and fecal coliform counts in the final treated effluent. Data for four of the plants represent information obtained as a result of our field sampling survey; data for the other six plants were obtained primarily from questionnaire information and of these, data for three plants were verified by the results of the field survey. Data for plant number 7 were included, although it was evident from visiting the plant and the results shown that the treatment system at this plant was not functioning properly; the effluent data were not used in determining the effluent limits. Similarly, the test results for SS for plant number 3 were found to be inconsistent and were not used for calculating the effluent limits.

The BOD5 effluent limitation of 0.17 kg/kkg RM is basically the average value of all available BOD5 data for all plants except plant number 7. The data of Table 24 show that five of the ten plants easily meet this limitation, while plants 3 and 5 come very close. It should be noted that the raw BOD5 waste loads for the five plants meeting the effluent range from 0.79 to 6.93 kg BOD5/kkg (lb/1000 lb) RM and that the raw waste load data from field sampling for plant 3, whose final effluent comes close to the limitation, was 16.2 kg/kkg RM. In fact, the average raw BOD5 value for the five plants meeting the limitation is 3.13 kg BOD5/kkg (lb/1000 lb) RM. The average of all plants stuided was 2.15 kg BOD5/kkg RM; thus even plants with higher raw BOD5 waste loads than these industry averages can meet the BOD5 effluent limitation.

The suspended solids (SS) effluent limitation value of 0.21 kg SS/kkg RM is close to the average of all the values except for that of plant 7. The values for four plants meet the effluent limitation for suspended solids. Also, the raw SS values for these four plants range from 1.45 to 6.69 kg SS/kkg (lb/1000 lb) RM with an average value of 3.43 kg SS/kkg (lb/1000 lb RM). The overall average for all plants studied is 1.13 kg SS/kkg (lb/1000 lb) RM.

The grease effluent limitation value of 0.10 kg grease/kkg RM is very nearly the average grease value for the nine values shown. There are six plants that meet the effluent limitation. These six plants have raw waste values ranging from 0.04 to 5.45 kg grease/kkg (lb/1000 lb) RM, with an average value of 2.30. This average raw grease value for plants meeting the guidelines is over three times as great as the average for grease for all plants included in the study, which is 0.72.

Table 24. Raw and Final Effluent Information for Ten Rendering Plants

Plant Number 1/	Flow, 1000 liters (1000 gal.)	RM/Day, kkg (1000 lb)	BOD Load, kg/kkg RM*		SS Load, kg/kkg RM*		Grease Load, kg/kkg RM*		Final Fecal Coliform**
			Raw	Final	Raw	Final	Raw	Final	(Counts/100 ml)
1	454 (120	170 (374)	1.77	0.06	2.81	0.08	0.04	0.006	--
2	57 (15)	9 (20)	0.79	0.04	6.96	0.21	1.050	0.10	3,600
3	132 (35)	86 (190)	16.22	0.16	6.69	0.006	5.45	0.035	70,000
4	45 (12)	68 (150)	2.66	0.06	1.45	0.09	1.070	0.150	50
5	3028 (800)	390 (860)	4.51	0.18	2.42	0.42	0.920	0.220	99 (Cl)
6	102 (27)	32 (70)	1.28	0.27	0.65	0.30	--	--	--
7	2120 (560)	300 (660)	5.86	0.86	3.50	4.4	1.340	0.300	270,000
8	106 (28)	75 (165)	6.93	0.09	2.77	0.14	3.120	0.028	99
9	625 (165)	265 (583)	3.64	0.34	0.80	0.20	1.150	0.038	100 (Cl)
10	19 (5)	26 (57)	3.50	0.07	--	--	0.63	0.040	4,700

*kg/kkg RM = lb/1000 lb RM
**(Cl) indicates chlorination of final effluent.

1/ For plant number 3, high raw wastes due to malfunction in grease/solids recovery system, and final SS value not used due to atypical final settling. Plant number 7 was not used to derive limits due to apparent severe malfunction in normally satisfactory treatment facility.

Based on the average raw waste load values for the ten plants, with biological treatment systems, these plants must achieve about 94 to 95 percent efficiency to meet the effluent limitation.

Although from four to seven of the plants used in developing the effluent limitations meet at least one of the three effluent limitations, only two plants are known to meet BOD_5, SS, and grease simultaneously. Another four plants meet the limitations for two of the parameters and come very close to meeting the third.

The fecal coliform effluent limitation of 400 counts/100 ml is a typical value resulting from the use of disinfection. Data from Table 24 show that four plants can meet this value, and that two of those are doing so without chlorination. These two plants not needing chlorination have large anaerobic lagoons plus aerobic lagoons for secondary treatment. The fecal coliform counts given in Table 24 were obtained using the membrane filter procedure. This method and the multiple-tube technique which results in a MPN (most probable number) value, yield comparable results.

The BOD_5 and SS effluent limitation adjustment factors for hide curing shown in Table 23 were developed using the data from Table 11 and the average BOD_5 and SS reduction required to meet the limitations. These reductions are 93 and 85 percent for BOD_5 and SS, respectively; the values produce adjustment factors of 0.008 kg (0.0176 lb) BOD_5/hide and 0.011 kg (0.0242 lb) SS/hide. As discussed earlier, no adjustment was developed for grease.

For all of the above limitations, a variability factor was derived for the relationship of the daily maximum to the average of daily values for 30 consecutive days. This factor was found to be 2.0; in other words, the daily maximum is 2.0 times the 30-day average.

This factor was developed by a direct comparative analysis of all available data regarding relationships of daily and monthly effluent values. Because of similarities in treatment systems and effluent quality, findings related to renderer plants were verified by comparisons with data on slaughterhouses and packinghouses for which a factor of 2.0 was also derived. Finally, the daily maximum limitations themselves were compared to field sampling results and other reported daily information as a practical check on the validity of the factor.

Engineering Aspects of Control Technique Applications

The specified level of control technology, primary plus biological treatment, is practicable because it is currently being practiced by plants representing a wide range of plant sizes and types.

Process Changes

Significant in-plant changes will not be needed for any plant to meet the limitations specified. Many plants will have to improve plant cleanup and housekeeping practices, both responsive to good plant management control. This can best be achieved by minimizing spills, containing materials upon equipment breakdown, and using dry cleaning prior to washdown. Some plants may find it necessary to institute better control of raw materials drainage, blood water, and tank water before mixing them with other waste waters prior to entering the materials recovery system. Some plants may also find it necessary to improve gravity separation systems. Additional cooling of the waste water before grease recovery may be required in some cases.

Nonwater Quality Environmental Impact

The major impact when the option of an activated sludge type of system or, possibly, chemical precipitation in the materials recovery system is used to achieve the limitations will be disposal of the sludge. 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 soil plots for drying without great difficulty.

It was concluded that the odor emitted periodically from anaerobic lagoons is not a major impact as it can be with the meat packing industry.[8] Also, there are no new kinds of impact introduced by the application of BPCTCA.

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 was also 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; and
- Nonwater 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, and other levels, 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" of pollutants. Although economic factors are considered in this development, the costs of 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

Table 25. Recommended Effluent Limitations for July 1, 1983**

Effluent Parameter	Effluent Limitation*
BOD_5	0.07 kg/kkg RM
Suspended solids (TSS)	0.10 kg/kkg RM
Grease	0.05 kg/kkg RM
Ammonia as N	0.02 kg/kkg RM
pH	6.0 - 9.0
Fecal coliform	400 counts/100 ml

**Applicable to any period of 30 consecutive days; daily maximum is 2.0 times values except pH and coliforms

*kg/kkg RM = lb/1000 lb RM

Table 26. Effluent Limitation Adjustment Factors for Hide Curing

	Adjustment Factor	
Effluent Parameter	kg/kkg RM	lb/1000 lb RM
BOD_5	3.6 x (no. of hides) / (kg of RM)	7.9 x (no. of hides) / (lb of RM)
Suspended Solids (SS)	6.2 x (no. of hides) / (kg of RM)	13.6 x (no. of hides) / (lb of RM)

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 this section and 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 25. The technology to achieve these goals is generally available, although it may not have been applied as yet to an independent rendering plant or on a full scale.

Hide curing at an independent rendering plant requires an adjustment in the limitations for BOD_5 and SS. These adjustments are listed in Table 26. An adjustment does not become significant, however, unless the number of hides handled by a plant is quite large. For example, an average size plant as found in this study, is one handling 94,000 kg (206,000 pounds) raw material (RM) per day, and that also cures 100 hides would have the following adjustment factors (AF):

$$AF(BOD_5) = \frac{3.6 \times 100}{94{,}000} = 0.0038 \text{ kg/kkg RM (lb/1000 lb RM)};$$

$$AF(TSS) = \frac{6.2 \times 100}{94{,}000} = 0.0066 \text{ kg/kkg RM (lb/1000 lb RM)}.$$

The effluent limitations for this plant would therefore be 0.074 and 0.107 kg/kkg RM (lb/1000 lb RM) for BOD_5 and SS, respectively (a 5.7 and 7 percent increase). An adjustment for grease was not included because there was no correlation between the raw and final grease values. For example, the six plants that had the lowest final grease loads (which ranged between about 0.006 and 0.10 kg grease/kkg RM) out of the nine plants for which final effluent data on grease were available, had raw grease loads ranging from 0.04 to 5.450 kg/kgg (lb/1000 lb) RM, with an average for the six raw values of 1.91 kg/kkg (lb/1000 lb) RM. Also, only two of the six plants had raw grease loads less than the industry average (which was 0.72); the other four plants had raw grease loads that were 1.5, 1.6, 4.3, and 7.6 times the average. It thus appears that the treatment system used can reduce grease in the final effluent to relatively low values, independent of the raw grease load.

It should also be pointed out that an independent renderer 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 most other types of treatment or control systems.

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 (Section IX), and a sand filter or equivalent following secondary treatment. In addition, some plants may require improved pretreatment, such as dissolved air flotation with pH control and chemical flocculation, and an ammonia stripping or nitrification-denitrification sequence.

In-plant controls and modifications may also be required to achieve the specified levels. Including, and in addition to, the housekeeping principals described in Section IX, these controls are as follows:

1. Materials recovery systems--catch basins, skimming tanks, air flotation, etc.--should provide for at least a 30-minute detention time of the waste water.

2. Reuse of treated waters for operating barometric leg condensers rather than fresh water. This minimizes net waste water volumes; for a given size of treatment system it permits a longer effective residence time.

3. Removal of grease and solids from the materials recovery system on a continuous or regularly scheduled basis to permit optimum performance.

4. Provide adequate cooling of condensables to ensure that the temperature of the waste water in the materials recovery system does not exceed 52°C (125°F). A temperature below 38°C (100°F) is even better. This allows for improved grease recovery and, incidentally, minimizes odor problems.

5. Scrape, shovel, or pick up by other means as much as possible, material spills before washing the floors with hot water.

6. Minimize drainage from materials receiving areas. This may require the pumping of the liquid drainage back onto the raw materials as it is conveyed from the area to the first processing step.

7. Repair equipment leaks as soon as possible.

8. Provide for regularly scheduled equipment maintenance programs.

9. Avoid overfilling cookers.

10. Provide and maintain traps in the cooking vapor lines to prevent overflow to the condensers. This is particularly important when the cookers are used to hydrolyze materials.

11. Contain materials when equipment failure occurs and while equipment is being repaired.

12. Steam sparge and screen liquid drainage from high water- and blood-containing materials such as poultry feathers on which blood has been dumped.

13. Plug sewers and provide supervision when unloading or tranfering raw blood. Blood has a BOD_5 of between 150,000 and 200,000 mg/l.[8]

14. Provide by-pass controls for controlling pressure reduction rates of cookers after hydrolysis. Cooker agitation may have to be stopped also, during cooker pressure bleed-down to prevent or minimize material carry-over.

15. Minimize water use for scrubbers by recycling and reuse.

16. Evaporate tank water to "stick" and use as tankage in dry inedible rendering.

17. Do not add uncontaminated water to the contaminated water to be treated.

18. By-pass the materials recovery process with low grease-bearing waste waters.

19. Provide for flow equalization (constant flow with time) through the materials recovery system.

20. Eliminate hide curing waste waters by mixing small volumes with large volumes of raw materials being fed to cookers.

If suitable land is available, land disposal is the best technology; it is no discharge. However, secondary treatment may still be required before disposal of waste waters to soil, although the degree of treatment need not be the same as that required to meet the 1977 limitations (Section IX). Any of the systems mentioned in Section IX are suitable.

Currently a number of independent rendering plants are achieving no discharge via land irrigation, ponding, and discharge to septic tanks followed by subsoil drainage (drain fields or large cesspools). Some plants use two of the above technologies to achieve no discharge. For example, evaporation and ponding may be used for disposal of wash water and drainage from raw materials receiving areas, and septic tanks followed by drain fields for disposal of condensables. This method of disposal of condensables also helps to contain the associated odor problem.

RATIONALE FOR SELECTION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The rationale used in developing the 1983 effluent limitations presented in Table 25 was based upon the performances of ten waste treatment systems and information contained in Sections III through VII. The ten treatment systems were considered to be complete secondary treatment systems. In addition, chlorination was being used by two of the ten plants.

Size, Age, Processes Employed, and Location of Facilities

The ten plants used for developing the effluent limitations cover operations using different processes, equipment, raw materials, and are of different sizes, ages, and locations of facilities. Data presented in Section IV showed that these factors do not have a distinct influence on the raw waste characteristics from independent rendering plants.

The final effluent data from these ten plants reveal that the raw waste loads can be substantially reduced by secondary treatment to a similar level regardless of in-plant operations, raw materials used, and size, age, and location of facilities. The levels to which secondary treatment can reduce the raw waste loads will be sufficient to allow the effluent from secondary treatment to meet effluent limitations for a number of the pollutants for 1983; however, some type of tertiary treatment may be needed to ensure that others will consistently meet 1983 standards.

Data Presentation

Table 27 presents the data for the ten plants. Included in Table 27A are the plant size (kkg or 1000 lb RM/day), effluent flow, raw and final waste loads for BOD_5, SS, and grease, and fecal coliform counts in the final treated effluent. Table 27B includes raw and final waste load data for total Kjeldahl nitrogen (TKN), ammonia (NH_3), nitrates (NO_3), nitrites (NO_2), and total phosphorus (TP). Data for four of the plants in Table 27A represent information obtained as a result of our field sampling survey; data for the other six plants listed were obtained primarily from questionnaire information, and of these, data for three plants were verified by the results of the field survey. The data included in Table 27B were all obtained from the results of the field sampling survey. Data for plant number 7 were included because the components of a satisfactory treatment facility were in place, although it was evident from visiting the plant and from the results shown in the table that the treatment system at this plant was not functioning properly.

The BOD_5 effluent limitation of 0.07 kg/kkg RM (0.07 lb/1000 lb RM) is a value being met by four of the ten plants (See Table 27A.) Two of the four plants meeting this limit have raw waste

Table 27. Raw and Final Effluent Information for Ten Rendering Plants

Table 27A. Flow, RM/Day, Final Fecal Coliform, and BOD_5, SS, and Grease Waste Loads

Plant Number 1/	Flow 1000 liters (1000 gal.)	RM/Day kkg (1000 lb)	BOD_5 Load, kg/kkg RM*		SS Load, kg/kkg RM*		Grease Load, kg/kkg RM*		Final Fecal Coliform**
			Raw	Final	Raw	Final	Raw	Final	(Counts/100 ml)
1	454 (120)	170 (374)	1.77	0.06	2.81	0.08	0.04	0.006	—
2	57 (15)	9 (20)	0.79	0.04	6.96	0.21	1.050	0.10	3,600
3	132 (35)	86 (190)	16.22	0.16	6.69	0.006	5.45	0.035	70,000
4	45 (12)	68 (150)	2.66	0.06	1.45	0.09	1.070	0.150	50
5	3028 (800)	390 (860)	4.51	0.18	2.42	0.42	0.920	0.220	99 (Cl)
6	102 (27)	32 (70)	1.28	0.27	0.65	0.30	--	--	--
7	2120 (560)	300 (660)	5.86	0.86	3.50	4.4	1.340	0.300	270,000
8	106 (28)	75 (165)	6.93	0.09	2.77	0.14	3.120	0.028	99
9	625 (165)	265 (583)	3.64	0.34	0.80	0.20	1.150	0.038	100 (Cl)
10	19 (5)	26 (57)	3.50	0.07	--	--	0.63	0.040	4,700

*kg/kkg RM = pounds/1000 pounds RM

**(Cl) indicates chlorination of final effluent.

1/ For plant number 3, high raw wastes due to malfunction in grease/solids recovery system, and final SS value not used due to atypical final settling. Plant number 7 was not used to derive limits due to apparent severe malfunction in normally satisfactory treatment facility.

Table 27. Raw and Final Effluent Information for Ten Rendering Plants (Continued)

Table 27B. TKN, NH_3, NO_2, NO_3 and TP Waste Loads

Plant Number	Total Kjeldahl Nitrogen Load as *N* kg/kkg RM		Ammonia Load as *N* kg/kkg RM		Nitrite Load as *N* kg/kkg RM		Nitrate Load as *N* kg/kkg RM		Total Phosphorus Load as *P* kg/kkg RM	
	Raw	Final	Raw	Final	Raw	Final	Raw	Final	Raw	Final
1	0.49	0.03	0.26	0.001	0.04	0.001	0.06	0.0004	0.01	0.029
2	0.38	0.02	0.17	0.005	0.0001	0.008	0.0001	0.001	0.013	0.001
3	0.94	0.27	0.08	0.26	0.0003	0.00015	0.0014	0.0024	0.08	0.046
4	0.38	0.034	0.19	0.0086	0.00002	0.00005	0.0015	0.00068	0.031	0.014
5	0.44	0.30	0.30	0.16	0.0004	0.0002	0.0001	0.0001	0.062	0.08
6*	--	--	--	--	--	--	--	--	--	--
7	1.2	1.92	0.66	0.53	0.00036	0.00036	0.012	0.012	0.28	0.26
8	0.33	0.35	0.14	0.11	0.00007	0.00009	0.0015	0.0018	0.04	0.029
9	0.82	0.32	0.29	0.11	0.00079	0.0013	0.018	0.0077	0.04	0.024
10	0.23	0.08	0.18	0.044	0.0013	0.00004	0.0075	0.001	0.023	0.013

*Nutrient values for this plant are missing because the plant was not sampled. The values shown in Part A of this table for this plant were obtained from the questionnaire.

BOD_5 loads greater than the industry average of 2.15 kg BOD_5/kkg RM. Thus, it appears that a well operated and properly sized secondary treatment system can produce an effluent with a BOD_5 load that will meet the 1983 limitation. The BOD_5 effluent limit value of 0.07 kg/kkg RM corresponds to a final effluent concentration of 56 mg/l for plants with low rates of water use (150 gal/1000 lbs RM) and about 21 mg/l for plants with higher rates of water use (400 gal/1000 lbs RM). A BOD5 concentration as low as 21 mg/l usually means that the majority of the BOD_5 remaining is contained in the suspended solids. In fact, this is supported by the results of a correlation analysis between final BOD_5 and suspended solids waste loads that showed a high correlation between the two--the correlation coefficient was 0.87 (a coefficient of 1 would be a perfect correlation). Consequently, to ensure that the final effluent from plants with higher water use rates will meet the 1983 BOD_5 limit during all periods of discharge may require the use of a sand filter or its equivalent to reduce the remaining SS and thus the BOD_5.

The suspended solids (SS) effluent limitation value of 0.10 kg/kkg RM (0.10 lb/1000 lb RM) is currently being met by three of the nine plants with secondary treatment for which there are data. These three plants all have raw SS loads greater than the industry average, which is 1.13 kg/kkg RM, as shown in Table 6. As mentioned in the above paragraph, a sand filter or its equivalent will be required to remove SS and hence to lower the BOD_5. This should therefore permit all plants to meet the SS limitation value. The SS limit, corresponds to a final concentration for SS of 80 mg/l for plants with low rates of water use and about 30 mg/l for plants with higher water use rates. This latter concentration is a readily achievable limit for SS removal via a sand filter. (See Section VII.)

The grease limit of 0.05 kg/kkg RM (0.05 lb/1000 lb RM) was chosen because five of nine plants for which grease data were available (See Table 27A.) met this limit. This limit should not be difficult to achieve via secondary treatment; four of the five plants meeting the limit had raw grease loads considerably greater than the industry average of 0.72 kg grease/kkg RM.

The ammonia limit of 0.02 kg NH_3 as N/kkg RM (0.02 lb/1000 lb RM) is being met by three plants that are showing substantial reduction in Total Kjeldahl Nitrogen. The reason for this is that the TKN value, which is the sum of the organic and ammonia nitrogen, is largely caused by ammonia in the final effluent, as can be seen in Table 27B. Thus, the same steps that are being used to reduce the TKN value will also help to reduce the ammonia value. Of course, the best approach to this problem is to eliminate or reduce the sources, one of which is blood.

With respect to treatment itself, most plants should find it advantageous to utilize nitrification processes for ammonia control. Treatment concepts such as modifications of single cell activated sludge or extended aeration systems would apply. In addition to the removal of ammonia, these systems include clarification with sludge return and thus are likely to obviate the need for final filtration to meet the BOD_5 and TSS limitations. In concentration units, the BOD_5 and TSS limitations are well within the range achieved by nitrification systems.

The pH limits of from 6.0 to 9.0 are not expected to require any special control since all plants for which there were data have effluents with pH in this range.

The fecal coliform effluent limitation of 400 counts/100 ml is the same as for the 1977 limits. Data from Table 27A show that four plants can meet this value, and that two of those are doing so without chlorination. The two plants not needing chlorination have large anaerobic lagoons plus aerobic lagoons for secondary treatment. The fecal coliform counts given in Table 27A were obtained using the membrane filter procedure. This method and the multiple-tube technique which results in a MPN (most probable number) value, yield comparable results.

Engineering Aspects of Control Technique Applications

The specified level of control technology, primary, plus secondary, plus tertiary (which will generally include at least the addition of nitrification systems or its equivalent if it is needed), is achievable; a number of plants without tertiary treatment are currently meeting the limits for the individual waste parameters as previously mentioned. In fact, one plant is currently meeting all waste parameter limits, and several others are meeting the majority. Tertiary treatment is required, however, to permit all plants to meet the limits for all pollutants. The specified tertiary treatment is practicable because it is currently being used in many other applications for waste water treatment.

Process Changes

Most plants will find it necessary to make in-plant improvements to meet the 1983 limitations. This will not require any substantial process changes *per se*; rather, this will involve improved plant cleanup and housekeeping practices, both responsive to good plant management control. This will include minimizing spills, containing materials upon equipment breakdown, using drycleaning prior to washdown, and additional cooling of the waste waters before the materials recovery system. Still, some plants may find it necessary to control drainage from trucks and raw materials, blood waters, tank water, and hide-curing waste waters. Specific suggestions on controlling these sources of waste water were made earlier in this section. Some plants may also find it necessary to improve the materials recovery system or replace it with an improved system such as air flotation with chemical precipitation.

Nonwater Quality Impact

The major impact will occur when the land disposal option is chosen. There is a potential long-term effect on the soil from irrigation of rendering plant waste water and on ground waters. To date, impacts have been generally obviated by careful water application management and by biological treatment prior to disposal.

The electrical energy consumption attributable to the waste treatment facilities required to achieve the 1983 effluent limitations is estimated to be 15 million KWh per year for the rendering industry. This is equivalent to about 0.2 percent of the total energy, including heat and power, consumed by the industry in 1967. It amounts to about 4 percent of the electrical energy consumed in 1967. This increase in energy consumption does not appear to raise serious supply or cost problems for the renderers.

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

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

INTRODUCTION

The effluent limitations that must be achieved by new sources are termed New Source 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 is made as to whether a standard permitting no discharge of pollutants is practicable.

Consideration was also given to:

- Operating methods;
- Batch, as opposed to continuous, operations;
- Process employed;
- Plant size; and
- Recovery of pollutants as by-products.

EFFLUENT REDUCTION ATTAINABLE FOR NEW SOURCES

The effluent limitations for new sources are the same as those for the Best Practicable Control Technology Currently Available for the pollutants BOD_5, SS, grease, and fecal coliform. (See Section IX.) In addition to these pollutant parameters, the following additional limits on nutrients are required for new sources:

Effluent Parameter	Effluent Limitation kg/kkg (lb/1000 lb) RM
Ammonia as N	0.17

These limitations are readily achievable in newly constructed plants since a number of existing well operated plants are meeting them. (For the actual data, see Section X.) 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 is no discharge; in many cases this will be the most attractive and economical option, particularly for small rendering plants. Table 28 shows the estimated costs for new sources (assuming low water use rates of 150 gallons/1000 pounds RM) to achieve the new source performance standards.

Table 28. Investment and Operating Costs for New Source Performance Standards*

	Waste Water Treatment System Costs				
	Investment Cost	Annual Cost		Operating Cost	
Plant Size	$	Total $/yr	¢/kg (¢/lb)	Total $/yr	¢/kg (¢/lb)
Small	78,000	32,125	0.67 (0.31)	19,325	0.40 (0.18)
Medium	148,000	50,025	0.26 (0.12)	25,425	0.13 (0.06)
Large	220,000	70,725	0.12 (0.05)	33,325	0.06 (0.03)

*Note: Based upon a treatment system of catch basin with skimmer, anaerobic-aerated-aerobic lagoons, ammonia control (nitrification) and disinfection.

Identification of New Source Control Technology

The control 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:

- o Segregation of drainage from trucks and raw materials, hide curing waste, blood water, and tank water from other waste waters for special treatment. This special treatment may be used to eliminate these wastes by adding them to the raw material as it enters a cooker or by evaporating them down to a point where they can be used as tankage for dry inedible rendering. Another special treatment method would be to steam sparge and screen some wastes before combining them with other waste waters. Of course, the formal methods are the best for lowering the raw waste load and particularly the TKN and ammonia loads.

- Materials recovery systems--catch basins, skimming tanks, air flotation, etc.--should provide for at least a 30-minute detention time of the waste water.

- Reuse of treated waters for operating barometric leg condensers rather than fresh water. This minimizes net waste water volumes for a given size of treatment system and permits a longer effective residence time.

- Removal of grease and solids from the materials recovery system on a continuous or regularly scheduled basis to permit optimum performance.

- Provide adequate cooling of condensables to ensure that the temperature of the waste water in the materials recovery system does not exceed 52°C (125°F). A temperature below 38°C (100°F) is even better. This allows for improved grease recovery, and minimizes odor problems.

- Scrape, shovel, or pick up by other means as much as possible, of material spills before washing the floors with hot water.

- Repair equipment leaks as soon as possible.

- Provide for regularly scheduled equipment maintenance programs.

- Avoid overfilling cookers.

- Provide and maintain traps in the cooking vapor lines to prevent overflow to the condensers. This is particularly important when the cookers are used to hydrolyze materials.

- Contain materials when equipment failure occurs and while equipment is being repaired.

- Plug sewers and provide supervision when unloading or transfering raw blood.

- Provide by-pass controls for controlling pressure reduction rates of cookers after hydrolysis. Cooker agitation may have to be stopped also, during cooker pressure bleed-down to prevent or minimize material carry-over.

- Minimize water use for scrubbers by recycling and reuse.

- o Do not add uncontaminated water to the contaminated water to be treated.

- o By-pass the materials recovery process with low grease-bearing waste waters.

- o Provide for flow equalization (constant flow with time) through the materials recovery system.

In addition, the following end-of-process treatments should be considered.

- o Land disposal (irrigation, evaporation) wherever possible; this should be a prime consideration, especially for economic reasons.

- o Sand filter or equivalent for polishing the effluent from secondary treatment.

Rationale for Selection of New Source Performance Standards

The BOD_5, SS, grease, and fecal coliform limits are discussed in Section IX on the rationale for Best Practicable Control Technology Currently Available.

The ammonia limit of 0.17 kg/kkg RM is the average ammonia value for the nine plants whose data are presented in Section X. Six of those nine plants meet this limit. Three are not meeting the limit because of poor practices: two were allowing too much blood to enter the sewer, and the third was adding nutrients (such as paunch manure) to the system to help sustain a natural scum layer (cover) on the anaerobic lagoon. A total Kjeldahl nitrogen (TKN) limit was not established because the majority of the TKN in the effluent is ammonia (the rest, organic nitrogen) and restricting ammonia will restrict the TKN load in the effluent.

Pretreatment Requirements

No constituents of the effluent discharged from a plant within the rendering 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 waste water treatment plant. The effluent, however, should have passed through materials recovery (primary treatment) in the plant to remove settleable solids and a large portion of the grease. The concentration of pollutants acceptable to the treatment plant is dependent on the relative sizes of the treatment facility and the effluent volume from independent rendering plants and must be established by the treatment facility. It is possible that grease remaining in the rendering 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 may require 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 such as anaerobic contact, aerated lagoons, etc., as pretreatment.

TABLE 29

METRIC TABLE

CONVERSION TABLE

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	killowatts
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
ton (short)	ton	0.907	kkg	metric ton (1000 kilograms)
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier

SECTION XII

ACKNOWLEDGMENTS

The Environmental Protection Agency gratefully acknowledges the assistance of the North Star Research and Development Institute under the overall supervision of Dr. E.E. Erickson. John Pilney was the Project Engineer; he was assisted by Messrs R.J. Reid and R.J. Parnow. Special assistance was provided by North Star staff members: Messrs R.H. Forester and A.J. Senechal.

The contributions and advice of Mr. William H. Prokop of the National Renderers Association and of the member plants operations committee and of Dr. H.O. Halvorson are gratefully acknowledged.

The cooperation of the independent rendering industry is greatly appreciated. The National Renderers Association and its members deserve special mention, as do several companies that provided information and cooperation in plant visits and on-site sampling programs.

Invaluable consultation and assistance was provided by Dr. Raymond D. Loehr, Director, Environmental Studies Program, Cornell University, and presently serving as Program Advisor, Effluent Guidelines Division.

The Agency also wishes to acknowledge the overall supervision and guidance provided by Mr. Allen Cywin, Director, Mr. Ernst P. Hall, Deputy Director, and Mr. John Riley, Chief, Technical Analysis and Information Branch of the Effluent Guidelines Division. Special mention is also due Mr. Richard Stevenson of the Economic Studies Division for his help in evaluations of costs and economic impact.

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.

Many State and local agencies were also most helpful and much appreciated.

And special mention is due Mrs. Pearl Smith, Effluent Guidelines Division, for her invaluable assistance in editing and compiling the final document.

SECTION XIII

REFERENCES

1. Standard Industrial Classification Manual, Executive Office of the President, Office of Management and Budget, U.S. Government Printing Office, Washington, 1972.

2. Dion, J.A., Osag, T.R., Bunyard, F.L., and Crane, G.B., Control of Odors from Inedible Rendering Plants: An Information Document, Environmental Protection Agency, Washington, 1973.

3. "Uniqueness of the Rendering Industry," National Renderers Association, unpublished, undated.

4. 1967 Census of Manufactures, Bureau of the Census, U.S. Department of Commerce, U.S. Government Printing Office, Washington, 1972.

5. Pollution Control Costs and Research Priorities in the Animal Slaughtering and Processing Industries, National Industrial Pollution Control Council, U.S. Government Printing Office, Washington, June 1973.

6. Protein Conversion Equipment, Chemetron Corporation, Chicago, 1973.

7. Personal communication, National Renderers Association.

8. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Red Meat Processing Segment of the Meat Product and Rendering Processing Point Source Category, U.S. Environmental Protection Agency, Report No. 440/174/012a, Washington, February 1974.

9. Doty, D.M., et al., Investigation of Odor Control in the Rendering Industry, by Fats and Proteins Research Foundation, Incorporated, for Environmental Protection Agency, Report No. PB-213 386, National Technical Information Service, Springfield, Va., October 1972.

10. Prokop, William H., "The Rendering Industry and Ecology Control," National Renderers Association for presentation at the 2nd Annual International Food and Beverage F.I.D. Symposium, Montreal, June 1973.

11. Meat Industry Waste Management, Robert S. Kerr Water Research Center, Ada, Oklahoma, Environmental Protection Agency, June 1972.

12. Development Document for Effluent Limitations Guidelines and Standards of Performance for New Sources for the Leather Tanning and Finishing Point Source Category, U.S. Environmental Protection Agency, March 1974.

13. Basics of Pollution Control, Gurnham & Associates, prepared for Environmental Protection Agency Technology Transfer Program, Kansas City, Mo., March 7-8, 1973, Chicago.

14. Public Health Service Drinking Water Standards, Revised, 1962, U.S. Department of Health, Education and Welfare, U.S. Public Health Service Publication No. 956, U.S. Government Printing Office, Washington, 1962.

15. Steffan, A.J., In-Plant Modifications to Reduce Pollution and Pretreatment of Meat Packing Waste Waters for Discharge to Municipal Systems, prepared for Environmental Protection Agency Technology Transfer Program, Kansas City, Mo., March 7-8, 1973.

16. Water Quality Improvement by Physical and Chemical Processes, Earnest F. Gloyna and W. Wesley Eckenfelder, Jr., Eds., University of Texas Press, Austin, 1970.

17. Rosen, G.D., "Profit from Effluent," Poultry Industry (April 1971).

18. Personal communication, J. Hesler, Greyhound Corporation, 1973.

19. Telephone communication with M. Hartman, Infilco Division, Westinghouse, Richland, Virginia, May 1973.

20. Upgrading Meat Packing Facilities to Reduce Pollution: Waste Treatment Systems, Bell, Galyardt, Wells, prepared for Environmental Protection Agency Technology Transfer Program, Kansas City, Mo., March 7-8, 1973, Omaha.

21. Private communication from Geo. A. Hormel & Company, Austin, Minnesota, 1973.

22. Chittenden, Jimmie A., and Wells, W. James, Jr., "BOD Removal and Stabilization of Anaerobic Lagoon Effluent Using a Rotating Biological Contactor," presented at the 1970 Annual Conference, Water Pollution Control Federation, Boston.

23. Culp, Russell L., and Culp, Gordon L., Advanced Waste Water Treatment, Van Nostrand Reinhold Company, New York, 1971.

24. Babbitt, Harold E., and Baumann, E. Robert, Sewerage and Sewage Treatment, Eighth Ed., John Wiley & Sons, Inc., London, 1967.

25. Fair, Gordon Maskew, Geyer, John Charles, and Okun, Daniel Alexander, Water and Waste Water Engineering: Volume 2. Water Purification and Waste Water Treatment and Disposal, John Wiley & Sons, Inc., New York, 1968.

26. Personal communication, H.O. Halvorson, 1973.

27. Fair, Gordon Maskew, Geyer, John Charles, and Okun, Daniel Alexander, Water and Waste Water Engineering: Volume 1. Water Supply and Waste Water Removal, John Wiley & Sons, Inc., New York, 1966.

28. Eckenfelder, W. Wesley, Jr., Industrial Water Pollution Control, McGraw-Hill Book Company, New York, 1966.

29. Eliassen, Rolf and Tchobanoglous, George, "Advanced Treatment Processes," Chemical Engineering (October 14, 1968).

30. Knowles, Chester L., Jr., "Improving Biological Processes," Chemical Engineering (October 14, 1968).

31. Personal communication, H.O. Halvorson, May 1973.

32. Witherow, Jack L., Small Meat Packers Wastes Treatment Systems, Presented at 4th National Symposium on Food Processing Wastes, Syracuse, N.Y., March 26-28, 1973

33. Personal communication, C.E. Clapp, United States Department of Agriculture, Agricultural Research Service, University of Minnesota, Minneapolis, May 1973.

34. Personal communication with Lowell Hanson, Soil Science, Agricultural Extension Service, University of Minnesota, 1973.

35. Financial Facts About the Meat Packing Industry, 1971, American Meat Institute, Chicago, August 1972.

36. "Survey of Corporate Performance: First Quarter 1973," Business Week, p. 97 (May 12, 1973).

37. Mckinney, Ross E., Microbiology for Sanitary Engineers, McGraw-Hill Book Company, New York, 1962.

38. Frazier, W. C., Food Microbiology, 2nd Edition, McGraw-Hill Book Company, New York, 1967.

39. "Water Quality Criteria - 1972", National Academy of Sciences and National Academy of Engineering for the Environmental Protection Agency, Washington, D. C. 1972 (U. S. Govt. Printing Office Stock No. 5501-00520).

40. Loehr, Raymond C. Agricultural Waste Management, Academic Press, New York, 1974.

41. Anthonisen, A.C., R. C. Loehr, et. al., "Inhibition of Nitrification by Unionized Ammonia and Unionized Nitrous Acid", presented at 47th Annual Conference, Water Pollution Control Federation, October, 1974.

42. Development and Demonstration of Nutrient Removal from Animal Wastes EPA-R2-73-095 U. S. Environmental Protection

Agency, January, 1973.

43. Prakasam, T.B.S. et al, "Approaches for the Control of Nitrogen With an Oxidation Ditch", Proceedings 1974 Agricultural Waste Management Conference, Cornell University, Ithaca, New York, pp 421-435.

44. "Control of Nitrogen in Waste Water Effluents", U. S. Environmental Protection Agency, ORD (NERC) Cincinnati, Ohio, March 1974.

45. "ABF Nitrification System, 1974 Pilot Plant Study", Interim Report, Neptune Microfloc, Inc. September, 1974.

46. Reeves, T.G., "Nitrogen Removal" a literature review", JWPCF volume 44, No. 10 pp 1895-1908, October, 1972.

47. Gonzales, J. G. and R. L. Culp, "New Developments in Ammonia Stripping", Public Works p. 78, May, 1973.

48. O'Farrell, T. P. et. al., "Nitrogen removal by ammonia stripping", JWPCF vol. 44, no. 8 pp 1527-1535, August, 1972.

49. "Nitrogen Removal from Waste Waters", Federal Water Quality Administration, AWT Laboratory Cincinnati, Ohio May, 1970.

50. "Evaluation of Anaerobic Denitrification Processes" Journal SED, American Society of Civil Engineers pp 108-111, February, 1971.

51. McLaren, J. R. and G. J. Farquhar, "Factors Affecting Ammonia Removal by Clinoptilolite" Jour. EED, American Society of Civil Engineers, pp 429-446 August, 1973.

52. Johnson, W. K., "Process Kinetics for Denitrification", Jour. SED, ASCE pp 623-634 August, 1972.

53. "How to Get Low Ammonia Effluent", Water and Sewage Works p 92, August 1974.

54. Duddles, Glenn A., et.al., "Plastic Medium Trickling Filters for Biological Nitrogen Control", JWPCF vol. 46 No. 5 pp 937-946, May 1974.

55. Lue-Hing, Cecil, et.al. "Nitrification of a High Ammonia Content Sludge Supernatent by use of Rotating Discs", presented at 29th Annual Purdue Industrial Waste Conference, May 1974.

56. Haug, R. T. and Perry L. McCarty, "Nitrification with the Submerged Filter" presented at Annual Water Pollution Control Federation Conference San Francisco, Ca., October, 1971.

57. Sutton, Paul M., et.al., "Biological Nitrogen Removal - The Efficacy of the Nitrification Step", presented at Annual

Conference WPCF, Denver, Colorado, October 1974.

58. Lawrence, Alonzo W and C. G. Brown, "Biokinetic Approach to Optimal Design and Control of Nitrifying Activated Sludge Systems "presented at Annual Meeting New York Water Pollution Control Association, New York, January 1973.

59. Baumann, R. E. and J. L. Cleasby, "Design of Filters for Advanced Waste Treatment" Engineering Research Institute, Iowa State University, Ames, Iowa, October, 1973.

60. Rice, G. A. and J. L. Cleasby, "Reported Efficiencies for Direct Filtration of Plant Effluents", Iowa State University, Ames, Iowa, March 1974.

61. Baumann, R. E., "Design of Filters for Advanced Waste Water Treatment", Engineering Research Institute, Iowa State University Ames, Iowa, June 1973.

62. "Water and Pollution Control Technology Report" Neptune Micro FLOC, Inc., Volume 4, Number 1, September 1970.

63. Weddle, C. L., et.al., "Studies of Municipal Waste Water Renovation for Industrial Water" presented before Annual Conference of the Water Pollution Control Federation, October, 1971.

64. "Comprehensive Monthly Report", Dallas Water Utilities Department, Water Reclamation Research Center, July 1973.

65. University Area Joint Authority, operating report of October 6, 1971, State College, Pa.

66. Metropolitan Sewer District, operating report of October, 1971, Louisville, Kentucky.

67. "Upgrading Existing Waste Water Treatment Plants" U. S. Environmental Protection Agency Technology Transfer Process Design Manual, October 1974.

68. Beckman, W. J., et al, "Combined Carbon Oxidation - Nitrification", Journal WPCF, p 1916-1931 volume 44, October 1972.

69. Drews, R.J. L.C. and A.M. Greef, "Nitrogen Elimination by Rapid Alternation of Aerobic/Anoxic Conditions in Orbal Activated Sludge Plants", Water Research Volume 7, Pergaman Press, 1973.

70. Lynam, B.T. and V.W. Bacon, "Filtration and Microstraining of Secondary Effluent", from Water Quality Improvement by Physical and Chemical Processes University of Texas Press, 1970.

71. Culp, Gordon L., "Physical Chemical Techniques

for Nitrogen Removal" prepared for EPA Technology Transfer Seminar, March, 1974.

72. "Ammonia Removal from Agricultural Runoff and Secondary Effluent by Selected Ion Exchange", U. S. Department of the Interior, FWPCA, Cincinnati, Ohio, March, 1969.

73. "Waste Water Filtration Design Considerations", U. S. Environmental Protection Agency, Technology Transfer, Washington, D. C., July 1974.

74. "Upgrading Existing Lagoons", U. S. Environmental Protection Agency, NERC, Cincinnati, Ohio, October, 1973.

75. Reynolds, J. H., et. al., "Single and Multi-Stage Intermittent Sand Filtration to Upgrade Lagoon Effluents" Utah State University, Logan, Utah, November, 1974.

76. Middlebrooks, E. J., et. al., "Evaluation of Techniques for Alage Removal from Waste Water Stabilization Ponds", Utah Water Research Laboratory, Utah State University, Logan, Utah January, 1974.

77. Clark, S. E., et. al., "Alaska Sewage Lagoons", Federal Water Quality Administration, Alaska Water Laboratory, College, Alaska, 1970.

78. "Lagoon Performance and the State of Lagoon Technology" U. S. Environmental Protection Agency, Office of Research and Monitoring, June, 1973.

79. "Supplementary Aeration of Lagoons in Rigorous Climate Areas", U. S. Environmental Protection Agency, October, 1971.

80. "Biological Waste Treatment in the Far North", Federal Water Quality Administration, Alaska Water Laboratory, June 1970.

81. Eckenfelder, W. W. and D. J. O'Connor, Biological Waste Treatment, Pergamon Press, New York, 1961.

82. "The 1974 Environmental Wastes Control Manual" Public Works, Ridgewood, New Jersey.

83. Stenquist, R. J., et.al., "Carbon Oxidation-Nitrification in Synthetic Media Trickling Filters," JWPCF, Vol. 46 p 2327, October, 1974.

84. "Ammonia Removal in a Physical-Chemical Waste Water Treatment Process," U.S. Environmental Protection Agency, Report EPA-R2-72-123, Washington, D. C.

November, 1972.

85. "Water Pollution Control in Cold Climates" Proceedings, International Symposium, U. S. Environmental Protection Agency, 1970 (U.S. GPO stock number 5501-0208).

86. "Development Document for Effluent Limitations and Standards of Performance for New Sources for the Petroleum Refining Point Source Category", U. S. Environmental Protection Agency, Washington, D. C. April, 1974.

87. Beychok, M. R. Aqueous Wastes from Petroleum and Petrochemical Plants, John Wiley and Sons, New York, 1967.

SECTION XIV

GLOSSARY

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

Activated Sludge Process: Aerated basin in which waste waters are mixed with recycled biologically active sludge for periods of about 6 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 plants. They occur as single cells, chains, filaments, well-oriented groups, or amorphous masses.

Biodegradable: The condition of a substance which indicates that the energy content of the substance can be lowered by the action of biological agents (bacteria) through chemical reactions that simplify the molecular structure of the substance.

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 or organisms, so that further biodegradation is very slow.

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; e.g., in a boiler.

BOD_5: A measure of the oxygen consumption by aerobic organisms over a five 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 water stream.

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

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

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

Clarifier: A settling basin for separating settleable solids from waste waters.

cm: Centimeter.

Coagulant: A material, which, when added to liquid wastes or water, creates a reaction which forms insoluble floc particles that absorb 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.

Coanda Phenomenon: Tendency of a flowing fluid to adhere to a curved surface.

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 waste water.

Condensables: Cooking vapors capable of being condensed.

Condensate: The liquid produced by condensing rendering cooking vapors.

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.

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

Digestion: Though "anaerobic" 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.

Dry Rendering: Cooking of inedible raw materials to remove all excess raw material moisture by externally applied heat.

Edible: Products that can be used for human consumption.

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

Equalization Tank: A means of liquid storage capacity in a continuous flow system, used to provide a uniform flow rate downstream in spite of fluctuating incoming flow rates.

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

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 waste waters 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.

Fat: Refers to the rendering products of tallow and grease.

Fatty Acid: A type of organic acid derived from fats.

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

Finger Dikes: Barriers or walls extending out into lagoons--in waste water treatment--to prevent or minimize the flow of incoming water directly to the outlet and thereby short circuiting the treatment process.

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

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

Grease: Fat that has a titre (or melting point) below 40°C. Grease is produced from poultry and hot fat.

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

Inedible: Products that can not be used for human consumption.

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.

Isoelectric Point: The value of the pH of a solution at which the soluble protein becomes insoluble and precipitates out.

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

kkg: 1000 kilograms.

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

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.

Low-Temperature Rendering: A rendering process in which the cooking is conducted at a low temperature which does not evaporate the raw material moisture. Normally used to produce a high-quality edible product such as lard.

m: Meter; metric unit of length.

Meal: A coarsely ground proteinaceous product of rendering made from such animal by-products as meat, bone, and feathers.

mg/l: 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.

mm: Millimeter = 0.001 meter.

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

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 runoff or total recycle of the waste water may be used to achieve it.

Noncondensables: Cooking gases that can not be condensed and are usually very odorous.

Nonwater 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.

Packed Tower: Equipment used in rendering plants for odor control. A cylindrical column loaded with a packing material used to increase the contact area between scrubbing solution and odorous air.

pH: 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 tenfold change in concentration of hydrogen ion concentration.

Point Source: Regarding waste water, a single plant with a waste water stream discharging into a receiving body of water.

Polishing: 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.

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

Pollution: The presence of pollutants in a system sufficient to degrade the quality of the system.

Polyelectrolyte Chemicals: 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 waste water treatment, particularly along with dissolved air flotation.

Ponding: A waste treatment technique involving the actual holdup of all waste waters in a confined space.

ppm: Parts per million; a measure of concentration usually currently as mg/l.

Prebreaker: A mechanical grinder used by rendering plants for size reduction of raw materials prior to cooking operations.

Pretreatment: Waste Water treatment located on the plant site and upstream from the discharge to a municipal treatment system.

Primary Waste Treatment: In-plant, by-product recovery and waste water treatment involving physical separation and recovery devices such as catch basins, screens, and dissolved air flotation.

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

Raw Material Moisture: Refers to the water content of raw materials used in rendering.

Raw Waste: The waste water 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 including the return of treated plant waste water 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: Referring to waste reuse. The subsequent use of water following an earlier use without restoring it to the original quality.

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

RM: Referring to the raw material used in the rendering process.

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

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

Screw Press: An extrusion device used to expel excess fat from proteinaceous solids after cooking.

Scrubber: Used as an odor control device in the rendering industry. Operates by the contacting of numerous droplets of scrubbing solution with odorous air streams.

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

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.

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 occurring over a limited period of time.

Skimmings: Fats and flotable solids recovered from waste waters for recycling by catch basins, skimming tanks, and air flotation devices.

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 the evaporated tank water from wet rendering operations. It is added to solids and may be further dried for feed ingredients.

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

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

Suspended Solids (SS): 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 waste water.

Tallow: Fat that has a titre (melting point) of 40°C or higher. Tallow is produced from beef cattle and sheep fat.

Tankage: Dried animal by-product residues used as feedstuff.

Tankwater: The water phase resulting from rendering processes usually occurring in 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 waste water that is soluble and is measured as total solids content minus the suspended solids.

Wet Rendering: Cooking with water or live steam added to the material under pressure. This process produces tank water.

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

*U.S. GOVERNMENT PRINTING OFFICE: 1975 582-421/259 1-3